Design for the environmental emergency: Plastic chairs and the transition to low-carbon product design

by Geoff Isaac

Thesis submitted in fulfilment of the requirements for the degree of

Doctor of Philosophy

under the supervision of:

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February, 2022

CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Geoff Isaac, declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Faculty of Design, Architecture and Building at the University of Technology Sydney.

This thesis is wholly my own work unless otherwise referenced or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Acknowledgments

I would like to thank my primary supervisor, Distinguished Professor Peter McNeil, for his encouragement to enrol for the PhD program at UTS and for his support and advice throughout my studies. I am extremely indebted to my co-supervisors, Dr Jesse Adams-Stein and Dr Stefan Lie. Stefan's experience as a practicing industrial designer provided invaluable feedback on both the manuscript and the development of the ERPR tool, designed to assist practitioners as they work with plastics. Jesse's timely and detailed feedback on all versions of this manuscript have substantially improved the end-product.

Sylvia Katz was generous enough to read Chapters 1 & 2 and provide feedback based on her expertise and experience from her distinguished career as a designer and author of several books on plastics.

I would like to thank the following for their assistance and support in accessing information for this dissertation: Jeffrey Meikle, Marcus Fairs (DeZeen), Angela Schad, Hagley Museum and Library (DuPont archive), Sanja and Steen Osterggard, Marjukka Törmi (Aarnio Design Ltd.), Virginia Marri (Archivo Gae Aultenti), Sarah Ferrall (Camron), Yana Swoboda and Nicole Cilia (ecoBirdy), Kathrin Hasskamp (Konstantin Grcic's office), Timothy Andreadis (Freemans), Emily Guthrie (Winterthur Museum), Trina Brown (National Museum of American History Library), Elizabeth Broman (Cooper Hewitt Library), Diane Toxopeus (Joris Laarman Studio BV), Soufiane Bensabra, Virginia Wright, Louise Dennis (MoDIP), Patsy Youngstein (Marc Newson's office), Kathy Hackett and Campbell Bickerstaff (MAAS), Lukas Holgersen (Thomas Pedersen's office). Plastics Historical Society: Alan Wells, Carolyn Clark, Sussan Mossman. Plastics Industry Manufacturers of Australia Inc: John Parrington, Karl Nethery and Troy Parker, Maud Bury (Eugene Quitllet's office), Jessica Pearson (Karim Rashid's office), Thales Melles (A Lot of Brasil), Steven Leclair(NRC Archives), Svein-Erik Hjerpbakk (Nordic Comfort Products AS), Therese Sanni and Leila Østerbø (Snøhetta), Mathilde Wadoux (Starck Network), Phillipa Atkinson (Studio Dirk Vander Kooij), Liliana Rodrigues (Marcel Wanders office).

I would also like to extend a special thanks to the designers and other industry participants who generously gave their time to participate in my research: Ron Arad, Dan Armstrong & Rene Linssen (Formswell), Edward Barber & Jay Osgerby, Gabriele Chiave (Marcel Wanders Office), Louis Durot, Tom Fereday, Mary Featherston, Manuel Garcia (Nagami), Sarah Gibson (DesgnByThem), Konstantin Grcic, Trent Jansen, Ander Lizaso (Iratzoki Lizaso), Ron Newman, Thomas Pedersen, Bertjan Pot, Tom Price, Eugeni Quitllet, Karim Rashid, Andrew Simpson (Vert Design), Philippe Starck, John Tree (Jasper Morisson), Gregg Buchbinder (CEO, Emeco), Ruben Hutschemaekers, (Head of Marketing and Communication, Magis), Kate Ringvall (Sustainability Business Partner, IKEA), Mayda Diaz, (Business Development & Technical Support, Bambacore), Victor Macadar (client of Bambacore), Andreas Maegerlein (Group Leader Creation Center, BASF).

Finally, I would like to thank my partner, Robert Wellington, for his support and advice throughout my studies.

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List of abbreviations

ABS	Acrylonitrile-Butadiene-Styrene
AM	Additive manufacturing
APCO	Australian Packaging Covenant Organisation
BPA	Bisphenol A
CAGR	Compound annual growth rate
CMHR	Combustion modified high resiliency
ERPR	Environmentally Responsible Product Rating
ESG	Environmental, Social and Governance.
EU	European Union
Fibreglass	Fibreglass reinforced plastic (usually epoxy or polyester)
GMOs	Genetically modified organisms
HDPE	High density polyethylene
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
LCA	Life-cycle assessment
LDPE	Low density polyethylene
MLP	Multi-level perspective
NSW EPA	New South Wales Environment Protection Authority
OECD	Organisation for Economic Co-operation and Development
OPEC	Organization of the Petroleum Exporting Countries
PB	Planetary boundaries
PBAT	Poly(butylene adipate-co-terephthalate) – a starch-based biodegradable composite,
PBS	Polybutylene succinate - poly(butylene succinate)
PC	Polycarbonate
PE	Polyethylene
PET	Polyethylene terephthalate - a polyester thermoplastic
PFAS	Per- and polyfluoroalkyl substances sometimes used as a grease and water repellent in food packaging – especially PLA
PHA	Polyhydroxyalkanotes – for example, poly-β-hydroxybuturate (PHB), the first of the biodegradable plastics made through a fermentation process
PLA	Polylactic acid – a polyester thermoplastic derived from renewable resources
PMMA	Poly(methyl methacrylate) acrylic glass often known by the trademark names Plexiglas, Lucite or Perspex
PP	Polypropylene
PU	Polyurethane
PVC	Polyvinyl chloride
RIC	Resin identification code
SKU	Stock-keeping unit
VCM	Vinyl chloride monomer – an ingredient of PVC
UN	United Nations
WWII	World War II

Abstract

Analysing the intersection between plastics, environmentally-conscious design, and consumption through a focussed study of plastic chairs, this dissertation casts new light on best practice for sustainable furniture design. Plastic chairs are ubiquitous but remain objects of constant innovation and experimentation by designers. With reference to historical and contemporary developments, I examine the shifting cultural attitudes to plastics. Product designers and furniture manufacturers are responding to mounting environmental concerns by experimenting with renewable carbon plastics (recycled plastic and bioplastics). My interviews with international contemporary designers and representatives from industry are critically evaluated, alongside case studies of recent plastic chairs made using renewable carbon plastics. Findings from that research led me to develop a quantitative eco-audit tool to enable a comparison of these designs and demonstrate that the best outcomes for sustainable design incorporate existing materials (recycled plastics) and traditional moulding technologies. This tool is presented in this dissertation as both a structural part of the research methodology, and as an output for the instrumentalisation of the study's findings.

Much research has been undertaken on sustainable design and there have been many calls for design-led societal change. But few studies have focused on how such change actually manifests, or identified the areas of research required to bring about transformation. In other words, what does it really take to shift design and manufacturing practices, at scale, across complex supply chains? The multi-level perspective (MLP) transition framework is used to identify strategies to scale-up the use of renewable carbon plastics in design. Providing a methodology for designers to embrace a more sustainable approach to the design of plastic products, this dissertation is also a call to arms for urgent action to mitigate the most devastating impacts of the environmental emergency.

Introduction

As I write, in August 2021, forest fires are burning across California, Canada, Greece, Italy, Turkey, Algeria, Lebanon, Cyprus, Russia, Bolivia, Brazil, and Peru, while the United Kingdom, Germany, China, Japan, Turkey, and Tennessee are recovering from recent devastating floods. The Intergovernmental Panel on Climate Change (IPCC) published a report detailing evidence to support its unequivocal claim that, 'human influence has warmed the atmosphere, ocean and land.' It concludes: 'many changes due to past and future greenhouse gas (GHG) emissions are irreversible for centuries to millennia, especially changes in the ocean, ice sheets and global sea level.'[1] The negative impacts of climate change are now regularly being experienced in daily lives around the globe. 'We knew it was coming and now here it is,' concluded one of the report's authors.[2] Meanwhile, calls for net zero emissions are met with platitudes from a petrochemical industry committed to the continuous expansion of production to deliver 3-4% more plastic every year through to 2050 or beyond.[3] At current rates, production of plastic will consume 15% of the remaining annual carbon budget by mid-century, making it impossible to reach global emission reduction targets.[4]

Plastics are inexpensive and available in an infinite colour range. They are lightweight, strong, durable, and malleable to virtually any shape. Combined with these benefits plastics

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[1] V Masson-Delmotte et al., "IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change" (Cambridge: Intergovernmental Panel on Climate Change, 2021), https://www.ipcc.ch/report/ar6/wg1/#SPM.
[2] Michael Byrne, a climate researcher at the University of Oxford and contributor to the IPCC report.
[3] Nova Institute, "The Future of the Chemical and Plastics Industry: Renewable Carbon - Bio-Based News -" (Cologne, 2020), 18, http://news.bio-based.eu/the-future-of-the-chemical-and-plastics-industry-renewable-carbon/.
[4] Carbon budget indicates how much Co2 can still be emitted while keeping warming below 1.5 degrees C as specified by the IPCC report. See also: Ellen McArthur Foundation, "The New Plastics Economy: Rethinking the Future of Plastics" (Cowes: World Economic Forum, Ellen MacArthur Foundation and McKinsey & Company, 2016), https://ellenmacarthurfoundation.org/the-new-plastics-economy-rethinking-the-future-of-plastics.

are warm to the touch, moisture, heat and chemical-resistant, all of which contribute to their popularity with product designers, manufacturers, and end-users alike. During the COVID-19 pandemic, plastics have proved indispensable in personal protective equipment (PPE), the first line of defence against the virus. It is estimated we are using 129 billion polypropylene disposable facemasks every month, highlighting the ongoing and accelerating waste issues caused by plastics.[5] As awareness of the environmental damage caused by both the creation and disposal of plastics increases, more urgent academic and other scientific attention is being directed to finding alternative materials.[6] But plastics are difficult, if not impossible, to replace for many applications, particularly in the health sector. Even when traditional materials such as glass, steel, or wood can be substituted, environmental impacts are often worse.[7] Plastics are a 'wicked' problem, presenting multiple challenges including the pollution caused by their creation and disposal and the absence of cost effective, environmentally-friendly alternatives.[8]

In response, there is growing interest in using recycled plastics or bioplastics (made from renewable biomass sources) for a growing range of applications.[9] Many of these renewable carbon-based materials were originally conceived in efforts to curb the use of

[5] Elvis Genbo Xu and Zhiyong Jason Ren, "Preventing Masks from Becoming the next Plastic Problem," *Frontiers of Environmental Science & Engineering* 15, no. 6 (February 28, 2021): 125, https://doi.org/10.1007/s11783-021-1413-7.

[6] For example, 180 recent studies covering the lifecycle of plastics were found to primarily focus on pollution and waste problems caused by the material. Tobias D. Nielsen et al., "Politics and the Plastic Crisis: A Review throughout the Plastic Life Cycle," *WIREs Energy and Environment* 9, no. 1 (2020): e360, https://doi.org/10.1002/wene.360.

[7] For examples see: Anthony L. Andrady and A L Andrady, *Plastics and Environmental Sustainability* (Hoboken, N.J: John Wiley & Sons, Incorporated, 2015), 126–29, http://ebookcentral.proquest.com/lib/uts/detail.action?docID=1895904.

[8] 'Wicked' problems were introduced in 1973 by Horst Rittel and Melvin Webber, as problems that cannot be solved by equations, logic or strategy alone and detailing ten properties of wicked problems specifically relevant to planning issues. In 2018, a paper outlined the plastic wicked problems, among them plastic's ubiquity, its persistence in nature, and the cross-boundary effects of plastic pollution. Micah Landon-Lane, "Corporate Social Responsibility in Marine Plastic Debris Governance," *Marine Pollution Bulletin* 127 (February 1, 2018): 310–19, https://doi.org/10.1016/j.marpolbul.2017.11.054.

[9] A bioplastic is a polymer prepared through fermentation and polymerisation processes using biomass or (potentially) Co2.

virgin fossil-based plastics (fossil plastics) in single-use packaging.[10] Renewable carbon plastics (renewable plastics) are now also being used to create consumer durable products, including chairs. I have chosen to focus on chairs for several reasons (explained in detail in the next section). Chairs are particularly relevant to my study as historically they have often been created to introduce and showcase a new material or technology. I found that designers and manufactures have experimented with recycled plastics or bioplastics to make chairs during the past fifteen years (between 2007 and 2021). In total I identified 32 chairs made from renewable plastics and these form the basis of case studies for my research. This dissertation will contribute to understanding the motivations for experimenting with renewable plastics and in turn examine how designs using these new materials and technologies compare in relation to their environmental impact. As with many product categories, chairs are often made by combining plastics with other materials, such as wood or metal. They can be the product of various manufacturing technologies. With so many different combinations available it is not immediately apparent which chairs are better for the environment. How can we tell whether a bioplastic shell attached to aluminium legs has a better environmental profile compared with a chair where the shell is made from recycled plastic with a base of recycled steel? The vast array of materials, technologies, and their combinations, makes for a perplexing problem that this dissertation seeks to resolve.

The efforts of those involved with developing of chairs using renewable plastics are to be commended. There is no intention to denigrate well-meaning work. However, without understanding the environmental impact of these innovations, future experimentation cannot fully benefit from, and build upon, the knowledge and experiences gained by these

[10] 'Renewable carbon-based plastics' includes all material made from recycled plastics, biomass (bioplastics), and direct CO2 usage, which remains largely undeveloped. (Carus & Raschka 2018, Nova Institute 2020).

pioneering efforts. Designers and manufacturers committed to improving the environmental profile of their work need practical guidance in their daily decisions. If designers want to be part of the transition to a more sustainable future, they need a clear vision of how they are expected to adapt and the pathways necessary to arrive there. Similarly, many end users want to be confident their purchases are supporting products that deliver sound environmental outcomes and that they are not simply victims of 'greenwashing', designed to promote feelings of righteousness.[11] This dissertation addresses these everyday dilemmas, by sharing the experiences of ground-breaking actors' experiments with renewable plastics and quantitatively comparing the environmental impact of their creations.

To enable a comparison of environmental profiles, I needed a methodology to evaluate the 32 chairs made using renewable plastics. Sourcing sufficient information to make detailed quantifiable comparisons on the environmental impacts of producing and transporting individual products proved elusive. The limited information available from company websites or other published data (such as press releases), proved insufficient to enable a comparison using existing eco-audit tools. A simpler approach was required based on product specifications provided by manufacturers.

I developed a simplified eco-audit tool, awarding each design an Environmentally Friendly Product Rating (ERPR). This innovative tool differentiates itself from other more complex offerings by highlighting the five most important considerations for actors involved with the creation of plastic products. For each of the five factors most likely to contribute toward the environmental profile of a design the user is asked to submit readily available information, avoiding the detailed technical information required by existing tools. The eco-

[11] Greenwashing, as defined by the Climate Social Science Network, is an umbrella term for the various misleading communications and other corporate practices that intentionally, or not, induce false positive perceptions of an organisation's environmental performance.

audit tool can then be used to guide the development of a project without the need for highly detailed information, often only available after a design is complete. An online version of the ERPR tool has been made available to enable students, designers, and manufacturers to investigate the impact of their decisions on the performance of designs.[12] Out of the 32 designs evaluated, five performed significantly better than the rest, with a further four chairs achieving above average scores. The development of the ERPR tool is explained in Chapter 4 while the application of the tool is discussed in Chapter 5.

To develop an understanding of the motivations of those working with renewable plastics I conducted a series of 27 interviews, 22 with product designers and an additional five with others actors involved with the manufacturing process. I gained access to leading industrial designers who have built international reputations for their work with market-leading manufacturers. These include designers Philippe Starck, Karim Rashid, and Konstantin Grcic, and representatives from manufacturers Magis and Emeco.[13] Qualitative data obtained from those interviews supplemented the quantitative data from the ERPR tool to develop case studies enabling a detailed understanding of the motivations of those involved with designing and making chairs. The qualitative data allowed me to analyse the agency held by those actors, and to identify specific actions that can promote the use of renewable plastics.

I examined the impact that designers can wrest by making particular decisions, selecting materials, and engaging in social and environmental advocacy through design. I identified strategies to promote the adoption of more environmentally-friendly plastics using case studies of plastic chairs. By categorising the systemic obstacles and interdisciplinary

[12] See: https://geoffisaac.com.au/erpr/
[13] A full list of research participants is given in the Interviews section below, see table 0.1.

tensions that slow the adoption of more sustainable technologies, I aim to provide a pathway for socio-technical change. The results of this investigation emphasise the essential role that designers and manufacturers can play in directing more sustainable design solutions and in transforming or reconfiguring the existing socio-technical system away from its dependence on fossil fuels. I argue that both designers and manufacturers have the agency and the ethical responsibility to accelerate the transition to more sustainable alternatives to virgin fossil plastics by promoting the uptake of renewable plastics. This dissertation casts new light on the best-practice for sustainability in furniture design.

1. Why chairs?

Chairs are central to our daily existence. Throughout our lives, as designer Galen Cranz observed, we spend most of our time seated: in different rooms in our home, in the office, on public transport or in cars, bars, cafes, restaurants or cinemas.[14] Many of us have a favourite chair with which we hold a very different relationship than with our expendable office chairs. Chairs have been in use since at least the time of the Egyptians, allowing us to accumulate, as design historian Judy Attfield noted, skill and experience in how things are made and put together from various materials.[15] Rolf Fehlbaum from the Vitra Design Museum reminded us that consistent construction principles enable chairs from different eras to be identified. Each historical period has its own distinct approach to constructing chairs revealing much about the materials, techniques, and tastes fashionable at the time. Fehlbaum argues that no other everyday object is quite as multifaceted.[16]

[14] Galen Cranz, *The Chair: Rethinking Culture, Body, and Design*, 1st ed (New York, NY: Norton, 1998), 15.
[15] Judy Attfield, *Wild Things: The Material Culture of Everyday Life*, Materializing Culture (Oxford New York: Berg, 2000), 16.
[16] *Atlas of Furniture Design* (Weil am Rhein: Vitra Design Museum, 2019), 24.

While the basic design of chairs (four legs, a back, and a seat) has remained largely unchanged over millenniums, they have been the subject of relentless attention from manufacturers and designers seeking to develop unique or distinctive versions. Manufacturers, keen to maximise profits, continue to invest in new designs to service an increasing variety of niche markets or to appeal to the latest fashions and trends. The brief for a chair is extremely challenging, requiring engineering and design skills. Chairs must be strong, appealing to look at, reasonably light, comfortable, and fit for purpose. Chairs are often characterised as representing the quintessential design challenge. Anna Ferrieri, co-founder of Kartell and a designer herself, emphasised the engineering challenge; chairs, 'suffer the greatest structural strain a designer is likely to encounter.'[17] Despite, or perhaps because of, these challenges, designers (with the support of their clients) continually seek to reinvent the chair, launching numerous new designs every year. Media scholar Ethan Zuckerman bluntly explained the allure of the challenge:

> Well, the chair has this really interesting place for the designers. Every designer wants to make a chair, but chairs are a fucking pain in the ass. They are really, really difficult. The back has to curve, it has to be slanted at a certain angle, and making it comfortable for people to sit on is a pretty serious challenge—that's why designers' chairs are signature artworks.[18]

While Zuckerman's comments highlight the allure of the design challenge presented by a chair, German design duo Vogt + Weizenegger acknowledge the significant impact of technological innovations on the development of chairs:

> A chair design always illustrates the current status of society and its technological achievements (by combining) know-how with materials and aesthetic sentiments to form a seating sculpture linked to man's cultural history like no other item might.[19]

[17] Augusto Morello, and Anna Ferrieri, *Plastic and Design* (Milano: Arcadia, 1988), 138.
[18] Jules Suzdaltsev, "White Plastic Chairs Are Taking Over the World," *Vice*, January 28, 2015, https://www.vice.com/en_us/article/bn5e4m/white-plastic-chairs-are-taking-over-the-world-128.
[19] Mel Byars and Cinzia Anguissola d'Altoé, *New Chairs: Design, Technology, and Materials* (London: Laurence King publ, 2006), 156.

Vogt + Weizenegger were not the first to note the impact of technology on the development of chairs with George Nelson, the director of design for Herman Miller (from 1947-1972), making a similar observation in 1953: 'Every truly original idea – every innovation in design, every new application of materials, every technical innovation for furniture – seems to find its most important expression in a chair.'[20] As will be shown in Chapters 1 and 2 this observation applies to developments in the plastic chair market. Plastic chairs are most often associated with the cheap mass-produced monoblocs (chairs manufactured in one piece using one material) which have flooded the market since the 1980s. But focusing on inexpensive monoblocs ignores a long history of high-quality, well-designed plastic chairs developed by some of the world's leading product designers. Plastics have been used to design chairs for every conceivable market segment; from the bottom-end of the mass-market to the upper echelons of high-end design collectors, where a luxurious, hand-crafted chair made from fake (acrylic) glass and fake flowers (plastic roses) can pass between owners for more than a quarter of a million pounds (fig. 0.1).[21]

Plastics freed designers from limitations imposed by the properties of traditional materials such as wood, metal, and textiles. Designers can choose from an estimated 60,000 polymers

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[20] George Nelson, ed., *Chairs*, Acanthus Press Reprint Series, v. 3 (New York: Acanthus Press, 1994) Nelson went on to argue chairs were likely to be selected by prosperity as most typically representative of Western culture in the first half of the twentieth century.

[21] Sotheby's London, November 2015, Lot 161.

Fig. 0.1. *Miss Blanche* featuring plastic roses painstakingly entombed in acrylic resin. Designed by Shiro Kuramata (1934-1991) in 1988 (edition of 56). Source: Sotheby's

available on the market or specify the mechanical properties required and obtain one created specifically to meet their needs.[22] During the past 80 years, product designers have experimented with plastics in many forms, enabling them to introduce curvilinear shapes to seating solutions previously unobtainable using traditional manufacturing techniques. A British industry report from the 1970s acknowledged that most of the pioneering development work on the use of plastics in the furniture industry focused on chairs.[23] Indeed,

[22] Zainul Huda and Robert Bulpett, *Materials Science and Design for Engineers*, Materials Science Foundations, v. 74 (Zurich-Durnten, Switzerland ; Enfield, NH: Trans Tech Publications, 2012), 338; Jennifer Gabrys, Gay Hawkins, and Mike Michael, eds., *Accumulation: The Material Politics of Plastic*, Culture, Economy and the Social (London: New York: Routledge, Taylor & Francis Group, 2013), 22.
[23] Furniture Industry Research Association, *An Economic Review for the Furniture Industry.* (Stevenage (Maxwell Rd, Stevenage, Herts.): Furniture Industry Research Association, 1973), 5.

chairs are still often developed specifically to showcase a new material or technology, with designers keen to explore what they can bring to the ultimate design challenge.

Fig. 0.2. *Myto* by Konstantin Grcic, Plank 2008. BASF commissioned a cantilevered chair in an effort to develop a wider market for PBT, a material originally developed for the automobile market.[24]
Source: Konstantin Grcic

In recent times, we have seen material manufacturers target leading industrial designers to develop chairs specifically to showcase the potential of new polymers for the furniture industry. In 2007, BASF held a competition to design a chair to demonstrate the potential of using Ultradore High Speed plastic (polybutylene terephthalate – PBT) for seating – resulting in the Konstantin Grcic's *Myto* cantilevered chair (fig. 0.2).[25] UK-based industrial designers Barber & Osgerby were commissioned by Emeco to design the *On & On Stacking* (recyclable) *Chair* (2019) with a plastic comprised of 70% recycled polyethylene terephthalate (PET) derived from waste plastic bottles that would otherwise end up in landfill

[24] Alice Rawsthorn, "Konstantin Grcic's New Chair Design, the MYTO," *New York Times*, Spring 2007.
[25] Alice Rawsthorn.

(see Chapter 5). A Lot of Brasil approached industrial designer Karim Rashid to develop the *Siamese Chair* using a plastic injection of the Amazonian fruit Acai and Ipe Roxo, probably the first bioplastic chair, launched in 2014 (also examined in Chapter 5).

Chairs have been designed by people drawn from a variety of professions; interior designers, industrial designers, and architects among them. In this dissertation the generic term 'designer' has been used to refer to the person who designed a chair. Where specific reference is made to an individual designer, I have used their preferred professional title. The design of a chair is usually attributed to an individual 'heroic' designer (or design duo) responsible for conceptualising the aesthetic and functional solution to the object.[26] This practice masks the contribution made by specialist engineers, model makers, and the entire team of professionals involved with the development of a chair. Anthropologist Arturo Escobar argues that it is becoming increasingly difficult to maintain this 'fiction,' of assigning credit to 'the designer genius at work in the studio,' in an era when agency power and expertise are increasingly distributed.[27]

Nevertheless, the practice of acknowledging the contribution of the designer over other participants continues. This has not always been so, as Mimi Hellman observed, in eighteenth-century France, chairs for the elite might be designed by an architect, patron, upholsterer, furniture maker, or dealer with the final design often the results of collaboration between various actors.[28] Hellman concludes that, 'the full cast of characters [involved with

[26] Attfield, *Wild Things*, 4.
[27] Arturo Escobar, *Designs for the Pluriverse: Radical Interdependence, Autonomy, and the Making of Worlds*, New Ecologies for the Twenty-First Century (Durham: Duke University Press, 2018), 85.
[28] Mimi Hellman, "Furniture, Sociability, and the Work of Leisure in Eighteenth-Century France," *Eighteenth-Century Studies* 32, no. 4 (1999): 418.

the production of a chair] could not have been known to or sought by the consumer.' [29] The cultural value of the chair was not as contingent upon makers as upon users.

Finally, focusing on plastic chairs affords the opportunity to examine separately the material and the artefact, and to interrogate that shifting relationship between them over time. We use hundreds, if not thousands, of plastic products every day, but many of those products include a mix of other materials too, introducing complexity to the material-consumer relationship and limiting our analyses of material-object relationships. Focusing on chairs that use plastic to provide support for the body allows a focused analysis of plastics in design and interrogates our relation with the material.

2. Literature review

Fig. 0.3 (below) represents a summary of the disciplines I engaged with during development of this dissertation. I began by consulting texts on the use of plastics in the furniture industry, focussing on chairs. Chairs, of course, form only a small part of the consumer durables created using plastic. I broadened my research to include the use of plastics in design, investigating its impact on designers and manufacturers. Research in the field of design history helped me to appreciate the changing cultural reception of plastics. As I became increasingly aware of the technical complexities of that material, I found it necessary to investigate the history of the many and varied materials called plastics, focussing on the years immediately following the end of World War II (WWII), when many of the polymers available today were first manufactured. In the twenty-first century, in response to increasing awareness of the environmental impacts of plastics, developments in plastic technologies

[29] Hellman, 418.

have grown to include replacements for fossil-based feedstocks (the base materials from which plastics are composed) in. My assessment of secondary literature then expanded to cover the negative impacts of fossil plastics and the development and application of bioplastics.

Fig. 0.3. Visual representation summarising topics of literature consulted for this study (highlighting major texts).

Another line of enquiry led me to consider the material selection process undertaken by those creating products, with a particular attention to the agency of both designers and manufacturers in relevant decision making. This led to an investigation of the tools available to assist both in the selection of materials and in developing an understanding of the environmental impact of design decisions. I then traced the history of major developments in the eco-design and sustainability to examine impacts on designers and manufacturers working with plastics in furniture. Finally, I reviewed recent developments in design for transition, with a particular focus on the development and application of MLP and its relevance in accelerating technological transitions.

Most design histories of plastics in design build upon design historian Jeffrey Meikle's comprehensive study, *American Plastic*, which traces the development of the industry and its growing acceptance by designers and consumers with a focus on the decades during and after WWII.[30] In a prior publication Meikle illustrated the warm reception afforded to plastics by both designers and consumers in the years following the end of World War II.

> Plastic, its forms and colours proliferating at the very moment the consumer culture was emerging into consciousness, materially embodied that culture and visually distinguished it as unique, as 'something new under the sun.' In the words of a designer who contributed to shaping machine-age products and environments, 'new materials' spoke 'in the vernacular of the twentieth century.[31]

Meikle celebrates the benefits plastics delivered as surplus manufacturing capacity, developed to support the WWII effort, was re-directed to fulfil pent up demands from a war weary and increasingly affluent population, keen to indulge in the shiny offerings of consumerism. But Meikle also exposes the problems of the material; the inexpensive, disposable, poorly made products which quickly earned plastic a reputation as being cheap, inferior, fake, and phony. Within a few decades, plastic began to lose some of its glossy shiny appeal as concerns about the, by this time omnipresent, substance began to surface. Meikle's rich, interdisciplinary investigation charting the rise of plastic and its cultural significance (across theme parks, books, and films among others) demonstrates an encyclopaedic knowledge of the industry, its admirers, and critics. Strangely, while Meikle covered the developmental years of plastics in laborious detail, he only lightly sketched out

[30] Jeffrey Meikle, *American Plastic: A Cultural History* (New Brunswick, N.J: Rutgers University Press, 1995).
[31] Jeffrey Meikle, "Into the Fourth Kingdom: Representations of Plastic Materials, 1920–1950," *Journal of Design History* 5, no. 3 (1992): 175.

the rapid technological advances that occurred during WWII. Throughout (as suggested by its title) his book focused on the American market, almost ignoring industry contributions from Europe or elsewhere. The same criticism can be levelled against its predecessor, Harry DuBois' *Plastic History USA,* which presents a highly detailed examination of the development of the industry focusing on the development of materials and manufacturing technologies but also featuring examples of the ever-growing list of applications developed for the material. In the history of plastics section of this dissertation (Chapter 2), I focus on the Australian context to offer a comparative example of regional modernism to showcase the global ubiquity of plastics in design during and after WWII.

Plastics are widely celebrated for overcoming scarcities of materials following WWII. They were the medium of choice for many popular products, fulfilling needs and creating wants among an ever-growing number of increasingly affluent consumers. But, as film theorist Peter Wollen observed, the development of plastics has also been blamed for producing a deluge of consumer goods, 'heralding a decadent and homogenizing retreat from nature into a nightmare world of artificiality and impermanence.'[32] Writing about plastics in France, linguist Douglas Smith claims plastics as, '"bad" modernity,' enabling a new consumer society to emerge based on mechanised mass production at the expense of the death of the artisanal way of life.[33] French literary theorist Roland Barthes also held negative views toward the material, accusing plastic of abolishing the class structure associated with the hierarchy of traditional materials that shaped the material world.[34] Italian design academic Ezio Manzini agrees, claiming the problem with plastic is it has no character of its

[32] Peter Wollen, "Plastics The Magical and the Prosaic," in *The Warhol Look: Glamour, Style, Fashion* (New York: Little, Brown, 1997), 148.
[33] Douglas Smith, "Le Temps Du Plastique: The Critique of Synthetic Materials in 1950s France," *Modern & Contemporary France* 15, no. 2 (May 1, 2007): 133, https://doi.org/10.1080/09639480701299954.
[34] Roland Barthes and Annette Lavers, *Mythologies*, 47. [print.] (New York, NY: Hill and Wang, 2006), 193–95.

own, an anti-material that assumes the character of other materials, destroying the identity and hierarchy of the material world.[35] Bernadette Vincent credits plastics with generating a deep change in design, and facilitating a new approach to materials.[36] These authors trace how plastics have become embedded in society, culture, and the economy over decades and highlight our constantly shifting and increasingly uneasy relationship with the material. These multiple interpretations of the material make plastic a rich target for further academic investigation. In Chapter 2 I examine the development of the plastics industry in Australia and examine local reactions to the material in the decades after WWII. As will be shown, geography and politics combined to encourage the development of a localised furniture manufacturing industry. While inspired by developments in Europe and America local designers and manufacturers delivered a wide range of uniquely Australian designs, to meet the changing needs and desires of a rapidly growing population.

Plastic's impact on design has been the subject of many historical investigations. For example, the technical properties of plastics and their application in industrial design have been examined by Joseph Gordon, Raymond Guidot, and Richard Thompson among others.[37] Andrea DiNoto and Doug Cleminshaw provide North American focused studies of the use of plastics in consumer products while Sylvia Katz's publications provide the British side of the story of plastics and their progressive use across multiple categories of

[35] Penny Sparke et al., eds., *The Plastics Age: From Modernity to Post-Modernity*, Repr. of the 1990 ed (London: Victoria & Albert Pubns, 1993), 90–91.
[36] Bernadette Bensaude-Vincent, "Plastics, Materials and Dreams of Dematerialization," in *Accumulation: The Material Politics of Plastic* (London: New York: Routledge, Taylor & Francis Group, 2013), 23.
[37] M. Joseph Gordon, *Industrial Design of Plastics Products* (Hoboken, N.J: Wiley-Interscience, 2003); Raymond Guidot, ed., *Industrial Design Techniques and Materials* (Paris: Flammarion, 2006); Richard C. Thompson et al., "Our Plastic Age," *Philosophical Transactions of the Royal Society B: Biological Sciences* 364, no. 1526 (July 27, 2009): 1973–76, https://doi.org/10.1098/rstb.2009.0054.

consumption.[38] Penny Sparke and Tom Fisher offer a European perspective on the broader impact of plastic across many areas of design.[39] Charlotte and Peter Fiell select 120 consumer goods made from plastic to accompany an essay explaining their significance while concisely summarising the history of the material.[40] Eli Rubin published an account of the role of plastics in everyday life behind the wall, in the German Democratic Republic during its isolation from West Germany.[41] And yet, the place of plastics in Australia has been only touched upon. The Australian focus to this study examines the local experience to reveal how local designers and manufacturers interpreted new materials and technologies for a relatively small and remote market.

Taking a wider perspective to consider the cultural impacts of the designed object, Alison Clarke has shown how a simple plastic container came to dominate kitchens across North America and Europe in the years following World War II.[42] Importantly, the food container was clearly made from plastic, with no attempt to conceal the identity of the material. Clarke examines the significance of airtight plastic containers designed to appeal to frugal consumers wanting to prolong the life of leftover food. Tupperware, simple, light, unbreakable polyethylene containers featuring a patented airtight seal and in a range of

[38] Andrea DiNoto and David Arky, eds., *Art Plastic: Designed for Living*, 2. Print (New York, NY: Abbeville Press, 1984); Douglas Cleminshaw, ed., *Design in Plastics: Successful Product Design in Plastics* (Rockport, Mass: Rockport Publishers, 1989); Sylvia Katz, *Classic Plastics: From Bakelite to High-Tech : With a Collector's Guide* (London: Thames and Hudson, 1985); Sylvia Katz, *Plastics: Designs and Materials* (London: Studio Vista, 1978); Sylvia Katz, *Plastics: Common Objects, Classic Designs ; with a Collector's Guide* (New York: H.N. Abrams, 1984).
[39] Penny Sparke, ed., *The Plastics Age: From Bakelite to Beanbags and Beyond* (Woodstock, N.Y: Overlook Press, 1993); Sparke et al., *The Plastics Age*.
[40] Charlotte Fiell and Peter Fiell, *Plastic Dreams: Synthetic Visions in Design* (Chipping Campden, UK: Fiell Publ., 2009).
[41] Eli Rubin, "Plastics and Dictatorship in the German Democratic Republic: Towards an Economic, Consumer, Design and Cultural History" (Ph.D., United States -- Wisconsin, The University of Wisconsin - Madison, 2004), http://search.proquest.com/docview/305110430/abstract/6FB4DFB9032B4696PQ/1; Eli Rubin, *Synthetic Socialism: Plastics & Dictatorship in the German Democratic Republic*, 1. ed (Chapel Hill, NC: Univ. of North Carolina Press, 2008).
[42] Alison J Clarke, *Tupperware: The Promise of Plastic in 1950s America.* (New York: Random House Publisher Services, 2014), https://public.ebookcentral.proquest.com/choice/publicfullrecord.aspx?p=5337861.

fashionable pastel shades, quickly became a highly sought-after symbol of post war abundance. The extraordinary success of the brand was achieved through a carefully crafted sales and marketing strategy that positioned the product as a desirable item or a lavish gift and allowed Tupperware to be sold for a premium, highlighting another plastic paradox.[43] Tupperware not only created a product category but launched an extraordinarily successful, and often copied, pyramid selling scheme that saw women take the leading role in marketing products to friends and associates in the comfort of their own home. The success of this sales approach introduced the hygienic benefits of plastic to kitchen across North America and Europe.

This dissertation is the first study focused specifically on the impact of plastics on seating solutions. A small number of publications focus on selected plastic chairs but none give an overview of the historical development of the category as a whole.[44] My research begins to address this gap by providing an overview of the use of plastics by chair designers from its introduction to the furnishing market (in the late 1930s) to the present day. I examine how plastics have been successfully adapted by the furniture industry to ensure their continued appeal despite changes in social concerns, tastes and fashions.

There are, of course, many texts related to chairs and their designers which, together with general writings on chairs, provide an overview of the cultural and market dynamics that have influenced the development of plastic seating solutions.[45] Together, these studies have

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[43] Clarke, 57.
[44] Brian Lutz, *Knoll: A Modernist Universe* (New York; London: Rizzoli, 2010); Elisa Storace et al., eds., *The Culture of Plastics* (Köln: TASCHEN GmbH, 2012); Arnd Friedrichs and Hajo Eickhoff, eds., *220°C Virus Monobloc: The Infamous Chair* (Berlin: Gestalten, 2010); Storace et al., *The Culture of Plastics*; Morello, and Ferrieri, *Plastic and Design*.
[45] Charlotte Fiell, Peter Fiell, and Angelika Muthesius, *Modern Chairs* (Köln: Benedikt Taschen, 1993); Byars and d'Altoé, *New Chairs*; Nadine Descendre et al., *Pierre Paulin: life and work* (New York: Vendome Press, 2016); Byars and d'Altoé, *New Chairs*; Lucy Ryder Richardson, *100 Midcentury Chairs and Their Stories* (Layton, Utah: Gibbs Smith, 2017); Witold Rybczynski, *Now I Sit Me down: From Klismos to Plastic Chair: A Natural History*

enabled the development of plastic chair designs to be viewed in the context of contemporary designs and developments in other materials. Monographic studies of product designers are useful sources of biographic information on individual designers and help us to an understand period and influences experienced by creators.[46] It must be noted that there is also considerable literature on French and German designer-makers ranging from small craft operations to entrepreneurs, and the chair as folk art or anonymous, vernacular production, which is not the focus here.

Monographic studies often reflect a style of writing that reinforces a particular design canon, often based in connoisseurship. Marilyn and John Neuhart's 2010 study of furniture produced by the Eames Office attempts to address that bias by highlighting the important role of intermediary actors in developing designs for production.[47] The Neuharts conducted in-depth interview with 22 collaborators, colleagues, and employees, many of which are reported verbatim, rewarding readers with a thorough understanding of the valuable contribution made by (often uncredited) actors. That study has been criticised for downplaying the role that Ray Eames played in the realisation of their furniture projects.[48]

(New York: Farrar, Straus and Giroux, 2017); Judith Miller and Nick Pope, *Chairs* (London: Conran Octopus, 2009); Mariana Gosnell, "Everybody Take a Seat," *Smithsonian; Washington*, July 2004; Robert Judson Clark et al., eds., *Design in America: The Cranbrook Vision, 1925-1950* (New York: Abrams, in association with the Detroit Institute of Arts and the Metropolitan Museum of Art, 1983); Richardson, *100 Midcentury Chairs and Their Stories*; Lesley Jackson, *Modern British Furniture: Design since 1945* (London: V&A Publishing, 2013).

[46] Ida Engholm, Anders Michelsen, and Verner Panton, *Verner Panton: Environments, Colours, Systems, Patterns* (London: Phaidon, 2018); Geoff Isaac, *Featherston* (Port Melbourne, Victoria: Thames & Hudson, 2017); "Jean-Pierre Laporte," *Authentic Culture Design* (blog), December 7, 2016, http://www.authenticdesign.fr/2016/12/jean-pierre-laporte/; Jay Osgerby, Edward Barber, and Jana Scholze, *Barber Osgerby: Projects* (London New York: Phaidon, 2017); Ronan Bouroullec and Erwan Bouroullec, *Ronan & Erwan Bouroullec - Drawing* (Ausstellung "A&W Designer of the Year 2013: Ronan & Erwan Bouroullec," Zürich: JRP Ringier, 2013); Joris Laarman et al., *Joris Laarman Lab* (New York: August Editions, 2017); Lutz, *Knoll*; Mats Linder, "Sven Ivar Dysthe," in *Store norske leksikon* (Oslo, March 8, 2020), http://snl.no/Sven_Ivar_Dysthe; Philippe Thomé et al., eds., *Sottsass* (London ; New York: Phaidon Press, 2014); Lesley Jackson, *Robin & Lucienne Day: Pioneers of Contemporary Design* (London: Octopus Pub., 2011).

[47] Marilyn Neuhart and John Neuhart, *The Story of Eames Furniture* (Berlin: Gestalten, 2010).

[48] Alexander Lange, "How Do You Solve a Problem Like the Eameses?," Design Observer, January 17, 2011, http://designobserver.com/feature/how-do-you-solve-a-problem-like-the-eameses/24008.

However, it still makes an important contribution by broadening the spotlight to develop an understanding of the contribution made by the entire team at the Eames Office. In a similar vein, Lesley Jackson's study of Robin & Lucienne Day broadens its focus to include a study of the manufacturer Hille and the contribution of other actors working to support the designers.[49]

Scholarly works on the design and material culture of chairs provide valuable insights into the role of seating technologies in different periods and societies.[50] Those studies focus on how chairs are used and particularly how they instantiate ideologies of social hierarchies. A throne is for sitting but more importantly it projects majestic dignity and inspires awe. Similarly in the office chairs, 'considerable ingenuity' is applied to convey the status of the occupant according to Linda Brown and Deyan Sudjic.[51] The Fiells highlight the significance of the chair as a barometer of social change and how seating habits have shifted over time.[52] While Jennifer Kaufmann-Buhler examines how, in addition to hierarchical differences between workers, chairs also reflect and reproduce gendered difference.[53] Galen Cranz highlights the clear distinction between bosses' and secretarial chairs still clearly apparent at

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[49] Jackson, *Robin & Lucienne Day*.

[50] Amy Hudson Henderson, "Material Matters: Reading the Chairs of the Republican Court," *Journal of the Early Republic; Indianapolis* 35, no. 2 (Summer 2015): 287–94; Susan Elmslie, "The Seat of Conflict: Design, Domesticity, and Material Culture in Marion Quednau's The Butterly Chair," *Essays on Canadian Writing; Toronto*, no. 68 (Summer 1999): 107–33; Dariusz Gafijczuk, "Bending Modernity: Chairs, Psychoanalysis and the Rest of Culture," *Journal of Historical Sociology* 22, no. 4 (December 1, 2009): 447–75, https://doi.org/10.1111/j.1467-6443.2009.01365.x; Judy Attfield, "'Give 'Em Something Dark and Heavy': The Role of Design in the Material Culture of Popular British Furniture, 1939-1965," *Journal of Design History* 9, no. 3 (1996): 185–201; Kristina Wilson, "Like A 'Girl in a Bikini Suit' and Other Stories: The Herman Miller Furniture Company, Gender and Race at Mid-Century," *Journal of Design History* 28, no. 2 (May 1, 2015): 161–81, https://doi.org/10.1093/jdh/epv006; Chun Tung Chen, "A Study of Design Demand of Applying Quality Function Deployment in Plastic Folding Chairs," *Applied Mechanics and Materials; Zurich* 284–287 (January 2013): 3632, http://dx.doi.org.ezproxy.lib.uts.edu.au/10.4028/www.scientific.net/AMM.284-287.3632.

[51] Linda Brown and Deyan Sudjic, eds., *Metropolis: New British Architecture and the City ; Exhibition Catalogue* (London: London Topographical Soc, 1988), A1.

[52] Fiell, Fiell, and Muthesius, *Modern Chairs*.

[53] Jennifer Kaufmann-Buhler, "If the Chair Fits: Sexism in American Office Furniture Design," *Journal of Design History* 32, no. 4 (December 6, 2019): 375, https://doi.org/10.1093/jdh/epz022.

the end of the twentieth century.[54] While my study only touches upon the subject of chairs as social objects, it does raise the fundamental questions around the critical social crises of our time by investigating how plastic chairs can contribute to, or lessen our impact on the environment.

From the late 1960s, awareness around issues of ecology and environmental degradation began to increase. *The Whole Earth Catalogue* commenced publication in 1969, followed by Buckminster Fuller's *Operating Manual for Spaceship Earth*. Victor Papanek's *Design for the Real World: Human Ecology and Social Change* was published in 1971, and the *Limits to Growth* the following year.[55] These titles were among a flurry of publications that drew the attention of end-users and designers to the environmental impacts of linear consumption models (where materials are transformed into products that are used until they are discarded as waste). Papanek's work is particularly significant in igniting debate about design's responsibilities toward sustainability. The need to harmonise our relationship with nature became an increasing concern.[56] A growing unease around the use of chemicals for plastics gained momentum after the publication of Rachel Carson's *Silent Spring* (1962). This was exacerbated by rising environmental concerns, prompting a dramatic reassessment of our relationship with plastics—a topic examined in more detail in Chapter 2 of this dissertation.[57]

54 Cranz, *The Chair*, 58.

55 Richard Buckminster Fuller and Jaime Snyder, *Operating Manual for Spaceship Earth*, New ed (Baden: Müller, 2013); Victor J. Papanek, *Design for the Real World: Human Ecology and Social Change*, 2nd ed., completely rev (Chicago, Ill: Academy Chicago, 1971); Donella Meadows et al., *The Limits to Growth* (New York: Universe Books, 1972), https://www.clubofrome.org/publication/the-limits-to-growth/ Stewart Brand published the Whole Earth Catalog regularly between 1968 and 1971 and occasionally until 1998.

56 For more on the relationship between designers and environmental movements see: Simon Sadler, "Design's Ecological Operating Environments," in *The Culture of Nature in the History of Design* (Abingdon, Oxon; New York, NY: Routledge, Taylor & Francis Group, 2019), 19–30.

57 Rachel Carson, *Silent Spring*, 40th anniversary ed., 1st Mariner Books ed (Boston: Houghton Mifflin, 2002).

Plastics briefly fell from favour among leading furniture designers of the day throughout the 1970s and well into the 90s. The celebration of brightly coloured, glossy, lustrous surfaces of mid-century designs gave way to more austere finishes. Traditional materials and finishes were revived, with plastics relegated to a supporting role, often out of sight. The popularity of plastic furniture recovered toward the end of the twentieth century as designers experimented with new materials and new manufacturing technologies. Throughout the twentieth century manufacturers focused on improving the efficiency of manufacturing processes, which happily coincided with any altruistic environmental motivations a designer (or end-users) may have held. Paul Burall's *Product Development and the Environment*, reflects the thinking of the day, claiming environmentally-responsible product design as being in-line with managerial objectives, with both seeking the most efficient use of resources.[58] More recently, Cameron Tonkinwise observed, 'sustainable design is then often an exercise in technocratic incremental performance eco-impact improvement.'[59] This observation summarises late twentieth century developments in the plastic chair market, where new materials combined with incremental improvements to production technologies delivered significant savings in both material and energy consumption but failed to address the underlying challenges of developing a sustainable consumption model.

Much research has been undertaken related to design for sustainability[60] and there are increasingly urgent calls for design-led societal change.[61] Scholars are increasingly

[58] Paul Burall, *Product Development and the Environment* (Brookfield, Vt: Gower, 1996).
[59] Cameron Tonkinwise, "Environments, Natures and Social Theory: Towards a Critical Hybridity," *Journal of Design History* 29, no. 3 (September 2016): 312, https://doi.org/10.1093/jdh/epw031.
[60] For a summary of the main developments in the evolution of DfS subject: Fabrizio Ceschin and Idil Gaziulusoy, "Evolution of Design for Sustainability: From Product Design to Design for System Innovations and Transitions," *Design Studies* 47 (November 1, 2016): 118–63, https://doi.org/10.1016/j.destud.2016.09.002; A

concerned with the role and responsibilities of designers in guiding us toward a more sustainable future.[62] The emphasis of academic endeavour has shifted to focus on design as a tool to bring about social change, rather than simply aiming to create more artefacts with fewer resources. The focus has expanded from the production processes to include patterns of consumption and equitable access to goods and services. In 2019, UK-based design academic Fabrizio Ceschin and Finnish design professor Idil Gaziulusoy published a diagram summarising the shifting focus of academic inquiry into design for sustainability (DfS) (fig. 0.4). In the twenty-first century the field has, 'broadened its theoretical and practical scope, gradually expanding its focus from the individual elements of products to product life cycles, PSSs [Product Service Systems] and, finally, on socio-technical system innovations.'[63]

Fabrizio Ceschin and İdil Gaziulusoy, *Design for Sustainability* (London: Routledge, Taylor & Francis Group, 2019), https://doi.org/10.4324/9780429456510.

[61] Tony Fry, *A New Design Philosophy: An Introduction to Defuturing* (Sydney: UNSW Press, 1999); Tony Fry, *Design Futuring: Sustainability, Ethics, and New Practice*, English ed (Oxford ; New York: Berg, 2009); Tony Fry and Adam Nocek, *Design in Crisis | Taylor & Francis Group*, 2021, http://www.taylorfrancis.com/books/design-crisis-tony-fry-adam-nocek/e/10.4324/9781003021469; Terry Irwin, "Transition Design: A Proposal for a New Area of Design Practice, Study, and Research," *Design and Culture* 7, no. 2 (April 3, 2015): 229–46, https://doi.org/10.1080/17547075.2015.1051829; Gideon Kossoff, Cameron Tonkinwise, and Terry Irwin, "Transition Design: The Importance of Everyday Life and Lifestyles as a Leverage Point for Sustainability Transitions" (STRN Conference, Sussex, 2015), 25; Tonkinwise, "Environments, Natures and Social Theory"; Cameron Tonkinwise, Gideon Kossoff, and Terry Irwin, "Transition Design Provocation," *Design Philosophy Papers,* 13, no. 1 (2015): 3–11.

[62] Fry, *Design Futuring*; Kossoff, Tonkinwise, and Irwin, "Transition Design: The Importance of Everyday Life and Lifestyles as a Leverage Point for Sustainability Transitions"; Terry Irwin and Gideon Kossoff, "2017 Transition Design Seminar Syllabus" (Carnegie Mellon University, 2017), https://www.academia.edu/30968703/2017_Transition_Design_Seminar_syllabus.pdf; Ezio Manzini, "New Design Knowledge," *Design Studies* 30, no. 1 (January 1, 2009): 4–12, https://doi.org/10.1016/j.destud.2008.10.001; İdil Gaziulusoy, "Postcards From the Edge: Toward Futures of Design for Sustainability Transitions," *Centro de Estudios En Diseño y Comunicación*, no. 73 (July 2019): 67–84; Jan Pieter Joore, "New to Improve – The Mutual Influence between New Products and Societal Change Processes" (PhD, Netherlands, Delft University of Technology, 2010); Dan Lockton, "Transition Lenses: Perspectives on Futures, Models and Agency" (Transition Design Symposium: Can Design Catalyse the Great Transition?, Schumacher College, Dartington, Devon, 2016), https://www.researchgate.net/publication/303372720_Transition_Lenses_Perspectives_on_futures_models_and_agency.

[63] Ceschin and Gaziulusoy, *Design for Sustainability*, 149.

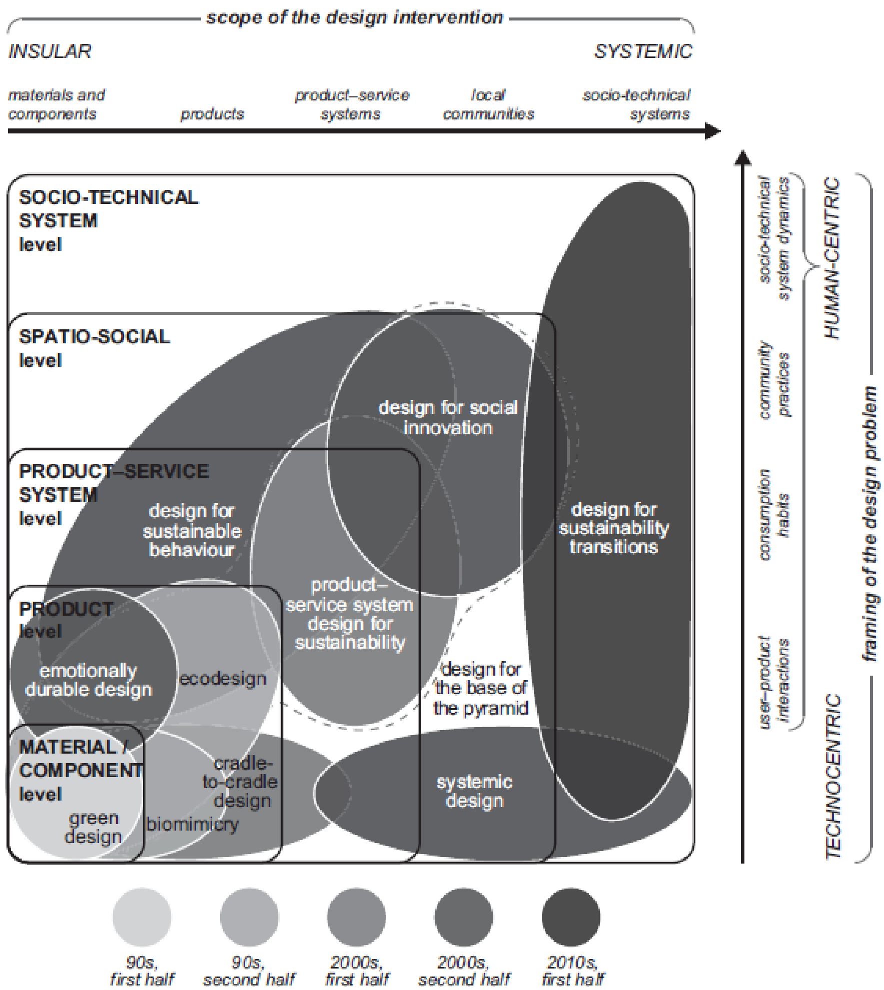

Fig. 0.4. Evolution of the Design for Sustainability field.
Source: Ceschin & Gaziulusoy (2019)[64]

The diagram above by Ceschin & Gaziulusoy (fig. 0.4) shows that green design, introduced in the early 1990s, with short term goals focused on improving the environmental profiles of individual products with a focus on materials. In the late 1990s design researchers looked to nature as a source of inspiration to address environmental sustainability. Cradle-to-cradle design emphasised designing products and systems based on biodegradable materials or recyclable/reusable materials. Products are designed to be disassembled and safely returned to the soil as biological nutrients, or materials re-used for new products. A

[64] Ceschin and Gaziulusoy, 149.

second approach, biomimicry, seeks inspiration from the natural environment to solve structural design challenges.[65]

By the end of the decade, the entire life cycle impacts of products began to be considered by those interested in the sustainability of their work. This approach recognised that the environmental impacts of many products (especially those that consume energy during use) must be calculated throughout the production, use and/or disposal of a product. Complimentary theories began to emerge including emotionally durable design, aimed at strengthening and extending the emotional product/user bond, with the aim of extending a product's life.[66]

Those technocentric theories focus on materials, products, and how they are used, with a move to sustainability described as technical challenge (for example, improving energy and material efficiency). They are directly relevant to the everyday work of environmentally conscious product designers. Throughout this period, as Ann Thorpe observed, neither policy makers nor designers were concerned with lifestyle, 'rather they were seeking less resource intensive production and consumption methods to facilitate existing lifestyles.'[67] By the end of the century, however, it became increasingly apparent that technocentric theories are unable to compensate for the continually increasing demand from a global economy addicted to limitless growth.

Fig. 0.4 shows the theories that have emerged during the early ears of this century, increasing directed toward system-level changes. Those theories are aimed at influencing consumer behaviour, community engagement or even entire shifts in prevailing socio-

[65] Ceschin and Gaziulusoy, 150.
[66] Ceschin and Gaziulusoy, 150.
[67] Ann Thorpe, "Design's Role in Sustainable Consumption," *Design Issues* 26, no. 2 (2010): 4.

technical regimes, promoting changes to how societal needs are fulfilled. Their direct relevance to the daily work of product designers working on artefacts such as chairs is less apparent, however. For example, design for sustainable behaviour, focuses on influencing users to adopt desired sustainable behaviours while using the product, not particularly relevant to the designers of chairs, or any product where production accounts for most of their environmental impact.

Product-service systems (PSS) have greater potential to significantly impact the way products are manufactured and consumed. PSS, 'shifts the business focus from designing (and selling) physical products only, to designing (and selling) a system of products and services which are jointly capable of fulfilling specific client demands.'[68] PSS redirects attention from a focus on the development of an artefact alone to develop a wider system offering both products and services which better satisfy consumer needs, potentially reducing the consumption of resources.

Importantly, PSS implies that ownership remains with the manufacturer of the product, thereby rewarding the development of robust long-lasting objects that and can be easily repaired, remade, or recycled rather than incentivising rapid replacement of products to drive turnover. PSS represents a radical shift from the production consumption model therefore, it is perhaps not surprising that the furniture industry is yet to launch any PSS solutions. Only one of the manufacturers included in this study reported any interest in the concept and they are yet to develop a lease-based solution. Due to this lack of interest from the furniture industry PSS was deemed irrelevant to this study. Reluctance from business to

[68] E. Manzini and C. Vezzoli, "A Strategic Design Approach to Develop Sustainable Product Service Systems: Examples Taken from the 'Environmentally Friendly Innovation' Italian Prize," *Journal of Cleaner Production*, Product Service Systems and Sustainable Consumption, 11, no. 8 (December 1, 2003): 861, https://doi.org/10.1016/S0959-6526(02)00153-1.

relinquish ownership combined with the financial implications present significant barriers to furniture manufacturers interested in pursuing PSS.[69]

In 2009, the concept of planetary boundaries marking precautionary limits for critical system processes that regulate the stability of the planet was introduced by Rockström et al.[70] At least four of these boundaries have now been crossed, including climate change, considered as one of the two 'core' PBs.[71] With climate change recognised as a core boundary, the significance of the environmental dimension of sustainability is highlighted. UK-based economist Kate Raworth developed planetary boundaries to introduce the concept of *Doughnut Economics,* outlining seven concepts to guide twenty-first century economists.[72] Raworth proposes a shift from the historic focus on gross domestic product growth, primarily benefiting 1% of the population, to goals designed to ensure, 'that no one falls short on life's essentials.[73] These publications helped reignite criticism of the prevalent growth-oriented economic paradigm.

In response, design for sustainable transition theories are emerging, explaining how innovation in socio-technical systems occur.[74] Adrian Smith observed that the focus of academic enquiry has shifted up to the regime level, and analysed the rules and norms that

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[69] In an example from a related industry, Interface introduced an Evergreen lease to make carpet available for lease but take-up has been low primarily due to financial considerations. Fabrizio Ceschin, "The Introduction and Scaling up of Sustainable Product-Service Systems. A New Role for Strategic Design for Sustainability." (PhD., Politecnico di Milano, 2012), 132, https://www.politesi.polimi.it/handle/10589/56785?mode=full&submit_simple=Show+full+thesis+record.
[70] Johan Rockström, "A Safe Operating Space for Humanity," *Nature* 461, no. 7263 (September 24, 2009): 472–75, http://dx.doi.org.ezproxy.lib.uts.edu.au/10.1038/461472a.
[71] The 4 PBs already exceeded are: climate change, biosphere integrity, biogeochemical flows, and land-system change. Biosphere integrity is the other core boundary. Will Steffen et al., "Planetary Boundaries: Guiding Human Development on a Changing Planet," *Science* 347, no. 6223 (February 13, 2015), https://doi.org/10.1126/science.1259855.
[72] Kate Raworth, "Why It's Time for Doughnut Economics," *IPPR Progressive Review* 24, no. 3 (2017): 216–22, https://doi.org/10.1111/newe.12058; Kate Raworth, *Doughnut Economics: Seven Ways to Think like a 21st-Century Economist*, Paperback edition (London: Random House Business Books, 2018).
[73] Raworth, "Why It's Time for Doughnut Economics," 219.
[74] Ceschin and Gaziulusoy, *Design for Sustainability*, 125.

frame the innovation and diffusion of technologies.[75] The realisation that we must embark on a great transition, whereby humanity adjusts to living within the limits of the planet, is gaining momentum. Systems need transforming so they are responsive to environmental signals and ecological principles.[76] The theories developed to address these issues involve a network of actors that extends well beyond the manufacturers and designers required to implement product level theories, thereby introducing the socially and culturally complex requirement of networking sustainable innovations.[77]

Escobar observed that transition discourses share the 'contention that we need to step outside existing institutional and epistemic boundaries if we truly want to strive for worlds and practices capable of bringing about the significant transformations seen as needed.'[78] A radical cultural and institutional transformation is required to transition to an altogether different world. Similarly, Tony Fry and Adam Nocek argue that transition cannot be achieved if design limits 'itself to changing the patterns of human consumption, to altering supply chains, or to sourcing biodegradable material.'[79] While Geels et al. claim transition studies should 'focus on transforming entire technology regimes, rather than separately analysing and prompting specific artefacts or practices.'[80] The important role that design, in its broadest sense, can play in transitions is increasing emphasised by these writers. Designers, design the world around us, from those involved with development of government policy to the end user interface on a smartphone app, guiding the actions of the

[75] Adrian Smith, "Transforming Technological Regimes for Sustainable Development: A Role for Alternative Technology Niches?," *Science & Public Policy (SPP)* 30, no. 2 (April 2003): 127, https://doi.org/10.3152/147154303781780623.
[76] Boelie Elzen, *System Innovation and the Transition to Sustainability Theory, Evidence and Policy* (Cheltenham, UK; Northampton, MA, USA: Edward Eldgar, 2004), 50.
[77] Escobar, *Designs for the Pluriverse*, 123.
[78] Escobar, 39.
[79] Fry and Nocek, *Design in Crisis | Taylor & Francis Group*, 3.
[80] Boelie Elzen, Frank W. Geels, and Kenneth Green, eds., *System Innovation and the Transition to Sustainability: Theory, Evidence and Policy* (Cheltenham, UK; Northampton, MA, USA: Edward Elgar, 2004), 50.

user while promoting engagement with the app. This does not imply the designer is the only decision maker; policy only becomes law with the support of elected representatives, end-user interfaces only go live when the goals of the app developers are satisfied.

Theories aimed at system-level change often place emphasis on the need for a clearly articulated visualisation of the future post-transition. This requires 'guiding visions' to be established, setting the direction of change, and mapping a path toward a more sustainable solution.[81] While establishing a clearly articulated and commonly agreed direction is desirable, practitioners also need guidance to find and follow the pathway toward that vision. At the product level, which combinations of materials, manufacturing technologies, transport, and end-of-life solutions deliver more sustainable outcomes? More specifically, without evaluating the lifecycle impact of products made from recycled plastics and bioplastics in products, including their market reception, how can designers know which combinations of materials and manufacturing technologies are less harmful to the environment? My study attempts to address this gap by analysing recent experiments with renewable plastics to make chairs. In developing a tool to examine the environmental profiles of these chairs I aim to provide designers and manufacturers with clear guidance on working with these materials in more sustainable ways.

Without this information, system-level theories are of little use to individual designers or manufacturers who feel the moral responsibility to develop more sustainable products but are faced with frequent, pressing design decisions. This is, perhaps, best illustrated by the response Philippe Starck gave when I asked him for his thoughts on recent theories (Design for Sustainability Transitions or Transition Design) in an interview conducted for this study:

[81] Johan Schot and Frank W. Geels, "Strategic Niche Management and Sustainable Innovation Journeys: Theory, Findings, Research Agenda, and Policy," *Technology Analysis & Strategic Management* 20, no. 5 (September 1, 2008): 537–54, https://doi.org/10.1080/09537320802292651.

> This is a joke. It's really, because there is no theory for me of this type. We have just to do what we have to do and try to make the best time without any rules. It's a war; it's the war for ecology… It's a war for less; it's the war for affordable price. The duty of the designer is to work for ecology and saving energy. The duty of manufacturer is the same and the duty for people for consumer is to buy this type of product that is all. There is nothing more complicated.[82]

Starck's comments reflect an emphasis on technocentric solutionism, the idea that social problems can be solved by technology. While this opinion may appear out-dated to some readers it is indicative of the practical priorities of working designers faced with making decisions daily. Design is practice-based, while transitions are theory-based. It is also worth noting that Ceschin & Gaziulusoy recognise that design for sustainability approaches aimed at the product level are no less important than those designed to deliver system-level change.[83] In an earlier work, Gaziulusoy reported that theory and concepts of system innovation were found to be too complex and deemed not useful by those who design and develop products.[84] While practitioners may want to play their part in the move toward a more sustainable future they want and need practical guidance on where to transition to and how to get there. This study aims to address these needs by providing a tool to guide the development of more sustainable plastic chairs and identifying strategies to promote the use of renewable carbon plastics in design more generally.

As illustrated in fig. 0.4, the links between theories describing design interventions aimed at the product level often do not align, or have clearly defined relationships with those aimed at the socio-technical level. One theory attempting to address this issue is the multi-level perspective (MLP) developed to understand how sustainable innovations emerge and

[82] Geoff Isaac, Interview with Philippe Starck, May 24, 2021.
[83] Ceschin and Gaziulusoy, *Design for Sustainability*, 147.
[84] İdil Gaziulusoy, "System Innovation for Sustainability: A Scenario Method and a Workshop Process for Product Development Teams" (PhD, The University of Auckland, 2010), 45, https://www.academia.edu/444370/System_Innovation_for_Sustainability_A_Scenario_Method_and_a_Workshop_Process_for_Product_Development_Teams_PhD_Thesis_.

how these can be developed to replace, transform, or reconfigure existing systems. The theory was originally developed in 1988 by Arie Rip and René Kemp and refined by Frank Geels and Johan Schot as a model to understand the diffusion of technology.[85] My interest is in evaluating MLP as a predictive tool that can assist those interested in driving the take of renewable plastics, by recognising and creating market conditions that favour their acceptance.[86] MLP is an interdisciplinary model. It recognises that technological transitions (major, long-term technological changes in the way societal functions are fulfilled)[87] do not result from technological innovations alone but require changes in, 'user practices, regulations, industrial networks, infrastructure, and symbolic meaning or culture.'[88] Such changes are usually slow, unfolding over decades. Significantly, MLP provides a bridge between evolutionary economics and technology studies. It acknowledges that society-level changes, while desirable, are beyond the influence of individuals or individual organisations. However, MLP operates above the level of individual technocentric improvements by seeking to scale up and scale out successful experiments with environmentally superior product, and thus influence technological regime change. This raises an important question: how can activities at product development level be related to the change that needs to take place at the wider societal level?[89] In response to this, I have applied MLP theory to examine how the knowledge and skills acquired by actors involved with the development of the 32 niche

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[85] Rene Kemp and Arie Rip, "Technological Change," in *Human Choice and Climate Change*, vol. 1 (Ohio: Battelle Press, 1988), 327–99; Schot and Geels, "Strategic Niche Management and Sustainable Innovation Journeys."

[86] Arnoud van Waes et al., "Business Model Innovation and Socio-Technical Transitions. A New Prospective Framework with an Application to Bike Sharing," *Journal of Cleaner Production* 195 (September 10, 2018): 1300–1312, https://doi.org/10.1016/j.jclepro.2018.05.223 "Only few studies have adopted a prospective lens regarding the future upscaling potential of niche innovations."

[87] Frank W. Geels, *Technological Transitions and System Innovations: A Co-Evolutionary and Socio-Technical Analysis* (Cheltenham, UK: Edward Elgar Publishing, 2005), 1257.

[88] Frank W. Geels, "Technological Transitions as Evolutionary Reconfiguration Processes: A Multi-Level Perspective and a Case-Study," *Research Policy*, NELSON + WINTER + 20, 31, no. 8 (December 1, 2002): 1257, https://doi.org/10.1016/S0048-7333(02)00062-8.

[89] Gaziulusoy, "System Innovation for Sustainability," 3.

experimental designs for chairs made with renewable plastics can be scaled-out and scaled-up to drive system level change and accelerate the shift away from virgin fossil plastics.

The ever increasing uses of plastics, and the waste issues created by its disposal, have been accompanied by an increase in the body of work examining the environmental impacts of the material and its contribution to global warming and the climate emergency.[90] Susan Freinkel traced both the rise of plastic in consumer culture while examining its detrimental impacts on our environment and health.[91] Freinkel's work highlighted the growing downstream impacts of plastic recorded in many thousands of academic papers.[92] In 2013, a collection of interdisciplinary essays examined plastics in action, the politics of plastic and the devastating consequences resulting from both the production and disposal of the material, highlighting the multiple dimensions of the emerging plastic crisis, particularly upstream environmental justice issues.[93] A 2017 paper investigating the fate of all the plastics ever made has been often cited, helping to broaden the debate about the end-of-life impact of the material.[94]

Few studies have investigated the potential of integrating production more tightly with other parts of the plastic life cycle, for example through improved design choices as explored by the Ellen McArthur Foundation.[95] An analysis of more than 180 articles conducted by the political scientist Tobias Nielsen found that academics engaged with the

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[90] Jiajia Zheng and Sangwon Suh, "Strategies to Reduce the Global Carbon Footprint of Plastics | Nature Climate Change," *Nature Climate Change*, no. 9 (April 2019): 374–78; Ellen McArthur Foundation, "The New Plastics Economy."
[91] Susan Freinkel, *Plastic: A Toxic Love Story* (Melbourne, Vic: Text Publishing, 2011).
[92] For example, this paper summarises 180 papers covering the lifecycle of plastics highlighting the academic focus given to pollution and waste problems caused by the material. Nielsen et al., "Politics and the Plastic Crisis."
[93] Gabrys, Hawkins, and Michael, *Accumulation*.
[94] Roland Geyer, Jenna R. Jambeck, and Kara Lavender Law, "Production, Use, and Fate of All Plastics Ever Made," *Science Advances* 3, no. 7 (July 1, 2017): e1700782, https://doi.org/10.1126/sciadv.1700782.
[95] Ellen McArthur Foundation, "New Plastics Economy - The Future Of Plastics" (Cowes, 2017), https://www.newplasticseconomy.org/.

natural sciences and engineering, 'are heavily represented in the upstream, production-oriented literature, dealing mainly with technical concerns,' while research by social scientists focuses downstream on consumption and waste. He goes on to suggest that, 'if social scientists were encouraged to look further upstream, we might also note an increasing politicization of plastic production in the future.'[96] Nielsen concluded:

> In general, the scientific literature on plastics pays too little attention to how the material properties of plastic are inextricably bound up with our dominant systems of production and consumption, thus facilitating and maintaining societies of disposability and overconsumption.[97]

Nielsen's observations still apply to the relatively new field of transition studies. Energy is often the primary focus of studies designed to map a course to a more sustainable society. Certainly, MLP has been applied to the energy regime far more frequently than plastics.[98] Focusing on energy and transport alone is insufficient to deliver the savings needed to reach global emissions targets. Chemical production is set to become the single largest driver of growth in global oil consumption by 2030.[99] While energy and transport regimes have access to technologies that can enable them to decarbonise, the petrochemical industry remains dependent on consuming ever increasing quantities of fossil fuels. It is not possible to decarbonise organic chemistry; nearly all plastics are made from carbon, a fact that demands our urgent attention. This study aims to contribute toward this imbalance, focusing attention

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[96] Nielsen et al., "Politics and the Plastic Crisis," 13.
[97] Nielsen et al., 13.
[98] A systematic search of the Scopus database conducted on 18/8/2021 returned 188 results for the search string: TITLE-ABS-KEY ("multi level perspective" AND energy) while TITLE-ABS-KEY ("multi level perspective" AND (plastic OR plastics)) returned only 5 results. Jochen Markard, Rob Raven, and Bernhard Truffer, "Sustainability Transitions: An Emerging Field of Research and Its Prospects," *Research Policy*, Special Section on Sustainability Transitions, 41, no. 6 (July 1, 2012): 961, https://doi.org/10.1016/j.respol.2012.02.013 Found: .'Sustainability challenges in the energy sector and the large variety of new technologies that have emerged here in recent years (e.g., renewable energy sources such as solar, wind, and biomass) represent by far the most dominant topic (36% of all papers), followed by studies on transportation (8%), water and sanitation (7%), and food (3%).
[99] Nova Institute, "The Future of the Chemical and Plastics Industry," 7.

on the need to address the plastics crisis upstream and contributing to developing a pathway to guide the transition to more sustainable materials.

While there is an increasing body of work focusing on design for transition, few studies have focused on how such change actually manifests, or identified the areas of research required. What does it really take to shift design and manufacturing practices, at scale, across complex supply chains? This study focuses on plastic chairs to examine the decision-making roles undertaken by in-house or independent designers and manufacturers when guiding everyday design decisions that impact environmental outcomes. As such I attempt to go 'beyond the canon,' by considering the role of all actors representing technology, innovation, design, and commerce as their roles entwine while developing new products. I identify strategies that progressive front-line actors can adopt to guiding system innovations and socio-technical transitions toward a more sustainable relationship with plastics. Designers and manufacturers must confront the facts that continued growth of fossil plastic manufacture is both undesirable and unsustainable and threatens our very existence. I aim to provide a blueprint for how designers working with plastics can use their influence to design a more sustainable future.

3. Methodology

I have combined several quantitative and qualitative methods to examine the role product designers and furniture manufacturers can take in guiding more sustainable solutions when working with plastics. To investigate the 80-year history of the plastic chair, I developed a database of 130 selected chair designs representing major developments in the industry (fig. 0.5). The database was supplemented with archival research to develop an analytical account of the shifting cultural reception afforded to plastics. A series of 27 interviews with designers and other actors involved with the development of selected chair design were conducted to inform a series of case studies which became the primary focus of this study. I developed a simplified eco-audit tool to quantify a comparison of the environmental profiles of recent chairs designed using renewable plastics. Having identified designs that have achieved lower environmental impacts I applied the framework of MLP to theorise the role of sustainably-minded designers and manufacturers in accelerating the transition to renewable plastics. This study is then premised upon critical analysis of materials drawn from primary and secondary sources, including archival research, interviews, site visits, image, and object analysis, explained in more detail below.

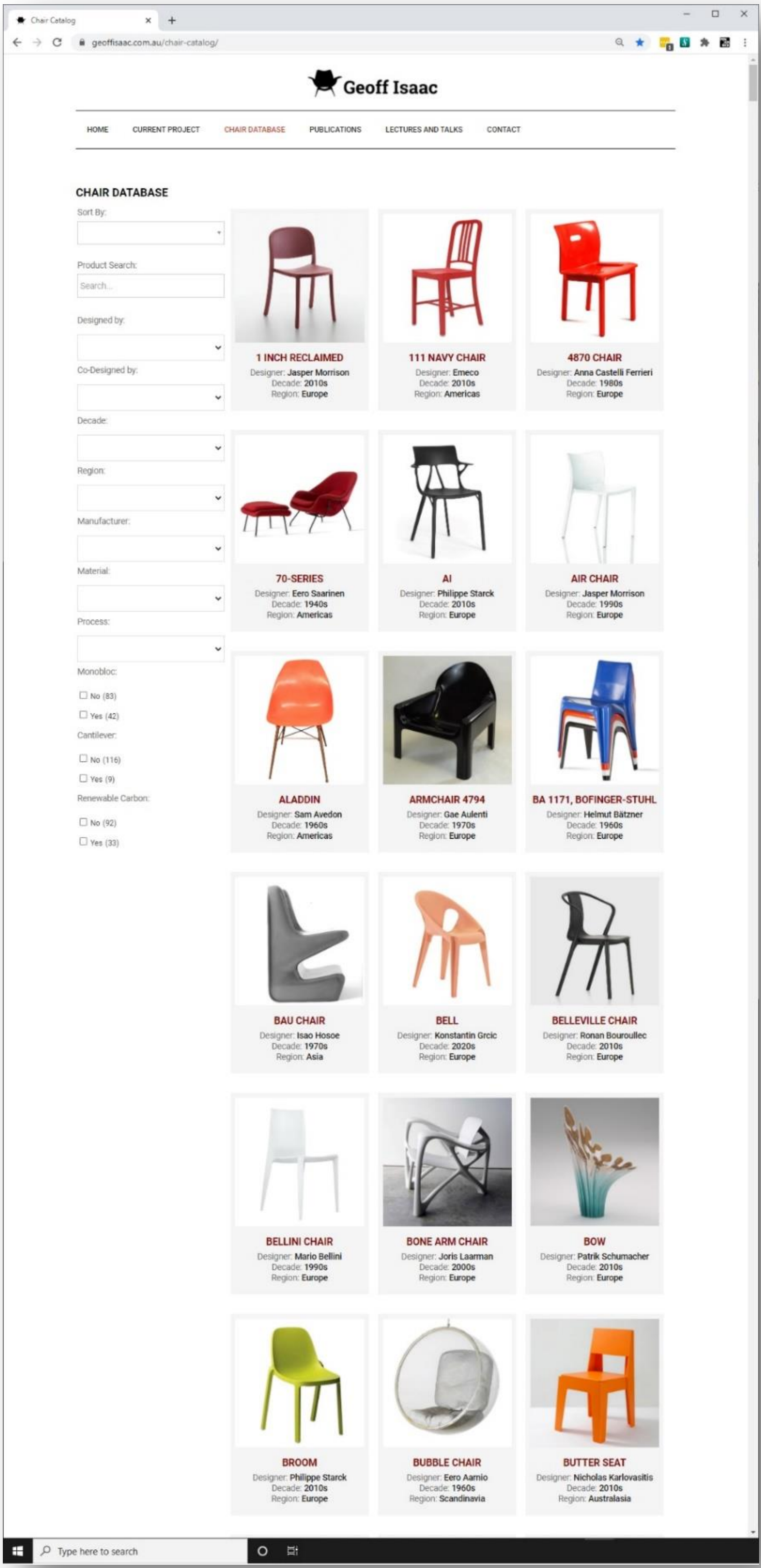

Fig. 0.5. Landing page for the plastic chair database at GeoffIsaac.com.au/chair-catalog

a. Database

The database is made up of 100 designs providing an overview of the plastic chair from its first appearance (in 1939) until 2020 and includes an additional 30 designs made from renewable plastics (the landing page for the database is shown in fig. 0.5 above).[100]

Fig. 0.6. Requirement for a plastic chair to be considered for inclusion in the chair database.

To be eligible for inclusion in this database the design must rely on plastic to provide support for the sitter – the legs and/or the seat and back of the chair must be made from plastic (see fig. 0.6). Hence, a chair comprising of a plastic shell resting on metal legs could be included in the database while a design completely covered in plastic, while relying on another material to provide support would not qualify. Similarly, office chairs dependent on metal frames to provide support (such as the Aeron) do not qualify for inclusion. Only designs that are (or were) commercially available are included in the database. One-off

[100] The database can be viewed at https://geoffisaac.com.au/chair-catalog

proof-of-concept pieces and other prototypes are also excluded.[101] The database can be searched by various criteria, including designer, manufacture, geographic region, and material type.

The database is not intended to be a catalogue raisonné of plastic chairs (of which there are many thousands). Database entries reserved for designs that incorporate advances in technology—the introduction of a new material or manufacturing technique. Chairs noteworthy for originality of design or for outstanding commercial success have also been included. While many chairs featured in this study are credited to designers who enjoy heroic celebrity status, entries are not restricted to 'good design,' based on modern aesthetic principles. The database also includes mundane designs often found in homes and places of work around the world.[102] Many of the older designs featured in this database have acquired iconic status over the years since first produced and made an undeniable impact through both their commercial success and the inspiration provided to others that followed. Others designs remain relatively unknown or are yet to have their cultural significance tested.

No such database can claim to be definitive. The list of entries has evolved over a period of at least four years with iterations shared with selected research participants (see interview section below) who were invited to contribute by suggesting designs they considered significant and not included in the database. This adaptation of snowball sampling or chain referral sampling, used by market research professionals, exploits the knowledge of the targeted research participant to make suggestions for additional

[101] There is one exception to this rule – a monobloc prototype designed by Donahue and Simpson has been included, despite not ever having been produced due to its historical significance – see Chapter 1.
[102] Jennifer Kaufmann-Buhler, Victoria Rose Pass, and Christopher S Wilson, eds., *Design History beyond the Canon* (London: Bloomsbury Publishing, 2019), 10. In which the authors claim modernism has been canonized though the heroic narratives of white European and American men masking complexities of taste and enshrining Modern design as "good" design.

research—in this case the focus was on objects for research rather than identifying additional participants.

For each design, a detailed record of the chair, together with details of its designer(s) has been created. Research notes have been added to each entry highlighting the main significance of the design (use of new materials or technologies etc.). Background information on the designer, their inspirations for this project, development of the project, and production processes has also been added. Attention has been given to ensure consistent terminology has been used to simplify analysis relating to materials and processes. Researching the information required for this database demanded that I learn about the designers selected for interview. Interrogation of the database yielded the information needed to develop the first two chapters of this dissertation tracing the historical development of the plastic chair, with a particular focus on the Australian market in Chapter 2. Additionally, the database includes the 32 chairs from the 21st century that incorporate renewable plastics. Those 32 chairs are the focus of enquiry for the remaining six chapters of the dissertation.[103]

The database (and hence this study) is inevitably biased, both geographically and demographically. Women are rarely credited as the lead designer (5 cases) and are nominated as a co-designer in only a handful more cases (7). Entries are biased toward American and European (including Scandinavian) designs. However, this geographic bias is reflective of the one-world Global North dominant forms of modernity which prevailed

[103] Recent chair designs were sourced from the Salon del Mobile (where major manufacturers traditionally launch new furniture designs) and Dezeen (modestly self-described as, 'the world's most influential architecture, interiors and design magazine'), which regularly features furniture designs promoted as sustainable.

throughout the second half of the twentieth century.[104] Indeed, the *Vitra Atlas of Furniture Design* features 1,740 objects drawn from their collection reports a similar bias. The world's largest collection of chairs largely, 'stems from cultures in Europe and America, mainly from the United States, Italy, Germany, and Scandinavia.'[105]

b. Archival research

To date there has been no study specifically focussed on the development of the plastic furniture industry in Australia. To examine the cultural reception afforded to plastic with particular focus on the furniture market in Australia I conducted a review of relevant local magazines and periodicals. Mass media publications reflect the, 'history, ideology and subjective experiences' of their time.[106] With no digitalised versions available I undertook a manual search of the two leading homemaker titles, *Australian Home Beautiful (Home Beautiful)* (launched in 1925) and *Australian House and Garden (House and Garden)* (launched in 1948) published monthly. While both publications serviced a national mainstream market, *Home Beautiful* was published in Melbourne, is saddle stitched and featured a more practical bent in the post war years, offering step-by-step how-to guides. *House and Garden* published in Sydney, is printed on higher quality paper and perfect bound, and considered itself more upmarket, featuring plans for small modern homes and introducing the work of modernists, 'such as Robin Boyd, Syd Archer, Harry Seidler, Grant Featherston and Marion Hall Best', with photography by Max Dupain.[107] Together the

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[104] The introduction of the term 'one-world' is attributed to John Law by Arturo Escobar when introducing the 'universalizing ontology of the dominant forms of modernity'. Escobar, *Designs for the Pluriverse*, 66.
[105] *Atlas of Furniture Design*.
[106] Norman K. Denzin and Yvonna S. Lincoln, eds., *The Sage Handbook of Qualitative Research*, 4th ed (Thousand Oaks: Sage, 2011), 91.
[107] Howard Tanner, "Celebrating Australian House and Garden and Its Founding Editor Beryl Guertner," *Australian Garden History* 20, no. 2 (2008): 4.

magazines chart the history of Australian interiors trends and provided a rich source of material to examine the cultural reception afforded to plastic furniture.

Architecture in Australia (published under this banner from 1955) gave emphasis to visual content, featuring photo-essays of new buildings by significant architects of the time. This publication is useful to observe the growing use of plastic furniture in affluent homes throughout the 1960s and 1970s. While the photographs in these magazines are often dressed or staged, they still reveal much about the changing role of plastics and their relationship with end users in real-life households of the time.

Fig. 0.7. Covers from the two leading Australian home maker publications available in the decades following WWII. Source: Author's collection

Supplementing the homemaker titles, I also conducted a survey of the two trade titles servicing the local plastics industry, *Australian Plastics* and *Plastics in Australia* (which changed its name to *Plastics News* in the mid-1960s). While editorial relevant to the furniture industry is comparatively scarce, those publications provided important background information on the development of plastic technologies in Australia, adding to my understanding of the impact of plastic on everyday life and in the Australian cultural context.

c. Interviews

I have undertaken a series of 27 interviews, 16 of which with a range of international product designers whose work has been selected for inclusion in the above database (table 1). Six Australian designers were interviewed, representing a range of experience working with plastics. Additional interviews were conducted with three manufacturers of plastic chairs and representatives from two material manufacturers (table 0.1).[108]

Interviews lasted between 45 minutes and one hour. Participants were recruited by email, either directly or through their public relations contacts. I originally planned to conduct most interviews face-to-face, primarily at the participant's place of work, and to make video recordings of the interviews. COVID-19 disrupted these plans and only eight interviews were conducted in person, and only one of these participants agreed to a video recording (Louis Durot).[109] The remaining interview were completed online using Skype often audio only) or Zoom. Using these conferencing solutions enabled recordings of conversations to be made with the consent of participants. More importantly, some of the interviews were conducted by video. These interviews generally achieved higher levels of

[108] University of Technology Sydney Human Research ethical clearance approval ETH19-3582. All research participants interviewed in person were asked to give their written consent to be identified in the research analysis while online participants indicated their consent verbally. Designs discussed in this study often feature the use of materials or technologies that will make them immediately identifiable. Therefore, any attempt at de-identity of designers would prevent linking specific comments to specific works, materials or technologies. Being unable to identify specific designs when discussing the use of materials and technologies would reduce the value of this research. No participants displayed any reluctance to participate in the research and none requested anonymity. I planned to interview more representatives from both furniture and material manufactures. However, many potential participants from these industries either failed to respond to requests to participate or were unwilling or unable to commit to an interview.

[109] An extract (7 mins) of my interview with French industrial designer Louis Durot can be viewed online on You Tube with a longer version (40 mins) also available.

List of interviews conducted between March 2019 and August 2021			
Name	**Organisation**	**Method**	**Date of interview**
Designers: 22			
Ron Arad		In person	22/07/2019
Dan Armstrong & Rene Linssen*	Formswell	In person	29/01/2020
Edward Barber & Jay Osgerby	Barber & Osgerby	In person	1/10/2019
Gabriele Chiave	Marcel Wanders	Skype	6/04/2020
Louis Durot		In person	18/06/2019
Tom Fereday*		Skype	8/04/2020
Mary Featherston		Email	17/08/2020
Manuel Garcia	Nagami	In person	23/07/2019
Sarah Gibson	DesignByThem	In person	25/02/2020
Konstantin Grcic		Skype	27/04/2021
Trent Jansen*		Skype	9/04/2020
Ander Lizaso	Iratzoki Lizaso	Skype	26/10/2019
Victor Macadar**	Bambacore client	Skype	11/04/2020
Ron Newman	Sebel	Zoom	18/08/2021
Thomas Pedersen		Skype	19/12/2019
Bertjan Pot		Skype	7/04/2020
Tom Price		Email	7/03/2019
Eugeni Quitllet		Skype	2/04/2020
Karim Rashid		Skype	24/10/2019
Andrew Simpson*	Vert Design	Skype	24/03/2020
Philippe Starck		Zoom	24/05/2021
John Tree	Jasper Morrison	In person	23/07/2019
Furniture manufacturers: 3			
Gregg Buchbinder (CEO)	Emeco	Email	8/11/2019
Ruben Hutschemaekers Head of Marketing and Communication	Magis	Zoom	2/12/2020
Kate Ringvall Sustainability Business Partner	IKEA	In person	20/03/2020
Material manufacturers: 2			
Mayda Diaz Business Development & Technical Support	Bambacore	Skype	2/04/2020
Andreas Maegerlein Group Leader Creation Center	BASF	Zoom	24/06/2021

*These participants have not designed plastic chairs but are locally based designers. My primary interest was in examining their role in the material selection decision making process.
**Designer of agricultural products using locally sourced bioplastics.

Table 0.1. Interviews conducted with designers, furniture manufacturers and material manufacturers

engagement with interviewees, as visual communications helped improve understanding and enabled observation of the participant's body language. Some of the online interviews were conducted at the interviewees place of residence, which created a more casual and relaxed environment than those conduced at the place of employment. The three interviews conducted by email were the least successful, as there was no opportunity to follow up or for questions to be guided by the interviewees' levels of interest or knowledge. COVID-19 therefore negatively impacted my research plans but failed to halt or completely disrupt them.

Fig. 0.8. Louis Durot pictured in his studio in Paris, June 2019. Photo: Geoff Isaac

Interviews were designed to supplement information already assimilated through archival and bibliographic based research during construction of the database (see Appendix 1 for an example of the questionnaire). Combining the interview with the results of the eco-audit tool (see below) enabled case studies to be constructed for analysis. I considered the use of case studies appropriate to investigate individual chair designs which are effectively niche experiments with new materials and/or manufacturing techniques, the focus of this study. Sampling was not random, with participants selected based on their recent experience with renewable plastics. Sample selection was then 'information-orientated,' selected on the basis of potential for revealing new knowledge gained from working with new materials and technologies.[110]

The focus of interviews examined if, why, and how environmentally friendly solutions were introduced to specific projects and the difficulties encountered in developing designs using emerging materials and technologies. I focussed on unpacking the drivers that led to the development of a design and the precise role of the participant in decision making that impacted the environmental credentials of a project. Participants were interviewed about: motivations for designing specific chairs; their approach to design and manufacturing technologies; attitudes to sustainability and environmental issues; and the impact on their work with plastics. Preparation for interviews was greatly assisted by the development of the database described above, which required me to learn about both the designer and their work.

The questionnaire developed to guide the interview adopted a semi-structured format allowing flexibility, guided by the participant's answers and their level of interest and

[110] Bent Flyvbjerg, "Case Study," in *The SAGE Handbook of Qualitative Research* (Thousand Oaks: SAGE Publications Inc, 2011), 307.

knowledge about each topic. This approach allowed for investigation of new topics introduced during an interview. Maintaining a flexible interview structure also facilitated follow up questions, helping to create a conversational atmosphere, encouraging participants to relax and be more forthcoming with their opinions.[111]

Fig. 0.9. Edward Barber from Barber & Osgerby in his London office, October 2019. Photo Geoff Isaac

Most of the questions were open-ended, providing a point of reference rather than restricting answers to choices from pre-determined list as suggested by qualitative research

[111] Steinar Kvale and Svend Brinkmann, *InterViews: Learning the Craft of Qualitative Research Interviewing*, Third edition (Los Angeles: Sage Publications, 2015), 147.

specialists Svend Brinkman and Steinar Kvale.[112] As recommended by psychologists Dorthe Thomsen and Svend Brinkmann the interviews commenced with a reassurance that my interest was in all the details of the project and encouraged a free narrative of their experience before asking more specific questions.[113]

All answers are dependent on memory. Of course, memories can be inaccurate and, as Judy Attfield pointed out, 'memory has just as strong a tendency to 'construct' or invent the past as history.'[114] This tendency threatened to be particularly significant when discussing designs developed by participants several years prior to interview. As Thomsen and Brinkmann observed, recent specific memories are likely to be more accurate as they have been subjected to less shaping or personal bias compared with long-term specific memories.[115] The authors went on to caution, 'specific memories do not correspond perfectly to the original experience, and the associated thoughts, emotions, and meanings may change over time.'[116] Further they warn that specific memories reflect re-interpreted versions of the original experience and that there is, 'no final agreement on the degree of correspondence between experience and memories or the proportion of an individual's memories that are relatively accurate.'[117] Experiences that at first seem unimportant can gain in significance over time and vice versa. Of particular concern, the passage of time can change appraisals and significance of decisions. Many of my enquiries concerned decisions regularly made by industrial designers (or others involved with the development of chairs) and therefore risk being forgotten as those decisions were not originally perceived as being

[112] Dorthe Kirkegaard Thomsen and Svend Brinkmann, "An Interviewer's Guide to Autobiographical Memory: Ways to Elicit Concrete Experiences and to Avoid Pitfalls in Interpreting Them," *Qualitative Research in Psychology* 6, no. 4 (November 11, 2009): 27, https://doi.org/10.1080/14780880802396806.
[113] Thomsen and Brinkmann, 309.
[114] Attfield, *Wild Things*.
[115] Thomsen and Brinkmann, "An Interviewer's Guide to Autobiographical Memory," 297.
[116] Thomsen and Brinkmann, 294.
[117] Thomsen and Brinkmann, 294.

remarkable or noteworthy. However, as the subject of enquiry focused on new materials and new manufacturing techniques, these projects and the decisions that went with them, are likely to stand out from the daily routine and seem more likely to form specific memories.[118]

Out of necessity, interviewees were made aware of the subject of my enquiries in advance, which may have created an opportunity for them to reconsider and reconstruct their motivations or reassess decision making responsibilities.[119] In most cases it was only possible to interview one actor involved with a project. In these cases, my understanding of the role of the actor and their contribution to the development of a design is confined by their answers together with any information available from publicly available sources. However, in several cases, an opportunity to interview multiple actors involved with the same project arose. Where the designer and a representative from the manufacturer were interviewed, I did not discover significant differences in the narratives provided to me.

As many of the research participants enjoy a high public profile and are accustomed to giving interviews with the press, I was concerned that replies to questions might be guarded or pre-prepared for public consumption. With many research participants regarded as elites in their field I was apprehensive that some might take the opportunity to promote prepared 'talk-tracks' to their advantage.[120] In particular, I was concerned that some participants might construct narratives to present an inflated version of their power in decision making when working on projects and their knowledge of (and commitment to) sustainability or environmental issues. However, research participants have not only been generous with their time but refreshingly candid in their replies—often criticising elements of

118 Thomsen and Brinkmann, "An Interviewer's Guide to Autobiographical Memory."
119 Martin A. Conway, "Memory and the Self," *Journal of Memory and Language* 53, no. 4 (October 1, 2005): 594–628, https://doi.org/10.1016/j.jml.2005.08.005.
120 Kvale and Brinkmann, *InterViews*, 147.

their work, or others involved with projects and openly discussing their confusion around sustainability claims. Although permission was secured to use interviews in full, I have used my discretion to ensure that negative statements are reported anonymously.

After each interview, I transcribed the recording and re-read records to identify recurring themes and ideas. Transcriptions are a representation of the original interview and are particularly prone to potential distortion where portions of a transcript are reported without full reference to the original context. Therefore, great care was taken to ensure an accurate record of the full interview was transcribed. By completing the transcription as close to the interview as possible I was able to reflect on my own interpretation of the participants' responses and demeanour during the interview.

Transcripts were re-read, and passages of interest labelled by theme to enable grouping within and across interviews. This manual analysis of the transcripts allowed for the grouping of answers around key themes and promoted the identification of significant differences and similarities.[121] A master file enabled the grouping of selected answers by topic across all participants. This process revealed the spectrum of opinion across the major themes investigated by this study. For example, as discussed in detail in Chapter 3, attitudes toward the importance of sustainability in design decisions varied considerably and the process of coding responses enabled a correlation with the age of the designer to be quickly observed. Of course, this observation does not imply all the older research participants did not consider sustainability to be important. However, older participants were less likely to highlight sustainability as a primary concern when creating designs.

[121] Consideration was given to using coding and analysis software but the small sample size meant this was unlikely to be a valuable tool for this study.

The process of coding transcripts quickly highlighted common frustrations among research participants and enabled me to refine the questionnaire to focus the path of questioning. For example, as discussed in Chapter 7, designers regularly commented on the difficulty of keeping abreast of developments in the renewable plastics market and sourcing information about new materials. Having identified this frustration I probed future participants on the issue and discovered that many of the information sources available are targeted at engineers or material scientists and therefore feature complex, scientific information too detailed for the requirements of designers. The low level of knowledge in relation to the technical aspects of bioplastics displayed by participants during some early interviews was also surprising. I therefore revised the questionnaire to introduce the topic using less-specific questions about attitudes towards these materials and allowed the participant to guide the direction of follow up questions.

Analysing the interviews with freelance designers allowed me to develop a deeper understanding and appreciation of the issues, pressures and commercial realities confronted daily. My research focused on new plastic technologies and attitude toward sustainability. However, the interview process highlighted the conflicting economic and social pressures which often divert attention to more mundane topics. Importantly, after completing a full draft of this dissertation, I listened again to all interview recordings to ensure that the contributions made by research participants accurately represented the context from which they were quoted.

Drawing together data relevant to address my research questions from different participants enabled an understanding of the full spectrum of opinions and beliefs relevant to my research enquiries. My background and experiences have undoubtedly influenced the direction of the interview and, doubtlessly the interpretation of results. As Denzin and Lincoln observed, ‘there are no objective observations, only observations socially situated in the worlds of—and between—the observer and the observed.’[122] I speak as part of, ‘a distinct interpretive community, which configures in its special way the multicultural, gendered components of the research act.’[123] Having spent 30 years researching and participating in corporate business decisions I have developed an understanding of the practical compromises that must be made by actors in making decisions and the complexities of introducing new technologies to both consumers and businesses. I have extensive experience commissioning creative agencies to develop advertising and marketing collateral and managing those relationships. I have also spent five years with the NSW State Government’s Environment Protection Authority (NSW EPA) working on waste programs where I gained an understanding of the complexities of encouraging more sustainable behaviours within entities primarily motivated by their duty to maximise profits for shareholders. While I consider these experiences an asset in this research project the reader should make their own assessment when interpreting results.

d. Eco-audit tool

Comparison of the environmental profiles of 32 chairs made from renewable carbon materials demanded a quantitative methodology. I originally anticipated that an existing tool would be suitable for this task. Life cycle assessment (LCA) is an eco-design tool which attempts to measure the impact on the environment throughout the entire life cycle (i.e., cradle-to-grave) of a product and reports across multiple impact sectors including resource use, human health, and ecological consequences. LCA is often referred to as the gold

[122] Denzin and Lincoln, *The Sage Handbook of Qualitative Research*, 12.
[123] Denzin and Lincoln, 11.

standard when measuring environmental impact.[124] I expected that LCAs could be easily obtained from manufacturers to enable direct comparison between designs. This proposed methodology was quickly abandoned due to several reasons but chief among these is the fact that the industry does not use LCAs.[125] In fact, I found only one LCA available from the 46 furniture manufacturers selected for inclusion in my analysis (detailed in Chapter 3). Manufacturers and designers frequently reported that the methodology is too complex, time consuming and expensive to implement (requiring specialist software and databases and the

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[124] For example, the British Plastics Federation claims LCAs, 'are as close to the gold standard of understanding the environmental consequences of a product as researchers can currently get.' British Plastics Federation, "Life Cycle Analysis (LCA) - A Complete Guide to LCAs," accessed February 3, 2022, https://www.bpf.co.uk/sustainable_manufacturing/life-cycle-analysis-lca.aspx.

[125] Other reasons for abandoning LCA: 1) LCA does not have a clearly defined and universally accepted methodology, despite attempted standardisation under the ISO-14040 series. In particular, there are frequent inconsistencies in establishing the boundaries of the system to be included in an analysis. OECD, "Policies for Bioplastics in the Context of a Bioeconomy," OECD Science, Technology and Industry Policy Papers, October 28, 2013, 7, https://doi.org/10.1787/5k3xpf9rrw6d-en. 2) Many LCA analyses fail to provide full transparency on the assumptions and methodology used for calculation and are not audited or verified by independent experts. Alastair Iles and Abigail N. Martin, "Expanding Bioplastics Production: Sustainable Business Innovation in the Chemical Industry," *Journal of Cleaner Production*, Sustainable Innovation and Business Models, 45 (April 1, 2013): 45, https://doi.org/10.1016/j.jclepro.2012.05.008. 3) LCAs for plastic products often consider the monomer (the building block of polymers) as the starting point, overlooking the emissions caused by extraction, refining, and cracking processes, making the quantification of GHG emissions of the plastic chain doubtful. Laura Pires da Mata Costa et al., "Capture and Reuse of Carbon Dioxide (CO2) for a Plastics Circular Economy: A Review," *Processes* 9, no. 5 (May 2021): 759, https://doi.org/10.3390/pr9050759. To accurately calculate a LCA for a plastic product the feedstock and processes used to create the material must first be identified (as this is often accounts for the biggest contribution to the environmental impact of a plastic product). While most plastics are made from oil, North American and even European plastics are increasingly likely to have been made using gas extracted in North America. Plastic from China is more likely to have been made from coal. Even where the feedstock and source of energy used to produce the plastic can be identified, LCA results can be heavily influenced by the source of the data input for the analysis. For example, a comparison of 14 datasets modelling the GHG emissions caused by refining petroleum in Europe found up to 300% variation in the results for major refined products and naphtha (often used as a feedstock for plastic). Eric Johnson and Carl Vadenbo, "Modelling Variation in Petroleum Products' Refining Footprints," *Sustainability* 12, no. 22 (January 2020): 9316, https://doi.org/10.3390/su12229316. This variation gets carried into LCA calculations where it can be magnified further, as GHG emissions typically get weighted highly. 4) For recycled plastics it would only be possible to obtain an accurate calculation when the history of the material is known (perhaps possible for industrial waste, but highly challenging when examining mixed post-consumer sources). When considering bioplastics, the analysis of feedstocks become more perplexing as the variety of feedstocks used is broad, with many potentially impacting ecosystem quality at the end of life, due to the use of pesticides and fertilisers. All these impacts together with the consumption of land and water need to be considered in a detailed LCA analysis. Vincenzo Piemonte and Fausto Gironi, "Land-Use Change Emissions: How Green Are the Bioplastics?," *Environmental Progress & Sustainable Energy* 30, no. 4 (2011): 685–91, https://doi.org/10.1002/ep.10518. The methodological challenges when comparing plastics made from alternative feedstocks are discussed more fully in: Constance Ißbrücker, "JRC's 'Plastics LCA Method' Is Not Fit for Purpose," *European Bioplastics e.V.* (blog), December 2021, https://www.european-bioplastics.org/jrcs-plastics-lca-method-is-not-fit-for-purpose/.

expertise to operate them). Designers further highlighted the fact that LCAs can only be accurately calculated after a product has been manufactured, therefore, they were seen as of limited value in guiding their work.

Having determined that LCA was not a suitable tool to evaluate the environmental profiles of the selected chair designs an alternative methodology was required. In 1999, environmental scientist Tomas Graedel, developed a less onerous version of the LCA tool.[126] Building on this work I simplified his approach further to enable a comparison of similar products to be made in the absence of detailed material and manufacturing specifications. More information on Graedel's work and how it has been adapted for this study is given in Chapter 4.

4. Overview of thesis structure

My project draws upon recent approaches to the relationship between design and ecology for an innovative investigation of the place of plastics technology in the history of chair design.[127] This dissertation adopts a transdisciplinary approach to develop understandings relevant to contemporary concerns in design practice, incorporating design history with learning from business and management studies. While there is a focus on individual artefacts, the chairs are not solely considered in isolation but also within the system of producers, retailers, marketing, promotion, and consumption that constitute culture. I argue that both designers and manufacturers often have both the agency and the ethical

[126] T. E. Graedel, *Streamlined Life-Cycle Assessment* (Upper Saddle River, NJ: Prentice Hall, 1998).
[127] Fry, *Design Futuring*; Ezio Manzini, "Design in the Transition Phase: A New Design Culture for the Emerging Design," *Design Philosophy Papers* 13, no. 1 (2015): 57–62.

responsibility to accelerate the transition to more sustainable alternatives to virgin fossil plastics by promoting the uptake of renewable plastics.

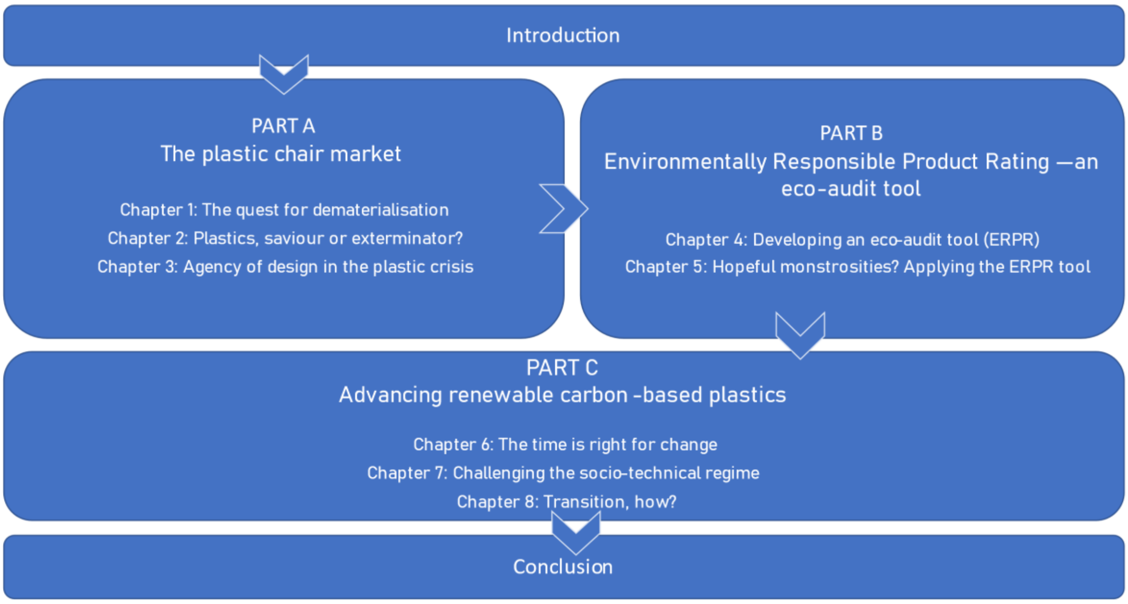

Fig. 0.10. Overview of thesis structure

The first section of this study (Chapters 1 & 2) traces the 80-year history of the plastic chair to examine how designers have incorporated technological advances in materials and production methods. Informed by this background, I then analyse the rapidly changing attitudes toward plastics that has gathered momentum over the past fifteen years and its impact on chair designers. In so doing, I aim, in the later chapters, to map the cultural and socio-technical ecology of plastic chair design across a range of pressing topics, including consumption, transition design, supply-chain transparency, and environmental impacts.

In Chapter 1, I begin by critically examining the history of plastic chairs with a particular emphasis on how new materials and technologies were experimented with by industrial designers and later adopted by industry. I argue that the main driver for developments in the plastic chair market during the twentieth century centred on *dematerialisation*; reducing the amount of energy and/or material needed to manufacture a chair. Chapter 2 maps the changing attitudes toward plastics by consumers with a particular focus on the Australian experience from WWII to the end of the twentieth century. Innovations in the plastics industry were led by Americans and Europeans in the decades after WWII and isolated Australian designers and manufactures were forced to adapt these new technologies for local market conditions. This is the first study to examine the development of the plastic furniture industry in Australia.

The allure of the glossy, shiny surfaces proudly displayed by the miracle materials emerging from science laboratories dulled as the lists of health and environmental concerns grew. In Chapter 3 the plastics industry is analysed with a particular focus on the growing environmental impacts implicit in current growth projections. A scenario or vision for a more suitable future for the industry is proposed. Chapter 4 describes the development of the eco-audit tool (ERPR) (introduced in the methodology section above) to enable a comparison of the environmental profiles of 32 recent renewable plastic chairs, the detailed result of which are discussed in Chapter 5. In Chapter 6, the MLP model is applied to the petrochemical industry with a specific focus on the plastic chair market. The focus here is on landscape changes, developments in macro-economics, macro-politics, and consumer preferences as a result of shocks caused by exogenous events. MLP theory posits that such shocks can cause disruption to the status quo and create opportunities for new technologies to breakthrough. Chapter 7 focuses on the issues confronting both manufacturers and designers seeking to work with renewable plastics. The final chapter (8) identifies the tactics and strategies that can be adopted by designers and manufacturers to accelerate a transition to renewable plastics. Ultimately this dissertation argues that both designers and manufacturers have both agency and a responsibility to participate in the solution to the wicked plastic problem by influencing the uptake of renewable carbon-based plastics, mitigating the wider impacts of design on the environment.

Part A

The plastic chair market

Chapter 1

The quest for dematerialisation

> The Marie, a pure 'mathematical' chair was created by the designer to have the least possible style, the least possible weight, the least possible material and the least possible presence.
> Jonathan Wingfield[128]

Fig. 1.1. Kartell stand at the *Salone del Mobile* in Milan, 1999 Source: © Kartell

Philippe Starck's small, transparent *La Marie* made its debut at the *Salone del Mobile* (Milan, 1999), with chairs displayed in a circle, withstanding heavy blows from a rotating industrial robot (fig. 1.1). Designed to demonstrate both the strength and flexibility that belie the design's petite appearance, the publicity stunt successfully ignited interest in polycarbonate furniture from both critics and retailers alike. Weighting just 3.5kg, with the transparency of glass, *La Marie* represents the ultimate expression of designer Philippe Starck's commitment

[128] Philippe Wingfield, "Starck Biography," Starck, 2018, https://www.starck.com/about.

to 'dematerialisation'.[129] His success in improving both material and energy efficiency was the upshot of 60 years of research and development in the plastic furniture industry, combined with 50 years' experience backed by the financial resources of plastic specialist manufacturer Kartell.[130]

I argue that the adoption of technology in the fossil plastic chair market during the second half of the twentieth century was primarily determined by its ability to contribute to dematerialisation by reducing material and/or energy use.[131] Although primarily driven by profit, this focus on dematerialisation coincided with emerging contemporary sustainability initiatives, thereby encouraging innovation and efficiency as a strategy to address environmental problems. The efficiency gains achieved through dematerialisation are most clearly illustrated in the work of designers and manufacturers developing monoblocs: that is, chairs made from a single piece of material. Technologies that remain most prevalent in the furniture industry today are those that deliver proven efficiencies in the materials or energy consumed during production and transportation, injection moulding, air-injection moulding, and flow simulation software among them.

1. Early plastic chairs

In the late 1920s the Simmons Company in Racine, Wisconsin, produced five prototypes of an armchair made from Bakelite. Despite investing $50,000 to develop the eight moulds

[129] Wingfield.
[130] Morello, and Ferrieri, *Plastic and Design*; Storace et al., *The Culture of Plastics*.
[131] Dematerialisation has long been a focus of academic enquiry by those concerned with sustainability. See for example: Robert Herman, Siamak A. Ardekani, and Jesse H. Ausubel, "Dematerialization," *Technological Forecasting and Social Change* 38, no. 4 (December 1, 1990): 333–47, https://doi.org/10.1016/0040-1625(90)90003-E; Demetris Petrides et al., "Dematerialization and Environmental Sustainability: Challenges and Rebound Effects," *Procedia CIRP*, 51st CIRP Conference on Manufacturing Systems, 72 (January 1, 2018): 845–49, https://doi.org/10.1016/j.procir.2018.03.131.

needed, the project was abandoned due to the chairs being excessively heavy.[132] Plastics historian Andrea DiNoto notes that by the 1930s designers began experimenting with plastics in furniture design using synthetic (celluloid-based) lacquers, and laminates such as Formica for decoration.[133] Rohm and Haas (now part of the Dow Chemical Company) discovered acrylic glass in 1936, while researching polymer adhesives, branding their offering Plexiglas. Acrylic glass offers significant benefits over silicate glass; it is less than half as dense, making products lighter and delivering savings during transportation through lower fuel consumption.[134] It also has good impact strength making acrylic glass suitable to provide structure for a chair.

Fig. 1.2. Acrylic glass chair most likely by Lorin Jackson for Grosfeld House, 1939
Source: © Suzy Gorman for Interior Motives

132 J. Harry DuBois, *Plastics History U.S.A* (Boston: Cahners Books, 1972), 180–81.
133 DiNoto and Arky, *Art Plastic*, 193; Katz, *Plastics*, 1978, 12–13.
134 1.16–1.20 g/cm. Michael F. Ashby and Kara Johnson, *Materials and Design: The Art and Science of Material Selection in Product Design* (Saint Louis, UNITED KINGDOM: Elsevier Science & Technology, 2014), 261, http://ebookcentral.proquest.com/lib/uts/detail.action?docID=5754493.

Grosfeld House, a New York retailer active from the 1930s to the 1950s, commissioned designers specialising in the Hollywood Regency (or Vogue) style to create acrylic glass furniture, launched at the 1939 New York World Fair (fig. 1.2).[135] Originating in the West Coast at the end of the 1920s, Hollywood Regency was based on neo-classical forms such as Adamesque and Biedermeier furniture and was quickly embraced by New York for its glitz and glamour. The translucent creations, developed by the company using acrylic glass, perfectly complemented the luxurious, silk, shearling, and leopard print upholstery typical of the look. These Plexiglas chairs quickly found support from the influential New York interior designer Elsie de Wolfe (1859-1950) who chose them for her clients.[136] Oscar Fitzgerald attributed the design of this chair (fig. 1.2) to the famous de Wolfe; however, the chair is more widely accredited to Grosfeld House.[137]

Simultaneously in California, Swedlow Plastics used Lucite (DuPont's brand of acrylic glass) to develop a range of transparent furniture including chairs from at least 1939, when they featured as props in a promotional film for DuPont that company (fig. 1.3).[138] New-York based cosmetics mogul Helena Rubenstein (1872-1965) commissioned Hungarian artist Ladislas Medgyes (1892-1952) to design plastic chairs as part of a furniture suite for her city penthouse. These 1941 designs are often claimed to be the first plastic chairs, even though

[135] Rohm and Haas (now part of the Dow Chemical Company), active in both Germany and the USA before WWII, discovered acrylic glass (in 1936) and branded their offering Plexiglas.
[136] Mitchell Owens, "Delving Into the Lore of Lucite," *New York Times*, June 18, 1999. 'Grosfeld House made the chair; Elsie de Wolfe just bought them,' Alan Moss, a leading New York dealer who specialised in Lucite.
[137] While Oscar Fitzgerald attributes a 'Biedermeier inspired chair with scalloped crest and tapering rod-shaped legs' to deWolfe, this appears to be a reference to the Grosfeld House creation which featured in her apartment and was sold by Christies, 15 September 1999, Lot 79 Oscar P. Fitzgerald, *American Furniture: 1650 to the Present* (Lanham Boulder New York: Rowman & Littlefield, 2018), 436.
[138] A 1939 promotional film for DuPont includes images of the chairs. I identified the manufacturer from the Swedlow Plastics catalogue 1941 (kindly supplied by Jeffrey Meikle). DuPont, *A New World Through Chemistry*, 1939, https://digital.hagley.org/islandora/object/islandora:2569884; Swedlow, "Plastics by Swedlow (Company Brochure)" (Swedlow, 1941); E. J. Pechin, "Design for Modern Living," *E. I. DuPont De Nemours & Co*, April 1940.

those of both Grosfeld House and Swedlow Plastics were produced earlier. As the manufacturer of the Rubenstein chairs was the inventor of Plexiglas, it is almost certain these chairs are not made from Lucite as is often reported.[139]

Fig. 1.3. Still from 1939 promotional film for DuPont showcasing furniture made from Lucite.
Source: Courtesy of the Hagley Museum and Library

The early east-coast designs were influenced by the Hollywood Regency style. Rejecting other simpler styles popular at the time, such as Streamlining or Art Deco, these designs proudly featured ornate embellishments and decorative features, most clearly seen

[139] Rhom and Haas manufactured the Rubenstein chairs; therefore, they are almost certainly made from Plexiglas, the brand name adopted by the company for their acrylic glass.

in the floral etchings on the back of the chairs designed for Helena Rubenstein (fig. 1.4).[140] Replicating this style attracted criticism. British industrial design historian, John Gloag, claimed: 'They were destitute of original inspiration in design; true they were unusual, but only in the way Cinderella's glass slipper was unusual.'[141] Gloag objected to the use of plastic as a direct substitute for traditional materials. Plastic had, by this time, earned a reputation for imitating more costly materials across a range of products traditionally made from ivory, tortoiseshell, mother of pearl among others, and these chairs reinforced that belief.[142] Gloag likely saw these early acrylic glass experiments as another example of plastic being used as a substitute, with the designs failing to explore the material's true potential.

Fig. 1.4. Helena Rubinstein Suite, Ladislas Medgyes, 1941. Source: Carnegie Museum of Art

[140] DiNoto and Arky, *Art Plastic*, 32.
[141] John Gloag, *Plastics and Industrial Design* (London: George, Allen & Unwin Ltd, 1945).
[142] DiNoto and Arky, *Art Plastic*, 28.

Experimentation with the new material was, however, restricted by some practical limitations. The glass transition temperature of acrylic glass is 105 degrees Celsius, inhibiting hands-on experimentation.[143] In addition, the material was typically available only as precast sheets, rods or tubes; well suited to replicating the traditional components of chairs but unlikely to inspire the investigation of new forms. These considerations guided designers to continue using traditional manufacturing techniques when working with acrylic glass. Perhaps, then, it is unsurprising that these early designs featured legs, seat, and back all designed as separate components joined together manually. Continued reliance on labour-intensive production was reflected in the price of these designs, restricting their appeal to an affluent niche market.

2. The Space Age

Glass-fibre reinforced plastic (fibreglass) quickly displaced acrylic glass as the material of choice among chair designers, as they could directly engage with all aspects of the design and pre-production processes when working with fibreglass. In the simplest process, glass fibres (glass blown into fine stands) can be spread in a mould by hand and brushed over with epoxy or polyester resin at room temperature. Additional layers can be added to strengthen as required, giving a new level of control over the design's strength at any point and facilitating economical use of the material.[144] Once the resin cures, the solidified moulded item can be removed for finishing, involving trimming and polishing. The entire process

[143] The glass transition temperature is when the physical properties of plastics change from being rigid and solid to become more flexible or rubbery, different from the melting point when the substance begins to flow.
[144] More mechanised production techniques using spray guns were introduced from the late 1950s. Meikle, *American Plastic*, 194.

facilitates the production of complex curvilinear shapes. Designers can materialise their ideas for plastic chairs all the way from the drawing board to the drawing room.

The futuristic, polished, glossy, reflective, warm-to-the-touch surface provided the perfect embodiment of the utopian ideals circulating during the Space Age (1957-1969).[145] Designers, freed to express themselves, broke away from previously popular historic references. Writing on the history of the chair, Galen Cranz argued:

> Designers in the twentieth century, starting with the proponents of Art Nouveau, were interested in finding ways to express their own age, so they did not want to use historical styles.'[146]

Finding 'ways to express their own age,' was chiefly facilitated by the availability of new materials and construction techniques and chief among these was glass reinforced polyester.

Unlike acrylic glass, working with fibreglass enabled designers to use their artisanal craft and sculpting skills to experiment using their own hands or by working closely with others, including model makers and sculptors. Moulds could be prepared from inexpensive traditional materials, like wood or plaster. Penny Sparke argued that plastics 'discouraged a reductive approach towards design and encouraged, instead, an expansion of possibilities.'[147] Designs could break free from the restriction imposed by traditional construction techniques.[148] Jeffrey Meikle claimed that the introduction of fibreglass to the furniture industry freed design from 'a "cubist" or "constructivist" project of assembling discrete parts,

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[145] Paul Dickson is among many who define the Space Age as the period between the launch of Sputnik 1 and the moon landing. Paul Dickson, *A Dictionary of the Space Age*, New Series in NASA History (Baltimore: Johns Hopkins University Press, 2009).
[146] Cranz, *The Chair*, 80.
[147] Sparke et al., *The Plastics Age*, 103.
[148] Katz, *Classic Plastics*, 14.

as in the early modern movement.'[149] Designers could break away from traditional styles and explore extreme organic compound curvilinear forms that had previously eluded them.

Fibreglass also featured the additional benefit of requiring minimal upfront financial investment, as the cost of expensive moulds is avoided. The advantages offered by the material made it ideal for independent designers and small businesses, resulting in wide-spread adoption.[150] While upfront investment was minimal, marginal costs were driven up by the manual lay-up and hand finishing required, reflected in expensive retail prices, ultimately restricting demand.

Fig. 1.5. *DAX* chair (Dining Height Armchair X-Base), Charles & Ray Eames, 1950
Source: ©Vitra Design Museum

[149] Meikle, *American Plastic*, 198.
[150] For example, Meikle notes, 'When the war ended, dozens of small companies started molding small boat of glass reinforced polyester' Meikle, 158.

The design process usually progressed from hand drawings to scale models and finally full-sized models, with each stage testing the artisan skills of the designer and their team. While this process slowed progress (usually at least two years from concept to production) it created the significant advantage of time. Designers could (literally and metaphorically) live with drawings, models, and prototypes, using the time to re-examine, reconsider, refine and revise every aspect of the design to perfect every join and curve.

Fibreglass enabled Charles and Ray Eames to finally develop a one-piece shell chair first envisaged by Charles, working with Eero Saarinen, for their winning entry to the *Organic Design Competition* organised by MoMA in 1940.[151] Original plans to develop the design using plywood failed and a decade passed before fibreglass provided the solution (fig. 1.5). Presented un-upholstered, the armchair proudly displayed the rough textured, semi-gloss finish of the fibreglass, available in a restricted colour range. With no springs or even padding these chairs presented a real challenge to the status quo.

Fig. 1.6. *Tulip Chair* and armchair, Eero Saarinen 1958. Source: Knoll

[151] Eliot Noyes, *Organic Design in Home Furnishings* (New York: The Museum of Modern Art, 1941), 1, 12–17.

Eero Saarinen disliked the raw finish featured on the Eames chairs and sought to find a technique to improve the surface for his *Tulip Chairs* (fig. 1.6).[152] Using veil matting, with fine-denier, on the surface of the chair during compression moulding encouraged more resin absorption, creating a skin that is perfectly smooth, free from blemishes and sensual to touch. Typical equipment used for compression moulding is shown in fig. 1.7. Compared to the Eames chairs, the finish achieved is smoother, exuding a promise of both cleanliness and ease of maintenance. The additional investment was immediately rewarded with the commercial success in the residential market that had initially eluded the Eames design.[153]

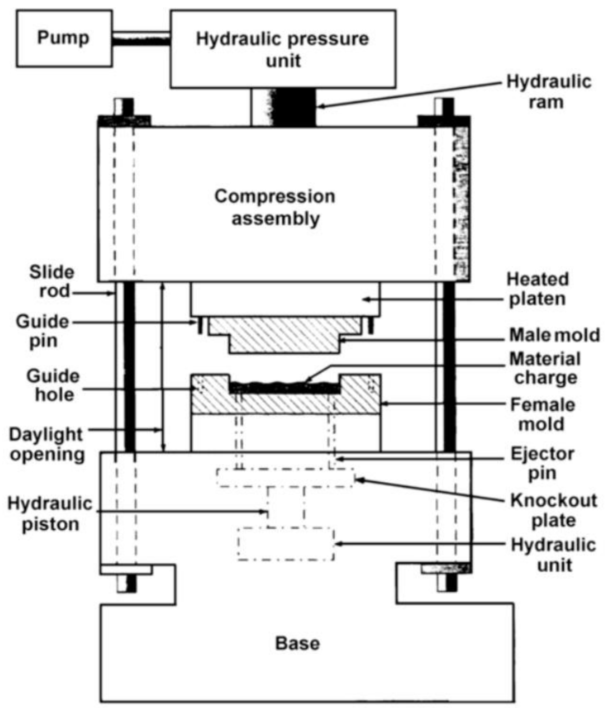

Fig. 1.7. Compression moulding equipment.
Source: Handbook of Thermoplastic Elastomers by Jiri George Drobny (2014)[154]

[152] Shultz reports that Saarinen disliked the swirly surface of the Eames chairs. Brian Lutz, Florence *Knoll*, and Niels Diffrient, *Eero Saarinen: Furniture for Everyman* (New York, NY: Pointed Leaf Press, 2012), 170.
[153] *Tulip Chairs* failed to find general acceptance in the corporate market with the pedestal base failing to find favour with the planners of office interiors. Lutz, *Knoll*, and Diffrient, 182.
[154] Jiri Drobny, *Handbook of Thermoplastic Elastomers, 2nd Edition* (Farnham: O’Reilly, 2014), 94.

To access the expertise needed to develop the chair Saarinen worked closely with a boat builder with experience in fibreglass.[155] The original plan to produce the Tulip as a plastic monobloc stalled when fibreglass proved unable to support the weight of a sitter. Saarinen solved this problem by casting the base in aluminium. Great attention was paid to matching the finish on the two surfaces, developing the curve and join between the shell and base, all to enhance the impression of a monobloc. It was perhaps the first example of a product being disguised to look like plastic, reflecting growing consumer acceptance of synthetics.

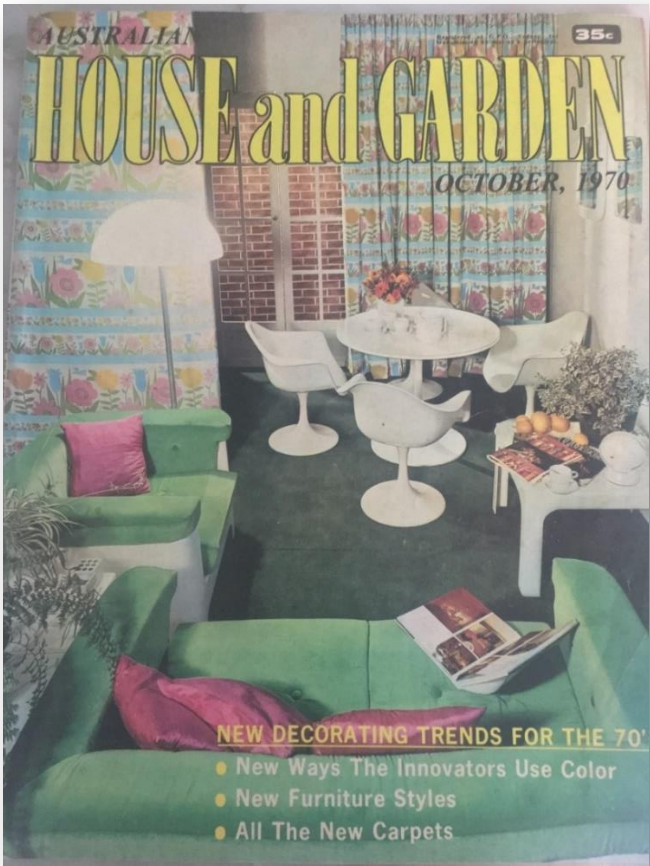

Fig. 1.8. *Tulip Armchairs*, featured on the October, 1970 front cover of *Australian House & Garden*, 12 years after their release. Source: Author's collection

[155] Saarinen had previously worked with the same company (Winner Manufacturing) to develop a range of furniture (the 70s Series), leveraging their wartime experience working with fibreglass for the US Navy. Lutz, *Knoll*, and Diffrient, *Eero Saarinen*, 112.

Fibreglass, summarised Bernadette Vincent, was originally developed for 'weight saving and cost reduction in transport and handing. However, [it] generated a deep change in design, and facilitated a new approach to materials research.'[156] Designers could create both the material and the product in the same single process. Vincent observed, 'in more philosophical terms, matter and form are generated in one single gesture.'[157] Ironically, it had taken the development of a totally synthetic material to enable the execution of the most extravagant, organic designs inspired by nature.

Fig. 1.9. *Pallo*, Eero Aarnio originally manufactured by Asko 1966. Source: Eero Aarnio Originals

[156] Bensaude-Vincent, "Plastics, Materials and Dreams of Dematerialization," 20.
[157] Bensaude-Vincent, 20.

Design historian John Collins observed at this time, ‘the industrial designer was someone completely involved in the manufacturing process, from initial conception and drawing, handling of materials, to final production stages.’[158] This observation particularly applied to designers using fibreglass to make furniture, allowing them to earn the status of the ‘heroic’ lone operator. For example, Eero Aarnio (1932-) created hand drawn sketches for the *Pallo* or *Ball Chair* and then fashioned a prototype of the design with the assistance of his brother-in-law, a pilot with experience in making gliders (fig. 1.9).[159]

French industrial designer Marc Held (1932-) created a full-size sketch for his *Culbuto*. He then spent two months creating a balsa wood model and the following two years working with a professional model maker (M. Cuicci) and the manufacturer (Knoll) to perfect the design for production (fig. 1.10).[160]

Richard Schultz (1926-), an industrial designer working with Knoll from 1956 to 1972, reported that during his early years with the company:

> Knoll was a very simple company, no department of design and development, so you had to do everything yourself. You designed the furniture, you invented the way to make it, you designed the jigs and the tooling, and for a little while you were in charge of production.[161]

While the reliance on manual labour provided an opportunity for the designer to be involved with all stages of production, this was also the downside of fibreglass. Models and moulds were handmade, the design and manufacturing process reliant on significant manual work and hand finishing, making the product expensive, often seen as avant-garde, restricted to

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[158] John B. Collins, "‘Design in Industry’ Exhibition, National Gallery of Canada, 1946: Turning Bombers into Lounge Chair," *Material Culture Review / Revue de La Culture Matérielle* 27 (January 1, 1988): 28.
[159] Eero Aarnio and Jukka Savolainen, *Eero Aarnio: Designer of Colour and Joy*, ed. Aila Svenskberg (Helsinki s.l: WSOY, 2016), 21.
[160] Éric Germain and Marc Held, *Marc Held: Du Design à l’architecture* (Paris: Norma, 2009); Marc Held, Michèle Champenois, and Eileen Powis, *Marc Held: 50 ans de design = 50 years of design* (Paris: Norma éditions, 2014), 126.
[161] Lutz, *Knoll*, and Diffrient, *Eero Saarinen*, 117.

an affluent niche market.[162] On the positive side, the prolonged hands-on involvement of the original designer was occasionally rewarded with a fully resolved design, destined to remain in production for decades. Many of the successful designs from that period display a chameleon-like ability: adapting to any surroundings; looking equally at home in modern, post-modern, minimalist and period rooms.

Fig. 1.10. *Culbuto*, Marc Held 1970. Source: 1stdibs

In a recent publication on material selection for designers, Elvin Karana, who leads the Materials Lab at Delft University, advises the observation of an important principle:

> People prefer products that are on the one hand maximally novel while being as familiar as possible… if you decide on a very novel shape, you may be well advised—from an aesthetic point of view—to stick to a familiar material for the product category.'[163]

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[162] A video showing the highly labour-intensive production process still required to make Yrjö Kukkapuro's Karuselli chair is available on [Artek's] website.

[163] Elvin Karana, Owain Pedgley, and Valentina Rognoli, *Materials Experience: Fundamentals of Materials and Design* (Oxford, UNITED KINGDOM: Elsevier Science & Technology, 2013), http://ebookcentral.proquest.com/lib/uts/detail.action?docID=1534948.

Many mid-century designers had the courage to move far away from this guiding principle of what makes good design, experimenting with both unfamiliar new materials and dramatic novel shapes at the same time. By breaking the rules many of these designs achieved both critical and commercial success, remaining in production for well over half a century.

The direct impact of fibreglass designs was limited. Expensive retail prices restricted sales. For instance, in 1971 Victor Papanek, a pioneering advocate of ecologically responsible design claimed that their high price meant 'the real impact [of the Eames chairs] on people has been negligible.'[164] No matter how modest the initial impact may have been, these designs directly inspired designers in other countries, leading to diverse experimentation with fibreglass to develop seating solutions. For instance, Eames and Saarinen inspired Marc Held and Arne Jacobsen, who went on to train the next generation of designers, including Verner Panton.

Interest in mid-century design has gained momentum in past decades, propelled by nostalgia and attention from mainstream media. Many fibreglass designs have regularly appeared in sets for films and television productions where they are often the centrepiece of aspirational interiors inhabited by heroes or villains alike. For example, Saarinen chairs have been featured in the American film *The Graduate* (1967), the British film *A Clockwork Orange* (1971) and *Star Trek* (1966-69). The Ball chair appeared in the British TV series *The Prisoner* (1967) and the films *Tommy* (1975) followed by the American films *Dazed and Confused* (1993) and *Mars Attacks!* (1996).[165] The popular television drama, *Mad Men* (broadcast from 2007 to 2015 and covering the period March 1960 to November 1970), featured many mid-century designs and popularised the style to a new generation of viewers. Dramatically

[164] Victor Papanek, *Design for the Real World*, 2nd ed. (London: Thames & Hudson, 2019), 122.
[165] See also Paula Benson, "Film and Furniture," accessed February 3, 2022, https://filmandfurniture.com/.

magnifying the impact of these designs, inexpensive copies (of variable quality) of many of these fibreglass designs have recently become available (at a fraction of the price of the originals), significantly broadening the market and introducing new generations of consumers to mid-century fibreglass design.[166] In such films they are often linked with modernity, masculine progress, and the rise of the USA in the post-war period.

3. Material efficiency

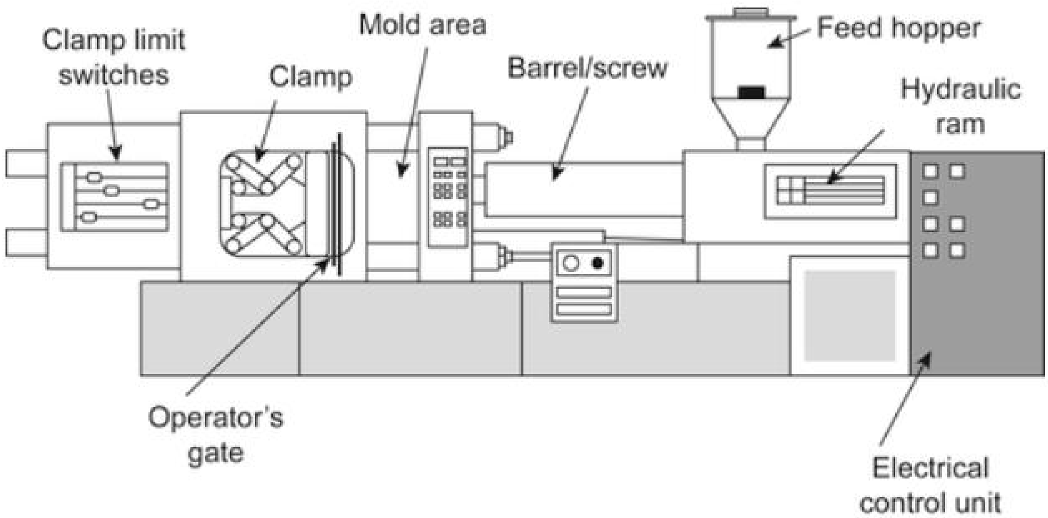

Fig. 1.11. Typical injection moulding machine.
Source: Handbook of Thermoplastic Elastomers by Jiri Drobny (2014)[167]

Injection moulding techniques pre-date the development of synthetic plastics.[168] Plastic pellets are fed from a hopper, heated, then the molten plastic is and forced under pressure into a mould as shown in fig. 1.11. After cooling, the component is removed from the mould ready for use (or requiring minimal finishing). When introduced to the industry, injection

[166] An original Ball chair can be purchased direct from the licenced manufacturer for 6,750 euros; copies are from AU$900.
[167] Drobny, *Handbook of Thermoplastic Elastomers, 2nd Edition*, 76.
[168] Injection moulding was first developed in 1872 and advanced by German industrialists in the 1920s. James Hendry introduced screw injection moulding in 1946. Meikle, *American Plastic*, 80–84.

moulding radically disrupted the economics of producing furniture and plastic seating. In addition to the financial disruption, injection moulding distanced the relationship between the designer and the manufacturing process and shifted the end-users' relationship with chairs.

The entire injection process (measured in seconds) is far quicker than compression moulding and produces consistent results of a higher quality, with injection moulding enabling a greater level of control over the process. Manual labour during production can be virtually eliminated, as only minimal (if any) hand finishing and packing are required, delivering significant economies of scale to the furniture manufacturer.[169] After incurring the (very considerable) up-front expense of the moulds the marginal cost of producing a monobloc using this technology is relatively insignificant—little more than the raw material cost. The process is therefore ideally suited to mass-production—the bigger the production run, the smaller the average cost per unit becomes, facilitating retail prices with broader audience appeal.

Injection moulding significantly altered the role of the designer. The skills of the designer, no matter how great, were no longer sufficient to succeed alone or with a small team. Injection moulding demanded a network of skilled specialists and significant financial resources to develop moulds and the machinery to drive them. To develop their work designers could no longer rely on their own resources. They needed the support of a manufacturing partner with access to the skills and resources needed in order to succeed.

[169] Even labelling becomes redundant as makers' marks and logos can be stamped or embossed directly into the product during the moulding process.

Big business became attracted to the industry, keen to concentrate ownership of production facilities to take advantage of the economies of scale offered by the new technology.[170]

Mechanised production distanced the finished object from the designer. Writing about the reproduction of works of art, Walter Benjamin claimed, 'that which withers in the age of mechanical reproduction is the aura of the work of art.'[171] Similarly, mass produced injection moulded chairs manufactured in seconds by an automated process can lack the 'aura' of fibreglass creations, which proudly display their maker's craft skill. In addition to the expertise required to develop moulds, the successful manufacture of fibreglass chairs depended upon labour-intensive processes (moulding, trimming, polishing, upholstery and assembly). For manufacturers and end-users alike, the cost advantages delivered by injection moulding quickly relegated fibreglass technology to high-end niche markets, where the 'aura' of the hand-finished chairs are appreciated sufficiently to overcome the substantial price differential.

Injection moulding dramatically transformed seating solutions. Lightweight, injection moulded chairs (typically around 5kg) were freed from the confines of the (then popular) three-piece suite, heavy static objects often placed in a single location for months or years at a time. Seating arrangements became dynamic; chairs could be picked up and moved around at will—grouped together for quiet conversations or re-arranged in rows for viewing. Inside or outside, even stacked out of the way when not needed, a new level of versatility

[170] For example, Australian manufacture Aristoc was sold to Furniture Makers of Australia in the early 1970s (who had already purchased major competitor, Fler). Market conditions were similar in the UK where Kandya merged with Meredew, in 1968. Isaac, *Featherston*, 237.

[171] Walter Benjamin, "The Work of Art in the Age of Mechanical Reproduction," in *Illuminations* (New York: Harcourt, Brace & World, 1935), 221.

was achieved. Spaces could be transformed to suit needs with minimal effort; particularly relevant as post-war families adapted to smaller living environments.[172]

Injection moulding is ideally suited to modernist principles, as it is much simpler and less expensive to make moulds devoid of ornamentation or decoration. As with compression moulding technology, curved edges are easier to produce than sharp-edged corners. Plastic is the perfect material for moulding. Natural materials vary in quality, wood is grained and knotted. Even metals, glass and ceramics can contain defects or variations in quality interrupting production. Polymers are isotropic, the consistency of mechanical properties ensuing production is uninterrupted.[173] Acrylonitrile Butadiene Styrene (ABS), polypropylene and polyethylene enabled single-shot injection plastics to near the performance of fibreglass but at significantly reduced cost. Reinforced fillers, fibre mats, lacquers and laminates no longer required, meant production times could be slashed.[174] Economic drivers propelled injection moulding, ensuring rapid adoption by the industry.

The downside to injection moulding is the division of labour demanded by the adoption of the more economically efficient technology. The designer can become alienated from the production process; as mould making (usually in steel or aluminium) requires an increasingly specialised skill set.[175] Moulds could no longer be made using wood and plaster alone. To ensure success the design must be adapted to incorporate feedback from experts on how the material will behave in the mould or where strengthening is required. When complete, the designer must hand over the design to a mould maker (or toolmaker). Once a mould is formed the ability of the designer to make changes is limited, as significant changes

[172] Isaac, *Featherston*, 23.
[173] Morello, and Ferrieri, *Plastic and Design*, 32.
[174] Meikle, *American Plastic*, 191.
[175] Gino Colombini likened the task to sculpting in steel. Morello, and Ferrieri, *Plastic and Design*, 45.

to the mould are usually deemed prohibitively expensive. Pursuing a program of continuous improvement to the production process, previously enjoyed by those working with fibreglass, became prohibitively expensive when working with injection moulding. The artisan skills, so useful when working with fibreglass, became largely redundant once a design entered the pre-production stage.

a. Development of the monobloc

Fig. 1.12. Monobloc chair, Arthur Donahue & Douglas Simpson, 1946
Source: © Library and Archives Canada

Injection moulding proved the perfect technology to deliver the modernist dream of 'machine furniture' and proved essential to the successful production of the first chair made using a single material using just one production process. Designers had experimented with wood and sheet metal to develop a monobloc since at least the 1920s but largely failed.[176] A prototype for a monobloc plastic chair was created using compression moulding by Arthur Donahue (1917-1996) and Douglas Simpson (1916-1967) for the *Design in Industry* exhibition, held in Ottawa during 1946, but the design failed to progress to production (fig. 1.12).[177]

By definition, plastics can be moulded into almost any shape. It is not surprising that the prospect of creating a monobloc using plastic quickly became an obsession for many leading designers of the day.[178] Grant Featherston (Australian mid-century designer active in furniture design from 1946-1975) held views typical of those stimulated by the challenge to achieve structural unity:

> Producing the integral one-piece plastic chair stands at the pinnacle of the furniture designer's aspirations. [179]
>
> The optimum design might be found in a product which comes complete from the mould, which for transport requires no wrapping, which also occupies a minimum of space – through its stackability [sic], foldability or volume reduction by compression. [180]

Featherston was also acutely aware that, in addition to the creative challenge, development of a monobloc held the promise of financial rewards, reflecting both lower costs and potential sales success. A durable design in plastic, suitable for both indoor and outdoor use, potentially opened lucrative (commercial and residential) market segments. Eliminating joints and welds reduces the need for expensive manual labour. Monoblocs can stack efficiently

[176] Gerald Summers' Bent Plywood Armchair of 1933 is a notable exception.
[177] Collins, "'Design in Industry' Exhibition, National Gallery of Canada, 1946," 34.
[178] Design historian John Collins observed, 'this process [creating a monobloc] would be the aesthetic and technical goal of every designer during the post-war period.' Collins, 34.
[179] "Design Plays a Stellar Role in Exports," *Australian Export Furniture Journal*, 1980, np.
[180] Grant Featherston, "The Future of Plastics in Furniture," *Australian Furniture Trades Journal*, August 1971, 32–35.

during transport or to conserve space when not in use, making them a popular choice for venues with dynamic seating requirements.

The ultimate success in creating a monobloc relied on collaboration—the designer had to develop techniques to ensure the structural integrity of the design under load, while the manufacturer had to develop injection moulding technology sufficiently large enough to produce an entire chair. Easy solutions to either of these tasks were not to be found and progress toward a monobloc was slow.

Fig. 1.13. *Polyside*, Robin Day 1963 Source: © Hille

European designers took the lead in exploring the potential offered by injection moulding. Robin Day (1923-2000), Britain's most successful mid-century designer, achieved outstanding commercial success with *Polyside*, developed with UK manufacturer Hille (fig.

1.13).[181] Injection moulded polypropylene formed the shell, textured to create a non-slip surface in contrast to the glossy, shiny surfaces typical of Space Age fibreglass chairs.

Some Italians, Kartell in particular, then took the lead in progress toward developing a monobloc. Kartell was founded in 1949, by the chemist Giulio Castelli and his wife, architect Anna Castelli Ferrieri. This combination of technical expertise and design talent proved crucial for the company's success. Castelli led the polymer research while Ferrieri went on to create many successful designs for the company.[182] Smooth shiny surfaces celebrating plastic-as-plastic, became a common characteristic among Italian designs in this period.

Fig. 1.14. *Empilable 4999/5*, Richard Sapper and Marco Zanuso, 1964. Source: Thessaloniki Design Museum

[181] "Produced in tens of millions, and has been manufactured under licence all over the world." Jackson, *Robin & Lucienne Day*, 122.
[182] Sparke et al., *The Plastics Age*, 84.

The *Empilable* was the first chair developed by Kartell using injection moulding. It took over four years and 50 prototypes to perfect the design and locate 'the point of coinciding—of the needs of the new technology to those of the design.'[183] Richard Sapper (1932-2015) and Marco Zanuso (1916-2001) child's chair was light, stackable and available in a range of bright colours (fig. 1.14 & 1.15). Only a children's chair could be made due to limitations on the size of injection moulding equipment available. [184] Production of the *Empilable* still required the legs to be moulded separately and clipped individually into place below the seat.

Fig. 1.15. Children experiment with the stacking feature of *Empilable 4999/5*. 1964.
Source: Kartell

[183] Morello, and Ferrieri, *Plastic and Design*, 136.
[184] Otakar Máčel, Sander Woertman, and Charlotte van Wijk, *Chairs: The Delft Collection* (Rotterdam: 010 Publishers, 2008).

Starting with the *Empilable* as the template, Joe Colombo (1930-1971) was challenged by Kartell to develop an adult version of the chair (fig. 1.16 & 1.17). Again, the legs had to be moulded separately from the shell due to limitations on the size of moulding machines available.

Fig. 1.16. *Universale* (No. 4867), Joe Colombo 1967. Source: © Vitra Design Museum

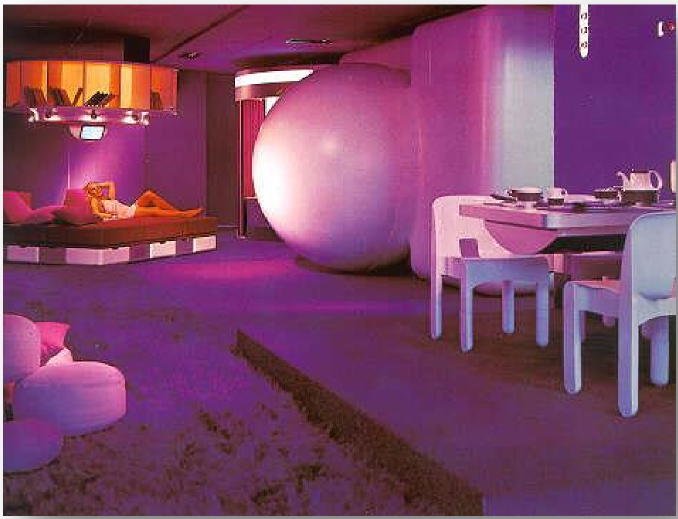

Fig. 1.17. The *Universale*, on display in one of Colombo's futuristic exhibition settings for Bayer AG Wohnmodel 1969 at Visiona. Source: DailyIcon

Despite the commitment and investments made by Kartell, German designer Helmut Bätzner (1928-2010) working with manufacturer Bofinger succeeded in creating the first monobloc chair (fig. 1.18). Research financed by German industry had led to significant advances in polymer adhesives, acrylic glass, and injection moulding machines. It is fitting, then, that despite the prolonged efforts of Italian designers, the first monobloc was developed in Germany.

Fig. 1.18. *Bofinger BA 1171*, Helmut Bätzner 1966. Source: © Vitra Design Museum

The *Bofinger BA 1171* (named in tribute to Rudolf Baresel-Bofinger, the owner of the manufacturer) became the prototype for the ubiquitous monobloc chair, of which countless millions have since been made by numerous manufacturers all over the world. During two years in development, scrupulous attention led to the L-shaped, splayed legs with triangular feet, developed to maximise strength while minimising the footprint. The efficiency of this design solution, simpler than that developed by Magistretti for the *Selene* (fig. 1.19), is best demonstrated by comparing the legs of the *Bofinger* with those of an inexpensive monobloc available from hardware stores today (fig. 1.21). The angle and shape have hardly changed in over 50 years, despite endless investment in computer technology (including CAD), materials, and manufacturing technologies.

The *Selene* was inspired by German technology, not the efforts of Kartell, according to manufacturer *Artemide's* founder (fig. 1.19). Ernesto Gismondi returned from a trip to Germany where he had seen Reglar (fibreglass reinforced polyester) being used to make photographers' developers trays. These trays directly inspired Vico Magistretti (1920-2006) to design the *Selene*, a complex process that took nearly eight years to complete.

Magistretti expressed the challenge:

> I didn't want a chair to be composed of several different parts, I wanted a single unit; nor did I want to create a chair like Joe Colombo's [*Universale*] that, with its thick, heavy legs, looked like an elephant, although it was well designed and very imaginative.[185]

Working with a fibreglass sheet (later replaced with ABS) just three millimetres thick to form the unique S-shaped legs allowed the design to retain an elegant simplicity while meeting the demands of regular use.[186]

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[185] Vanni Pasca, *Vico Magistretti: Elegance and Innovation in Postwar Italian Design* (London: Thames and Hudson, 1991).

Fig. 1.19**.** *Selene*, Vico Magistretti 1969 Source: © Vitra Design Museum

[186] "Vico Magistretti – Heller," accessed February 3, 2022, http://hellerinc.com/designers/vico-magistretti/.

Fig. 1.20. The *Selene*, as featured on the set of the British TV sci-fi *Space 1999*, 1975. Source: Films and Furniture

Fig. 1.21. *Fauteuil 300* (left), Henry Massonnet, 1972. Standard monobloc chair from hardware store (right) 2021. Source: © Vitra Design Museum Source & Bunnings

Engineer and entrepreneur Henry Massonnet (1922-2005) arguably perfected the monobloc with his design, available from 1972.[187] The *Fauteuil 300* was produced in a single injection moulding process in less than two minutes (since reduced to one), with no hand finishing required (fig. 1.21). Massonnet linked the front legs to the backrest using the armrests, minimising the material required for support while enhancing stability, as the chair flexes to distribute applied weight over all four legs, adjusting to support the sitter regardless of their position.[188] Using the armrests to enhance stability provided an engineering solution to the monobloc challenge yet to be surpassed. The monobloc also set a new benchmark in energy efficiency, with the reduced cycle time reflected in energy saving as the motors and pumps serving the machines are used less for each unit of output.[189]

During the 1980s, low-priced monoblocs based on this design started appearing globally but, in a tribute to the efficiency of Massonnet's solution, no visibly significant improvements to the basic design have been made since (fig. 1.21 & 1.22). Virtually identical chairs are available from hardware stores or garden centres anywhere, with the design remaining almost unchanged over the past fifty years. Global distribution was aided by Western manufacturers replacing their (expensive) moulds when they began to show signs of wear.

[187] The Fauteuil derives its name from its shape, consistent with what we now call a traditional standard chair as developed from the French seventeenth century. The definition of the French word *fauteuil*, popular in the eighteenth and nineteenth centuries, is 'wooden a seat in the form of an armchair with open sides and upholstered arms', and connotes an armchair generally today.
[188] Ingo Niermann, "Ingo Niermann: Plastic Chair at Functionalfate.Org - Jens Thiel´s Monoblock Plastic Chairs Weblog," April 26, 2004, https://web.archive.org/web/20080121033144/http:/www.functionalfate.org/archives/2004/08/26/light-seems-heavy/.
[189] Hanieh Mianehrow and Ali Abbasian, "Energy Monitoring of Plastic Injection Molding Process Running with Hydraulic Injection Molding Machines," *Journal of Cleaner Production* 148 (April 1, 2017): 804–10, https://doi.org/10.1016/j.jclepro.2017.02.053.

Empilable 4999/5, 1964

Universale (No. 4867), 1967

Bofinger BA 1171, 1966

Selene, 1969

Fauteuil 300, 1972

Bunnings, 2021

Fig. 1.22. Development of the monobloc. Source: © Vitra Design Museum except Thessaloniki Design Museum (top left) and Bunnings (bottom right)

Second hand, worn moulds are then sold for a fraction of their replacement cost to manufacturers in low- and middle-income earning countries, enabling even more cost-effective production and lower retail prices.[190]

The monobloc is divisive among designers and consumers alike, perhaps explained by the dichotomy between its indisputable engineering success and its design credentials, often viewed as dubious. Critics argue the white monobloc has become ubiquitous. It is the ultimate symbol of global mass consumption homogenising the world, guilty of cross-cultural convergence, a definitive example of globalising one-worldism.[191] An image of a monobloc offers no clue about its location—both in time and space. Ethan Zuckerman, then at MIT, said of it: 'I have a hard time thinking of other objects that are equally independent of context.'[192] However, Zuckerman also acknowledges the monobloc as a victory of high modernist design.'[193] Suggesting the designer's goal is to achieve universal acceptance for their objects:

> They never want them to be only culturally specific. They want to transcend, so it can be used by all people. So maybe this is the high modernist design culture just on a cultural level where everybody can afford it.[194]

While Zuckerman applauds the ubiquitous nature of the monobloc, regional variations do occur. While the white monobloc dominates Western markets, bright primary colours are often favoured across Asia.[195] 'Red is a favourite amongst the Chinese, green is well-liked by

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[190] Grosfillex's vice president of manufacturing explained that an expensive mould (well over $1 million dollars), 'might be used to make a million copies of a monobloc for the Western market and after, five or seven years, the mould would be sold to a less demanding manufacturer in Africa for $50,000, and they will make another million chairs with the same mould and sell them very inexpensively.' Gosnell, "Everybody Take a Seat," 76.
[191] Fry and Nocek, *Design in Crisis | Taylor & Francis Group*, 39.
[192] Ethan Zuckerman, "Those White Plastic Chairs – The Monobloc and the Context-Free Object | … My Heart's in Accra," June 4, 2011, http://www.ethanzuckerman.com/blog/2011/04/06/those-white-plastic-chairs-the-monobloc-and-the-context-free-object/.
[193] Suzdaltsev, "White Plastic Chairs Are Taking Over the World," np.
[194] Suzdaltsev, "White Plastic Chairs Are Taking Over the World."
[195] Friedrichs and Eickhoff, *220°C Virus Monobloc*, 12.

the Malays and blue is preferred by Indians.'[196] In Sri Lanka, monoblocs come in many colours and with ornate floral and flame-like designs. Malaysian manufacturer *Mah Sing* claims the market for their white chairs is limited to funeral parlours.[197]

An article for Smithsonian Magazine claimed the monobloc is 'in the worst possible taste, so cheap, ugly and everywhere.' The monobloc is accused of turning outdoor eating spaces in America 'into tawdry, second-rate imitations' of European style cafés.[198] Indeed some European cities (including Bern, Zurich, Bratislava and Barcelona) have gone as far as banning monoblocs from public spaces.[199] Hank Stuever, a Washington Post writer, accused the resin stacking patio chair of being, 'the Tupperware container of a lard-rumped universe.'[200] Ralph Caplan (a design consultant) says the chair is a sad reflection of consumer society, satisfying the lowest common denominator with little regard for quality.[201] The monobloc is the ultimate incarnation of the plastic paradox, an engineering triumph that has made relatively comfortable seating available to billions of people across the planet for the first time. It delivered the modernist ideal of democratising design. In this achievement, the monobloc has homogenised the world, perhaps more so than any other single design and is responsible for a significant contribution to the environmental disaster caused by plastic waste. Monoblocs symbolise the complexity of material culture; they are the definitive symbol of globalised consumer modernity while destined to become the most common future relic of the fossil plastic age.

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[196] Justin Zhuang, "The Chair That's Everywhere by Justin Zhuang," Works That Work magazine, 2018, https://worksthatwork.com/10/the-chair-thats-everywhere.
[197] Zhuang.
[198] Gosnell, "Everybody Take a Seat."
[199] Friedrichs and Eickhoff, *220°C Virus Monobloc*.p14 & 19
[200] Gosnell, "Everybody Take a Seat."
[201] Rybczynski, *Now I Sit Me Down*.

Fig. 1.23. *Cantilever 290*, Steen Østergaard 1966/1970? (left) *Panton*, Verner Panton 1967 (right)
Source: Steen Østergaard and © Vitra Design Museum

Development of a cantilevered chair had long intrigued designers and, in the 1960s two Danish designers raced to develop the first monobloc solution (fig. 1.23).[202] Steen Østergaard's (1935-) *290* possibly pre-dates the *Panton Chair* commonly described as the first cantilevered monobloc. The *290* features a sweeping curved base, giving more legroom while enhancing gravity defying illusion of the design. The chair may not have entered production until 1970, although the designer insists the *290* was available from 1966.[203] Getting the *290* into production required the manufacturer, Cado, to invest in what they claimed to be the world's largest injection moulding tool. Once in production a chair could be moulded in just 132 seconds. After being removed from the mould the chair had to be allowed to dry before the seams were sanded, varnished, and packed for delivery. This

[202] In the 1920s, tubular steel and leather had been used by at least four German designers (Ludwig Mies van der Rohe, Marcel Breuer, Willem Gispen and Mart Stam) to develop cantilevered seating solutions. In the 1930s, Gerrit Rietveld developed the Zig Zag chair using solid wood, having previously experimented with plywood and steel to develop a continuous shape. This design also fell short of being a monobloc as it is constructed from four separate flat boards.
[203] In emails to the author Østergaard (through his daughter) insists his design was available before the *Panton Chair*. However, no documentary evidence has been supplied to support this claim. The original manufacturer Cado is no longer trading.

design then still fell short of the ultimate goal—to design a chair that could be moulded in one-piece and emerge from the mould ready for use.

The S-shaped *Panton Chair* is one of the best-known plastic chairs. Peter Fiell nominates it as 'one of the most important events in the entire history of furniture design.'[204] Of all the Scandinavian designers Danish Vernon Panton's (1926-1998) work is the most synonymous with the Space Age movement. He used vibrant and exotic colours to create a futuristic world using the latest materials and manufacturing techniques for products and interiors that can be best described as funky or 'out there.'[205] Panton worked on the design for the S-shaped chair from at least 1956. By the end of the 1950s, Panton had built full-scale model of the stackable chair made from polystyrene foam.[206] Panton did then have arguably the first design for a one-piece moulded cantilevered chair. However, getting the design into production proved to be both problematical and time consuming. Scandinavian manufacturers were unwilling to take on the challenge, but Panton eventually (in 1962) secured the backing of Vitra. Five years and ten prototypes later, the *Panton Chair* launched in the Danish design journal, *Mobilia*, in August 1967, causing a sensation, (despite the first series being restricted to just 150 copies).[207] In 1998, Vitra introduced polypropylene to the production process, enabling a true monobloc (i.e., one process with no finishing required) version of the design to be finally produced.[208]

[204] Gosnell, "Everybody Take a Seat."
[205] Panton studied architecture at the Royal Danish Academy of Fine Arts in Copenhagen before going on to work with Arne Jacobsen (who would design the Swan, Egg and Drop chairs) from 1950-'52 where curved plywood was being used extensively. Engholm, Michelsen, and Panton, *Verner Panton*, 34.
[206] Vitra Design Museum.
[207] Panton worked with another company (A. Sommer, distributed by Thonet) to develop a plywood version of this design (S-chair) which was available from 1965 or 1966 James Christopher Postell, *Furniture Design*, Second edition (Hoboken, New Jersey: John Wiley & Sons, Inc, 2012), 228..
[208] "Panton-Chair - Verner Panton," accessed February 3, 2022, http://www.verner-panton.com/furniture/archive/7/.

Fig. 1.24. Marianne Panton sat on the *Panton Chair*, with The Shell Lamp and a Unika Vaev rug, 1967. Source: Verner Panton

Fig. 1.25. *Air Chair*, Jasper Morrison 1999 Source: © Jasper Morrison

Jasper Morrison fêted the introduction of the next step change injection moulding technology to the furniture industry by naming his design after it (fig. 1.25). Air injection technology made it possible to create highly resistant, super-lightweight products and eliminated the necessity for structural ribs to provide strength. The owner of manufacturer Magis introduced Morrison to the capabilities of the technology by showing a section of tube made using the air injection process. John Tree, Senior Designer at the Jasper Morrison office, explained in an interview with the author, 'it looked like a bone section.'[209] Morrison was invited to experiment with the new technology leading to the development of the *Air Chair*.

[209] Geoff Isaac, Interview with John Tree from Jasper Morrison Office, July 23, 2019.

While the technology had been used to make components by the automobile industry, air injection was relatively new to the furniture industry.[210] Nitrogen gas is pumped into the mould to create hollows in the still-molten plastic, minimising the material required (*Air Chair* weighs just 4.4kg). The pressured gas also ensures the plastic does not shrink away from the mould's surface preventing warping when developing complex and challenging forms. Gas helps distribute the pressure evenly, eliminating the stress and flow lines that can occur during a standard injection process.

Monoblocs typically provide adequate strength in the legs through folding or wrapping a sheet of material. Air injection enabled new approaches, freed from the need for uniform thickness as Tree explained:

> It was plastic becoming flexible enough to do very simple designs that allowed the exploration of the kind of typology of the object, rather than have the material dictate its form… before that time, no one would consider this possible in plastic because of the size of the sections and the thickness and the use of gas really was what opened those possibilities up.[211]

Air injection quickly became widely adopted by the furniture industry, with manufacturers attracted by the potential for lower unit costs. While upfront tooling costs are relatively expensive, marginal costs are low, although a longer cycle time is required on the moulding machine compared with traditional injection processes. Material and transportation costs are lowered because of the light weighting effects of the process.

London-based design duo, Barber &Osgerby, developed the *Tip Ton Chair* specifically for the education market (fig. 1.26). The chair can tip between two positions simply by the sitter shifting their weight, with the forward-leaning sitting position designed

[210] Air injection had previously been used to make parts of chairs (for example, Alberto Homann's Ensemble chair for Fritz Hansen in 1992), but the *Air Chair* was the first to be made entirely using this process.
[211] Isaac, Interview with John Tree from Jasper Morrison Office.

to straighten the pelvis and spine. The skid base abolished the expensive levers, knobs, and mechanisms required by many adjustable chairs designed for workstation use.

Fig. 1.26. *Tip Ton Chair*, Edward Barber and Jay Osgerby, 2011 Source: © Vitra Design Museum

The *Tip Ton Chair* (2011) is among the first chairs developed using flow simulation software. Edward Barber explained the advantage of incorporating the digital technology and the efficiency the software delivers to the injection moulding process during our interview:

> Vitra had recently acquired new software that enabled them to [conduct] very accurate mould flow simulations. That enabled them to make the sections really quite thin, as small as possible. We could simulate what the outcome was going to be before they cut the tool and this was quite new for them at this point... his was the first time they [Vitra] had done a whole plastic chair using this simulation. In the past, they always had to overcompensate because

> you invest so much money in a tool you can't afford to have a chair come out and it's not strong enough.[212]

Colombo's *Universale* had to be adapted in pre-production, as the hole in the back of the chair interfered with the flow of material in the mould.[213] Using flow simulation software allows for similar issues to be identified before the design progresses to tooling. More efficient use of materials and the ability to develop ideas reliant on thinner components ensured the rapid adoption of flow simulation software by the furniture industry.

Fig. 1.27. Ron Arad *MT Chair*, 2004 Source: Ron Arad Studio

To develop a plastic version of the *MT Chair* (originally made from wood) manufacturer Driade encouraged Ron Arad to revisit rotational moulding (fig. 1.28 for an

[212] Geoff Isaac, Interview with Barber & Osgerby, September 30, 2019.
[213] Morello, and Ferrieri, *Plastic and Design*.

explanation of the process). Arad explained the choice of process in an interview with the author:

> Rotational moulding is favoured by young designers because the tooling cost is a lot lower; it's a fraction of the cost of injection moulding. If you are not anticipating doing a hundred thousand units a year, but only a few a year, rotation moulding makes more sense. For that reason, because it had street credibility with young designers, manufacturers started to look at it [at this time]. It makes each unit more expensive, but the whole process is cheaper [as expensive moulds are not needed]. It is industrial, but semi-industrial… it has its charm.[214]

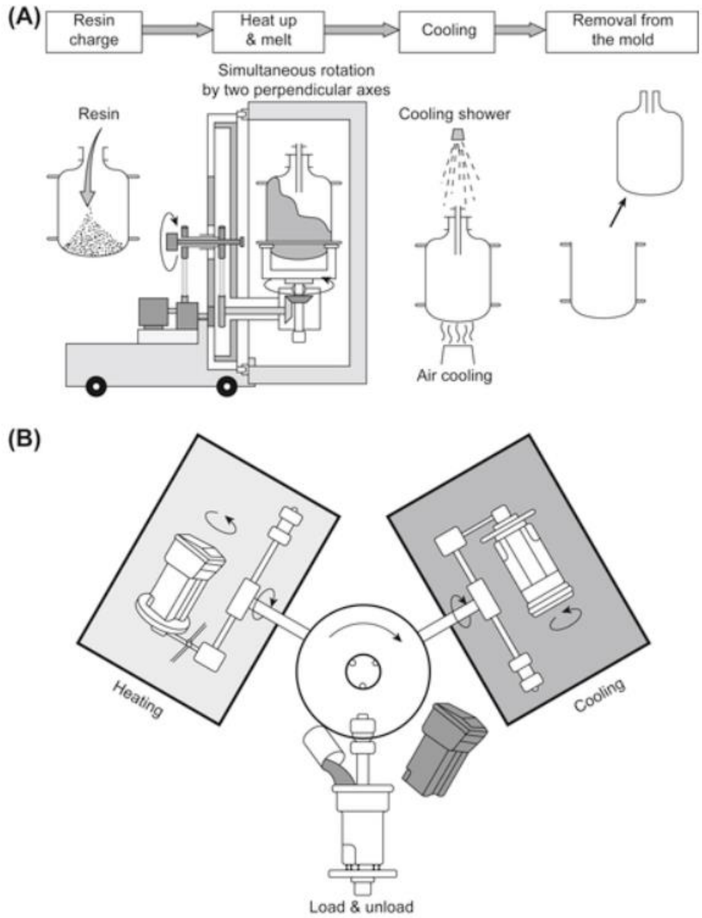

Fig. 1.28. Rotational moulding equipment. Source:
Source: Handbook of Thermoplastic Elastomers by Jiri George Drobny[215]

Arad adapted the technology by asking Sergio Buttiglieri, the project manager at Driade, to experiment with a two-stage moulding process allowing the finished product to emerge in two colours. Buttiglieri explained that the first layer forms the outside of the piece,

[214] Geoff Isaac, Interview with Ron Arad, July 22, 2019.
[215] Drobny, *Handbook of Thermoplastic Elastomers, 2nd Edition*, 124.

providing both structure to the chair and the external colour. The second colour is overlaid in a thin layer with a smooth surface, contrasting with the outer layer which displays a rough texture caused by contact with the mould. Uniform heat distribution across the mould was achieved through much trial and error.[216]

Ron Arad's experience explains why, despite the relatively inexpensive start-up costs, rotational moulding remains a niche technology within the furniture industry. The unit cost of rotationally moulded chairs cannot compete against the economies delivered by injection moulding for any mass-produced quantity.

4. Disappearing chairs

As the end of the twentieth century, Philippe Starck, backed by the financial resources of Kartell, launched the first polycarbonate design, *La Marie*. Anticipating the small transparent design could be perceived as fragile; Kartell confronted any reservations these deceiving looks could instil through their innovative use of an industrial robot at the launch event. Released in time to celebrate Kartell*'s* 50th birthday, the polycarbonate chairs, 250 times stronger than glass, easily survived their rough treatment and the design went on to be rewarded with both critical and commercial success.

[216] Francesca Picchi, "Ron Arad MT 3," Domus, 2005, https://www.domusweb.it/en/design/2005/12/06/ron-arad-mt-3.html.

Fig. 1.29. *La Marie* by Philippe Starck, 1999 Source: © Kartell

During extended production experimentation, Kartell and Starck discovered polycarbonate to be more suited to moulding straight edged designs. Thus, the final form of *La Marie* marked a return to geometric forms favoured by early modernists such as Breuer and Le Corbusier.[217] This style had remained virtually absent during the first 60 years of plastic chairs, with designers having favoured exploration of organic curves. Starck's transparent creation therefore stood out in a crowded market, the unique design complimented by the original use of polycarbonate. Interior designer, Sormeh Rienne, summarised the broad appeal, 'Whether you're a minimalist or a maximalist, this chair

[217] Fiell, Fiell, and Muthesius, *Modern Chairs*, 12.

works.'[218] Transparent furniture quickly became a popular choice for furnishing apartments and small spaces, as it de-clutters while fitting into any style. The design has also proved popular with museums and art galleries around the world where the chairs recede and do not compete with items on display.

La Marie marked a turning point for the industry and transparency has since become a major feature of Kartell*'s* catalogue, with numerous designs added (and since widely copied), (fig. 1.29). Sixty years since the first acrylic glass chairs became available transparent furniture finally became available to, and accepted by, the mainstream market. Competitive pricing from Kartell contributed to the commercial success of the transparent series.[219] Transparent furniture also took Starck closer to his stated ideal of 'democratising' design (improving the quality while striving to make it accessible to the greatest number of people, at affordable prices).[220]

5. Conclusion

In addition to the manufacturing technologies already discussed the petrochemical industry continually diversified their portfolio of plastics, increasing the variety offered while developing materials mouldable at lower temperatures, delivering cost and energy savings.[221] While many of these new materials and technologies were trialled by the furniture industry the pursuit of profit ensured only those improving energy and/or material efficiently

[218] Amanda Lauren, "Why Philippe Starck's Ghost Chair Is Here For Eternity," Forbes, October 31, 2019, https://www.forbes.com/sites/amandalauren/2019/10/31/why-phillipe-starcks-ghost-chair-is-here-for-eternity/.
[219] *La Marie* was released at 250 euros, considerably less than other offerings by named designers at Kartell at that time. By 2014, Kartell claimed they had sold over one million copies of Louis Ghost alone. "Kartell Timeline," accessed February 3, 2022, https://www.housingunits.co.uk/Kartell-timeline.
[220] Wingfield, "Starck Biography."
[221] There are over 60,000 varieties of polymer available. Zainul Huda and Robert Bulpett, *Materials Science and Design for Engineers*, Materials Science Foundations, v. 74 (Zurich-Durnten, Switzerland ; Enfield, NH: Trans Tech Publications, 2012), 338.

were likely to be retained and become more widely adopted. The pursuit of profit happily coincided with the industry adopting technologies delivering improved environmental outcomes. Technologies that promised a quick payback through reduced material, energy, and transportation costs rapidly diffused across the furniture industry. Although the primary motivation is often financial, the outcome closely aligns with eco-efficiency objectives. Introducing new, more efficient technologies is an effective decoupling strategy. The environmental impact of delivering the same (or better) functionality is reduced while cost savings are also achieved.[222]

During the first sixty years of plastic chair production the most significant change was the shift from compression moulding (using lay-up fibreglass) to injection moulding as the main production method. The economics of injection moulding, undoubtedly, made plastic products (including chairs) accessible to a much wider audience. However, injection moulded chairs can lack the 'aura' of fibreglass creations that proudly display their maker's craft skills.[223] Advances in plastic technology made it impossible for designers, using mass production techniques, to benefit from hands-on involvement with the entire process. French design theorist Raymond Guidot claimed that designers working in the early days of injection moulding often had the least opportunity for involvement with the production of their creations.[224] Guidot's opinion is in line with Papanek's, who claimed that objects bearing the signs of their maker's hand create a 'spiritual link between the producer and the user,' suggesting that, when using modern production methods, the connection is lost.[225] In the

[222] Jane Penty, *Product Design and Sustainability: Strategies, Tools, and Practice* (Abingdon, Oxon; New York, NY: Routledge, 2020), 129.
[223] Walter Benjamin claimed, 'that which withers in the age of mechanical reproduction is the aura of the work of art. Benjamin, "The Work of Art in the Age of Mechanical Reproduction," 221.
[224] Guidot, *Industrial Design Techniques and Materials*, 278.
[225] Victor Papanek, *Design for the Real World: Human Ecology and Social Change* (London: Thames and Hudson, 1985).

digital age, designers benefit from greater control over their creations, keeping them longer than when it was necessary to hand a design project over to the R&D or engineering departments.[226] With both digital technology and fibreglass, designers have the ability to retain direct control over their creation from design to finished product, not possible in the early days of injection moulding.

By the end of the twentieth century fossil-based plastic technology had matured. Future advances, such as flow simulations software, were iterative, still improving efficiencies (and often reducing environmental impacts) but signalling the end to step change improvements such as those delivered by air injection moulding. Manufacturers were achieving more with less. However, awareness that dematerialisation was nearing its limits was growing. As Starck observed, 'you cannot dematerialize a chair completely, because you must continue to sit on it.'[227] The limits of infinite progress became increasingly apparent. Plastic chairs simply could not get much smaller, lighter, thinner, or even less visible.

As the industry entered the twenty first century it became increasingly apparent the environmental benefits achieved through dematerialisation were continually outstripped as demand for more goods and services grew, driven by an increasingly numerous and affluent global population.[228] As sustainability issues became of increasing concern, the need for a new approach became ever more apparent. While the focus of sustainability discourse has since shifted from the product level to the system level, the dematerialisation advances made

[226] Guidot, *Industrial Design Techniques and Materials*, 278.
[227] "Q&A: Philippe Starck on Bioplastics, Virgin Galactic, and His Impossible Chair," *Wired*, accessed February 3, 2022, https://www.wired.com/2008/08/pl-design-9/.
[228] Escobar, *Designs for the Pluriverse*, 33.

during the twentieth century are not automatically irrelevant.[229] Investment and experimentation in dematerialisation led designers to focus on material and energy optimisation, generating solutions that form the foundation of efforts toward a more sustainable future. The quest for dematerialisation led to the development of many designs that have since earned iconic status while educating designers and consumer alike on the true value of doing more with less.

[229] For example, “addressing sustainability challenges requires an integrated set of DfS approaches spanning various innovation levels.” Ceschin and Gaziulusoy, “Evolution of Design for Sustainability,” 147.

Part A

The plastic chair market

Chapter 2

Plastics, saviour or exterminator?

At the end of the nineteenth century elephants faced extinction. Nearly half a million kilograms of ivory was taken every year, mainly to supply the rapidly expanding market in Europe and the United States for billiards, the most sought-after entertainment pastime among society elites.[230] Faced with the prospect of dwindling supplies, a New York billiard-table manufacturer announced a competition in 1863 to find an alternative to ivory.[231] The generous prize effectively kick-started research into synthetic polymers. Following six years of trial and error, John Hyatt produced a billiard ball made from celluloid (cellulose nitrate).[232] Unfortunately, this first semi-synthetic polymer proved ultimately unsatisfactory for the task; on impact the balls produced an explosive sound, like a gunshot.[233] Indeed, a Colorado saloonkeeper reported that guns were drawn in his bar, 'every time the balls collided.'[234]

Hyatt used celluloid as a substitute for a traditional material, contributing to plastic's reputation as a cheap and inferior imitator. Soon discarded, those billiard balls were to be joined by other early plastic items that had proved equally unsuitable for their intended purpose. Although often poorly made, those rejected goods proved difficult to dispose of and certainly did not biodegrade; the most dangerous characteristic of most plastics. Ever growing quantities of discarded plastics accumulated in landfills or littered our environment.

The introduction of plastics delivered an immediate reprieve for the elephants, but the true cost of their salvation remained uncalculated for over a century. Throughout the

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[230] Freinkel, *Plastic*, 15.
[231] Smithsonian, "The Age of Plastic: Ingenuity and Responsibility" (2012 MCI Symposium, Washington, DC, 2012), https://smithsonian.figshare.com/articles/book/The_Age_of_Plastic_Ingenuity_and_Responsibility_Proceedings_of_the_2012_MCI_Symposium_/9761735.
[232] National Museum of American History.
[233] Robert D. Friedel, *Pioneer Plastic: The Making and Selling of Celluloid* (Madison, Wis: University of Wisconsin Press, 1983); Freinkel, *Plastic*, 17.
[234] Freinkel, *Plastic*, 17.

twentieth century, inexpensive, lightweight fully synthetic plastics became indispensable to daily life resulting in ever-increasing demand. One hundred years after the discovery of celluloid, concerns around the health impacts of synthetic polymers began to emerge. By the 1970s, as these revelations permeated the public consciousness, the material fell from favour among furniture designers and consumers alike.

This chapter examines the uptake of plastics with a specific focus on to their use in Australian homes, particularly when used for furniture. Northern hemisphere counties took the lead in developing and responding to the plastics industry. In Europe and the United States plastic furniture was designed and developed specifically to exploit the significant economies of scale made attainable by very large production runs, to service multi-national markets. Australian designers and manufacturers, operating in a remote market with a small population, faced unique challenges in attempting to produce furniture using the latest plastic technologies. Success depended on developing innovative strategies to develop and promote furniture while avoiding the upfront costs associated with many of the new manufacturing techniques. In addition to the geographic, demographic and political limitations of the Australian market, local designers and manufacturers had to navigate the oscillations in economic conditions and fluctuations in health and environmental concerns which affected the entire plastics industry, with devastating effects on the local industry. Examination of how local designers and manufactures historically adopted -and adapted plastic technologies has much to reveal about successful small-scale innovation of plastic technologies many of which remain relevant for those seeking to experiment with renewable carbon plastics.

1. Early plastics

Elephants were not the only beneficiaries of synthetic plastics. The Celluloid Manufacturing Company claimed, ‘as petroleum came to the relief of the whale, [so] has celluloid given the elephant, the tortoise, and the coral insect a respite in their native haunts.’[235] Plastics’ chameleon-like ability to mimic other materials was exploited to make convincing, affordable versions of small objects traditionally made from ivory, bone, tortoise shell, hoof, and horn among others. Indeed, the ability of plastics to be easily moulded to virtually any shape gave them a unique advantage over these traditional materials.

As historian Robert Friedel observed, the ability to convincingly imitate traditional materials was crucial to the acceptance of plastics.[236] Disguised as the familiar, suspicions around the laboratory origins of the new materials were avoided. For instance, material scientist, Odile Madden suggested, ‘by emphasizing the connection to ivory and tortoiseshell, manufacturers of celluloid were also communicating the material properties of the new, unfamiliar substance.’[237] However, imitating these natural materials to produce combs, buttons, knife handles, collar stays, dressing table and manicure sets also exposed the material to criticism; with many regarding plastic as the, ‘poor, ersatz cousin that was not quite as authentic or good as the original.’[238] French historian Bernadette Vincent argues the very fact that plastics could be used to imitate other materials meant the material was regarded with suspicion, its versatility and multipurpose nature causing the unease.[239]

[235] Meikle, *American Plastic*, 12; Friedel, *Pioneer Plastic*, 17.
[236] Making objects look like they were made from ivory or tortoiseshell allowed manufacturers to produce objects “in an indisputably acceptable form." Friedel, *Pioneer Plastic*, 61.
[237] Odile Madden, “Balancing Ingenuity and Responsibility in the Age of Plastic” (The Age of Plastic: Ingenuity and Responsibility, 2012 MCI Symposium, Suitland: Museum Conservation Institute, 2012), 8.
[238] Madden, 8.
[239] Bensaude-Vincent, “Plastics, Materials and Dreams of Dematerialization,” 19.

Vincent also highlights another concern for users; extremely light composites displayed the toughness, heat resistance, and stiffness of steel – what could be more unnatural than that?[240]

But plastics held an irresistible advantage; they could be moulded into products of acceptable quality that could be offered at a price point that appealed to a wider market, helping to overcoming scarcities endured throughout WWII.[241] British design academic, Tom Fisher observed that the significant investment of time, skill, and money needed to perfect the surfaces of moulds is reproduced perfectly on the surfaces of even the cheapest plastic objects, imbuing them with a sense of luxury.[242] Convincing imitations of traditionally expensive luxury items were, for the first time, made available to people of moderate means.[243]

The undeniable economic advantages of working with the material led to its rapid adoption by manufacturers and consumers alike. The efficiencies achieved by manufacturing with plastics could be passed on through lower prices to consumers. At the same time, these advantages were also regarded by others as proof that these new materials were no more than cheap substitutes, second–class or inferior materials, offering a merely 'plausible counterfeit of natural materials,' suggests curator and writer, Jane Boyd.[244] They originated

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[240] Bensaude-Vincent, 25.
[241] Writing in 1940, Van Doren appreciated the significance of plastics for 'the mass production designer. Here was a material that offered a chance for infinitely delicate detail; they were pleasant to the touch and lustrous, and offered an infinite colour range. Small wonder that designers welcomed them with open arms.' Harold Van Doren, *Industrial Design* (New York: McGraw-Hill, 1940), 303.
[242] Tom Fisher, "Fashioning Plastics," *The Social Life of Materials*, 2015, 119–35.
[243] The economic advantage offered by synthetic polymers proved irresistible to producers as well, DuPont claimed a single operator could produce 10,000 combs in one day using an early (small) injection moulding machine, compared with just 350 when working by hand. Susan Freinkel, "A Brief History of Plastic's Conquest of the World," Scientific American, May 29, 2011, https://www.scientificamerican.com/article/a-brief-history-of-plastic-world-conquest/.
[244] Jane Boyd, "Celluloid: The Eternal Substitute," *Science History Institute*, November 11, 2011, https://www.sciencehistory.org/distillations/celluloid-the-eternal-substitute.

from alchemists' laboratories and not from nature; plastics were unnatural, lacking, 'social and physical authenticity,' suggests Fisher.[245]

Design academic Ezio Manzini argues that for plastics to enter high culture they had to take on their own form and find their own image. He argues that plastics became accepted when their economic value combined with cultural value. By showing their own qualities such as clarity or colourfulness, glossy surfaces, fluid forms, and ability to be moulded in a single piece, plastics demonstrated marks of the new not imitating the old. By not pretending to be anything other than plastics, and by not denying their manufacturing processes, or apologising for what they are, the materials were accepted, allowing them to 'take their place in the collective memory alongside existing materials.'[246]

Transparent acrylic glass could be used as a substitute for silicon glass. However, its strength combined with its ability to be moulded allowed acrylic glass to be used for a far wider range of applications. DuPont capitalised on these attributes in an attempt to differentiate their acrylic glass (Lucite), with a 1940 sales brochure asserting that Lucite, 'has been acclaimed, not as an imitation of something else, but as a material capable of standing upon its own merits.'[247] No details of any evidence to support the claim are provided, but the same issue of the company magazine devoted three pages to an article illustrating the wide applications to which Lucite has already been applied—across all aspects of interior design, including furniture (fig. 2.1). Clearly it would not be practical to make most of these items with silicon-based glass. Acrylic glass opened up new possibilities, quickly exploited by

[245] Fisher, "Fashioning Plastics," 126.
[246] Ezio Manzini and Erik, *Design, When Everybody Designs: An Introduction to Design for Social Innovation* (Cambridge, UNITED STATES: MIT Press, 2015), 54, http://ebookcentral.proquest.com/lib/uts/detail.action?docID=3339947.
[247] "Design for Modern Living," *The DuPont Magazine*, April 1940, 7.

designers developing products, including chairs, which proudly celebrated plastic-as-plastic and not as an imitator of other materials.

Fig. 2.1. The DuPont Magazine, April 1940 (page 8 &9) showing various applications of Lucite across all aspects of interior design. Although not identified in the article, the chair, stool, lamp and side table can be attributed to LA-based Swedlow Plastics as featured in the company's 1941 brochure.[248]
Source: Courtesy of the Hagley Museum and Library

[248] Swedlow, "Plastics by Swedlow (Company Brochure)." Brochure kindly supplied by Jeffrey Meikel.

Significantly, these new offerings were not aimed at the mass market commonly associated with most early plastic products, but priced to only be obtainable by the most affluent. News of these developments quickly reached Australia, with a January 1940 edition of the *Mercury* reporting, 'chairs and tables of a crystal-like plastic material, transparent yet strong, have appeared to astonish as well as please the home decorator looking for new ideas.' [249] The article went on to concede that 'their cost as yet gives them the fashionable exclusiveness of very fine furnishings.'[250]

Plastic then began to develop a dual existence, cheap and poorly-made products continued to flood the market while the material, simultaneously, became increasingly used in products designed specifically for the most affluent members of society. This is an example of the paradox of plastic. Writing at this time, Victor Yarsley and Edward Couzens predicted that plastics held the promise of 'a new, brighter, cleaner and more beautiful world.[251] The book concludes with a utopian vision of the future predicting:

> This plastic man will come into a world of colour and bright shining surfaces where childish hands find nothing to break, no sharp edges, or corners to cut or graze, no crevices to harbour dirt or germs.... The walls of his nursery, his bath ... all his toys, his cot, the moulded light perambulator in which he takes the air... [252]

The authors then describe in detail (over three pages) how plastics will be incorporated into every aspect of life until the very end:

> [In his old age the plastic man] wears a denture with silent plastic teeth and spectacles with plastic lenses ... until at last he sinks into his grave in a hygienically enclosed plastic coffin.[253]

[249] "Crystal-Like Furniture," *Mercury (Hobart)*, January 8, 1940.
[250] "Crystal-Like Furniture."
[251] Victor Yarsley and Edward Couzens, *Plastics* (London: Penguin, 1941), 158.
[252] Yarsley and Couzens, 149.
[253] Yarsley and Couzens, 152.

Yarsley and Couzens' prediction is often quoted, but it is not unique, with many observers sharing similar visions. Five years earlier, the regional press in Australian published its own utopian prophecy—with an August 1935 edition of the *North Western Courier* claiming:

> Soon everybody will be sitting on plastic chairs, sleeping in plastic beds, eating food from plastic dishes set on plastic tables.[254]

By 1942, the local vision had been expanded with the *Woman's Mirror* claiming:

> You will soon rise from your plastic bed, bathe in your plastic bath, use your plastic brush and comb, and breakfast from a plastic table while seated on a plastic chair. Later on you will pick up your plastic mounted handbag and hop into your plastic bodied car on your weekly shopping jaunt.[255]

Throughout the Western world these utopian predictions circulated as World War II (WWII) began, with profound consequences for the development of the plastics industry. During the war output from most industries was completely consumed in support of the war effort.[256] By the time America joined WWII, Japan had invaded many of its neighbours, preventing allied forces from accessing their traditional sources of rubber, tin, and silk among other commodities.[257] The plastics industry quickly expanded production and developed variants as substitutes for these materials to feed the war machine.[258] At that time chemists learnt to

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[254] "All Plastic Home on Way," *North Western Courier*, August 12, 1935 the 1933 ABS Census shows the total population of Narrabri and West Narrabri was just under 4,000.

[255] Francesca Bacon, "Science in the Home," *Woman's Mirror*, October 27, 1942, https://nla.gov.au/nla.obj-505817600.

[256] In the USA, 85% of output from the plastics industry had been diverted to the war effort. Young America Films, *History of Plastics: Plastics in World War II: Plastics (1944) - CharlieDeanArchives*, 1945, https://www.youtube.com/watch?v=GirvOmjPZrc., while in the UK 80% of furniture manufacturer were involved with 'some sort of war work' *Atlas of Furniture Design*, 354. In Australia, 'the Australian plastics industry, which concentrated almost 100% on war goods during 1939-45, is now sturdily pushing ahead with peacetime expansion' "New Australian Plastics," *Pix*, April 20, 1946, 20.

[257] See for example, Ronald H. Bailey, "Iron Will," *World War II; Leesburg* (Leesburg, United States, Leesburg: Weider History Group, Inc, August 2010); "The Bars Go Up," *TIME Magazine* 36, no. 3 (July 15, 1940): 60–62.. Another article in Time magazine highlighted the impact on women – "The U.S. woman, it appeared, by 1941's end would have a choice of 1) going barelegged, 2) buying Nylon stockings which might be unprocurable, or 3) wearing cotton stockings' "The Presidency The Last Step Taken," *TIME Magazine* 38, no. 5 (August 4, 1941): 11–12.

[258] Production of plastics in the USA alone nearly quadrupled, from £213 million in 1939 to £818 million in 1945 Meikle, *American Plastic*, 125. In Australia, Pix magazine reported, 'Well on its feet throughout the world before the war, the industry benefited in wartime by finding new used for its products, because of shortage of materials like rubber, metal.' "New Australian Plastics."

design at the molecular level delivering strong and tough plastic variants, specifically engineered to suit an ever broadening variety of demands.[259] Importantly, armed service personnel relied on plastics to protect or even save their lives, commanding a new respect for the material. Mortar fuses, parachutes, aircraft components, antenna housing, bazooka barrels, enclosures for gun turrets, helmet liners, were among the countless applications depended on by service personnel.[260]

The opportunity to gain an appreciation of the true potential of plastics extended beyond those serving on the front line, with John Gloag, at the end of WWII, predicting:

> Women... who have helped to build Spitfires and Hurricanes, are likely to welcome light and easily cleaned equipment in their houses, and especially in their kitchens; they are going to appreciate the smooth translucent and gaily coloured plastics that will be available for the making of kitchen equipment and furniture.[261]

Gloag went on to claim that plastic will 'bring to the service of industry an array of new properties—new gifts of lightness, translucency, transparency, texture and colour.'[262] He was right, demand soared—in the US alone production of plastics reached 2.4 billion lbs. in 1951, up over tenfold (from just 213 million lbs.), in the year WWII broke out.[263]

Wartime advances and applications demonstrated that plastics had uses well beyond their pre-war applications. Manufacturers learnt that 'plastics have inherent advantage as structural materials in their own right, and that plastics often prove superior to other materials.'[264] In 1945, the inaugural issue of the local trade magazine, *Australian Plastics*, gave special attention to the material's use in the post-war home including plumbing,

[259] Meikle, *American Plastic*, 126.
[260] See for example, *Plastics in War,* Australian Plastics, August 1951, 9&11.
[261] Gloag, *Plastics and Industrial Design*, 41.
[262] Gloag, 17.
[263] Meikle, *American Plastic*, 125.
[264] *Plastics in War*, Australian Plastics, August 1951, 9.

furniture, and the vast scope of moulded plastics in the building industry.'[265] Together with government, industry was keen to reposition the material as war time uses were no longer in demand, resulting in excess supplies of plastic at a time when most resources remained scarce. A year after WWII ended Sydney's *Daily Telegraph* bluntly announced:

> There's a lot of perspex *[sic]* about, because it was made for aeroplanes, which aren't in such big demand as they were a few years ago… You've only got to look around the city shops, however, to see that it's going to be a plastic Christmas. Start in early with those guiding hints if you want to avoid receiving a transparent aeroplane part twisted into a toast rack, a coat-hanger, a set of swizzle sticks, or an occasional table.[266]

Fig. 2.2. Perspex table being manufactured at Paul and Gray Ltd, Melbourne.
Source: Pix. Vol. 17 No. 13, 20 April 1946

[265] "Australian Plastics," *Illawarra Mercury*, June 22, 1945.
[266] Norman Bartlett, "The Plastic Refrigerator Is Here (Wot, No Beer?)," *Daily Telegraph*, November 28, 1946.

Faced with chronic shortages of most traditional materials governments placed high expectations on the plastics industry to meet increasing demands for housing and furniture from people returning from active duty. There was also pent-up demand for the many consumer goods unavailable during the war.[267] Plastics displaced craft-based production but ushered in a new era of plenty, allowing an ever-increasing range of consumer goods to be made available to households on even the most meagre budgets.

a. Sensory appeal of plastics

Michael Ashby, a metallurgical engineer who has written extensively on material selection, emphasises the importance of sensory experiences in selecting products:

> Anaesthetics numb the senses, suppress feeling; anaesthesia is a lack of sensation. Aesthetics do the opposite; they arouse interest and stimulate and appeal to the five senses, particularly the sense of vision. It is through the senses that we experience material.[268]

Egyptian scholar, Alaa Anssary claims: ‘aesthetic perceptions play a significant role in the actual and perceived experience of products.’[269] He goes on to argue that aesthetics connects the personal experiences of the observer with the product. The properties of new plastics displayed impressive technical specifications. However, for any material to be accepted by a designer or consumer it must first satisfy their aesthetic needs as argued by materials specialist from Delft University, Elvin Karana et al., ‘the sensorial component of

[267] Professor of art history and critic Giulio Argan has a sceptical explanation of the role of the designer in this transition: ‘It is no mere accident that interest in design became accentuated immediately after both World Wars, at a time when the vast war industry was under the accusation of having been primarily responsible for these disasters’ Emilio Ambasz, *Italy: The New Domestic Landscape Achievements and Problems of Italian Design* (New York: MoMA, 1972), 358.

[268] Karana, Pedgley, and Rognoli, *Materials Experience*, xx.

[269] Alaa El Anssary, “An Approach to Support the Design Process Considering Technological Possibilities” (PhD., Germany, Universidad de Duisburg-Essen, 2006), 119, https://www.academia.edu/28054251/An_approach_to_support_the_design_process_considering_technological_possibilities.

experience is omnipresent and inevitable.'[270] In addition to being visually pleasing the user experience must meet, 'or supersede the tactile perceptions.'[271]

A 2017 survey of twenty Turkish design professionals led by Karana found that industrial designers understand the importance of the aesthetic appeal of materials and give them appropriate priority when creating a new product.[272] The survey found that in the conceptual design stage, designers are primarily interested in sensorial aspects of materials ('the appearance of the material, that is texture, final surface finish, color and all properties appealing to the senses').[273] As a concept develops, the technical properties of the material become more important but to even be considered plastics (or any material) must firstly satisfy the aesthetic requirements of the designer.[274]

The attribution of meaning is a dynamic and continuous process; our understanding of artefact and the emotions elicited change through use and over time.[275] From a distance of over sixty years it is difficult to imagine the emotional response to the materiality of plastics from designers or consumers in the domestic market let alone another country.[276] As Hekkert and Karana observed: 'histories of materials are shifting. The meaning attributed to

[270] Elvin Karana, Giaccardi Elisa, and Rognoli Valentina, "Materially Yours," in *Routledge Handbook of Sustainable Product Design* (Abingdon, Oxon; New York, NY, 2017), 207.
[271] Cleminshaw, *Design in Plastics*, 131.
[272] Elvin Karana, Paul Hekkert, and Prabhu Kandachar, "Material Considerations in Product Design: A Survey on Crucial Material Aspects Used by Product Designers," *Materials & Design* 29, no. 6 (January 1, 2008): 1087, https://doi.org/10.1016/j.matdes.2007.06.002.
[273] Karana, Hekkert, and Kandachar, 1087.
[274] Karana, Hekkert, and Kandachar, 1088.
[275] Elvin Karana, "How Do Materials Obtain Their Meanings?," *METU Journal of the Faculty of Architecture* 27, no. 2 (December 2010): 280, https://doi.org/10.4305/METU.JFA.2010.2.15.
[276] Lutz claimed, 'emotional experiences is not pre-cultural but pre-eminently cultural' Catherine Lutz, *Unnatural Emotions: Everyday Sentiments on a Micronesian Atoll & Their Challenge to Western Theory* (Chicago: The University of Chicago Press, 1988), 5. Meikle agrees, 'No matter how articulate the designers, no matter how clever or articulate the economic records, we have no way of knowing with certainty how and why consumers at a given historical moment responded to particular products, graphics or environments' Jeffrey L. Meikle, "Material Virtues: On the Ideal and the Real in Design History," *Journal of Design History* 11, no. 3 (1998): 194.

plastics in 20 years by someone… will certainly be different from what plastics mean to those of us still in possession of a Bakelite radio.'[277] A 1988 magazine article expressed similar views, suggesting that children who first experienced the world through toys and games from Toys 'R' Us developed a different set of material values compared with adults who enjoyed childhood interactions with traditional materials.[278] The author highlights that some basic understanding of materials like wood and metal could be gained through hands on experimentation with basic tools and heat. On the other hand, plastics require specialist industrial skills to mould them, precluding the same level of familiarity. To the average consumer in the early post war years plastics could appear mysterious, even unworldly, but also practical and useful.

Fisher also emphasises the difficulty in attempting to enact an historical study of sensory experiences arguing that, in the case of plastics, people often do not differentiate the object from the material compounds the complexity. A plastic object is often understood only through its performance as a product, rather than through an appreciation of the qualities of plastic.[279] This merger of the object and material compounds the difficulty in understanding what plastics signified to consumers in the middle of the twentieth century.[280]

[277] Karana, Pedgley, and Rognoli, *Materials Experience*, 11.
[278] F Wilson, "Plastics, Past and Future," *Architecture*, no. 77 (April 1988): 108.
[279] Tom Fisher, "A World of Colour and Bright Shining Surfaces: Experiences of Plastics after the Second World War," *Journal of Design History* 26, no. 3 (September 1, 2013): 285, https://doi.org/10.1093/jdh/ept012.
[280] Elizabeth Shove, ed., *The Design of Everyday Life*, Cultures of Consumption Series (New York, NY: Berg, 2007), 105–6.

b. Australian early market development

The focus of attention on products rather than the material helped plastics to gain acceptance to many markets, often by stealth. Plastics quickly became incorporated, almost unnoticed, into products designed to support every aspect of human endeavour. By the end of the 1940s, the new materials were fully entrenched in Western societies, including Australia, with an article in *Decoration and Glass* ('a journal of architecture and home building') highlighting how plastics had already invaded every aspect of interior design and décor:

> "What are plastics?" Your house and mine are full of these products; but because they are not all of one kind and frequently replace wood, bone or pottery, they often pass without recognition. We have come to accept them as part of everyday life without question… [in] countless objects in daily use in every home.[281]

This 1948 article illustrates that, even during WWII, plastics had already made large inroads into every aspect of the daily life of Australians, displacing traditional materials in their wake. Plastics slipped almost unnoticed into daily life without need of significant advertising or editorial support from Australia's homemaker titles at that time. Among *Home Beautiful's* editorial covering all aspects of home and garden wares I found only one (short) mention of a plastic item, a nutcracker, in all the editions from 1945 to the end of that decade, and no mention in *House and Garden.* Plastic products, including chairs, were notable for their absence from all images.

[281] "Modern Plastics," *Decoration and Glass*, August 1948.

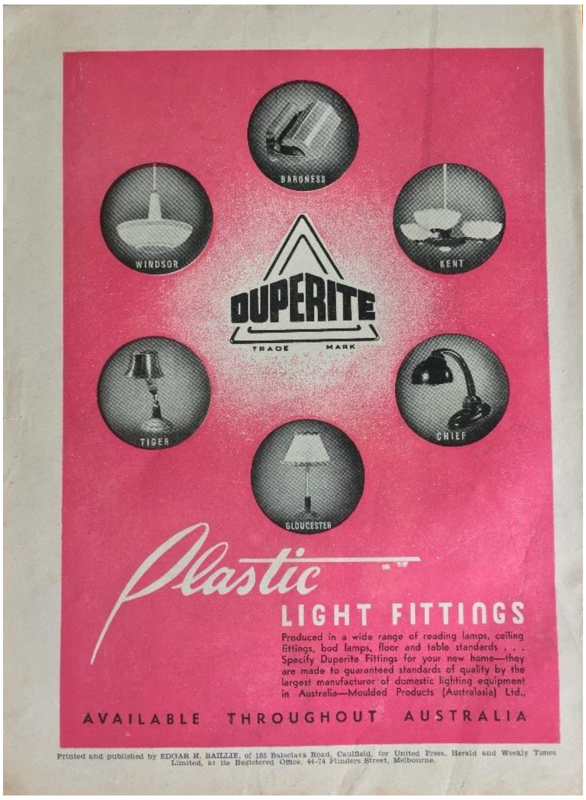

Fig. 2.3. During the 1940s the plastic products being regularly advertised in Australia's homemaker magazine were Rayon from Courtaulds, plastic light fittings from Duperite, Nylex moulded products and Dulux, who started promoting 'synthetic' paint toward the end of the decade.
Source: *Australian Home Beautiful*: November 1945, October 1946, December 1947, and September 1949 (author's collection)

Only three advertising campaigns for plastic products, together with one for paint, benefitted from sufficient media budgets to appear regularly in *Home Beautiful* (fig. 2.3), again, with none appearing in *House and Garden.* Three campaigns promoted specific functional moulded products with only one campaign highlighting the future potential of the material, presumably to revive the pre-war enthusiasm for a plastic utopia:

> Rayon is relatively young… in the last decade the usefulness of Courtaulds rayon has ranged further, and it now provides beautiful fabrics for curtains and upholstery, for tablecloths, towels, sheets and household linen of all kinds. In the post-war years rayon will do more—much more. You will walk on luxurious rayon carpets, ride on rayon cord tyres, wear rayon raincoats, and keep dry under rayon umbrellas.[282]

Despite the lack of advertising and editorial support the scarcity of traditional materials continued to help drive demand for plastics. In 1950, *The Age* reported:

> The future of raw materials may well resolve itself into a major world problem. Only recently it was announced that the wool industry In the U.S.A. was rapidly falling off. Plastics may take the place of these threatened shortages. The world of tomorrow may be entirely dependent on plastic materials.[283]

At the same time it became increasingly apparent that many plastic products simply still did not live up to the utopian dream promised before the outbreak of WWII by Yarsley and Couzens and others.[284] The local trade magazine *Australian Plastics* reported on problems with a range of plastic products including 'riveted plastic baby harnesses which ripped apart, plastic patent handbags which lifted varnish from the counter, belts which stretched to ridiculous lengths, circular trays that warped and therefore wobbled…' The article went on to

[282] Advertisement in *Australian Home Beautiful*, November, 1946. Several versions of this advertisement appeared in the publication throughout the late 1940s.
[283] "The Age of Plastics," *Age*, July 7, 1950.
[284] As early as 1940 Van Doren observed, 'In the proper use of plastics you will find a real challenge. Before their special beauties were fully understood, they were abominably misused, to the point where bad design definitely retarded their advancement.' Van Doren, *Industrial Design*, 303.

complain that people had stopped buying plastic products to avoid further poor experiences.[285]

These concerns were also reported in the consumer press with the February 1951 edition of *House and Garden* reporting:

> You may have bought a mixing bowl because some one *[sic]* has told you that "plastic is unbreakable." Then you are justifiably annoyed when it breaks the first time it is dropped, or when the tumblers you bought for the children withstand breakage, but melt when placed near the heat of the kitchen stove.[286]

An Australian Government report included similar findings and noted that 'the general reputation of the industry has suffered in the past through particular instances of shoddy production.'[287] Plastic became increasingly associated with 'tacky' in all its senses: cultural, structural, and sensorial.[288] A large number of small producers constituted the local industry, with little regulation or standards in place in Australia (or overseas). Inferior goods remained commonplace and continued to tarnish the industry's reputation. Disappointing consumer object-interactions shaped their material-object relations, negatively impacting the reputation of plastic.[289]

285 *Australian Plastics*, September 1951, 59.
286 *Australian House and Garden*, February 1951, 25.
287 "The Australian Plastics Industry," *Building and Engineering*, April 24, 1950.
288 Tom H. Fisher, "What We Touch, Touches Us: Materials, Affects, and Affordances," *Design Issues* 20, no. 4 (September 2004): 24, https://doi.org/10.1162/0747936042312066.
289 Shove, *The Design of Everyday Life*, 110.

Fig. 2.4. Plastic toilet seats and acrylic sinks being advertised in 1950 editions of *Australian Home Beautiful*. Source: *Australian Home Beautiful*, June, 1950 (author's collection)

Despite these challenges, the home invasion continued. A 1952 newspaper article listed 'new' (synthetic) plastic versions of many commonly found household objects including, tableware, ashtrays, clock cases, lighting equipment, brushes, radio cabinets, and cosmetic jars. The writer observed that plastics were making their way into the kitchen and bathroom where polymers were used for everything from the kitchen sink to aprons and tablecloths. They concluded: 'laminated plastic veneers have come into extensive use as a building material and for furniture,' (fig. 2.4).[290]

Plastics began to represent particular cultural values. Advertising frequently emphasised the durable, hygienic, easy-to-clean, heat resistant surfaces, available in an unprecedented wide choice of colours, as the main benefits of plastic for the homemaker.

[290] "Plastics Invade the Home," *Illawarra Daily Mercury*, October 1, 1952.

This extended to furniture with *House and Garden* reporting that hard-wearing laminated kitchen furniture 'will not stain and can be wiped clean with a damp rag.'[291]

Fig. 2.5. Front page from Aristoc brochure featuring laminated top table (Laminex) with bent chrome chairs upholstered in vinyl. c1952. Source: Ian Howard (CEO of Aristoc), personal archive

[291] *Australian House and Garden*, February 1951, 76.

While plastics had gained a foothold in most markets by stealth, they made a more dramatic intrusion into the furnishing industry. Designers who introduced the material to the industry chose to celebrate the material, unashamedly displaying brightly coloured laminates, transparent acrylic glass, and raw fibreglass (fig. 2.5). As we have already seen, Saarinen even went as far as disguising the metal bases of his tulip series to resemble plastic. Referring to the Eames chair among others, the *Sydney Morning Herald* attempted to explain why upholstery was unnecessary, claiming that although these new designs might, 'look sometimes fantastic, sometimes funny,' they were shaped to support the body in its, 'natural sitting position'.[292]

Local homemaker titles remained unconvinced, publishing only a single image including an Eames fibreglass armchair without any editorial commentary in the year of its release (1950).[293] The Eames fibreglass chairs featured in a small number of interior shots throughout the 1950s but were not the focus of editorial coverage in either of the mainstream homemaker titles or in the local trade magazines. Saarinen's Womb chair made only one appearance during the entire decade, in the cover shot of *House and Garden's* 1954 annual.

The lack of interest by the homemaker titles reflects the fact that modern furniture appealed to a very small market in Australia during the 1950s. Clement Meadmore (1929–2005) and Gordon Andrews (1914—2001) both abandoned promising careers in furniture design to pursue more lucrative opportunities. Even the local furniture trade title, *The Australian Furnishing Trade Journal*, failed to cover any local modern designers, or their work,

[292] "New Ways With Tables And Chairs," *Sydney Morning Herald*, February 19, 1953.
[293] *Australian Home Beautiful*, June 1950, 16.

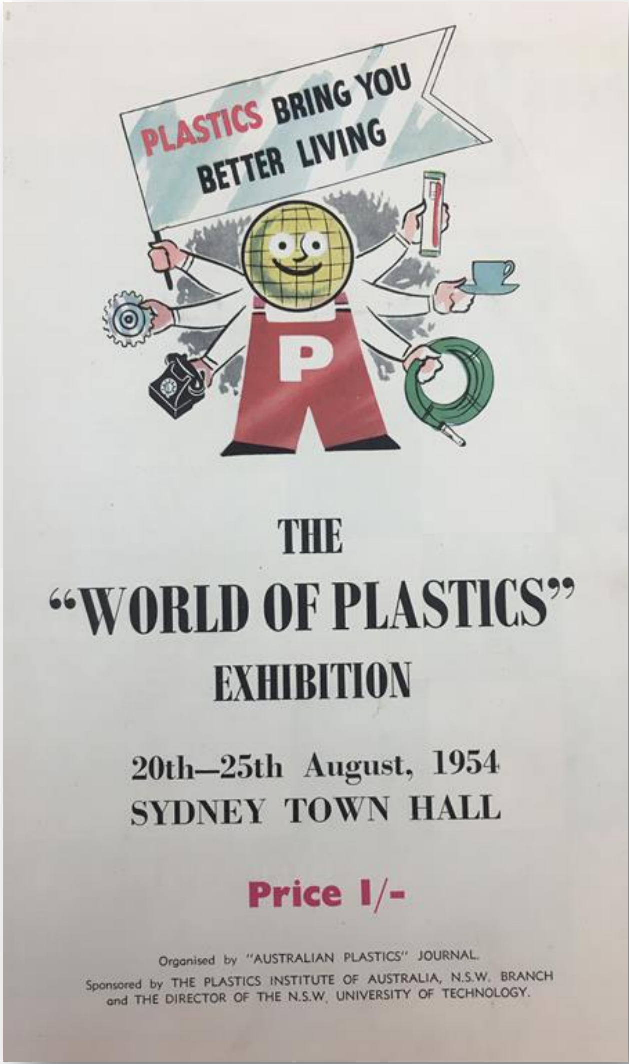

Fig. 2.6 Cover of *World of Plastics* exhibition catalogue, Sydney, August 1954. The local industry organised this exhibition to demonstrate that, 'plastic goods we're no longer substitutes, but recognised materials, having a special application in their own right.' [294] Source: National Library

until the second half of the 1950s.[295] Retailers remained conservative, preferring to stock designs with a proven track record.[296] In 1954, the President of the Society of Designers for Industry, Richard Haughton James, issued a direct challenge to the industry claiming that 'Australian furniture is ugly, costly, and 30-50 years out of date', and asking why

[294] "Australia's First Plastics Show," *Morning Bulletin*, September 1, 1954.
[295] Isaac, *Featherston*, 267.
[296] *Plastics News*, July 1971, 13.

competitively priced contemporary furniture was not available locally.[297] The article, published in both *Home Beautiful* and the widely-read *Sun-News Pictorial* encouraged support for the local modern design community. Editorial support from *Home Beautiful* summarised the key issues:

> But the manufacture of contemporary furniture is still in the pioneering stage here. It lacks the capital backing and multitude of retail display and outlets which it has elsewhere. Consequently, almost all of it is doomed to be relatively expensive.[298]

Haughton James succeeded in shaming the Guild of Furniture Manufacturers and The Furniture Society of Victoria into announcing a competition for local designers to promote modern furniture. Despite these efforts, the mainstream market continued to resist modern furniture with an executive from Hoechst Australia noting, in 1973, that 'even the very rich, generally approach their life styles [sic] with a caution of conservatism.'[299]

Sales of international modern furniture were additionally hampered by the protectionist policies introduced by the Menzies government designed to restrict imports. In 1952, Australia imported only 4,500 chairs, down from 56,000 the previous year.[300] Additionally, transporting furniture from overseas to the remote Australian market was slow and costly. As a result, imported furniture remained scarce and expensive, putting it well beyond the reach of all except the most affluent consumers, serviced by specialist retailers such as Marion Hall Best in Sydney.[301] The October 1962 edition of *Home Beautiful* featured Saarinen's *Tulip Chairs* and matching pedestal table with a price of £500, while in comparison, an entire house could be built from £3,000 at this time.[302]

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[297] *Australian Home Beautiful*, September 1954, 22-23.
[298] *Australian Home Beautiful*, September 1954, 7.
[299] *Plastics News*, May 1973, 22.
[300] Isaac, *Featherston*.
[301] Best has a retail shop in Queen St Woollahra from 1938 – 1974 and offered interior design consultancy.
[302] See, for example, '*Home quality for £3000'*, *Australian Home Beautiful*, Jan 1963, 5.

Government policy also impacted Australian production. A 55% tariff on imported moulding equipment together with tariffs on imported plastics inflated costs. When combined with high local labour and transportation costs this effectively limited the development of the plastics industry. [303] The relatively small market made it economically unviable to build large petrochemical facilities like those being developed overseas.[304]

An executive from Hoechst Australia observed that plastic furniture was only 'purchased by a modish elite, who are drawn to the design dynamic,' adding that avant-garde furniture would look 'ludicrously misplaced' in the average home.[305] Modern furniture, including imported furniture, remained practically ignored by the local media throughout the 1960s, with little attention given to developments in plastic furnishing.

While plastic furniture remained scarce, this did not signify a rejection of the material. By the time the first locally produced plastic chair appeared in 1956, local consumption had reached 5lbs per head of population per year and 'ranged from garden hose to children's toys, tablecloths and curtains, glass reinforced plastic boats and car bodies.' [306] Plastic components were also now commonplace in 'electrical switch gear, radio and TV circuits, telephone handsets, translucent corrugated sheeting, and self-lubricating bearings, and gears.'[307]

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[303] *Plastics News*, August 1966, p9. See also Australian Plastics Annual Convention 1962, 30.
[304] Australian Plastics Annual Convention 1962, 30.
[305] *Plastics News*, May 1973, 22.
[306] "Plastics: Giant Grows," *Argus*, May 10, 1956.
[307] "Plastics."

Fig. 2.7. *Australian Home Beautiful* heralds the use of plastic in furniture, presumably referring to the local market. Source: *Australian Home Beautiful*, October 1956 (author's collection)

By the end of the 1950s, any reservations regarding plastics were dwarfed by benefits as perceived by consumers both here, across Europe and in North America. Parents held sufficient faith in the material to allow their children to play with an increasing range of plastic toys. The Hula Hoop was introduced in 1957, followed by Lego in 1958, and Barbie in 1959. Even money went plastic, with American Express launching the first credit card in 1958.

Plastics quickly 'went from being the stuff of imitation in the 1950s, to being valued in their own right as the materials of fashionable design.'[308]

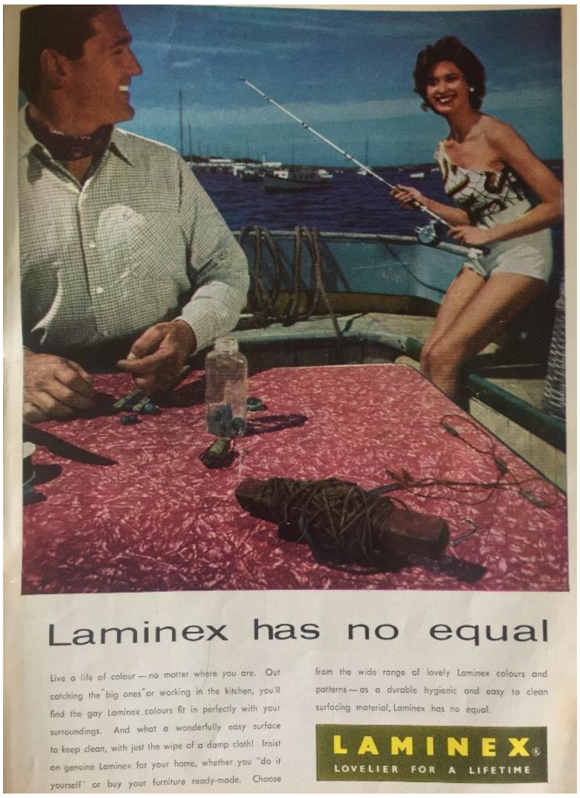

Fig. 2.8. At the end of the 1950s Australian homemaker magazines frequently featured advertisements for plastic laminates. Source: Left*, Australian House and Garden*, February 1958 (Laminex held the inside back cover position for most of the year). Right, *Australian House and Garden*, June 1958 (author's collection)

By 1962, plastics had become common place across every aspect of Australian interior decoration with a local press report claiming that the 'plastic invasion' had begun in the kitchen, spread to the bathroom and was now infiltrating the lounge, the bedroom and the remaining rooms of the house, even being used for outdoor furniture (fig. 2.9 & 2.10).[309] Having exhausted original markets, the industry searched for opportunities to diversify, adding more products to compete in ever-increasing marketplaces.

[308] Fisher, "A World of Colour and Bright Shining Surfaces," 287.
[309] "Plastics Give Luxury Living," *Biz*, January 31, 1962.

Fig. 2.9. Early editorial and advertisement for plastic outdoor furniture.
Source: *Australian Home Beautiful*, November 1960 and November 1961 (author's collection)

Throughout the 1960s the price of oil held steady at around US$3 per barrel, making plastic inexpensive, further driving demand for the material. The decade saw the introduction of numerous plastic chair designs featuring brightly-coloured, highly-polished, glossy surfaces. Bernadette Vincent observed that during the 1960s and into the 1970s shining, fluorescent and flashy surfaces prevailed over the traditional preference for more natural looking pastel colours across most product categories and this applied to furniture.[310] This coincides with Kartell developing a monobloc, and producing several designs featuring glossy surfaces, as previously discussed. The alien appearance of these high-gloss chairs can be expected to have initially shocked many of those used to traditional materials.

[310] Bensaude-Vincent, "Plastics, Materials and Dreams of Dematerialization," 24–25.

MOULDED CHAIRS FOR THE PATIO

THE Berwin "Riviera" outdoor chair (above) is the first injection-moulded plastic (as distinct from polyester fibre-glass) chair to be produced in Australia.

The seat and back, in one smooth piece of excellent design, are injection-moulded from high density polyethylene.

The material is said to be completely weatherproof and resistant to corrosive salt air at beach houses. In the garden or patio after rain, it is easily wiped and there is no risk of rust marks or sharp edges to damage clothes.

Plastic colors are red, yellow, green, blue, white and fawn. Metal colors, in baked enamel, are black, charcoal, bronze, silver grey and chrome-plate finish.

The chairs are a co-operative effort — British Xylonite (Aust.) Pty. Ltd. moulded the plastic to suit the tubular steel chassis and legs produced by Berwin Manufacturing Pty. Ltd., Victoria.

They cost £4/19/6 each.

Fig. 2.10. Possibly Australia's first injection moulded plastic chair.
Source: *Australian Home Beautiful*, January 1961 (author's collection)

Early plastic chairs also differed from most traditional seating solutions as they featured curved edges rather than sharp-edged corners. The main driver for their appearance was purely practical – the material flows in the mould better where edges are curved. However, the production process delivered a seductive aesthetic.[311] The curve also serves to reflect light from at least one highlight when viewed from any angle, delivering a glint, or blink, to catch the eye. Karana suggests curves continued to appeal to consumers in more recent times reporting that the materials of rounded shape products are considered

[311] Meikle, *American Plastic*, 115–16.

cosier, sexier, more elegant, and less masculine when compared with the materials of sharp-edged products. Rounded shaped plastic was still perceived as more futuristic than sharp-edged plastic.[312]

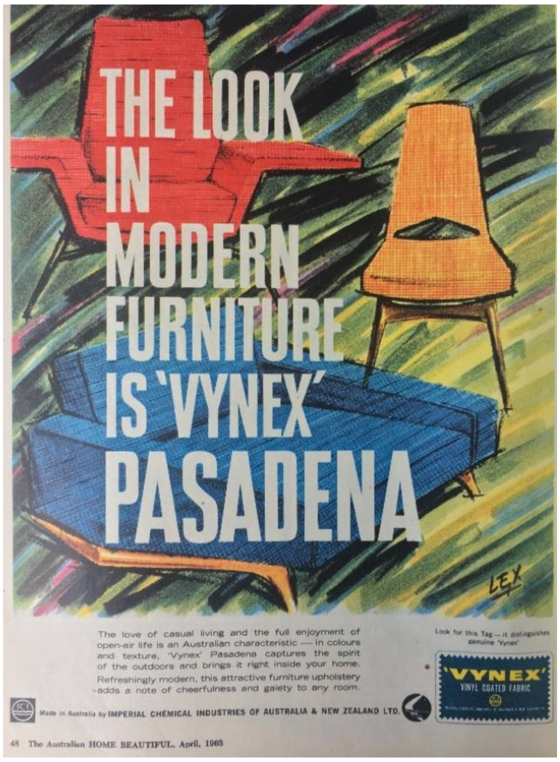

Fig. 2.11. Australia became enamoured with vinyl. Early advertisement on the left from the late 1950s with a slightly later advert featuring a more modern look.
Source: *Australian Home Beautiful* February 1959 and April 1963 (author's collection)

Australians quickly became infatuated with vinyl, using it to upholster both traditional and modern furniture (fig. 2.11).[313] Aristoc alone sold over 250,000 *Mitzi* and *Delma* chairs each, just two examples from a range of vinyl covered steel framed chairs designed for the company by Grant Featherston during the late 1950s and 1960s.[314] By 1965, vinyl had

[312] Karana, "How Do Materials Obtain Their Meanings?," 278.
[313] *Plastics in Australia*, Annual Convention, Plastics in the Service of Australia, 1965, 55. *Plastics News*, May 1972, 48.
[314] Isaac, *Featherston*, 157 & 182.

become 'universally accepted as the most durable and economical upholstery material.'[315] Demand for the material, which could be printed in any colour or embossed to create the texture of leather, supported at least six major local suppliers.[316] Available in a wide range of patterns and colours, vinyl is extremely durable, washable, chemical resistant, and can be made flame and mildew resistant.[317] Australians became so enamoured with the material that, during the mid-1960s a Porsche optioned in vinyl cost more than the leather version.[318] By 1970, vinyl enjoyed a 50% market share among lounge suites sold and 'a higher share of the overall furniture market because of its dominance in kitchen and dining areas.'[319]

2. Plastickoptimsimus

At the end of the 1960s plastics reached their zenith in Europe and the United States. Jeffrey Meikle refers to this time as 'plastickoptimsimus'. When the Americans won the Space Race they chose to memorialise their first walk on the moon with a flag made from nylon (fig. 2.12). Success in winning the Space Race owed much to plastics, as highlighted by Meikle, with the mission relying heavily on 'high-performance synthetics, on Mylar, Teflon and nylon, on heat-resistant composites and form-fitting foams.'[320]

[315] *Plastics in Australia*, Annual Convention, Plastics in the Service of Australia, 1965, 55.
[316] Vynex (ICI), Nylex (Moulded Products), Vynoid (Plastic Coatings of Sydney), Dynide (JJ Davis and Sons), Geltex (Gleson Industries, Melbourne) and Muralionide (imported from Jas Williamon & Sons), *Australian Home Beautiful*, 1963.
[317] *Plastics News*, August 1965 & *Plastics News*, May 1972, 47.
[318] Roy Williams and Martin Lloyd, *The Australian Room: Antiques and Collectibles from 1788* (Port Melbourne, Vic.: Lothian Books, 1999), 127.
[319] *Plastics News*, May 1970, 21.
[320] Meikle, *American Plastic*, 216.

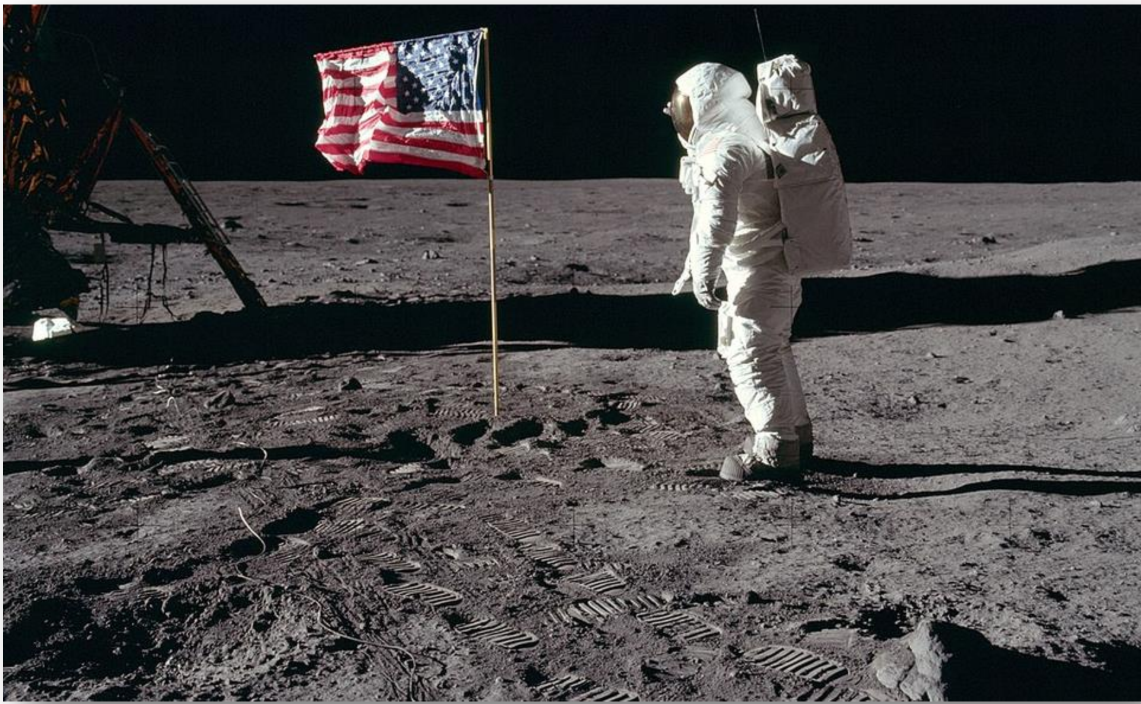

Fig. 2.12. Apollo 11 moon landing, July 1969 - Buzz Aldrin salutes a nylon flag at Tranquillity Base. Source: NASA

Meanwhile, back on earth, in December 1967, *The Graduate* (Dustin Hoffman) is advised, by his older lover's husband, that a lucrative future can be found in plastics. *Barbarella,* starring Jane Fonda in a futuristic erotic plasticised world, was released the following year. Director Stanley Kubrick's *2001: A Space Odyssey*, (featuring and further popularising Space Age design including Arne Jacobsen flatware cutlery and Olivier Mourgue's red upholstered *Djinn Chairs*) was also released. In 1970 the Victoria and Albert Museum, London, presented an international exhibition of modern chairs dating between 1918 and 1970. The exhibition catalogue denotes that over a third of the 120 chairs, (48) featured plastics.[321] In 1972 *Italy: The New Domestic Landscape*, the most ambitious exhibition yet presented at Museum of Modern Art, New York, featured 180 objects for

[321] Victoria and Albert Museum and Whitechapel Art Gallery, eds., *Modern Chairs, 1918-1970* (Boston: Boston Book and Art, 1971).

household use and 11 environments commissioned for the event. [322] These exhibitions clearly demonstrating that plastic products, despite not being rare or precious, had achieved significant cultural value. Plastickoptimsimus had peaked, or as Meikle wrote, it reached its apogee.[323]

The Australian furniture industry had to wait slightly longer than their contemporaries in Europe and the United States before the country reached plastickoptimsimus. The trade press noted at the start of the 1970s that ‘plastics-as-plastics’ were gaining ground in the furniture industry especially among young designers and retailers with an eye on the youth market.[324] Traditional seating solutions, with their dull colours, arranged in formal fixed positions did not suit the times. Traditional materials and labour were becoming more expensive while plastics remained inexpensive.[325] Seating requirements became more casual, adaptable, and laid back. Modular seating components, which could be assembled and reassembled into a variety of combinations at will, became increasingly popular. Even sacks full of plastic ‘beans’ became fashionable. The mainstream press, having ignored plastic furniture for so long, suddenly embraced it as a symbol of the new, future-focused decade. Reporting for *House and Garden*, Erica Worse exclaimed:

> For years, with a few exceptions, our wail has been “Yuk, it’s plastic”. Now the cry is changing to a joyful “Wow, it’s plastic!”[326]

Both mainstream homemaker titles regularly featured plastic furniture and even devoted three covers to the topic during the first year of the new decade (fig. 2.13).

[322] MoMA press release, 26/5/1972
[323] Meikle, *American Plastic*, 231.
[324] ‘The potential market for modern plastic furniture is the 25–35-year age groups who are less conformist and show a decided swing away from traditional furniture.’ *Plastics in Australia*, September 1971, p31.
[325] *Plastics in Australia*, 1971, 5.
[326] *Australian House and Garden*, February 1974, 47

Fig. 2.13. Plastic furniture featured on the front cover of three issues of prominent homemaker titles in 1970. Source: *Australian House and Garden* October 1970, *Australian Home Beautiful* October & November 1970 (author's collection)

Operating in a relatively small market, local manufacturers developed innovative approaches to avoid the high tooling and set up costs associated with many plastic manufacturing technologies.[327] Herman Miller opened a local dealership in 1965. Prior to that, Descon held the licence to produce Eames furniture, giving them access to the research and developments and tooling from the parent company. In 1971, Winton Plastics, a division of Advanced Industries, announced a licencing agreement with Kartell and started producing selected designs locally, reducing tooling costs by borrowing dies (weighing six or seven tons) from Italy, allowing products to be offered at half the price of the imported furniture.[328] Furniture Makers of Australia (Formerly Aristoc) produced licensed copies of Robin Day's *Polyside* chair economically in Australia by accessing dies from Hille in the UK. In May 1973, the company announced plans to introduce five new plastic ranges, but it was not a willing convert to the material, complaining to the trade press that it has been forced to expand its use of plastics as timber became more difficult to obtain and prices were going 'sky high'.[329]

Melbourne manufacturer Module experimented with compression moulded fibreglass, releasing the Featherston designed *Polio* in 1971 but found more commercial success with a range of acrylic glass furniture designed by James Farrell (fig. 2.15).

[327] '… injection moulding and the die cost and unit take off in those bulk markets has generally discouraged the Australian manufacturer from even enquiring about its possibilities in Australia.' Ron Thomas, Monk Plastics quoted in *Plastics News*, May 1973, 28. 'Paying the designer and making dies, which could cost $10,000 each, and then hoping the market would be large enough to amortise this amount.' *Plastics in Australia*, September 1971, 33.
[328] *Plastics News*, July 1971, p41. Advance quickly added Casala products to their range also Presidea International started producing Artemide and Catelli furniture locally under licence, including the Plia fold-up chair. *Plastics News*, May 1973, 35.
[329] *Plastics News*, May 1973, 5.

Fig. 2.14. Locally produced Kartell side tables displayed near modular polyurethane seating. Keith Andrews. Source: Artes Studio for *Australian House and Garden*, November 1973 (author's collection)

Acrylic glass offered the advantage that fibreglass moulds could be used, avoiding the expensive steel tooling associated with injection moulding.[330] Amalgamated Industries started producing copies of fibreglass designs from overseas, including the *Bubble Chair*, a replica of Aarnio's *Pastil* design.[331] All of these designs were developed with a clear focus on the younger market.[332] An executive from Hoechst Australia suggested their general cultural

330 *Plastics News*, May 1970, 31.
331 *Plastics News*, December 1970, 36.
332 *Plastics News*, May 1970, 33.

and educational standard gave youth, 'greater perceptive powers to appreciate the aesthetics of the new plastic designs'.[333]

Fig. 2.15. Example of the acrylic glass furniture designed by James Farrell for Module in the early 1970s. This design (*Oroglass*) was also available with a star base for the domestic market. Source: *Australian Home Beautiful*, April 1971 (author's collection)

In 1973, Sydney-based manufacturer Sebel invested in injection moulding technology and released two designs by Charles Furey (1917-2009): the *Hobnob* and the *Integra*. While

[333] *Plastics News*, May 1973, 22.

the Hobnob owed much to Robin Day's *Polyside* armchair, the *Integra* was more innovative. Sebel, like many plastic furniture manufacturers of that time, was keen to develop a monobloc (already manufactured in Europe from 1966) and had been evaluating a design developed by another designer, Grant Featherston. The brief called for the design to stack vertically and for 'no space penalty to be imposed on the user by having legs which splayed out,' a condition which proved difficult to fulfil.[334] In the end, Sebel decided to back Furey's project, and the *Integra* entered production, with the 12.5-ton dies costing $35,000 (with total tooling and development costs of over $100,000).[335]

Sebel made the right choice. The commercial success of the project was assured when prisons in the United States started ordering them, over one million in the first 15 years.[336] The significance of an order of that size must be highlighted. In 1970, the Danish furnishing industry released a list of its top selling designs. At the top of the list, Arne Jacobsen's *Ant Chair* (available from 1952), achieved total sales of 1.3 million units over 18 years, 'almost a million more than its nearest [Danish] rival'.[337] Sebel's *Integra* has been in continuous production since 1973, securing over 5 million sales according to the company. To fulfil such large orders Sebel arranged licencing agreements with manufacturers in major overseas markets. Harry Sebel also adopted a unique distribution strategy as he refused to pay commissions to retailers. Sebel relied entirely on selling direct through contract sales and to the public, through mail-order advertising (fig. 2.16) supported by showrooms in at least four major cities.[338]

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[334] *Plastics News*, July 1974, 31.
[335] *Plastics News*, August 1972, 38.
[336] Anne Watson, *Mod to Memphis: Design in Colour 1960s-80s* (Sydney: Powerhouse Pub, 2002), 59.
[337] *Australian Home Beautiful*, December 1970, 37.
[338] Geoff Isaac, Interview with Ron Newman, formerly of Sebel, August 18, 2021.

Fig. 2.16. Sebel mail order advertisement promoting the *Integra* range together with the *Hobnob*. Source: *Australian Women's Weekly* June 1975 (author's collection)

In April 1973, both leading Australian homemaker titles featured the *Stem Chair*, designed by Grant and Mary Featherston, on their front covers (fig. 2.17). Released in 1969, just before the local media began to show interest in plastic furniture, the *Stem Chair* was ignored, and sales did not materialise. Aristoc quickly deleted the design from their catalogue, having failed to recoup their 18-month investment in development of the rotationally moulded seat and injection moulded base.[339]

Fig. 2.17. *Stem Chair* by Grant and Mary Featherston as featured on the front cover
Source: *Australian Home Beautiful*, April 1973 (author's collection)

[339] Isaac, *Featherston*, 235.

Media interest in plastic furniture did arrive in time to support a different project that the Featherstons had been working on with another manufacturer, Uniroyal.[340] The *Numero* series comprised of modular polyurethane foam cubes that could be arranged to form a variety of seating solutions (fig. 2.18).

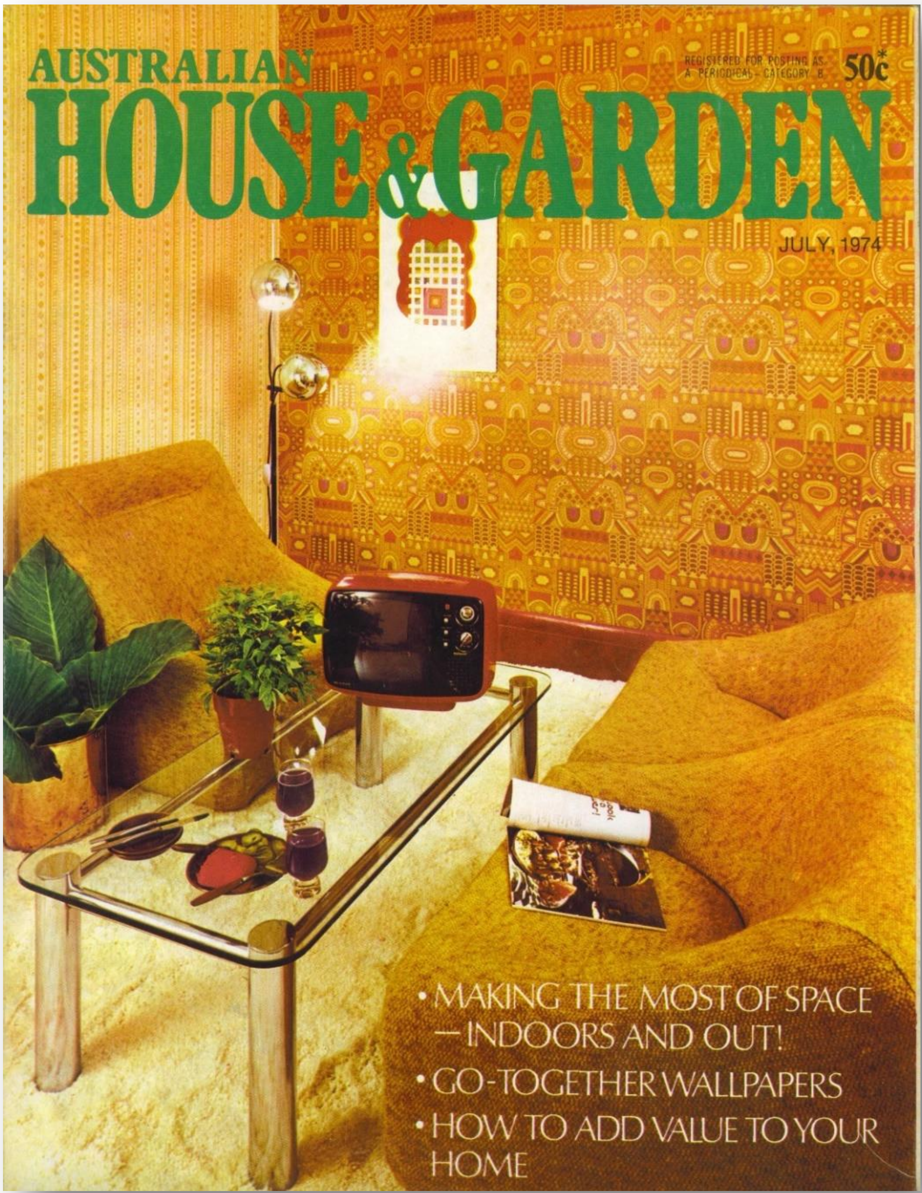

Fig. 2.18 The *Numero IV* by Grant and Mary Featherston as featured on the front cover
Source: *Australian House and Garden*, July 1974 (author's collection)

[340] Isaac, 252–56.

Urethane modular furniture was becoming popular in Europe and the Featherstons were well placed to capitalise on this trend thanks to the three years this project spent in development.[341] The series featured a low seat (33cm high) which, combined with the modularity of the units, made them an ideal solution for young homemakers seeking a more casual and mobile alternative to the traditional three-piece suite. Remarkably, despite being launched on the eve of the oil crisis, the *Numero* series became a commercial success for Uniroyal, who went on to release several variants to the original design over the remainder of the decade.[342] The success of the series is made more remarkable by the fact that many local and overseas manufacturers introduced similar offerings to the market at this time.[343]

In 1941, Yarsley and Couzens predicted the life of a future 'plastic man'. Thirty years later Australians might well have been tempted to scoff at their vision of the future but, during the intervening years, plastics had quietly and successfully oozed into every aspect of life. Standing in their new home, Australia's plastic people might point out that their walls were not, as Yarsley and Couzens had predicted, made from plastic. Walls were, however, coated with plastic paint and featured plastic light switches and power points. Behind those synthetic polymer painted walls lay a web of plastic plumbing and plastic insulated electrical wires. Above their heads, more acrylic paint featuring plastic light fittings. Cabinets, tables and even the television were covered in laminates, with drawers and cupboards lined with sticky backed plastic.

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[341] *Plastics News*, May 1972, p27

[342] Isaac, *Featherston*, 254–56.

[343] Locally Fler launched the *FlerPad* and *Fleresque* ranges while Furniture Makers of Australia offered the *Idler* (designed by Fred Lowen), Fairline Furniture promoted the *Sophia* range and Parker offered *K'ang*. International competitors featured in homemaker magazines of this time include *Vario Pillo* (unspecified German manufacturer), *Pool* (designed by Luigi Colani), *Brenda* from Doamni, *Mussey* by Vanderoza and *Softcell* by Campaign.

Fig. 2.19. Sticky backed plastics advertisement.
Source: *Australian Home Beautiful*, December 1960 (author's collection)

The floor was either laminate, vinyl or varnished with polyurethane. In the bathroom the bath, vanity, and toilet seat were all made from pastel shaded plastic, while in kitchen, brightly coloured laminates covered every surface and even the kitchen sink was plastic. Countless plastic canisters, Teflon coated saucepans, food storage containers, melamine dishes, together with often long forgotten 'labour saving' devices, unwanted novelties and toys crammed the cupboards alongside the plastic Christmas tree. Dining chairs, easy chairs and sofas were not made from plastic but padded with polyurethane foam and covered with vinyl or fabric laminated with thick clear plastic to preserve their looks. Under a plastic wall clock sat the plastic telephone on a laminated table with elegantly tapered tubular steel legs, powder coated with plastic. Rubbish, collected in plastic bins, was taken outside, and fed into plastic garbage cans, hidden from view, past the plastic lined pool and polyester clothes drying on plastic clothes lines.

Fig. 2.20. Plastic garbage bins coming off the injection moulding machine at Advanced Industries in Melbourne c1970s. Source: National Archives of Australia, Item ID 6592623

Plastic hoses watered plants in plastic pots. Weary gardeners sought respite on plastic outdoor furniture or retired to their beds to rest on plastic foam mattresses.

While the plastic Australians probably did not think they would end their days in Yarsley and Couzens' plastic coffin, they most likely ended up in a medium-density fibreboard box veneered, with painted paper, and varnished (with plastic) to look like wood, lined with nylon or polyester, padded with polyurethane foam, and all held together with polymer adhesives. Plastickoptimsimus had finally arrived in Australia, but its reign was to be short lived. Global events were about to impact the local market.

3. Plastic love fades

In July 1969 Apollo 11 took off to return to earth, the rocket blast melting the plastic flag planted to memorialise the event.[344] The year before, shortly after celebrating its decade-long run at Disneyland, Monsanto's plastic *House of the Future* was demolished. Young cinema goers sneered cynically when Hoffman's character in *The Graduate* was advised to pursue a career in plastics.[345] *NASA* announced, in 1970, the cancellation of the last three planned Apollo missions; public interest in the Space Race had fallen to the extent that few Americans could even name the first person to walk on the moon.[346] History professor Matthew Tribbe observed that sci-fi films switched their focus 'from utopian to dystopian' (*THX 1138, Logan's Run* and *Silent Running*) with terrifying portrayals of plastic futures.[347] Accusing someone of being plastic had become a common derogatory term implying, 'no

[344] Matthew D. Tribbe, *No Requiem for the Space Age: The Apollo Moon Landings and American Culture* (Oxford & New York: Oxford University Press, 2014), 9. Speculation on the condition of the flags left on the moon can be found at https://history.nasa.gov/alsj/ApolloFlags-Condition.html.
[345] Meikle, *American Plastic*, 3.
[346] Several polls, conducted in 1970, showed that Americans quickly forgot the names of the astronauts who had been celebrated as heroes just one year before. For example, a Philadelphia Sunday Bulletin poll found 70% of locals were unable to remember Neil Armstrong's name. Tribbe, *No Requiem for the Space Age*, 9.
[347] Tribbe, 209.

personality, no depth, of mass production'.[348] The brief era of plastickoptimsimus was over, love of plastic faded.

Aware of its increasingly negative public image, the plastics industry introduced strategies to improve it. In 1971, the Plastics Institute of Australia joined forces with the Industrial Design Council of Australia to organise a touring exhibition *Design in Plastics*, specifically aimed at showcasing plastic products to 'counter any image of plastics as a "cheap and nasty" substitute for a better class of material.'[349] Altering the opinions of consumers with first hand experiences with early poorly manufactured products proved more difficult than the industry imagined, particularly with the older cohort. A 1972 consumer market research study, evaluating attitudes toward plastic housewares, found that participants under 35 years of age were, 'much more positive in their acceptance of plastic goods'. However, participants over that age displayed distrust reflecting their early experiences with inferior plastic products.[350] The same study also found that plastic products were generally considered to be of inferior quality.

The growth and prosperity of the post war years stagnated, and social unrest swept across the United States and touched many allied countries, especially in Europe. OPEC tested their power and put global energy markets into turmoil, raising concerns about dwindling fossil fuels.[351] These exogenous events occurred as environmental and health concerns about plastics began to gain public attention. Additionally, the first seeds of doubt

[348] *Plastics News*, April 1978, 9.
[349] *Plastics News*, August 1971, 7.
[350] *Plastics News*, August 1972, 19.
[351] Meikle, *American Plastic*, 231.

regarding the ability of the linear economy to deliver indefinite growth emerged, ignited by Euston Mishan's *The Costs of Economic Growth*, in 1967.[352]

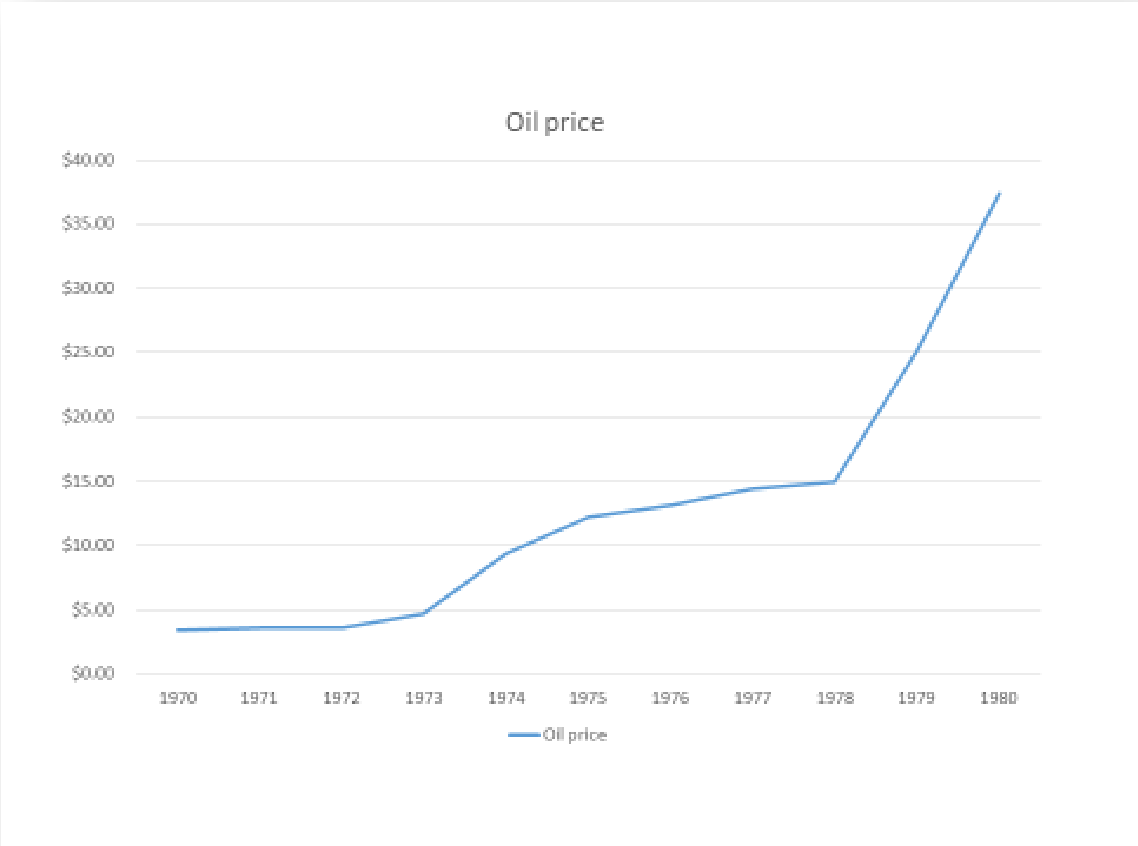

Fig. 2.21. Impact of 1970 crises on oil prices. Source: Statista (data)

The oil crisis acted as a catalyst causing significant disruption to the energy market with impacts on the plastic industry compounded as the decade unfolded (fig. 2.21). Initiated by the OPEC oil embargo (commencing October 19, 1973), the oil price quadrupled in six months, taking the price of plastics with it and disrupting the entire industry. Although the oil-crisis was brief (ending in March 1974), the price of oil and plastics never returned to pre-embargo levels. The Iranian Revolution (1979) further disrupted supplies at the end of the

[352] Publicised in Australia by a 1971 visit from Professor James Weaver, The American University, Washington.

decade with the Iran/Iraq war (1989-88) extending the crisis throughout the next decade. In addition, concerns about peak oil and predictions that reserves could run out by the end of the century gathered momentum.[353] Judy Attfield noted: 'the realisation dawned that some natural resources were non-renewable.'[354]

In the short term, designers and manufacturers were forced to re-evaluate their use of plastic with many increasing their use of traditional materials.[355] In Finland, Asko gave up production of plastic furniture leaving their star designer Eero Aarnio out of work.[356] In France, Jean-Pierre Laporte abandoned his career as a plastic furniture designer and took up cabinetmaking.[357]

In Australia, Uniroyal found a way to work around the problem; completely redesigning Grant and Mary Featherston's modular *Numero* series of polyurethane foam chairs to reduce their reliance on the material, introducing a steel frame and incurring significant costs along the way.[358] These changes added considerable complexity to what had been a simple design, previously reliant on just three components. A tubular steel frame had to be assembled and webbing manually applied to support the reduced amounts of foam, providing a dramatic illustration of the impacts that reverberated throughout the industry because of higher oil prices.

From the start, the plastics industry was associated with shoddily made goods. Despite efforts to counter this reputation, the fact remained that many plastic products were

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[353] See for example, 'Plastics in an energy short world', *Plastics News*, November 1976, 6-12.
[354] Attfield, *Wild Things*, 246.
[355] Reviewing the events of the early 1970's the authors of this history of Plexiglas conclude that, "furniture manufacturers in particular were hard-hit by this." Kai Buchholz et al., eds., *Plexiglas, Werkstoff in Architektur und Design* (Köln: Wienand, 2007).
[356] Aarnio and Savolainen, *Eero Aarnio*.
[357] Karoll Audibert, *65-75: Jean-Pierre Laporte, dix ans de création* (Montpellier: K. Audibert, 2010), 121.
[358] Geoff Isaac, Interview with Mary Featherston, August 18, 2020.

simply not fit for purpose. The industry maintained that it could not be held accountable where products have been poorly made or the wrong material had been used and complained that consumers blamed the material and not the manufacturer of the inferior product. But early plastics frequently suffered from quality issues. The first semi-synthetic plastic, celluloid, can degrade irreversibly and according to a museum curator can 'induce the breakdown of objects in its vicinity.' [359] Cellulose nitrate had been used for film stock and could (and often did) explode.[360] Early acrylic glass furniture became notorious for being easily scratched.[361] Many early plastics were often not UV resistant and colours bled or faded, others became brittle over time while some (particularly foams) disintegrated completely. Colour fading and bleeding affected most plastics manufactured during the 1950s while chemists struggled to find ways to permanently attach colour to plastics.[362] Remnants of these quality issues can still be found in mid-century furniture; for instance, polyurethane foam breaks down to dust after about forty or fifty years destroying the padding under upholstery on chairs.

While these problems with early plastics took years or decades to reveal themselves, another significant issue became more immediately visible. The utopian perfection of 1960s plastic furniture was expressed through its uniform glossy surface, which promised to resist time and show no signs of wear or patina as it aged. The public were assured that the flawless surface of plastics could be kept that way with minimal maintenance, requiring just a

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[359] Louise Dennis, "A Matter of Material: Exploring the Value of the Museum of Design in Plastics" (Ph.D., University of Brighton, 2020), 115, https://research.brighton.ac.uk/en/studentTheses/48e01187-3748-44b4-8660-0b9fc9159a88.
[360] Fisher, "A World of Colour and Bright Shining Surfaces," 110.
[361] *Plastics News*, May 1972, 29.
[362] Humphry McQueen, "The Age of Plastic," *Australian Cultural History* 25 (2006): 83–114.

wipe from a damp cloth.[363] But the appealing glossy, shiny, flawless surfaces, popular throughout the 1960s, quickly began to scratch and show signs of wear, losing their promise of perfection. 'The magic is broken,' suggested Fisher, while Manzini claimed the surfaces 'degrade without dignity.'[364]

Glossy fibreglass and injection-moulded polyester were not the only plastics whose appearance deteriorated with use. Early plastic laminates such as melamine were particularly prone to showing signs of wear. The decline in popularity of melamine tableware throughout the 1960s can be attributed to dissatisfaction with the staining and scratching that occurred with use of tableware produced in the 1950s.[365] Gloag summed up the process of plastic's ageing, and the effects of this on its shine, claiming that shrinkage or absorption of water caused flaws on the surface resulting in a loss of 'brilliance'.[366]

With traditional materials we accept and even celebrate signs of aging—signifiers of past experiences. Every piece of wood is unique, displaying the story of its growth and position within a tree through attractive patterns of grain. Danish modern furniture became increasingly popular in European and American markets during the 1950s and 1960s. Oiled or waxed wood, as preferred by Danish designers (as distinct from varnished or lacquered), became a unique attribute of the style. Without a protective barrier, wood quickly changes as the surface reacts to exposure to light and the natural oil in the hands of users.[367] This ever-

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363 Italian manufacturer Kartell was an early convert to celebrating the material in its own right—plastic-as-plastic, producing an ever-increasing range of brightly coloured consumer products with sleek surfaces. Science journalist Susan Freinkel observed: 'Kartell's designs made it possible for people to believe that plastic, like traditional materials had some noble presence,' Freinkel, *Plastic*, 38.

364 Ezio Manzini and Pasquale Cau, *The Material of Invention*, 1st MIT ed (Cambridge, Mass: MIT Press, 1989).

365 S Akhurst, "The Rise and Fall of Melamine Tableware," *The Plastiquarian*, 2004, 8.

366 Tom Fisher, "The Death and Life of Plastic Surfaces: Mobile Phones," in *Accumulation: The Material Politics of Plastic* (London: New York: Routledge, Taylor & Francis Group, 2013), 287.

367 In her PhD dissertation on Danish Modern furniture, Maggie Daft describes the appeal of this finish: 'The matte, oiled woods of Danish Modern register the body specifically and particularly. Not only do they take onto their surfaces the marks and stains of quotidian encounter, but they will also wear the shape of their

changing appearance appealed to a public accustomed to the worn appearance of old furniture and antiques. Most of the plastics used for furniture lack patina. The promised benefit of resistance to the impact of wear and tear has not meet with universal acceptance. Dutch art critic, Albert Plasschaert claimed:

> There is no real affection between a man and this type of [plastic] furniture; no memories will ever linger around them. They will never be like a familiar face in which we can perceive the reflection of our own personality. There is no intimacy.[368]

When abraded, glossy plastic surfaces trap dirt, get stained and those plastic objects are then discarded. Dirt can be trapped so effectively it cannot be removed by washing, quickly making the object less desirable. Parents became concerned that scuffed and porous surfaces might retain bacteria.[369] Unlike traditional materials, plastics cannot be repainted or repolished with replacement the only option, again reinforcing the perception that plastic was synonymous with disposable, inferior goods.

The industry responded to quality issues by developing an ever-increasing range of additives to enhance desirable attributes such as strength while compensating for deficiencies, like fading. Reinforcing fibres, fillers, plasticisers, compatibilisers, surface modifiers, chain extenders, impact modifiers, coupling agents, scratch-and-mar resisters, colorants, ultraviolet stabilisers, flame retardants, peroxides, anti-oxidants, and antistats (anti-statics) were continually modified and optimised to improve the material's performance and stability. Unfortunately, most of these additives are made from (often unregulated and

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user, with, for instance, the arms of a chair coloring, over time, to show their sitters stance. In the encounter between body and furniture, the furniture's surface shifts. Though its shape remains fixed, the furniture's form does not'. Maggie Leah Taft, "Making Danish Modern, 1945-1960" (Ph.D., The University of Chicago, 2014), 49, http://search.proquest.com/docview/1559962072/abstract/BC30A7FBCB204779PQ/1.

[368] Taft, 48.

[369] *Plastics News*, August 1972, 19.

frequently unidentified) chemicals.[370] Rachel Carson's enormously influential 1962 publication *Silent Spring* documented the environmental impacts of pesticides and received wide publicity in Australia, alerting consumers to the potential dangers of chemical additives.[371] The petrochemical industry attempted to discredit Carson's work but only succeeded in further raising public concern, causing increased levels of anxiety toward the industry.[372]

The negative environmental impacts of plastics had gone largely ignored or unnoticed until the end of the 1960s. In 1968 Yarsley and Couzens published a completely revised version of their work for a non-specialist audience, but they do not make a single reference to any adverse environmental impacts.[373] Prior to the late 1960s, environmental impacts caused by plastics received little coverage in the local media. At least in Australia, ignorance might have been a reasonable excuse. Things were about to change dramatically. Buckminster Fuller published his *Operating Manual for Spaceship Earth,* focusing attention on the planet's finite resources in 1969.[374] Paul Ehrlich drew attention to the contribution exponential population growth would have on environmental degradation. In the same year, and for the first time, global environmental problems including pollution, resource loss, and wetlands destruction were discussed by scientists from around the world at the UN's Biosphere Conference in Paris. On Christmas Eve 1968 Apollo 8 sent the Earthrise image back

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[370] Nils Simon et al., "A Binding Global Agreement to Address the Life Cycle of Plastics," *Science* 373, no. 6550 (July 2, 2021): 44, https://doi.org/10.1126/science.abi9010"Most additives are therefore not addressed comprehensively under any international agreement, even though more than 1500 have been identified as chemicals of concern in plastics."
[371] "Pesticides A Threat To Human Life?," *Canberra Times*, May 11, 1963; "The Buds and the Bees," *The Bulletin*, November 2, 1963.
[372] For example, in March 1988, a local paper reported, 'Since the publication of books like Rachel Carson's Silent Spring the idea of progress has never been quite the same. Too many people have become painfully aware that the triumphs of technology are often accompanied by "unintended consequences".' Sharon Beder, "The Social Shaping of Technology," *Tharunka*, March 18, 1986.
[373] Victor Yarsley and Edward Couzens, *Plastics in the Modern World* (London: Penguin, 1968).
[374] Fuller and Snyder, *Operating Manual for Spaceship Earth*.

to earth where the photo featured on the front cover of the *Whole Earth Catalog* that same year. Hailed as 'the most influential environmental photograph ever taken,' the image dramatically impacted public attitudes, alerting us to the finite resources available on this fragile planet.[375] The natural sphere and the human sphere were seen as co-dependent.[376] Ecological awareness entered the public discourse.

In 1970, a week after the near-disastrous Apollo 13 mission returned, 20 million Americans observed the first *Earth Day* and the Environmental Protection Agency was established in the United States. Barry Commoner published *The Closing Circle* the following year, which focused on sustainability and called for reduced use of plastics in both products and packaging. Despite these industry claims, public concern grew as the landfills filled and plastics increasingly polluted the landscape. A growing unease with the excesses of consumerism began to gather momentum. The pristine luscious surfaces of plastics began to lose their appeal.

Design for the Real World: Human Ecology and Social Change, 1971, by Designer and educator Victor Papanek drew attention to the environmental challenges created by the consumer society, focusing on the role of the designer. Papanek referred to designers as a 'dangerous breed' in designing unnecessary things they are 'partially responsible for all types of pollution.'[377] In 1972, an association of scientists and political leaders published *The Limits to Growth* for the Club of Rome. The report drew attention to the growing pressure on natural resources from human activities. Predictions emerged that the earth's limits would be

[375] For a full discussion on the impacts of Earthrise see Robert Poole, *Earthrise: How Man First Saw the Earth* (New Haven, Conn.; London: Yale University Press, 2010).
[376] Kjetil Fallan, *The Culture of Nature in the History of Design* (Milton, UNITED KINGDOM: Taylor & Francis Group, 2019), 21, http://ebookcentral.proquest.com/lib/anu/detail.action?docID=5741693.
[377] Papanek, *Design for the Real World*, 1971, 17.

reached in the following 100 years if rates of population growth, resource depletion, and pollution generation continued at the pace of the time.[378]

With the shine rubbing off plastic's glossy surfaces, attention focused on the material that lay beneath. The suspected carcinogenicity of vinyl chloride monomer (VCM), an ingredient of polyvinyl chloride (PVC), raised concern about the potential health impacts of plastic in 1973. Health concerns were quickly substantiated, with severe forms of liver cancer (hemangiosarcoma) found in workers involved with the production of PVC.[379] Reporting on the traces of phthalates (from PVC) in the blood of laboratory workers the *Washington Post* declared: 'we're all a little plastic.'[380] By 1975 the industry was fighting a total ban on the use of PVC in food packaging in America. The following year the Australian Plastics Institute, keen to reassure consumers of the safety of PVC food packaging, wrote to the press, 'plastic food-packaging now manufactured from Australian PVC conforms to the maximum levels of VCM recommended by Federal Government authorities.'[381]

Health concerns started to emerge concerning other polymers. Polyurethane foam, by now commonly used in household and office furnishings, cushions, pillows, mattresses, car seats and as insulation, was shown to be highly flammable with potential to release toxic fumes.[382] This issue continued to drag on the industry for many years after being raised to the attention of the Australian public in 1976. In 1982, *Choice Magazine* reported that

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[378] Meadows et al., *The Limits to Growth*.
[379] Andrea Westermann, "When Consumer Citizens Spoke Up: West Germany's Early Dealings with Plastic Waste," *Contemporary European History* 22, no. 3 (August 2013): 78, http://dx.doi.org/10.1017/S0960777313000246.
[380] Sarah A. Vogel, *Is It Safe?: BPA and the Struggle to Define the Safety of Chemicals* (Berkerley, UNITED STATES: University of California Press, 2012), 48, http://ebookcentral.proquest.com/lib/uts/detail.action?docID=1062236.
[381] "PVC Food Containers," *Canberra Times*, January 27, 1976. See also Plastics News, December 1976, 9-10 for a detailed response from the industry.
[382] "Plastics and You," *Victor Harbour Times*, September 22, 1976.

inflammable foam increased the severity of house fires and released toxic gases, including hydrogen cyanide and carbon monoxide.[383]

Early plastics often emitted strong odours, some of which consumers found alluring. Today the importance of smell is well understood by automobile manufacturers; Ford in Germany employs a 'Head of Smells' and Ford in Britain deploys an 'electronic nose' to check that cars are exuding the right smell before they leave the production line.[384] The new car aroma consists of fumes given off by plastics, coatings, and glues used in the assembly process. Maintaining the new car smell is so important to some owners that it supports businesses selling aerosols specifically designed to recreate, 'the musk of clean carpets, and the pure essence of clean plastic and rubber car parts.'[385] This example highlights the important role plastics play in creating the alluring odours that appeal to end users.

From the early 1970s evidence that inhaling these aromas (particularly those emitted by early plastics) might well have detrimental health impacts began to emerge. In 1972, Australian scientists began investigations into possible health dangers from inhalation of these fumes, including the 'new car smell'.[386] In the case of thermoplastics like polyvinyl chloride (PVC), the smell emits as the volatile elements of the material evaporate, a key result of this volatility signifying the death of the material as it becomes less 'plastic'.[387] Other early plastics could produce unsavoury odours. In 1964, author (and long-time critic of plastics) Norman Mailer characterised America as, 'a sick nation, we're sick to the edge of vomit and

[383] "'Frightening' Risk in Foam Stuffing," *Canberra Times*, July 8, 1982.
[384] Nigel F. Piercy, *Market-Led Strategic Change: A Guide to Transforming the Process of Going to Market*, 3rd ed, Chartered Institute of Marketing Series (Oxford: Butterworth-Heinemann, 2002), 99.
[385] See for example, Chemical Guys website, accessed February 3, 2022, https://www.chemguys.com.au/New-Car-Scent-470-ml-p/air_101_16.htm
[386] "Plastics Fumes 'Hazard,'" *Canberra Times*, June 19, 1972.
[387] Gabrys, Hawkins, and Michael, *Accumulation*, 111.

so we build our lives with materials that smell like vomit, polyethylene and Bakelite and fibreglass and styrene.'[388]

While some academics have written about the alluring properties of plastics and their sensory appeal with a focus on sight and touch, surprisingly little has been written about their effect on the sense of smell. In a rare celebration of the smell of plastic emitted by consumer goods, Cecilia Fredriksson acknowledges the importance of plastics in the mix of smells that encapsulated the excitement of modern consumption in her account of a Swedish low-cost department store. The smell summed up the 'new world of things' that the store represented and created a strong sensory memory for many visitors to the store.[389] French philosopher Henri Bergson contended that although the same smells we encounter can be experienced by others, their interpretations of those smells will be different, as they are associated with different experiences and memories—the 'personal element.'[390] For the Toys 'R' Us generation (referred to above) a smell can transport the recipient to childhood encounters with their favourite toys. Their parents (early baby boomers), experienced plastic chairs as they began to appear on the market. The odours these chairs produced would have been new and unfamiliar, likely creating a similarly powerful and memorable impression on first encounter. By the middle of the 1970s these same odours were more likely to signal danger.

[389] Cecilia Fredriksson, "The Making of a Swedish Department Store Culture," in *The Shopping Experience*, vol. 110 (London, UNITED KINGDOM: SAGE Publications, 1997), http://ebookcentral.proquest.com/lib/uts/detail.action?docID=1001336.

[390] Henri Bergson, *Time and Free Will: An Essay on the Immediate Data of Consciousness* (Mineola, N.Y: Dover Publications, 2001), 161–62.

Fig. 2.22. Gaetano Pesce's (1939-) *Up5 Chair*, 1969 Source: B&B Italia

Gaetano Pesce's (1939-) *Up5 Chair* (1969), arrived flat packed inside a PVC, vacuum sealed disc just 10cms thick. Upholstered in jersey nylon, it expanded to ten times its size, dramatically popping up from the floor when removed from its PVC envelope (fig. 2.22). A sweet chloroform smell, like nail polish, emitted from the leavening ingredient added to the polyurethane, doubtlessly enhancing the futuristic experience (while damaging the environment and banned shortly thereafter).[391]

In a very short space of time the public image of plastics changed. Quality, health, and environmental concerns shifted consumer perceptions—glossy shiny surfaces lost

[391] Production halted just four years later after realising that the sweet-smelling leavening agent, Freon, harmed the ozone layer. The chair was re-introduced from 2000, made from Freon-free Bayfit (cold flexible polyurethane) and is delivered fully formed and odourless.

their appeal—no longer admired for their perfection plastics were now seen as, 'potentially oozing poisons.'[392] Additionally, the price differential between plastics and traditional materials had been eroded by the energy crisis and threated to impact demand.

4. Crisis? What crisis?

Despite the significant impact of these crises on the furniture market the effect on the overall demand for plastic was negligible. The local trade press noted that demand had been mostly unaffected by the price increases caused by the energy crisis. Oil, and therefore plastics, were more expensive, but still competitively priced when compared with alternatives.[393]

In 1975, the production of plastics accounted for consumed only 2% of the oil produced and the industry complained that despite its negligible impact on energy markets it was being treated as the 'whipping boy' for the crisis.[394] The industry need not have been concerned. While demand was dented in the years immediately after the energy crises, growth quickly resumed and continued unabated until the global financial crisis (2007-8), which impacted growth for only two years as can been seen in the graph shown in fig. 2.23.

[392] Fisher, "A World of Colour and Bright Shining Surfaces," 300.
[393] *Plastics News*, August 1974, 3.
[394] *Plastics News*, November 1975, 6.

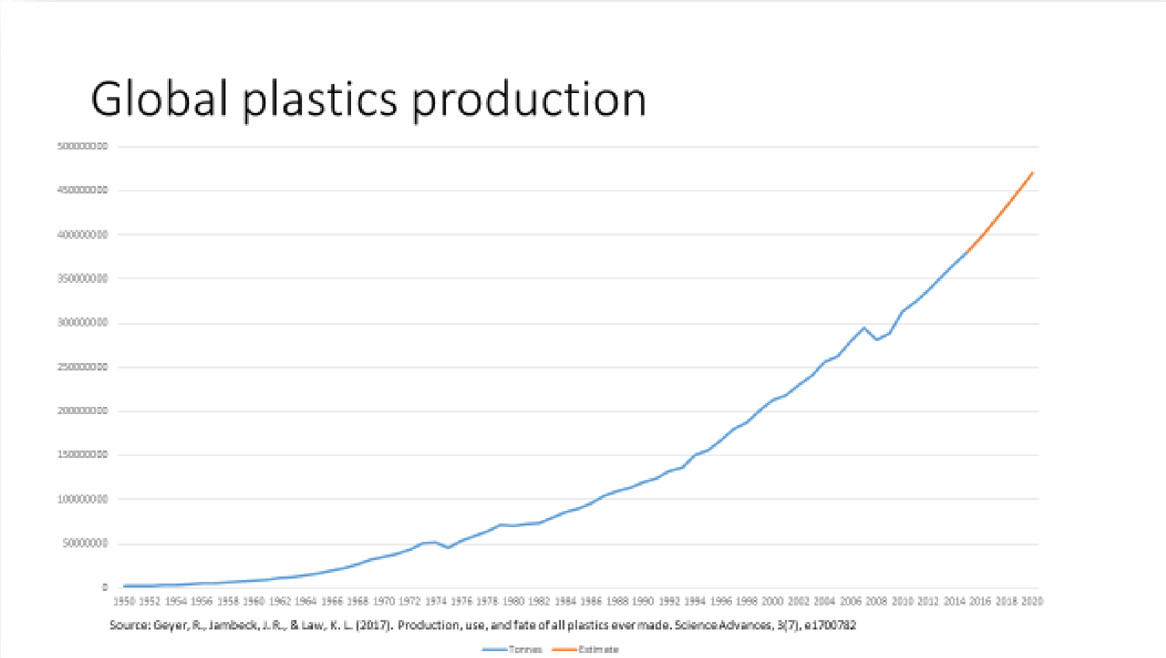

Fig. 2.23. Graph showing plastic production 1950-2020. Source: Geyer et.al. 2017 [395]

While overall demand for plastic remained buoyant, interest in furniture celebrating plastic as plastics dwindled. Glossy shell chairs, which had featured prominently during the first three years of the decade, practically disappeared from interior shots and advertisement in the homemaker titles.[396] This reflected a global trend with Tribbe reporting: 'Space Age lifestyle became a future that few Americans any longer embraced'. [397] He reports that the 'natural' look made a comeback, with rustic earth tones (avocado and ochre) replacing bright bold colours as the preferred aesthetic. The sleek Space Age was replaced by a handcrafted look with an emphasis on traditional materials.[398] Australia followed a similar trend with the bright colours associated with the Space Age quickly giving way to more muted tones. Anne

[395] Roland Geyer, Jenna R. Jambeck, and Kara Lavender Law, "Production, Use, and Fate of All Plastics Ever Made - Supplementary Material," *Science Advances* 3, no. 7 (July 2017): 3, https://doi.org/10.1126/sciadv.1700782.

[396] During 1973 plastic furniture featured on at least 50 pages of the two homemaker titles. By 1975, I counted only 20 pages, including modular furniture.

[397] Tribbe, *No Requiem for the Space Age*, 212.

[398] Tribbe, 212.

Watson noted that, 'exuberant colour also fell victim to the conservatism engendered by the changed economic conditions.'[399] Penny Sparke suggests the 'ecological outcry of the 1970s' led to plastics being considered as inferior to natural materials.[400] In the UK, a revival of interest in Victorian and Art Deco interiors also came at the expense of plastics, according to curator Mark Suggitt.[401]

Despite these changes in taste, the industry retained its position inside the home market by stealth. Plastic-as-plastic had become unfashionable, but upholstered modular furniture continued to sell well for the remainder of the decade and into the 1980s. Ironically, the modular lounge units were typically made from polyurethane foam and, as the upholstery needed to stretch in two dimensions, the fabric was invariably plastic based. Modular bookcases and shelving remained popular but local suppliers began to emulate wood finishes to accommodate the change in tastes.[402] Other apparently 'wooden' furniture was increasingly likely to be made from veneered composite boards held together with polymer adhesives, varnished with polyurethane with plastic glides to protect wooden floors (which were varnished with polyurethane). Inside the home, plastics maintained a presence, often disguised, or mixed with other materials to make them less obvious. While plastic kettles fell from favour, metal models featured plastic handles. The industry had simply revisited the strategy that succeeded in getting the material accepted in the first place;

[399] Watson, *Mod to Memphis*, 13.
[400] Sparke et al., *The Plastics Age*, 54.
[401] Susan Lambert, *Provocative Plastics Their Value in Design and Material Culture.* (Cham: Springer International Publishing AG, 2021), 170, http://public.eblib.com/choice/PublicFullRecord.aspx?p=6452756.
[402] Plastics News, June 1978, 6 describes how Michael Bayley Plastics introduced a simulated wood grain effect to its range of modular shelving.

plastics were integrated or camouflaged so that users hardly noticed them.[403] In short, plastics became invisible.[404]

Commenting on industry trends for 1979 in *The Australian Furnishing Trade Journal,* a general manager of a furniture business abruptly summarised the outlook for plastics in the industry:

> Plastics has had it as a fashion story. It has found it's [sic] place as a purely structural material for the garden and office furniture.[405]

While these comments appear exaggerated, they do highlight an important growth segment in the domestic market which the industry exploited in the following decade—outdoor furniture.

5. Plastic furniture revived

152 world leaders signed conventions on biological diversity, desertification, a framework on climate change and principles for sustainable forestry at the Rio de Janeiro *Earth Summit* in June 1992. The report accused industrialised countries of pursuing a pattern of consumption and production which aggravated poverty and wealth imbalances.[406] The ability of linear economies, dependent on high levels of production, consumption, and waste, to deliver endless growth became increasingly questioned. The role and responsibilities of professional designers in supporting the system came under increased scrutiny. Papanek's *The Green*

[403] Industrial designer Sebastian Conran even invented his own term "deplastification" to describe this action of making things feel and appear less "plasticky". Lambert, *Provocative Plastics Their Value in Design and Material Culture.*, 104.
[404] Fisher, "Fashioning Plastics," 120.
[405] DG Martin, "Furnishing Trends for 1979," *The Australian Furnishing Trade Journal*, 1979.
[406] Agenda 21 of United Nations Conference on Environment and Development, 1992

Imperative (1995) claimed that the 'ethical' role of design involves considering the environmental consequences of products, and he urged industrial design professionals and end users to recognise their ecological responsibilities.[407] He accused designers of being complicit with marketing professionals in producing and making unnecessary and wasteful objects.[408]

Against this background, and largely absent for nearly two decades, new designs for plastic chairs began to be developed right at the end of the twentieth century. This revival arrived too late for most Australian manufacturers. Furniture Makers of Australia, who purchased both Aristoc and Fler, closed down in 1975 and Module shortly afterwards. Amalgamated Industries delisted from the stock exchange in 1981. Frustrated by their inability to secure commissions, the Featherstons stopped designing furniture in the mid-1970s and concentrated on other activities.[409] Larger international firms survived the downturn. Kartell worked with Philippe Starck to develop the translucent *La Marie* using polycarbonate. The success of the design launched a series of polycarbonate furniture from Kartell. The most popular of these, *Louis Ghost*, sold over one million copies by 2014 and has since been widely copied.[410] Karim Rashid also used polycarbonate to develop his *Oh Chair* (1999), again enjoying enormous commercial success with over six million copies of the low-priced design sold (fig. 2.24). Jasper Morrison released the *Air Chair* that same year, heralding the introduction of air injection moulding to the furniture industry. Reservations concerning the quality of plastic apparently disappeared with the pre-war generation.

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[407] Victor J. Papanek, *The Green Imperative: Natural Design for the Real World* (New York: Thames and Hudson, 1995), 2.
[408] Papanek, 17.
[409] Isaac, *Featherston*, 259.
[410] Kartell press release 2014: Kartell, 15 years of transparent design, accessed February 3, 2022, https://www.Kartell.com/file/general/15anniditrasparenzaPressReleaseEN.pdf

Fig. 2.24. *Oh Chair*, Karim Rashid for Umbra, 1999. Source: Umbra

Against a background of health and environmental concerns, the success of those polycarbonate designs is yet another example of plastic's paradox. Polycarbonate lacks a unique Resin Identification Code (RIC). It is grouped as other (RIC 7), signalling that it is unlikely to be recycled. Meanwhile the chairs continued to sell by the millions.

Reflecting on 15 years of success with its polycarbonate range, Kartell announced that following the introduction of *La Marie* (at 3.5kg), 'minimalism was no longer necessary.'[411] *Louis Ghost* weighed 4.8kg and the company's press release proudly boasted that the company had produced even larger and heavier products using polycarbonate, including the 18kg *Ghost Buster* and culminating in the 30kg *Uncle Jack* sofa by Starck. It seems all efforts toward dematerialisation were apparently abandoned by Kartell. Yet many other organisations were beginning to consider their corporate social responsibilities.[412] Hawken et al. published *Natural Capitalism: Creating the Next Industrial Revolution,* claiming capitalism to be in rapid decline and arguing that the natural capital on which our existence depends was being disproportionately lost in comparison with the material gains achieved.[413]

6. Conclusion

Plastics quickly became ubiquitous across many categories of consumer goods following the end of WWII. Australia was exposed to developments in plastic furniture in Europe and America but geography and post war government protectionist policies combined to severely restrict imports. Designers and manufacturers working in Australia grappled with the challenge of adapting plastic manufacturing technologies developed primarily for mass production to produced economically viable modern furniture for a relatively small market. Through the ingenuity of these Australian actors, local consumers gained access to fashionable, competitively priced plastic furniture. As will be shown in later chapters many of the manufacturing technologies employed by these pioneering Australian designers and

[411] Kartell press release 2014: Kartell, 15 years of transparent design, accessed February 3, 2022, https://www.Kartell.com/file/general/15anniditrasparenzaPressReleaseEN.pdf
[412] Simon Dresner, *The Principles of Sustainability* (London ; Sterling, VA: Earthscan, 2002) Which includes chapters on Taking Sustainability into Economics and The Ethics of Sustainability.
[413] Paul Hawken, Amory B. Lovins, and L. Hunter Lovins, *Natural Capitalism: Creating the next Industrial Revolution*, 1. paperback ed., [Nachdr.], A Back Bay Book (New York: Little, Brown and Co, 2000), 2.

manufacturers remain relevant to contemporary actors developing experimental designs using renewable plastics.

From the late 1960s, the negative impacts caused by both the creation and disposal of plastics became increasingly apparent. Combined with substantial price increases caused by a succession of oil crises, growing environmental awareness prompted a re-evaluation by designers and consumers of their relationship with plastics. These shifts in attitude demonstrably impacted the furniture industry, with the Australian industry particularly affected. However, overall demand for plastics continued to grow as manufacturers developed an ever-increasing variety of products incorporating plastics.

Although Celluloid ultimately proved to be poor ivory substitute to produce billiard balls, new fully synthetic plastics quickly gained acceptance by designers, manufacturers, and consumers across many applications. Plastics led to a reduction in demand for scarce resources like ivory, helping to ensure the survival of the elephants throughout the twentieth century. Today elephants are under threat again; while poaching continues to take its toll, climate change also threatens their survival.[414] Plastics undoubtedly contributed to the elephants' reprieve last century, but the long-term effects caused by the extraction and consumption of the fossil fuels needed to make them are destroying the natural environment. Having spared the species for the twentieth century, the fossil feedstocks exploited to make plastics are now threatening wild elephants in the twenty-first century. This is yet another example of a paradox caused by plastic.

[414] The African forest elephant is listed as critically endangered and the African Savanna elephant is rated endangered on the International Union for Conservation of Nature's Red List of Threatened Species. Droughts caused by climate change are among the threats to their survival. IUCN 2021, "The IUCN Red List of Threatened Species," IUCN Red List of Threatened Species, accessed February 3, 2022, https://www.iucnredlist.org/en.

Elephants are not the only species threatened with extinction by the continued production of fossil-based plastics. Mounting evidence suggests that phthalates, including per- and polyfluoroalkyl substances (PFAS) and bisphenol A (BPA) used in the production of plastics, are causing significant reduction in fertility rates. One researcher has claimed that sperm counts among western men have more than halved in the past 40 years and 'will be dry by 2045.'[415] BPA is a precursor monomer used in the production of polycarbonate and can have alarming impact on 'essential communication functions of neurons in mature vertebrate brains,' with the researchers calling for the rapid development of alternative plasticisers.[416] Philippe Starck's translucent material designs, hailed as the pinnacle of efforts to reduce consumption through dematerialisation, should now be seen in a different light.[417]

With the beginning of the new millennium issues critical to humanity, including the exhaustion of fossil fuel resources, GHG emissions, and climate change, demanded our urgent attention. The need to take action gained consensus.[418] Plastics are increasingly seen as an emblem for everything that is wrong with mass consumption, yet the material remains an indispensable part of our daily lives.[419] This plastic paradox represents a 'wicked problem' that has remained unresolved for over a century. During that time the negative impacts of plastics have been slowly accumulating and now, faced with our own threat of catastrophe,

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[415] Shanna H. Swan and Stacey Colino, *Count down: How Our Modern World Is Threatening Sperm Counts, Altering Male and Female Reproductive Development, and Imperiling the Future of the Human Race*, First Scribner hardcover edition (New York: Scribner, 2021).

[416] Elisabeth Schirmer, Stefan Schuster, and Peter Machnik, "Bisphenols Exert Detrimental Effects on Neuronal Signalling in Mature Vertebrate Brains," *Communications Biology* 4, no. 1 (April 12, 2021): 1–9, https://doi.org/10.1038/s42003-021-01966-w.

[417] Kartell announced, in late 2020, that it was switching production to "polycarbonate 2.0" based on "second generation renewable polymer" promising it, "reduces carbon dioxide emissions by 60% compared to fossil-based polycarbonates." No mention of BPA can be found in the material issued by the company. Kartell did not respond to requests for an interview, accessed February 3, 2022, https://www.Kartell.com/file/general/CS%20Re_Transparency_EN.pdf.

[418] "IPCC - Climate Change 2001: Synthesis Report | GRID-Arendal" (Cambridge: Intergovernmental Panel on Climate Change, 2001), https://www.grida.no/publications/267.

[419] Westermann, "When Consumer Citizens Spoke Up."

require addressing. The next chapter examines the alternative materials available to replace virgin fossil plastics. Having identified viable alternatives, I question the role that designers can play in driving demand for those materials.

Part A
The plastic chair market

Chapter 3
Agency of design in the plastic crisis

Of the total 8.3 billion tons of virgin fossil plastic produced by the end of 2020, 59% (4.9 billion tons) ended up in landfills or our environment.[420] This chapter examines the potential environmental impact of the petrochemical industry's plans to continually grow the market for virgin fossil plastics through to 2050. Having established that this forecast is incompatible with the GHG emission reduction targets adopted by the UN, an alternative scenario is proposed, relying on the development and use of renewable carbon-based plastics (renewable plastics). I argue that those involved with the design of plastic chairs have agency in the transition to a more sustainable relationship with the material.

Renewable plastics are being introduced primarily to replace packaging, previously made from virgin fossil plastics. But packaging accounts for only about a third of the plastic produced. To achieve real progress toward the more sustainable future, renewable plastics must be more widely adopted.[421] Development of a more sustainable plastics industry will be reliant on consumer acceptance of products made using renewable plastics. Designers and manufacturers must be prepared to experiment with renewable plastics to develop products that appeal to consumers. By analysing transcripts of interviews with designers and manufacturers conducted for this study I identify the actors involved with material selection process. I identify the agency and decision-making authority among the actors involved with the selection of renewable plastics.

Sustainability is, ever-increasingly, the subject of multi-disciplinary research, and debates about the role of plastics in a sustainable future continues. A representative from the Center for International Environmental Law (CIEL) declared at the start of 2020 that due to

[420] Geyer, Jambeck, and Law, "Production, Use, and Fate of All Plastics Ever Made," 1.
[421] Based on 2015 data see: Geyer, Jambeck, and Law, "Production, Use, and Fate of All Plastics Ever Made - Supplementary Material," 10.

the volume of GHG emissions and toxic chemicals released during production of plastics it is essential to find ways to lessen the damage caused by these materials if we are to solve the climate crisis.[422]

Industry proponents highlight the substantial economic and environmental benefits offered by plastics when compared with traditional materials. For example, it is estimated that replacing polyethylene terephthalate (PET) with glass would increase transportation costs by to five times and consume 40% more energy.[423] Boeing claims their Dreamliner consumes 20% less fuel than their previous generation of jets, mainly achieved by replacing 1,500 riveted aluminium sheets with lighter carbon composites.[424] Plastics also feature unique benefits that make them irreplaceable for many applications. Food can be kept hygienic and fresher for longer, reducing waste by up to half, delivering household savings, and reducing methane impacts from landfill.[425] Our health system depends on plastics, from personal protective equipment (PPE) designed for our safety, to the tubes and machines that keep us alive in a time of need.[426]

Meanwhile, the downstream impacts caused by the inappropriate disposal of plastic (and particularly single-use plastics) are increasingly the cause of public concern. The past decade has seen greater focus on the problem of ocean plastics. A report from the Ellen

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[422] Steven Feit quoted in: Benjamin Storrow, "Plastics Plants Are Poised to Be the Next Big Carbon Superpolluters," Scientific American, January 24, 2020, https://www.scientificamerican.com/article/plastics-plants-are-poised-to-be-the-next-big-carbon-superpolluters/.
[423] According to an LCA analysis by CleanMetrics Corp
[424] Boeing, "Boeing: 2014 Environment Report," accessed February 3, 2022, https://www.boeing.com/aboutus/environment/environment_report_14/2.1_cleaner_products.html.
[425] Wrapping a cucumber in plastic can extend its shelf life from three days to two weeks. Manoj Dora, "Why Some Plastic Packaging Is Necessary to Prevent Food Waste and Protect the Environment | Brunel University London," July 6, 2019, https://www.brunel.ac.uk/news-and-events/news/articles/Why-some-plastic-packaging-is-necessary-to-prevent-food-waste-and-protect-the-environment. Rajinder Kumar Dhall, Sanjeev R. Sharma, and B. V. C. Mahajan, "Effect of Shrink Wrap Packaging for Maintaining Quality of Cucumber during Storage," *Journal of Food Science and Technology* 49, no. 4 (August 2012): 495–99, https://doi.org/10.1007/s13197-011-0284-5.
[426] PPE includes: face masks, ventilators, sterile gloves, eye visors, hazmat suits, N95 masks, visors, shoe covers and goggles, all mostly made from polypropylene.

McArthur Foundation forecast that if current trends continue the weight of plastic in the ocean will outweigh the total weight of fish by 2050. This startling fact has generated wide publicity and stirred the consumer backlash against plastics.[427] The ever-growing quantities of plastic waste circulating in ocean gyres have attracted increased awareness of the problem.[428] 'Plastiphobia' has been fuelled (particularly in Europe but also in Australia) by David Attenborough's *Blue Planet II* program.[429] The final episode of the series dedicated six minutes to the impact of plastic on sea life, showing a turtle hopelessly tangled in plastic netting, and an albatross killed by ingesting plastic shards. This segment generated the 'biggest reaction to anything in the whole series,' according to the Head of Commissioning at the BBC Tom McDonald.[430]

Ocean plastics are just a symptom of a much bigger problem: 'the highly visible tip of the iceberg,' as one recent study described them.[431] Between eight and ten million tonnes of plastic are estimated to be entering waterways every year.[432] This quantity represents less than five per cent of the 200 million tonnes of plastic waste estimated to have been generated during 2020, most of which ends either up in landfills, gets incinerated, or is left to litter our environment. In addition to the enormous waste challenges created by plastics there are ongoing concerns about its impact on our health. The leaching of chemicals from plastics and microplastics potentially transferring chemicals to wildlife and humans through

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[427] National Geographic Society, "Great Pacific Garbage Patch," National Geographic Society, July 5, 2019, http://www.nationalgeographic.org/encyclopedia/great-pacific-garbage-patch/; Ellen McArthur Foundation, "New Plastics Economy - The Future Of Plastics."
[428] See: L. Lebreton et al., "Evidence That the Great Pacific Garbage Patch Is Rapidly Accumulating Plastic," *Scientific Reports* 8, no. 1 (March 22, 2018): 1–15, https://doi.org/10.1038/s41598-018-22939-w.
[429] Broadcast in the UK from October 2017 and in Australia from February 2018.
[430] Stephen Buranyi, "The Plastic Backlash: What's behind Our Sudden Rage – and Will It Make a Difference?," *The Guardian*, November 13, 2018, sec. Environment, https://www.theguardian.com/environment/2018/nov/13/the-plastic-backlash-whats-behind-our-sudden-rage-and-will-it-make-a-difference.
[431] T. Hundertmark et al., "How Plastics Waste Recycling Could Transform the Chemical Industry," *Hydrocarbon Processing*, April 2019, 9.
[432] Ellen McArthur Foundation, "New Plastics Economy - The Future Of Plastics."

the air or through the food chain have all raised public concerns.[433] A 2009 report from the Centers for Disease Control and Prevention in the United States found bisphenol A (BPA), flame retardants, phthalates, and poly-brominated diphenyl ethers in the bodies of Americans.[434] A more recent report based on an analysis of 52 studies found that humans are ingesting five grams of microplastics every week; equivalent to eating a credit card.[435] We are eating and breathing plastic. Plastics simply refuse to go away. Their material recalcitrance is forcing us to acknowledge the ways in which plastics persist in our environment and in our bodies long after their use value is exhausted.[436]

A *War on Plastics* has been declared led by the BBC (kick-started by a television program of the same name) and, to a lesser extent, the ABC in Australia. Consumer outrage has focused on single-use plastics and in response an increasing number of jurisdictions are moving to ban plastic bags and/or other single-use plastics. By the end of 2019, more than 120 countries had banned single-use plastic bags and 60 more countries said they would impose taxes on them. *Plastic free July*, encouraging consumers to avoid single-use plastics for a month, enjoys growing support from the global community with organisers estimating 326 million people across 177 countries participated in 2021.[437]

While efforts to address the downstream impact caused by plastics are commendable, they often overlook the potential costs implicit in eliminating all plastics.

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[433] Jan Zalasiewicz et al., "The Geological Cycle of Plastics and Their Use as a Stratigraphic Indicator of the Anthropocene," *Anthropocene* 13 (March 2016): 4–17, https://doi.org/10.1016/j.ancene.2016.01.002.

[434] Max Liboiron, "Plasticizers: A Twenty-Forst-Century Miasma," in *Accumulation: The Material Politics of Plastic* (London: New York: Routledge, Taylor & Francis Group, 2013), 139.

[435] Dalberg, "No Plastic in Nature: Assessing Plastic Ingestion from Nature to People" (Sydney: University of Newcastle, June 2019), 6, https://www.wwf.org.au/news/news/2019/revealed-plastic-ingestion-by-people-could-be-equating-to-a-credit-card-a-week.

[436] Richard C. Thompson, "Plastics, Environment and Health," in *Accumulation: The Material Politics of Plastic* (London: New York: Routledge, Taylor & Francis Group, 2013), 150–68.

[437] See: Plastic Free July, "Plastic Free July – Be Part of the Solution," Plastic Free July, February 3, 2022, https://www.plasticfreejuly.org/.

Lightweight, strong plastics often command a formidable environmental and economic advantage when compared with traditional materials. For example, a comprehensive European survey of 57 products packaged in a range of plastics and alternative materials reported energy savings of 50% by using plastic packaging.[438] There is little to be gained, and often much more to lose, by reducing or banning the use of virgin fossil plastics without precisely specifying the materials that should be used to replace them for any given application.

Designers participating in research undertaken for this dissertation often highlighted that when used appropriately plastics can be the most environmentally sustainable material choice. Industrial designer and academic Manuel Garcia reported:

> Plastic is a material that can be revitalised… We have a huge effort to get people to understand plastic is actually a viable material and can contribute to our sustainability level in our planet.[439]

Well-designed, well-made plastic products, including chairs, can last decades. Even at the end-of-life plastic products can often potentially be recycled. As negativity toward plastics generally increases so does the need for more nuanced messaging to distinguish the appropriate use of the material and to highlight the life-cycle environmental benefits that can be achieved. Garcia's comments illustrate the willingness of some designers to participate in this debate.

The issue of plastics has become politicised. While designers and manufacturers often understand the economic and environmental benefits of working with plastics, the downstream negative impacts of plastic (particularly marine pollution) are becoming the

[438] For details of these and other similar studies see: Andrady and Andrady, *Plastics and Environmental Sustainability*, 126–29.
[439] Geoff Isaac, Interview with Manuel Garcia, July 23, 2019.

focus of attention. Ocean plastics are the subject of increased scrutiny from both the academic community and legislators.[440] While the amount of research and policy attention given to ocean plastics is most welcome, it risks detracting from issues such as climate change and overfishing. Those are potentially much greater environmental threats according to marine biologists Richard Stafford and Peter Jones.[441] While the media and public are distracted by ocean plastics, governments and corporations can earn goodwill and appear proactive by addressing a symptom of the plastics issue while foregoing action in other areas of urgent environmental need.[442] Allowing ocean plastics to become a single-issue focus of environmental concerns distracts attention from the upstream links between plastic production and climate change. Instead, the focus remains on downstream impacts, a relatively small symptom of a much larger plastics problem. A review of 180 scientific articles on plastics drawn from the fields of environmental science and environmental studies found a similar pre-occupation with a focus on marine pollution, leading the authors to a similar conclusion:

> If the debate continues to constrain itself to marine plastic pollution, plastic producers may feel free to ramp up the total supply of plastics entering the system while attention remains fixed on straws, cup lids, and sea turtles. [443]

By focusing on downstream impacts attention is drawn away from the unsustainable trajectory of our plastic consumption and failing to tackle the underlying issue: our dependence on fossil-fuels. That review concludes by emphasising that too little academic attention has been given to investigate 'how the material properties of plastic are

[440] Nielsen et al., "Politics and the Plastic Crisis."
[441] Richard Stafford and Peter J. S. Jones, "Viewpoint – Ocean Plastic Pollution: A Convenient but Distracting Truth?," *Marine Policy* 103 (May 1, 2019): 187, https://doi.org/10.1016/j.marpol.2019.02.003.
[442] Stafford and Jones, 187.
[443] Nielsen et al., "Politics and the Plastic Crisis," 13.

inextricably bound up with our dominant systems of production and consumption.' [444] By ignoring that topic societies based on disposability and overconsumption are maintained.

The ongoing debate around the benefits and impacts of plastic has prevented the development of a consensus definition of the plastic problem. Solutions for symptoms are being developed without fully understanding the cause of the problem. If the problem is not properly defined, then it is near impossible to find the solution.[445] Unique among the environmental challenges facing the planet, there is currently no recognised global scientific or political authority tasked with identifying and addressing the plastic problem.[446]

The plastics industry has actively supported efforts to maintain focus on the downstream impacts of plastic by supporting initiatives such as Keep America/Australia Beautiful to point the finger or blame at the consumer as the source of litter. This diverts attention away from the plastic producers and their clients, the true source of the plastics pollution crisis. A Changing Markets Foundation report from 2020 presents case studies from 15 countries across five continents to illustrate the activities of the ten largest plastic polluters and their attempts to obfuscate the plastics crisis.[447] The report also details the plastics industry's ongoing efforts to block anti-plastic legislation. The success of these efforts is reflected in current industry forecasts which anticipate continued growth in demand

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[444] Nielsen et al., 13.
[445] Nine environmental scientists and academics, working in sustainability, made this point specifically related to the plastics problem in this paper: Maarten Hajer et al., "Beyond Cockpit-Ism: Four Insights to Enhance the Transformative Potential of the Sustainable Development Goals," *Sustainability; Basel* 7, no. 2 (2015): 1651–60, http://dx.doi.org.ezproxy.lib.uts.edu.au/10.3390/su7021651.
[446] Nielsen et al., "Politics and the Plastic Crisis," 2.
[447] Changing Markets Foundation, "Talking Trash" (London: Changing Markets Foundation, September 2020), https://talking-trash.com.

for plastics. Revealing the defuturing of the current regime is the first step to confronting change.[448]

1. Future Scenarios

According to industry projections, demand for plastics is projected to more than triple to 1.5 billion tonnes by 2050 (fig. 3.1).[449] The petrochemical industry has enjoyed a compound annual growth rate (CAGR) of around 8.4% for plastics so far this century.[450] A CAGR of at least 3.5% is forecast to continue until 2050, despite the short-term impact of COVID19 or the activities of governments and not-for-profits encouraging a reduction in the consumption of plastic. Demand is forecast to continue to grow driven by an increasingly affluent, populous, and urbanised world.[451] To meet this demand, GHG emissions from plastic production will increase from 4% to 15% of the available global annual carbon budget by 2050, making it virtually impossible to reach global emissions-reduction targets.[452]

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[448] Fry defines “defuturing” as the negation of world futures for us, and many of our unknowing non-human others.’ Tony Fry, *Defuturing: A New Design Philosophy*, Radical Thinkers in Design (London: Bloomsbury Visual Arts, 2020), 10.

[449] Ellen McArthur Foundation, “New Plastics Economy - The Future Of Plastics,” 24.

[450] Geyer, Jambeck, and Law, “Production, Use, and Fate of All Plastics Ever Made,” 1.

[451] American Chemistry Council, “Population Growth and Materials Demand Study (PLASTICS),” August 2019, 10, https://plastics.americanchemistry.com/Reports-and-Publications/. China now produces 30% of the world’s plastic, doubling market share over the past decade. European Environment Agency, “Plastics, a Growing Environmental and Climate Concern,” News, 2021, 19, https://www.eea.europa.eu/highlights/plastics-environmental-concern.

[452] Ellen McArthur Foundation, “The New Plastics Economy,” 24.

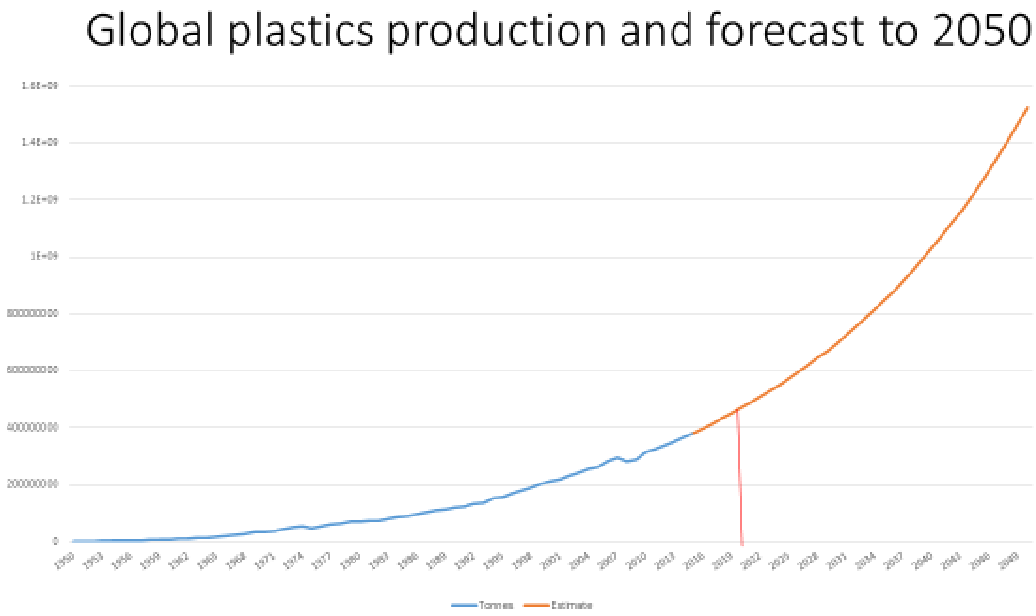

Fig. 3.1. Global plastics production and forecast to 2050.
Source: Geyer, R.et al. (2017) & Ellen McArthur Foundation (2016)[453]

To produce this quantity of plastic the industry has plans to exploit all available fossil fuels. Increased production of plastics will drive nearly half (45%) the forecast growth in demand for oil during the next three decades. The relatively small plastics market is then crucial to maintain the global petrochemical industry growth.[454] But oil will not be the only fossil fuel used to meet burgeoning demand for plastics. Gas has become plentiful (and therefore cheaper) due to dramatically increased fracking activities across the USA. The petrochemical industry is adapting to exploit this opportunity. To make plastics from gas requires investment in ethane fracking plants to convert gasses released during the process of extracting shale oil to ethylene. Ethane is extracted from natural gas liquids and fed into a cracker where it is exposed to high temperature and pressure, thereby 'cracking' the ethane

[453] Geyer, Jambeck, and Law, "Production, Use, and Fate of All Plastics Ever Made - Supplementary Material," 7–8; Ellen McArthur Foundation, "The New Plastics Economy," 24.
[454] George Harding-Rolls, "Fossil Fashion," *Changing Markets* (blog), 5, accessed February 3, 2022, https://changingmarkets.org/portfolio/fossil-fashion/ BP even expects 95% of future growth in demand for its oil to come from plastic production.

molecule into ethylene together with small quantities of bi-products such as hydrogen and carbon monoxide.[455]

The petrochemical industry has already committed investment of between US200-US$300 billion in more than twenty ethane cracking plants across the USA.[456] A recently completed, mid-sized ($6 billion) plant is expected to produce enough GHG emissions to wipe out all the annual reductions in carbon dioxide achieved by the nearby city of Pittsburgh in their efforts to combat climate change.[457] Another $9.4 billion plant in Louisiana planned for completion in 2029 is expected to emit 13.6 million tons of carbon dioxide into the atmosphere annually, making it the single largest polluting entity in the USA.[458] This expenditure is just part of an expected US$1.4 trillion to be invested by oil and gas companies between 2020 and 2024 to finance new extraction projects (many of which are in North America), effectively locking in our dependence on fossil fuels until 2050.[459] Reduced production costs achieved by switching to gas will allow the price of virgin plastic to be cut, shoring up demand while effectively pricing recycled polymers out of the market. There is

455 Center for International Environmental Law, "Plastic and Climate - The Hidden Costs of a Plastic Planet" (Washington, DC, May 2019), 44–45, https://www.ciel.org/project-update/plastic-climate-the-hidden-costs-of-a-plastic-planet/.

456 James Bruggers, "Plastics: The New Coal in Appalachia?," InsideClimate News, February 25, 2019, np, https://insideclimatenews.org/news/25022019/plastics-hub-appalachian-fracking-ethane-cracker-climate-change-health-ohio-river; John Vidal, "The Plastic Polluters Won 2019 – and We're Running out of Time to Stop Them | Environment | The Guardian," February 1, 2020, np, https://www.theguardian.com/environment/2020/jan/02/year-plastic-pollution-clean-beaches-seas?CMP=Share_iOSApp_Other; Center for International Environmental Law, "Oil, Gas and the Climate: An Analysis of Oil and Gas Industry Plans for Expansion and Compatibility with Global Emission Limits" (Washington, DC, December 2019), 8, https://www.ciel.org/reports/oil-gas-and-climate-an-analysis-of-oil-and-gas-industry-plans-for-expansion-and-compatibility-with-global-emission-limits/; Food & Water Watch, "The Fracking Endgame: Locked Into Plastics, Pollution, and Climate Chaos" (Washington, DC, June 3, 2019), https://www.foodandwaterwatch.org/wp-content/uploads/2021/03/rpt_1905_fracking-2019-web_2.pdf.

457 Bruggers, "Plastics." The Shell plant was due to open in 2020 but has been delayed by COVID19

458 Storrow, "Plastics Plants Are Poised to Be the Next Big Carbon Superpolluters."

459 Center for International Environmental Law, "Oil, Gas and Climate," 2.

some evidence to suggest that price differential is already having an effect.[460] When prices for virgin polymers are low it is hard to mount an economic argument to justify recycling. In 1991 there were 12 polyethylene resin recovery facilities operating in the USA, by April 2015 none were left.[461]

Forecasts can be useful as an alarm to inform us when the prevailing trend will lead us to an undesired future state. But those forecasts have nothing to offer as a planning tool.[462] Unfortunately, they appear to be correct in this instance. Despite the efforts of David Attenborough, the Ellen McArthur Foundation, and countless other organisations and community groups to call for action, demand for plastics continues to grow unabated.

To avoid that potentially devastating scenario mapped out by the petrochemical industry an actionable plan for radical change is necessary. Transition management literature places significant emphasis on the important role that 'guiding visions' play in directing efforts and interventions toward more sustainable solutions.[463] Individual actors are not capable of changing the entire system, nor can they identify the desirable direction of change. Profit-driven companies are adept at developing incremental improvements using the technologies with which they are familiar. It is difficult and often prohibitively expensive for an individual actor to evaluate and compare the environmental impact of decisions where multiple options are available. Providing a meta-vision can guide actors to deal with the

[460] In the second half of 2019, European prices for virgin polyethylene terephthalate (PET) collapsed and were lower than for recycled PET (rPET). International Energy Agency, "The Oil and Gas Industry in Energy Transitions" (Paris: International Energy Agency, January 2020), 87.
[461] Mark A. Spalding and Ananda Chatterjee, *Handbook of Industrial Polyethylene and Technology: Definitive Guide to Manufacturing, Properties, Processing, Applications and Markets Set* (Somerset, UNITED STATES: John Wiley & Sons, Incorporated, 2017), 1248, http://ebookcentral.proquest.com/lib/uts/detail.action?docID=5106965.
[462] Mattias Höjer and Lars-Göran Mattsson, "Determinism and Backcasting in Future Studies," *Futures* 32, no. 7 (September 1, 2000): 428, https://doi.org/10.1016/S0016-3287(00)00012-4.
[463] Adrian Smith, Andy Stirling, and Frans Berkhout, "The Governance of Sustainable Socio-Technical Transitions," *Research Policy* 34, no. 10 (December 1, 2005): 1491–1510, https://doi.org/10.1016/j.respol.2005.07.005.

challenge of creating fundamental change.[464] Visions map paths toward plausible future alternatives by provoking debate and providing guidance on system innovations, highlighting the technical, institutional, and behavioural problems that need to be resolved. Ambitious strategic visions covering the entire value chain can spur innovation. Once a vision is established organisations can revise policy settings and identify the actor-network participation required to execute the desired change, allowing targets and goals to be defined and progress monitored. By establishing an overarching vision, participants are directed toward the same goals and can help to secure the external resources and support needed to meet them.

Debate continues within the transition management literature on how specific the guiding visions should be. Transition theories such as multi-level perspective (MLP) are reliant on more sustainable solutions emerging from a process of experimentation. Groups of actors work together to develop niche experiments which are evaluated by the market and other industry participants. Competitors benefit from this experience to guide their own project which might incorporate or adapt solutions from previous experiments or introduce a radically new approach. The process of trial and error is accelerated by observing the success and failure of experimentation by other industry participants. Critics argue that in developing specific visions experimentation is restricted or narrowed—all activities are focused in a single direction—thereby effectively discouraging the investigation of more radical solutions.[465] Establishing wider visions can encourage broad and diffuse solutions to be explored as the path ahead is less predetermined. Contrarily, it has been argued that highly

[464] Schot and Geels, "Strategic Niche Management and Sustainable Innovation Journeys," 542.
[465] For example, see: Schot and Geels, 542.

specific visions can be more efficient by virtue of the fact open-ended and potentiality wasteful experimentation has been discouraged.[466]

The UN has established two high-level sustainability goals with potential impacts on the plastics industry. Sustainable Development Goal 12.5 targets substantially reducing waste generation through prevention, reduction, recycling, and reuse by 2030. While goal 14.1 seeks to prevent and significantly reduce marine pollution of all kinds, particularly from land-based activities and including marine debris and nutrient pollution, by 2025. While these sustainable goals are admirable, they provide little actionable guidance for actors within or downstream from the plastics industry wishing to support those aims. But ambitious normative visions can play a central role in guiding transitions.[467]

Providing a more detailed vision, the Nova Institute suggests it is possible to eliminate the need for virgin fossil-based chemicals and plastics by the middle of the century, replacing them entirely with renewable carbon-based materials. In this scenario over half (55%) the global demand for plastics would be met through recycling (fig. 3.2).[468] The Nova Institute is not alone in predicting a significant move to recycling. A 2019 report by the consulting firm McKenzie has ambitiously projected that 50% of the demand for plastics could be satisfied through recycling by 2030.[469] At the start of 2021 the CSIRO set out a

[466] Bruno Turnheim and Frank W. Geels, “Incumbent Actors, Guided Search Paths, and Landmark Projects in Infra-System Transitions: Re-Thinking Strategic Niche Management with a Case Study of French Tramway Diffusion (1971–2016),” *Research Policy* 48, no. 6 (July 1, 2019): 1415, https://doi.org/10.1016/j.respol.2019.02.002.
[467] Elzen, *System Innovation and the Transition to Sustainability Theory, Evidence and Policy*, 56.
[468] The Nova Institute is a private research institute established to promote the transition of the chemical and material industry to renewable carbon. Nova Institute, “The Future of the Chemical and Plastics Industry,” 19.
[469] Hundertmark et al., “How Plastics Waste Recycling Could Transform the Chemical Industry.”

vision for Australia, also aiming for half the demand for plastics to be satisfied through increased recycling by 2030.[470]

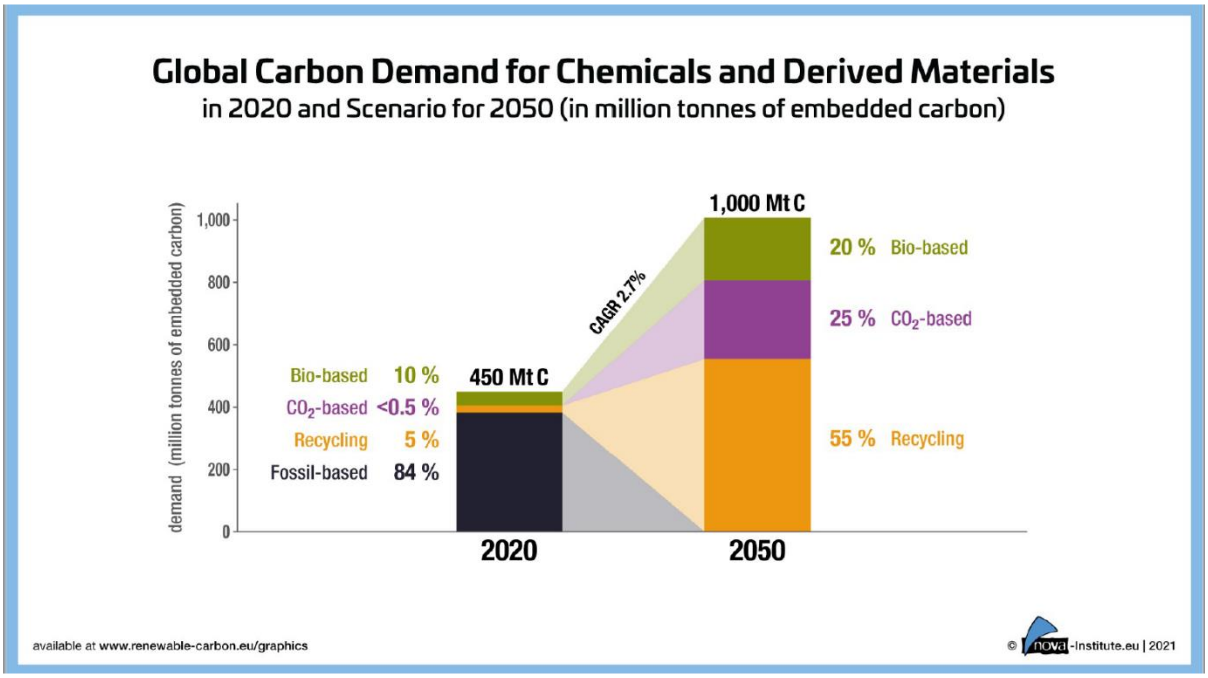

Fig. 3.2. Global carbon demand for chemicals and derived materials to 2050. Source: Nova Institute (2020)[471]

Achieving these ambitious goals is dependent on several assumptions as detailed in the Nova Institute’s report. Notably, achieving the recycling target relies on a very aggressive adoption of chemical recycling (also known as advanced recycling), which includes technologies in the early stages of development.[472] Nova Institute acknowledge that even if can be demonstrated that chemical recycling is environmentally and commercially viable, and succeeds in attracts sufficient investment to deploy the technology at massive scale, there will still remain a requirement for new sources of carbon to maintain the structural

[470] Commonwealth Scientific and Industrial Research Organisation CSIRO, “A Circular Economy Roadmap for Plastics, Tyres, Glass and Paper in Australia” (CSIRO, January 2021), 35, https://www.csiro.au/en/research/natural-environment/circular-economy.
[471] Nova Institute, “The Future of the Chemical and Plastics Industry,” 19.
[472] Chemical Recycling Europe defines chemical recycling as, ‘any reprocessing technology that directly affects either the formulation of the polymeric waste or the polymer itself and converts them into chemical substances and/or products whether for the original or other purposes, excluding energy recovery’.

integrity of recyclates. To meet that need, researchers optimistically assume that the required carbon can be extracted from carbon dioxide (Co2) and this will replace the need for virgin fossil plastic, again using technologies that remain undeveloped, or largely unproven at a commercial scale.[473]

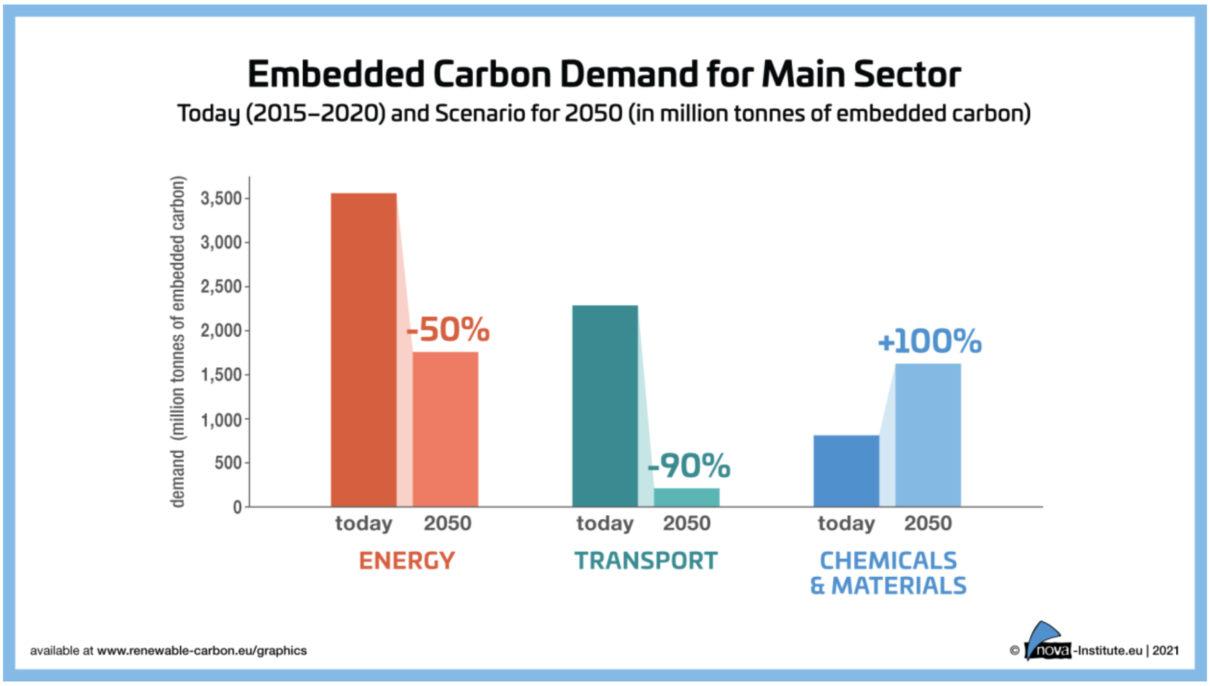

Fig. 3.3. Embedded carbon demand by regime. Source: Nova Institute (2021)[474]

Given the dependence on these assumptions the recycling targets might well appear overly optimistic. By 2050, energy and transport regimes will have significantly reduced their Co2 emissions through investment in renewable power and electric vehicles, decreasing the quantity of carbon embedded in their products. Meanwhile, the petrochemical industry will continue to produce ever increasing volumes of products, including plastics, which are nearly

[473] For a detailed review of Co2 capture and use technologies see: Laura Pires da Mata Costa et al., "Capture and Reuse of Carbon Dioxide (CO2) for a Plastics Circular Economy: A Review," *Processes* 9, no. 5 (May 2021): 759, https://doi.org/10.3390/pr9050759.
[474] Nova Institute https://renewable-carbon.eu/publications/product/embedded-carbon-demand-for-main-sector-today-and-2050-png/

all based on carbon (fig. 3.3). As the total embedded carbon increases the regime will come under increased scrutiny from those concerned with the preservation of our environment.

While an increasing use of renewable energy is implicit in the projections from the Nova Institute, it is made explicit in a study by two academics from the University of California. Jiajia Zheng and Sangwon Suh identified four components central to reducing the environmental impact of fossil-plastics: demand management, energy source, recycling rates and raw materials (fig. 3.4).[475]

Fig. 3.4. Strategies to reduce the environmental impacts caused by plastics.
Source: Adapted from: Zheng & Suh (2019)[476]

Firstly, the authors suggest that demand for plastics could be managed. This observation is significant as the models previously discussed focused exclusively on supply. By highlighting the role demand plays in constructing this scenario the potential agency of other actors in mapping the future trajectory of the plastics industry, including product

[475] Zheng and Suh, "Strategies to Reduce the Global Carbon Footprint of Plastics | Nature Climate Change," 374.
[476] Zheng and Suh, 374.

manufacturers, designers, and consumers is acknowledged. Demand is most easily managed through price. Oil price increases resulting from wars in the Middle East have the potential to stem demand, but wars and price increases are usually short-lived.[477] Carbon taxes or virgin plastic levies are a more permanent solution. Australia is, at least in the short term, unlikely to actively pursue such policies but the international community may take the lead, effectively forcing price increases on fossil fuels and putting downward pressure on the demand for plastics.[478]

Secondly, switching to renewable energy to manufacture plastic would dramatically reduce the GHG impact from the industry (with life cycle GHG emissions from plastics reduced by between 51% and 62%).[479] While the Nova Institute's model assumes an overall shift to renewable power no specific reference is made to the impact of this change on GHG emissions from the production of plastics. The Zheng and Suh model highlights the impact the source of energy used to make plastic has on its overall environmental impact of plastic. Decarbonising the energy system is a long-term solution requiring political will and serious investment (and, ironically, many plastic components). The urgency with which local industry is addressing this issue is best illustrated by a sustainability report from, Qenos, the only producer of polyethylene in Australia. The most recently published report (from 2016) makes

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[477] For a summary of how war in the Middle East has affected oil prices since 1973 see: Mario Arturo Ruiz Estrada et al., "Simulations of US-Iran War and Its Impact on Global Oil Price Behavior," *Borsa Istanbul Review* 20, no. 1 (March 2020): 3, https://doi.org/10.1016/j.bir.2019.11.002.

[478] The EU is planning to introduce a tax on "non-recyclable" plastic (expected to be EUR 0.80 per kilogram) from January 2021. Australian entrepreneur, Andrew Forrest has launched a global initiative to persuade major material manufacturers to sign up for a voluntary levy on fossil-fuel plastics. Although, with thousands (or even tens of thousands) of small plastic manufacturers eager to expand production and with competition between Chinese and American producers fierce, progress will be challenging. Lisa Cox, "Andrew Forrest Launches US$300m War on Plastic to Tackle Ocean Pollution," *The Guardian*, September 25, 2019, sec. Australia news, https://www.theguardian.com/australia-news/2019/sep/25/andrew-forrest-launches-us300m-war-on-plastic-to-tackle-ocean-pollution.

[479] Zheng and Suh, "Strategies to Reduce the Global Carbon Footprint of Plastics | Nature Climate Change," 375.

no reference to renewable energy or any plans to investigate it as a strategy to reduce emissions.[480] International progress is slightly better. DuPont are targeting 60% renewable energy by 2050 and claim that 20% of their electricity supply in 2020 came from renewable sources.[481]

Designers do not have agency over these first two strategies to reduce demand for fossil plastics however they are closely involved with the remaining two; increasing the use of recycled plastics and bioplastics. Increasing recycling rates reduces the demand for virgin fossil fuels. If the proportion of plastics recycled increased steadily to 100% by 2050 (which the authors acknowledge to be unrealistic), life cycle GHG emissions would decrease by 25% but that could reach 77% if renewable energy is used. The authors emphasise the synergy that can be obtained by using renewable energy to power increase recycling activity.[482]

Finally, the use of bioplastics (where renewable organic material replaces fossil fuels as the main ingredient for polymers) can be increased.[483] The authors only consider bioplastics made from corn or sugar in their analysis and briefly discuss the impact on agricultural land use. This leads them to conclude that in terms of GHG life cycle emissions

[480] Qenos (a private company owned by China National Chemical Corporation) was invited to supply more recent information about their sustainability efforts. The company claimed to be preparing an updated publication for release at the end of q1, 2021 (not available as at December 2021). American owned, LyondellBasell, the only other plastics manufacturer in Australia, specialising in polypropylene, publishes only generic statement about measure to minimise environmental impact on its website. No sustainability report or information on energy sources for the Australian operation is publicly available.

[481] Although this includes 'credits', details of which were not supplied. Plans to use Virtual Power Purchase Agreements are mentioned. DuPont, "Thriving Together (Sustainability Report)" (DuPont de Nemours Inc., 2021), 33, https://www.dupont.com/about/sustainability-2021.html.

[482] Zheng and Suh, "Strategies to Reduce the Global Carbon Footprint of Plastics | Nature Climate Change," 375.

[483] 'Bioplastics' is often used to describe very different materials, and the terms 'bio-based', 'biodegradable' and 'compostable' may be misleading. Bio-based plastics are fully or partially made from biological resources, rather than fossil raw materials. They are not necessarily compostable or biodegradable. Biodegradable and compostable plastics biodegrade in certain conditions, and may be made from fossil-fuel based materials. Throughout this thesis the term 'boplastics' is used to describe materials made entirely from renewable organic feedstock.

recycling conventional plastics may be equally beneficial as the switch to bioplastics.[484] This analysis fails to investigate the GHG impact of higher generation feedstocks (such as algae and Co2), which, when used to make bioplastics, are likely to have different environmental profiles.[485] Despite these limitations, the authors conclude that the best GHG emissions scenario from their analysis can be achieved when plastics are all derived from sugarcane using 100% renewable energy. In this unlikely scenario a 93% reduction in GHG emissions could be achieved.

The bioplastic market is embryonic, accounting for only less than 1% of all the plastic produced in 2020. But it is growing fast with a projected CAGR of over 16% through to 2027.[486] This forecast might well be superseded by more aggressive growth. At the end of 2020, *Greenpeace International* reported that 36 Chinese producers had planned or built new biodegradable plastic manufacturing facilities during the year. These new investments added production capacity of more than 4.4 million tonnes per year, representing a sevenfold increase in Chinese production of bioplastics in less than 12 months.[487] Despite those gains, and given the expected increase in demand for plastics in the coming decades, the role bioplastics can play in transitioning toward renewable carbon sources for plastics is likely to remain limited in the period to 2050.

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484 Zheng and Suh, “Strategies to Reduce the Global Carbon Footprint of Plastics | Nature Climate Change,” 375.

485 An extensive review of relevant LCA studies (from 2020) found that higher generation feedstocks solve the problems of land use and food competition associated with first- and second-generation feedstocks. This reduces emissions during cultivation; however, higher input intensity (especially of energy) is required in the refinery stages, but this may be a reflection of the embryonic nature of these materials. Claudia Wellenreuther and André Wolf, “Innovative Feedstocks in Biodegradable Bio-Based Plastics: A Literature Review” (Hamburg: Hamburg Institute of International Economics, 2020).

486 The global bioplastics market size was valued at USD 8.3 billion in 2019 and is expected to achieve a compound annual growth rate (CAGR) of 16.1% from 2020 to 2027 according to a report by Grand View Research, “Bioplastics Market Size, Share, Growth Report, 2020-2027,” June 2020, https://www.grandviewresearch.com/industry-analysis/bioplastics-industry.

487 Greenpeace International, “Biodegradables Will Not Solve China’s Plastics Crisis,” December 2020, 11, https://www.greenpeace.org/international/press-release/46066/biodegradables-will-not-solve-chinas-plastics-crisis.

After comparing the potential GHG savings that could be achieve by adopting a mix of the four strategies detailed above the authors concluded that the only way to achieve an absolute reduction in GHG emissions is through demand management (reducing industry growth to 2% per annum) in addition to a combination of the other three strategies.[488] Zheng and Shu highlight the enormous magnitude of the changes required to be adopted by the petrochemical industry to limit growth in GHG emissions in the face of burgeoning demand.

Another scenario with a focus on the demand side has been developed by the Ellen McArthur Foundation. By the end of 2020, the Foundation had secured commitments from more than 500 major FMCG organisations (responsible for 20% of all the plastic packaging used) to eliminate the use of plastics where possible or move to reusable, recyclable, or compostable packaging by 2025.[489] Addressing the aims of UN goal 12.5, the Ellen McArthur Foundation has been successful in publicising the concept of a circular economy where 'business models, products, and materials are designed to increase use and reuse, replicating the balance of the natural world, where nothing becomes waste and everything has value.'[490] The Foundation's work is focused on the important challenge of reducing the use of virgin fossil plastics in packaging. While packaging is the sector that accounts for the largest proportion of virgin fossil plastics consumed the remaining 64%, which find uses other than packaging, are ignored by these efforts (fig. 3.5).

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[488] Zheng and Suh, "Strategies to Reduce the Global Carbon Footprint of Plastics | Nature Climate Change," 377.
[489] Ellen McArthur Foundation, "Global Commitment 2020 Progress Report" (Cowes, 2020), 7, https://www.ellenmacarthurfoundation.org/resources/apply/global-commitment-progress-report.
[490] See: Ellen McArthur Foundation, "Ellen McArthur Foundation Mission," accessed February 3, 2022, https://ellenmacarthurfoundation.org/about-us/what-we-do.

None of the visions included in Ellen McArthur Foundation review offer a solution to the problems caused by our ever-increasing consumption of plastics, but the review does provide a framework to guide decision making by those concerned with reducing the environmental impacts caused by plastics. These narratives serve to challenge the entrenched regime and emphasise opportunities arising from alternatives. The visions expressed by this foundation, and other similar organisations, are helping to drive interest in recycled plastics and bioplastics by highlighting the need to reduce demand for virgin fossil-based polymers as an important step toward developing a more sustainable relationship with plastics.

Significantly, visions expressed by organisations dedicated to tackling environmental issues highlight the potential agency of actors outside the petrochemical industry to impact demand and drive change within the plastics sector. For individual actors the scale of changes required to create a more sustainable relationship with plastics can be daunting. However, to disrupt the growth plans of the fossil plastics industry it may not be necessary to reduce demand or even completely eliminate growth. The Carbon Tracker Initiative (a London based not for profit think tank) suggest that just by making changes at the margin, reducing the CAGR for virgin fossil plastics from 4% to 1%, will be sufficient to cause significant disruption to the market, and to strip the fossil fuel industry of much of its forecast profit growth.[491] That report highlights the important role consumers, designers, and product manufacturers can play in demand management without relying on government intervention. Reducing packaging, improving product life expectancy, or giving preference to refillable containers are given as example of the agency held by these three actors

[491] Carbon Tracker Initiative, "The Future's Not in Plastics: Why Plastics Demand Won't Rescue the Oil Sector," Carbon Tracker Initiative, 2020, 18, https://carbontracker.org/reports/the-futures-not-in-plastics/.

respectively.[492] Avoiding the use of virgin fossil plastics altogether, by replacing them with renewable carbon materials, will potentially exert an even bigger impact on the industry's growth plans.

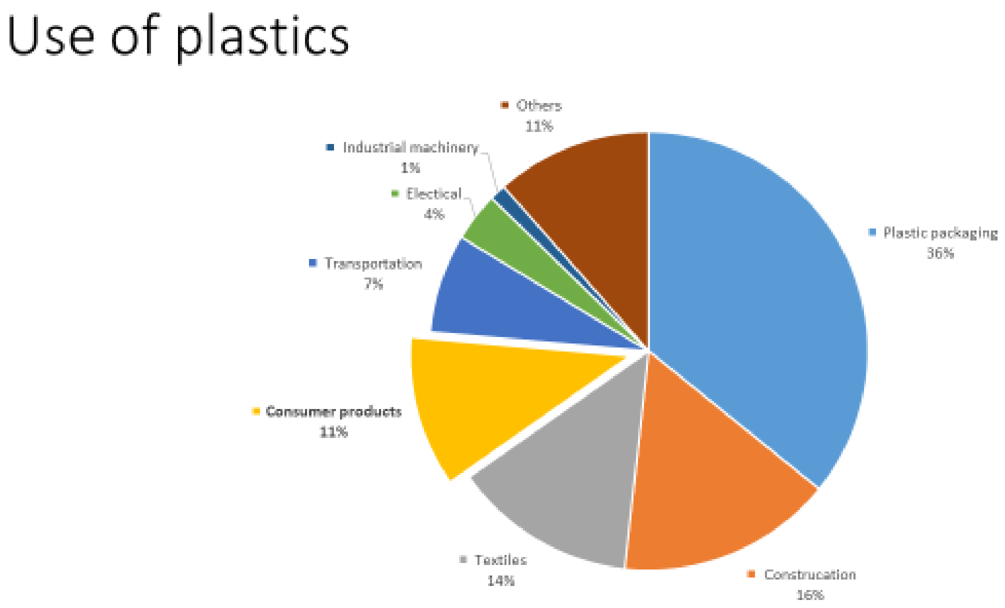

Fig. 3.5. Breakdown showing where plastic used during 2015. 11% of plastics were used to make consumer products. Source: Production, use and fate of all the plastics ever made. Geyer et al. (2017)[493]

As consumer products account for just 11% of all plastics used (fig. 3.5) it may be better to focus on reducing the use of virgin fossil-based plastic elsewhere, particularly by developing more sustainable solutions for packaging. Many efforts are already underway to focus on that problem, including those led by the Ellen McArthur Foundation.[494] As the amount of virgin plastic used for packaging decreases, the continued use of traditional

[492] Carbon Tracker Initiative, 23.
[493] Geyer, Jambeck, and Law, "Production, Use, and Fate of All Plastics Ever Made - Supplementary Material," 10.
[494] For example, the recent European Union directive on the reduction of the impact of certain plastic products on the environment and (as discussed above) the Ellen McArthur Foundation which has (as at November 2020) secured commitments from over 500 major organisations to eliminate single-use packaging made from virgin plastics by 2025.

plastics in consumer durables is likely to attract more criticism as evidence mounts about the environmental and health impacts of plastics. It is almost certain that product designers, together with clients and manufacturers, will face increased scrutiny as they participate in the production of an endless array of consumer goods, many of which are designed to be quickly disposed of simply to make way for the next improved model.

Incorporating renewable plastics into consumer products positively influences the speed with which these markets develop. Designers can capitalise on the shifts in consumer sentiment away from fossil plastics and design consumer products using renewable carbon-based materials. Incorporating those materials in consumer products develops an important niche market that will support the expansion of production of these more environmentally friendly polymers. Branching the use of renewable plastics into new market segments will increases demand and help develop much needed economies of scale for material manufacturers.[495] Expanding the renewable plastic market to include consumer products is also likely to disproportionality increase its value, as higher quality (more expensive) materials will be needed for consumer products designed to last in contrast to the short-term requirements of single-use packaging. Potential for higher profit margins is significant for bioplastics where, currently, existing markets are all relatively low value (packaging, agricultural film and mulch, disposable plastics bags, and disposable plastic tableware).[496] Increasing both the size and value of the market will attract more investment to bioplastics, hastening the development of the market. But do designers or other actors involved with the production of products such as plastic chairs can have the necessary agency to preference the selection of renewable plastics?

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[495] Geels, *Technological Transitions and System Innovations*, 59–60.
[496] Grand View Research, "Bioplastics Market Size, Share, Growth Report, 2020-2027."

2. Agency of the designer

In 1971, Victor Papanek accused designers as being responsible for planned obsolescence and choosing materials and processes that result in pollution. He concluded his argument with the often-cited quote, 'there are professions more harmful than industrial design, but only a few of them.'[497] Papanek's views were not well received when first published, as design historian, Deborah Andrews observed: 'he was derided and verbally attacked by his peers who also forced him to resign from their professional body.'[498] Papanek, however, succeeded in igniting a long-running debate about the ethical responsibilities of designers. Can environmentally conscious product designers be expected to have any agency in how their designs are manufactured and especially in the choice of materials? In more recent times, some theorists are calling for extreme action by product designers—who they say have the moral responsibility to take the leading role in guiding society toward a more sustainable existence.[499] Tony Fry encourages designers to end their complicity with the creation of defuturing conditions and 'place the needs of the market in second place to the political-ethical project of gaining sustain-ability.'[500] Fry challenges designers to ask themselves what they 'can see taking the future away, and what can [they] do to reduce the impacts of [their] own actions which defuture?'[501]

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[497] Papanek, *Design for the Real World*, 1971, IX.
[498] Deborah Andrews, "The Circular Economy, Design Thinking and Education for Sustainability," *Local Economy* 30, no. 3 (May 1, 2015): 311, https://doi.org/10.1177/0269094215578226.
[499] Fry, *Design Futuring*; Tonkinwise, Kossoff, and Irwin, "Transition Design Provocation"; Irwin and Kossoff, "2017 Transition Design Seminar Syllabus."
[500] Fry, *Design Futuring*, 46 Sustain-ability (in contrast to sustainability) acknowledges the need for change, based on the growth of the 'development of ecological sustainment'. Such 'development' implies the adoption of fundamental directional change, the creation of new economies and a rejection of a 'steady state' model as the other of existing forms of growth.
[501] Fry, *Defuturing*, 143.

Dutch designer and academic Jan Joore highlights the significance of the size and complexity of a project. Where a single problem owner or client commissions a project they ultimately decide the course of action to be taken. As the scope of systems get larger, the precise agency of any actor, including designers, becomes less clear.[502] A designer working as part of a large team on components for a consumer durable has less agency than when specifically commissioned to design a standalone item. Dutch designer Bertjan Pot agreed, commenting during an interview with me that 'if you want to change something in a car, imagine how many meetings there will be to make a small change?'[503] The complexity increases further for those designing transportation systems.[504] Indeed, in the course of my research, I have found that when a designer acted as a maker, they often retained control over design decisions. This observation held true when designers had direct responsibility for production through their own studios (e.g., Tom Fereday, Louis Durot) and when they contracted out manufacturing to their own specifications (e.g., DesignByThem, Bertjan Pot).

My interviews with designers for this study revealed a wide range of attitudes towards their influence of sustainability considerations on their overall design process. A small number of designers freely admitted that sustainability is not their primary consideration when creating new products. Those designers tended to be older and included French industrial designer Louis Durot (1939-) and Ron Arad (1951-) who reported:

> When you work you have to look at the effect of the process on the environment. It is not my first consideration; I am not expecting brownie points...[505]

[502] Joore, "New to Improve – The Mutual Influence between New Products and Societal Change Processes," 197.
[503] Geoff Isaac, Interview with Bertjan Pot, July 4, 2020.
[504] Joore, "New to Improve – The Mutual Influence between New Products and Societal Change Processes," 197.
[505] Isaac, Interview with Ron Arad.

At the other end of the scale, some designers expressed extreme concern over the sustainability impacts of their work, to the extent that several reported considering giving up the profession—Ander Lizaso (Spanish industrial designer) among them:

> Actually, in our studio, we are very critical about the role of the designer and design in general. If you're really deep and honest about it, the best thing we could do is to just stop... I mean the amount of pollution that we create... But if we are really going to not harm, we shouldn't be a [cog] in this assembly of consumption and production.[506]

Dan Armstrong, from Australian design agency Formswell, also discussed how sustainability issues had made him question his agency's work:

> How much do you go back and indulge your beautiful plastic chair and keep making those things? When do you start becoming guilty about everything that you're doing? It is a weird line there... Do I keep going? Do I adjust what I'm doing?[507]

In response to those concerns and an awareness of the environmental impacts caused by their work, designers reported employing various strategies in efforts to lessen those effects. Focusing on developing lasting, quality products, likely to last a long time thereby prolonging any end-of-life impacts was frequently nominated as a valuable contribution toward sustainability. Edward Barber and Jay Osgerby (UK-based industrial designers) among those who expressed this, claiming to only work with manufacturers that make high-quality products, designed to last. [508] John Tree, senior designer at Japer Morrison's office echoed similar views, reporting:

> Every designer is very aware of the impact of making more stuff has on the world really. There's a focus in our office on working with brands that believe in longevity and sustainability and things that are designed to function rather than fashion or something like that. I think that Jasper's products are a testament to that in a way, a lot of the things that he designed maybe 20 or 30 years ago are still in production now, still selling very well and it's a

[506] Geoff Isaac, Interview with Ander Lizaso, October 26, 2019.
[507] Geoff Isaac, Interview with Dan Armstrong and Rene Linssen, January 29, 2020.
[508] "The perception of it is why do we need all this stuff? As a studio we definitely try to use things that are going to last as long as possible. We work with the best manufactures who make high quality products that, in theory will last two or three lifetimes? That in itself is an environmental stand point." Isaac, Interview with Barber & Osgerby.

> very deliberate part of this office's work is to try to find, to treat the object as the client and not the time it is designed in.[509]

Those claims are borne out by a recent survey of furniture manufacturers undertaken by London-based design practice, Dodds and Shute.[510] Only wanting to specify furniture manufactured by organisations with a commitment to sustainability and frustrated by a lack of publicly-available information to prove claims, Dodds and Shute surveyed their suppliers to identify the sustainable practices undertaken by those who chose to participate in the research. In addition to identifying the manufacturers with the most demonstrable commitments to sustainability, Dodds and Schute went on to identify the designers who had completed the most projects with these organisations. Barber and Osgerby, together with Jasper Morrison, ranked among the top six designers (out of 500) based on having completed the largest number of projects with manufacturers who demonstrated the most commitment to sustainability.[511]

Although not included in the Dodds and Shute survey, Gregg Buchbinder (owner and CEO of American manufacturer Emeco) also focuses his attention on ensuring product longevity, arguing the best way to improve the impact of a product is to reduce the energy needed to manufacture and design the product to last as long as possible. He claimed: 'our main environmental focus is to create chairs that last—we focus on lengthening the life first.'[512]

Lizaso reported that his design studio attempts to make a difference by only working with organisations with a committed to sustainability principles. However, he highlighted

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[509] Isaac, Interview with John Tree from Jasper Morrison Office.
[510] Dods & Shute, "Dodds and Shute Sustainability Report" (London: Dodds and Shute, October 2020).
[511] Dods & Shute, 20.
[512] Geoff Isaac, Interview with Gregg Buchbinder, August 11, 2019.

that it is easier for designers with a significant public profile to make sustainability commitments but much harder for those without an established name. Lisazo also reported struggling with the conflict of designing more furniture while being increasingly concerned with sustainability and over consumption.[513]

Designers are not the only actors influencing the sustainability of a design. Buchbinder outlined the important role of manufacturers in driving sustainability:

> With regards to the role of product designers, their role—just like ours as a manufacturer—is evolving to reflect the now urgent need to address our environmental impact. Every product development process must take into consideration the complete product lifecycle, and give careful consideration to both material and process. This is the joint responsibility of product designers and manufacturers. But we believe that it remains the responsibility of any manufacturer to explore new, sustainable solutions for their production. Our experience is that product designers welcome the opportunity to experiment with new, sustainable materials. Unfortunately, not all manufacturers offer that possibility.[514]

These comments highlight the challenge faced by designers with a commitment to sustainability, they must secure the support from manufacturers who hold similar opinions and have access to the resources and expertise needed to develop their designs.

Designers of products, particularly those made from plastic, can follow some basic principles to improve the sustainability of their work. They are uniquely placed to immediately impact the consumption of fossil-based plastics by encouraging and facilitating the recycle of their products by incorporating design for disassembly principles. In addition to simplifying disassembly, designers can further promote recycling by ensuring all plastic components are made from polymers that can be easily recycled in the markets where the products are most likely to be consumed. Plastic components should be permanently labelled to allow materials to be easily identified, facilitating economically viable sorting and recycling. By observing those principles, it is possible for all designers to contribute toward

[513] Isaac, Interview with Ander Lizaso.
[514] Isaac, Interview with Gregg Buchbinder.

the more sustainable vision for the future development of the plastics market. Several of the designers interviewed for this dissertation highlighted disassembly as an important consideration in their work. For example, Armstrong highlighted that many of his clients are concerned about this aspect of sustainability:

> We definitely design thinking we want to be able to pull out the parts and recycle it. I think that's something clients care about. When we design something for them, they want to know that each part can be pulled apart, people are aware of that.[515]

Operating in a global market adds complexity to the challenge as Armstrong highlighted, some compounds might be suitable for recycling in some markets while other jurisdictions lack the infrastructure to process the same material.[516] Designers might not have complete visibility of where their projects are destined to be sold. Even when the destination is known, the designer might be unable to access detailed information on the waste and recycling infrastructure available in those markets.

While recycling rates remain low (largely due to a lack of infrastructure in most Western markets), disassembly should remain an important consideration for designers, but is unlikely to significantly impact demand for virgin polymers in the short term. Increasing the supply of plastics available to be recycled will not automatically increase the supply of recycled plastics. China, quickly followed by other Asian countries, has banned the import of mixed plastic waste.[517] High-income countries (including Australia) had become accustomed to exporting their plastic waste problem and lack the infrastructure needed to recycle plastics on shore. It will take years for those countries to develop strategy, arrange finance, negotiate

[515] Isaac, Interview with Dan Armstrong and Rene Linssen.
[516] Isaac.
[517] From January 2018, China began to restrict the importation of mixed waste plastics under its National Sword policy. For more on the immediate impact of this policy see: https://e360.yale.edu/features/piling-up-how-chinas-ban-on-importing-waste-has-stalled-global-recycling Nielsen et al., "Politics and the Plastic Crisis," 10.

feedstock arrangements, obtain planning permission, and develop the infrastructure required to significantly impact the proportion of plastics recycled.[518] The CSIRO estimate Australia needs to increase recycling capacity by 150% to compensate for the lost export markets.[519]

Designers regularly make decisions which have environmental impacts. Dematerialisation, designed to reduce the amount of material and energy required to manufacture a product, are aligned with the capitalist goal of maximising profits, while delivering environmental benefits. Design decisions also impact how a product is transported. Chairs that can be stacked enable more efficient transportation and storage, lowering costs while delivering environmental benefits through reduced fuel consumption.

a. Material choice

With many actors involved in the development of a product (including clients, manufacturers, sales and marketing teams, ergonomics experts, brand consultants and engineers), identifying the decision-making process for materials and defining the precise role of each actor is a complex process. Reporting on an experiment in the Netherlands with 20 Turkish professional designers, Elvin Karana et al. suggest that designers should move from material selection to material inspiration. Rather than follow a traditional linear approach, for example, deciding to manufacture an object from plastic and then a class of plastic and then a particular brand, the designer should consider materials during the initial

[518] In March 2020, more than 2 years after the China Sword policy came into effect, the Council of Australian Governments produced a white paper on how to respond to the need to develop a local recycling industry. When the promised $190 million funding for new waste infrastructure is made available, interested parties will need to participate in a competitive grants process. Successful applicants will then need to apply for planning permission (likely to be opposed by resident action groups), arrange long term supply commitments for feedstocks from local councils and build and commission the new recycling infrastructure, a process that is likely to take several years. In February 2021, (three years after China Sword) the NSW government announced its first grants, of up to $5 million ($35 million in total), to support the waste industry in its response to Australia's waste export bans.

[519] Even when sufficient capacity has been developed to compensate for the amount of waste previously exported that will be equivalent to just 12% of plastic consumed. The CSIROS vision that Australia can satisfy 50% of its demand for plastics through recycling by 2030 appears ambitious given these facts. CSIRO, "A Circular Economy Roadmap for Plastics, Tyres, Glass and Paper in Australia," 14.

stages of design and be inspired by their properties.[520] This approach suggests that designers have ultimate control over the selection process. The designers included in this study overwhelmingly reported that the decision on the specific type of plastic to be used is unlikely to rest with the designer alone for most projects. The increased complexity of manufacturing techniques has been accompanied by the development of specialists. Manufacturing organisations employ or consult with engineers and other specialists who make recommendations for materials based on the technical requirements of the project.

Reflecting the above finding on design decision making, research participants who took responsibility for production through their own studios (e.g., Tom Fereday, Louis Durot) or by contracted out manufacturing to their own specifications (e.g., DesignByThem, Bertjan Pot) were more likely to have greater agency in the material selection process. Where designers provided their services to clients, creating designs for large scale mass production, the influences of other actors became more prominent (especially as the client typically acted in the role of manufacturer as well). Ron Arad illustrated this point by highlighting the difference between limited-edition studio pieces where he maintains total control over the selection of materials, and high-volume production pieces for manufacturers, where the commissioning client has a, 'lot of say in it'.[521] Pot agreed, reporting that the manufacturers of his commissioned production pieces have the most agency in material selection.[522]

Gabriel Chiave, studio manager for Marcel Wanders, suggested that designers do take the leading role in creating and problem solving, but claimed they are the least

[520] Karana, Hekkert, and Kandachar, "Material Considerations in Product Design," 1088.
[521] Isaac, Interview with Ron Arad.
[522] Isaac, Interview with Bertjan Pot.

impactful in the final decision on materials and method of manufacturing.[523] Designer and academic Trent Jansen highlighted that decisions around material choice can also be influenced less overtly:

> There's a commercial project that's being manufactured just recently, [they] have been coming back to me with some suggestions about changes on material … It's always my choice, you know, they always say, 'Look it's up to you, we don't have to do this.' They're not at all forceful about it, but they do kind of set up a relationship whereby this will mean it will be less expensive than therefore, we will sell more.[524]

In that example, the material choices are potentially nudged by emphasising the economic impact of the selection process.

Ruben Hutschemaekers, Head of Marketing and Communication at Magis observed that the designer's agency over material choice is also constrained by the material and technology available to them:

> The designer has maybe the leading role in it… but the designer is also limited to what the industry is offering. I mean, he's not inventing the material he's not inventing the technology to produce it, maybe he's leading the orchestra but all the different instruments need to be played by [themselves].[525]

This consideration is particularly applicable to renewable plastics, where the complexity of the material is reflected in the wide variety of polymers available, and this requires expert advice. As we have seen, the industry is likely to face shortage of recycled materials as demand increased. Bioplastic production is in its infancy and access to supplies varies greatly by geographic region, again impacting choice. Material choices are also restricted by the manufacturer's access to or willingness to invest in production equipment.

Many of the designers I have interviewed are very familiar with the benefits of working with plastics and keen to communicate the combination of attributes that often make them the only suitable candidate for a design project. Lizaso commented:

[523] Geoff Isaac, Interview with Gabriel Chiave, June 4, 2020.
[524] Geoff Isaac, Interview with Trent Jansen, September 4, 2020.
[525] Geoff Isaac, Interview with Ruben Hutschemaekers, Magis, February 12, 2020.

> We had a meeting last week with another client and they have a mono shell thing, [they want to] produce. But they don't want it to be in plastic... they want for it to be strong; they want for it to be economically viable to sell. Those inputs don't make a result yet, I think.[526]

Plastics are often the only material which can fulfil all the requirements of a design brief at an accessible price point. Barber and Osgerby highlighted the economic advantage of the material:

> We try to use less and less plastics... The problem is wooden chairs are really expensive and are for a high-end market.... We want to design simple everyday chairs but no one wants to spend a ton of money on a simple every day chair.'[527]

Barber & Osgerby's comment highlight the need to meet a price point while both quotes illustrate the fact that plastic is often not only the most appropriate solution to a design problem but is the only material capable of delivering a project with the constraints of the brief.

b. Specifying renewable plastics

Barber and Osgerby explained the materials section process for their *On & On Stacking Chair* (2019); made from a plastic comprised of 70% recycled PET from waste plastic bottles and strengthened using wood. The designers confirmed the manufacturer, Emeco, commissioned them specifically to create a design using that material. In this case the designers benefited as they were absolved from all responsibility to investigate the mechanical properties of the material:

> We work with manufacturers that have a lot expertise and have good partners for materials. Emeco didn't develop the material themselves they worked with a plastic company [BASF] and ultimately, we have to rely on them. [Emeco] tell us what the performance of the plastic is, how it is and we run simulations on the computer and they invest in the moulding and it if does not work it is their responsibility. We delegate the responsibility to Emeco–they are so professional; they research and research. We are very fortunate that we are freed from that side of it as they cover it off.'[528]

[526] Isaac, Interview with Ander Lizaso.
[527] Isaac, Interview with Barber & Osgerby.
[528] Isaac.

Their claim was supported in an interview with Buchbinder, who also saw it as his responsibility as the manufacturer to explore new, sustainable solutions for production.[529] Importantly, in this case, the furniture manufacturer always intended to use a recycled material for the project. While the precise material specifications were defined in consultation with an expert material manufacturer, the designer was not directly involved.

There are other examples where manufacturers have commissioned leading industrial designers to showcase new developments in plastic technologies, taking the lead in material specification. BASF held a competition to design a chair to demonstrate the benefits of Ultradore High Speed plastic (polybutylene terephthalate – PBT)—resulting in Konstantin Grcic's *Myto* cantilevered chair (2008).[530] Grcic worked with Magis to develop the *Bell Chair* commissioned to utilise recycled plastic, in this case primarily sourced from the manufacturers own waste stream. Kartell and *Autodesk* commissioned Philippe Starck to develop a chair using Artificial Intelligence (AI), minimising the amount of recycled polymer needed to fulfil the function. Hence, both the material and design technique were new to both designer and manufacturer. Starck had previously worked closely with Kartell to successfully introduce polycarbonate to the seating market at the end of the 20th Century, again in direct response to the manufacturer's material specifications.

In contrast, USA-based designer Karim Rashid provided an example of how product designers can influence the choice of renewable plastics when developing a chair. Explaining that he approached the company A Lot of Brasil to develop the *Siamese Chair* (2014) using a plastic injection of the Amazonian fruit Acai and (renewable) bark from the Ipe Roxo tree. It was probably the first commercially-available bioplastic chair. In an interview for this

529 Gregg Buchbinder, Gregg Buchbinder, Email, August 11, 2019.
530 Alice Rawsthorn, "Konstantin Grcic's New Chair Design, the *MYTO*."

dissertation, Rashid stated that he wanted to work with this specific bioplastic and waited for a manufacturer to identify a suitable supply before proceeding with the project.[531] Although Rashid noted that in many cases the manufacturer will be more knowledgeable about the material choice than the designer, and usually takes the leading role in material selection. Only 'in 10% of cases,' Rashid proposed, can the designer have the final say.[532]

Rashid also provided an illustration to demonstrate a creative way that a designer can influence the demand for plastics more generally. He reported that in introducing a company to the 'addition by subtraction strategy,' that company had reviewed their entire range and rationalised their (mainly plastic) product offerings from 600 SKUs (stock-keeping units) down to just 120. By rationalising their product range, the company simplified its business, reduced stocks (of raw materials and finished goods), and improved profitability. Even a high-profile designer like Rashid, however, admitted that it is challenging for a client to empower a designer to act in the role of a business strategist.

Research participants displayed different attitudes to pioneering the use of renewable plastics. Pot reported that he did not want to be the one pioneering the use of the latest materials or techniques just for the sake of being first.[533] Others saw the need for someone to be first and experiment with these materials despite the risks as Lizaso explained:

> There was a big possibility, a high risk for the whole exercise not to be something exemplary. But we felt that this kind of jump was needed so that in some iterations someone can arrive to something that is really cohesive and kind of exemplary.[534]

[531] Geoff Isaac, Interview with Karim Rashid, October 25, 2019.
[532] Isaac.
[533] Isaac, Interview with Bertjan Pot.
[534] Isaac, Interview with Ander Lizaso.

Along with the risks inherent in experimenting with a new material come significant costs. Mayda Diaz, Business Development Manager at Bambacore (Australian supplier of bioplastics) reported that in her experience, designers are excited to see and learn about the materials available. Translating that excitement to sales is challenging, as the costs inherent in developing new manufacturing processes are often considered prohibitive.

3. Conclusion

This preliminary analysis of my research highlights that designers do not always have agency in the material selection process. Designers are important actors in the specification of material for at least some projects, but other factors and other actors frequently limit experimentation with renewable plastics. However, the debate around agency could shortly be redundant as attitudes to plastics change. Designers are beginning to be called to account for their role in the plastics waste crisis by those working on the front line. Parley for the Oceans is an organisation dedicated to raising awareness of the beauty and fragility of oceans.[535] Founder, Cyrill Gutsch pointed the finger of blame squarely at the industry reporting:

> I really see it as the obligation of the creative industry, to really reinvent all toxic materials within the next 10 years. We have to put a strong focus on that and say, we don't want to create and we don't want to produce products anymore that contribute to the destruction of our planet.[536]

Gutsch's comments put the spotlight on the designer. With the equivalent of a garbage truck load of plastic being dumped in the ocean every minute, public frustration can be expected

[535] See: Parley for the Oceans, "Parley for the Oceans," PARLEY, accessed February 3, 2022, https://www.parley.tv.

[536] Kieron Marchese, "'Recycling Is Only a Bandaid,' Says Parley for the Oceans Founder Cyrill Gutsch," designboom | architecture & design magazine, January 3, 2020, https://www.designboom.com/design/ocean-plastic-cyrill-gutsch-interview-parley-for-the-oceans-03-01-2020/.

to eventually turn to revolution.[537] All actors across all industries using virgin fossil plastics will undoubtedly face growing criticism from Gutsch and many others. I return to the topic in the final two chapters of this dissertation to provide a vision for how designers can have agency in this process.

Since the beginning of the 21st Century there has been growing interest from both designers and manufacturers in experimenting with renewable plastics. Pioneering designers such as Jane Atfield experimented with making chairs from recycled plastics (in this case HDPE) as far back as 1992, when a small batch of *RCP2 Chairs* were produced (fig. 3.6). It is only in the 21st century that designs using renewable plastics have begun to regularly feature in mainstream large-scale production. They include designs made from recycled plastics (pre-consumer, post-consumer, and ocean plastics), and bioplastics derived from organic material.

[537] Ellen McArthur Foundation, "New Plastics Economy - The Future Of Plastics," 12.

Fig. 3.6. *RCP2 Chair* - Batch Production, Jane Atfield, 1992, Crafts Council Collection: W115. Source: Todd-White Art Photography. Source: Courtesy of the Crafts Council

I have identified 32 recent chair designs manufactured using recycled plastics or bioplastics. Some of those chairs have been manufactured using relatively new technologies that promise to reduce the material and/or energy required to manufacture products, promising potential to significantly reduce environmental impacts next to comparable designs. Each of those designs might be considered a niche experiment with renewable plastics. Many of them have been developed by combining plastics with other more traditional materials such as wood or metal. With so many different mixes of materials and manufacturing technologies used to make those chairs, it is difficult to measure and compare the environmental profile of each design. Without an accurate assessment it is impossible to know if these niche experiments have succeeded in delivering sustainable solutions. By examining the impacts of each design, a contribution is made to direct designers and manufacturers interested in working with renewable plastics in efforts to improve the environmental impact of their work. Identifying which of those niche experiments has been most successful can help direct future experimentation and drive the wider adoption of renewable plastics. But first a method is needed to compare those 32 chairs and this is the topic of the next chapter.

Part B

Environmentally Responsible Product Rating—an eco-audit tool

Chapter 4

Developing an eco-audit tool (ERPR)

This chapter explains the development of an eco-audit tool to compare the environmental footprint of products made from renewable carbon-based plastics (renewable plastics). I start by reviewing manufacturers' websites to assess their level of engagement with sustainability issues and to establish how much information is available to support an analysis of the environmental profiles of designs included in this study. Armed with this knowledge I investigate the potential of applying existing eco-audit tools to develop a comparative assessment of designs. The most sophisticated method to compare products is by conducting life cycle assessments (LCAs). However, accurate LCAs can only be calculated when detailed information about a product is available. For example, precise quantities and specifications of the materials (and their sources) are required. It also requires details of the manufacturing processes used to make the product and information about the methods and distances of transport for its distribution. My analysis of company websites revealed that this level of detail has not been provided for any of the 32 chairs included in this study. I then evaluate alternative eco-audit tools, also developed to compare the environmental profiles of products but with less onerous data input requirements. Unfortunately, these existing eco-audit tools also proved unsuitable for the task as, again, manufacturers do not provide the required information.

Having exhausted available options, I developed a new solution: the Environmentally Friendly Product Rating (ERPR) tool.[538] This new eco-audit tool is designed to compare products based on the limited information commonly made available by manufacturers. By tailoring the tool to a specific product category—plastic chairs—much of the complexity that

[538] A digital version of the tool is available at: Geoff Isaac, "ERPR Tool," accessed February 3, 2022, http://geoffisaac.com.au/erpr/.

makes generic tools difficult to use is avoided. My immediate need was to compare the environmental profiles of the 32 chairs I have selected, but the tool has been designed to easily adapt to other products made from renewable plastics. The online ERPR tool can be used to guide designers toward more sustainable decisions while they conceptualise and develop products. More accurate tools, such as LCAs, require detailed data inputs. Apart from the time and expense involved much of the required can only be accurately determined after a product has entered production. The ERPR tool addresses this limitation by simplifying the environmental assessment of a product and making pro-active recommendations to users on how to reduce environmental impacts.

1. Sustainability in the furniture industry

The precise definition of sustainability remains contested. Designer and academic Jane Penty interprets sustainability as:

> Design that enhances the wider human experience by meeting 'needs' more intelligently and creatively within the Earth's capacity supported by an enabling economic framework… Sustainable products are those that create net positive value socially, economically and environmentally.[539]

This definition highlights the social dimension of sustainability and this is being adopted by some organisations that have begun to involve a wider range of stakeholders into their decision making: 'recognising that the continuing survival of their businesses depends upon ethical practices across their supply chains.'[540]

To understand how broadly the furniture industry interprets sustainability I conducted an audit of company websites. While I argue that designers hold a key role to

[539] Penty, *Product Design and Sustainability*, 232.
[540] A. Avendano, "The Role of Design Practice in Packaging Sustainability in Australia" (PhD., RMIT, 2013), 11, http://researchbank.rmit.edu.au/view/rmit:160353.

play in guiding more sustainable design, implementation of their work requires the consent, financial support, and active participation from manufacturers (among other actors). To assess what sustainability policies and initiatives are being undertaken by furniture manufacturers and how they measure and report their progress, I conducted an analysis of the website content of 45 organisations included in my research database, all of whom are currently involved with the manufacture of plastic chairs.[541]

I examined relevant claims, targets, or goals as published on company websites, and categorised them across the three dimensions of sustainability: economic, environmental, and social. This analysis illustrates that industry's current interpretation of 'sustainability' is premised on the economic and environmental with an emphasis on resource efficiency. Those industry priorities are reflected in this study.

Six out of ten furniture manufacturers surveyed identified at least one sustainability initiative on their websites, while only four published a standalone sustainability report.[542] Two fifths of companies (40%) failed to make any claims regarding sustainability initiatives or policies. Where the issue of sustainability was addressed, most manufacturers published generic statements about their commitments, without specifying actions or committing to targets for their organisation. Far from the detailed product level information I expected to find, only one manufacturer published the results of a single LCA study on their website (and not for a design under consideration in the present study).

Only 19 manufacturers (41%) either stated they are committed to eco-efficiency principles or reported they are pursuing a strategy to reduce consumption of energy or

[541] A total of 85 manufacturers are included in my database, all of whom have been involved with the production of at least one plastic chair. Apart from manufacturers that are no longer in business small studio producers (for example, Louis Durot and Tom Price) were also excluded from this analysis.
[542] IKEA, Hay, Herman Miller and Vitra published recent sustainability reports.

water resources. Seven manufacturers claimed to focus on reducing their packaging (or incorporate higher quantities of recyclable/renewable packaging material). Surprisingly, only one manufacturer reported the details of their strategy to reduce the impact of product transportation. All businesses are motivated to improve the efficiency of their production processes, as any savings made are immediately reflected in profits delivered to shareholders. With business efficiency closely aligned with the capitalist goal of maximising profit, manufacturers ought to focus on resource efficiency for that reason alone. It is surprising, then, that more than half of the companies (57%) included in this analysis do not declare any cost-saving initiatives among their sustainability claims. Any efficiency effort resulting in a reduction of the materials or energy consumed to manufacture a product not only reduces costs but lowers the GHG emissions from the company. Failure to identify those initiatives under the banner of sustainability perhaps reflects the low level of importance attached to the topic by those companies.

Nearly half the manufacturers (47%) reported using recycled materials in their products. This is the most common claim made by manufacturers under the environmental dimension of sustainability initiatives.[543] Manufacturers all failed to specify what proportion of their total materials were recyclates, and they often failed to make it easy to identify which specific products contained those materials. A commitment to making long-lasting furniture was made by 14 manufacturers, with eight of these reporting a preference for producing

[543] This commitment has been classified as 'environmental' as recycled materials, particularly plastics, often cost more than their virgin equivalents.

Sustainability claims by furniture manufacturers September 2020

	Commit -ment		Economic						Environmental										Social		Metrics	
Manufacturer	Sustainability report	Sustainability claims on website	Eco design principles	Energy consumption reduced	Waste reduced/ recycled	Water efficiency	Transportation efficiencies	recyclable/ sustainable sourced	Anti-fashion/timeless design	Long lasting products	Wood sustainable (FSC)	Local Suppliers	Renewable energy commitments	CO2 reduced	Circular economy mentioned	Take-back for recycling/ resale	Repurpose/renew	Recycled content	Employment - diversity	Employment - suppliers/ contractors rights	ISO 14001 (EMS)	LCAs
A Lot of Brasil																						
ACTIU		Y	y	y		y					y		y	y								
Alias		y	y					y														
Alki		y									y	y										
Artifort		y	y		y						y	y		y			y				y	
Bonaldo																						
Casala		y	y	y	y				y	y	y	y	y	y	y	y	y	y		y	y	c/s
Cassina		y								y												
Design by them																		y				
Driade																						
DroogDesign																						
Dutchland																						
ecoBirdy																		y				
Emeco		y	y	y	y	y			y	y	y		y	y		y		y				
Fritz Hansen		y			y			y	y		y(l)										y	
Hay	y	y	y						y	y	y(l)									y		
Heller Incorporated																						
Herman Miller	y	y	y	y	y	y					y		y	y	y				y	y	y	
Hille																						

Houe																		y				
IKEA	y	y	y	y	y	y		y			Y()		y	y	y	y	y	y	y	y		
Kartell		y	y					y			y		l					y			y	
Knoll Associates		y	y	y	y	y					y(l)			y		y		y			y	y
Label/Breed																		y				
M114		y							y													
Magis		y							y	y		y						y				
Mater		y			y					y	y(l)							y		y		
MDF Italia																						
Moooi																						
Moroso		y								y												
Nagami																		y				
Nordic Comfort Products		y										y			y			y				
Offect		y							y	y					y		y	y				
Plank																						
Poltronova																						
Polywood		y			y					y								y				
Saporiti																						
Scab Design (Go Green range)		y	y		y								y		y			y				
ScanCom		y	y	y	y					y	y(l)			y				y		y	y	
Sebel		y	y	y	y	y				y								y			y	
Skipper		y	y		y					y												
Tramontina											y(l)							y			y	
Umbra		y						y		y												
Vitra	y	y	y	y	y	y	y	y	y	y	y		y	y	y	y		y	y	y	y	
Vondom																		y			y	

Red = no sustainability related statements reports or commitments found, l = limited, c/s= coming soon (and still 'coming soon' in September 2021!)

Table 4.1. Sustainability related claims made on furniture manufacturer websites, September 2020

timeless designs/avoiding fashions so that their products are more likely to remain in use.[544] Despite the significant environmental impact created by their energy consumption, only seven of the companies reviewed (15%) reported a commitment to sourcing some or their energy needs from renewable sources. Where statements concerning emissions (GHG or chemical) from production facilities are made these are limited to acknowledging compliance with local environmental laws and have not, therefore, been included. Only five manufacturers stated they focus on sourcing all their needs from local suppliers, shortening supply chains. Take-back schemes (11%) and repurposing initiatives (9%) remain rare (and sometimes experimental).

The social dimension of sustainability was only touched on by seven of the companies reviewed (16%) and only two activities were identified under this heading. All seven said they had an agreement or code of conduct with their suppliers to ensure labour rights are respected. However, only one manufacturer (Vitra) undertakes regular, annual reviews to ensure their agreements are upheld. Four of those companies went on to specify they are actively pursuing strategies to ensure diversity in their workplace. No organisations volunteered any details of their workplace employment practices. As many of the companies reviewed are public-listed entities it seems likely that diversity issues are being addressed on a wider scale. As with the economic dimension, it is noteworthy that these manufacturers do not see merit in publicising these activities through the lens of their sustainability initiatives.

The most comprehensive sustainability report included in my analysis is IKEA's, People & Planet Positive strategy, launched in 2012, setting out goals for the company while adopting a broad interpretation of sustainability:

[544] These two commitments have been classified as 'environmental' as they potentially conflict with a business's desire to constantly pursue growth by focusing on driving sales.

> Sustainability at IKEA means ensuring environmental, economic and social well-being for today and tomorrow. It means meeting the needs of people and society, without compromising the ability of future generations to meet their needs – acting in the long-term interests of the many people and not just the few.[545]

With ambitious plans across all three pillars of sustainability, IKEA, which turns over about US$50 billion a year from 800 million customers, aims to be powered by 100% renewable energy (by 2030).[546] As the fourth largest retailer in the world, IKEA claim to be moving toward a circular economy (by promoting repurposing, repair, reuse, resale and recycling), exploring ways to capture carbon, and working with suppliers and partners to reduce GHGs. IKEA was the only manufacturer to align their sustainability ambitions with the UN Sustainable Development Goals. The company showcases its buy back and resale initiative for unwanted furniture, which it is trailing in at least 26 countries (as at May 2021).[547] IKEA embraces the social dimension of sustainability and aims to be an inclusive business that promotes equality. The company states: 'our customers want to enjoy a decent quality of life without negatively impacting the environment—but not at the expense of price, quality or convenience'.[548] While IKEA's aspirational targets are commendable it should be noted that they have ambitious grown targets for the same period. No details of plans, actions, or interim targets to reach the stated goals are specified and serious challenges need to be overcome for their plan to be achievable. For example, in my interview with Kate Ringvall, Australia's Sustainability Business Partner at IKEA, she revealed:

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[545] IKEA, "IKEA People & Planet Positive - Sustainability Strategy" (Delft, August 2020), 6, https://about.ikea.comhttps://about.ikea.com//en/Sustainability.
[546] Company performance estimates for 2020 from: Statista, "IKEA Performance," Statista, accessed February 3, 2022, https://www.statista.com/topics/1961/ikea/.
[547] If this initiative drives sustainable behaviour or merely makes the process of upgrading or exchanging furniture to suit changes in tastes or style remains to be seen.
[548] IKEA Australia, "IKEA Australia - People and Planet Positive 2020," 2021, 6, https://www.ikea.com/au/en/files/pdf/71/bb/71bb29d8/ikeasustainabilityreportnew2020july3.pdf.

> If we are going to be 100% circular by 2030 some of our products will have to be made here in Australia. There is no manufacturing at the scale we need to do it—there is no reprocessing capacity at the moment [to recycle materials].

While IKEA's ambition should be applauded, the lack of transparency on annual targets together by the absence of strategies designed to reach them make it difficult to assess their progress. Ringvall also highlighted another significant issue facing the entire company at the international level. 'The biggest issue with IKEA products is that they are not made to be disassembled and re-assembled constantly—we know that they are not.' [549] Currently products are optimised to be assembled once only, with Ringvall suggesting the systems to enable easy assembly are hangovers from a time when consumer were less mobile. With younger customers in particular frequently changing their place of abode, there is demand for products that can be knocked down for transportation and reassembled.[550] However, any success in developing products capable of withstand repeated re-construction will most likely conflict with IKEA*'s* ambitious growth targets.

Vitra publishes an extensive annual sustainability report that, disappointingly, fails to commit to any specific targets. The German manufacturer claims that its biggest contribution to sustainability is an emphasis on the durability and longevity of the products it creates. Vitra emphasises its commitment to timeless or classic designs, purposely avoiding stylistic trends (6 others made similar claims). The manufacturer is committed to reducing the use of energy, raw materials, packaging, and other resources—thereby reducing the environmental impact caused by emissions. All wood used by Vitra is Forest Stewardship Council (FSC) certified (with 14 other manufacturers claiming all or 'some' of their wood came with this certification). The company reports using renewable energy at two of its manufacturing

[549] Geoff Isaac, Interview with Kate Ringvall, March 20, 2020.
[550] ABS data from 2016 shows one third of young Australians aged 20 to 29 change address every 12 months and two thirds move every five years.

facilities. However, no indication of what proportion of the company's output comes from these two sites is given. Perhaps surprisingly, Vitra was alone in stating attempts to reduce the impacts caused by transportation. Yet, they give no specific goals or commitments, just references to a preference for the efficient use of low impact transport solutions. Similarly, they commit to increasing the percentage of recycled and recyclable materials in their products, without specifying by what proportion or by when.[551] Vitra also refers to the social dimension of sustainability claiming to 'promote healthy and sustainable working conditions not only within our own company, but also amongst our partners and suppliers.'[552] They also highlight the diversity of their workforce. Vitra emphasise their requirement for all suppliers to observe a code of conduct that is evaluated annually. They differentiated themselves from the other manufacturers by declaring this annual evaluation process; the seven other manufacturers who claimed to have such an agreement or policy in place apparently relying on one off self-reporting from suppliers.

Together with Vitra, a further 13 manufacturers claim that the quality of their products makes a contribution toward sustainability, but Kartell expressed this most eloquently:

> Kartell's vocation is to create value: not simple objects, but pieces that can contribute towards building a cultural project; not objects that risk being cast aside when no longer used, but instead become treasured memories.

Kartell claims that all the materials it uses are recyclable, including all product packaging. Wood is Forest Stewardship Council (FSC) certified, although the material is scarcely used by this plastic specialist. The company showcases the bioplastic version of its *Componibili*

[551] Vitra, "Vitra | Sustainability," 2019, 11, https://www.vitra.com/en-au/about-vitra/company/sustainability.
[552] Vitra, 4.

storage unit and the *AI Chair* that is made from recycled industrial waste plastic as the embodiment of its sustainability claims.

Scarcity forced Emeco to use recycled aluminium to make chairs for the US Navy during WWII. Since that time, they have developed a reputation for maximising the use of recycled materials, highlighting this to differentiate the company from its competitors. Despite this unique positioning, the company makes only brief mention of its commitment to sustainability on its website and details of initiatives are lacking. They claim to be committed to minimising their impact by choosing materials, methods, and processes that offer the least risk to our environment. Efforts are made to recycle waste and use recycled materials where possible, and to reduce energy consumption with a preference for renewable energy too. Emeco’s sustainability statement is typical of many of manufacturers included in the database developed for my study. Most choosing to only publish a brief statement, light on detail, and devoid of any targets or supporting data. Magis was alone in emphasising their use of local suppliers (from Northern Italy) to minimise their ecological footprint. The company has been experimenting with alternatives to regular plastics. Consistent with Vitra and Emeco, Magis highlight that their products are built to last supported by a commitment to craftsmanship.

a. Limitations of the industry review

The results of my analysis are presented with some reservations. Listing individual activities does not necessary signify alignment with sustainable principles. Creator of the *Natural Step* framework, Karl-Herik Robèrt, illustrates this point by highlighting that switching to renewable energy does not necessarily guarantee a better environmental outcome if the end-of-life outcome for the photovoltaic cells has not been considered, for example.[553] It cannot be guaranteed that any of the self-reported activities of the organisations I analysed actually improved their overall environmental profile. With only four organisations publishing a sustainability report, there can be little confidence that all the actions identified across all manufacturers are motivated by, or linked to, a strategy specifically aimed at delivering better environmental outcomes.

Another factor to consider is that while 11 manufacturers reported compliance with the ecological management system, ISO 14001, only some reported any of the eco-design initiatives essential to achieve that certification.[554] Those organisations are presumably taking action to obtain this certification, but have chosen not to report details of their initiatives. This appears to be a common problem. Other (often smaller) organisations with a demonstrable commitment to sustainability initiatives, failed to highlight this aspect of their products. For example, ecoBirdy only makes chairs using recycled toys. Despite avoiding virgin fossil-fuel based plastics, no other sustainability initiatives were highlighted on the company's website (or any information on the energy consumed during the collection and reprocessing of toys). Likewise, Australian company, DesignByThem, uses 'sustainably sourced recycled plastic components to create durable indoor/outdoor products.'[555] No other references to sustainability initiatives could be found on their website.[556] It is almost certain that all these organisations are engaged in activities that could be portrayed as eco-design initiatives such as reducing energy use and waste. They under-report their

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[553] Karl-Henrik Robèrt, "Tools and Concepts for Sustainable Development, How Do They Relate to a General Framework for Sustainable Development, and to Each Other?," *Journal of Cleaner Production* 8, no. 3 (June 1, 2000): 243–54, https://doi.org/10.1016/S0959-6526(00)00011-1.
[554] "ISO - ISO 14000 Family — Environmental Management," ISO, accessed February 3, 2022, https://www.iso.org/iso-14001-environmental-management.html.
[555] See: DesignByThem, "Recycled Furniture," DesignByThem, accessed February 3, 2022, https://www.designbythem.com/collections/recycled?page=2.
[556] DesignByThem have since added a sustainability report to their website.

commitment to sustainability. It is also likely (or at least possible) that some manufacturers and retailers are engaged in additional activities across the environmental and social dimensions of sustainability. It remains unclear why they chose not to publicise their activities, and this highlights that my review is limited to self-reported sustainability initiatives and might not fully represent all relevant activities. Conversely, it is not possible to check the claims made by manufacturers, which could potentially identify cases of over-reporting or 'greenwashing.'

My review of sustainability reporting by furniture manufacturers and retailers shows that sustainability (in its broadest sense) is not a central focus for the majority of the companies studied. Over 30 years after the Brundtland report, most organisations are still in the very early stages of adopting sustainability as a core business strategy.[557] Many websites feature static out-of-date content that has not been updated for several years.[558] While there is more likely to be interest in the economic aspects of sustainability, demonstrable commitment to the other dimensions of sustainable business practice is scarce. For instance, despite recent attention given to the subject, only seven companies (15%) mention efforts to engage with the concept of a circular economy. Apart from IKEA, none of the companies referenced the UN Sustainability Goals/ UN Global Compact. I found no mention of *The Natural Step (TNS)* framework or any commitments or ambitions around *Factor X*. There was little evidence of companies broadening their focus beyond shareholders to consider the priorities of all stakeholders.

[557] Brundtland Commission, "Our Common Future" (Oxford: United Nations, 1987), http://www.un-documents.net/ocf-ov.htm#1.2.
[558] For example, Casala's make the claim that LCAs are 'coming soon' on their website for over a year.

Konstantin Grcic was among the designers interviewed for this study who commented on this lack of progress toward implementing sustainability goals or targets by furniture manufacturers:

> The furniture industry is not the most dynamic, progressive, forward-moving industry. It's fairly static and slow... they keep on doing things forever. But I think the world around us is changing very fast and we have to adapt, you know that, but the furniture industry [has] very little contact with end-users.[559]

Grcic's comments are further supported by the fact the industry is failing to take full advantage of recent innovations in digital technology that allows for greater interaction with clients and potential customers. QR (quick response) codes could be embossed on the underside of a chair, added to labels or point of sale material as a simple, low-cost tool to directly link consumers to web content explaining how chairs are designed and manufactured to present the environmental credentials of the design with engaging, interactive content. Manufacturers could also benefit from savings on training with that strategy, relying less on point-of-sale channels to disseminate this information and reducing waste created by out-of-date sales collateral.

Furniture manufacturers are not alone in their casual attitude toward sustainability. A 2021 survey, conducted by the International Consumer Protection Enforcement Network (ICPEN) of 500 randomly-selected websites from across the word found that 40% made unsubstantiated claims about their sustainability credentials. Vague claims, unclear language, selective presentation of relevant information, and the use of own brand 'eco' labels were among the most common issues reported.[560] While the issue of plastic waste has been the

[559] Geoff Isaac, Interview with Konstantin Grcic, April 27, 2021.
[560] International Consumer Protection Enforcement Network (ICPEN), "Global Sweep Finds 40% of Firms' Green Claims Could Be Misleading" (Brussels: European Commission, January 28, 2021), https://www.gov.uk/government/news/global-sweep-finds-40-of-firms-green-claims-could-be-misleading.

subject of increased scrutiny from the public and academia alike, the furniture industry has yet to feel sufficiently pressured to publicly address its use of virgin fossil plastics.

2. Simplified eco-audit tool (ERPR)

Reviewing manufacturers' website failed to reveal sufficient information to enable a comparison of commitments to sustainability principles. I anticipate that this analysis could be further refined to focus specifically on environmental impacts at a product level. But my appraisal of manufacturers' websites demonstrated that consistent, accurate data is unavailable at the company level, let alone the product level. Recall that only one LCA study was found, and only one manufacturer specified the precise source of material used for just one of the designs included in my survey. For most chairs we are not told where their materials come from or how those materials are transported from point of origin to factory floor. Unfortunately, those are among the details required to precisely calculate the environmental profile of a product.

The furniture industry is serviced by a global network of suppliers adding complexity to the task of identifying the source of individual components. Most furniture 'manufacturers' are more accurately described as fabricators or assemblers, primarily involved with the machining and coating of components sourced from external suppliers who, in turn, often sub-contract production to third party specialists across the globe. Supply chains are unlikely to remain fixed too, with changes in market competitiveness or international exchange rates impacting the allocation of contracts. New suppliers might use different materials or production technologies to deliver an equivalent component.

The convoluted nature of those arrangements is reflected by the fact that only 20 manufacturers hold EU Ecolabels for any furniture designs as at September 2021. No manufacturers applied for accreditation in the two years following the criteria being expanded (in 2016) to include materials other than wood (and including plastics), according to a paper by Shane Donatello, an academic working with the European Commission.[561] Where furniture includes plastic components, Ecolabels are only available where the manufacturer can demonstrate that no dangerous, toxic, or banned substances are included in the plastic. Additionally, the manufacturer needs demonstrate that at least 30% of the plastic content has been recycled (and that the recycled content also complies with the safety requirements). Critical of the labelling system, Donatello concludes that most compliance control rests in the hands of the plastic converter.[562] It is difficult, if not impossible, for most assemblers to satisfy those certification requirements. Those challenging criteria impact the manufacturer's ability to report on their environmental credentials.

Whether manufacturers are unwilling or unable to provide the detailed information on materials used that information remains unavailable to me. The primary focus of my study is to evaluate the environmental profiles of designs, which requires a methodology for the comparison of chairs. To compare the 32 niche experiments with renewable plastics I needed a simplified eco-audit tool, and I began by considering the simplest tool available, the waste hierarchy.

[561] Shane Donatello et al., "Are the Existing EU Ecolabel Criteria for Furniture Products Too Complex? An Analysis of Complexity from a Material and a Supply Chain Perspective and Suggestions for Ways Ahead.," *The International Journal of Life Cycle Assessment*, no. 25 (2020): 869.
[562] Donatello et al., 873.

The waste hierarchy was developed to evaluate waste management by ranking the environmental impact of processes from most favourable to least favourable.[563] I adapted this tried and tested tool, popular with design academics in the 1980s (the early years of green design), to assess its relevance to designers and manufacturers who are keen to evaluate the environmental profile of their creations.[564]

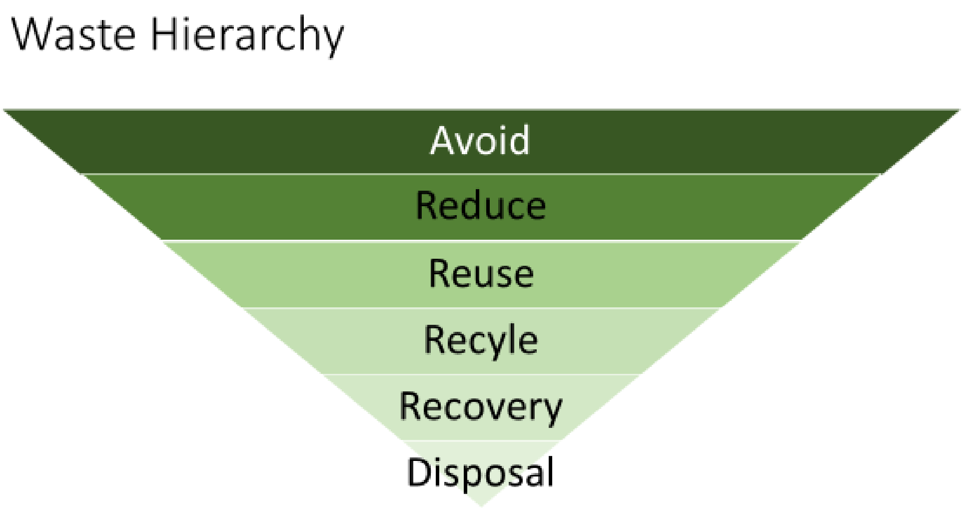

Fig. 4.1. The waste hierarchy – Avoiding waste altogether is the preferred option with disposal (usually to landfill) the least preferred option. Source: Adapted from NSW EPA

The accuracy of the rankings within the hierarchy applied specifically to plastic waste (see fig. 4.1), were confirmed by research undertaken by the Waste and Resources Action Programme in the UK (WRAP). A detailed comparison of eight LCA studies identified mechanical recycling as the best disposal alternative when compared for climate change impact, depletion of

[563] NSW EPA, "The Waste Hierarchy," NSW Environment Protection Authority, 2019, np, accessed February 3, 2022, https://www.epa.nsw.gov.au/your-environment/recycling-and-reuse/warr-strategy/the-waste-hierarchy.

[564] Dorothy Mackenzie, *Green Design: Design for the Environment*, 2nd ed (London: L. King, 1997); Pauline Madge, "Ecological Design: A New Critique Old," *Design Issues* 13, no. 2 (1997): 44–54, https://doi.org/10.2307/1511730.

natural resources, and energy consumption.[565] Recycling delivers both energy security and environmental benefits. The amount of fossil feedstock required for chemical production is lessened and, more importantly, recycling reduces energy needed and therefore GHG emissions, for the production of plastics. This is a net saving of about 0.6 t of Co2 per ton of plastic recycled compared with landfilling.[566] That is why recycling is the preferred end of life option for plastics from an environmental perspective.

A review of 222 LCA studies of solid waste management systems undertaken in 2014 consistently confirmed recycling and energy recovery as having a lower environmental impact than disposal to landfill.[567] Incinerating plastics (instead of coal or gas) to create energy conserves fossil fuels but does not deliver significant GHG benefits. Therefore, energy recovery is ranked as the least preferred option, just one step above disposal to landfill.

In the 1990s, it became fashionable for manufacturers to start using and identifying plastics as being recyclable. Plastic chairs were no exception, and many designs continue to be promoted as ‘recyclable.’ This claim makes no guarantee concerning the end-of-life prospects for the chair. I have differentiated between designs that are theoretically recyclable from those actually made from recycled plastic, with reuse the more preferable outcome.

This century (and particularly the past decade), has seen a growing number of innovations aimed higher up the waste pyramid. These new approaches focus on designs

[565] WRAP UK, “Environmental Benefits of Recycling,” 2010, 32–38, February 3, 2022, http://www.wrap.org.uk/content/environmental-benefits-recycling.
[566] Simon J. Bennett, “Implications of Climate Change for the Petrochemical Industry: Mitigation Measures and Feedstock Transitions,” in *Handbook of Climate Change Mitigation*, ed. Wei-Yin Chen et al. (New York, NY: Springer US, 2012), 319–57, https://doi.org/10.1007/978-1-4419-7991-9_10.
[567] Alexis Laurent et al., “Review of LCA Studies of Solid Waste Management Systems – Part I: Lessons Learned and Perspectives,” *Waste Management* 34, no. 3 (March 1, 2014): 579, https://doi.org/10.1016/j.wasman.2013.10.045.

made from recycled plastic, manufactured using new technologies developed to reduce the amount of energy or material required, or incorporating alternative materials to avoid the use of petrochemical plastics altogether. I have modified the waste hierarchy to reflect those innovations (fig. 4.2). The most significant difference is in the definition of 'avoid.' In the waste hierarchy 'avoid' is defined as avoiding waste all together by encouraging 'the community, industry and government to reduce the amount of virgin materials extracted and used'.[568] In my adaptation to guide designers working with plastics 'avoid' is redefined as: 'avoiding the use of fossil-based plastics'. While 'reuse' includes all activities aimed at avoiding the use of virgin fossil-based plastics (i.e., using recycled plastics), 'reduce' includes all efforts to minimise the use of resources included in the design or consumed during production. Appling this analysis to the 32 chairs using plastics made from renewable carbon delivered the results shown in table 4.2.

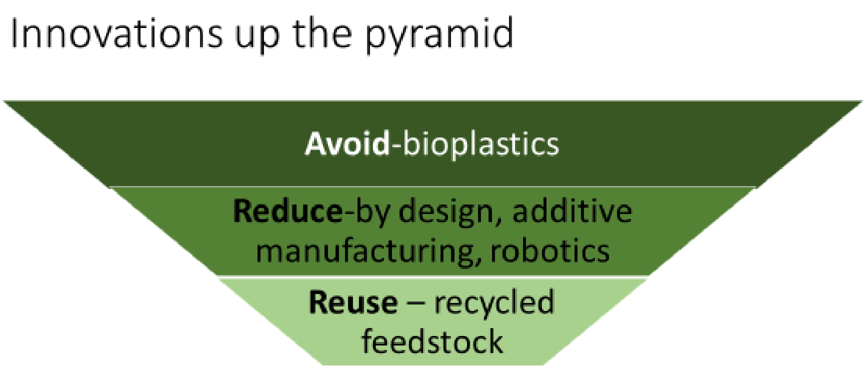

Fig. 4.2. Preferred solutions from the waste hierarchy. Source: Adapted from NSW EPA

[568] NSW EPA, "The Waste Hierarchy," np.

Chair	Designer	Manufacturer	Date	Material 1	Material 2
Avoid - Natural fibres					
Flax chair	Christien Meindertsma	Label/Breed	2015	flax	PLA
Hemp chair	Werner Aisslinger	Moroso	2011	hemp (70%)	water based resin
Jin	Jin Kuramoto	Offect	2018	flax fibre	bio-resin
Coastal Furniture	Nikolaj Carlsen	TangForm	2019	seaweed	wood (legs)
Avoid - Bioplastics					
Jet and *Paco*	Tramontina	Tramontina	2018	renewable polyethylene	
Kuskoa Bi	Ander Lizaso	Alki	2015	PLA (hybridised)	wood (legs)
Siamese Chair	Karim Rashid	A Lot of Brasil	2014	plant based plastic	aluminium legs
Puzzle chair	Joris Laarman	Joris Laarman Lab	2014	PLA	
Avoid and reduce – Bioplastics (3D printed)					
Voxel	Manuel Garcia	Nagami	2016	PLA	
Ice-Dream	Fabio Novembre	WASP	2019	PLA recycled	
Reduce – 3D printing					
Chubby Chair	Dirk Vander Kooij	Dirk Vander Kooij	2012	recycled refrigerator plastic (96%)	
Reduce – Artificial Intelligence					
AI Chair	Philippe Starck	Kartell	2019	thermoplastic technopolymer	
Recycled - ocean plastics					
DuraOcean	ScanCom	ScanCom	2020	recycled fishing industry waste	plastic debris
Ibiza (chair)	Eugeni Quitllet	Vondom	2019	ocean plastic (PP)	fibreglass
Love	Eugeni Quitllet	Vondom	2018	ocean plastic (PP)	fibreglass
Ocean Collection	Jørgen & Nanna Ditzel	Mater	2018	ocean plastic (PP - 960g)	steel (legs)
S-1500	Snøhetta	Nordic Comfort	2019	ocean plastic (PP - 1500 g)	steel 20% recycled (legs)

Chair	Designer	Manufacturer	Date	Material 1	Material 2
Ocean Chair	Polywood	Polywood	2020	ocean plastics (HDPE)	
Recycled - small scale projects					
Butter Chair	Nicholas Karlovasitis & Sarah Gibson	DesignByThem	2011	HDPE recycled (80%)	
ChairCharlie	Vanessa Yuan & Yoris Vanbriel	ecoBirdy	2018	recycled toys	
Meltdown Chair	Tom Price	Tom Price	2007	polypropylene	
Recycled PET					
111 Navy Chair	Emeco	Emeco	2010	PET (65%)	fibreglass (35%)
Nobody	Boris Berlin & Poul Christiansen	Hay	2007	PET felt	
On & On Stacking Chair	Edward Barber & Jay Osgerby	Emeco	2019	PET (70%)	fibreglass (20%) non-toxic pigments (10%)
Recycled post-consumer polypropylene					
Summa Range (Sissi and *Diana)*	Tramontina	Braskem and Tramontina	2019	polypropylene	
Falk	Thomas Pedersen	Houe	2019	polypropylene 75%	fibreglass 20% + wood (legs)
N02 Recycled	Oki Sato	Fritz Hansen	2019	polypropylene	steel (legs)
Recycled post-industrial polypropylene					
Broom Stacking Chair	Philippe Starck	Emeco	2012	polypropylene (75%)	wood (15%)
Green Chair	Javier Mariscal	M114	2016	polypropylene (100%)	wood or metal bases
Odger	John Löfgren & Jonas Pettersson	IKEA	2017	polypropylene (70%)	wood (30%)
1 Inch Reclaimed	Jasper Morrison	Emeco	2018	polypropylene (88%)	wood (2%)
Bell Chair	Konstantin Grcici	Magis	2020	polypropylene (almost all)	fibreglass

Table 4.2. Waste hierarchy analysis of renewable plastic chairs

The waste hierarchy is useful to assist in guiding material selection toward more sustainable outcomes. However, it is not sufficiently detailed to evaluate and compare designs within each category. Additionally, there is no guarantee that material selection alone defines the ultimate environmental profile of a product.

At the end of the twentieth century, Yale Professor of Environmental Studies, Tomas Grandel, led the development of a streamlined LCA, requiring users to enter key data for a project into a matrix summarising the main lifecycle phases.[569] In addition to material selection, manufacturing process, transportation, use, and disposal were identified as the key life cycle stages. For each stage five key impacts were identified (as shown in the matrix below). Scores were awarded on a scale of 1 (highest impact) to 4 (lowest impact) and displayed as a target plot. The results for the product with the least environmental impact are shown nearest the centre of the chart, ideally forming a bullseye when top scores for each attribute are awarded (fig. 4.3):

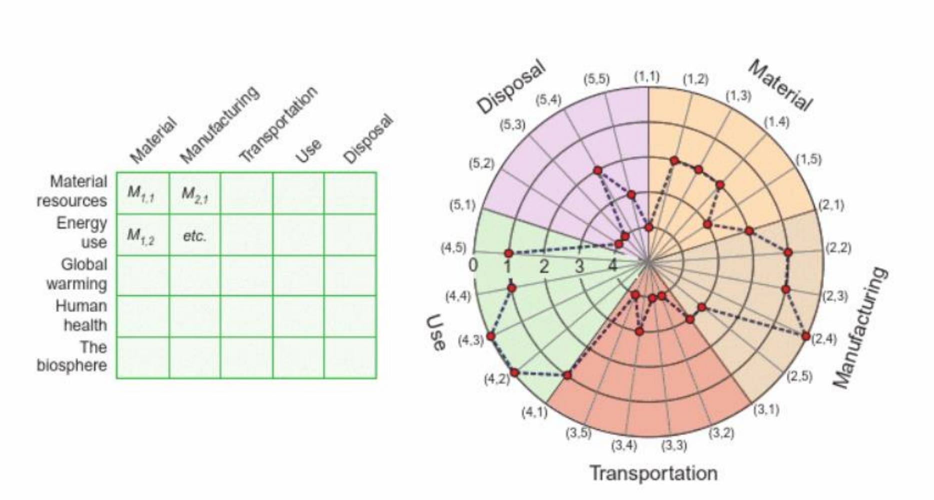

Fig. 4.3. An example of a streamlined LCA matrix and a target plot displaying the rankings in each element of the matrix. In this example the use phase gets a poor rating. Source: Ashby (2012)[570]

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[569] Graedel, *Streamlined Life-Cycle Assessment*.
[570] Michael F. Ashby, *Materials and the Environment: Eco-Informed Material Choice* (Oxford, UNITED STATES: Elsevier Science & Technology, 2012), 61, http://ebookcentral.proquest.com/lib/uts/detail.action?docID=900127.

The overall Environmentally Responsible Product Rating (ERPR) is given by the sum of the scores. While simpler than the full LCA this model still requires detailed data and relies on experienced practitioners to implement.[571]

At about the same time, Danish academic Niki Bey, also identified the need for a more user-friendly simplified LCA to assist designers interested in understanding the environmental profile of their work during the early stages of a project.[572] For a tool to be useful the data required for input should be readily available and results should be delivered in a format that is easy to understand and does not require detailed environmental knowledge. Further, results should not be subject to misinterpretation, they should be easy to communicate and allow for comparison between products.[573] The Oil Point Method was Bey's response to this. It is like an LCA but relies exclusively on primary energy relationships, using material and process-specific indicators for the calculations.[574] This method enables a comparison of products based on the lifetime impacts of a product as expressed through an estimation of the equivalent kilograms of crude oil consumed. Despite simplifying the LCA methodology, accurate estimates are still needed to perform the necessary calculations including: the weight of materials used in a product; the manufacturing processes to be used; distances travelled during transportation; impacts during use (if any); and impacts caused by disposal. Data demands therefore remain intensive and the tool falls short of its

[571] Ashby, 64.
[572] Niki Bey, "The Oil Point Method - A Tool for Indicative Environmental Evaluation in Material and Process Selection" (PhD., Technical University of Denmark, 2000).
[573] T Lenau and N Bey, "Design of Environmentally Friendly Products Using Indicators," *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture* 215, no. 5 (May 1, 2001): 638, https://doi.org/10.1243/0954405011518575.
[574] Lenau and Bey, 638.

aim to provide designers with 'a method that can be used easily in order to discuss with other people environmental consequences and the actions to be taken [to reduce them]'.[575]

While not immediately servicing my needs these simplified LCA methodologies helped identify the most significant variables to be considered when evaluating a product. I built on these studies to create an eco-audit tool of specific use to designers and other actors involved with the development of plastic chairs.

3. Proposed simplified tool (ERPR)

Michael Ashby, a material science engineer, states the first step in understanding a product's impact is to consider the total life-energy demands of a product and apportion it across its lifecycle.[576] For a plastic chair the energy requirements to manufacture the plastic will dominate the impact (fig. 4.4). In fact, the largest component of the energy is consumed during the production of the material itself.

This simple analysis shows that as material production dominates the impact, the greatest environmental benefits for a chair can be made by selecting plastics with lower embodied energies, minimising the amount of material being used. Designing chairs to last will reduce their impacts, as no significant energy demands are generated while using the product and any end-of-life impacts are delayed. To enable a comparison between products within the same product category my eco-audit tool includes an analysis of the type and amount of plastic, and considers impacts generated throughout the lifecycle of a chair.

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[575] Lenau and Bey, 638.
[576] Ashby, *Materials and the Environment*, 67.

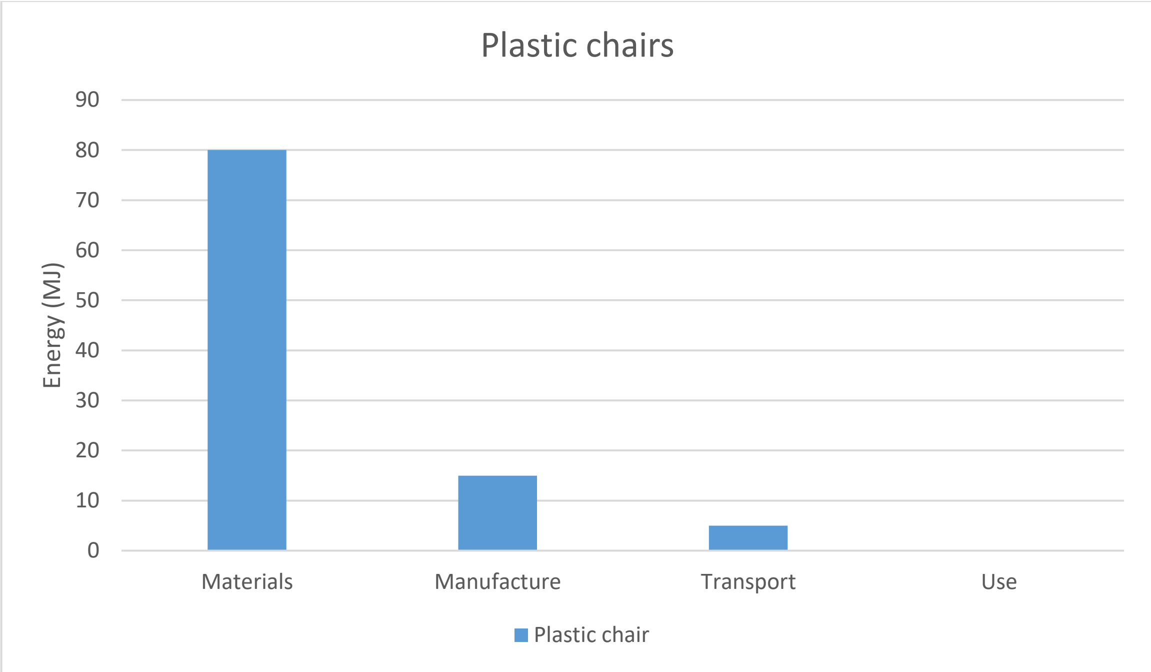

Fig. 4.4 Estimated lifetime energy demands of a plastic chair.
Source: Adapted from Ashby's analysis of similar products (2012)[577]

Note: Energy consumption is used as a proxy for CO2 emissions as recommended by Ashby. The disposal phase is not shown as the final destination of chair is unknown - the chair could be recycled (in which case a credit would he earned), or composted if bioplastic. In practice most chairs end their days in landfill, and this will have an environmental impact.

Building on the tools developed by others, particularly Graedel, I simplified data requirements focusing on five attributes: the type and quantity of plastic used; the efficiency with which chairs can be transported; their appeal to the market; and their end-of-life prospects (fig. 4.5). The use phase has been ignored as plastic chairs require little maintenance and do not consume energy or other resources during use. Ideally, this analysis would include consideration of where and how both the product and material were manufactured. Without knowing the precise content and source of energy for every component it is not possible to accurately assess these environmental impacts, so the overall weight of the chair is used as a surrogate here. Production processes are not compared as

[577] Ashby, 67.

details of the precise quantity of resources consumed during manufacture, and the relative efficiency of the processes remains unknown. Products within the same category and produced using the same process are assumed to generate similar impacts. Scoring for each attribute had been determined based on information commonly provided by manufacturers. A discussion on the relevance of those attributes and the scoring system developed is outlined below.

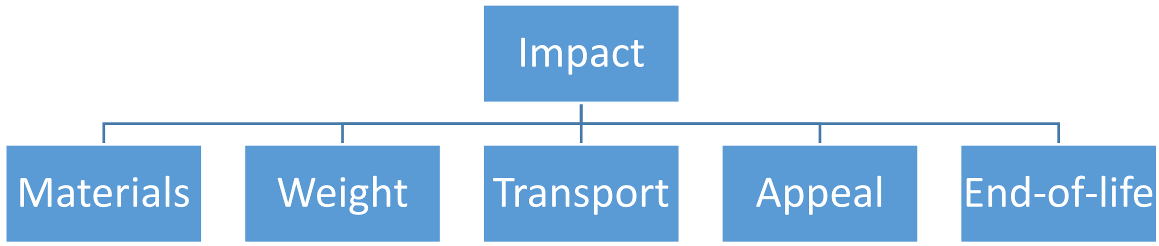

Fig. 4.5 Attributes of plastic chairs to be evaluated by the eco-audit tool

Note: End-of-life prospects have been included in this analysis. While the final destination of an individual chair remains unknown the end-of-life prospects of a design are influenced by the choice of materials and manufacturing techniques which enable a relevant comparison to be made within the product category.

a. Materials

Material selection for a plastic chair is the most important decision facing a designer or manufacturer as the resources consumed producing materials represents the largest proportion of the product's environmental impact. A review of industrial design and mechanical design books concerned with materials selection (published between 1967 and 2005) by materials specialist Elvin Karana found that 'in most of the pre-1996 sources, environmental (and later on "sustainability") issues were placed at the bottom of lists showing material requirements for designers.'[578] Priorities started to adjust shortly after, with an engineering design book by Pat Mangonon, published in 1998, emphasising that consideration should be given to a material's environmental profile throughout the product's lifecycle: manufacture, use, reuse, and through to disposal.[579]

Sustainability is only one of many criteria to be considered by designers when making their selection of materials. Cost is an important concern and acts against the selection of renewable plastics, as these are invariably more expensive. Technical engineering performance (strength, flexion, and durability), aesthetics, cultural, emotional, and social factors also influence choices.[580] Safety, quality, and legal requirements are also concerns, many of which are often still given precedence over environmental concerns.[581] As the choice of materials has the biggest impact on the environmental performance of a chair it is vital that careful consideration is given to their selection.

Top scores of four points were awarded to monobloc designs made from a single material that is either produced from renewable organic (organic) sources or has been recycled in its entirety (over 90%). By relying on a single material, monoblocs offer the advantage of eliminating the need to join elements, thereby avoiding the use of screws, adhesives, and welding. Where designs rely on two fully recycled or organic materials a score of three points is awarded, as separate manufacturing processes and assembly are required. Specifying renewable plastics will significantly reduce the embedded energy contained

[578] Karana, Pedgley, and Rognoli, *Materials Experience*, pxxvii.
[579] Pat L. Mangonon, *Principles of Materials Selection for Engineering Design Hb* (Upper Saddle River, NJ: Pearson, 1998).
[580] Karana, Pedgley, and Rognoli, *Materials Experience*, 63–72.
[581] Sergio A. Brambila-Macias and Tomohiko Sakao, "Effective Ecodesign Implementation with the Support of a Lifecycle Engineer," *Journal of Cleaner Production* 279 (January 10, 2021): 2, https://doi.org/10.1016/j.jclepro.2020.123520.

within a design. The energy required to produce virgin fossil polymers averages around 100 MJ/kg compared with about half that amount for both bioplastics and recycled plastics (depending on the type of plastic, as shown in table 4.3).

Score	Virgin polymers Embodied energy MJ/kg	Recycled polymers Embodied energy MJ/kg	Indicative percent saving
Polypropylene	79	50	36.7%
PET	85	39	54.1%
HDPE	81	50	38.3%
Polyamide	122.5	42.5	65.3%

*Indicative embodied energy estimates calculated as the mid-point of ranges shown in source.

Table 4.3. Comparison of the embodied energy of virgin and recycled polymers.
Source: Ashby (2012)[582]

Where different materials are mixed or the legs of a chair have been made from virgin material, then the design is marked down. Some designs feature recycled polymers that have been mixed to create compounds (usually with fibreglass). Although mixing materials diminishes the end-of-life prospects this is not relevant here (it is considered when evaluating the end-of-life score), only the proportion of recycled or organic content is of concern when awarding the materials score (table 4.4).

[582] Ashby, *Materials and the Environment*, 490–525.

Score	Material
4	90%+ single material (recycled or organic)
3	90%+ recycled/organic materials (mixed e.g. legs different material)
2	75%+ recycled/organic materials mixed together
1	>50%,<75% recycled/organic materials mixed together OR legs not made from recycled material
0	<50% recycled/organic content

Table 4.4. ERPR scoring sheet for materials

b. Weight

After ‘avoid,’ ‘reduce’ is the preferred strategy according to the waste hierarchy. Weight provides a good indication of the embodied energy contained within the chair and directly impacts the energy consumed during transportation. The larger the quantity of material, the larger the energy and resources consumed during production. The lower the weight of the final product the higher the score awarded, to reflect the improved material efficiency achieved by the design (table 4.5). A quintile was calculated using the weights of the 32 chairs to allocate scores:

Score	Kg
4	<3
3	3 - 4.99
2	5 - 6.99
1	7 - 9.99
0	10+

Table 4.5. ERPR scoring sheet for weight (sample organised into quintiles to determine score)

It could be argued that incorporating large quantities of recycled plastic into a design achieves a good environmental outcome, as carbon is locked into durable products rather than escaping to the atmosphere. However, the transition to renewable plastics demands significant increase in the use of recycled plastics across all product categories. For supply to be sufficient for this to occur at scale the principle of minimising the use of materials should continue to be observed.

c. Transport

Most manufacturers produce chairs in one location and then distribute globally, usually with an emphasis on their local market(s). Without detailed information on the distribution of sales and methods of transport it is not possible to accurately calculate the comparative efficiency of distribution strategies. However, the efficiency with which chairs can be transported for distribution is a function of their volume and weight. Chairs designed to be stacked during transportation positively affects the resources consumed, as volume is reduced, together with the quantity of packaging required. This is important across the supply chain, as the environmental impacts caused by shipping small quantities of chairs short distances by diesel truck can significantly exceed the contribution to impacts made during a long journey on a container ship.[583]

Designing self-assemble chairs is another approach to reducing transport impacts, as separate components occupy less shipping space compared with a fully assembled chair (fig. 4.6). Designs that can only be shipped in cartons, either singularly or in pairs represent the least efficient examples for transportation and have been awarded a score of zero pints.

[583] For details see: Matthew J. Nahlik et al., "Goods Movement Life Cycle Assessment for Greenhouse Gas Reduction Goals," *Journal of Industrial Ecology* 20, no. 2 (2016): 317–28, https://doi.org/10.1111/jiec.12277.

Fig. 4.6. The *Odger* arrives in four pieces designed for easy self-assembly, reducing transport and storage costs for client IKEA. Source: From Russia with Love

UK-based designers Edward Barber and Jay Osgerby were among those interviewed for this research who claim to pay particular attention to transportation and storage considerations with their work:

> The thing about really good industrial design it is not just about the end product. It's about how you ship that product and how you warehouse that product. We did a project with Dedon last year [2018], outdoor sofa system [Brea] made from bent tube. We did it in such a way that, once it is constructed, it looks like a fairly luxurious sofa but when you deconstruct it, it's just really simple tubing and casting and you can break it down. Basically, it is like a KD [knockdown] thing without it looking like a KD thing. They could warehouse the whole thing really efficiently and ship it really efficiently so their carbon footprint, in getting it to the end destination, was massively improved. In fact, they said they have completely reconfigured their warehouse based on this product. As a designer that is quite rewarding, almost more rewarding than having a nice-looking thing at the end of it.[584]

[584] Isaac, Interview with Barber & Osgerby.

While knockdown and stacking are old solutions for transportation efficiency, digitalisation promised to eliminate them. Proponents of 3D printing frequently emphasise that the technology has the potential to eliminate transportation, but this ignores the fact the raw materials (filament) must be shipped to the point of printing. Shipping relatively small quantities of raw materials to supply individual printing outlets can cause significantly greater impacts that those obtained by shipping large volumes of polymer to factories and batches of injection moulded chairs to retail warehouses. Therefore, 3D printed chairs scored relatively weakly against this criterion and were awarded a score of just one point (table 4.6).

Score	Transport
4	Stacks 8+
3	Stacks 4-7
2	Stacks 2 or 3
1	Legs and shell separate for shipping OR 3D printed
0	Shipped in carton containing 1 or 2

Table 4.6. ERPR scoring sheet for transport

The often GHG-intensive impact of the ‘last mile’ of the journey—from the retailer’s warehouse to the end-user—has not been included here as this will vary considerably. Also, a more detailed analysis of the packaging used to protect chairs during transportation and storage would facilitate a more accurate assessment of the environmental impact of the transportation phase. Unfortunately, details of the composition and quantity of packaging are not readily available from all suppliers.

d. Appeal

To date, no one has attempted to quantify the appeal of a product and include this in an environmental profile. Appeal is broadly defined here as product attributes that command attention and persuade people to purchase a product. It includes the aesthetic characteristics of a chair, its style and looks, plus an assessment of how comfortable it is. All characterises that are largely subjective. However, appeal is vital in driving sales. If an environmentally-friendly product fails to appeal to the market it will, most likely, be substituted with less sustainable alternative. The environmentally-conscious designer must extend their concern from a focus on production to include a consideration of consumption. This is particularly important in the case of a product that has relatively inelastic demand like a chair. Once a consumer has identified a need for a chair, they are going to satisfy that need by making a purchase, they are unlikely to impulse buy more chairs than required just because they like them.

While a small segment of the market might actively seek out more sustainable seating solutions, consumers are more likely to give preference to other criteria (including aesthetics) when making decisions. If an environmentally friendly design is deemed unappealing by a prospective purchaser a more traditional solution will be sought. Purchasers hold the most power in determining the ultimate success of any design and by extension, the product’s environmental impact. Further, when an ‘environmentally-friendly’ design fails to sell, retailers and manufacturers will quickly abandon the product, or risk financial penalty. To secure the best chance of sales success a design must appeal to a wide cross-section of potential purchasers. Including appeal in my study encourages designers to consider the life of their products beyond the factory gate. The act of consumption is made implicit in the act of creation. Appeal is crucial to both sales success and sustainability outcomes and should be considered when evaluating the potential impact of a design.

Despite the difficulty in evaluating the appeal of any product, I have considered three easily quantifiable criterions as crucial to creating broad appeal for of a chair: its price, the range of colours available, and the number of configurations available. Lower-priced chairs are likely to appeal to a wider audience. Retail prices of the chairs included in this study (converted to Australian dollars from the retail price in the country of manufacture) were arranged into quintiles to determine the allocation of scores. Recycled polymers or bioplastics sometimes demands a compromise on colour choices. Plastics have their own personality which, as Karana et al. observed: 'lend themselves, particularly to brightly coloured, light-hearted and humorous, design.'[585] The lack of bright colours can make renewable plastics less appealing than their traditional fossil-based counterparts. Recycled plastics are frequently only available in a limited range of (often muted) colours (see *1 Inch Reclaimed* colours in fig. 4.7 for example). Some designers have chosen to live with this limitation, while others have succeeded in developing wider and brighter colour choices that can be expected to broaden the appeal of a design.[586]

[585] Karana, Pedgley, and Rognoli, *Materials Experience*, xx.
[586] Limiting the colour choice can deliver greater economies of scale (and associated environmental benefits), as moulding machines can potentially be run more efficiently with fewer colour changes. Even if these savings could be accurately quantified, it would still not be possible to evaluate the impact on sales of reducing the colour range. Therefore, this analysis is restricted to assuming increased colour choice results in broader appeal and more sales.

Fig. 4.7. Examples of colours available for chairs made from industrial waste
Source: (clockwise top left) Emeco, Emeco, Magis, M114

If a chair can be adapted to suit the varying needs of different market segments, potential sales can be increased significantly. By making a variety of bases available and offering shells with or without arms a design can be adapted to suit a variety of uses and tasks across the residential, corporate and contract market segments. Monoblocs are disadvantaged—by definition they are only available in a single configuration. Fig. 4.8 illustrates a sample of the variety of base options available for the *N02 Recycled* from Fritz Hansen contrasted with the single option available for the *Bell Chair* from Magis:

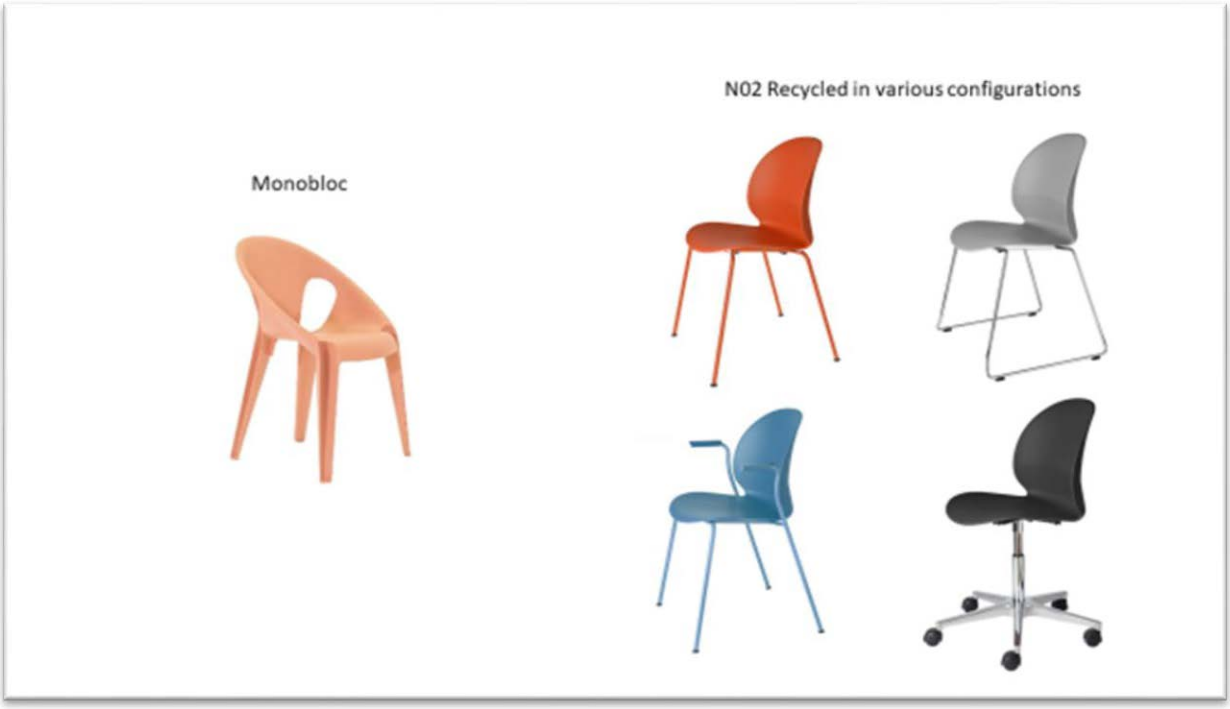

Fig. 4.8 The *Bell Chair* (on the left) is a monobloc produced in one style only. On the right, the *N02 Recycled* is available with a selection of bases and offered with or without arms. Source: Magis (left), Fritz Hansen

The appeal score is calculated as the arithmetic mean of the three scores achieved for each dimension as shown in table 4.7. A perfect score of four points indicates a design offered at a comparatively low price (<$200) and available with a wide choice of colours (9+) and a variety of configurations (5+).

Score	Price	Colours	Configurations
4	<$200	9+	5+
3	$200-$399	7-8	4
2	$400-$599	4-6	3
1	$600-$999	2-3	2
0	$1000+	1	1

Note: Scores were determined by examining the sample and constructing quintiles for each attribute. Local prices (based on place of manufacture) converted to AUD as at September 2020.

Table 4.7. ERPR scoring sheet for appeal (sample arranged in quintiles to determine score for price)

There are many other aspects to appeal, perhaps most importantly how the comfort offered by a chair is perceived. Some designs included in this analysis look very different from a typical chair, and that might deter purchasers. The use of curves or geometric components and how the chair feels are all likely to impact its appeal. Many renewable plastic chairs feature different textures. Surfaces can feel slightly rough or textured compared with virgin fossil polymers—some buyers might be put off, while others interpret these feelings as exciting new sensual experience. Recycled plastics can display impurities in their surface in contrast to the perfect, uniform finish of virgin plastics, which can reduce their appeal to both designers and consumers. Such differences are difficult to quantify and their individual bearing on the overall appeal and ultimate sales of a design is impossible to assess. To avoid these difficulties, this analysis is restricted to evaluating criteria for which quantitative data is available.

e. End-of-life

Most chairs are designed to last years of use. Finnish designer, Eero Aarnio, claims his products are 'recycled from grandfather to grandson. No one will throw away quality goods or art objects with resale value.'[587] If this is true for all plastic chairs the end-of-life phase can safely avoided in any assessment of environmental impacts. But furniture is discarded due to changing needs or taste in fashions or due to damage. Consideration, therefore, needs to be given to what will happen to the chair at the end of its useful life. Many plastic chairs (including all monoblocs) cannot be disassembled or have parts replaced in the event of breakage.[588] Plastic chairs often cannot be upgraded to alter their look—while chairs made with traditional materials can be re-polished or reupholstered to suit current trends. Many

[587] Aarnio and Savolainen, *Eero Aarnio*, 150.

[588] In developing countries, where labour is cheaper and materials relatively more expensive, repairs do occur see Friedrichs and Eickhoff, *220°C Virus Monobloc*, 158–80.

plastic chairs are relatively inexpensive, and some are poorly made, with both factors encouraging disposability. For those reasons, it is likely that plastic chairs have a shorter average life compared with chairs made from traditional materials.[589] Plastic chairs are often used outdoors, which can significantly shorten their life expectancy. Despite improvements in colour fastening, plastics can fade when exposed to UV for extended periods of time. Additionally, the surface finish of a chair will become compromised over time, and this will be accelerated if (although not recommended by manufacturers) cleaning agents containing bleach are used. As colours and surfaces deteriorate over time plastic chairs are increasingly likely to be discarded.

The real-life final destination for a plastic chair (or any other product) largely depends on where and how it is disposed of. Fully recyclable chairs can end up in landfill if they are disposed of inappropriately or if they are discarded in a remote or undeveloped area without access to recycling infrastructure. Chairs properly disposed of through the waste stream could be recycled, incinerated, used as fuel for energy from waste, or recycled depending on local policies and infrastructure availability. Some manufacturers acknowledge their producer responsibilities by offering take-back schemes to reuse or recycle their products. However, these schemes are tokenistic. The economic and environmental costs of returning unwanted furniture back to the manufacturer are most likely prohibitive (except for locally-based customers).

While the end-user has responsibility for managing the end-of-life prospects for a chair, the designer and manufacture can encourage circularity through: (limiting) the choice

[589] It is noteworthy that while Emeco backs it aluminium chairs with a lifetime guarantee and chairs made from wood with a seven-year guarantee, plastic chairs come backed with a warranty of only between three- and five-years duration: https://www.emeco.net/support, accessed February 3, 2022.

of materials, ensuring all plastic components are permanently labelled (using the internationally recognised resin indication codes (RIC)), and by designing for disassembly. Monoblocs made from a single material that can potentially be recycled using typical existing waste processing facilities, were awarded the top score of four points. Designs that require manual disassembly, or materials that require specialist infrastructure to facilitate their sorting, recycling, or composting were awarded lower scores. Chairs made from bioplastics tended to perform poorly against this criterion, as these materials will only degrade when exposed to consistent heat and humidity conditions that only exist at industrial composting facilities, which remain scarce (table 4.8).[590]

Score	End-of-life prospects
4	Fully recyclable (using existing infrastructure)
3	Fully recyclable (requires disassembly)
2	Recyclable/compostable (requires specialist facilities)
1	Recyclable through EPR scheme (or equivalent) OR partially recyclable (e.g. legs)
0	Not recyclable OR insufficient information available

Table 4.8. ERPR scoring sheet for end-of-life prospects

f. Weighting

Scores are presented unweighted. Consideration was given to weighting scores; however, this would introduce another level of subjectivity to the results. For example, the end-of-life prospects for chairs in general might be considered less important, as most chairs are designed to withstand years of continuous use. It could be argued, therefore, that the end-of-life scenario is irrelevant in assessing the environmental profile of a chair, and certainly of less importance than some of the other factors considered. Conversely, the choice of

[590] Less than 2% of the population of the USA have access to industrial composting facilities. As You Sow, “Plastics: The Last Straw for Big Oil?,” 20, accessed February 3, 2022, https://www.asyousow.org/report-page/plastics-the-last-straw-for-big-oil.

material has the single biggest bearing on the environmental impact of a plastic chair; therefore, it could be argued that the score awarded for this criterion could even be given more weight. I tested a variety of result-weighting scenarios but this did not significantly impact overall rankings, so I chose not to apply weighting in my final assessment.

4. Conclusion

A review of websites revealed little commitment to sustainability initiatives from most furniture manufacturers included in this study. In addition, the quantity and specificity of data relevant to evaluate the environmental profile of an individual product remains scarce. Informed by the information available, I evaluated existing eco-audit tools to assess their ability to facilitate a comparison between the 32 chairs made from renewable carbon materials. That review concluded that sufficiently accurate and detailed data is currently not available from furniture manufacturers to enable any of these tools to be used. I then developed a simplified eco-audit tool to enable a comparison of chairs to be made within the confines of the available data. I developed a digital version of the Environmentally Responsible Product Rating (using REDCap software) and it is available for researchers, designers, and manufacturers to use. In addition to displaying detailed rating across the scoring categories the tool also uses the information provided to make suggestions for how the environmental performance of the design can be improved. In the next chapter the ERPR tool is applied to the 32 chairs made from renewable carbon-based plastics.

Part B

Environmentally Responsible Product Rating—an eco-audit tool

Chapter 5

Hopeful monstrosities? Applying the ERPR tool

[591] Joel described new technologies as 'hopeful monstrosities,' 'they are 'hopeful', because product champions believe in a promising future, but 'monstrous' because they can perform crudely,' which can be particularly true when examining their environmental impact. Joel Mokyr, *The Lever of Riches: Technological Creativity and Economic Progress* (Oxford: Oxford University Press, 1990), 291.

The aim of this chapter is to apply my Environmentally Responsible Product Rating (ERPR) tool to identify which of the 32 niche experiments in chair design selected for analysis deliver better environmental outcomes, and which are little more than 'hopeful monstrosities.'[592] Economist Joel Moyr introduced the term with reference to technological innovation in 1990, highlighting that there are lessons to be learnt even from poorly performing experiments. In this chapter a detailed analysis of the performance of those chairs under study is presented to reveal what can be learnt from these designers and their innovations with new materials. Their experience provides a rich source of reference for the following chapters that develop a model to support wider use of renewable plastics.

To simplify comparisons between such a large selection of case studies, similar chairs have been grouped together by the primary materials used in their manufacture. Six of the designs are made using post-industrial recycled plastics, ten are made from post-consumer recyclates, six feature ocean plastic, and ten utilise bioplastics derived from renewable organic sources. Manufacturing innovations that promise to optimise the material and/or energy required to manufacture products are increasingly available. If these goals can be achieved, technologies such as 3D printing and artificial intelligence software could reduce the environmental impact of manufacturing activities. Selected designs using those innovative manufacturing technologies in combination renewable plastic are also assessed for their impact on environmental profiles.

I use the 'waste hierarchy' to organise the groupings from least favourable to most favourable, with designs that avoid the use of materials derived from fossil fuels (the most desirable outcome in the hierarchy) considered last. Grouping and ranking chairs in that way

[592] Mokyr, 291.

does not impact overall results, as the same scoring system is applied to all chairs, enabling direct comparison across categories. Relevant data was sourced from manufacturers' websites supplemented with other sources in the public domain. Selected exerts from interviews with designers and manufacturers conducted for this research are used to illuminate results and findings.

The relevant information and specifications required to calculate an ERPR score for each chair are shown in the tables at the start of each section below. Results can be replicated using the online version of the ERPR tool. Applying the tool successfully differentiated between the renewable plastic chairs included in this study and identified designs with superior environmental profiles. The chapter ends by showing the combination of materials and technologies most likely to deliver significantly better environmental impacts. Finally, a discussion of the weakest performing chairs—the 'hideous monstrosities'—demonstrates that there is much to be learned from these less successful experiments with renewable carbon materials. The results of this analysis provide clear guidance on the factors to be considered by product designers and other actors seeking to develop more sustainable solutions when working with plastics.

1. Evaluating designs incorporating recycled plastics

Increasing recycling rates is an important step toward developing a circular economy, moving away from a wasteful linear pattern of production and consumption resulting in large volumes of waste. A circular economy recognises value in waste and recovers and recycles resources from products at the end of their useful life. Reusing plastic as feedstock for new products maximises the longevity of previously extracted hydrocarbons, thereby reducing the consumption of virgin fossil fuels. The GHG emissions from recycling plastics are significantly below those released during the manufacture of virgin material. In the case of PET, for instance, the reduction in GHG can be up to 60% when using 100% recycled material.[593] This improved circularity addresses not only climate change (through reduced emissions) but also growing concerns regarding land use (either for landfills or growing feedstock for bioplastics).[594] The waste hierarchy recognises the relative benefits of recycling, ranking it above landfill or incineration in order of preference for waste disposal.

Many designers have experimented with recycled plastics for chairs. The first challenge for a designer seeking to work with recycled polymers is to decide on the source and type of plastic to be used. Waste plastic can be collected from industry, households, or the ocean. Plastics are sorted by type prior to being recycled, enabling designers to specify their material preferences using the standard resin identification codes (RIC). Polypropylene and PET are the most popular resin types used by those experimenting with recycled materials to make chairs.

[593] Franklin Associates, "Cradle-to-Resin Life Cycle Analysis of Polyethylene Trephthalate Resin," March 2020, 24, https://napcor.com/wp-content/uploads/2020/05/Final-Revised-Virgin-PET-Resin-LCA.pdf. See also Ashby, *Materials and the Environment*, 503., who estimates 54%.
[594] Ellen McArthur Foundation, "New Plastics Economy - The Future Of Plastics," np.

a. Recycled post-industrial polypropylene

The main advantages of recycling post industrial waste plastic is that it avoids the costs and carbon impacts associated with collecting, sorting, and cleaning mixed waste (usually post-consumer) plastic. The material can be collected directly from the primary production facility, allowing users to be certain of the material's composition and to be assured of a consistent supply (both quality and quantity are assured). Users can be certain the material is being recycled for the first time, important as plastics typically degrade in quality with each cycle.

Five chairs manufactured using industrial waste polypropylene are compared to assess their environmental profiles: Philippe Starck's *Broom Stacking Chair*, Javier Mariscal's *Green Chair,* John Löfgren & Jonas Pettersson's *Odger*, Jasper Morrison's *1 Inch Reclaimed*, and Konstantin Grcic's *Bell Chair* (fig. 5.1).

Fig. 5.1. Chairs made using industrial waste polypropylene
Source: (clockwise top left) Emeco, M114, IKEA, Magis, Emeco

Recycled post-industrial polypropylene chairs

Chair	Designer	Manu-facturer	Date	Material 1	Material 2	Kg	Stacks	Cols	Styles	Price (AUD)
Broom	Philippe Starck	Emeco	2012	polypropylene (75%)	wood (15%)	4.5	6	6	1	321
Green Chair	Javier Mariscal	M114	2016	polypropylene (100%)	wood or metal bases	5*	8 (metal base)	4	2	252
Odger	John Löfgren & Jonas Pettersson	IKEA	2017	polypropylene (70%)	wood (30%)	5*	0	4	2	99
1 Inch Reclaimed	Jasper Morrison	Emeco	2018	polypropylene (88%)	wood (2%)	5.2	10	8	1	270
Bell	Konstantin Grcic	Magis	2020	polypropylene (almost all)	Fibreglass	2.7	24	3	1	125

*Weights are estimates as only total weight of chair and transport packaging disclosed.

Table 5.1. Details of chairs made from post-industrial waste polypropylene

Environmentally Responsible Product Rating

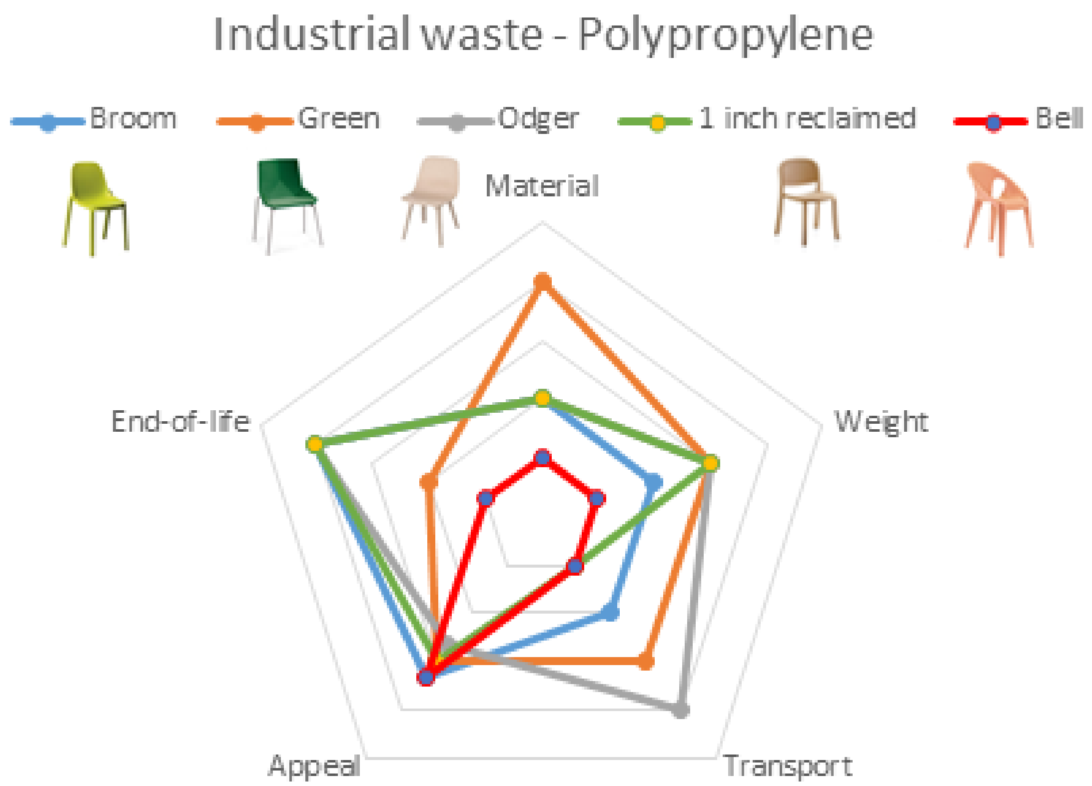

Fig. 5.2. Chart illustrating ERPR scores awarded to chairs made from recycled industrial waste polypropylene

Chair	Material	Weight	Transport	Appeal	End of life	ERPR
Broom	3	3	3	2	1	**12**
Green Chair	1	2	2	2	3	**10**
Odger	3	2	1	2	1	**9**
1 Inch Reclaimed	3	2	4	2	1	**12**
Bell Chair	4	4	4	2	4	**18**

Table 5.2. ERPR scores awarded to chairs made from recycled industrial waste polypropylene

German industrial engineer, Konstantin Grcic's *Bell Chair* only requires only about half the quantity of material needed to create the other chairs (table 5.1). At just 2.7kg the *Bell Chair* is the lightest of the 32 chairs I analyse. While it is not possible to source the information necessary to accurately compare the resources required to manufacture the chairs, some observations on significant differences between the designs can be made. The three monoblocs (*Broom Stacking Chair*, *1 Inch Reclaimed*, and *Bell Chair*) are most likely to consume fewer resources during their production, as they are manufactured in a single automated process. The *Bell Chair* is particularly noteworthy as it can be moulded in less than one minute, with lower variable costs that can be passed on through a lower retail price. In contrast, the *Odger* requires four separate components to be manufactured and packaged (together with a leaflet giving instructions for self-assembly), while the *Green Chair* is constructed from a large number of components using different materials (depending on the base selected).

The efficiency with which chairs can be transported for distribution is a function of their volume, weight, and the distance travelled. The designer can influence the first two of those factors. All designs benefit from the use of polypropylene that, with a specific density of between 0.895 and 0.92 g/cm^3, is the lowest among plastics. The three monobloc designs have the advantage here as they can be stacked for transportation and storage to reduce volume (the metal-based version of the *Green Chair* can also be stacked). The *Bell Chair* leads the field with its low unit weight combined with its ability to be stacked vertically up to 24 units high. Indeed, the *Bell Chair* leaves the factory stacked 12 units high ready for transportation, on its own purpose designed pallet (also made from recycled polypropylene). Stacked *Bell Chair*s occupy the same floor space as a single chair, further improving the efficiency of the design, which has been optimised for containerisation. Taking a different approach to save space during transportation and storage, IKEA*'s Odger* arrives disassembled, allowing the size of the packaged chair to be dictated by the size of the shell.

End of life prospects are best for the *Bell Chair*, made 'almost entirely' from recycled polypropylene it can, theoretically at least, be recycled using existing infrastructure. The shell and legs of the *Green Chair* can be manually disassembled, with the two components recycled separately, again using existing infrastructure. Emeco chairs are sold with a take-back guarantee but this (as with similar schemes offered by other manufacturers) is of limited value. Both the cost and environmental impact of returning the chairs to their single point of manufacture is prohibitive for most users. Together with the *Odger*, Emeco designs are made from polypropylene mixed with wood which precludes them from recycling using existing infrastructure.

While all the chairs in this section are, at least in part, made from the same material, there are some significant differences in aesthetics worthy of comment. Some of the designs include recycled wood, which gives a 'warmer, more natural touch than raw polypropylene,' according to Jasper Morrison.[595] However, when the *1 Inch Reclaimed* launched it contained 15% wood fibre and this has been reduced to just 2% in recent years.[596] With such a low percentage of wood currently used for this chair the impact on touch is substantially less than when the design was first introduced. IKEA's *Odger* contains 30% wood fibre content, visible on the surface and creating a very different texture from traditional polypropylene. Grcic's *Bell Chair* contains visible speckles also signalling the use of recycled plastic. Chairs manufactured by Emeco are available in a broader colour range that their competitors, with the *1 Inch Reclaimed* available in eight colours and the *Broom Stacking Chair* in six. While the *1 Inch Reclaimed* and *Bell Chair* are available in muted colours (typical of products made from recycled materials) the other three designs offer brighter colour options that broaden the appeal of the designs. The *Bell Chair* offers the least variety in colour choice with dark blue and white versions complimented with only one other colour choice, pink.

By far the highest ERPR score in this section was awarded to the *Bell Chair* (table 5.2). A well-defined brief was cited by both the designer and a representative from the manufacturer as crucial to the success of that project.[597] Magis specified their requirement for a competitively-priced, injection-moulded, monobloc chair in polypropylene. Additionally, the brief dictated that the amount of material used should be minimised together with the cycle time required on the injection moulding machine, as these are key

[595] Designboom, "Jasper Morisson's 1 Inch Reclaimed Chair for Emeco," designboom | architecture & design magazine, May 5, 2018, 1 accessed February 3, 2022, https://www.designboom.com/design/jasper-morisson-1-inch-reclaimed-chair-emeco-05-05-2018/.
[596] Isaac, Interview with John Tree from Jasper Morrison Office.
[597] Isaac, Interview with Konstantin Grcic; Isaac, Interview with Ruben Hutschemaekers, Magis.

contributors to costs. Finally, the brief demanded that the chair, when stacked, should occupy the same footprint as a single chair. Konstantin Grcic reported that this was the first time he worked within such strict parameters but found the experience rewarding, as the detailed brief developed by the client directed his design enquiries.[598] Key to success was forming a close relationship with the third-party engineering partner responsible for making the moulds, pre-mould testing, and production management. The egg-shape shell was arrived at quite quickly, as the most efficient solution to weight and strength requirements. Similarly, the shape of the legs was informed by previous efficient monobloc solutions, dating back to the first sheet metal chairs from the 1920s and Henry Massonnet's design for the *Fauteuil 300* plastic monobloc in 1972. Having quickly arrived at the basic shape it took nearly a year to perfect the final design, incorporating feedback from the mould flow analysis while the project was imbued with comfort and beauty.[599]

b. Post-consumer recycled plastics

Recycling post-consumer plastics introduces cost and complexity to the process. Plastic waste usually must be separated from mixed-waste streams from households at material recovery facilities. To be recycled, plastics must first be sorted by type (RIC) using a range of technologies but still requiring significant manual effort. Waste plastic is then cleaned and transported again to enter the recycling process. Other plastics are recycled after being recovered from the environment or even the ocean, again adding cost to the process. Despite those additional hurdles, it is imperative that applications for recycled post-consumer plastics identified as they make up the largest component of the plastic problem. In Australia, during the 2016/17 financial year, nearly half of all plastic waste came from

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[598] Isaac, Interview with Konstantin Grcic.
[599] Isaac.

households with manufacturing accounting for just 15% from manufacturing.[600] It is important to reiterate that delivering on the more sustainable vision for the future of plastics is dependent on identifying productive uses for recycled household plastics.

i. Recycled post-consumer PET

PET is the most commonly recycled plastic and has lower embodied energy (39 MJ/kg) compared with the other common plastics, making the polymer an ideal material for environmentally-conscious designers to consider.[601] I have analysed three chairs made from recycled PET: Boris Berlin & Poul Christiansen's *Nobody Chair*, Emeco's *111 Navy Chair*, and Edward Barber & Jay Osgerby's *On & On Stacking Chair* (fig. 5.5).

Fig. 5.5. Chairs using post-consumer PET Source: (clockwise top left) Hay, Emeco, Emeco

[600] See: Australian Bureau of Statistics, "Waste Account, Australia, Experimental Estimates, 2018-19 Financial Year," June 11, 2020, accessed February 3, 2022, https://www.abs.gov.au/statistics/environment/environmental-management/waste-account-australia-experimental-estimates/latest-release.

[601] Ashby estimates 20-22% of PET is recycled compared with average of just 9% for all plastics Ashby, *Materials and the Environment*, 503.

Recycled PET chairs

Chair	Designer	Manu-facturer	Date	Material 1	Material 2	Kg	Stacks	Cols	Styles	Price (AUD)
Nobody Chair	Boris Berlin & Poul Christiansen	Hay	2007	PET felt	N/A	4.7	4*	1	1	1800
111 Navy Chair	Emeco	Emeco	2010	PET (65%)	Fibreglass (35%)	5.4	0	7	1	480
On & On Stacking Chair	Edward Barber & Jay Osgerby	Emeco	2019	PET (70%)	Fibreglass (20%) non-toxic pigments (10%)	3.5	7	6	1	550

* Estimate based on available information.

Table 5.5. Details of chairs made using post-consumer recycled PET

Environmentally Responsible Product Rating

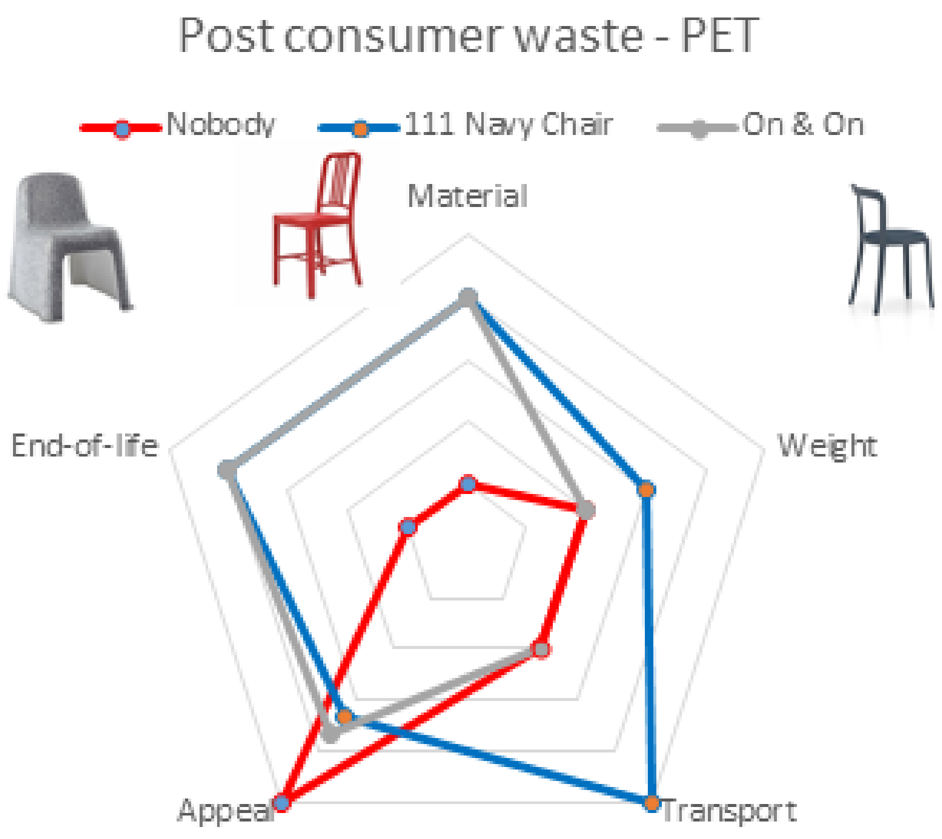

Fig. 5.6. Chart illustrating ERPR scores awarded to chairs made from recycled PET

Chair	Material	Weight	Transport	Appeal	End of life	ERPR
Nobody Chair	4	3	3	0	4	**14**
111 Navy Chair	1	2	0	2	1	**6**
On & On Stacking Chair	1	3	3	1	1	**9**

Table 5.6. ERPR scores awarded to chairs made using post-consumer recycled PET

While the two Emeco chairs are both primarily recycled PET, the material has been mixed with relatively large quantities of fibreglass reducing the scores awarded to these products for both materials and end-of-life prospects (table 5.6).[602] The *111 Navy Chair* failed to score well for any attribute, as the chair cannot be stacked to improve transport efficiently and can only be recycled if returned to the manufacturer. While available in a range of seven colours, the Navy chair is offered only in one configuration. Despite the lacklustre ERPR, the commercial success of the *111 Navy* Chair should be highlighted. Commissioned by Coca Cola, this plastic version of the company's aluminium 1006 chair (in continuous production since 1944) reportedly includes 111, recycled 600ml PET Coke containers. In an interview for this research the CEO of Emeco claimed that nearly 40 million containers had been diverted from landfill because of that project.[603]

Also manufactured by Emeco, the *On & On Stacking Chair* is noteworthy for its minimal use of material. In an interview for this research the designers claimed:

> The chair has been designed to use as little material as possible, making it extremely lightweight. The efficient use of plastic ensures lower carbon emissions when shipping, making this chair completely sustainable[604]

[602] Recently decreased from 35% to 20% see: Emeco, "Sustainability Report 2020," 2021, https://www.emeco.net/about/sustainability/sustainability-report-2020.
[603] Buchbinder, Gregg Buchbinder.
[604] "Barber and Osgerby Create Chair for Emeco That Can Be Endlessly Recycled," Dezeen, April 5, 2019, https://www.dezeen.com/2019/04/05/emeco-on-and-on-chair/.

The designers were keen to highlight the sustainable aspects of that design and developed a spiral stacking system (up to seven units high) to minimise the footprint during transport or storage. Emeco has developed a range of colours for both of those chairs, which are brighter than those offered by most competitors working with recyclates. Like the *111 Navy Chair*, the *On & On Stacking Chair* must be returned to the manufacturer for recycling, another consideration contributing to the mid-range ERPR achieved by this design.

The *Nobody Chair* achieved the highest ERPR among the chairs made from recycled PET. The unusual form was inspired by the cloths thrown over furniture for protection when a house is being locked up.[605] Promoted as the first monobloc made from textiles, *Nobody Chair* is shaped from a single sheet of PET felt, giving the impression of floating without support. Using technology developed by the automobile industry designed to make shelves for cars, the chair is moulded in one process from a mat made from recycled drink containers. Compression moulding consumes less energy than the injection moulding process used to create most of the designs included in my study. It also avoids the cost of expensive moulds. *Nobody Chair* is offered in two colours, affecting the score awarded for appeal (although the child's version was previously offered in four colours).

[605] See: Boris Berlin Design, "Nobody," accessed February 3, 2022, https://www.borisberlin.design/work/nobody/.

ii. Recycled post-consumer polypropylene

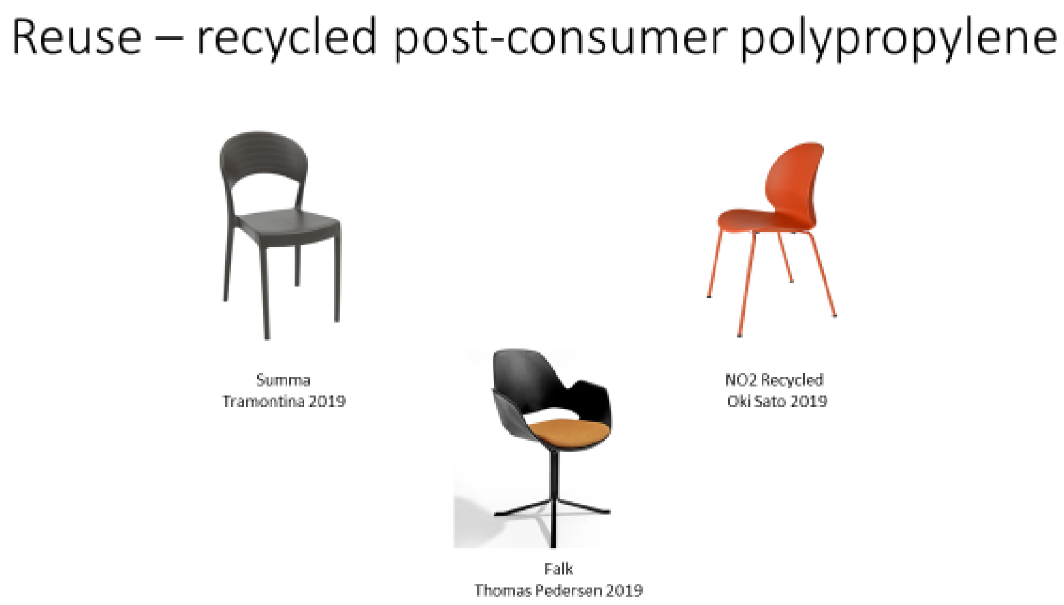

Fig. 5.3. Chairs made using post-consumer polypropylene
Source: (clockwise top left) Tramontina, Fritz Hansen, Houe

Three chairs manufactured using post-consumer recycled polypropylene are compared in this section: Tramontina's *Sissi* (from the *Summa* range), Thomas Pedersen's *Falk,* and Oki Sato's *NO2 Recycled* (fig. 5.3).

Recycled post-consumer polypropylene chairs

Chair	Designer	Manu-facturer	Date	Material 1	Material 2	Kg	Stacks	Cols	Styles	Price (AUD)
***Sissi* (Summa range)**	Tramontina	Tramontina	2019	PP	N/A	2.8	8	2	2	71
Falk	Thomas Pedersen	Houe	2019	PP 75%	fibreglass 20% + legs + recycled polyester padding	5*	5	4	5	307
N02 Recycled	Oki Sato	Fritz Hansen	2019	PP	steel or aluminium base	5.8	10	7	6	400

*Estimates only as no specific details given by manufacturer.

Table 5.3. Details of chairs made using post-consumer recycled polypropylene

Environmentally Responsible Product Rating

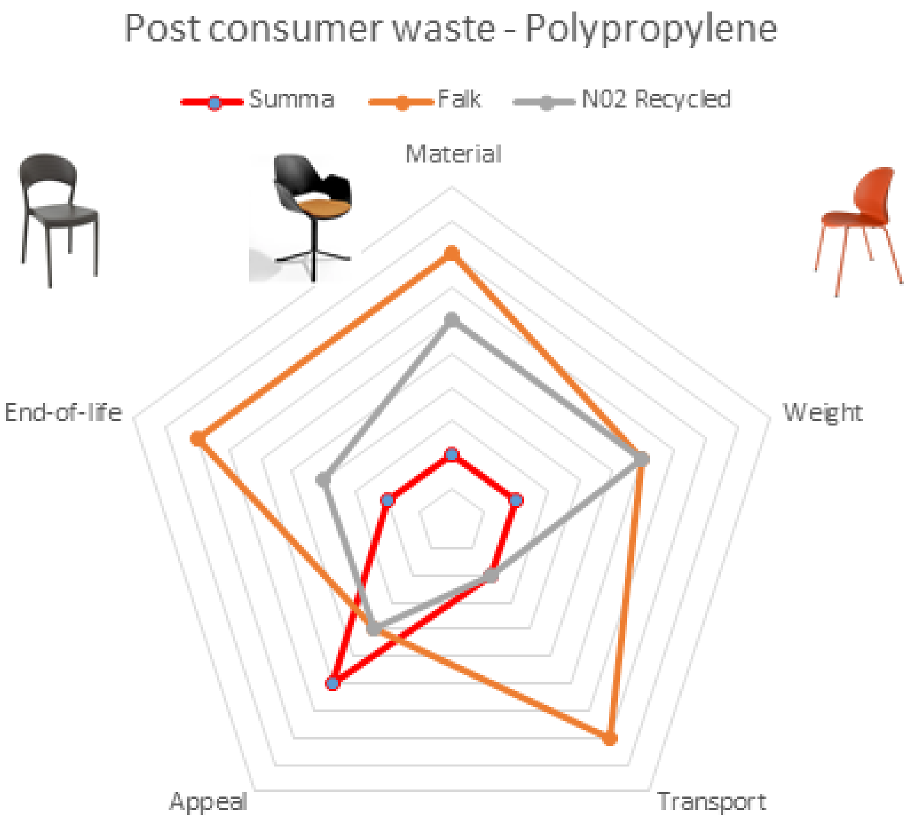

Fig. 5.4 Chart showing ERPR scores awarded to post-consumer polypropylene chairs

Chair	Material	Weight	Transport	Appeal	End of life	ERPR
***Sissi* (Summa range)**	4	4	4	2	4	**18**
Falk	1	2	1	3	1	**8**
N02 Recycled	2	2	4	3	3	**14**

Table 5.4. ERPR scores awarded to chairs made using post-consumer recycled polypropylene

While all three of the designs are primarily made from recycled polypropylene, the *Sissi*, by the Brazilian manufacturer/retailer Tramontina in partnership with chemical giant Braskem, is the only monobloc, meaning the design earned the highest score for both materials and end-of-life prospects (table 5.4). The *Sissi* is the second lightest chair included in my study, weighing just 100g more than Grcic's *Bell Chair* and earning the design a top EPRP for weight. By contrast, the *Falk* lost points for both material and weight, as 20% fibreglass has been added to the plastic shell and different (virgin) materials are used for the base, affecting the score awarded for end-of-life prospects too. The *NO2 Recycled* weighs about the same as the *Falk* but the steel-sledge base is made from 50% recycled content and the pedestal base version is made with 95% recycled aluminium. None of the manufacturers provide specific information about the source of their recycled plastics or the associated environmental impacts of collecting, sorting, and recycling post-consumer waste.[606]

Both the *Sissi* and the *NO2 Recycled* (sledge and tube version) can be stacked at least eight units high, allowing them to be transported more efficiently and earning a top score for this criterion. By contrast, the base and shell of the *Falk* are shipped separately in two boxes. To appeal to both the domestic and corporate markets the *Falk* and *NO2 Recycled* are both available with or without arms and with a range of base options including a pedestal or a more traditional four leg solution. While the *NO2 Recycled* is available in seven colours, shell colour choices for the *Falk* are limited (black and dark grey) but the padded seat (filled with 98% post-consumer recycled polyester) has been used to enhance variety, being available in a range of four colours. The *Sissi* failed to achieve an impressive score for appeal, as it comes in just two colours and only two other variations of the design are available. Despite that low score for appeal the *Sissi* emerged with the highest ERPR rating in this category.

[606] Plastic for the *N02 Recycled* is sourced from Eastern Europe (country not specified) and the chair is made in Poland.

iii. Recycled post-consumer plastics – small scale projects

Fig. 5.7. Small projects using recycled plastics
Source: (clockwise top left) Tom Price, Arne Jennard for ecoBirdy, DesignByThem

Three smaller scale projects are considered in this section: Tom Price's *Meltdown Chair*, Nicholas Karlovasitis & Sarah Gibson's *Butter Chair*, and Vanessa Yuan & Yoris Vanbriel's *ChairCharlie* (fig. 5.7).

Smaller recycled plastic projects

Chair	Designer	Manufacturer	Date	Material	Kg	Stacks	Cols	Styles	Price (AUD)
Meltdown Chair	Tom Price	Tom Price	2007	polypropylene	8*	0	m	1	high
Butter Chair	Nicholas Karlovasitis & Sarah Gibson	Design by them	2011	HDPE (80%)	6.4	0	9	1	550
ChairCharlie	Vanessa Yuan & Yoris Vanbriel	ecoBirdy	2018	recycled toys	2.9	0	6	1	259

Table 5.7. Details of small projects made using recycled plastics

Environmentally Responsible Product Rating

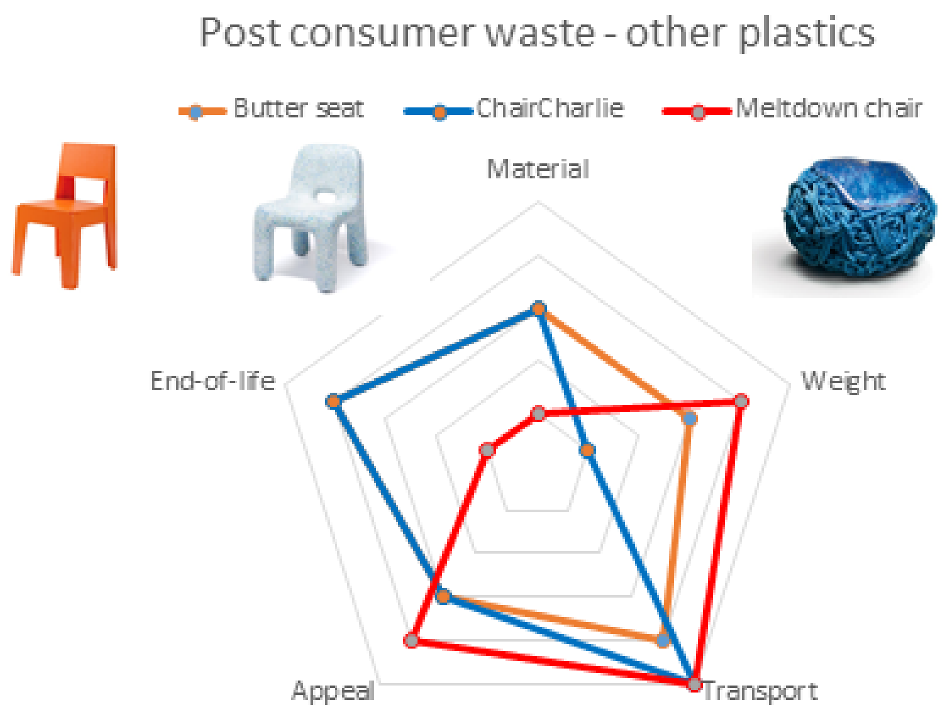

Fig. 5.8. Chart illustrating ERPR scores awarded to small projects using recycled plastics

Chair	Material	Weight	Transport	Appeal	End of life	ERPR
Meltdown Chair	4	1	0	1	4	**10**
Butter Chair	2	2	1	2	1	**8**
ChairCharlie	2	4	0	2	1	**9**

Table 5.8. ERPR scores awarded to small projects using recycled plastics

The designers responsible for those projects have avoided (or were unable to access) expensive manufacturing processes (especially injection moulding), instead investigating alternative methods to work with recycled materials. While those projects are commendable for the initiative they display, it should be noted that none of them achieved sufficiently high ERPR scores to feature among the best performing designs in my study (table 5.8).

The *Meltdown Chair* is made from polypropylene nautical rope (of any available colour), rolled into a ball, heated, and a form pressed into it. Designer, Tom Price used the shell from an Eames armchair to create the form used to melt an impression into the ball of material. In an interview with me, Price explained that the process, nine months in development, had:

> Originated from playing with a length of polypropylene rope. I was interested in the way it was possible to melt and reform sections of the rope simply by applying heat. Pressing a flat piece of metal onto the rope as it melted enabled me to reform the material from something quite rough and flexible into something smooth and rigid.[607]

Weighing in at 8kg, the *Meltdown Chair* does not economise on volume materials (which take up to two hours to melt), but the broad range of colours available and good end-of-life prospects for the chair mean the design achieved relatively good scores.

Designed and distributed by the Australian company DesignByThem, the *Butter Chair* entered development in 2010. When I interviewed Sarah Gibson, co-founder of DesignByThem and co-designer of the *Butter Chair*, she explained that the project was created in response to her desire to create a chair using recycled plastic available in Australia.[608] The only material available (apart from pellets for prohibitively high-volume injection moulding) was a recycled high-density polyethylene (HDPE) sheeting material, developed for use as a sound barrier at roadside construction sites. Plaspanel is made from a core of 80% recycled content, with a UV stable and waterproof outer. The outer core is made from virgin material allowing the *Butter Chair* to be offered in a range of bright colours not traditionally associated with recycled materials, increasing its aesthetic appeal. Chairs and stools in the *Butter* range are all constructed by simply scoring and bending sheets of the

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[607] Geoff Isaac, Interview with Tom Price, March 7, 2019.
[608] Geoff Isaac, Interview with Sarah Gibson, February 25, 2020.

Plaspanel material. Although the concept sounds simple it took years to perfect the design as Gibson explained:

> We had come across some hinging ideas in packaging where they cut the material very fine and use that weak point to fold the material in different ways. We started mocking things up in paper a lot of trial and error trying to machine the grove just right—if it is too thin it snaps, if it is too thick it doesn't fold properly. It took three or four years to get that process right.[609]

The design was modified to accommodate the material as the project evolved—the height and width of the chair adjusted so that four stool could be made from a single sheet of HDPE, minimising waste. Additionally, the legs were made quite thick and stocky to accommodate four plastic screws needed to attach the leg to the shell. Unfortunately, the material is no longer available locally and manufacturing has been moved overseas (using recycled industrial waste HPDE). To reduce volume and associated transport costs, chairs are shipped flat, assembled locally and distributed to purchasers fully assembled. At the end-of-life chairs can be returned to the manufacturer for recycling.[610]

EcoBirdy, a small organisation based in Antwerp, was established to recycle discarded plastic toys into colourful, kid-sized furniture. According to the designers, the idea for EcoBirdy was sparked by an UNEP report which claimed: 'the toy sector has by far the highest intensity' in its use of plastics.[611] Toys are often made from a combination of different plastics preventing them from being recycled along with ordinary household waste and often end up in landfill.[612] Following two years research and development the designers developed ecothylene—a patented technology that requires 'no pigments or new plastics need to be added. Making ecothylene significantly more eco-friendly than most recycled

[609] Isaac.
[610] Isaac.
[611] UNEP Valuing plastics, 2014, 7.
[612] "Plastic Toys: Is It Time We Cut Back?," *BBC News*, April 11, 2019, sec. Science & Environment, accessed February 3, 2022, https://www.bbc.com/news/science-environment-47868871.

plastics.'[613] The process of developing the 2.9kg child's chair does still require some manual sorting of materials but automated colour sorting has enabled ecoBirdy to move away from the 'greyish, dullish' image of recycled plastics and produces ecothylene in a range of six bright colours without the use of pigments.[614] The terrazzo effect finish produced by this process is promoted as a benefit, ensuring every product produced from ecothylene displays a totally unique finish.

All three of these experiences give an insight into one of the main challenges of experimenting with a new material or adapting an existing material for a new use. Designers and their supporters seeking to experiment with new materials must be prepared to invest significant resources (particularly time) into developing designs for production. While those three designs failed to rank among the highest scoring ERPRs, they all achieved average ratings, outperforming many designs from leading competitors. Perhaps driven by economic necessity those designers have all developed highly innovative solutions to working with renewable plastic and learnings from those projects will be examined in more detail in following chapters.

iv. Recycled ocean plastics

Since 2017, the use of recycled ocean plastics to create new consumer products has increased significantly. This section considers six chairs promoted as being made from ocean plastics: Eugeni Quitllet's *Love* and *Ibiza*, *Ocean Collection*, an update on a design by Jørgen & Nanna Ditzel, Snøhetta's *S-1500*, Polywood's *Ocean Chair (*from the *Wave* series*)*, and ScanCom's *DuraOcean* (fig. 5.9).

613 "Ecothylene®," ecoBirdy, accessed February 3, 2022, https://www.ecobirdy.com/blogs/news/ecothylene%25c2%25ae.
614 "Ecothylene®."

Fig. 5.9. Chairs made using recycled 'ocean' plastics
Source: (clockwise top left) Vondom, NCP, Mater, ScanCom, Polywood, Vondom

Recycled ocean plastics

Chair	Designer	Manufacturer	Date	Material 1	Material 2	Kg	Stacks	Cols	Styles	Price (AUD)
Love	Eugeni Quitllet	Vondom	2018	polypropylene	fibreglass	4	4*	3	1	155
S-1500	Snøhetta	Nordic Comfort Products	2019	polypropylene (1500g)	steel (20% recycled)	4.2	6*	8	1	Low?
Ocean Collection	Jørgen & Nanna Ditzel	Mater	2018	polypropylene (960g)	steel legs	4	6	2	1	415
Ibiza (chair)	Eugeni Quitllet	Vondom	2019	polypropylene	fibreglass	5	4*	3	4	235
Ocean Chair	Polywood	Polywood	2020	polypropylene	N/A	17.7	0	14	1	300
DuraOcean	ScanCom	ScanCom	2020	polypropylene	plastic debris	4.7	0	1	1	300

* Estimate based on available information.
? Price not known (highest score awarded although chair is likely to be more expensive).

Table 5.9. Details of chairs made from recycled ocean plastics

A formal definition of ocean plastics is yet to be agreed upon. In common usage the term is used to refer to the estimated 8 to 10 million tons of plastic that end up in the oceans every year, some of which accumulates in gyres, the Great Pacific Garbage Patch probably the most famous.[615] At the other end of the scale, the term is confused (sometimes deliberately) with the term 'ocean bound plastics.' In the absence of a formal definition, the term is usually applied to any plastic waste within 50km of the coastline.[616] Proponents of this definition argue that plastic items littered within this distance are likely to end up in waterways and eventually the ocean. But it is unlikely that this would be the final destination of all such litter. Consumers purchasing products made from ocean plastics probably expect that their consumption is contribution to a reduction in the quantity of plastic actually in the ocean, but this is often not always the case.

Manufacturers, perhaps keen to capitalise on the media attention given to ocean plastics, appear to have taken a liberal approach to its definition, with some even including plastics that may have been used in the ocean but were never destined to end up in that environment. For example, Danish firm ScanCom manufacture the *DuraOcean* using recycled plastics with the 'majority' of the 3.5 kg plastic sourced from fishing nets and 'other salvaged plastic debris' (the chair is also available in a version using recycled household plastics).[617]

[615] Expected to increase to 29 million tonnes a year by 2040. Juliano Calil et al., "Neglected: Environmental Justice Impacts of Marine Litter and Plastic Pollution" (Nairobi: United Nations Environment Programme, April 1, 2021), 11, http://www.unep.org/resources/report/neglected-environmental-justice-impacts-marine-litter-and-plastic-pollution.
[616] The term 'ocean bound plastics' appears to have become popular since a 2015 paper published in Science reported on a model build to estimate the volume of plastic entering the ocean. This paper focused on communities living within 50km of the coastline. Jenna R. Jambeck et al., "Plastic Waste Inputs from Land into the Ocean," *Science* 347, no. 6223 (February 13, 2015): 768–71, https://doi.org/10.1126/science.1260352..
[617] See, https://www.scancom.net/products/duraocean/, accessed February 3, 2022.

Environmentally Responsible Product Rating

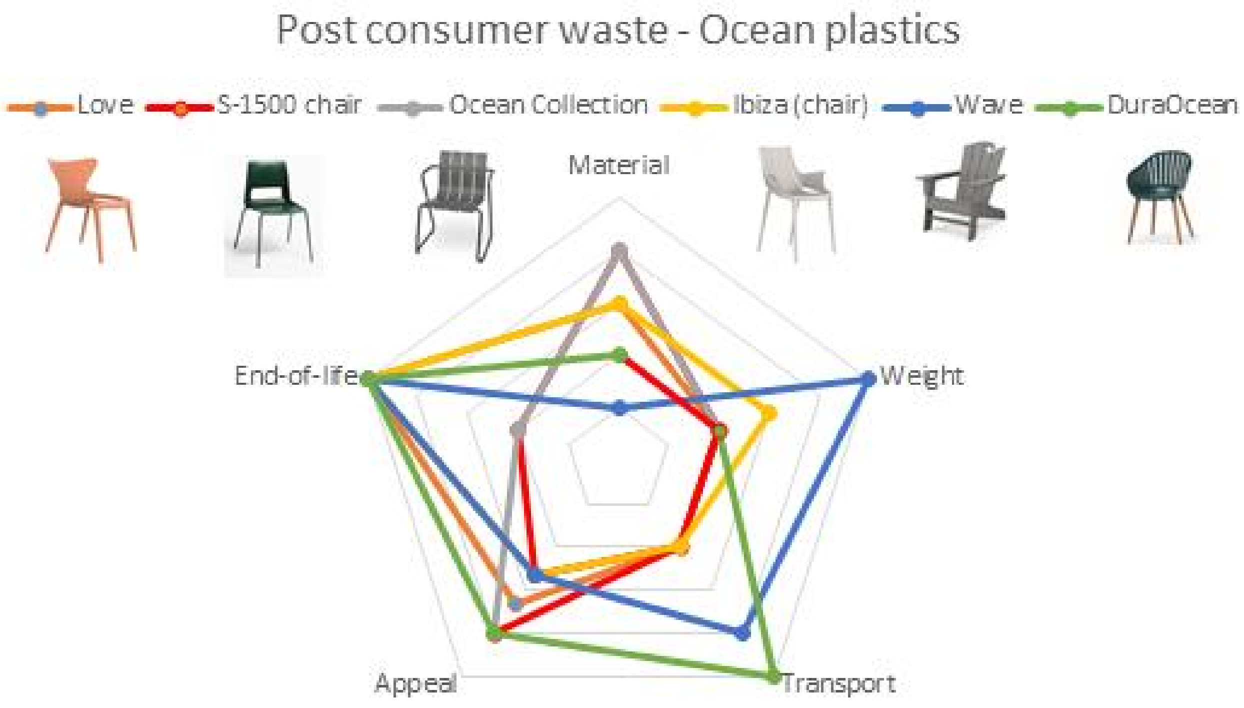

Fig. 5.10. Chart illustrating ERPR scores awarded to chairs made from recycled ocean plastics

Chair	Material	Weight	Transport	Appeal	End of life	ERPR
Love	2	3	3	2	0	**10**
S-1500	1	3	3	2	3	**12**
Ocean Collection	1	3	3	1	3	**11**
Ibiza (chair)	2	2	3	2	0	**9**
Ocean chair	4	0	1	2	0	**7**
DuraOcean	3	3	0	1	0	**7**

Table 5.10. ERPR scores awarded to chairs made using recycled ocean plastics

Similarly, NCP (*S-1500*) and Danish manufacturer, Mater (*Ocean Collection*), both source plastics from the Scandinavian fishing industry.[618] However, far from rescuing 'ghost nets,' it would appear that the unwanted fishing equipment was never actually destined to end its days in the ocean and would be recycled in any event.[619] NCP's claim that, 'when buying the *S-1500*, you contribute to reduce 1500 grams of plastic from the ocean,' could not be substantiated. Vondom manufacture two (gas injected) chairs designed by Eugeni Quitllet that feature material that is probably the closest to the common use definition of ocean plastics, as they are made from 'fishing nets, recycled plastic from the Balearic Islands and bottles collected from our seas.'[620] Yet, Vondom strengthen their recycled ocean plastic with fibreglass, with negative consequence for the end-of-life scores awarded to these two designs (table 5.10).

The *S-1500*, designed by the Norwegian architectural firm Snøhetta, features a metal base, also partially (20%) made from recycled steel, again recovered from the fishing industry, both the shell and base can be recycled at the end of its life. The *S-1500* is also noteworthy for the fact it comes in a range of eight marble effect colours that can be mixed and matched with a choice of seven colours for the frame available in two versions which helped secure the design the best overall scores in this section. As with ecoBirdy, NCP

[618] It is estimated that plastic lines, ropes, and fishing nets make up half (52 percent) of the plastic mass in the 'Great Pacific Garbage Patch' Lebreton et al., "Evidence That the Great Pacific Garbage Patch Is Rapidly Accumulating Plastic."

[619] In a press interview Snøhetta did reveal, 'the local farmed salmon industry would frequently wear out plastic components like its fishing nets, and it would actually need to pay a service to collect and dispose of them' Mark Wilson, "This Chair Made from Ocean Waste Hints at the Furniture of the Future," Fast Company, February 4, 2019, https://www.fastcompany.com/90300006/this-chair-made-from-ocean-waste-hints-at-the-furniture-of-the-future. It is highly unlikely that this plastic was ever destined for the ocean. Another online article reveals that Mater use the same (or similar) supplier Cajsa Carlson, "Mater Designs Stools Made of Spent Grain from Beer Production and Plastic from Insulin Pens," Dezeen, September 4, 2020, https://www.dezeen.com/2020/09/04/mater-mask-stool-earth-studio-eva-karlou-beer-carlsberg-sustainable/.

[620] Tim Spears, "Vondom Revolution Furniture to Be Made from Recycled Ocean Plastic," designboom | architecture & design magazine, November 5, 2019, https://www.designboom.com/design/vondom-revolution-sustainable-furniture-recycled-ocean-plastic-11-05-2019/.

promote the random marble effect obtained from the recycled material as a benefit, highlighting it as a unique feature of each chair. Mater's chair features a steel frame, but this is made from virgin material, negatively affecting the materials score awarded to that design.

North-American manufacturer Polywood's *Wave* series is promoted as being made from 'ocean bound' plastics, but, according to the company's website, the material comes from the manufacturer's own in-house recycling division that processes 'landfill-bound and ocean-bound plastic [HDPE] containers.'[621] At over 17kg the non-stackable Wave is, by far, the most material and transport intensive design in this section. However, the weight of an individual chair should not detract from the fact the company claim to recycle 400,000 containers a day across its entire range, equivalent to 146,000,000 milk cartons in 2019.[622] Sales of the *Ocean Chair* are probably assisted by the wide range of bright colours available.[623] Nonetheless, the *Ocean Chair* and *DuraOcean* are the weakest performing designs made from 'ocean plastics.' With ERPRs of only seven points both designs are among the poorest rating designs in my study.

2. Evaluating resource optimisation technologies

Designers have begun to experiment with 3D printing to produce chairs, while others are beginning to explore the potential of artificial intelligence (AI) software. Organic structures are often the source of inspiration for many of these designs. Many mid-century and Space Age designers were inspired by nature and incorporated shapes and curves into their

[621] See: https://www.polywood.com/new-and-featured/genuine-stories/recycling.html, accessed February 3, 2022.
[622] See: https://www.polywood.com/new-and-featured/genuine-stories/recycling.html, accessed February 3, 2022.
[623] According to the company's website "Genuine Recycling - Genuine Stories - New & Featured | POLYWOOD® Official Store," Polywood, accessed February 3, 2022, https://www.polywood.com/new-and-featured/genuine-stories/recycling.html.

designs. Today designers are looking beyond form to exploit the structural secrets of nature, enabling them to create forms with maximum strength while minimising the use of materials.[624]

a. Additive manufacturing - 3D-printing

Fig. 5.11. Chairs made using 3D printing
Source: (clockwise top left) Dirk Vander Kooij, Joris Laarman Lab, WASP, Nagami Design SL

Four chairs created using 3D printing are compared in this section Dirk Vander Kooij's *Chubby Chair*, Joris Laarman's *Puzzle Chair*, Manuel Garcia's *Voxel Chair v1.0,* and Fabio Novembre's *Ice-Dream* (fig. 5.11).

[624] James Harris, *Fractal Architecture: Organic Design Philosophy in Theory and Practice* (Albuquerque [N.M.]: University of New Mexico Press, 2012); Guidot, *Industrial Design Techniques and Materials*, 269–311; Laarman et al., *Joris Laarman Lab*.

3D-printing

Chair	Designer	Manufacturer	Date	Material	Kg	Stacks	Cols	Styles	Price (AUD)
Chubby Chair	Dirk Vander Kooij	Dirk Vander Kooij	2012	recycled refrigerator polypropylene (96%)	9	0	multi	1	1025
Puzzle Chair	Joris Laarman	Joris Laarman Lab	2014	PLA	5*	0	multi	1	135
Voxel Chair v1.0	Manuel Garcia	Nagami	2016	PLA	15	0	1	1	high
Ice-Dream	Fabio Novembre	WASP	2019	PLA (recycled)	10*	0	1	1	high

* Estimates only – based on available information.

Table 5.11. Details of chairs made using 3D printing

Environmentally Responsible Product Rating

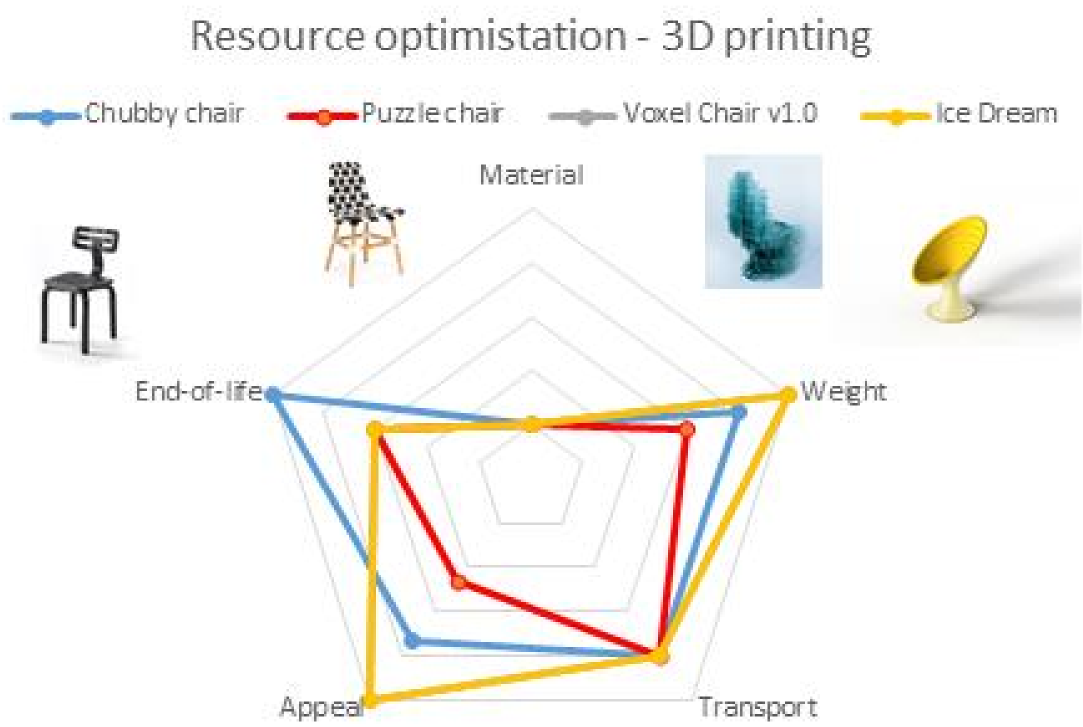

Fig. 5.12. Chart illustrating ERPR scores awarded to chairs made using 3D printing

Chair	Material	Weight	Transport	Appeal	End of life	ERPR
Chubby Chair	4	1	1	1	0	**7**
Puzzle Chair	4	2	1	3	2	**12**
Voxel v1.0	4	0	1	0	2	**7**
Ice-Dream	4	0	1	0	2	**7**

Table 5.12. ERPR scores awarded to chairs made using 3D printing

Significant material and energy efficiencies can be achieved by using 3D printing to produce plastic chairs. According to London-based designer and academic, Manuel Garcia, who told me in our interview:

> I specialise in 3D printing furniture. The very first comment we get is that is horrible for the planet because you printing in plastic. Actually, my production chain is so short that my carbon footprint is almost non-existent. We use very clean, non-emissive machinery, also very versatile machines—an industrial robot runs on very low energy. It is not even file to factory it is file to machine —our factory could be as small as this room. We don't have any shipping, we don't have any parts to be assembled, and expensive polluting processes. For example, ABS injection moulding that machine is very efficient, to make a *Panton Chair* in a number of seconds, the machine is already much more polluting than extruding the plastic in the way we do. People don't think we can save the world with plastics—I actually think we could—not just the plastics the way we use them. [625]

While Garcia claims his production process to be energy efficient much of the literature reports an opposing view. The 3D printing process can make significant energy demands. Energy is necessary to liquefy the filament needed to feed the extruder that deposits layers of the molten material to build objects. Energy is also consumed to heat the printer plate and chamber, which can make 3D printing an energy intensive exercise compared with industrial processes such as injection moulding.[626] Garcia's method uses a robot to position

[625] Isaac, Interview with Manuel Garcia.
[626] Valeria Annibaldi and Marianna Rotilio, "Energy Consumption Consideration of 3D Printing - IEEE Conference Publication," 2019, https://ieeexplore-ieee-org.ezproxy.lib.uts.edu.au/document/8792856.

the extruder and avoids the need for a plate and chamber, but the energy consumption of the robot needs to be considered to accurately assess the total energy needed to manufacture a chair. While my simplified eco-audit tool does not attempt to evaluate the energy consumed in manufacturing a design, it must be noted that 3D printing typically consumes significantly more energy compared with traditional manufacturing processes such as injection moulding.[627]

The *Voxel Chair v1.0* is modelled on Vernon Panton's famous cantilevered chair from 1967. While the original *Panton* was designed to be injection moulded, the *Voxel Chair v1.0* has been redesigned for computer-controlled robotic printing. Manuel Garcia explained the significance of his approach to me:

> Normally when you design an object to 3D print, you would first model a mesh-representation of the object in one software, and then slice it into layers or triangular toolpaths in another software [program]. These types of geometries are the easiest to control, and that's why we see them now so often. We turned the process upside down: the software allows to design a series of toolpath patterns, and then define the way they combine together in to an object, that consists of one continuous line (2.4km long) which can then be extruded (in PLA) by the robot.[628]

The designer claims to be able to create more intricate and functional objects using that technique. The parts of the chair that need to be very strong are printed with dense patterns while the seat is made flexible by incorporating a looser pattern. The self-written software is based on voxels (3-dimensional pixels) a technology grounded in the medical imaging

[627] In fact, 'the SEC [specific energy consumption] of additive processes was ~100-fold higher than that of conventional bulk-forming processes.' 3D printing introduces a new level of complexity when calculating LCAs as the energy source must be identified. If power is generated from renewable sources the environmental impact embodied in a 3D printed product is significantly decreased. Without calculating (or modelling) how the electricity was generated for each product printed the LCA cannot be calculated accurately. As detailed in this same paper, the resolution of the printer and the experience of the operator can also have significant impacts on energy consumption, further complicating comparisons of energy use. Felipe Cerdas et al., "Life Cycle Assessment of 3D Printed Products in a Distributed Manufacturing System," *Journal of Industrial Ecology* 21, no. S1 (2017): S80–93, https://doi.org/10.1111/jiec.12618.
[628] Isaac, Interview with Manuel Garcia.

industry. With traditional design software, objects are defined by modelling surfaces, but designers are not able to design the actual volume within. Using this new design software allows designers to consider and optimise every part of their creation. Importantly, the designer's focus shifts from defining the form of the chair to directly specifying the behaviours and properties required of the material in each location.

Despite the significant media attention given to the *Voxel Chair v1.0* following its inclusion in an exhibition at the Centre Pompidou in 2017, many of the designers I interviewed were unimpressed by this version. For example, Ron Arad asked:

> Does it look minimised to you? You only use technology because if it is the best technology to use not because it is 3D printed. You don't have to tell people it is 3D printed what you see is what you see.[629]

Garcia admits it is early days for the technology, and with the *Voxel Chair v1.0* weighing over 15 kg, there is little evidence to support the claims of material efficiency. Additionally, the chair is now printed using virgin fossil-based feedstock (as PLA proved too brittle for the task) increasing the environmental impact of the design.

Dutch designer Dirk Vander Kooji became fascinated by early 3D printers aimed at the consumer market while he was at college. The designer acquired an industrial robotic arm (due for retirement from a car production line), added an extruder, modified the software, designed and printed a chair, all within eighteen months (and while completing his undergraduate degree).[630] His *Chubby Chair* looks like it is piped straight from an icing bag or squeezed from a tube of toothpaste. The wide range of vibrant colours available also adds to the playfulness of the design. The low-resolution finish enabled production to be

[629] Isaac, Interview with Ron Arad.
[630] See: https://mydesignlife.com/objects/chubby-chair/

optimised to print up to 40 times faster than standard 3D printing at that time (2012). A chair that weighs 9 kg can be produced in 3 hours. The *Chubby Chair* is produced in two parts, with the legs bent into shape after they have been printed and then bolted to the shell by the end-user, delivering savings for transport. Material to manufacture *Chubby Chair*s is recovered from refrigerators; the white plastic (HDPE) interiors are stripped and pelleted to provide feedstock. The designer claims the provenance of the material was more important in its selection than environmental concern.[631] As an added environmental bonus, unsuccessful designs (or rejected prototypes) can be pelleted and re-cycled back into the manufacturing process. The *Chubby Chair* is the only chair in this section made using recycled material, the other two made from virgin PLA.

As a demonstration of its commitment to sustainability *Sammontana*, a 70-year-old Italian ice cream company, commissioned Fabio Novembre to develop a 3D printed chair using recycled PLA. The shape was inspired by a vortex or the swirl of an ice cream. WASP printed the design to showcase their technology, with each chair taking ten hours to print. The outer shell of the *Ice-Dream* is printed in a translucent material, contrasting with the bright yellow internal shells and creating an illusion that the chairs are melting. Despite the use of recycled PLA, the fact that the chair is only available in one colour and cannot be dismantled for transportation resulted in the relatively low ERPR awarded to this design.

Another Dutch design, Joris Laarman, conceived the *Puzzle Chair* to enable anyone with access to a 3D printer to download and print it.[632] The end-user becomes a participant in the design process (a 'prosumer') with the ability to specify their own choice of colour(s)

[631] 'The best thing about recycled plastic is it has history,' claimed Vander Kooji. "Fanuc & Dirk Vander Kooij's - Endless Project @ Milan Design Week 2011," *Dedece Blog* (blog), April 15, 2011, http://www.dedeceblog.com/2011/04/15/dirk-vander-kooij-faruc-milan-design-week-2011/.
[632] For the 3D print files and instructions visit, accessed February 3, 2022: https://www.bitsandparts.org/

and adjust the chair to their own requirements, limited only by their knowledge of programming. This project confronts one of the most pressing issues concerning digital fabrication, the potential for loss of control over intellectual property (IP). Once a design is distributed the original designer becomes a passive partner in the creation of the final object.[633]

Laarman's design takes full advantage of the potential for 3D printing to eliminate the retail sales channel, as the product can be materialised at or near the point of consumption.[634] Although 3D printing is often touted as eliminating distribution costs and associated environmental impacts this is not entirely true—the filament required for printing must still be shipped to the printer. In the case of the *Puzzle Chair*, sufficient filament to print 85 pieces is required together with two broom handles used for legs. Hobbyists tempted to print a chair need also to be aware that it will take about 240 hours on a standard domestic 3D printer.

All four of the designs considered in this section strive to avoid time consuming and potentially expensive post-printing activities associated with 3D printing. Manual finishing is typically required at the end of the 3D printing process which impacts time and cost efficiency. In particular, achieving a high-quality finish can be a 'considerable labour-intensive processes, such as sanding, filling/puttying, and polishing.'[635] In those three examples, built in support structures (or rafts) have been minimised, reducing the need for

[633] David Dick-Agnew, "On Now: Joris Laarman's Bits & Crafts," *Azure Magazine* (blog), May 13, 2014, https://www.azuremagazine.com/article/on-now-joris-laarmans-bits-crafts/.
[634] The other two chairs in this section are distributed from a single point of manufacture using traditional channels.
[635] Stefan Lie, "Assisting Product Designers with Balancing Strength and Surface Texture of Handheld Products Made from 3D Printed Polymers" (PhD, Sydney, University of Technology Sydney, 2020), 31, https://opus.lib.uts.edu.au/handle/10453/142440.

washing, scrubbing, peeling, and cutting to remove them before use. Similarly, the designs do not need polishing, sanding, chemical processing or painting to finesse their surfaces.

The relative light weight of the *Puzzle Chair*, together with the fact the end-user can choose their own colours, contributed to the *Puzzle Chair* being awarded the strongest ERPR in this section. However, none of the 3D printed designs achieved sufficiently high enough ERPRs to rank among the overall best scoring designs in this analysis (table 5.12).

b. Artificial Intelligence

Fig. 5.13*. AI Chair*, Philippe Starck *2019, made using* Artificial Intelligence software
Source: Kartell

At the 2019 *Salone del Mobile* in Milan, Kartell launched their latest plastic chair designed by Philippe Starck, claimed as the world's first production plastic chair designed using Artificial Intelligence (AI) (fig. 5.13).

Artificial Intelligence

Chair	Designer	Manufacturer	Date	Material	Kg	Stacks	Cols	Styles	Price (AUD)
AI Chair	Philippe Starck	Kartell	2019	recycled thermoplastic technopolymer	3.9	3	5	1	314

Table 5.13. Details of chairs made using Artificial Intelligence

Environmentally Responsible Product Rating

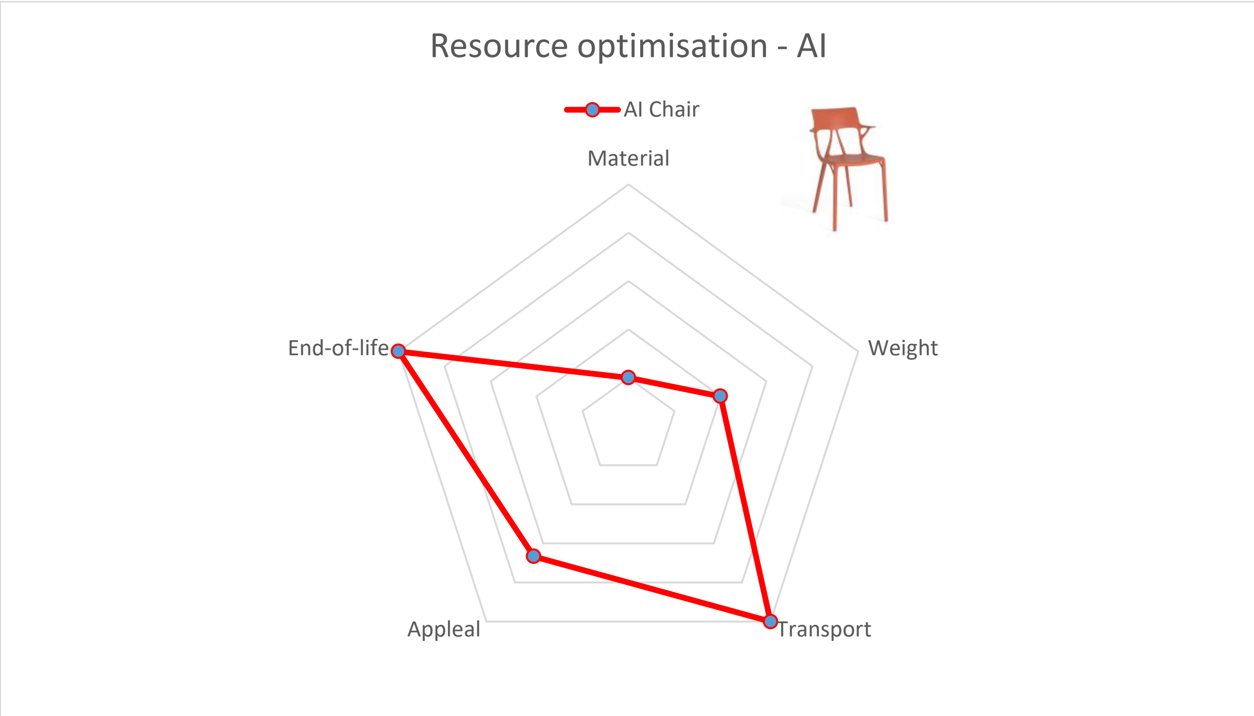

Fig. 5.14. Chart illustrating ERPR scores awarded to chairs made using artificial intelligence

Chair	Material	Weight	Transport	Appeal	End of life	ERPR
AI Chair	4	3	0	2	0	**9**

Table 5.14. ERPR scores awarded to chairs made using artificial intelligence

French industrial designer, Philippe Starck designed the injection moulded chair using prototype generative design software developed by *Autodesk*. A decade earlier, Joris Laarman pioneered the use of similar techniques to develop his *Bone Chair* (originally created in aluminium but also released in a polymer version).[636] While the *Bone Chair* was not conceived as a sustainable design, for that project Laarman developed software designed to minimise the use of materials while ensuring structural integrity to the furniture industry.

Originally developed for engineering solutions, AI software mimics the growth structures of bones and trees to optimise strength in designs. In contrast to additive 3D printing, the process starts with a virtual cube and subtracts matter to model an efficient form to fulfil the defined parameters. The design process is more akin to working with mechanical techniques with wood rather than moulding with plastics. Although AI assisted in the development of both chairs, they still relied on human intervention to refine the designs, and in the case of Starck's chair, to ensure the final product is stackable.

Despite combining leading-edge AI software with recycled material in a monobloc, Starck's chair only achieved an ERPR in the average range (table 5.14). The design is promoted as being made from 100% recycled 'thermoplastic techopolymer with mineral filler.'[637] While that might sound impressive to unsuspecting customers, the chair is actually made from mixed plastic production scraps, perhaps more accurately described as factory floor sweepings.[638] Unlike Starck's *Broom Stacking Chair*, which is made from polypropylene

[636] See: https://www.jorislaarman.com/work/bone-chair/, Accessed February 3, 2022.
[637] See: https://www.Kartell.com/BE/best-sellers/ai/BU05886, accessed February 3, 2022.
[638] Virtually all plastic chairs are made from thermoplastics and there appears to be no official definition of 'technopolymer.' ChemEurope.com claim the term is simply marketing jargon for plastic. 'Often used in products being marketed as high quality and, hence, the product makers prefer not to have the word "plastic"

factory waste, the materials for the *AI Chair* mixes different types of plastic with fillers, diminishing the end-of-life prospects for this design. Although the *AI Chair* can stack three units high the chair is shipped in cartons containing only two units, bringing down the score for transportation. As a monobloc there are no alternative versions of the model available and colour choice is restricted to five options.

3. Evaluating designs made from organic materials

Right at the top of the waste hierarchy are designs which completely avoid the use of fossil-based plastics. Some designers have begun experimenting with plastics made from organic material and with natural fibres.

a. Natural fibres

Fig. 5.15. Chairs using flax or hemp
Source: (clockwise top left) Moroso, Label/Breed, Danish Design Centre, Offect

mentioned in the marketing materials,' accessed February 3, 2022, https://www.chemeurope.com/en/encyclopedia/Technopolymer.html

Four chairs made from natural fibres are compared in this section: Werner Aisslinger's *Hemp Chair*, Christien Meindertsma's *Flax Chair*, Jin Kuramoto's *Jin*, and Nikolaj Carlsen *Coastal Furniture* (fig. 5.15).

Natural fibre chairs

Chair	Designer	Manufacturer	Date	Material 1	Material 2	Kg	Stacks	Cols	Styles	Price (AUD)
Hemp Chair	Werner Aisslinger	Moroso	2011	hemp (70%)	Water based resin	<3	4*	4*	1	high
Flax Chair	Christien Meindertsma	Label/Breed	2015	flax	PLA	<3	0	1	1	800
Jin	Jin Kuramoto	Offect	2018	flax	N/A	2.5	0	1	1	high
Coastal Furniture	Nikolaj Carlsen	TangForm (SeaweedShape)	2019	seaweed	Wood legs	8?	0	1	1	high

* Estimate based on available information.

Table 5.15. Details of chairs made from natural fibres

The cantilevered, monobloc *Hemp Chair* designed by German designer Werner Aisslinger, achieved the highest ERPR in this section, and ranked among the overall top performers (table 5.16). This extremely-light chair can be stacked for transportation (at least 4 units high) and is available in a variety of bright colours featuring a rough texture. The chair is made from natural fibres bonded with water-based glue, developed in conjunction with BASF, containing no phenols or formaldehyde. Hemp is particularly attractive as a renewable resource as it grows quickly without the need for fertilisers and removes carbon from the atmosphere. As with the *Nobody Chair*, compression moulding technology borrowed from the automobile industry is used to manufacture the *Hemp Chair*, with the design optimised to avoid waste. Cantilevered chairs are challenging to develop and only a handful of designers have succeeded in developing one using plastics.[639] This makes Aisslinger's achievement in developing the cantilevered *Hemp Chair* using natural fibre impressive. While most cantilevered designs depend on the give of the material to enhance comfort, the *Hemp Chair* is quite solid and does not yield significantly when sat on.

Environmentally Responsible Product Rating

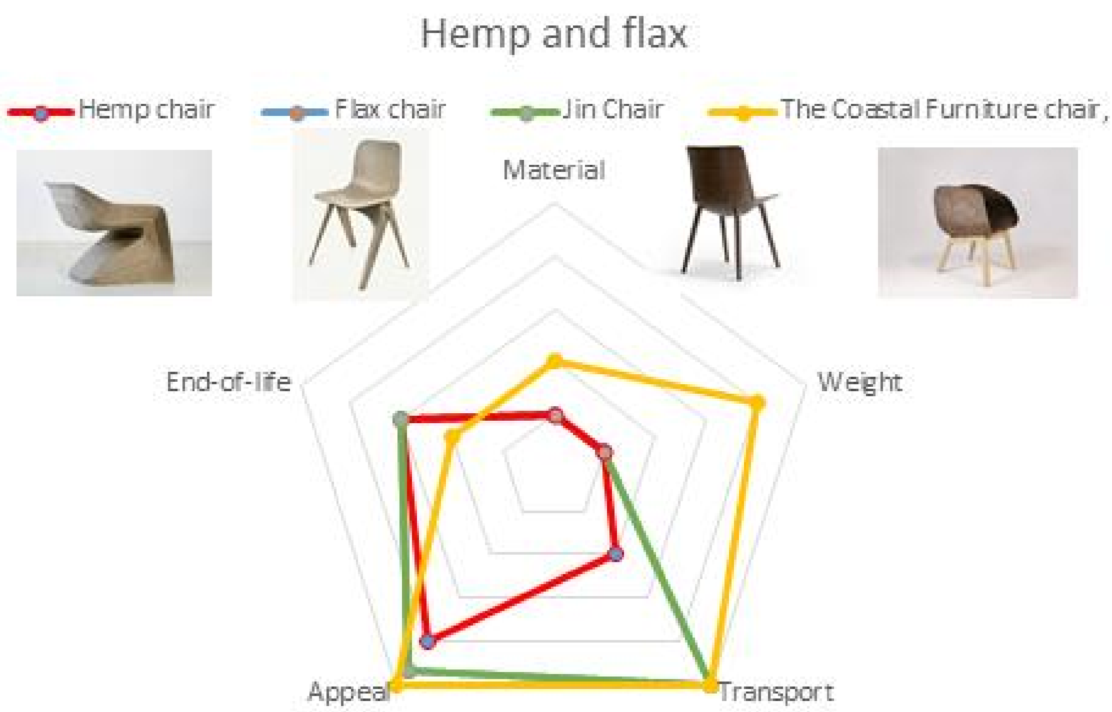

Fig. 5.16. Chart illustrating ERPR scores awarded to chairs made from natural fibres

Chair	Material	Weight	Transport	Appeal	End of life	ERPR
Hemp Chair	4	4	3	1	2	**14**
Flax Chair	4	4	0	0	2	**10**
Jin	4	4	0	0	2	**10**
Coastal Furniture	3	1	0	0	3	**7**

Table 5.16. ERPR scores awarded to chairs made using natural fibres

[639] Only nine plastic cantilevered designs were identified during research for this project, see: https://geoffisaac.com.au/chair-catalog and select the Cantilever option from the left-hand menu.

By avoiding the need for glass fibres, the *Hemp Chair* and *Flax Chair* are very light.[640] The two chairs I analysed made from flax scored poorly for transport, however, as they cannot be stacked or dismantled. Additionally, *Flax Chairs* are only available in only one natural colour and no variation to the basic design is available, limiting the aesthetic appeal.

The *Coastal Furniture* has received several sustainability awards but performed poorly when compared with the other chairs in this section.[641] The chair is made from seaweed (eelgrass) bound together with red algae (carrageenan). Those materials were familiar to the Danish designer, Nikolaj Carlsen, as they are used for roofing on the island of Læsø (in Denmark) where the seaweed-based material has demonstrated its resilience, often lasting many decades. The shell is biodegradable and is attached (using four brass brackets) to wooden legs made from recycled floorboards but is shipped fully assembled. Components need to be manually separated to facilitate composting and recycling. The weight of the chair combined with low scores for transport and end of life prospects resulted in the *Coastal Furniture* achieving the weakest ERPR rating in this section.

All the designs developed using natural fibres performed poorly for appeal. All four designs are offered in a single configuration. Only the *Hemp Chair* is available in a range of colours (four), while the remaining three designs offer no choices. The *Hemp Chair* is the only chair designed for stacking. Finally, all four designs are expensive, further limiting their market.

[640] Additionally natural fibres only require about one fifth of the energy required to make glass fibres and display mechanical properties that compare favourably. Lut Pil et al., "Why Are Designers Fascinated by Flax and Hemp Fibre Composites?," *Composites Part A: Applied Science and Manufacturing*, Special Issue on Biocomposites, 83 (April 1, 2016): 196, https://doi.org/10.1016/j.compositesa.2015.11.004.
[641] Awards include Nordic Design Competition: Sustainable Chairs COP24 in Poland. Stockholm Furniture & Light Fair in February 2019

b. Bioplastics

Fig. 5.17. Chairs using bioplastics. Source: (clockwise top left) A Lot of Brasil, Alki, Tramontina

Three designs made from bioplastics are included in this section: Karim Rashid, *Siamese Chair*, Ander Lizaso's *Kuskoa Bi*, and Tramontina's *Jet* (fig. 5.17).

Bioplastic chairs

Chair	Designer	Manufacturer	Date	Material 1	Material 2	Kg	Stacks	Cols	Styles	Price (AUD)
Siamese Chair	Karim Rashid	A Lot of Brasil	2014	plant based plastic	aluminium legs	9.8	0	11	1	1358
Kuskoa Bi	Ander Lizaso	Alki	2015	PLA (hybridised)	wood (legs)	6.5	0	2	1	915
Jet and *Paco*	Tramontina	Tramontina	2018	bio-based polyethylene	N/A	5.8	0	3	2	135

Table 5.17. Details of chairs made from bioplastics

Environmentally Responsible Product Rating

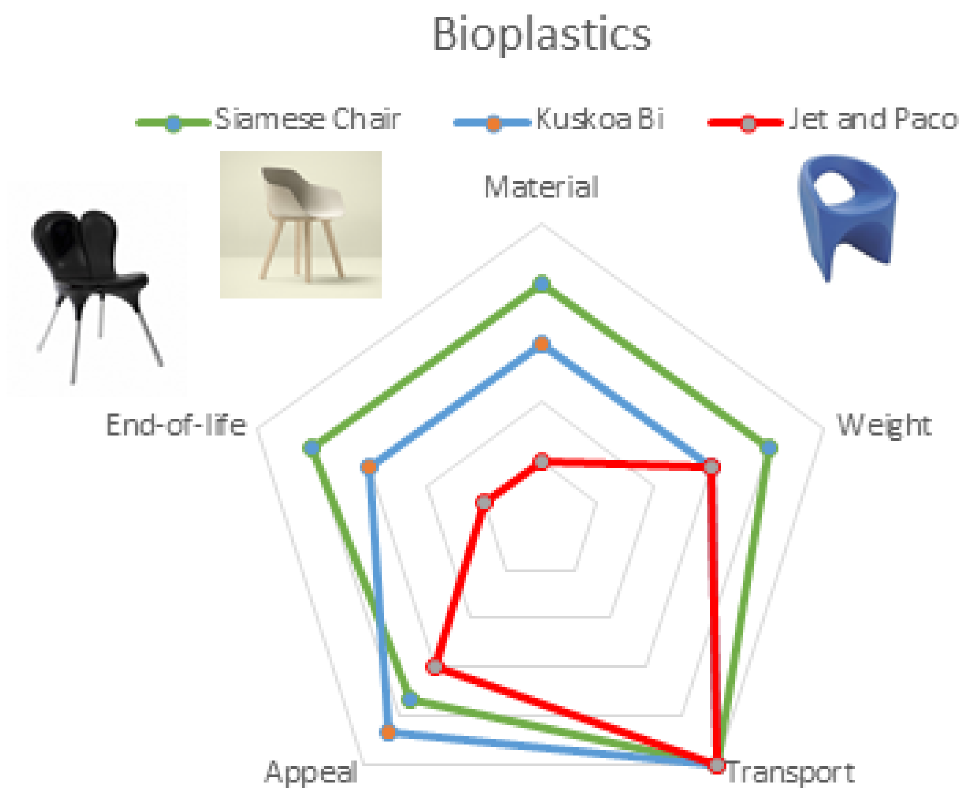

Fig. 5.18. Chart illustrating ERPR scores awarded to chairs made using bioplastics

Chair	Material	Weight	Transport	Appeal	End of life	ERPR
Siamese Chair	1	1	0	1	1	**4**
Kuskoa Bi	2	2	0	1	2	**7**
Jet	4	2	0	2	4	**12**

Table 5.18. ERPR scores awarded to chairs made using bioplastics

Brazilian companies have been pioneers in the use of bioplastics, benefiting from years of investment in biofuels by local industry.[642] Braskem and Tramontina partnered to

[642] See for example, Fernando C. De Oliveira and Suani T. Coelho, "History, Evolution, and Environmental Impact of Biodiesel in Brazil: A Review," *Renewable and Sustainable Energy Reviews* 75 (August 1, 2017): 168–79, https://doi.org/10.1016/j.rser.2016.10.060.

develop two chairs (*Jet* and *Paco*) using renewable polyethylene (Bio-PE), made from ethylene derived from sugarcane. Braskem claim that the renewable polyethylene they invented has the same characteristics as the fossil-based version.[643] The material is theoretically an ideal 'drop in' solution, as it can replace traditional fossil-based plastics without the need to modify existing production facilities. The chairs have excellent end-of-life prospects as the material can be recycled together with fossil-based polyethylene. Despite being derived from bio-mass, however, renewable polyethylene is not biodegradable.[644] The ERPRs of both the *Jet* and *Paco* are impacted by the fact neither of the designs stack, the chairs are heavier than average and colour choices are limited (table 5.18). Despite those limitations, the designs achieved the strongest overall scores in this section.

The *Siamese Chair* (named after the two co-joined components which form the seat) was designed by Karim Rashid, for another Brazilian company A Lot of Brasil, who specialise in manufacturing furniture using sustainable, locally sourced materials. The shell of the chair is made from a plastic derived from the Amazonian fruit Acai and the bark stripped from the Ipe Roxo tree that regenerates within two years (although the exact composition of the bioplastic is unknown).[645] Significantly, the characteristics of the ecoplastic impacted the final form of the design. Rashid revealed to me in our interview that his original intention was to design a monobloc, but this approach had to be abandoned following the discovery that the material lacked sufficient strength to be used for the legs. In addition,

[643] Ironically, the feedstock for the first polyethylene plant in the USA (1938) was ethanol, quickly displaced by oil. Bennett, "Implications of Climate Change for the Petrochemical Industry," 332.
[644] A 2015 study found, 'bio-based polyethylene results in GHG emissions 140% lower than petrochemical polyethylene; savings on non-renewable energy use are approximately 65%.' However, the authors caution: 'In human health and ecosystem quality, the impact of the bio-based polymers is up to 2 orders of magnitude higher, primarily due to pesticide use, pre-harvesting burning practices in Brazil and land occupation.' I. Tsiropoulos et al., "Life Cycle Impact Assessment of Bio-Based Plastics from Sugarcane Ethanol," *Journal of Cleaner Production* 90 (March 1, 2015): 114, https://doi.org/10.1016/j.jclepro.2014.11.071.
[645] Rashid was unable to confirm the exact ingredients of the material and A Lot of Brasil did not respond to requests to participate in this research.

the new the new plastic could not be used in thin moulds, so a bulky design was developed to ensure sufficient strength.[646] The use of virgin aluminium for the legs of the chair, together with the weight of the shell, negatively affected the ERPR of this design.

Inspired by Robin Day's *Polyside* armchair from 1963, the *Kuskoa Bi* features a bioplastic shell attached to a solid, sustainably sourced, oak base. When I interviewed Spanish designer Ander Lizaro, he explained that he wanted to use a plastic semi-concave shell to provide support for the body as he believed this could create a 'comfortable, enveloping shell'.[647] A suggestion to make the chair from plastic was rejected by the French manufacture Alki who are committed to sustainable development.[648] To find a solution, the design team investigated bioplastics and selected a polymer made from sugar cane (stover). It was later discovered that the PLA had been hybridised with plastic made from fossil-fuel.[649] Apart from the environmental impact of creating the material, mixing organic and fossil-based materials reduces their end-of-life prospects. The manufacturer claims the shell can be recycled through specialised processing facilities. (I have awarded a score of two points, despite this claim being unsubstantiated.) While only available in two colours, an attempt has been made to broaden the appeal of the char by adding an upholstered version. While this addition has reportedly met with sales success, the upholstery causes an unfortunate negative environmental impact as virgin, combustion modified high resiliency (CMHR) polyurethane foam has been used for the padding. The designer expressed his disappointment to me that this version is selling well.[650] However, a review of marketing collateral developed by Alki reveals that the environmental impact of the upholstery is not

[646] Isaac, Interview with Karim Rashid.
[647] Isaac, Interview with Ander Lizaso.
[648] See: http://alki.fr/en/us/
[649] Isaac, Interview with Ander Lizaso.
[650] Isaac.

mentioned. It is possible, therefore, that purchasers are choosing this chair for its environmentally-friendly credentials, unaware that their selection of upholstery negatively affects the environmental performance of the chair.

4. Limitations of the analysis model

This analysis is based on information published by manufacturers or designers that has not been independently verified. Some of their claims are questionable, but it was not possible to interrogate all manufacturers regarding every claim they made. In some instances, not all the required information could be found for each of the designs included in this study. Missing data has been estimated and noted in the tables showing individual product scores. The greatest impact on the embodied energy of plastic is the energy source used in its manufacture, with renewable energy considerably reducing the embodied energy. Ideally, my analysis would include consideration of where and how the materials used are manufactured and transported; however, relevant data is not publicly available.

Production processes are often outsourced to third parties, with the named manufacturer responsible for assembling components or even, in some cases, restricting their involvement to sales and marketing efforts. Without detailed information on where and how individual components are made and transported the environmental impact cannot be accurately measured.[651] In the absence of this information some assumptions have been made. Manufacturers are keen to differentiate their products—anything remarkable about the material or production process will most likely be featured in sales and marketing material. For example, Magis highlight the use of post-industrial plastic, recycled from their

[651] A video of the processes involved to make a *Nobody Chair* shows different manufacturing activities being undertaken at various facilities across Europe including: Holland, Ireland and Sweden. *HAY Nobody Chair*, 2014, accessed February 3, 2022, https://www.youtube.com/watch?v=3qU1CZIlXAM.

own supplier's production facilities, to create the *Bell Chair*. Where such claims are made, they are noted in my study.

Another limitation of this simplified analysis is the absence of consideration for the production process. It is assumed that all manufacturers are equally motivated to reduce costs—incentivising them to pursue both energy and material efficiency strategies. As my study is restricted to a single-product category it can be assumed that the energy requirements per unity of production are similar. This assumption is further reinforced by the fact that most designs I analyse are made using the same process—injection moulding—suggesting energy demands per unit of production are reasonably consistent. Where different production processes have been used (for example, compression moulding & 3D printing) I comment on the likely impact on resource requirements.

How efficiently chairs are shipped from the manufacturer, through their distribution channels and on to the final place of use (and eventually disposed of) are factors beyond the scope of my study as the data required is unavailable. As noted above, transport efficiency is significantly improved if chairs can be stacked to save space. The environmental impact of diesel-powered delivery vehicles, making the relatively short trip from a retailer or warehouse to the place of use can be significant, even outweighing the impact of the journey from an overseas factory to the country.[652] I have not accounted for the commercial success of the chairs under study as this data is not in the public domain, with most manufacturers operating as private companies and choosing not to publish this information.

The overall ranking of the environmental performance of designs might be affected by those limitations. For example, an online video showing the production process for the

[652] For an analysis of relative transport impacts see: Nahlik et al., "Goods Movement Life Cycle Assessment for Greenhouse Gas Reduction Goals."

Nobody Chair reveals the material is sourced from recycling activities undertaken in Holland which is then sent to Ireland for conversion to PET felt, before being sent to Denmark for manufacturing.[653] I have not included the environmental impact of those multiple journeys in my analysis and cannot be accurately determined, as the method of transport remains unknown.

5. Summary of findings

This chapter examined and compared the environmental profiles of the 32 plastic chairs made from renewable plastics, using my ERPR tool for comparative analysis. First the designs were grouped using the waste hierarchy. Chairs made from the same material together were grouped together and then ranked following the waste hierarchy; with the expectation this would identify the chairs most likely to deliver better environmental outcomes. An Environmentally Responsible Product Rating was then calculated for each chair with the details of the scores achieved shown in table 5.19. The average score awarded was ten points with scores in the range between four and eighteen.

[653] Rolf Hay, *From Plastic Bottle to Nobody Chair*, 2008, https://www.youtube.com/watch?v=D0igC3YEUxk.

Environmentally Responsible Product Ratings							
Chair	Date	Material	Weight	Transport	Appeal	End-of-life	ERPR
Bell Chair	2020	4	4	4	2	4	18
Sissi	2019	4	4	4	2	4	18
Hemp Chair	2011	4	4	3	1	2	14
N02 Recycled	2019	2	2	4	3	3	14
Nobody Chair	2007	4	3	3	0	4	14
1 Inch Reclaimed	2018	3	2	4	2	1	12
Broom Stacking	2012	3	3	3	2	1	12
Jet and Paco	2018	4	2	0	2	4	12
Puzzle Chair	2014	4	2	1	3	2	12
S-1500	2019	1	3	3	2	3	12
Ocean Collection	2018	1	3	3	1	3	11
Flax Chair	2015	4	4	0	0	2	10
Green Chair	2016	1	2	2	2	3	10
Jin Chair	2018	4	4	0	0	2	10
Love	2018	2	3	3	2	0	10
Meltdown Chair	2007	4	1	0	1	4	10
AI Chair	2019	4	3	0	2	0	9
ChairCharlie	2018	2	4	0	2	1	9
Ibiza	2019	2	2	3	2	0	9
Odger	2017	3	2	1	2	1	9
On & On	2019	1	3	3	1	1	9
Butter Chair	2011	2	2	1	2	1	8
Falk	2019	1	2	1	3	1	8
Chubby Chair	2012	4	1	1	1	0	7
Coastal Furniture	2019	3	1	0	0	3	7
DuraOcean	2020	3	3	0	1	0	7
Ice-Dream	2019	4	0	1	0	2	7
Kuskoa Bi	2015	2	2	0	1	2	7
Voxel Chair v1.0	2016	4	0	1	0	2	7
Wave	2020	4	0	1	2	0	7
111 Navy	2010	1	2	0	2	1	6
Siamese Chair	2014	1	1	0	1	1	4

Key:	Excellent	Above average	Average	Below average	Poor

Table 5.19. Chairs ranked by ERPR scores (Average score =10)

From the 32 chairs included in this study the five best performing designs are shown below:

Fig. 5.19. Highest scoring chairs using the ERPR tool Source: (clockwise top left) Magis, Tramontina, Hay, Fritz Hansen, Moroso

Only one chair made from organic material ranked among the top performers: the *Hemp Chair*. The remaining four designs, including the two that achieved the highest scores, are made from recycled plastics. Results therefore contradicted the waste hierarchy rankings, which predict that designs made from renewable organic sources would achieve superior ratings. My findings also contradict design for sustainability guidelines that often recommend choosing natural materials over synthetic ones.[654] Although the focus here is on these top-scoring designs, it should be noted that an additional five designs achieved scores

[654] For example, see: Helen Lewis and John Gertsakis, *Design + Environment: A Global Guide to Designing Greener Goods* (Sheffield: Greenleaf, 2001), 63.

of 12 points (see table 5.19), rating these designs significantly above average for their environmental profile.

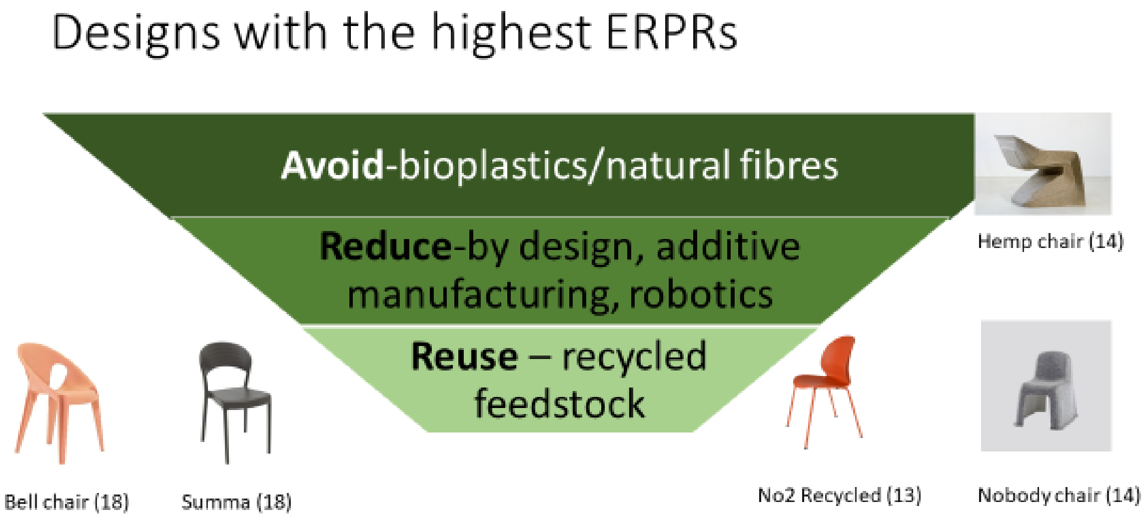

Fig. 5.20. High ERPR scoring designs ranked on the waste hierarchy

Chair	Material	Weight	Transport	Appeal	End of life	ERPR
Bell Chair	4	4	4	2	4	**18**
Sissi	4	4	4	2	4	**18**
Hemp Chair	4	4	3	1	2	**14**
Nobody Chair	4	3	3	0	4	**14**
N02 Recycled	2	2	4	3	3	**14**

Table 5.20. ERPR scores awarded to the best performing chairs

The chairs with the highest ERPRs had been designed to stack during transport, with above average scores awarded for this attribute (see table 5.20). High-scoring chairs generally achieved above average scores for the material, weight, and end-of-life categories.

Except for the *NO2 Recycled*, the four remaining top scoring designs were awarded relatively-weak scores for appeal. Lack of colour choices and no selection of base and shell options limited scores awarded for this criterion. While those compromises have often been consciously made to contain costs, the lack of choice offered to consumers is almost certain to negatively impact sales potential.[655]

Of the 32 designs examined, nine were awarded ERPRs of seven points or less. Figure 5.21 shows that those designs cannot be categorised using the waste hierarchy as a guide and many did not share common materials or production methods. However, three of the four designs made using 3D printing earned ERPRs of seven points ranging them in the below-average category.

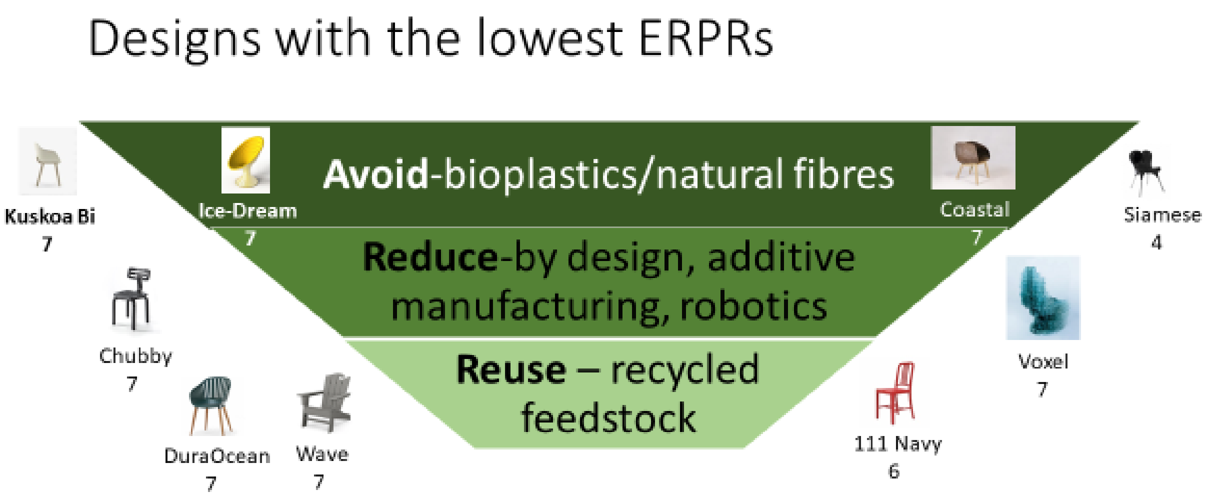

Fig. 5.21. Lowest ERPR scoring designs ranked on the waste hierarchy

[655] Grcic and Magis deliberately limited colour choice to three options for the Bell. In an interview for his study Grcic explained that this decision minimised the wastage caused by changing colour and allowed production runs to be optimised to contain costs. Isaac, Interview with Konstantin Grcic.

Chairs with the lowest ERPRs

Chair	Material	Weight	Transport	Appeal	End of life	ERPR
Chubby Chair	4	1	1	1	0	**7**
Coastal Furniture	3	1	0	0	3	**7**
DuraOcean	3	3	0	1	0	**7**
Ice-Dream	4	0	1	0	2	**7**
Kuskoa Bi	2	2	0	1	2	**7**
Voxel v1.0	4	0	1	0	2	**7**
Ocean Chair	4	0	1	2	0	**7**
111 Navy Chair	1	2	0	2	1	**6**
Siamese Chair	1	1	0	1	1	**4**

Table 5.21. ERPR scores awarded to the worst performing chairs

The poorly performing designs lost points for transport (see table 5.21 above), as chairs could not be stacked or dismantled to optimise space during distribution. Similarly, most of the chairs with the lowest ERPRs lost points for appeal, with limited colour choices, high prices and lack of options for the designs affecting scores. Many of the low-scoring designs are relatively heavy, indicating poor material efficiency, with follow on implications for production and transportation impacts.

Perhaps most surprisingly, three of the designs made using bioplastics or natural fibres feature in the list of poorly performing chairs. All three chairs made from renewable organic sources achieved low scores for weight, transport, and appeal. Limited colour choices combined with high prices affected scores awarded for both the bioplastic and natural fibre designs. The worst performing chair overall was the first design to be made using a bioplastic: Rashid's *Siamese Chair*. The bulky, non-stackable chair is expensive and available in only one combination of shell and base, with legs made from virgin aluminium. The *Siamese Chair* earned low scores across the board. However, as I will show in more detail in Chapter 7, working with new materials demands experimentation, as little is understood about their real-world performance. Actors brave enough to experiment with these materials might produce designs in danger of being labelled 'hideous monstrosities' but, in so doing, limitations of the material are exposed, benefiting the designers and manufacturers who come after them. As advanced manufacturing technologies mature and the range of bioplastics increases it is likely that designs incorporating these as inputs will display better environmental outcomes. Proof will require continued experimentation. In the short term, recycled materials are shown to be the most suitable renewable carbon option currently available to designers concerned with improving the environmental profile of their plastic products.

My findings also reveal that good environmental outcomes cannot only be achieved by designers and manufacturers with access to expensive production facilities. While three of the top-rated designs are injection moulded, two are formed using compression moulding technology. With less pressure requirements and the need for expensive moulds avoided, compression moulding is financially accessible to far more actors interested in developing more sustainable plastic products. In the next chapter I further analyse the results of my comparative study and apply them to a theoretical model, adapted to support the scaling-out and scaling-up of the use of renewable carbon-based plastics.

Part C

Advancing renewable carbon-based plastics

Chapter 6

The time is right for change

Actors involved with creating chairs using renewable carbon-based plastics (renewable plastics), must be recognised for their bravery in experimenting with alternatives to virgin fossil plastics. However, most plastic chairs (and most plastic products) currently sold are still made from virgin fossil sources. While many of these designs have been developed to minimise the use of materials and energy, I have already argued in previous chapters that the benefits achieved from dematerialisation are diminishing. Significant improvements in efficiencies were achieved by the plastic furniture industry during the second half of the twentieth century but those marginal gains have significantly decreased in the new millennium. Far from being confined to the furniture industry alone it has become apparent that efficiency gains at the product level are unable to compensate for the growth in demand from an increasingly populous, affluent, and urbanised population.[656] As design academic Ezio Manzini observed:

> Current products and services, taken one by one, use far less energy and materials than those of some decades ago. However, no indicator of aggregate consumption (residence, mobility, tourism, etc.) indicates a decrease: even in countries where research on eco-efficiency has been most successful. Overall consumption of environmental resources continues to increase. This clearly tells us that increasing improvements in the current system are not enough.[657]

Driven primarily by economic considerations, a focus on cleaner production and efforts to improve the total lifecycle impact of products (particularly those that consume energy during use) has failed to address ever-increasing consumption and the mounting environmental damage caused by the prevailing linear consumption model.

While a system addicted to profit and growth has driven a focus on efficiency it has prevented, or at least restricted, the uptake of many designs where the benefits are primarily

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[656] Chris Ryan, "Climate Change and Ecodesign, Part II: Exploring Distributed Systems," *Journal of Industrial Ecology* 13, no. 3 (June 2009): 350–53, https://doi.org/10.1111/j.1530-9290.2009.00133.x.
[657] Manzini, "New Design Knowledge," 8.

long-term ecological and not short-term financial gain.[658] Innovation at the product level is insufficient to drive the change required to our established systems of production and consumption. Replacing virgin-fossil plastic with renewable-carbon materials significantly reduces the GHG emissions released during their production. From the analysis of what influences the need for fossil-fuel plastics we have seen that increasing demand for renewable plastics is the only viable short-term strategy to lessen consumption of fossil-plastics. But how can environmentally successful innovations using these materials at the product level be scaled-out and scaled-up? How can valuable lessons from the successful niche experiments identified in the previous chapter be applied more broadly if products fall foul of vagrancies of fads and fashions? How can industry participants be persuaded to adapt or even abandon manufacturing process, the product of decades of investment? Those are the questions that are addressed in this chapter which seeks to provide guidance to designers and their industry partners on the use of renewable and bioplastics to play an active role in the transition to a sustainable future.

Academic interest in sustainable transitions has grown significantly in the past ten years.[659] Research interest driven by the recognition that many environmental problems, including climate change, represent grand societal challenges that require system-level transformations.[660] Multi-level perspective (MLP), a model developed to explain the successful diffusion of technology, has been widely adopted as a framework for analysing

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[658] Joanna Boehnert, *Design, Ecology, Politics: Towards the Ecocene* (New York: Bloomsbury Academic, An imprint of Bloomsbury Publishing Plc, 2018), 19.
[659] Jonathan Köhler et al., “An Agenda for Sustainability Transitions Research: State of the Art and Future Directions,” *Environmental Innovation and Societal Transitions* 31 (June 2019): 3, https://doi.org/10.1016/j.eist.2019.01.004 Shows the number of academic papers published since 2000, increasing from around 100 to 500 a year in the ten years to 2018.
[660] For a summary of four prominent theoretical approaches on transformation to more sustinable modes of prodution and consumption see: Markard, Raven, and Truffer, “Sustainability Transitions.”

socio-technical transitions toward sustainability.[661] It predicts that innovations are most likely to occur when exogenous events cause major disruptions to the market and interrupt the status quo. New emerging technologies are then well-placed to breakthrough, provided they are at a sufficiently advanced stage of development, as actors seek innovative solutions to adapt to new market conditions. In this chapter I analyse current disruptions to the fossil-plastics market and examine their potential impacts on the furniture industry. Current disruptions are creating an opportunity for new emerging, more environmentally friendly, alternatives to breakthrough and challenge the entrenched socio-technical regime.

An early proponent of MLP, Fabrizio Ceschin, focuses on the multiple roles that designers can play in sustainability transitions. These roles include designing socio-technical experiments within which new sustainable products can be developed. Ceschin argues designers should conceptualise transition paths for embedding new sustainable products in the societal context.[662] The designer is seen as an intermediary with the power to affect socio-technical change.[663] Manzini claims our transition toward a sustainable society is likely to be mix of three transitions: legislation to force change, consumers making their own decisions to buy sustainably, and finally, where sustainable options become the default, with everyone acting in the interests of everyone else. While acknowledging the third transition to be utopian, he highlights the important role of designers in demonstrating tangible solutions to encourage the uptake of sustainable innovations.[664]

[661] Frank W. Geels, “The Multi-Level Perspective on Sustainability Transitions: Responses to Seven Criticisms,” *Environmental Innovation and Societal Transitions* 1, no. 1 (June 1, 2011): 24, https://doi.org/10.1016/j.eist.2011.02.002.
[662] Ceschin, “The Introduction and Scaling up of Sustainable Product-Service Systems. A New Role for Strategic Design for Sustainability.,” 115.
[663] Paula Kivimaa et al., “Towards a Typology of Intermediaries in Sustainability Transitions: A Systematic Review and a Research Agenda,” *Research Policy* 48, no. 4 (2018): 1062–75.
[664] Manzini, *Design, When Everybody Designs*, 203.

The designers interviewed for this study form only part of a network of actors involved with design and manufacturing decisions. The ability of designer to directly influence material selection or to specify manufacturing methods varies from project to project but the designer rarely has the final say. For some projects the designer does have significant influence over the selection of materials and/or the manufacturing process. Importantly, this research has shown the designer does play an important role in driving experimentation with recently developed renewable carbon-based plastics. Designers can be agents for change.

All 32 chairs included in this study are effectively the results of experiments with renewable plastics. Manzini argues that a pathway to transition can be formed by experimenting with new solutions, consolidating and replicating the best ones. Sustainable design evolves through knowledge sharing of successful interventions that could result in the development of new market niches. Good design solutions are imitated, successful strategies copied, and these new projects can create more effective solutions. Eventually these solutions coalesce, enabling the multiplicity of small initiatives to make a greater impact.[665] The challenge then is to identify what can be learned from those diverse experiments by studying those that achieved the best environmental outcomes and applying these findings to accelerate the transition to more sustainable solutions. Acceleration is vital, particularly in relation to plastics, as sustainable transitions can often take decades to achieve.[666] A transformative restructuring of socio-technical systems is required to effect

[665] Manzini, 5.
[666] For example, Loorbach reports. "When an experiment has been successful (in terms of evaluating its learning experiences and contributions to the transition challenge), it can be repeated in different contexts (broadening) and scaled up from the micro- to the mesolevel (scaling up). This requires a considerable amount of time—approximately 5–10 years" Derk Loorbach, "Transition Management for Sustainable Development: A Prescriptive, Complexity-Based Governance Framework," *Governance* 23, no. 1 (2010): 176, https://doi.org/10.1111/j.1468-0491.2009.01471.x.

societal change. The focus must shift from artefacts and broaden to consider the socio-technical systems. The focus of MLP is then on the role of socio-technical systems in achieving societal transformations, differentiating the theory from the debate at the macro level (changing the nature of capitalism) or at the micro level (changing individual choices and motivations).[667]

1. Multi-Level Perspective

MLP is a nested hierarchy of three concepts or levels: landscape, socio-technical regime, and niches.[668] The landscape level refers to external socio-economic environment that is beyond the influence of individual actors. Globalisation, climate change, population growth, international trade rules all form part of the landscape, with changes exerting pressure on the existing regime. Individual actors do not hold sufficient agency to affect change at the landscape level in the short-term.[669] The social-technical regime (regime) refers to the prevailing rules and entrenched supporting infrastructure that govern the engineering practices, production processes, product characteristics, skills, personnel, and actor-networks, established ways of handling relevant artefacts, ways of defining problems; all of them developed over decades and embedded through institutions and continued investment.[670] Regimes do generate innovations but they are usually incremental rather than radical; marginal improvements gained by reconfiguring resources with the confines of the existing

[667] Köhler et al., "An Agenda for Sustainability Transitions Research," 2.
[668] Loorbach introduced the concepts of macro/meso/micro in his theory of transition management introduced in his 2007 dissertation and summarised in his article: Loorbach, "Transition Management for Sustainable Development."
[669] Frank Geels, "Typology of Sociotechnical Transition Pathways," *Research Policy* 36, no. 3 (April 1, 2007): 402–5, https://doi.org/10.1016/j.respol.2007.01.003.
[670] Kemp and Rip, "Technological Change," 340.

regime.[671] Radical innovations are generated in niches, the third concept in the model. Step-change innovations are incubated in environments with sufficient resources to encourage experimentation with 'technological novelties.[672] Often emerging from outside or from the fringes of an existing regime, niches foster innovations that differ fundamentally from the prevailing regime. Niches can produce tangible demonstrations that a new technology works to some degree, arousing the curiosity of other industry participants, as Adrian Smith observed.[673]

The MLP model attempts to theorise how such desirable niche innovations can be scaled-up and gain sufficient momentum to successfully breakthrough and challenge the status quo enjoyed by the existing regime. The theory recognised that transitions cannot be managed in the strictest sense, as they cannot be steered by a single actor. Transitions emerge due to co-evolutionary process involving negotiations between many actors.

Early critics of MLP noted the complexity and subjectivity involved in defining the socio-technical regime.[674] The electricity regime could be examined at the primary level (based on fuel source) or across the entire system of production, distribution, and consumption. 'What looks like a regime shift at one level may be viewed merely as an incremental change in inputs for a wider regime at another level,' is how Frank Geels summarised those criticisms.[675] MLP, then, requires the empirical levels of analysis to be

[671] Hamid El Bilali, "The Multi-Level Perspective in Research on Sustainability Transitions in Agriculture and Food Systems: A Systematic Review," *Agriculture* 9, no. 4 (April 2019): 74, https://doi.org/10.3390/agriculture9040074.
[672] Sibylle Bui et al., "Sustainability Transitions: Insights on Processes of Niche-Regime Interaction and Regime Reconfiguration in Agri-Food Systems," *Journal of Rural Studies* 48 (December 1, 2016): 92–103, https://doi.org/10.1016/j.jrurstud.2016.10.003.
[673] Adrian Smith, "Translating Sustainabilities between Green Niches and Socio-Technical Regimes," *Technology Analysis & Strategic Management* 19, no. 4 (July 1, 2007): 428, https://doi.org/10.1080/09537320701403334.
[674] Frans Berkhout, Adrian Smith, and Andy Stirling, *Socio-Technological Regimes and Transition Contexts*, *System Innovation and the Transition to Sustainability* (Cheltenham, UK: Edward Elgar Publishing, 2004), 54, https://www-elgaronline-com.ezproxy.lib.uts.edu.au/view/1843766833.00013.xml.
[675] Geels, "The Multi-Level Perspective on Sustainability Transitions," 31.

designed before the theory can be operationalised. The first task is then to assess the relevance of the model to a study of plastic chairs. Are plastic chairs significant when they represent a small niche within the furniture market?

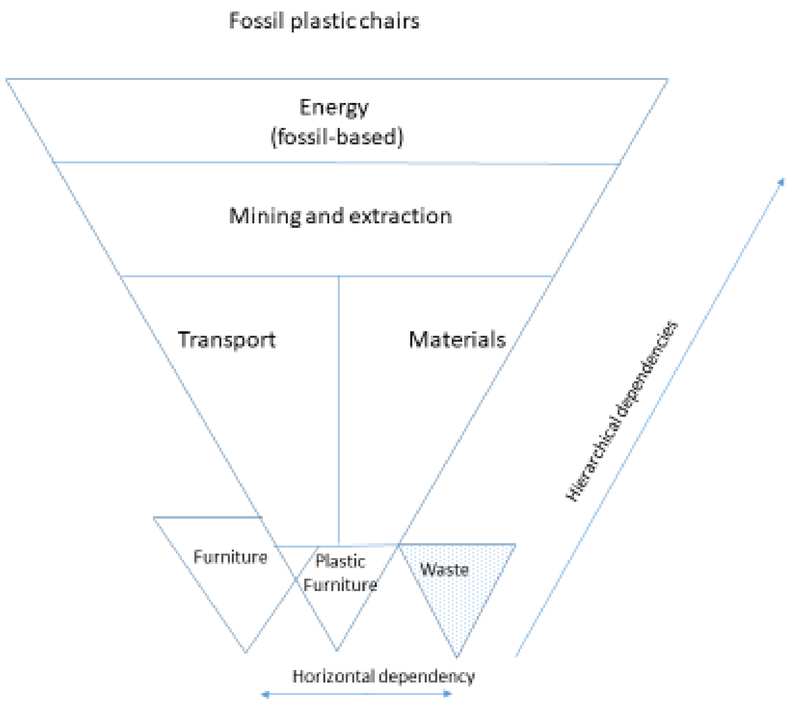

Fig. 6.1. Regime dependency for fossil plastic chairs. Adapted from Gaziulusoy (2010)[676]

Plastic chairs are even a niche within the plastic furniture market (fig. 6.1). But analysts estimate that this small niche, representing about only 4% of the total furniture market, to be worth between US$15 billion and US$23 billion (in 2018) with a projected compound annual growth rate (CAGR) of 6% through to 2028.[677] (Well above the 3.5% growth predicted for the

[676] Gaziulusoy, "System Innovation for Sustainability," 98.
[677] Fact.MR, "Plastic Furniture Market Forecast, Trend Analysis & Competition Tracking - Global Review 2018-2028," Fact.MR, May 2019, https://www.factmr.com/report/3574/plastic-furniture-market; Grand View Research, "Plastic Furniture Market Size Worth $15.5 Billion By 2025 | CAGR: 3.9%," accessed February 3, 2022, https://www.grandviewresearch.com/press-release/global-plastic-furniture-market (For smaller estimate of current value).

plastics market overall, according to the market research company Fact MR).[678] The production of all furniture globally (estimated to be worth US$500 billion a year), including plastic furniture, is dependent on inputs from the transport and material regimes, which are dependent on the mining and extraction regimes, with all of them dependent on the all-encompassing energy regime.[679] Fossil fuels generate the majority of energy required to manufacture furniture and provide the raw ingredients for the production of plastic. When furniture is discarded it becomes dependent on the waste regime for disposal. This complex network of regime interdependency is illustrated in fig. 6.2.

The enormity of the challenges to be faced in moving to renewable plastics is highlighted by considering the impact on the dependent regimes (fig. 6.2). In this more sustainable scenario, energy is primarily generated from renewable sources. Agriculture replaces the extractive industries to become a source of raw materials for renewable carbon-based plastics. The waste industry is redefined. It is no longer regarded as the end-of-pipe solution for getting rid of unwanted items but now acknowledged as the resource recovery industry, a key supplier to the materials regime, and the primary supplier of plastics for all their uses, including furniture. In this ideal scenario the fossil-based energy regime together with the mining and extraction regimes are redundant. This ideal scenario is unlikely to be fully realised. However, the potential threat posed to the very existence of the powerful regimes that have dominated human activities since the Industrial Revolution is illustrated by a comparison of the two charts showing regime dependencies.

[678] Fact.MR, "Plastic Furniture Market Forecast, Trend Analysis & Competition Tracking - Global Review 2018-2028."
[679] Statista, "Furniture Market Value Worldwide 2027," Statista, September 2021, https://www.statista.com/statistics/977793/furniture-market-value-worldwide/.

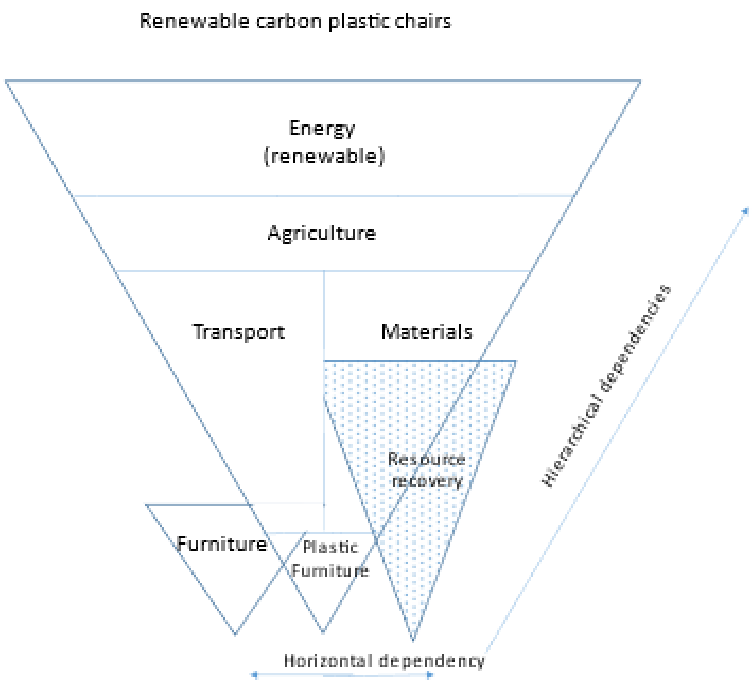

Fig. 6.2. Regime dependencies for renewable carbon-based plastic chairs.
Adapted from Gaziulusoy (2010)[680]

This nested hierarchy of inter-dependent, entrenched regimes that can be interpreted as presenting formidable opposition to change. Yet, this same inter-dependency is also a weakness. Just a small change in one market can cause catastrophic ripple effects. Reducing demand for fossil plastics to cause a reduction in the CAGR to 1% (compared with the 3-4% growth forecast) would cause significant disruption to the business plans of the petrochemical industry market according to an analysis by Carbon Tracker.[681] Projected growth and shareholder returns would be cut significantly by a small impact on demand, as investments made to support industry growth would be left stranded.

Some might argue that the real radical change required is the development of renewable plastics. That material manufacturers are key to driving change and transitioning

[680] Gaziulusoy, "System Innovation for Sustainability," 98.
[681] Carbon Tracker Initiative, "The Future's Not in Plastics," 21.

toward more sustainable materials and that the focus of this enquiry should be on these organisations. However, simply creating and supplying new materials does not automatically create demand. As we have seen, renewable plastics are already well supported as a replacement for virgin fossil plastic by the packaging industry. Packaging accounts for only about a third (36%) of all plastic consumption. Therefore, renewable plastics must branch out and demonstrate their aptness as a replacement for virgin fossil plastics across other applications.[682] If renewable plastics can be used to create a product that can withstand the rigorous demands of a chair, the materials are more likely to be considered for the multitude of less demanding consumer goods. An incremental change in the quantity of virgin fossil plastics used to make consumer goods, added to the promised reductions taking place in the packaging market have the potential to cause massive disruption to the status quo, possibly prompting the radical shift required to favour more sustainable materials.

The key strategy of MLP is to encourage and protect niche incubation, to generate novelty in the form by experimenting with new techniques and initiatives (fig. 6.3).[683] Niche innovations rarely bring about regime transformation without the help of external forces.[684] Niches are constantly confronted, but often have no direct influence on the landscape-induced and regime-inherent processes. The fossil-based energy regime is entrenched and institutionalised, having established the ultimate dominant position at the pinnacle of all regime dependency models across all sectors of the economy. For regime change to occur, entrepreneurs, niches, and institutional support from actors within existing

[682] Elzen, Geels, and Green, *System Innovation and the Transition to Sustainability*, 55 The authors agree a shift at a lower level of the nested hierarchy might hold transforming potential at a higher level.
[683] Kossoff, Tonkinwise, and Irwin, "Transition Design: The Importance of Everyday Life and Lifestyles as a Leverage Point for Sustainability Transitions," 6.
[684] John Grin, Jan Rotmans, and Johan Schot, *Transitions to Sustainable Development: New Directions in the Study of Long Term Transformative Change* (Abingdon, Oxon; New York, NY: Routledge, 2010), 88.

regimes are all required.[685] Importantly, it is the middle level (regime level) where change must first occur for niche level innovations to advance.

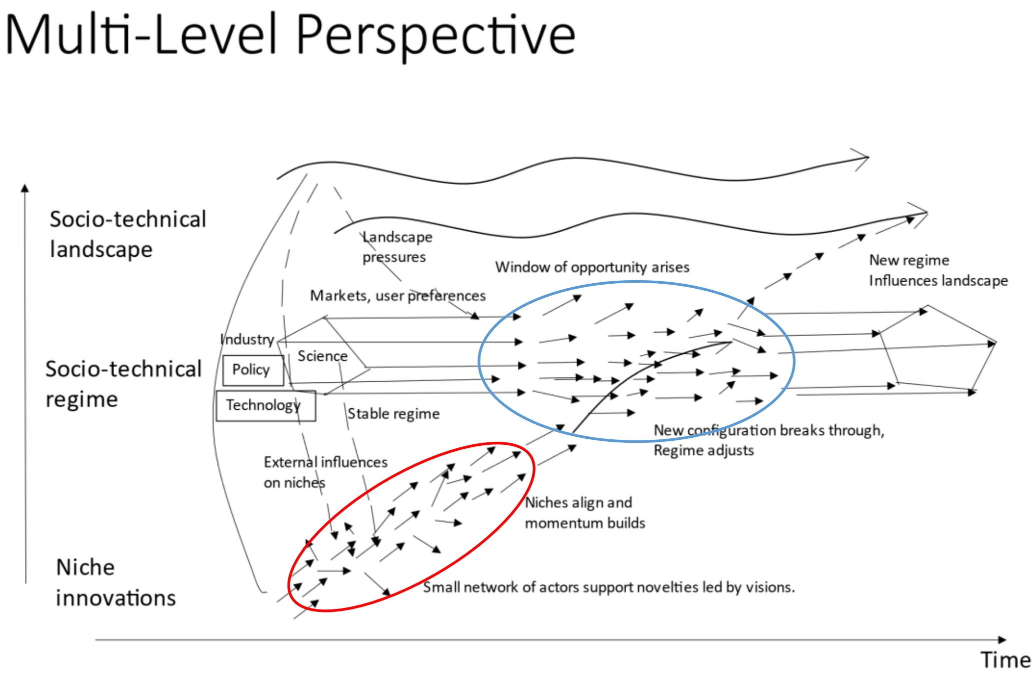

Fig. 6.3. MLP model illustrating how niches can take advantage of landscape shifts or resultant tensions within the regime to breakthrough. Source: Adapted from Schot & Geels (2008).[686]

MLP theory anticipates significant friction resisting change from: pre-exiting standards and regulations, technical systems, sunk investments in machines and equipment, infrastructures, employee skills sets and competencies. All these factors form the entrenched socio-technical regime, with participating actors in a balanced symbiotic relationship, with well-established routines and relationships.[687] Nevertheless, as Swiss environmental scientists, Lea Fuenfschilling and Bernhard Truffer highlight, all socio-technical regimes have

[685] R. P. M. Kemp, Arie Rip, and Johan Schot, "Constructing Transition Paths Through the Management of Niches," in *Path Dependence and Creation* (New York: Psychology Press, 2001), 276, https://doi-org.ezproxy.lib.uts.edu.au/10.4324/9781410600370.
[686] Schot and Geels, "Strategic Niche Management and Sustainable Innovation Journeys," 546.
[687] Debra J. Davidson, Kevin E. Jones, and John R. Parkins, "Food Safety Risks, Disruptive Events and Alternative Beef Production: A Case Study of Agricultural Transition in Alberta," *Agriculture and Human Values* 33, no. 2 (June 1, 2016): 368, https://doi.org/10.1007/s10460-015-9609-8.

internal contradictions or tension that can create opportunities for change to occur.[688] These shifts or tensions can also create opportunities for niche innovations, as they pressure the regime to search for alternatives. Similarly, dramatic shifts at the landscape level can create opportunities for niche innovations to achieve breakthrough.

The MLP model predicts that tensions might arise between the actors that constitute the socio-technical regime because of their varied interests. In fig. 6.3 the resulting weakened links between these participants of the regime are represented by short diverging arrows at the regime level (circled in blue). Niche innovations arise as the result of efforts by actors represented at the bottom of the chart. With no recognised dominant solution, various alternative solutions are experimented with (represented by arrows pointing in random directions at the niche level, circled in red). At least some of these niche experiments will fail It is this process of learning from real life experiences which, Manzini argues, is the main design strategy to change complex systems. Favourable eco-systems can be developed to enable new innovations to flourish, scaling-up and scaling-out as successful innovations gather support and interest from other actors.[689] Over time, a dominant or preferred solution might emerge from the niche experiments and breakout of the niche-level, taking advantage of a window of opportunity created by tension within the regime or as the result of a shift at the landscape level.

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[688] Lea Fuenfschilling and Bernhard Truffer, "The Structuration of Socio-Technical Regimes—Conceptual Foundations from Institutional Theory," *Research Policy* 43, no. 4 (May 1, 2014): 772, https://doi.org/10.1016/j.respol.2013.10.010.
[689] Manzini, "Design in the Transition Phase: A New Design Culture for the Emerging Design," 59. Manzini argues that there is no need for Transition Design as a separate field within design as long-term impacts and visions of a sustainable future should become normal for all expert designers.

2. Landscape disruptions

Major disruptions at the landscape level can create opportunities for niches to gain momentum.[690] While individual manufacturers and designers do not hold sufficiently agency to directly influence the landscape, any significant disruptions at this level will be felt by all actors. Therefore, it is relevant to scrutinise the disturbances currently occurring at the landscape level and their likely impact on the petrochemical industry, and for the production of plastic furniture.

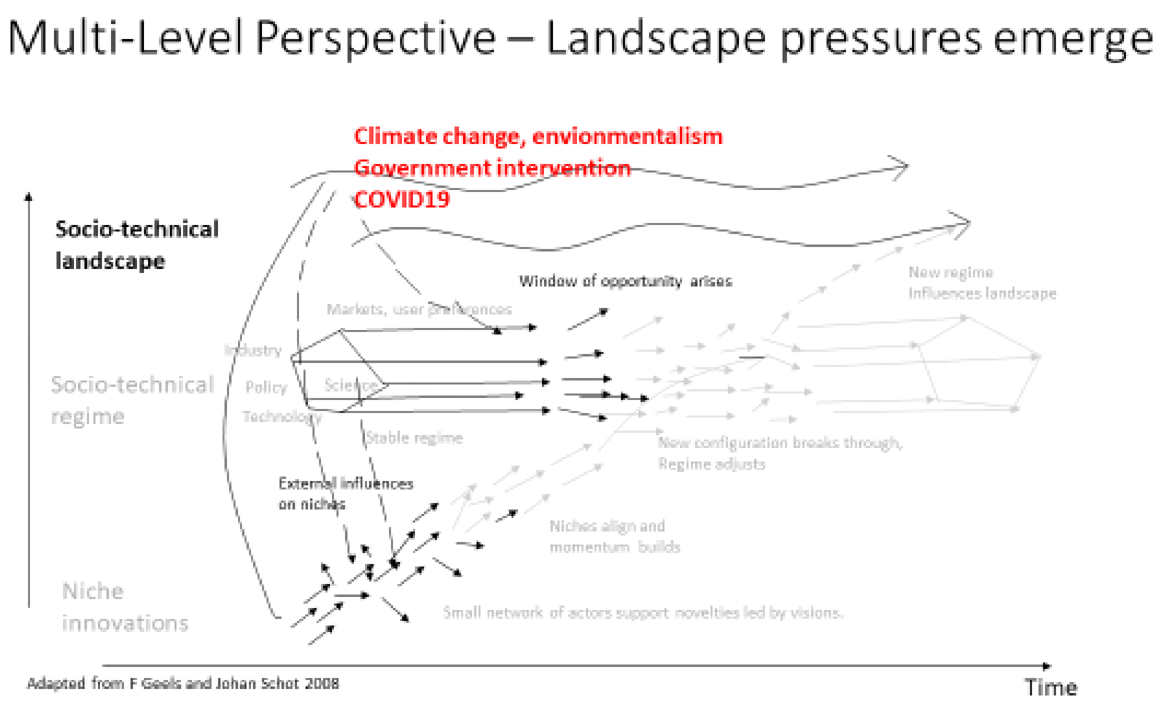

Fig. 6.4 Landscape pressures emerge and create tensions with the existing socio-technical regime. Source: Adapted from Geels and Schot (2008)[691]

At least four major components of the landscape level are experiencing disruptions, creating tensions within the existing fossil plastic social-technical regime (fig. 6.4). While all

690 Smith, "Transforming Technological Regimes for Sustainable Development," 131.
691 Schot and Geels, "Strategic Niche Management and Sustainable Innovation Journeys," 546.

four of these landscape disturbances are exerting pressure on the existing regime there can be no guarantee that the disruption is sufficient to allow the challenging technology to breakthrough or that a niche can gather sufficient momentum to take advantage of the opportunity. Indeed, there have been previous attempts at challenging fossil fuel's dominance of the plastic market. Beginning in the 1920's, Henry Ford experimented with soybeans to produce a polymer material for automotive body panels, even producing a prototype for a car made from bioplastics in 1941.[692] Following the end of WWII, an abundance of inexpensive petroleum supported investment in the rapidly developing petrochemical industry and Ford's plastic car failed to make it into production.[693] Following the oil crisis of 1973, ICI began to develop Biopol, a (PHB) polymer made from fermented glucose. As the oil market faced further disruption toward the end of the decade, opportunities for the commercialisation of bioplastics were ideal. In 1974, Hayaskihara Biochemical Research Institute announced it had 'applied for patents in 25 countries for a plastic [starch based] material which dissolves in water, emits no poisonous gas if burned and can be eaten.'[694] In the 1980s the price of oil dropped together with interest in developing the new technology.[695] Industry focused on a program of efficiencies, but did not seek to replace fossil fuels.[696] Drops in the price of oil effectively de-incentivised development of alternatives to fossil fuels. A focus on short-term profits ignored the long-term environmental consequences of the continued use of fossil fuels to make ever growing quantities of plastic, the existing fossil regime regained stability.

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[692] The Henry Ford Museum, "Soybean Car - The Henry Ford," accessed February 3, 2022, https://www.thehenryford.org/collections-and-research/digital-resources/popular-topics/soy-bean-car/.
[693] Throughout the 1940s oil averaged US$1.55 per barrel, less than the US$1.65 average for the 1920s. See: https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=PET&s=F000000__3&f=A
[694] Plastics News, May 1974, 5.
[695] Bennett, "Implications of Climate Change for the Petrochemical Industry," 332.
[696] Kemp, Rip, and Schot, "Constructing Transition Paths Through the Management of Niches," 279.

As the start of 2018 China banned the import of mixed waste plastics. Just as the enormous impact of China's ban was beginning to be realised the issue was dwarfed as the world confronted a pandemic. Meanwhile, mounting evidence (and impacts) of both climate change and plastic pollution are being met with increasingly urgent demands for action from politicians and activists alike. It is not possible to predict whether any of these changes to the landscape are significant enough to cause the regime to be disrupted and eventually replaced. However, the market for renewable carbon materials is more advanced than it was in the 1920s or 1980s and much better placed to take advantage of these disruptions. An analysis of the landscape today reveals the magnitude of disruption currently confronting the petrochemical regime, while highlighting the opportunity awaiting renewable carbon alternatives.

a. China Sword

China caused the first major disruption to the plastic market with the introduction of the National Sword (China Sword) policy at the start of 2018, effectively banning the import of mixed plastic waste. For decades high-income countries have dealt with their plastic waste problem by exporting it. In response to China's new policy countries (Australia among them) started trying to redirect their waste to other Asian countries including: Indonesia Thailand, Malaysia and Vietnam. This response proved to a short-term solution as these countries swiftly introduced similar bans forcing Europe, Canada, the United States, Japan and Australia to finally confront their own plastic waste issues for the first time.[697] A recent CISRO report highlighted the scale of the problem faced by Australia. Even with favourable

[697] Nithin Coca, "Asian Countries Spurn and Burn Waste Imports," *China Dialogue* (blog), January 23, 2020, https://chinadialogue.net/en/cities/11801-asian-countries-spurn-and-burn-waste-imports/.

conditions it will be at least a decade before Australia can develop the infrastructure required to reach the relatively low recycling rates achieved in 2017.

China's actions acted as a catalyst, focusing attention on the negative environmental impacts of plastics, particularly packaging and single-use plastics. The China Sword policy is severely disrupting the established regime and might yet prove to be the single most important landscape event in driving a re-evaluation of both the production and our consumption of virgin fossil plastics.

b. Climate change

Debates in wider society can influence public policy perceptions, industry strategy and the investment of capital.[698] Unlike conventional economic analysis the MLP model allows for consideration to be given to broad political and social attitudes and trends that serve to frame the functional reproduction and change of socio-technical regimes.[699] Scientific consensus has emerged over the link between anthropogenic GHG emissions and climatic change. Extreme weather events are demanding a reinterpretation of the reality created by the existing regimes.[700] In Australia, a Lowry Institute poll of 2,448 adults conducted during March 2020 found that three of the top five perceived critical threats to Australia's vital interests related to the environment: droughts and water shortages, environmental disasters such as bushfires and floods, and climate change. Consistent with the past five years of Lowy polling, 9 out of 10 participants accepted the need for Australians to act on climate change. Over half (56%) of Australians want action on climate change now, even if this involves

[698] Smith, Stirling, and Berkhout, "The Governance of Sustainable Socio-Technical Transitions," 1494.
[699] Smith, Stirling, and Berkhout, 1494.
[700] Fuenfschilling and Truffer, "The Structuration of Socio-Technical Regimes—Conceptual Foundations from Institutional Theory," 776.

significant costs, while a further third (34%) want low-cost gradual steps to address the problem.[701]

In response to scientific evidence and growing political pressure for action on climate change, the international community is introducing policies designed to encourage less carbon-intensive energy use and promote energy efficiency in attempts to cut carbon emissions. Additionally, as the supply of renewable energy increases and demand for fossil fuels falters, further pressure is exerted on petrochemical companies to defend their profitability. Adding to their woes, demand for oil is forecast to remain flat or increase only slightly during the next decade.[702] In contrast, the plastics market is forecast to grow by at least 3.5% CAGR until 2030, representing a rare and valuable growth segment for the petrochemical industry. Efforts to combat climate change by reducing demand for fossil fuels has, paradoxically, increased the importance of plastics as a key growth segment for the petrochemical industry.

Renewable plastics can demonstrate favourable GHG impacts compared with traditional fossil-based materials. Bioplastic production emits about 80% less carbon dioxide and consumes up to 65% less energy during manufacture. In addition, bioplastics emit about 70% less GHGs during degradation in landfill.[703] Recycled plastics offer similar advantages. A 2010 review of eight Life Cycle Assessment (LCA) studies undertaken by WRAP in the UK estimates that (mechanical) recycling lowers GHG emissions by about 0.62 tons of CO_2-equivalent per ton compared with being landfilled.[704]

[701] Natasha Kassam, "Lowry Institute Poll Report 2020" (Sydney: Lowry Institute, June 2020), np, https://poll.lowyinstitute.org/report.
[702] Center for International Environmental Law, "Oil, Gas and Climate," 12.
[703] M. Selvamurugan Muthusamy and Sivakumar Pramasivam, "Bioplastics – An Eco-Friendly Alternative to Petrochemical Plastics," *Current World Environment* 14, no. 1 (April 28, 2019): 49–59, https://doi.org/10.12944/CWE.14.1.07.
[704] WRAP UK, "Environmental Benefits of Recycling," 54.

Current industry projections forecast demand for fossil plastics to triple by 2050, consuming 15% of the available annual GHG emissions budget, and widely viewed as unsustainable.[705] Growing public pressure, international agreements, and increasingly restricted access to finance for fossil extraction activities will force even the most reluctant governments and companies to take more action to combat climate change. The GHG benefits offered by renewable plastics will likely be increasingly valued as a solution to the climate emergency.

i. Environmentalism

Recent increases in concern for the environmental impacts of plastic represent an important cultural shift. Plastics end up in our environment killing wildlife and reducing soil fertility. Growing concerns about ocean plastics have fuelled public debates and focused demands for action. These environmental concerns have led to wider debate about the role of plastics and demands for change at the socio-technical level. In a paper analysing changes in the Australian urban water sector since market the 1970s, Fuenfshilling and Truffer attribute the rise of environmental concerns, which introduced a different 'field logic' to the sector, as creating tension in the water market and contributing to the significant structural changes adopted by the industry.[706] Environmental lobbying can be a powerful tool to weaken faith in incumbent regimes.

Environmental concerns are not only expressed through political protests and petitions. Organisations such as the Ellen McArthur Foundation are affecting change in the sector, and their efforts to persuade producers of FMCGs to abandon packaging made from virgin fossil plastics is ongoing.

[705] Ellen McArthur Foundation, "The New Plastics Economy," 24.
[706] Fuenfschilling and Truffer, "The Structuration of Socio-Technical Regimes—Conceptual Foundations from Institutional Theory," 781. In particular, the authors point to the adoption of recycling technologies and the adoption of integrated water cycle management.

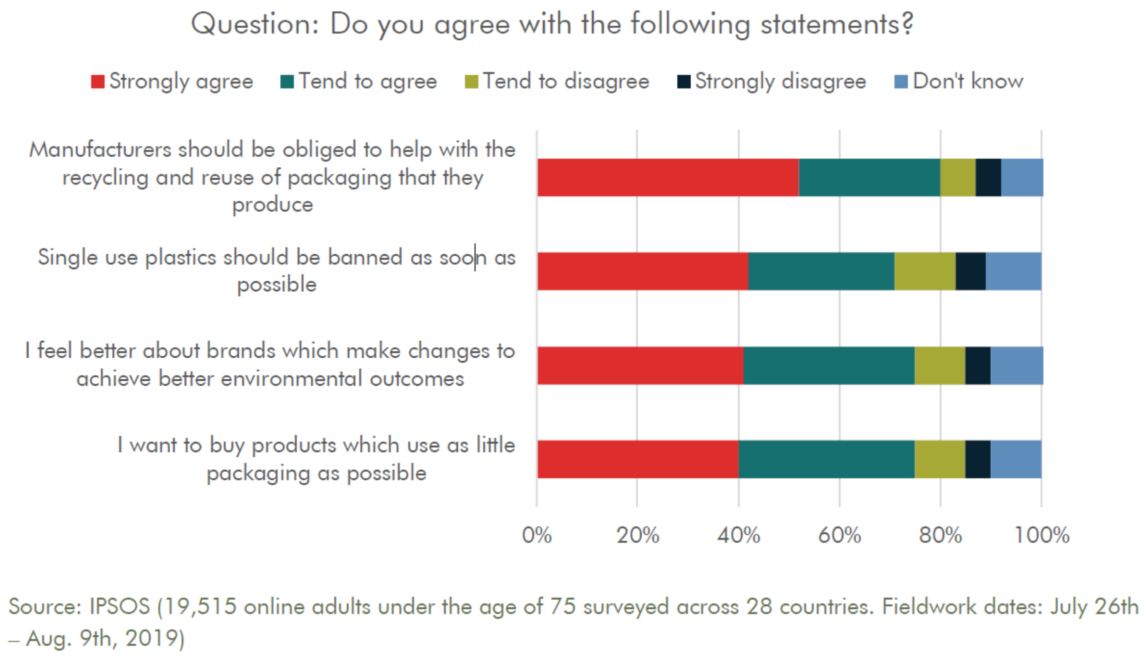

Fig. 6.5 International survey of attitudes toward packaging. Source: IPSOS

Public opinion can be monitored through market research, with results often considered by organisations when developing strategy. A 2019 survey conducted across 28 countries found public support for governments to ban single-use plastics and introduce product stewardship schemes (fig. 6.5 for detailed results). Over 70% of participants agreed they felt better about brands that made changes to improve environmental outcomes and participants wanted to support efforts to minimise packaging. Tony Fry highlights the importance of making visible the unmaking caused by products such as straws as key to driving these policy outcomes. Once people became aware of the devastating impacts straws have on our environment and on wildlife, they were motivated to alter their consumption patterns.[707]

[707] Fry, *Defuturing*, 78.

Focusing attention upstream on the devastating unmaking caused by the manufacture of plastic is also driving change. Mounting evidence demonstrates that environmental concerns are causing tension, weakening faith in the incumbent fossil-based regime. Increased community environmental concern and action around plastics has already directly impacted the development of at least one planned fossil plastics plant in the USA. The Louisiana Bucket Brigade is an action group dedicated to partnering 'communities to help residents amplify their voices and challenge the petrochemical industry's relentless expansion.'[708] In November 2020, the group succeeded in persuading the US Army Corps of Engineers to suspend the permit for the Formosa Plastics Plant in St. James Parish, Louisiana, planned to be the largest petrochemical plant in the USA. In fact, the proposed facility is expected to emit 800 tons of GHGs each year, doubling the current level of emissions from the entire St. James Parish. The group opposed the project as 'the plant would pollute a predominantly Black community, disturb unmarked burial sites of enslaved people, degrade wetlands and add to the ocean plastic pollution crisis.'[709] Although motivated by a range of community concerns, the petrochemicals expansion plans have been interrupted, at least in part, due to increased concerns around the environmental damage caused by plastic.

The Louisiana Bucket Brigade is not the only local environment group causing disruption to the fossil-fuel regime. Increasing community environmental concerns are credited with discouraging international investors from joining the anticipated ethane fracking boom in America. Finance professor Kathy Hipple reported: 'more and more we're seeing from earnings calls and financial reports that local opposition has become a material

[708] Louisiana Bucket Brigade, "Army Corps Suspends Permit for Formosa Plastics' Controversial Louisiana Plant," *Louisiana Bucket Brigade* (blog), November 4, 2020, np, https://labucketbrigade.org/army-corps-suspends-permit-for-formosa-plastics-controversial-louisiana-plant/.
[709] Louisiana Bucket Brigade, np.

risk factor.'[710] For foreign companies looking to get in on a petrochemical build out, understanding the patchwork of local state and federal regulations is complex enough without the addition of lawsuits from community groups.

Concerns about increased fracking activities in North America extend well beyond its national boundaries. In Antwerp, Belgium, fourteen civil society associations successfully challenged a deforestation permit issued to Ineos Group for 'Project One,' established to produce polyethylene and polypropylene from fracked natural gas imported from the USA. The Flemish government suspended the permit in November 2020, citing inadequate assessment of the global environmental effects of the project.[711]

These shifting community attitudes toward plastics are being felt by product designers. Industrial designer Bertjan Pot revealed to me during our interview that he would no longer use carbon fibre, a material he had previously used for designs:

> I know for myself that I wouldn't make the *Carbon Chair* again. I mean, I like the chair and I think it's a good thing and they should keep making it because it's a good thing. Worst thing about the product is that you throw it out, but I don't think the *Carbon Chair* is something you throw [away] easily. So, on that point, it's quite safe, but to recycle this it's horrible. It's all composite are when you glue materials together, you know you are not making it really usable in a cradle-to-cradle way.[712]

Speaking more generally about plastics he revealed his growing concern with working with the material and its end-of-life prospects:

> For Moooi I did propose another light to them last year, actually a few, when one of them had quite a lot of plastic in it. And then Marcel [Wanders] said. Yeah, it's too much plastic. I think he's right... Where is this block of light, a block of plastic, ending up through the life cycle?[713]

[710] Kristina Marusic, "Appalachia's Fracking Boom Has Done Little for Local Economies: Study," EHN, February 10, 2021, https://www.ehn.org/fracking-economics-2650429410.html.
[711] Service of the Administrative Law Courts, "Antwerp - INEOS environmental permit - suspension," November 13, 2020, https://www.dbrc.be/persbericht-antwerpen-omgevingsvergunning-ineos-schorsing.
[712] Isaac, Interview with Bertjan Pot.
[713] Isaac.

Gabriel Chiave, from Marcel Wanders office made similar comments, reporting the studio is actively trying to reduce its involvement with projects that involve plastic:

> If it's not extremely innovative or if it's not extremely revolutionary in a way because the world doesn't need another huge roto-moulded plastic base or seat. So, we try to avoid those type of projects as much as we can.'[714]

Other designers reported that environmental concerns are driving changes in consumer preferences. Barber & Osgerby even suggested that the public might abandon some of the more harmful plastics:

> Now everyone has realised that bioplastics are the new way forward. If you are going to continue to product polycarbonate, people aren't going to buy that in a couple of years, if not by next year. Companies like Kartell must seriously be considering their business plan by now. Most other companies probably have a more diverse base of products. It's great, thank God it is happening now.[715]

Likewise, Louis Durot predicted the demise of polyurethane:

> Today I use polyurethane that contains a highly toxical [sic] component before production. After production the product, if not burnt, is not offensive/dangerous, but the components to produce it are dangerous. Just like for Bakelite, my artwork, that I am still allowed to produce now, will be forbidden to produce within a few dozen of years.[716]

Pot even went further, suggesting that environmental concerns are directly impacting consumer preferences:

> I think there's also this almost visual need for things being lighter, more transparent less material. So, in a way like the visual trend is keeping up with the [environmental] trend or with the real issue, or the practical issue, of why we shouldn't use plastic that much.[717]

Those designers, prompted by increased awareness of the environmental impacts caused by plastics, are actively reconsidering their relationship with the material. Some have even gone so far to commit to stop using specific types of plastic. Even major companies like Kartell,

[714] Isaac, Interview with Gabriel Chiave.
[715] Isaac, Interview with Barber & Osgerby.
[716] Geoff Isaac, Interview with Louis Durot, June 18, 2019.
[717] Isaac, Interview with Bertjan Pot.

who have built their entire business around fossil plastics, are actively revaluating their dependence on them, discussed in more detail in Chapter 8.

These shifts in actor-related perceptions provide examples of how 'mood' can accelerate or slow down diffusion and affect breakthrough.[718] There is danger that a single symptom of the plastics problem (ocean plastics) becomes prioritised in political debate and monopolises scientific attention to that problem.[719] By focusing on a niche downstream impact attention is potentially diverted from the source of the problem. The challenge is for more force to be directed, upstream at the originating source of the problem. Every designer or manufacturer who decreases their use of fossil plastic resists the petrochemical industry's expansion.

c. Government intervention

Government can adopt the role of a transition manger, directly affecting the success of a technology or the speed with which it is adopted.[720] Intervention is useful to support currently financially unviable innovations (such as many bioplastics) that can deliver long-term benefits. Regime change can be accelerated by protecting and encouraging or mandating, desirable, niche innovations. However, policymakers often effectively form alliances with incumbent organisations that become resistant to fundamental change. Geels provided an example, observing:[721]

[718] F. W. Geels, "Processes and Patterns in Transitions and System Innovations: Refining the Co-Evolutionary Multi-Level Perspective," *Technological Forecasting and Social Change*, Transitions towards Sustainability through System Innovation, 72, no. 6 (July 1, 2005): 692, https://doi.org/10.1016/j.techfore.2004.08.014.
[719] Nielsen et al., "Politics and the Plastic Crisis."
[720] Köhler et al., "An Agenda for Sustainability Transitions Research," 3.
[721] Frank W Geels, "Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective," *Theory, Culture & Society* 31, no. 5 (September 1, 2014): 21–40, https://doi.org/10.1177/0263276414531627.

> The problem for sustainability transitions is that many unsustainable industries have many economic resources and good political contacts, which may hinder, delay or water down strict environmental regulations.[722]

The mutually advantageous, symbiotic relationship that has developed between governments and the fossil-fuel regime, due to an industry led strategy of lobbying supported by donations. Neo-liberal market economics has resulted in an alignment of policymakers and businesses, who share goals and problems.

With the established fossil-fuel regime in a powerful alliance with government it is often challenging to implement policy interventions designed to deliver long-term environmental benefits. Sustainability is a public good. Therefore, individual private actors have limited incentives to address it. Public policy needs to play a central role in shaping the directionality of transitions through environmental regulations, standards, taxes, and subsidies.[723] Macro level policy guides individual choices at the micro level.[724]

Consistent international action is the most efficient method to drive change in the plastics industry. The Basel Convention on the *Control of Transboundary Movements of Hazardous Wastes and Their Disposal,* enjoys near-universal support. Mixed plastic waste can only be exported with the prior consent of the importing country. Also on the positive side, an attempt to implement a global governance arrangement that addresses the whole lifecycle of plastics is underway. The agreement calls for the use of virgin plastics to be largely phased out by 2040, and most plastic products should be made from recycled

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[722] Frank W. Geels, "Ontologies, Socio-Technical Transitions (to Sustainability), and the Multi-Level Perspective," *Research Policy*, Special Section on Innovation and Sustainability Transitions, 39, no. 4 (May 1, 2010): 504, https://doi.org/10.1016/j.respol.2010.01.022.

[723] Köhler et al., "An Agenda for Sustainability Transitions Research," 3.

[724] Emma Dewberry and Jeffrey Johnson, "Design Interventions, Prediction and Science in the Sustainable Transition of Large Complex Systems" (The 2nd International Conference on Design Engineering and Science (ICDES2010), 17-19 November, Tokyo, UK: The Open University, 2010), 2.

content as feasibly possible. The proposal will be presented to the Nations Environment Assembly in February 2022 but, even if approved, it will take years before details are finalised, raising a concern that the 2040 target for implementation is unrealistic.[725]

The UN has also involved itself with specific cases, particularly where there is evidence of environmental racism. In March 2021, the UN Human Rights Commission raised serious concerns about further industrialisation of 'Cancer Alley,' an area of Louisiana that is home to multiple petrochemical complexes.[726] The UN found the proposed Formosa Plastics Plant could increase the cancer risks in predominantly African American Districts in St James Parish to about 105 cases per million, while in other predominantly-white districts the cancer risk is in the range 60 to 75 per million.[727] These environmental justice concerns are reinforced by the fact 90% of GHG emitted from plastic production in the USA occurs in just 18 communities, are 67% more likely to be people where residents earn 28% less than the average and are 67% more likely to be inhabited by people of colour.[728] But the UN has no power to stop this or any future developments in Louisiana or elsewhere.

International initiatives have so far failed to tackle the issues of microplastics or toxic chemical additives. Currently plastic manufacturers face little regulation over their product offerings despite more than 1,500 substances, often used in plastics being listed as chemicals of concern. [729] Fillers, additives, and colouring agents mixed with polymers to improve mechanical properties or aesthetic appearance can contain toxins. This issue is not restricted to fossil plastics, for instance, per- and polyfluoroalkyl substances (PFAS) are often used as a

[725] Simon et al., "A Binding Global Agreement to Address the Life Cycle of Plastics."
[726] The Center for International Environmental Law defines cancer alley as an industrial chemical corridor along the Mississippi River, the 85-mile stretch between New Orleans and Baton Rouge, Louisiana. The stretch contains seven out of ten census tracts with America's highest cancer rates.
[727] See: https://news.un.org/en/story/2021/03/1086172
[728] Beyond Plastics, "The New Coal: Plastics & Climate Change" (Bennington, Vermont: Bennington College, October 2021), 7, https://www.beyondplastics.org/plastics-and-climate.
[729] Simon et al., "A Binding Global Agreement to Address the Life Cycle of Plastics."

moisture and grease resistant coating on the most commonly available bioplastic, polylactic acid (PLA), despite known health concerns.[730] Bisphenol A (BPA) is often found in polycarbonate and can be used in the manufacture of baby bottles, again despite serious health concerns.[731] In October 2021, a ten-year longitudinal study following 5,300 inhabitants of the USA found that phthalates (additives designed to increase the durability and flexibility of plastics), may contribute to the early deaths of around 100,000 elder Americans each year, with a cost of $40bn to the economy.[732] International agreement on definitions, standards, and labelling (particularly the bewildering and confusing array of eco-labels) is needed.

At the national level the politics of plastic have primarily focused on single items with plastic bags, plates, cutlery or microbeads (found in toiletries and cosmetics) commonly targeted by legislation in response to public concern. Recently, there is a shift to initiatives aimed at banning 'single-use plastics,' the focus of politics is shifting towards the entire system, no longer focusing on single items.[733] Some jurisdictions have already used policy to encourage post-consumer recycling, such as the EU Directive (94/62/EC), requiring all plastics packaging used throughout the EU to reusable or recyclable in an economically viable way by 2030. Germany has legislated extended producer responsibility, launching the Green Dot scheme to implement recovery and recycling of packaging.[734] The USA has proposed a tax of 20 cents per pound on virgin plastic resins, but this is being resisted by

[730] For a list of academic references detailing the health impacts of PFAS see: Greenpeace International, "Biodegradables Will Not Solve China's Plastics Crisis," 16.
[731] The EU banned the use of bans of bisphenol A in baby bottles in 2011European Environment Agency, "Plastics, a Growing Environmental and Climate Concern," 78.
[732] Leonardo Trasande, Buyun Liu, and Wei Bao, "Phthalates and Attributable Mortality: A Population-Based Longitudinal Cohort Study and Cost Analysis," *Environmental Pollution*, October 12, 2021, 118021, https://doi.org/10.1016/j.envpol.2021.118021.
[733] Nielsen et al., "Politics and the Plastic Crisis."
[734] Jefferson Hopewell, Robert Dvorak, and Edward Kosior, "Plastics Recycling: Challenges and Opportunities," *Philosophical Transactions of the Royal Society B: Biological Sciences* 364, no. 1526 (July 27, 2009): 2122, https://doi.org/10.1098/rstb.2008.0311.

industry participants.[735] The UK plans to implement a plastics tax of £200 per tonne of packaging that does not reach a threshold of 30% recycled plastic in April 2022. The EU has enjoyed more success here, introducing a tax of 0.8 euros per kg of non-recycled packaging waste in 2021. Although it remains to be seen if that tax will be passed on to polluters or absorbed into members' general budgets.[736] Other justifications are relying on voluntary commitments from FMCGs (such as those being led by the Ellen McArthur Foundation) to eliminate their use of virgin fossil plastics. With the price of recycled plastics now exceeding that of virgin fossil plastics it is yet to be determined if these voluntary commitments will be honoured in the long term.

An increasing number of jurisdictions are introducing container deposit schemes (CDS) to tackle plastic littering. By offering cash incentives to return beverage containers reductions in littering have been reported.[737] Such schemes facilitate sorting at the point of collection, allowing plastics to be more accurately separated by type and producing cleaner streams for potential recycling. Governments can go further and mandate the use of use of recycled plastics and bioplastics in products purchased by government agencies or even by industry. China has led the way here, stepping into the role of an active transition manager, mandating the use of recycled materials by key industrial sectors including the automobile industry.[738]

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[735] In October 2021, 67 companies from throughout the plastics industry value chain, delivered a letter to leaders in the U.S. House of Representatives and U.S. Senate expressing concerns about the proposed tax.

[736] "Europe Is Implementing a Tax on Plastic," *C&EN Global Enterprise* 99, no. 2 (January 11, 2021): 34–34, https://doi.org/10.1021/cen-09902-cover7.

[737] For example, the NT government operates the longest running CDS in Australia and claims, "The proportion of regulated containers in the litter stream decreased from 5-10% prior to the commencement of the CDS to 3.1% in the first year of the commencement of the CDS, and maintained an average of 3.1% across the first five years of operation of the CDS.' Department of Environment and Natural Resources, "Evaluation of the Operation of the Northern Territory Container Deposit Scheme" (Northern Territory Government, August 2018), https://ntepa.nt.gov.au/publications-and-advice/container-deposit-scheme-reports.

[738] The European Commission is considering introducing similar rules on mandatory recycled content for vehicles due to be announced in 2022.

Following the introduction of the China Sword policy, governments in high-income countries are being forced to intervene to encourage rapid expansion of domestic plastic recycling infrastructure. Grants and loans (and planning application shortcuts) are being made available to stimulate development.[739] While cheap finance is popular with the entrenched waste regime and is likely to eventually increase the supply of recyclates, it does nothing to stimulate demand. Europe has attempted to address that imbalance by (creating demand for recycled plastics by introducing a plastic tax of €800 per tonne on plastic packaging that is not recyclable.[740] This approach mimics petrol taxes (estimated as averaging €80 per tonne of CO2 globally), which raises revenue by making polluters pay to compensate for the externalities created by its consumption (estimated at over €100 per tonne of CO2).[741] Having stimulated demand for recyclates, governments can then distribute the money raised from forcing polluters to pay for externalities to build the recycling infrastructure now required to meet increased demand.[742]

Renewable plastics and bioplastics have not received the level of support afforded by governments to assist the biofuels industry. For example, in the 1970s the Brazilian government committed to purchasing fleets of cars running on biofuels, while in 2003, the EU introduced the Biofuels Directive. Both initiatives are elements of broader strategies designed to accelerate the uptake of ethanol.[743] Other technologies that are more sustainable than carbon-based biofuels could be developed for transport—electric vehicles,

[739] In 2020 the Australian Government has announced plans to invest $190 million to support investment in recycling facilities across the country.
[740] Directive (EU) 2018/852 of the European Parliament and of the Council of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste
[741] Carbon Tracker Initiative, "The Future's Not in Plastics," 35.
[742] Carbon Tracker Initiative, 35.
[743] Semida Silveira and Francis X. Johnson, "Navigating the Transition to Sustainable Bioenergy in Sweden and Brazil: Lessons Learned in a European and International Context," *Energy Research & Social Science*, Energy Transitions in Europe: Emerging Challenges, Innovative Approaches, and Possible Solutions, 13 (March 1, 2016): 180–93, https://doi.org/10.1016/j.erss.2015.12.021.

for example. 'But there is not really any alternative to all the plastic and rubber materials that society needs.'[744] Policies could be targeted to promote bio-based chemicals, replacing petrochemicals while reducing GHG emissions. While Western governments have been keen to support the development of biofuels, policies to incubate the bioplastic market have been generally absent.

Developing an entire new industry takes years or decades. While many bioplastics show promise in the laboratory, there are no guarantees that production at an industrial scale is technically or economically feasible. Venture capital investors are more likely to support projects with a lower-risk profile and faster, guaranteed payback.[745] The important role government could play in driving demand for bioplastics was illustrated by the industrial designer, Louis Durot, in my interview with him:

> To date no company has asked me to help them to research biodegradable plastics… because without special laws there is no market or need for fully biodegradable plastic. With time, plastic becoming more and more polluting, probably a legal system will come.[746]

Indeed, China has led the way in introducing policy to promote bioplastics. Fuelled by a desire to break away from its dependency on imported oil, China has ambitious plans to expand production to 2.38 million tonnes by 2025 tonnes, a sevenfold increase on 2019.[747] Thailand has also been quick to recognise the potential of bioplastics, offering tax incentives to companies to encourage the use of biodegradable plastic packaging with the aim of persuading 10% of existing plastic manufacturers to change production to bioplastics.[748]

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[744] Simon J Bennett, "Using Past Transitions to Inform Scenarios for the Future of Renewable Raw Materials in the UK," *Energy Policy*, Special Section: Past and Prospective Energy Transitions - Insights from History, 50 (November 1, 2012): 102, https://doi.org/10.1016/j.enpol.2012.03.073.
[745] Bennett, 102.
[746] Isaac, Interview with Louis Durot.
[747] Greenpeace International, "Biodegradables Will Not Solve China's Plastics Crisis," 1.
[748] Axel Barrett, "Thai Government Gives Tax Deduction for Using Bioplastics Packaging," Bioplastics News, June 9, 2019, https://bioplasticsnews.com/2019/06/09/thai-government-gives-tax-deduction-for-using-bioplastics-packaging/.

Regulators need to be weary of unwanted outcomes. Caution must be shown when setting high-level targets designed to tackle waste and promote recycling. For example, the Australian Packaging Covenant Organisation (APCO) is charged with meeting Federal Government targets, including that an average of 50 per cent recycled content is to be used in all packaging by 2025.[749] In 2018/19 HDPE containers averaged only 2% recycled content.[750] The industry chose to focus on the easy solution, increasing the use of recycled paper and cardboard allowing them to meet the target while ignoring the more complex plastics issue. These actions will make it virtually impossible to reach the government's second target: for 70% of plastic packaging to be being recycled or composted by 2025. Government targets could have been better designed to compel industry to immediately act on phasing out virgin plastic packaging.

Critics of the MLP theory highlight inconsistencies in the consideration of policy, with some practitioners allocating local policy to the regime level and national (and international) policy at the landscape level.[751] In this analysis I have included all government interventions as affecting the landscape for the plastics industry. Longstanding ongoing government policy is treated as entrenched in the socio-technical regime. I realise this involves some arbitrary decisions, for example, the IMF estimate that $5.2 trillion dollars are given in tax subsidies by governments to support the fossil fuel industry every year.[752] In my interpretation of the theory I consider these subsidies as part of the status quo. In the

[749] See: https://apco.org.au/national-packaging-targets, accessed February 3, 2022.
[750] See: https://www.sustainabilitymatters.net.au/content/waste/article/demand-will-drive-soft-plastics-recycling-1311372333, accessed February 3, 2022.
[751] El Bilali, "The Multi-Level Perspective in Research on Sustainability Transitions in Agriculture and Food Systems," 15.
[752] David Coady et al., "Global Fossil Fuel Subsidies Remain Large: An Update Based on Country-Level Estimates" (Washington, DC: International Monetary Fund, May 2019), 2.

unlikely event that governments intervened to significantly reduce these subsidies that activity would represent a landscape shift.

Government intervention has the potential to quickly create opportunities for designers interested in sustainability. Policy needs to go beyond supporting the entrenched waste regime by financing recycling infrastructure in isolation and invest in the development of bioplastics. Demand-generation initiatives, largely neglected to date, need to broaden to shift their focus beyond packaging; mandating or incentivising manufacturers to decrease their use of virgin fossil plastics. With the right policy settings in place manufacturers will actively seek to engage designers with a demonstrable commitment to sustainability.

d. COVID-19

COVID-19 has severely disrupted the oil and plastic markets. The price of oil fell from around US$60 per barrel at the start of 2020, to a low of about $US11 in April, stabilising at around $40 for the remainder of 2020 as the market adapted to decreased global demand.[753] This decrease in the price of oil resulted in the price of virgin fossil plastics (including the monomers used to make them) falling, in some cases below the cost of recycled materials (fig. 6.6). Some plastic markets have since recovered, buoyed by increased demand for personal protection equipment (PPE) and significant increases in demand for packaging caused by the rapid increases in online sales and home delivered takeaway food.[754] Conversely, demand has been affected by the cancellation of sports events and concerts,

[753] "WTI Crude Oil Prices - 10 Year Daily Chart," accessed February 3, 2022, https://www.macrotrends.net/2516/wti-crude-oil-prices-10-year-daily-chart.
[754] An estimated 129 billion face masks are being used every month during the pandemic. Xu and Ren, "Preventing Masks from Becoming the next Plastic Problem" In May 2021, Braskem reported the shortage of demand for durables (cars, electronics, etc.) was counter-balanced with a peak in demand for medical and hygiene products, as well as for packaging products. During 2020, Amazon generated an estimated 599 million pounds of plastic packaging waste, representing a 29% increase on the previous year. Oceana, "Exposed: Amazon's Enormous and Rapidly Growing Plastic Pollution Problem" (Washington, DC: Oceana, December 2021), 4, https://oceana.org/reports/amazon-report-2021/.

reducing requirements for single-use plastics.[755] Overall Wood Mackenzie forecast a 4% fall in global plastic demand during 2020, in spite of rising demand for PPE (with a significant fall in demand for cars contributing to this).[756]

The price of ethylene per tonne in US$

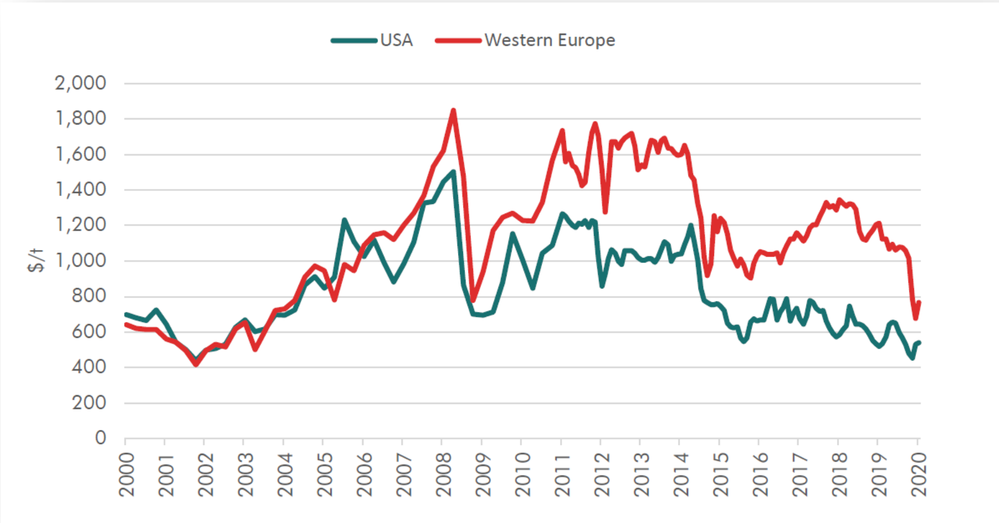

Fig. 6.6 Price of ethylene 2000-2020. Source: Bloomberg[757]

The falling oil price has also impacted the financial models driving investment in gas-fired cracking plants across the USA. A major global transformation away from reliance on oil as the major source of plastics (primarily manufactured in Asia) toward cheaper gas from fracking activities (primarily in the USA) has been disrupted by COVID-19. The lower oil price has impacted the business plans upon which capital raising for investment in fracking is

[755] Joshua Poole, "EUBP Foresees Dynamic Global Bioplastic Growth Inspired by Portfolio Diversification and COVID-19 Navigation," Packaging Insights, accessed February 3, 2022, https://pi.cnsmedia.com/a/SHV8hthPC04=.
[756] Carbon Tracker Initiative, "The Future's Not in Plastics," 17.
[757] Carbon Tracker Initiative, 31.

dependent. According to research firm S&P Global Platts, capacity to produce ethylene from gas rose 41% on the Gulf Coast over the past five years while margins dropped more than three-quarters over that period. The Gulf Coast ethylene margin dropped to $127 a metric ton in 2020 (from a high of $558 in 2015) (fig. 6.6). In response, Saudi Aramco, LyondellBasell Industries, and Chevron Phillips, have delayed plans for three Gulf Coast investments totalling $17 billion.[758] Near Pittsburgh, construction of a Shell cracker at Beaver County, Pennsylvania due for completion in 2020 has been delayed by COVID-19. Four additional petrochemical facilities planned for the same area have been placed on hold indefinitely as the appetite to finance these projects has evaporated.[759]

The petrochemical industry has exploited the COVID-19 crisis to argue against the introduction of policies banning single-use plastic, presenting, 'scientifically dubious studies to cast doubt over reusables,' while calling for the reversal of both deposit schemes and bans on single-use plastics.[760] In April 2020, the UK government announced a six-month delay to the introduction of a ban on plastic straws, stirrers, and cotton buds, citing health and hygiene concerns raised by the industry.

Beyond the health impacts caused by COVID-19 global economies have experienced significant disruption, with businesses closing and unemployment increasing.[761] COVID-19 has caused turmoil in energy markets, disrupted the long-term investments plans of petrochemical organisations, creating significant disruption to the landscape in which the

[758] Saabira Chaudhuri and Colin Eaton, "Firms Like Dow Bet Billions on Plastics. Now There's a Glut.," *Wall Street Journal*, October 15, 2020, sec. Business, https://www.wsj.com/articles/firms-like-dow-bet-billions-on-plastics-now-theres-a-glut-11602754200.
[759] Marusic, "Appalachia's Fracking Boom Has Done Little for Local Economies."
[760] Changing Markets Foundation, "Talking Trash," 8.
[761] Anne Sraders and Lance Lambert, "Nearly 100,000 Establishments That Temporarily Shutdown Are Now out of Business," Fortune, September 29, 2020, https://fortune.com/2020/09/28/covid-buisnesses-shut-down-closed/.

current social-technical regime operates. COVID-19 is shocking the system and has demanded radical re-orientations within the established regime.

3. Conclusion

In the real world, changes at the landscape level are not confined to the presented above. COVID-19 has resulted in many countries borrowing to support their economies through increased government spending. As countries attempt to reduce these debts, governments are more likely to be receptive to introducing levies and taxes (including carbon or plastic taxes) to raise revenue. After the oil crisis of 1973, governments took the opportunity to significantly increase the taxation on oil to help resuscitate their debt laden economies.[762] If history repeats, then this government response could be beneficial to supporting the development of the renewable plastics industry.

The long-term impact of COVID-19's disruption to the fossil plastic market is still being played out. However, what is clear from the analysis in this chapter is that COVID-19 is only one of a number of significant disruptions being experienced simultaneously by both the fossil-fuel and petrochemical industries. Previous shocks to the industry, like the 1970s oil crises, were primarily driven by sudden price changes, from which the regime quickly recovered. In the current situation price shocks are being compounded by a range of factors including growing concern around climate change and the environmental impacts of plastic, together with a growing awareness of the plastic waste problem (thanks to China's ban on importing waste from developed countries).

The MLP model recognises landscape events such as these for their potential to act as a catalyst, creating sufficient disruption to the status quo, providing an opportunity for

[762] Carbon Tracker Initiative, "The Future's Not in Plastics," 34.

new, more sustainable technologies to breakthrough challenging the dominance of the entrenched socio-technical system. However, the model also cautions that to take advantage of these temporary disruptions niche innovations need to be developed and sufficiently mature to take advantage of the opportunity.[763] The next chapter examines the barriers inhibiting the uptake of renewable plastics before identifying strategies that can be adopted by designers and manufacturers interested in playing an active role in driving the transition away from virgin fossil plastic.

[763] Geels, "Typology of Sociotechnical Transition Pathways," 405.

Part C

Advancing renewable carbon-based plastics

Chapter 7

Challenging the socio-technical regime

For a new technology to be widely adopted it must ultimately be accepted by the market, but it cannot succeed without first gaining support from a range of actors, including designers and manufacturers. This chapter begins by examining the decisions required when designing a chair and identifies the actor most likely to hold the ultimate authority over each choice. This analysis traces the web of interdependent design decisions that are affected by the choice of renewable plastics.

This is the first of two chapters that operationalise the multi-level perspective (MLP) to examine its relevance in accelerating the take up of renewable plastics. MLP is a transition framework that attempts to identify the conditions required for a new technology to succeed. Findings from MLP studies provide an analytical framework to interrogate the original research conducted for this dissertation. Extracts from my interviews with designers and manufactures have been selected to illustrate the complexity of issues and decisions that require addressing when working with renewable plastics to create chairs. While plastic chairs represent a relatively small niche market, many of the same challenges will confront all those seeking to use renewable plastics to develop any consumer goods.

MLP posits that transitions emerge from a process of interactions within and among three analytical levels: niches, socio-technical regimes (regimes) and a socio-technical landscape (landscape).[764] The theory relies heavily on niche technologies emerging through a process of learning and networking, allowing actors to benefit from the successes of other industry participants and learn from their failures. This chapter examines the real-life experiences of actors who have already experimented with renewable plastics to make chairs. Nurturing learning and encouraging sharing from those innovators can accelerate the

[764] El Bilali, "The Multi-Level Perspective in Research on Sustainability Transitions in Agriculture and Food Systems," 73.

scaling-up and scaling-out of the use of renewable plastics by all those involved with the production of consumer goods.

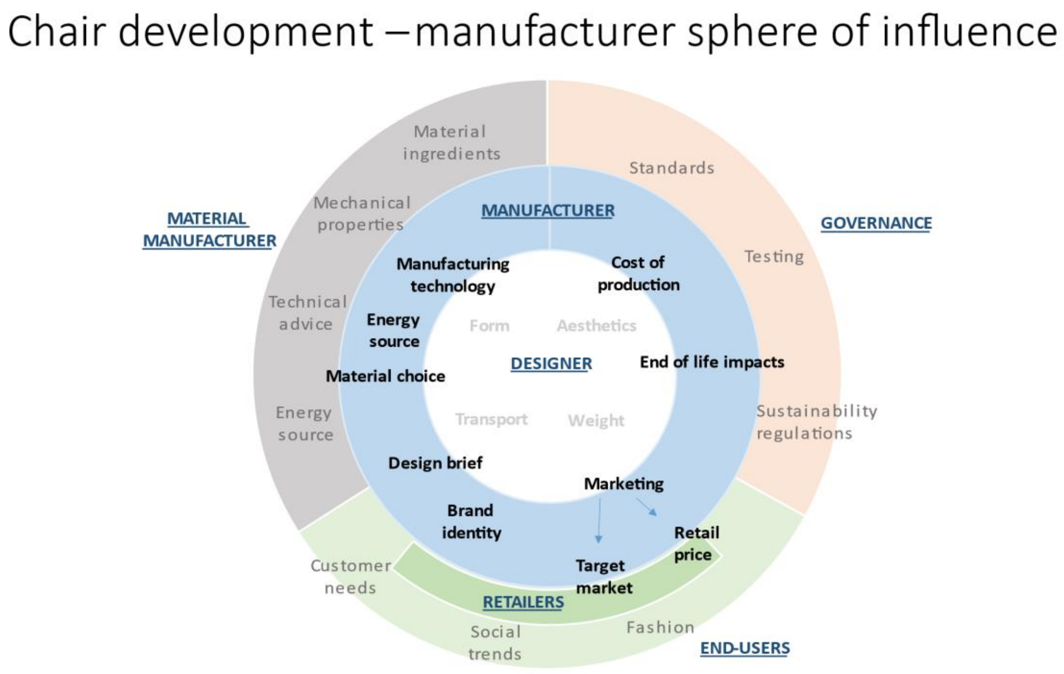

Fig. 7.1. Chair design—sphere of influence. Many factors must be considered during the development of any design. The decision-making responsibility of the main six actors (labelled in dark blue caps) is indicated by the position of the relevant label.

Fig. 7.1 captures the many decisions required while designing a chair. Six major actors are identified (in dark blue caps) and their role in the decision-making process is indicated by the positioning of the decision labels. The role of the manufacturer has been highlighted, as they usually ultimately decide on material choice—the focus of this chapter. Manufacturers can be expected to take some decisions without consulting with stakeholders. The choice of energy provider together with any commitments to support renewable sources is likely to be the sole responsibility of the manufacturer. For many other decisions consultation with designers, retailers, and/or material manufacturers is likely to occur before decisions are finalised and this is indicated by the placement of decision labels. For instance, material choice is usually decided by the furniture manufacturer, but they most likely seek input from the designer and advice from the material manufacturer before making their decision.

Many decisions are not mutually exclusive. The cost of production will be partly determined by the materials chosen and the manufacturing technology employed. The choice of materials is central to the environmental performance of a plastic chair (or most other products that do not consume energy during use for that matter). Material choice is a potentially complex decision, especially where new or unfamiliar materials are being considered. First, those involved with the decision must access reliable and up-to-date information on materials, their availability and cost. Designers and manufacturers need to be confident that the material's mechanical properties are sufficient for the task. Manufacturers must satisfy themselves that the required means of production and skilled labour needed to work with the material are available. The complexity of those factors can deter the selection of renewable plastics, stymying change. My analysis highlights the knowledge gap that needs to be filled for furniture manufacturers to explore the potential of renewable plastics. Here I articulate the role of designers as agents of change by educating, supporting, and advocating for renewable plastics.

In the previous chapter it was shown that various disruptions to both the energy and petrochemical regimes are occurring because of significant landscape events. MLP theory predicts that disruptions of this magnitude can cause cracks and tensions within the incumbent socio-technical regime, creating windows of opportunities for niche innovations to become mainstream by breaking through to the socio-technical regime level. However, incumbent regimes are predisposed to resist the costs and risks inherent in any change of technology. Innovations require investment and challenge the status quo, threatening the existence of some actors and imposing significant costs on others. The existing regime, therefore, tends to become institutionalised and resistant to change.[765] Where a regime's very existence is threated by a new technology resistance can be expected to intensify. However, it is not mandatory for an emerging technology to replace the established social-technical regime, incumbent actors can choose to adopt or adapt to the new technology, and this can apply across the petrochemical industry.[766] The success of any individual technological innovation cannot be guaranteed. Innovations such as bioplastics, with the potential to undermine the dominance of both the fossil-fuel and petrochemical regimes, can expect to be confronted with extreme resistance.

Four major categories of issues that confront those who seek to incorporate renewable plastics into their product designs have been identified from research undertaken for this study and are shown in fig. 7.2. In effect all four of these issues (awareness, misinformation, availability/cost, and lock-in) act as barriers to experimenting with new materials. It is far easier and less costly to maintain the status quo and continue to use established processes and materials. By understanding those barriers and the experiences of those who have overcome them designers and manufactures are better prepared to advocate for the adoption of renewable plastics.

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[765] Fuenfschilling and Truffer, "The Structuration of Socio-Technical Regimes—Conceptual Foundations from Institutional Theory," 772.

[766] Geels describes how sailing ships were adapted to take advantage of the benefits offered by steam. Geels, "Technological Transitions as Evolutionary Reconfiguration Processes," 1268 Some participants in the petrochemical industry are adapting by introducing recycled feedstocks to replace virgin fossil fuels, discussed in more detail below.

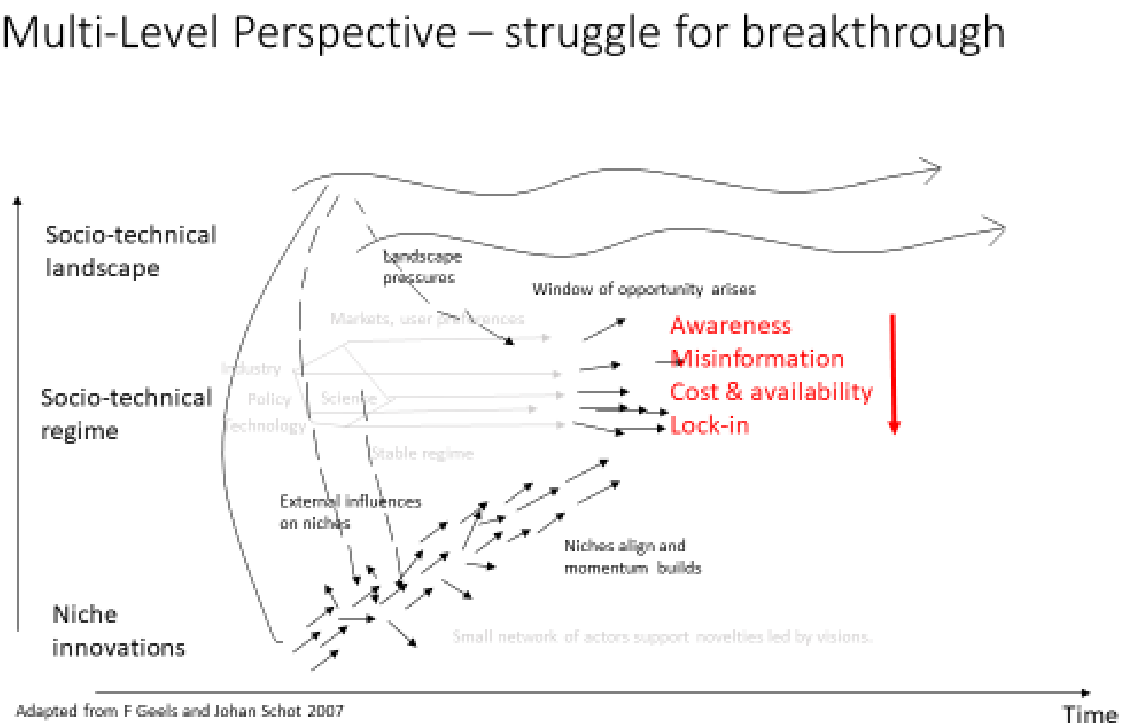

Fig. 7.2 Issues resisting challengers to the established socio-technical regime
Source: Adapted from Geels and Shot (2008)[767]

1. Lock-in

Lock-in is defined as: 'the metaphor to describe actors within a socio-technical regime that gain from perpetuating an existing technology at the expense of a new one blocking incoming innovations.'[768] Previous investments in manufacturing equipment create an overhang of technological inheritance that shapes, directs, and influences ongoing research. Continuous investment to create mature manufacturing processes operated by skilled and experience staff can make it prohibitively expensive to adjust for new materials or manufacturing technologies. Indeed, staff can become biased toward new technologies

[767] Schot and Geels, "Strategic Niche Management and Sustainable Innovation Journeys," 546.
[768] Martin E. Wainstein and Adam G. Bumpus, "Business Models as Drivers of the Low Carbon Power System Transition: A Multi-Level Perspective," *Journal of Cleaner Production* 126 (July 10, 2016): 575, https://doi.org/10.1016/j.jclepro.2016.02.095.

offering incremental improvement to existing systems rather than those threatening radical change.[769] Dependable and reliable supply chains have been built together with mutual dependence built on trust. Regulations, technical standards and policies have evolved around existing technologies and can complicate or prohibit change.[770] Sustainable technologies can differ significantly from existing technologies and demand new standards. Attempts to modify or adapt standards are often a challenging political process, as the interests of the incumbents are usually well represented in the controlling bodies.[771]

Material suppliers are also locked in. Fossil plastic, a niche market for the energy industry, is essentially a valuable bi-product from the extraction of fossil fuels with a constant and consistent supply guaranteed. In the case of the oil segment of the energy market, a small fraction of each barrel is effectively allocated to making chemicals, including plastics, supporting the economic advantage of maintaining oil in the energy mix. Energy analyst Simon Bennett highlights the fact there are only about 700 oil refineries worldwide controlling both the fuel and chemical markets, with entrenched interests resisting a shift to renewable feedstocks.[772]

Since 2012 (when the Bennett paper was published), gas has emerged as an increasingly common feedstock for plastics. The principle remains unchanged—plastics represent a profitable additional niche market to support fracking activities. A small number of multi-nationals dominate the fossil fuel markets and many of them have interests in (or control) petrochemical organisations increasing pressure to maintain the

[769] Elzen, *System Innovation and the Transition to Sustainability Theory, Evidence and Policy*, 7.
[770] Magda M. Smink, Marko P. Hekkert, and Simona O. Negro, “Keeping Sustainable Innovation on a Leash? Exploring Incumbents’ Institutional Strategies,” *Business Strategy & the Environment (John Wiley & Sons, Inc)* 24, no. 2 (February 2015): 90, https://doi.org/10.1002/bse.1808.
[771] Smink, Hekkert, and Negro, 90 & 97.
[772] Bennett, “Implications of Climate Change for the Petrochemical Industry,” 351.

status quo.[773] While plastics are produced all over the world, just 10 organisations dominate the market with only about 100 significant players.[774] It is in the interest of these organisations and their shareholders to maintain business as usual.

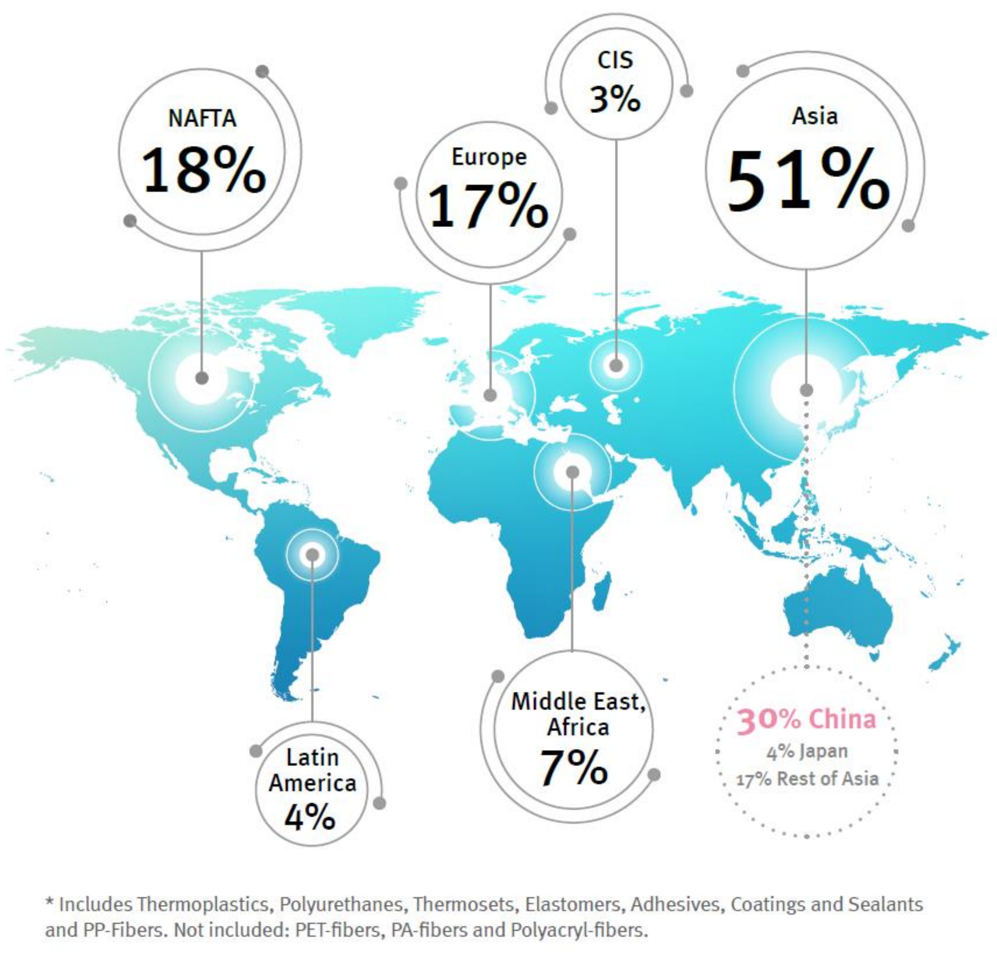

Fig. 7.3 Distribution of global plastic production. Source: Plastics Europe Market Research Group (PEMRG) and Conversio Market & Strategy GmbH (2019)[775]

Plastic furniture represents a small niche of both the plastics market and the furniture market. Plastic manufacturers and furniture makers are locked into a symbiotic relationship forged by decades of investment in research, manufacturing infrastructure, and training of

[773] For example, China's Sinopec and PetroChina, America's ExxonMobil Chemical, India's Reliance Industries, and France's Air Liquide are among the largest petrochemical organisations in the world and are directly owned by entities primarily focused on the extraction of fossil fuels.
[774] "Polymer Market Size, Share, Trend, Revenue & Forecast 2030," P&S Intelligence, accessed February 3, 2022, https://www.psmarketresearch.com/market-analysis/polymer-market.
[775] Plastics Europe, "Plastics the Facts," 2019, 15, https://www.plasticseurope.org/en/resources/publications/1804-plastics-facts-2019.

staff. Dedicated to maximising profits for shareholders it is challenging (and often illogical) for those organisations to invest in new technologies that threaten to compete with what has become the conventional mode.[776]

Chiave, from Marcel Wanders office, outlined the high-level issues confronting designers wishing to work with renewable plastics:

> As much as we designers wants to explore the territory of recycled materials much of the industry (not all) does not because of cost. When you have to start a new production, with new materials it means a new process. It means a new cycle and means investment. So not everyone is very keen for now... The problem is that we need the system around us. We need the system of people and the industry in order to really have a system that is making recycling work. Our countries, our cities, our environment needs to [be more circular].[777]

Examples of regime pressures locking-in existing investments at all levels of the industry were often cited by designers participating in this research. For instance, Armstrong reported that, despite specifying the set-up of jobs for production, he experienced both domestic and overseas suppliers wanting to deliver projects in their own way, to suit their established manufacturing processes.[778]

Karim Rashid offered an example of how this resistance can manifest when trying to introduce new materials to clients. He told me about a time that he presented to a 'very large company' that produces food goods and snacks to encourage the use of alternative packaging. His suggestion did not receive a welcome reception, as Rashid said: 'a lot of these companies don't want to hear that from me. It's kind of like this isn't really your business or this is our supplier.'[779]

Rene Linsenn, an industrial designer at Formswell, is keen to use bioplastics but has heard reports from others who had taken five years to develop products in-house. He viewed

[776] Wainstein and Bumpus, "Business Models as Drivers of the Low Carbon Power System Transition," 574.
[777] Isaac, Interview with Gabriel Chiave.
[778] Isaac, Interview with Dan Armstrong and Rene Linssen.
[779] Isaac, Interview with Karim Rashid.

the material as inaccessible to him, citing the associated development costs and claiming that those who had successfully experimented with bioplastics wanted to protect their investment and not share what they had learnt.[780] Linsenn makes a particularly important point with that statement. The MLP model is dependent on continued experimentation with an emerging technology; an unwillingness to share their findings impedes future experimentation.

Designers are also locked into a model of industrial design with the focus on the artefact. Clients commission designers to develop chairs, the brief might specify a niche market, such as education, but patrons do not instruct (or pay for) designers to question the seating requirements of educational establishments and develop alternative business models to satisfy those needs. While designers continue to be engaged on short term contacts as 'service providers' they enjoy limited opportunity to go beyond their brief and suggest radical alternatives such as product service solutions (PSS).

Outsourcing production can also lead to lock-in. Many furniture manufacturers outsource some or all their production processes, often taking advantage of globalised markets to source the lowest price to help contain their costs. This focus on price limits the capacity of suppliers to invest in new technologies or staff training. In large manufacturing facilities staff are often trained to undertake very specific tasks and not given the opportunity to develop an understanding of the entire production process, which can further hinder the implementation of any change. Even if resources are available, production facilities servicing multiple clients from around the world are unlikely to be receptive to requests to accommodate new technology for a single project, especially from a relatively small customer.

[780] Isaac, Interview with Dan Armstrong and Rene Linssen.

Magis outsource all of their production to companies in the north of Italy. During our interview Ruben Hutschemaekers, the head of marketing and communications, rejected the suggestion that his company, with its established network of trusted local suppliers, is better placed to experiment with new production techniques or materials. This was especially true, he suggested, when compared with manufacturers who have sunk considerable investments in in-house facilities.[781] Hutschemaekers made the point that the success of any material or technological innovations was reliant on securing support from the existing network of suppliers, who are themselves constrained by their previous investment decisions and the skills of their staff. Introducing new materials requires extra work to identify and connect with new partners and suppliers, a time-consuming process which may generate friction with established suppliers.

Language barriers and cultural differences can add to the complexity of adapting existing manufacturing processes to accommodate new materials. Belgium-based Victor Macadar sourced bioplastic from an Australian supplier and then worked with a Chinese injection moulding specialist to produce his bioplastic product. His experiences offer insights into some of the complexities an international supply chain can encounter. At first his idea of using bioplastic from the factory was met with resistance, as they preferred to carry on working with conventional plastics, based on familiarity and expertise with those materials. When the factory did agree to develop his design, Macadar encountered further cultural barriers as he explained to me:

> …most moulds are being produced in China… they do not know how to work with this [bioplastics] and this is a social problem. It's not a resistance. It's a lack of capability to work to learn something. It's social, culturally how they teach and [learn]. You give them this material [the bioplastic]… and they put in the machine. You give them the parameters and they [enter] in the machine the parameters of traditional plastic… This is a real problem, the most

[781] Isaac, Interview with Ruben Hutschemaekers, Magis.

> producers are in China, you have to go there and explain them—that is a lot of you lose time. You lose a lot of money because you have to travel that's what happened to me.[782]

Supply chain management and relationship management are separate fields of academic enquiry beyond the scope of this dissertation.[783] However, Macadar's comments highlight the different attitudes and methods of conducting business in different cultural contexts. A representative from the material supplier (Bambacore) agreed with Macadar's sentiments, adding that in her experience operators in China preferred to learn by doing, using trial and error but this resulted in a significant waste of material.[784] To address the issues encountered by Macadar, Bambacore have since employed a fluent Mandarin speaker in efforts to improve communications between clients and their manufacturers going forward (representing a significant cost increase for the material supplier). Macadar's experience highlights the added complexity of attempting to introduce new work practices into globalised manufacturing networks.

a. Industry consolidation

Industry consolidation can increase lock-in effects, as larger organisations require more investment to change or adapt their existing infrastructure. Some plastic furniture manufacturers remain independently owned (Vitra, Kartell, Vondom, and Magis among them), but they are exceptions. The constant search for continued growth and profits demands ever larger economies of scale which drives mergers and acquisitions. Recently, the Italian conglomerate Investindustrial acquired furniture producer B&B Italia and lighting manufacturers Louis Poulsen and Flos creating a new company: Design Holding. The

[782] Geoff Isaac, Interview with Victor Macadar, December 4, 2020.
[783] For a discussion focusing on China see: Xiande Zhao et al., "The Impact of Power and Relationship Commitment on the Integration between Manufacturers and Customers in a Supply Chain," *Journal of Operations Management* 26, no. 3 (May 1, 2008): 368–88, https://doi.org/10.1016/j.jom.2007.08.002.
[784] Geoff Isaac, Interview with Diaz Mayda, April 2, 2020.

American office furniture specialist Haworth acquired furniture brands Cappellini, Poltrona Frau and Cassina, creating one of the world's largest companies dedicated to furniture production.[785] In April 2021, Herman Miller announced plans to acquire Knoll, merging two large North American furniture manufacturers.[786] The larger a company gets the more constrained by convention it becomes, as the costs associated with change rapidly escalate.

Delay becomes an increasingly rational option the larger organisations become. This can lead to inertia and the formation of a 'cartel of fear' in which no firm wants to take the first step because of the risks involved.[787] While possible first-mover advantages form an incentive to pioneer green innovations, companies also face many uncertainties, especially around consumer willingness to pay for sustainability. But, when one company does make a move, an innovation race often rapidly follows.[788] The barriers for plastic chair manufacturing are relatively modest when compared with the airline or automobile industries. Chairs allow smaller, more agile manufacturers to take the lead in introducing renewable carbon chairs to the market and forcing the larger organisations to compete or risk losing market share.

2. Awareness and knowledge

Previous studies have shown that furniture designers often limit their selection of materials and processes to those they are familiar with, and this can often be attributed to a lack of

[785] Johanna Ross, "A Herculean Task," DisegnoDaily, June 17, 2020, https://www.disegnodaily.com/article/a-herculean-task.
[786] See https://newleaderinmoderndesign.com for more details.
[787] STRN Research Agenda 2012 p15. F. W. Geels, "Co-Evolutionary and Multi-Level Dynamics in Transitions: The Transformation of Aviation Systems and the Shift from Propeller to Turbojet (1930–1970)," *Technovation* 26, no. 9 (September 1, 2006): 999–1016, https://doi.org/10.1016/j.technovation.2005.08.010.
[788] As happened with the Toyota Prius see STRN Research Agenda 2012, p15

awareness of alternatives.[789] Rapid developments in renewable plastics and, particularly, the bioplastic segment, make it challenging for designers and manufacturers (and their educators) to keep informed. Awareness, then, is the first barrier to overcome for the introduction of these new materials. Developing knowledge of new materials is further challenged by confusing and conflicting messaging circulating in the market and deliberate misinformation campaigns initiated by incumbents (discussed separately below).

For designers and manufacturers to work with new materials they need to become knowledgeable about their mechanical properties and processing requirements. Developing or accessing reliable knowledge about the catalogue of renewable plastics is particularly challenging. The role that intermediary actors such as professional associations can take to promote and diffuse new technologies is emphasised by research undertaken by the pioneering MLP theorists Frank Geels and Jasper Deuten.[790] Associations can play a leading role in monitoring multiple projects, aggregating generic lessons, and promoting knowledge through journals, conferences, or dedicated workshops.[791] Despite the number of associations and publications servicing the design industry, participants in this research failed to identify common sources of information on materials. Designers often told me that they discovered new materials by accident. Other designers, for example, Sarah Gibson, co-owner of DesignByThem, reported using search engines, blogs, and industry contacts when seeking new materials. To date there are no established, trusted sources of information for designers seeking to work with renewable plastics.

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[789] Alaa Anssary's PhD, focused on how new materials and production techniques are considered by designers involved with furniture production Anssary, "An Approach to Support the Design Process Considering Technological Possibilities," 160.
[790] Frank Geels and J. Jasper Deuten, "Local and Global Dynamics in Technological Development: A Socio-Cognitive Perspective on Knowledge Flows and Lessons from Reinforced Concrete," *Science & Public Policy (SPP)* 33, no. 4 (May 2006): 265–75, https://doi.org/10.3152/147154306781778984.
[791] Geels and Deuten, 9–10.

British metallurgical engineer, Michael Ashby, working with design consultant Kara Johnson reported similar findings. While engineers had ready access to information about new materials and shaping techniques, they found industrial designers to be frustrated by the fact they did not have access to equivalent support.[792] Alaa El Anssary conducted research on German and Egyptian product designers and engineers, discovering a lack of information about new material or techniques were common among designers. While engineers could access the information they needed, designers often found the available information to be presented in a complex, scientific fashion, too detailed for their requirements.[793] Anssary also reported the lack of a central, trusted source of information among the designers he interviewed. Instead, he discovered a reliance on information gathered during previous projects, with none of the participants reporting a formal approach to research during the early stages of the design process.[794] Additionally, he found designers lacked formal methods to explore new knowledge or transfer it to their work.[795]

Australian industrial designer, Dan Armstrong summarised additional challenges facing designers trying to get the information they need in a globalised market:

> If the client [asked] can I make it totally environmentally friendly, whatever that means. [We would say], "Let's look into that." Then you go to China and talk to them about it and they will always give you an option and say, "Yes, no worries, we have this." It's just a business relationship and keeping people happy. But the truth, the real truth of those materials and the end results I'm not sure of. No one really knows. People want just desperately to put an eco-sign somewhere on their packaging and go, "Is it all good? Sure? Cool, let's go let's make some money".[796]

Armstrong's experience illustrates the challenges faced by many designers operating in a world where production is increasingly outsourced around the globe, introducing another

[792] Michael F. Ashby and Kara Johnson, "The Art of Materials Selection," *Materials Today* 6, no. 12 (December 1, 2003): 25, https://doi.org/10.1016/S1369-7021(03)01223-9.
[793] Anssary, "An Approach to Support the Design Process Considering Technological Possibilities," 184.
[794] Anssary, 62.
[795] Anssary, 185.
[796] Isaac, Interview with Dan Armstrong and Rene Linssen.

layer of complexity to their attempts to get accurate information about materials. When seeking information about renewable plastics prospective purchasers will also encounter additional complexities specific to the category of material.

b. Recycled plastics

Recycled plastics have been available for many years, allowing designers and manufacturers to become acquainted with them. Despite that, the designers and manufacturers I interviewed expressed significant confusion about those materials, particularly the energy consumed during their production and the impact on their environmental performance. Rashid commented:

> Most people think plastics become cool when they are recycled. People like this thing of taking plastic out of the sea and creating something out of it—to be honest all the machinery, infrastructure transport—and the whole recycling process to first of all find that plastic, move it somewhere else, move it to a few different places, then process it is probably more polluting than creating something with plastic in the first place.[797]

Rashid was not alone in that observation, with designer and academic, Manuel Garcia, claiming that 'in most cases it [recycled plastic] is actually a marketing tool—people don't evaluate how much you are saving in energy consumption and carbon footprint because of your method— they just look at the material.'[798]

Incorporating recycled materials into a design does not necessarily lead to better environmental outcomes. How the material is collected and sorted by type, the amount (and source) of energy consumed during the recycling process, and the end-of-life options for the material are among the significant factors affecting the environmental profile of a design. In addition, reuse strategies can only offer part of the solution toward a sustainable system as continuous population and economic growth mean that even in a perfect recycling regime,

[797] Isaac, Interview with Manuel Garcia.
[798] Isaac.

where 100% of material is recycled, virgin material would still need to be added to meet the increased demand.[799]

The claim that plastics can be continuously recycled is, however, a myth that maintains a strong hold in the design community. Several designers told me that they believed that plastics can be recycled infinitely, without loss of performance. Thomas Pedersen (Danish designer) claimed that if plastic is in a closed circle, then it can be used forever.[800] UK based design team Barber & Osgerby, talking about their *On & On Stacking Chair* said: 'for us the important thing was that it is recycled plastic that can be infinitely recycled without downgrading, which is brilliant.'[801] Garcia claimed polypropylene can be recycled forever and went on to claim that PET can be infinitely recycled without losing mechanical properties.[802] Gibson commented:

> We've always thought that recycled plastics—HDPE—can be used over and over again without any deterioration, so I have always had this strong trust that they will be used again.[803]

In fact, HDPE (one of the easiest polymers to sort and recycle) is affected by thermomechanical degradation during processing which changes the structure depending on the temperature and stress exerted during the recycling process.[804] Similarly, all plastics are impacted by the heating and processing treatments involved with recycling, weakening the links between the polymer chains.[805] Reprocessing recycled polymer is always

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[799] Anders Bjørn and Michael Z. Hauschild, "Absolute versus Relative Environmental Sustainability," *Journal of Industrial Ecology* 17, no. 2 (2013): 329, https://doi.org/10.1111/j.1530-9290.2012.00520.x.
[800] Geoff Isaac, Interview with Thomas Pedersen, December 19, 2019.
[801] Isaac, Interview with Barber & Osgerby.
[802] Isaac, Interview with Karim Rashid.
[803] Isaac, Interview with Sarah Gibson.
[804] "Recycling of High Density Polyethylene Containers," *Polymer Degradation and Stability* 57, no. 1 (July 1, 1997): 77, https://doi.org/10.1016/S0141-3910(96)00230-3.
[805] Architect William McDonough and chemist Michael Braungart, who introduced the term 'cradle-to-cradle,' in their book of the same name, which helped to popularise the circular economy concept. Their highly

accompanied with degradation resulting from molecular chain scission, branching, and crosslinking.'[806]

All post-consumer recycling is affected by the difficulty of accurately sorting plastics, with polluted streams further compromising the quality and consistency of the recycled product. Melt blending is the preferred strategy to overcome these issues. Blending recyclates with virgin material creates a blended composite which displays performance similar to the virgin plastic products. However, a UK paper summarising the challenges and opportunities of plastic recycling found that it is usually not technically feasible to add recovered plastic to virgin polymer without decreasing at least some quality attributes of the virgin plastic such as colour, clarity or mechanical properties such as impact strength.[807] The vast majority of current recycling activities can be more accurately described as downcycling, with recycled HDPE commonly used for applications such as milk crates and bins, plastic lumber, underground pipes, or plant pots. Polypropylene is usually recycled only once and mixed with 50% virgin material to make new products (including outdoor furniture and playground equipment). While PET can be infinitely recycled, producers add antioxidants or blue colourants to counter discolouration (yellowing) that is often caused by other additives or contaminants. Multiple heating cycles can cause the breakdown of long polymer chains rectified by the addition of additives to improve the flow rate of the material.[808] PET can only be indefinitely recycled with the addition of more chemical products.

influential work specifically excluded plastics as they recognised that recycling invariably leads to downcycling, resulting in materials of a lesser quality. Despite the popularity of this work the myth that plastics can be continuously recycled endures. William McDonough and Michael Braungart, *Cradle to Cradle: Remaking the Way We Make Things*, 1st ed (New York: North Point Press, 2002).

[806] Shi Yin et al., "Mechanical Reprocessing of Polyolefin Waste: A Review," *Polymer Engineering & Science* 55, no. 12 (2015): 2899, https://doi.org/10.1002/pen.24182.

[807] Hopewell, Dvorak, and Kosior, "Plastics Recycling," 2119.

[808] Hopewell, Dvorak, and Kosior, "Plastics Recycling."

The petrochemical industry is now promoting chemical recycling as a method that avoids the degradation caused by mechanical (open-loop or cascade) recycling. The term 'chemical recycling' (or the more palatable 'advanced recycling' as the petrochemical industry is attempting to rebrand it) includes several technologies that break down mixed plastics with some combination of heat and pressure in a depleted oxygen environment.[809] By breaking down plastics to their component chemicals they can theoretically be reborn, displaying the same properties as their virgin patents. Industry representatives promote this technology as: 'true circular recycling'.[810] In practice most existing chemical recycling plants produce pyrolysis oil that is then burnt as fuel, releasing GHGs, and exiting the circular economy.[811] The scalability of the technology (largely still emerging from laboratory experiments), its energy and resource efficiencies, together with the environmental and health impacts of toxins released during the process, all remain the subjects of both industry and academic debate.[812]

Sufficient information to enable a detailed assessment of the environmental impacts caused by chemical recycling is often unavailable. For example, it is often claimed that chemical recycling eliminates the need and cost of sorting plastics by type, but ignores the fact that plastics will still need to be separated from contaminants collected from mixed household recycling bins. In a more specific example, a BBC article announcing a chemical recycling facility being built in the UK claimed, 'with a conversion rate of more than 99%,

[809] Raju Francis, *Recycling of Polymers: Methods, Characterization and Applications* (Newark, GERMANY: John Wiley & Sons, Incorporated, 2016), 59, http://ebookcentral.proquest.com/lib/uts/detail.action?docID=4714031.
[810] Katherine Latham, "The World's First 'infinite' Plastic," accessed February 3, 2022, https://www.bbc.com/future/article/20210510-how-to-recycle-any-plastic.
[811] Jumoke Oladejo and Andrew Rollinson, "Chemical Recycling: Status, Sustainability, and Environmental Impacts" (Berkeley: Global Alliance for Incinerator Alternatives, June 19, 2020), 14, https://doi.org/10.46556/ONLS4535.
[812] Oladejo and Rollinson, 21 The report found the process can release toxic substances such as bisphenol-A, cadmium, benzene, brominated compounds, phthalates, lead, tin, antimony, and volatile organic compounds.

nearly all the plastic turns into a useful product'.[813] The operator went on to make the unchallenged claim: 'the hydrocarbon element of the feedstock will be converted into new, stable hydrocarbon products for use in the manufacture of new plastics and other chemicals.'[814] Exactly how much energy is consumed in this process, what the 'other chemicals' are, what (if any) additional processes are needed to complete the manufacture of these products, and for what purposes they will be used is not specified. If these end products include pyrolysis oil or ash that needs to be landfilled then these need to be considered when evaluating the environmental impacts of chemical recycling.

As the quantity of recycled plastics entering the market increases, it will become increasingly necessary for manufacturers and designers to interrogate suppliers to establish both the source of the recyclates and the environmental impacts caused by their reprocessing. While recycling rates remain low these limitations are largely irrelevant. However, in a truly circular system designers will need to become more knowledgeable about the source of their materials and understand the potential impact on mechanical properties caused by multiple recycling cycles.

c. Bioplastics

Bioplastics offer the potential to change the reputation of plastics, from being viewed as an environmental criminal to a material that is valued as coming from and returning to nature. However, the term 'bio' in bioplastics only promises that the material contains some proportion of organic content and says nothing about the end-of-life prospects for the material. Bio-based plastics are partly or entirely made from biological feedstock, although the proportion of renewable organic content can be as low as 20%. Not all bioplastics are

[813] Latham, "The World's First 'infinite' Plastic," np.
[814] Latham, np.

biodegradable.[815] Manufacturers and marketers have used the absence of standards to promote and exploit confusion in the market, often implying environmental benefits but offering little explanation.[816]

Conflicting priorities among the actors involved with the development and use of bioplastics add to the complexities involved with understanding this material as summarised by material scientist, Sean Ferguson:

> Petrochemical companies want materials that integrate into existing processes, agribusiness want to promote heavily subsidised crops, environmental groups push for fossil-based alternatives, without fully understanding the impacts of these new materials.[817]

All these interest groups can and do exert influence over the information made publicly available regarding the environmental credentials of bioplastics. That makes it extremely challenging for designers and manufacturers to understand the environmental impact of working with these materials. The material properties of bioplastics can be different from the fossil-based substances they are designed to replace. Makers seeking to work with those new materials must develop a detailed understanding of their properties and how they differ from traditional plastics. As we shall see in the following chapter, for designs created with recycled plastics, designers must respond to the properties and characteristic of bioplastics that can have affect the final form of the design.

A material promoted as biodegradable does not come with a standard definition of how long it will take to decompose. All substances will biodegrade eventually—although it might take a few hundred years. Currently 'degradable plastics' is defined to include oxo-

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[815] Sean Michael Ferguson, "Plastics Without Petroleum History and Politics of 'Green' Plastics in the United States" (Ph.D., United States -- New York, Rensselaer Polytechnic Institute, 2012), 20, http://search.proquest.com/docview/1347639560/abstract/71F5B6F7E52D472APQ/39.

[816] A supplier's website claims, 'The biograde family of compounds includes mainly blends of fossil and bio-based biodegradable polymers. We increasingly replace the plastic substrate by a biodegradable alternative. Adding wood creates a look and a feel that emphasizes the biodegradable characteristics.' "Beograde | Ultrapolymers," accessed February 3, 2022, https://ultrapolymers.com/en/product/beograde.

[817] Ferguson, "Plastics Without Petroleum History and Politics of 'Green' Plastics in the United States," 18.

degradation, thermal-degradation, photo-degradation, biodegradation, and compostable plastics.[818] As an indication of how contested this space is even the definition of 'compostable' is still being debated. A German court ruled it is deceptive to market plastics as compostable as they do not convert into compost, arguing they convert 90% into Co2 gas (without leaving any nutrients).[819] A Danish court ruled that plant pots made from a bioplastic (PLA) could not be described as biodegradable, because they only degrade in the special conditions found in industrial composting facilities and will not decompose, within a reasonable time frame, in a domestic compost environment.[820] Understandably, there is much confusion about the end of life prospects for bioplastics among designers and end-users alike, with evidence to demonstrate that consumers are particularly baffled by often conflicting claims.[821]

Victor Macadar is a client of Bambacore, an Australian supplier of bioplastics. He told me that the time taken for the material to degrade is usually the first question asked by his perspective clients. Attempts to obtain a definitive answer from the material supplier on the life expectancy of the material were not successful. Macadar called for more regulation or certification, specifying how long materials take to degrade and under what conditions, to better inform the market and provide certainty for end users.[822]

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[818] In a 2006 standard (GB/T 20197-2006).

[819] Güthoff v Deutsche Umwelthilfe (2014). The German court held that it is deceptive to market plastic as "compostable."

[820] Ellepot v Sungrow (2019). The Danish court ruled that "compostable" PLA plant pots must not be described as biodegradable.

[821] During the summer of 2018, the European BioForever project commissioned 60 in-depth interviews with consumers, aged 25-55, across Poland, Germany, and Italy. Fossil plastics were seen as non-degradable by consumers while products based on plants were considered degradable. Not all bioplastics are degradable and some fossil plastics do degrade. Consumer did not fully understand the difference between 'degradable' and 'biodegradable'. Michael Carus, Asta Partanen, and Stephen Piotrowski, "BIO-Based Products from FORestry via Economically Viable European Routes" (Cologne: Nova Institute, August 30, 2019).

[822] Isaac, Interview with Victor Macadar.

Some of my interview subjects were confused about the biodegradability of materials. One designer stated that all bioplastics biodegrade, making them unsuitable for use in manufacturing consumer durables in their opinion. Others are confused about the feedstocks used to create bioplastics and their properties. Despite the fact industrial designer Louis Durot works in research for a traditional plastic manufacturer his opinions on bioplastics are out-dated. He believed, for example, that bioplastics are not suitable for developing innovative shapes. He argued there would be supply problems if bioplastics became widely adopted as their manufacture consumes food crops.[823] Another French designer, Quitllet held similar views, stating:

> But [with] bioplastic there was this ethical thing of saying well we are using corn which is food for some people we are using lots of water to grow the corn we're using process to make this bioplastic which are not hundred percent ethical.[824]

While first generation bioplastics are made from food crops, subsequent generations can be made from stover (second generation), algae or bacteria (third generation) and even Co2 (fourth generation) and, therefore, do not compete for agricultural land used to produce food. Rashid has vast experience with plastics but even he appeared to be talking about a sub-set of bioplastics when he offered this opinion:

> Sugar cane is amazing for that [making bioplastics], you know, and sugar basically at this point is causing cancer all over the world, you know, and diabetes so perfect... You're not taking away someone's food resource... there's an abundance of it, you know, and you know there's not necessary any chemicals involved... Sugar has three stages to go - it goes from sugar to ethylene to polyethylene. Oil, to get to polyethylene, take seven stages. So, the amount of energy to make the polymer is far less.[825]

While Rashid has oversimplified the production of bioplastics he focused on first generation bioplastics, apparently ignoring subsequent generations of bioplastics.

[823] Isaac, Interview with Louis Durot.
[824] Geoff Isaac, Interview with Eugeni Quitllet, April 2, 2020.
[825] Isaac, Interview with Karim Rashid.

With global population expected to exceed nine billion by the middle of the century any activities that divert already-scarce agricultural land away from food production will be increasingly challenged. The current demand for bioplastics is being met with negligible impact on land use—estimated at only 0.015 per cent of the global agriculture area.[826] If production of all plastics switched to biomass the amount of land needed is subject to much debate.[827] The debate is likely to be redundant well before it concludes, with higher generation feedstocks (such as, algae, bacteria and Co2), which do not compete with food crops, increasingly preferred for the production of bioplastics. In the short-term, opponents highlight the use of agricultural land as a negative impact of bioplastics creating uncertainty in the policy community. Further, while the industry distinguishes between first and subsequent generations of feedstocks it is unlikely that the distinction is understood in the public discourse, representing another communication challenge for those working with these materials.[828]

Confusion around bioplastics is further compounded by the common industry practise of hybridisation. Mixing bioplastics with fossil plastics enables material manufacturers to supply 'bio-based drop-in' polymers that can be used with existing

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[826] European Bioplastics, "Market Update 2020: Bioplastics Continue to Become Mainstream as the Global Bioplastics Market Is Set to Grow by 36 Percent over the next 5 Years," *European Bioplastics e.V.* (blog), accessed February 3, 2022, https://www.european-bioplastics.org/market-update-2020-bioplastics-continue-to-become-mainstream-as-the-global-bioplastics-market-is-set-to-grow-by-36-percent-over-the-next-5-years/.
[827] For example, a 2020 LCA based study claimed that, 'it does not seem feasible to replace all the petrochemical plastic packaging with bioplastic because this will inevitably result in a considerable increase of land and water use.' Janis Brizga, Klaus Hubacek, and Kuishuang Feng, "The Unintended Side Effects of Bioplastics: Carbon, Land, and Water Footprints," *One Earth* 3, no. 1 (July 2020): 45, https://doi.org/10.1016/j.oneear.2020.06.016. This study concluded that satisfying global demand for packaging with bioplastics, 'would require a minimum 61 million ha of land (which is larger than the total area of France) and at least 388.8 billion m3 of water (60% more than the EU's annual freshwater withdrawal).' Brizga, Hubacek, and Feng, 50. In contrast Zheng and Suh found, in 2019, that a complete shift of 250 million tonnes plastics production to bio-based plastics would only require 5% of all arable land. Zheng and Suh, "Strategies to Reduce the Global Carbon Footprint of Plastics | Nature Climate Change," 374.
[828] Nova Institute, "Bio-Based Products: Green Premium Prices and Consumer Perception of Different Biomass Feedstocks" (Cologne, September 2020), 8 As will be shown in the next chapter this survey of attitudes toward second generation biomass and found that end-users are generally unlikely to be aware of the difference between first- and second-generation feedstocks.

manufacturing infrastructure originally designed for fossil plastics. Further, hybridisation gives more control over the mechanical properties of new polymers, making them even more attractive to manufacturers. However, mixing bioplastics and fossil-based plastics (sometimes promoted as bio-based) diminishes the end-of life prospects of the material, as it cannot be recycled and will not biodegrade. We have already seen that it is difficult to identify the exact ingredients of hybridised materials making it challenging for designers to calculate a detailed assessment of the environmental impact of their material choice.[829]

The differing sources of raw materials used for bioplastics and the variety of methods to make them introduce more variation in the quality of materials produced. Unlike oil refineries that are relatively homogenous, individual bio-refineries differ depending on the availability of raw materials (cane, beet or maize, for example). Different conversion technologies are available.[830]Additives are often used to improve the mechanical properties of bioplastics, which may impact their biodegradability or result in ecotoxicity effects.[831] All this diversity creates another barrier to adoption causing uncertainty around securing consistent supplies with identical mechanical properties.[832]

Bioplastics create complexity for recyclers, designers, and manufacturers interested in understanding the end-of-life prospects for their products. Ideally bioplastics need to be

[829] Hybridisation as a strategy to advance the uptake of renewable plastics is discussed in more detail the next chapter.
[830] Including thermal (gasification), chemical catalytic (synthesis or dehydration), or biochemical (fermentation) Simon J. Bennett, “Implications of Climate Change for the Petrochemical Industry: Mitigation Measures and Feedstock Transitions,” in *Handbook of Climate Change Mitigation*, ed. Wei-Yin Chen et al. (New York, NY: Springer US, 2012), 319–57, https://doi.org/10.1007/978-1-4419-7991-9_10.
[831] F. Gironi and V. Piemonte, “Bioplastics and Petroleum-Based Plastics: Strengths and Weaknesses,” *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* 33, no. 21 (August 1, 2011): 1949–59, https://doi.org/10.1080/15567030903436830. ‘Compostable’ plastics should degrade into humus with an absence of toxic chemicals in line with international standards. At least 90% of the compostable polymers must be converted to carbon dioxide in industrial composting plants within six months, with remaining particles below 2mm diameter.
[832] Diversity can create uncertianty (preventing full commitment). Schot and Geels, “Strategic Niche Management and Sustainable Innovation Journeys,” 544.

sorted from fossil plastics in the waste stream but that is practically impossible. The Resin Identification Code (RIC) labelling scheme has not been extended to cover bioplastics making it challenging to identify the material, even by manual inspection. To meet the high-volume, high-speed sorting requirement of material recovery facilities investment in expensive, sophisticated sorting equipment is required. This investment is unlikely to occur until bioplastics account for a significant proportion of the material entering recycling facilities. Meanwhile bioplastics cause significant problems for recyclers and can cause enormous environmental damage. A very small level of contamination from bioplastics can cause entire batches of recyclates to be sent to landfill or incinerated.[833]

Even if biodegradable bioplastics are sorted from the waste stream and make their way to industrial composting facilities it is likely they will be rejected, as the complexity of identifying and sorting appropriate feedstock means it is easier for facilities to refuse to accept any plastic waste. Additionally, biodegradable bioplastics often take longer than organic waste to fully decompose, adding costs and complexity for operators.[834] As more bioplastics are developed the challenges around identifying, sorting, and processing them will increase, potentially driving up waste processing costs as additional investment in sorting technologies will be required. The OECD warns these trends could make investment in energy to waste facilities an attractive solution for all plastic waste, locking in a less

[833] For example, PET, the most commonly recycled plastic can be contaminated if mixed with just 0.1% of PLA, reducing the transparency of recycled plastic. At 0.3% the recycled PET would become opaque and show yellowing. If the PLA content is increased to 2-5%, the different melting temperature could result in clusters of PLA forming, hamper recycling efforts. Greenpeace International, “Biodegradables Will Not Solve China’s Plastics Crisis,” 24.

[834] I. Körner, K. Redemann, and R. Stegmann, “Behaviour of Biodegradable Plastics in Composting Facilities,” *Waste Management*, 1st UK Conference and Exhibition on Biodegradable and Residual Waste Management, 25, no. 4 (January 1, 2005): 409, https://doi.org/10.1016/j.wasman.2005.02.017.

preferable solution to recycling from an environmental perspective.[835] Meanwhile designers and manufacturers working with bioplastics need to understand and clearly articulate the preferred end-of-life treatment for their products in communications with end users. While this communication can be achieved with a universally recognisable RIC for fossil plastics the messaging and labelling for bioplastics is yet to be determined.

All these factors combine to make it challenging for those interested in working with bioplastics to develop a detailed and up-to-date understanding of their suitability for specific projects and their full life-cycle environmental impacts. With new materials entering the market sourced from different generations of feedstocks the debate around the merits of bioplastics is likely to become more complex and therefore more difficult for both designers and manufacturers interested in working with them.

d. Intellectual property

One of the biggest challenges facing those who seek to work with renewable plastics is material manufacturers' secrecy about their products. The reluctance to release details of ingredients and/or additives prohibits a detailed assessment of environmental impacts and can create uncertainty around the mechanical properties of the material. UK-based designers, Barber and Osgerby reported they were unaware of the detailed composition of the recycled plastic used for their *On & On Stacking Chair*, manufactured by Emeco. Having converted manual sketches into 3D models these were then shared with the engineering team at Emeco who were relied upon to ensure the structural integrity of the design.[836]

> Emeco didn't develop the material themselves they worked with a plastic company and ultimately, we have to rely on them—they tell us the performance of the plastic is how it is

[835] OECD, "Policies for Bioplastics in the Context of a Bioeconomy," 52.
[836] Isaac, Interview with Barber & Osgerby.

> and we run simulations on the computer and they invest in the moulding and it if does not work it is their responsibility.[837]

In this case the separation of responsibility was crucial for the designers to have the confidence to experiment with the new material. For designers operating without the backing of a committed manufacturer these unknowns are a formidable barrier to experimenting with new recycled plastics.

My interviews with designers and industry representatives revealed just how hard it is for designers to access the information they need to examine the environmental impact of the materials they are working with. In the rapidly developing and competitive bioplastic market, material manufacturers seek to protect their investments and remain guarded around revealing details of their materials; in efforts to prevent competitors taking advantage of their R&D. Making the 'right' sustainable choice requires transparent access to detailed information on the material sources, ingredients, and supply chains.[838] In addition to commercial confidentiality concerns, information on the environmental impacts of materials if often simply unavailable (not yet gathered), too costly to obtain, or has not been independently verified.[839]

In some cases, this lack of transparency can lead to designers inadvertently using hybridised products. This was the case for industrial designer Ander Lizaso's project for Alki, a manufacturer committed to sustainability principles.[840] As the *Kuskoa Bi* project progressed

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[837] Isaac.
[838] Felix Reed-Tsochas and Simon Ford, "Unlocking Value for a Circular Economy through 3D Printing: A Research Agenda," *Technological Forecasting & Social Change*, 2017, np, https://www.academia.edu/38896656/Unlocking_value_for_a_circular_economy_through_3D_printing_a_research_agenda.
[839] Sissel Waage, "Re-Considering Product Design: A Practical '"Road-Map"' for Integration of Sustainability Issues," *Journal of Cleaner Production* 15 (2007): 648.
[840] Peio Uhalde, Alki's Managing Director, claims, 'through Alki we try to do everything in our power, such as prioritizing the use of natural materials: oak, virgin wool and natural fibers. The quality of the products is another key consideration, thus ensuring a lifetime of use. It's also important to collaborate with other

it emerged that the 'PLA' they were using was a hybridised product with a percentage of fossil-based plastics mixed with the bioplastics:

> There is a percentage that is fossil fuel based… I don't know if the other part of the percentage is PP, I don't think it is…When we approached the people, we work with for this material they were quite opaque and it was kind of a guess…[841]

Finding out the source used to create the bioplastic component of the material proved equally difficult:

> We had a very wide, very broad definition of the material and we didn't know if it came from corn starch or sugar cane or even beetroot and well, you know, we also were quite conscious about the implication of each of them. The marketing [department] went for corn because it was really, you know a visual. But in the studio, we were hoping that it wasn't corn because the implication is quite you know, that corn shouldn't be used for making chairs. We know [now] that it comes from sugar cane [stover].[842]

Lizaso's experience illustrates that designers working with bioplastics face additional challenges when attempting to evaluate the environmental impact of their work. Where new materials are being used, detailed information on how the material is made and ingredients used might not be available.[843] Lizaso was not alone here; Rashid reported he has been unable to identify the exact contents of the 'bioplastic' used for his *Siamese Chair* as this information was not available to the furniture manufacturer. Even when material suppliers are prepared to share information, they might source organic ingredients from different suppliers (depending on season and availability), which could impact any attempt to measure the sustainability of their outputs. When sourcing different crops, the use of genetically modified organisms (GMOs) together with the use of pesticides and fertilisers are likely to vary. Transportation methods used and distances travelled to the processing plant

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workshops located within 100 km, whose skills complement our own.' Alki, "Alki - Company Background," accessed February 3, 2022, http://alki.fr/en/meeting/.

[841] Isaac, Interview with Ander Lizaso.

[842] Isaac. Stover is a second-generation feedstock as it does not compete with agricultural land that could be used for food crops.

[843] In an interview with the author Ander Lizaso, the designer of the Kuskoa Bi chair, reported that the supplier of the material would not reveal the percentage of fossil plastic used in the bioplastic and only revealed the source of the organic content when pressed by the designer. Isaac.

will invariably change with the feedstock, with varying downstream impacts on the overall environmental performance when bioplastics are used in products.[844]

In many cases, in the absence of full disclosure on the contents of materials, prospective product manufacturers are unable to complete detailed lifecycle assessments or any detailed level of eco audit of their products, as the information required is simply not available. While it is understandable that organisations investing in the development of new materials want to protect their intellectual property, this secrecy also threatens to slow diffusion of new materials.

e. Mechanical Properties

When working with recycled plastics, designers have the advantage that many of the materials have established a track record, meaning their mechanical properties are well understood. Although the materials might not have been used for a similar project, their previous applications can provide some insights to their suitability for the task. Gibson used sheets of recycled HDPE, a material developed to be used outdoors as a sound barrier at construction sites for the *Butter Chair* and *Butter Stool*, which she designed with Nicholas Karlovasitis:

> I guess we just thought we looked at the context it was being used that would be appropriate for furniture and similarly with the Confetti range [made from recycled post-consumer and factory waste plastic], that material is put in the ground all the time – used for pipelines so probably sufficiently resilient.[845]

Knowledge of this history made the designers sufficiently confident that the mechanical properties of the material were up to the task.

[844] In particular, nitrous oxide, used in cheap fertilisers and favoured for non-food crops, can have significant GHG impacts.
[845] Isaac, Interview with Sarah Gibson.

Issues arising from working with other commonly recycled plastics are well understood. Using recycled polypropylene typically comes at the price of increased part defects including flashing, sink marks, and short shots.[846] Processors can compensate by using a high ratio of virgin material or by running at higher temperatures to improve the melt flow and fill out their moulds (consuming more energy). The solution involving higher temperatures can degrade the plastic and affect mechanical properties requiring expensive modifiers to compensate. Petrochemical companies are responding to the increased demand for recyclates and investing to address those shortcomings. Chemical company Milliken recently launched an additive designed to boost the properties of recycled polypropylene, claiming it eliminates the need to combine virgin feedstock with recyclate to maintain structural integrity. However, while reductions in both energy consumption and processing time are promoted (and undoubtedly appreciated by clients), the precise ingredients of this additive and their environmental impacts remain unknown.[847]

Working with bioplastics, pioneering actors are faced with the problem of little independently verifiable information about many of the new materials emerging onto the market; certainly very few have been exposed to rigorous testing over an extended period. Armstrong summarised the issue:

> Things haven't been around long enough. Polypropylene and ABS have been around long enough so you know what is going to happen. But that is, unfortunately, saying we are such a slow-moving vehicle, it is going to take long time because we don't trust anything that's new.[848]

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[846] "Performance Modifier Additives Make Standard Polypropylene Resins Perform Like Premium Grades," accessed February 3, 2022, https://www.ptonline.com/articles/game-changing-polypropylene-additives-improve-impact-resistance-and-processing-costs-.

[847] See: http://chemical.milliken.com/products/deltamax-performance-modifiers-for-polypropylene Milliken did not respond to requests to provide more information on the environmental impact of this (or any) of their products.

[848] Isaac, Interview with Dan Armstrong and Rene Linssen.

Benefiting from decades of research and development, designers and manufacturers working with virgin fossil plastics can confidently predict how the material is going to behave when processed using well established manufacturing technologies.

Grcic identified this lack of track record as the main inhibitor to him experimenting with bioplastics:

> My clients… do want to use new materials but… they have to have certain certificates or guarantees that you know they have gone through testing that the material will more or less look the same and perform the same after five years of exposure to UV light for example or [can withstand] the structural stress and so on.[849]

To circumvent the limited availability of data and lack of real-world experience, some designers have resorted to less sophisticated techniques. Lizaso explained the process when selecting material for the *Kuskoa Bi* chair:

> The first thing we did was of course the mechanical testing that you should do, but also leaving a shell outdoors and we knew that we didn't have three years to look at it, but we exposed it to some extreme conditions. We dumped it in water and it's very rainy here. That was the process at that stage.[850]

Similarly, Rashid developed a bioplastic chair for A Lot of Brasil, explaining in an interview for this study, the surprisingly casual process he undertook to satisfy himself that the proposed material was suitable for the task.

> You know you just you do a little research. I mean you take a piece of the moulding and you see the strength of it, you know, you rub things on it. I do things I can take keys and scratch things and you kind of get a good feeling of its durability.[851]

Of course, some experiments with materials are not immediately successful. Rashid went on to explain how he was forced to adjust his original concept for the *Siamese Chair* to accommodate inherent weakness in the bioplastic. The material proved to be insufficiently strong enough to be used for the legs and the shell of the chair had to be thickened

[849] Isaac, Interview with Konstantin Grcic.
[850] Isaac, Interview with Ander Lizaso.
[851] Isaac, Interview with Karim Rashid.

considerable, with both adjustments negatively impacting the environmental performance of the chair. Rashid's experiences, together with the examples provided by Gibson, Anderson, Lizaso, and Grcic during interviews for this study illustrate the commitment required from designers to experiment with new materials.

Commitment is an expensive commodity. Experimentation takes time and can consume significant resources, requiring substantial financial backing. This was the situation facing Barber & Osgerby, when I interviewed them in July 2019. Referring to a bioplastic chair project they had been working on for four or five years with an unnamed manufacturer the designers reported the material turned out to not be sufficiently durable. Barber & Osgerby had to work with the material manufacturer to re-engineer it:

> The problem is, with this eco-plastic, they are not brilliant in rain, not brilliant in extreme heat, they tend to warp a bit, which would be fine if it was a very low-cost product. But, if it is going to cost the same as a high-end product people are going to say, "I can't afford to have my chair start moving in the sun."[852]

Barber and Osgerby have found partners prepared to invest in this project. At the time of our meeting the designers hoped to launch it at the *Salone del Mobile* in April 2020. The exhibition was cancelled due to COVID-19. However, to date (February 2022), the bioplastic chair had not been launched. The manufacturer Magis reported experimenting with some (unnamed) renewable plastics but abandoned the projects following trials that failed to deliver the required results.[853] Gabriele Chiave, the Creative Director at Marcel Wanders office, also reported working with Magis and Philippe Starck on a liquid bamboo pressed chair. The project was abandoned after eighteen months after the chair repeatedly failed engineering tests.[854] All three of these experiences highlight the financial risks involved in

[852] Isaac, Interview with Barber & Osgerby.
[853] Isaac, Interview with Gabriel Chiave.
[854] Isaac.

attempting to work with renewable carbon materials. While these well-established actors are well placed to absorb unexpected costs, many others are unlikely to be able to take such risks.

Once a suitable bioplastic has been identified, designers and manufacturers still need to experiment further to understand its properties and to optimise production. Macadar discovered that his (bamboo reinforced) bioplastic could be injection moulded at lower temperatures (saving both energy and money), but at slower injection speeds (which meant longer expensive time on the machine). However, cooling time is reduced, and the product can be removed from the mould at a higher temperature. Overall, the cycle time is not significantly impacted, but he warns that these factors can vary, with significant costs as experiments must be undertaken in conjunction with the moulding company. Macadar highlighted during our interview that both designers and manufacturers need to understand that bioplastics can also show different shrinkage rates when removed from the mould. Lizaso also reported experiencing significant shrinkage of the shell for his *Kuskoa Bi* chair, only detected after the project had entered production, causing inconsistencies in the end-product and requiring the base to be redesigned to accommodate the variance:

> You can have a shell that is almost two centimetres wider than the other because in the cooling process it [hybridised PLA] moves quite a bit, much more than normal PP shells.[855]

Shrinkage can also be an issue when working with recycled plastics. Pedersen reported that the shells for his Flak chair were too open when first removed from the mould. At the time of our interview Pedersen was working closely with the manufacture (Houe) to resolve the issue. They were developing a new tool for the robot operating the injection moulding machine to use, attempting to reduce the cost by fine tuning the process so it could be completed

[855] Isaac, Interview with Ander Lizaso.

within the three-minute downtime between cycles. The new tool is designed to force the shell closed and hold in place for a few seconds before releasing, in the hope this would be sufficient to rectify the issue. Solving such problems after the project has entered production can have significant financial consequences.[856]

Designers working with bioplastics also reported that those materials can be more corrosive in the mould, potentially leading to higher wear-and-tear and associated costs.[857] The moisture level must be minimised during the injection moulding process or the end product might become brittle and weak.[858] Disappointingly, at least one of the designers interviewed had abandoned bioplastics due to such negative experiences. Garcia 3D printed *Voxel Chair v1.0* from PLA but found the material degraded over time and discoloured in sunlight. He has since moved away from using that material in favour of recycled PET.[859] Poor experiences with early bioplastics made from first-generation feedstocks risks tarnishing the reputation of the sector before the industry is given a chance to mature.

3. Regime resistance—misinformation

a. Recycled plastics

Recycling has long been promoted by the plastics industry as the solution for the plastic waste crisis. At a time when less than 10% of all the plastics ever produced have been recycled and with global recycling markets in turmoil (due to China restricting imports of waste plastic), the industry continues to promote recycling as the solution to reducing the

[856] Isaac, Interview with Thomas Pedersen.
[857] Isaac, Interview with Ander Lizaso.
[858] PLA offers a comparatively lower processing window and has a lower melting temperature while PHA also has a narrow processing window and a slower crystallisation rate. For a useful guide to the issues around the performance characteristics of bioplastics see: Fachagentur Nachwachsende Rohstoffe e. V., "Processing of Bioplastics," 2016, http://ifbb-knvb.wp.hs-hannover.de/db/ Website also hosts a database to enable comparison of the performance of specific polymers.
[859] Isaac, Interview with Manuel Garcia.

industry's environmental impact.[860] Fossil plastic is often positioned as an ideal candidate for the circular economy, infinitely recyclable, the ideal cradle-to cradle material, with the aim of promoting continued use without guilt. The problems associated with these claims and the difficulty in obtaining accurate and reliable information about the content and impacts of recyclates have already been discussed above.

b. Oxo-(bio)degradation

Oxo-degradable plastics are an adaptive response by the petrochemical regime to increased public concern around the prevalence of plastic waste in our environment. Importantly, for the prevailing regime, oxo-degradable plastics can be manufactured by fossil plastic factories at little or no extra cost, with no need to change their machinery or workforce practices. As the name suggests, oxo-biodegradable plastics degrade when exposed to oxygen and bacteria in the open environment. Critics argue this process simply results in the material fragmenting, leaving microplastics to persist in our environment. Industry proponents claim 'the degradation process is not only a fragmentation, but is an entire change of the material from a high molecular weight polymer, to monomeric and oligomeric fragments, and from hydrocarbon molecules to oxygen.'[861] Oxo-degradable plastics have been developed primarily as an alternative material, suitable for single-use packaging that will decompose when littered. This group of plastics are unlikely to be of interest to designers and other actors involved with the development of consumer products. I only provide a summary of the ongoing debate around these materials here to illustrate the ferocity with which the existing regime is defending its territory.

[860] Geyer, Jambeck, and Law, "Production, Use, and Fate of All Plastics Ever Made," 1.
[861] Professor Ignacy Jakubowicz quoted in Axel Barrett, "Questions and Answers on OXO-Biodegradability," Bioplastics News, July 1, 2019, https://bioplasticsnews.com/2019/07/02/questions-and-answers-on-oxo-biodegradability/.

c. Bioplastics

Following an extensive literature review, Jonathan Kohler et al. constructed an agenda for sustainability transitions, observing that as transitions threaten the profitability of entrenched incumbents, they are likely to protect their vested interests and contest both the need for and speed of transitions.[862] With the most powerful incumbent actors controlling the established fossil plastics regime it is not surprising that those organisations pursue powerful lobbying strategies in efforts to maintain stability for the existing regime. Generous donations are made to political parties by the petrochemical industry.[863] Professional lobbyists and industry associations are then used to present the case for maintaining the status quo to thought and opinion leaders and policy makers.[864] Technologist Adrian Smith contents that:

> The greater the extent to which pressures for a particular form of change diverge from the norms and rules of the incumbent regime, the more acute become these issues of power.[865]

Smith goes on to warn that displacing a profitable regime with a more sustainable alternative might not be a credible option owing to the power of incumbents.[866] That warning is particularly apt for those challenging the petrochemical regime. [867]

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[862] Köhler et al., "An Agenda for Sustainability Transitions Research," 3.

[863] In Australia, the resources industry is by far the largest donating industry according to the Centre for Public Integrity. 'Mineralogy and Queensland Nickel, donated $98.6 million and $21.1 million over the period from 1999 to 2019. They were followed by gas companies Woodside and Santos, with $2 million and $1.5 million respectively, and Ausgold Limited with $1.1 million. Other big donors included Western Mining, which donated $755,000 (bought by BHP Billiton in 2005), and Australian Gypsum Industries, a resources company in Western Australia that paid $555,777.' David Crowe, "'Highly Problematic': Australian Political Donations Revealed," The Sydney Morning Herald, January 17, 2021, https://www.smh.com.au/politics/federal/highly-problematic-for-public-trust-australian-political-donations-revealed-20210117-p56up0.html.

[864] Unearthed (Greenpeace), "Inside Exxon's Playbook: How the Oil Giant Works through Front Groups to Head-off Regulations on Toxic Chemicals and Plastics Inside Exxon's Playbook on Plastics and 'Forever Chemicals,'" Unearthed, July 1, 2021, https://unearthed.greenpeace.org/2021/07/01/exxon-undercover-pfas-plastic-chemicals/ An Exxon consultant gives details of his involvement with misinformation campaigns on climate change and plastics.

[865] Smith, Stirling, and Berkhout, "The Governance of Sustainable Socio-Technical Transitions," 1503.

[866] Smith, Stirling, and Berkhout, 1504.

In July 2021, Greenpeace released a recorded conversation with a lobbyist working for Exxon, in which he admitted working with the industry to introduce the Save Our Seas Act that encouraged the investigation of chemical recycling as a delaying tactic. He went on to say:

> It's just like on climate change right… when it started you started to have conversations to say well you can't completely change the electric grid from coal and gas into wind and here's why. It's the same conversation, you can't ban plastics because here's why or you can't recycle you know, legislate 100% recycling, because here's why.[868]

Greenpeace claim this to be the first time someone from the energy industry has been documented admitting participation in strategies deliberately designed to delay or avoid legislation to lessen production of fossil plastics. Those revelations demonstrate the voracity of resistance that can be exerted by a powerful, entrenched regime.

For designers and manufacturers interested in exploring renewable plastics, the confusion caused by a lack of consistent messaging about the properties and potential of new materials has slowed the adoption of bioplastics. In our interview, Gregg Buchbinder (CEO of Emeco) told me that despite their well-publicised commitments to sustainability, they preferred to adopt a wait-and-see approach, believing it is too early to experiment with bioplastics. Buchbinder specifically cited 'misleading or glorified information' as a reason for the company's hesitancy adding: 'we always want to be sure we are cognisant before putting in the time and effort necessary to work with a new material.'[869] Emeco is not alone. John Tree, senior designer at Jasper Morrison's office, held similar views saying that he considered bioplastics: 'something to keep an eye on, as it is maturing very fast,' but went on to say: 'we are at a point of inflection at the moment where things become possible and realistic to

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[867] For a detailed analysis of how the fossil regime resisted the introduction of biofuels see: Smink, Hekkert, and Negro, "Keeping Sustainable Innovation on a Leash?"
[868] Unearthed (Greenpeace), "Inside Exxon's Playbook."
[869] Isaac, Interview with Gregg Buchbinder.

do.'[870] Ron Arad also told me that he preferred to wait and see how well bioplastics performed in real life before working with them.[871] Likewise, Bertjan Pot commented that he did not have the resources or interest in experimenting with new materials. His preference is to wait for the market to mature and 'then I know if I have something to add to it as a designer or an artist or not.'[872]

By promoting hybridised products as bioplastics, material manufacturers have introduced more confusion into the market. Designers are struggling to understand the environmental impact of these mixed materials, as Armstrong explained:

> The promoters of bioplastic sometimes have just 20% organic content and the rest is just traditional plastic and then, of course, at the end of life is crazy…That's my biggest problem—you've really spruiked this, you made your brochures all look eco and there's a rainforest on the front cover, that's nice and you when you look into page one you see what you've done you are not really there yet, it's 10% or something.[873]

No matter how well-meaning designers or manufacturers are, misinformation can lead to material choices with disappointing environmental outcomes. In addition, all the actors involved with the development of products incorporating those materials risk professionally-damaging accusations of greenwashing.

4. Availability

For renewable carbon-based plastics to be incorporated into the portfolio of materials used by product designers the materials need to be readily available, and their availability publicised. Availability of bioplastics is particularly challenging. Macadar had to conduct a global search to find a material suitable for his product. Summarising the problem, Macadar reported that as bioplastic producers are relatively scarce and often in start-up mode, they

[870] Isaac, Interview with John Tree from Jasper Morrison Office.
[871] Isaac, Interview with Ron Arad.
[872] Isaac, Interview with Bertjan Pot.
[873] Isaac, Interview with Dan Armstrong and Rene Linssen.

do not have well-resourced marketing and communication departments and are often difficult to find.

In a comparatively small and remote market, like Australia, the choice of renewable carbon materials is extremely limited, as Gibson discovered when surveying the market for recycled plastics during the first decade of this century. During an extensive search for suitable materials, Gibson only sourced recycled pellets suitable for injection moulding, and one other product, developed for roadside use as a sound barrier, later used for the *Butter* range.[874] Since introducing the *Butter* range, the designer has had to look overseas and change the material supplier three times as the recycled plastics market struggled to establish. Referring to the Fenster range (released in 2020) Gibson added that despite extensive searching, she had failed to locate a sustainable alternative to acrylic glass used for the back and seat. The company decided, reluctantly, to release the product made from acrylic glass and continued to try and source a more environmentally friendly replacement.[875]

Gibson was not alone in reporting shortages of suitable recycled plastics. Even internationally celebrated designers with access to well-resourced manufacturers reported difficulties in locating renewable carbon materials. Starck developed the *Broom Stacking Chair* for Emeco in 2001. Emeco wanted to avoid the use of virgin resin but failed to locate a suitable alternative. The chair was finally produced in 2012, after Emeco worked with material scientists to develop a recycled PET/wood blend with sufficient strength for the task.[876]

[874] Designed with her business partner Nicholas Karlovasitis. Isaac, Interview with Sarah Gibson.
[875] Isaac.
[876] Isaac, Interview with Gregg Buchbinder This was not a new idea in the 1940s, Chicago architects Brenner, Speyer and Prestini entered a lounge chair made from resin impregnated wood fibre to the MOMA competition. Nelson, *Chairs*, 57.

Emeco have continued to improve the performance of their recycled material, making the recylate stronger and able to withstand harsher weather conditions.[877]

Pedersen also reported difficulty in identifying a source for recycled household waste plastic for the shell of his *Falk* design. Local suppliers were unable to meet the accuracy of sorting required to develop the material. Early supplies of suitable material came from Germany, although, at the time of our interview (December 2019) Pedersen expressed confidence that a Danish supplier could soon meet the requirements and develop a suitable locally sourced material. Pedersen was keen to establish a local supplier as plastic waste is incinerated in Denmark (to generate electricity).[878] By diverting this resource, he hoped to interest other local designers in using the recyclate and raise public awareness of issues around waste to energy.[879]

In addition to availability, the minimum order size offered by material manufacturers was also raised as an issue by some designers who reported difficulty in obtaining the modest quantities required for some projects. Mayda Diaz, from the Australian bioplastic agent, Bambacore, were only able to supply materials by the hundreds of kilos, which is prohibitive for those wanting to experiment with the material before committing to purchasing a large quantity.[880]

a. Cost

Another major obstacle for renewable plastics is that virgin polymers are cheaper than recycled alternatives.

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[877] Isaac, Interview with Gregg Buchbinder.

[878] Household mixed plastics waste contains approximately 32 MJ per kg, which is favourable compared to coal (approximately 25 MJ per kg). Hence, energy recovery from plastics can substitute fossil fuels in heat or power production. Bennett, "Implications of Climate Change for the Petrochemical Industry," 342.

[879] Isaac, Interview with Thomas Pedersen. As at November 2020 the manufacture's website claims the recycled plastic for the *Falk* series is sourced from Denmark.

[880] Isaac, Interview with Diaz Mayda.

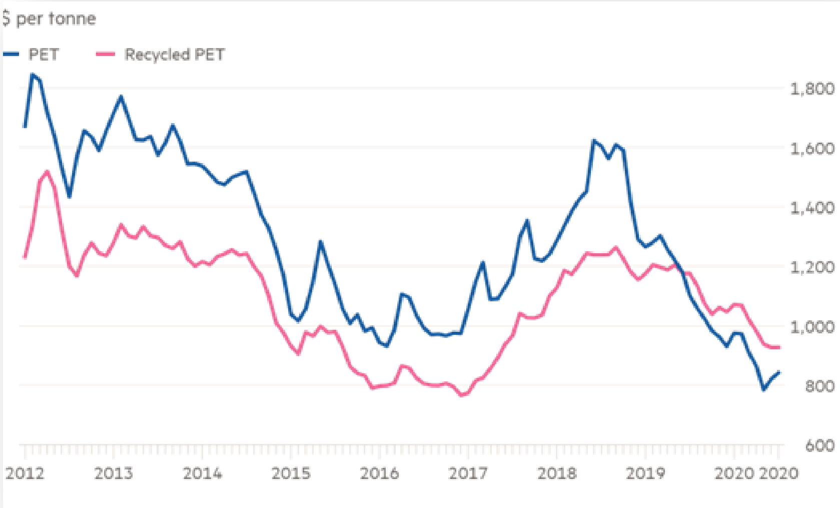

Fig. 7.4. Chart showing price of virgin vs recycled PET, 2012-2020.
Recycled PET became more expensive than virgin PET in late 2019. Source: S&P Global Platts

Prices for recycled plastics have risen relatively as the price of virgin fossil-based plastics has fallen (fig. 7.4). During 2018, bioplastics cost two to three times more than conventional fossil plastic resins.[881] With new bioplastics based on higher generation feedstocks the cost differential can be even greater. Prices for renewable plastics are likely to increase further as demand increases due to rising demand from organisations fulfilling their commitments to eliminate or reduce single-use virgin fossil plastic packaging.[882]

[881] Kunnika Changwichan, Thapat Silalertruksa, and Shabbir H. Gheewala, "Eco-Efficiency Assessment of Bioplastics Production Systems and End-of-Life Options," *Sustainability* 10, no. 4 (April 2018): 952, https://doi.org/10.3390/su10040952.
[882] As at the end of 2020, 250 major FMCG businesses committed to achieve four key commitments by 2025: eliminating all single-use plastics packaging which is problematic or unnecessary; ensuring that all plastic packaging is reusable, recyclable or compostable; ensuring that 50% of plastic packaging is effectively recycled or composted and reaching 30% recycled or responsibly sourced, bio-based content in packaging. Ellen McArthur Foundation, "Global Commitment 2020 Progress Report," 5.

In the case of chairs, the cost of materials represents a small part of the final retail price in most cases. Chairs aimed at the middle and high-end of the market can absorb small changes in the cost of a few kilograms of materials without affecting the retail price. However, in the competitive market for cheap monobloc chairs retailing for as little as $11 and containing between two and four kilograms of plastic—the price of materials in crucial.[883]

In the long-term the cost differential for bioplastics is expected to lessen as producers increase production and enjoy greater economies of scale. To succeed, bio-based technologies (like any new technology) need to prove sufficient demand to encourage large scale industrial production.[884] However, while the International Energy Agency recognises bio-based feedstock as a potential alternative to oil, they expect bioplastics to remain a niche industry, highlighting the considerable cost gap that bio-based processes need to close to be competitive.[885] This forecast is consistent with the market projections presented in Chapter 3 where the bulk of increased demand for renewable plastics is expected to be met by recycled fossil plastics.

Obtaining new renewable plastics will almost certainly be more expensive. When I interviewed Andreas Maegerlein, Group Leader Creation Center at BASF, he highlighted this as a significant barrier for all new materials, as small quantities are initially produced at a relatively high cost which must be passed on to the purchaser.[886] He went on to say that many clients (particularly those looking for packaging solutions) had expressed interest in

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[883] Penty, *Product Design and Sustainability*, 279.
[884] René Kemp, "Technology and the Transition to Environmental Sustainability: The Problem of Technological Regime Shifts," *Futures* 26, no. 10 (December 1, 1994): 1024, https://doi.org/10.1016/0016-3287(94)90071-X.
[885] International Energy Agency, "The Oil and Gas Industry in Energy Transitions," 57.
[886] Geoff Isaac, Interview with Andreas Maegerlein, Group Leader Creation Center, BASF, June 24, 2021.

renewable plastics but quickly changed their minds when they learnt it cost more. Konstantin Grcic told me that those higher costs act as a deterrent for his clients to use bioplastics for consumer goods.[887] In addition to their higher upfront costs, bioplastics and recycled materials have different mechanical properties when compared with virgin fossil polymers. Renewable carbon materials behave differently, demanding experimentation to enable production processes to be modified or adapted to suit the characteristics of these materials. Those costs are passed on in higher retail prices affecting sales.[888]

5. Conclusion

This chapter focused on the issues confronting both manufacturers and designers seeking to work with renewable plastics. The focus here has been on factors affecting the choice of material, where the manufacturer usually holds the balance of power. The first major obstacle to the adoption of renewable plastics is the difficulty in obtaining up-to-date and reliable information about new materials and where to source them. Those that I interviewed highlighted a lack of relevant sources of information tailored to their needs. A lack of transparency from material manufacturers, combined with the quantity of misinformation in the market, some of which has been deliberately circulated by the incumbent regime, further complicates this. The availability of renewable carbon materials (both recycled plastics and bioplastics) and the resilience of the supply chain are significant concerns, particularly for actors operating in relatively small and remote markets like Australia.

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[887] Isaac, Interview with Konstantin Grcic.

[888] The exact premium charged is difficult to quantify as there are limited examples of precisely the same product being offered simultaneously in both virgin fossil-based plastic and renewable carbon-based plastics. Kartell sell a three-module version of their *Componibili* storage unit made from ABS for $118 while the same model made from bioplastic costs $175, a 48% premium. IKEA sell *Odger* for $99 but offer similar designs made from virgin feedstocks prices at between $40 and $75.

Designers and manufacturers who have completed projects using renewable carbon materials warn that significant investments of both time and money are required to develop the skills and experience needed to work with the new materials. Actors interested in working with new materials are likely to encounter resistance from others who are effectively locked-in to fossil plastics by their previous investments in both infrastructure and skills. The need for investment in time, combined with the higher cost of renewable plastics (bioplastics in particular) has implications for retail prices, threatening to constrain demand for products based on these materials.

Bioplastics are more likely to encounter resistance than recycled plastics. Bioplastics are not dependent on fossil fuels. Bioplastics include at least a proportion of renewable organic feedstock. Any increase in their acceptance will come at a cost to the fossil-based incumbent, a fact which motivates them to defend business as usual. The increasing diversity of bioplastic and hybridised products, compounded by various generations of feedstocks, is adding yet more complexity to an already-confused market. Misinformation campaigns and the resultant public and academic debates over the ecological benefits of bioplastics are compounding the problem. As many of these materials are new, they are only available (often in limited quantities) from specialist suppliers that can be hard to find. Bioplastics currently cost much more than traditional plastics and while that price differential is expected to erode as production expands, the premium is unlikely to be eliminated entirely. Many bioplastics have been developed to biodegrade, in response to the needs of the packaging industry. Bioplastics suitable for highly durable products like chairs destined for prolonged (and often outdoor) use remain comparatively scarce. Material manufacturers are faced with many obstacles in their efforts to grow demand for bioplastics tailored for use in consumer products.

Despite the formidable list of barriers confronting those seeking to experiment with renewable carbon materials many designers and manufacturers have launched products that celebrate the use of more environmentally friendly plastics. The final chapter that follows examines those projects and identifies the decisions confronting designers when working with new materials. I identify strategies that can be adopted by actors interested in promoting the uptake of renewable plastics.

Part C

Advancing renewable carbon-based plastics

Chapter 8

Transition, how?

'To be' we have to be another way.
Tony Fry[889]

Designers are traditionally primarily tasked with responsibility for the form and aesthetic appearance of a project. Their expertise and experience are, however, valuable resources that can assist other actors with decision making across the entire process of creating and selling a product or service. Those decisions affect the environmental profile of a design. This chapter examines the agency of designers in decisions that affect a plastic product's environmental performance from its production to the factory gate and beyond. While switching from virgin fossil plastics to renewable carbon-based materials can deliver emission savings, environmental benefits are optimised only if the sustainability implications of all aspects of a design project are considered. Emphasis is then given to how experiences from projects which have already succeed (or failed) in delivering significant environmental benefits can be applied to other designs.

This chapter also identifies strategies to accelerate the transition to renewable plastics. Retrospective application of the multi-level perspective (MLP) by scholars examining various transitions has identified successful strategies employed by those seeking to challenge an established regime.[890] Those studies also demonstrate that widespread adoption of a new technology does not automatically make the entire entrenched socio-technical regime redundant. In this case, the existing fossil regime can reconfigure and adapt to incorporate new materials while continuing to employ long-established manufacturing technologies used by the furniture industry.

[889] Fry, *Design Futuring*, 22.
[890] Among the first of these was this study of how steamboats displace sailing ships. Geels, "Technological Transitions as Evolutionary Reconfiguration Processes."

With decades of investment in fossil plastics, the fossil regime wants to maintain business as usual in the interests of maximising profits for shareholders. Manufacturers have sunk investments, locking them in to fossil-based materials and technologies, making it difficult to justify additional investment in alternative technologies on economic grounds. Hybridisation addresses those challenges by enabling material manufacturers, furniture makers, and designers to continue business as usual, while potentially reducing the environmental impact of their products. More adventurous (and adequately resourced) designers and manufacturers can experiment with new manufacturing technologies that, when used in combination with renewable plastics, have the potential to deliver further environmental benefits.

To maximise the potential for commercial success, products are often developed to meet the specific needs of a tightly defined market segment. My research reveals that while some actors could identify market segments more likely to purchase chairs made from renewable plastics, few designs have yet been developed to meet the precise needs of these end-users. Identifying and addressing the needs of those users is a potentially lucrative strategy to advance the uptake of renewable plastics.

Despite the pressure to maintain business as usual, the continued use of virgin fossil plastics will come under increasing criticism as the health and environmental impacts of the material become more apparent, and the petrochemical industry will be increasingly held to account. Renewable plastics will be gain in popularity and increasingly be demanded by manufacturers and consumers alike. As the era of post-extractivism approaches, the petrochemical industry will have no alternative but to find another way to be. In this final chapter of my dissertation, I argue that designers do have both the agency and the moral responsibility to play a leading role in accelerating the transition toward renewable plastics.

1. The agency of design

Multi-level perspective (MLP) case studies have shown that transitions often take decades to occur as new technologies mature and the incumbent socio-technical regime either adapts or is eventually displaced.[891] Transitions do not follow simple cause–effect schemata but result from the interplay of multiple factors and actors.[892] The success of any discreet technological innovation or an entire regime transition is dependent on acceptance by all involved with the production, distribution, and purchase of products incorporating new technology. A single actor, a designer, or even a manufacturer of a single artefact such as a chair faces a daunting task if they seek to nudge a socio-technical regime toward a more sustainable and resilient orientation, let alone the extractivist regime on which all others depend, energy.

Despite those obstacles, designers can and should play a leading role in encouraging the use of renewable plastics. Philippe Starck (who has enjoyed a very commercially successful career thanks, in part, to his work in plastics, particularly his numerous chair designs for Kartell) told me about the responsibility he takes in such matters:

> Before [in the 1980s] this plastic bashing was stupid and this eco trend was stupid. But now it's serious, we have problem, we have to solve it… the eco trend today is not a trend it is

[891] Case studies in this paper show it can take between 40 and 90 years for transitions to occur. Audley Genus and Anne-Marie Coles, "Rethinking the Multi-Level Perspective of Technological Transitions," *Research Policy* 37, no. 9 (October 1, 2008): 1438, https://doi.org/10.1016/j.respol.2008.05.006. More optimistically Bennett suggests a timeframe of 2025-2050 as realistic for the widespread displacement of petrochemical feedstocks in the UK. Bennett, "Using Past Transitions to Inform Scenarios for the Future of Renewable Raw Materials in the UK," 103.

[892] Georg Holtz, Marcela Brugnach, and Claudia Pahl-Wostl, "Specifying 'Regime' — A Framework for Defining and Describing Regimes in Transition Research," *Technological Forecasting & Social Change* 75, no. 5 (2008): 630, https://doi.org/10.1016/j.techfore.2007.02.010.

> something final... It's not a choice, we have to work with it. A producer like me have [*sic*] to take their own responsibility on all that. And we do it, we take our responsibility, we work, especially on plastic.[893]

It is no longer sufficient for designers to encourage their leaders and educators to declare a climate emergency and while maintaining business as usual. Designs destined to be manufactured using fossil derived materials and/or processed using fossil-based energy increasingly must be challenged as suitable renewable carbon-based alternatives become available. The agency of the designer can be used to influence the uptake of renewable plastics.

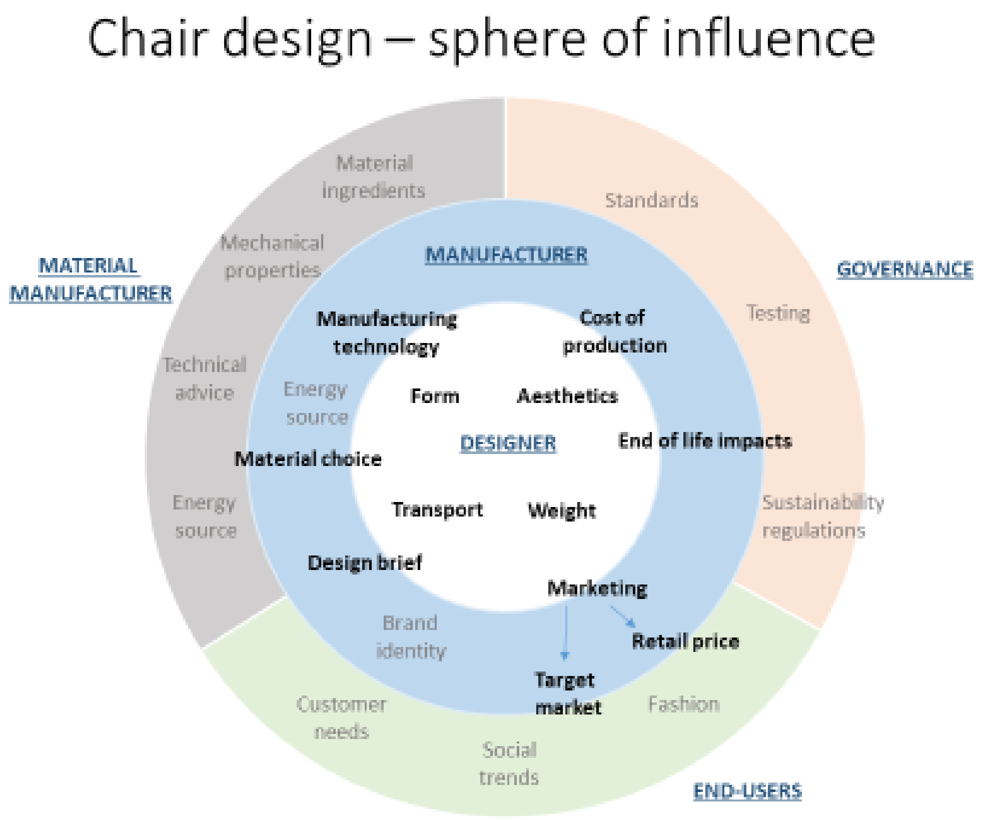

Fig. 8.1. Chair design—sphere of influence. The decisions that need to be taken when developing a design are shown with those influenced by the designer highlighted in bold. The actors (labelled in dark blue caps) with influence over specific design decisions are indicated by the position of the relevant factor.

[893] Isaac, Interview with Philippe Starck.

Fig. 8.1 highlights the decisions most likely to be influenced by the designer. While the designer can be expected to exert the most control over the four topics shown in the centre of the diagram—form, aesthetics, transport, and weight—they can only contribute to most of the other decisions highlighted. For example, cost of production is ultimately the responsibility of the furniture manufacturer, but decisions taken by the designer directly affects those costs. In many cases, the manufacturer makes the final decision, but it is likely that the designer (and in some cases the material manufacturer) will be consulted for their expert advice or opinion.

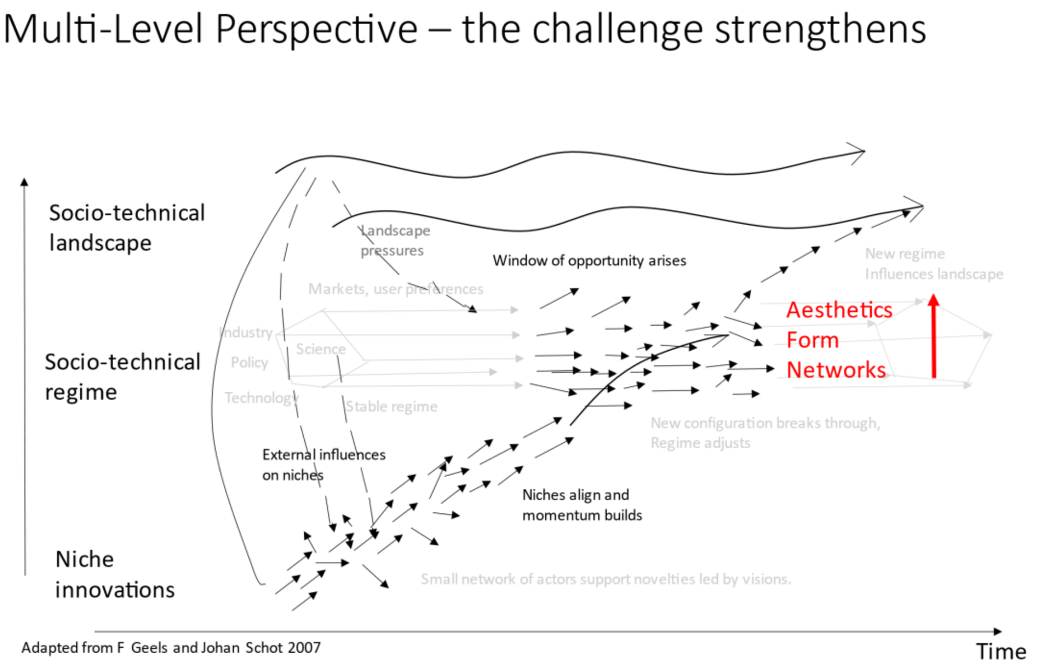

Fig. 8.2. Strengthening the challengers—enabling strategies to challenge the existing socio-technical regime. Source: Adapted from Geels and Schot (2008)[894]

Reference to the MLP model highlights the role designers can play in accelerating the transition toward renewable plastics (fig. 8.2). Designers can act as enablers, increasing the

[894] Schot and Geels, "Strategic Niche Management and Sustainable Innovation Journeys," 546.

probability that their renewable carbon designs will be commercially successful and thereby increasing the probability of achieving regime breakthrough.

a. Sensory experience of renewable carbon plastics

A potential end-user is likely to form their first impressions of a product based on its appearance, which could be to detriment of products made from renewable plastics. The form is perceived as a surface. 'Multi-dimensional looks and tactile qualities' affect the sensory imagination of the would-be buyer: is it warm/cold, hard/soft, heavy or light?[895] The importance of the surface appearance of fossil plastic is well recognised by the industry that focuses much attention on perfecting it. Glossy surfaces with a shiny or lustrous, metallic appearance are appealing to many observers. Perfecting and replicating that finish is so important that the industry has developed tools specifically to monitor the reflection and diffraction of light from glossy surfaces.[896] Recycled plastics are less shiny, and cannot reach the same consistency and homogeneity as their virgin fossil equivalents. Surfaces can be rough and swirls or other blemishes can appear on the surface. When presented to a market grown accustomed to the perfect surfaces of virgin fossil polymers, the imperfect finish of recycled plastics can put buyers off, as Emeco discovered to their cost. CEO, Gregg Buchbinder reported a buyer rejecting an entire shipment of *111 Navy Chairs* (made from recycled PET) on arrival in Japan, as they found the level of finish unacceptable.[897]

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[895] Anssary, "An Approach to Support the Design Process Considering Technological Possibilities," 118.

[896] A gloss meter measures specular reflection, the ratios of incident light and reflected light, by measuring the amount of light reflected from a beam applied to the surface a measurement of glossiness can be obtained (reported in gloss units [GU]). By measuring the light diffraction near the reflected light beam, gloss meters can also measure this attribute allowing makers to precisely control the visual appearance of plastic products Plastics Technology, "Quantifying the Appearance of Plastics," August 26, 2020, https://www.ptonline.com/articles/quantifying-the-appearance-of-plastics.

[897] Emeco have since addressed this issue by working with the material supplier (BASF) to improve the polymer, which can now be injected at lower temperatures, producing a more consistent finish nearly equivalent to the virgin product Gregg Buchbinder, Gregg Buchbinder on Making Things That Stand the Test of Time | At a Distance, August 10, 2020, https://at-a-distance.simplecast.com/episodes/gregg-buchbinder-making-things-that-stand-the-test-of-time.

Developing mass production techniques requires standardisation and typically results in products with a perfectly homogenised appearance. Technological development has driven a desire to achieve perfection, with quality control procedures fine-tuned to eliminate any deficiencies. However, the heterogeneity of recycled plastics creates opportunity, as imperfections can potentially be positioned as adding value to a product, they even can be considered endearing (at the sensory level), according to materials scientist Elvin Karana.[898] While not a philosopher of aesthetics, Karana has been interested in the sensorial qualities of design objects. She claims that imperfections can contribute to products lasting longer, when their appearance is interpreted as more natural, helping to create an emotional bond with the user at an affective level. [899] The difference in appearance between recycled and virgin plastics can be exploited to signal the ecological credentials of the material. However, while a product displaying a recycled look might appeal to some, there is a danger that the mass market will judge the telling signs of human detritus as austere, inferior, or cheap and reject it. The challenge for designers working with recycled materials is to embrace the natural colour shades, random patterns, rough textures, imperfections, irregular surface properties of the materials and shift cultural value systems to make them appeal to end users. Renewable plastics create unique opportunities for designers to push beyond imitating natural materials and create new sensual experiences.

[898] Karana, Elisa, and Valentina, "Materially Yours," 209.
[899] Karana, Elisa, and Valentina, 207–9.

Fig. 8.3. Detail showing textured surface of *Broom Stacking Chair*, designed by Philippe Starck for Emeco (2012). Source: Emeco

Philippe Starck was among the first designers to take on the challenge of exploiting the inherent aesthetic properties of recycled plastics for a chair. During our conversation, he claimed that far from being concerned by this challenge he relished the opportunity to create new sensual experiences as he was bored with working with 'perfect plastic.'[900] Starck told me that he relished the opportunity to work with a recycled polymer mixed with wood, that creates a slightly rough texture and a matt finish, unique to the market when the *Broom Stacking Chair* first appeared in 2012 (fig. 8.3).

[900] Isaac, Interview with Philippe Starck.

Resilience is another material characteristic often lacking when working with recycled plastics Danish designer, Thomas Pedersen explained to me the consequences of this deficiency on the appearance over time:

> [Recycled plastics are] going to be looking a bit more used than a virgin plastic version after [a few] years… it's the surface, it is a bit more scratchy or something. It's probably, maybe, 90-95 percent as good as virgin plastic, but actually, we don't know yet. We haven't tried it out in places for several years… maybe the surface is a bit softer. [901]

Softer surfaces are more prone to scratching, trapping dirt and affecting the appeal of the product, resulting in a reduced lifecycle caused by their disposal and early replacement that potentially cancels out the environmental benefits of the material.

Renewable plastics are often only available with limited colour choices. Pedersen, who used recycled household plastics to produce the shell for his *Falk*, reported, 'The only problem is that you can't get it in every colour. You can only get it in black.'[902] Where more colour choices are available, these are often restricted to limited earthy, muted pallets. Those muted pallets can be appealing to those consumers wishing to make a public display of their environmental credentials but risks limiting products to a market niche (fig. 8.4).

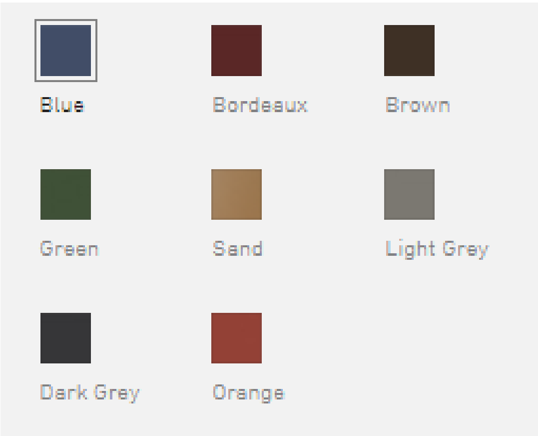

Fig. 8.4. Example of typical muted colour pallet available for chairs made from recycled plastics. Jasper Morrison's *1 Inch Reclaimed* by Emeco. Source: Emeco

[901] Isaac, Interview with Thomas Pedersen.
[902] Isaac.

Bioplastics also have a limited palette of colours that might be described as 'mushy and muddy' as German industrial designer, Konstantin Grcic claimed in our interview.[903] Some designers have addressed that issue by performing their own experiments to broaden the range of choices available. For example, Spanish designer, Ander Lizaso reported that he had developed his own colours for the bioplastic shells of his *Kuskoa Bi* chair. The designer emphasised to me the role of trial and error and experimentation to achieve the final range of colours.[904]

Fig. 8.5. Detail showing the marbleised appearance of the *S-1500* designed by Snøhetta for NCP. Source: NCP

Colour variations of recycled plastics are often regarded as a significant deterrent by designers and manufacturers alike. But some have chosen to celebrate this property, even promoting it as a benefit. NCP celebrates the irregular patterns that appear on the surface of its *S-1500* chairs, claiming them as marble patterned 'celebrating the ocean's movements'

[903] Isaac, Interview with Konstantin Grcic.
[904] Not all of these were successful, a terracotta colour was abandoned when inconsistencies and imperfections in the finished products resulted in high rates of rejection. Isaac, Interview with Ander Lizaso.

and creating a unique finish for every chair (fig. 8.5).[905] Likewise, *ChairCharlie* features a terrazzo effect, ensuring that every chair is slightly different. A feature considered sufficiently important for the manufacturer to claim, 'each chair is unique,' as one of the main selling points (fig. 8.6).[906] Grcic even went as far as to 'fake' the recycled look by adding 'black sprinkles' to the material used to make the *Bell Chair*. Through experimentation the designer discovered that the recycled polypropylene included some impurities which would display on the surface of the chair. Concerned that end-users might consider this a mistake or fault, additional impurities were deliberately added to the material to give a more uniform appearance. Grcic claimed: 'it tells the story of the recycled material and makes the look and feel different to the other plastic.'[907]

Fig. 8.6. Showing the unique terrazzo finish on a *ChairCharlie*.
Source: Arne Jenard for ecoBirdy

[905] See: https://ncp.no/wp-content/uploads/2020/10/S-1500-product-sheet-EN.pdf, accessed February 3, 2022.
[906] See: https://www.ecobirdy.com/blogs/news/five-features-that-make-charlie-chair-the-best-chair-for-children, accessed February 3, 2022.
[907] Isaac, Interview with Konstantin Grcic.

That approach to individualising designs, incorporating anomalies or defects inherent in materials, is not new even in the relatively short history of plastics. Every one of Gaetano Pesce's *543 Broadway Chairs* (1993) were made unique by allowing workers to add colour of their own preference while pouring resin into the mould.[908] The opportunity to own a unique design in the age of mass production remains an appealing proposition.

In efforts to overcome the often-limited colour ranges offered by renewable plastics, some designers have developed some innovative solutions. Working with recycled household plastics for the shell of his *Falk*, Thomas Pedersen had just one colour choice. To improve comfort, he added a removable cushion filled with 98% post-consumer recycled polyester, creating the opportunity to broaden the visual appeal of the design by making the cushion available in a range of colours (fig. 8.7).[909]

Fig. 8.7. While the shell of Thomas Pedersen's *Falk* is only available in one colour, the seat cushion is available in a range of colours. Source: Houe

908 Karana, Elisa, and Valentina, "Materially Yours," 210–11.
909 Isaac, Interview with Thomas Pedersen.

Australian manufacturer DesignByThem overcame the colour limitations of recyclates by avoiding them. For the *Butter* range, they used recycled HDPE (80%) sandwiched between veneers of virgin HDPE (fig. 8.8). This hybridised material allows some of the properties of the virgin material (especially those that affect the senses) to be retained without affecting the end-of-life prospects of the hybridised material. The design is offered in a range of bright primary colours, while the surface displays the perfect homogenous finish typically associated with virgin polymer.

Fig. 8.8. *Butter Chair* from DesignByThem is made from recycled HDPE boards veneered with virgin HDPE, allowing a range of bright colours to be offered. Source: DesignByThem

Emotions are not evoked by visual stimuli alone. Barber & Osgerby's *On & On Stacking Chair* for Emeco (like Starck's *Broom Stacking Chair*) is made from recycled plastic mixed with wood. The material developed for Emeco was designed to provide adequate strength while minimising the use of fibreglass. However, the process imparts a unique textual experience to the finished product and makes it warmer to the touch. Features that Jasper Morrison noticed when he used the same material for his *1 Inch Reclaimed* design (also for Emeco) rating the material as having a 'warmer touch, more natural touch than raw polypropylene.'[910] In addition to this unique sensorial experience, the use of wood—a familiar raw material—might also signal to users that the product to be more

[910] Designboom, "Jasper Morisson's 1 Inch Reclaimed Chair for Emeco."

'environmentally friendly' or 'natural,' encouraging app appreciation for the product and possibly even extending its useful life.[911]

Longevity might also be extended by the imperfect nature of these materials, as they often wear the effects of time more gracefully than the perfect shiny, smooth surfaces of virgin polymers that deteriorate. In contrast, the aging process for traditional materials that gain a patina over time is often interpreted as a sign of maturity and can be highly valued, leading to product longevity according to, Karana.[912] Indeed, in 1995, Papanek predicted that environmentally and socially orientated design of the twenty-first century would include 'graceful aging' as the first fundamental principle, materials that aged well hold great appeal.[913]

Bioplastics offer the potential to be fine-tuned—their characteristics, including appearance, can be adjusting adjusted to suit the task at hand and the taste of the designer. In our interview Mayda Diaz, from the Australian bioplastic supplier Bambacore explained that by adjusting the proportion of bamboo fibres include in their bioplastic range, both the look and mechanical properties of the material can be controlled. Impact resistance can be improved by increasing the fibre loading and adding modifiers, for example. This technique can also be used to modify the surface; with mirror, polished, glossy, matt, smooth, and rough textured versions available.[914] Karana contends that the unique properties of bioplastics present opportunities for designers to explore all aspects of the material including touch, smell and appearance.[915] Starck was among the designers to appreciate that potential, encouraging material manufacturers to retain visible traces of the source materials

[911] Karana, Elisa, and Valentina, "Materially Yours," 209.
[912] Karana, Elisa, and Valentina, 212.
[913] Papanek, *The Green Imperative*, 24.
[914] Isaac, Interview with Diaz Mayda.
[915] Karana, Pedgley, and Rognoli, *Materials Experience*, 203.

used to make bioplastics.[916] The designers working with flax and hemp have followed a similar approach; their creations proudly display the use of natural fibres on their surfaces, which also imbues each chair with a distinctive and unique finish (fig. 8.9).

Fig. 8.9. The source of material for the polymer used for Werner Aisslinger's *Hemp Chair* is clearly visible on the surface of the design. Source: Michel Bonvin for BASF & Studio Aisslinger.

Renewable plastics create the opportunity for designers to completely reimagine our relationship with plastic—modifying market expectations of pristine surfaces by promoting an appreciation of 'graceful aging' with signs of use and wear adding to the history of the material. The challenge is to find connections between the unique properties of the material, its production processes and the potential for renewable plastics to establish satisfying emotional connections with the viewer, purchaser and end-user.[917] Growing and securing

[916] Isaac, Interview with Philippe Starck.
[917] Cleminshaw, *Design in Plastics*, 130.

consumer acceptance of the aesthetic qualities of renewable plastics in consumer products is essential for the niche to develop.

b. Form

No matter what plastic is used to manufacture a chair (or any plastic product or component that does not consume energy during the use phase) by far the biggest environmental impact is caused by the production of the polymer. An environmentally conscious designer's priority should first be to concern themselves with minimising the amount of material used in any of their plastic creations. Lightweighting or dematerialising plastic products reduces the energy needed to process them and delivers downstream benefits, through savings in both transportation costs and environmental impacts.[918] Ultimately, this approach reduces the amount of material entering the waste stream. The *Bell Chair* and the *Sissi* chairs set the benchmark for plastic seating. Dematerialisation can only deliver finite savings. Two decades after Starck developed his 3.5kg *La Marie* for Kartell the lightest chair available weighs 2.7kg. While this represents an impressive 23% reduction the absolute weight, a saving of 0.8kg is small compared with the gains made during the two decade prior to *La Marie* (around 2kg). Further reductions are likely to be negligible, as other design specifications for strength and stability crucial to the satisfactory performance of the chair must take precedence over weight-saving objectives. [919]

In my analysis of sustainability claims made by manufacturers, I found that seven of the companies surveyed claimed to favour producing timeless or classic designs. The goal to deliberately avoid stylistic trends and extend the life of their products both in production and in use. Countless plastic chairs have been created over the past eighty years but only a

[918] Lightweighting is defined as the science and art of making things as light as possible, within constraints.
[919] Elzen, *System Innovation and the Transition to Sustainability Theory, Evidence and Policy*, 1.

few have withstood the test of time, continuing to stimulate sufficient demand to keep them in (sometimes continuous) production for decades. Perhaps more importantly, many examples of those designs remain in constant use, sometimes becoming heirlooms, postponing end-of-life environmental impacts. Those design classics, with their proven timeless stylistic appeal, add to the bank of ideas providing inspiration for others. By revisiting those tried and tested solutions designers minimise the risk of commercial failure. Spanish designer Eugene Quitllet referred to this during our interview: 'furniture designers are inspired by the interpretations of other designers who successfully made use of technological possibilities in good products.'[920] Ashby and Johnston go further, stating that designers get most of their ideas from other designers past and present (and from their environment).[921]

Revisiting classic designs from the recent past can also help to create an air of familiarity, potentially connecting prospective purchasers with nostalgic memories and promoting an emotional bond with the product. Designs that have endured are proven to be fit for purpose. In the case of chairs, prospective purchasers can be reassured the design has withstood the ultimate test of prolonged real-life use and is comfortable and fit for its task. By deliberately minimising ornamentation that could fall from fashion, leading modernist designers successfully developed products, including chairs, which continue to enjoy sufficient demand to keep them in production.

[920] Isaac, Interview with Eugeni Quitllet.
[921] Michael Ashby and Kara Johnson, "The Art of Materials Selection," *Materials Today*, December 2003, 137, https://www.researchgate.net/publication/223096174_The_art_of_materials_selection.

Fig. 8.10. Ander Lizaso's *Kuskoa Bi* (2015) on the left and Robin Day's *Polyside* armchair (1967)
Source: Mito for Alki, Hille

The mid-century period is the preferred source of inspiration for many of the designs included in this study. Robin Day's *Polyside* armchair inspired Lizaso (and his partner Iratzoki) when developing the *Kuskoa Bi*, the profiles of the shells of the two chairs are virtually identical (fig. 8.10). Mater revised a Jørgen & Nanna Ditzel design from 1955 to develop their *Ocean Collection*, only updating the chair to accommodate an increase in average weight of people since the chair made its first appearance in 1955.[922] The *S-1500* is a 'structural redesign' of Bendt Winge's classic R-48 chair from the late sixties (part of a series which sold over five million units in Norway alone).[923] Garcia's *Voxel Chair v1.0* is an update of the cantilevered *Panton Chair*, available from 1967. Tom Price used an Eames armchair (from

[922] The manufacturer claims the only change made was to make the chair 5% bigger to compensate for the increase in average weight of people during the decades following the original design.
[923] Matslinder, "BENDT WINGE – KLASSISKE OG MODERNE MØBLER," *Mats Linder* (blog), January 21, 2017, http://www.matslinder.no/2017/01/21/bendt-winge-klassiske-og-moderne-mobler/.

1950) as a mould to make a direct impression of the chair in balls of polypropylene rope (fig. 8.11).

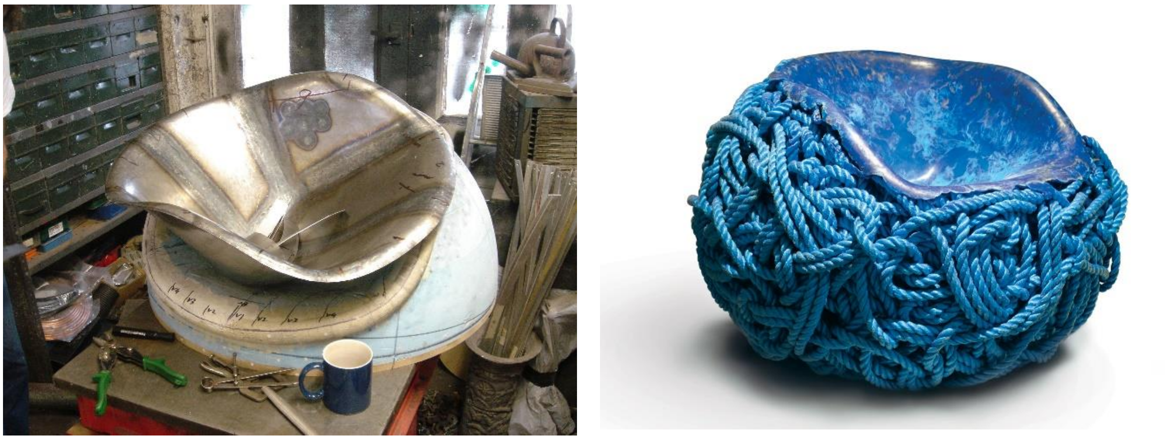

Fig. 8.11. Former based on Eames arm chair used to make impression for Tom Price's *Meltdown Chair*. Source: Tom Price

Three further designs included in my study were directly inspired by popular, pre-mid-century chairs (fig. 8.12). Again, all three of the original designs have enjoyed continuous commercial success since their launch, testament to the timeless appeal achieved by their original creators.

The *111 Navy Chair* from Emeco is a plastic version of the company's signature (recycled aluminium) Navy chair developed for use in WWII. Polywood's *Ocean Chair* revisits the *Andirondack Outdoor Chair* from the early 1900's. In my interview with Barber & Osgerby, they acknowledged the influence of *Thonet's Bentwood Chair* in developing their *On & On Stacking Chair*.

> We are in a really fortunate position when we can bring in a new material and reference historic precedent so that we have a chair which brings something new which looks deliberately familiar.[924]

[924] Isaac, Interview with Barber & Osgerby.

While not inspired by a single work, references to previous designs can be found in other examples. The *Bell Chair* adopts the L-shaped leg solution, long accepted as delivering the most economical use of material to provide the required strength. The shell of Laarman's *Puzzle Chair* is like that used by the Eameses for their plastic shell chairs (*DSX*), while Day's *Polyside* (1963) appears to be inspiration for the shell shape featured in Meindertsma's *Flax Chair.*

Fig. 8.12. *111 Navy Chair* by Emeco, *Ocean Chair* by Polywood and *On & On Stacking Chair* also by Emeco. All three designs are inspired by designs that appeared before mid-century.
Source: Emeco, Polywood, Emeco

Other designers include in my study took a different approach and sought their inspiration from historical examples, or even the ancient forms found in the natural world. Many of the designs manufactured using new technologies such as 3D printing or AI, were inspired by the natural environment. Designers working with new manufacturing technologies have gone beyond a study of form, concerning themselves with exploring the structural secrets developed by nature over billions of years of evolution. As Ceschin and Gaziulusoy observed: 'nature has learnt what works and what is appropriate.'[925] Nature has evolved to be conservative with mass, minimising the amount of material needed to deliver the required function. Mimicking structure and process has allowed designers to explore new, more efficient use of materials.

Fig. 8.13. *AI Chair by* Philippe Starck for Kartell. Starck claims the design is reminiscent of Art Nouveau. Source: Kartell

Starck used AI software designed to mimic the growth of trees and bones to minimise the quantity of material needed for Kartell*'s AI Chair* (fig. 8.13). When we spoke, Starck acknowledged the similarities to nature-inspired Art Nouveau design and his chair developed using the latest in software technology. Marcel Garcia is experimenting with 3D printing techniques directly referencing structures in nature in efforts to minimise both

[925] Ceschin and Gaziulusoy, "Evolution of Design for Sustainability," 127.

material consumption and faults, which can arise during the printing process resulting in wastage (fig. 8.14). Karim Rashid claims his bulbous *Siamese Chair* is 'amorphous, from the earth and an extension of nature' reflecting the characteristics of the bioplastic used for his design.[926]

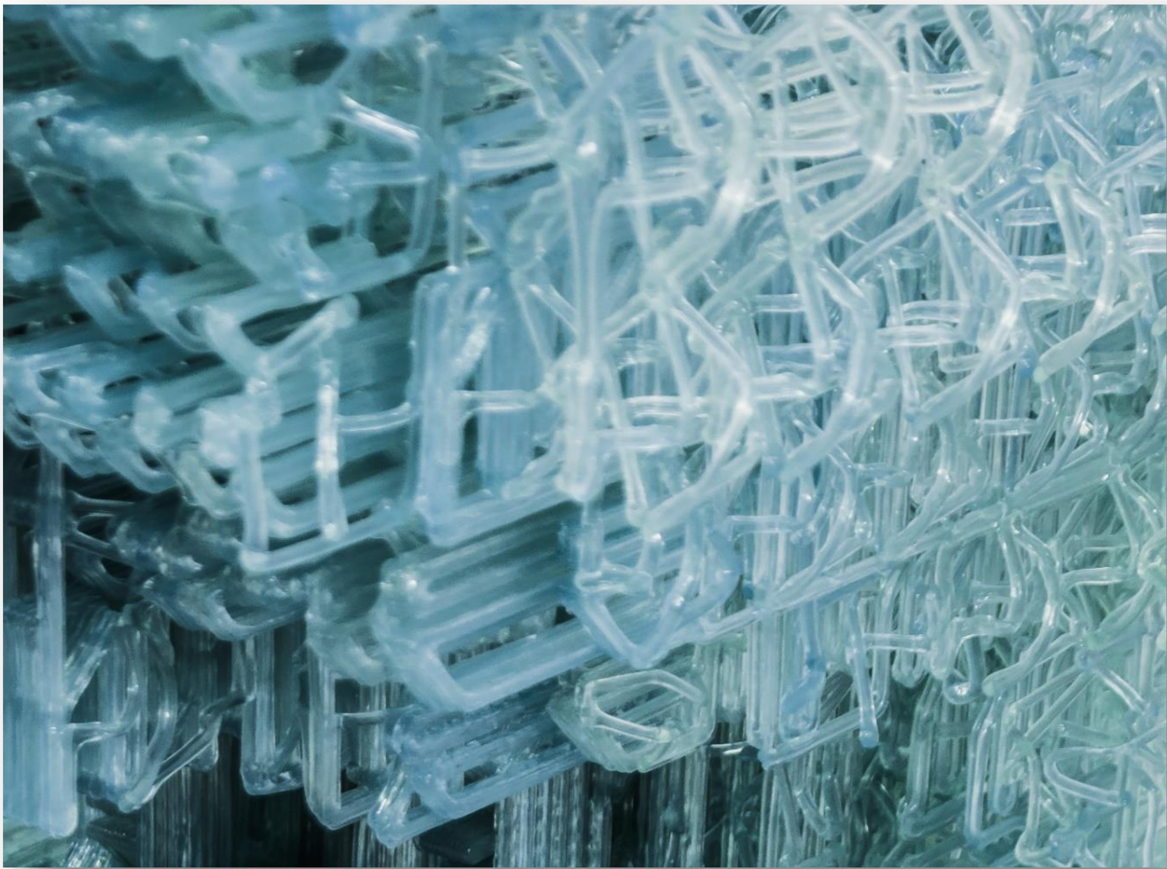

Fig. 8.14. Detail from Manuel Garcia's *Voxel Chair v1.0* showing unique 3D printing process claimed to be based on nature and developed to minimise the impact of errors encountered during the 3D printing process. Source: © Nagami Design S.L.

Form can also be affected, dictated even, by the mechanical properties of the particular material selected. There are risks working with new materials as mechanical limitations might only reveal themselves during the production process. Recall the

[926] Isaac, Interview with Karim Rashid.

adjustments Lizaso had to make to both the shell and the frame of the *Kuskoa Bi*, to accommodate unexpected shrinkage of the bioplastic. Rashid's experience in developing the *Siamese Chair* was similar, with plans for a monobloc aborted to accommodate the mechanical properties of the bioplastic selected for the project. To succeed in delivering those chairs, design concepts were compromised to accommodate the technical limitation of the renewable carbon material. In Rashid's' case, the design has been commercially unsuccessful, highlighting the financial and reputational risks designers expose themselves to when experimenting with untried materials.

When making decisions on form the implications for transport and storage must be considered. Many of the chairs I have studied (for example *AI Chair*, *Kuskoa Bi*, *Siamese Chair* and *Voxel Chair v1.0*) are not designed to stack. In many cases those chairs are packaged for transportation in individual cartons, taking up space in containers and warehouses with negative financial and environmental implications. How the chair will be transported is an important design consideration when creating a more sustainable design. Creating stacking chairs does impose limits on the overall design, as the back legs of one chair often need to slot through the shell or seat. If these design limitations are unacceptable there are other solutions to optimise for transport. For example, the *Odger* occupies less space when shipped as the end-user is required to attach the legs to the shell. The *Butter Chair* arrives in Australia flat packed from the Chinese production facility and is assembled for local distribution, helping to reduce the environmental impact of international transport. Experimentation with new manufacturing technologies can open new possibilities for innovative solutions to minimise transport impacts.

c. Networks

Any transition is beyond the unilateral control of a single actor, with niche actors lacking the agency required to effect regime change. MLP theorises that niches and regimes are reliant on networks and strategic alliances composed of groups of actors that align and subscribe to common rules and practices.[927] Technologist Adrian Smith argues that sustainable technology transitions are better understood as changes mediated by the resources, interests, and expectations of institutionally-embedded networks of actors.[928] For transitions to occur, any individual participant needs to build a coalition of actors to accumulate the skills and resources needed to effect transition. Those relationships can be nurtured by developing a detailed understanding of the motivations, interests, and expectations of each actor, allowing a pathway for coevolution to develop. [929]

MLP theory has been criticised for a lack of attention to the processes through which niches and regimes interact, although the theory relies on these interactions as a key process for transition to succeed.[930] In an attempt to bridge that gap, an actor network theory approach to the emergence and structure of relationships between niche and regime participants involved with a specific transition was undertaken by Marion Diaz et al.[931] Having mapped the development of such relationships over several decades the authors found that niche–regime interaction is not a sequential process—there is no requirement that the niche

[927] El Bilali, "The Multi-Level Perspective in Research on Sustainability Transitions in Agriculture and Food Systems," 11.
[928] Smith, Stirling, and Berkhout, "The Governance of Sustainable Socio-Technical Transitions," 1508.
[929] For example, Hartmut Esslinger (who has created many successful designs for Apple and Sony among other) claims 'for the power is in the factories – and beyond that, however old they are designers need to know what factories can do today. Because the best designs and products always emerge through collaboration with the manufacturing side.' Bernhard E Bürdek, *Design History, Theory and Practice of Product Design* (Berlin: de Gruyter, 2005), 92.
[930] Geels, "The Multi-Level Perspective on Sustainability Transitions," 30.
[931] Marion Diaz et al., "Green Tides in Brittany: What Can We Learn about Niche–Regime Interactions?," *Environmental Innovation and Societal Transitions* 8 (September 1, 2013): 62–75, https://doi.org/10.1016/j.eist.2013.04.002.

must mature before building links with the regime. Those relationships are, they argue, 'an on-going and recursive process, where the niche needs to cope with how regime actors transform and selectively appropriate its message and practices.'[932] Developing such networks enables the cross-fertilisation of ideas that can drive system reconfiguration through learning and negotiation.[933] Common interests can be identified enabling the niche to incorporate and address the concerns of other actors in their approach to framing sustainability challenges.[934] This process often necessitates compromise from actors to maintain the support of collaborators.

The first chairs to be designed using renewable plastic emerged from independent designer/makers with access to their own production facilities (Tom Price, Marcel Garcia, Dirk Vander Kooij and Joris Laarman) or from designers working with smaller manufacturers (A Lot of Brasil, Alki, DesignByThem, Hay, Label/Breed, M114 and Moroso).[935] Niche innovations like those are crucial to initiate transition. As Smith observed, 'mainstream' actors only become interested in new technologies when niches have been proven 'in terms of scope for profitable application'.[936] To affect the overall market the support of larger manufacturers with established distribution networks is needed. But even for a designer with a track record of commercial success, finding furniture manufacturers with a demonstrable commitment to sustainability goals remains challenging. Large incumbent manufacturers are often locked in by their investments, with established supplier networks (with their own lock-in issues)

[932] Diaz et al., 72.
[933] Geels, "Ontologies, Socio-Technical Transitions (to Sustainability), and the Multi-Level Perspective," 495.
[934] Adrian Smith and Rob Raven, "What Is Protective Space? Reconsidering Niches in Transitions to Sustainability," *Research Policy*, Special Section on Sustainability Transitions, 41, no. 6 (July 1, 2012): 1031, https://doi.org/10.1016/j.respol.2011.12.012.
[935] The only exception to this is Emeco, who are a special case as the company has specialised in using recycled materials since the 1940s.
[936] Smith, "Transforming Technological Regimes for Sustainable Development," 1.

adding pressure to continue business as usual and defend the status quo.[937] Sustainability is not currently a priority for most furniture manufacturers.

Despite those difficulties some designers have succeeded in securing support from major furniture manufacturers to develop chairs using renewable plastics. Designer, Eugeni Quitllet emphasised the importance of his relationship with the owner of manufacturer Vondom in developing his designs during our interview:

> He [Pepe Jose Albania, the owner of Vondom] is going to put a lot of… him into the project and that's nice because he's not just a businessman who's going to say, "Okay this can sell we do it, but it's my team who's going to work I'm just making the business." He likes to be involved in the process (like Kartell also love to) and that says something. To create things that really respect the original thought, the original intensity from the beginning to the end. You need to have this kind of relation and you can't just send the drawing and say, "Okay. I'll just put my name on it."[938]

These comments reinforce the importance of the social component of social-technical transitions.[939] Quitllet was not the only designer I interviewed to emphasise the significance of maintaining close personal relationships with manufacturers. Starck has the benefit of a long-established personal relationship with Claudio Luti, CEO of Kartell, contributing to his successful partnership with the company and resulting in many designs that have achieved outstanding commercial success.

The *Bell Chair* resulted from a two-year collaboration between Grcic, Magis, and the engineering team at a third-party injection moulding company. Magis (including owner and CEO, Alberto Perazza) had previously established and developed relationships with both the designer and engineering company over many years as part of a network of relationships

[937] For instance, a MLP study of the emergency of the LED market revealed how an established manufacturer devoted resources to attacking the technology before finally being forced to catch up, by acquiring companies with experience with the new technology. Resistance bought the incumbent time – allowing them to sweat their existing investments and maximise returns while developing capacity to embrace the new technology. Smink, Hekkert, and Negro, "Keeping Sustainable Innovation on a Leash?," 1808.
[938] Isaac, Interview with Eugeni Quitllet.
[939] Diaz et al., "Green Tides in Brittany," 62.

with suppliers and mould makers across Northern Italy. Grcic attributes the success of the *Bell Chair* project to deep engagement with the engineering team that finessed the development of a lightweight design using a new recycled material.

> Most chairs are developed in this kind of dialogue with engineering but never to that extent in my in my own experience… I was really excited about this because I enjoyed the dialogue with this guy. I felt I was learning so much and… [working in] a very kind of natural, synchronized way… because you know all his rules or where he said, "We can't do this". We [disagreed] and then found a way forward rather than [making] a bad compromise.[940]

While the importance and benefits of such a relationship appears obvious, they rarely occur. Grcic claimed he had never before been so closely involved with the production of a product.[941] As we have already seen, Grcic was also involved with the development of messaging and collateral used to promote the *Bell Chair*. Although acting as a consultant rather than an employee, Grcic became involved with all aspects of design for this project from negotiating with technical teams and finalising the colour choices, through to negotiating with the marketing team to finesse the commercial presentation of his work.[942]

Efficient and effective communications across all the professions involved in a project are essential to ensure timely production. However, maintaining effective communications is challenging, as different actors are focused on different priorities and exchange ideas using specific terminology. Design academic Tom Fisher explained the different priorities facing designers and engineers when work working on a project involving plastics, summarising:

> While design engineers are concerned with physical, mechanical performance, product designers think of plastic in terms of consumers' engagement with objects through the tactility of their surfaces and the visual effects of their forms - aesthetic relationships with objects activated by culture [943]

[940] Isaac, Interview with Konstantin Grcic.
[941] Isaac.
[942] Isaac.
[943] Fisher, "Fashioning Plastics," 123.

Fishers' comments further emphasise the benefit of the close working relationship that Grcic had experienced. However, designers face particular communications challenges as they work with engineers and specialists to develop their creations for production, especially as actors are often in separate geographic locations, with language barriers adding further complexity.[944] Research undertaken by Alaa Anssary illustrates the range of challenges to communication between designers and engineers including: 'perceptual gaps, the use of different languages, and a lack of tools to describe the interplay between material attributes, shaping techniques and form aspects.'[945]

Anssary's study investigated the difference in terminology used by designers and engineers, finding significant variances. Designers preferred 'soft vocabulary based on their aesthetic experiences' while engineers used 'hard terminology based on their technical experiences.'[946] As shown by the examples in fig. 8.15, the different vocabulary used to describe the same attributes can create confusion between designers and engineers when developing a project. Designers participating in the study went on to report they found engineers to be patronising, unimaginative, and inflexible, further highlighting the difficulties in maintaining cordial relations between those actors.[947]

[944] In Grcic's case the engineer spoke Italian while Grcic's first language is German. Isaac, Interview with Konstantin Grcic.
[945] Anssary, "An Approach to Support the Design Process Considering Technological Possibilities," x.
[946] Anssary, 139.
[947] Anssary, 132.

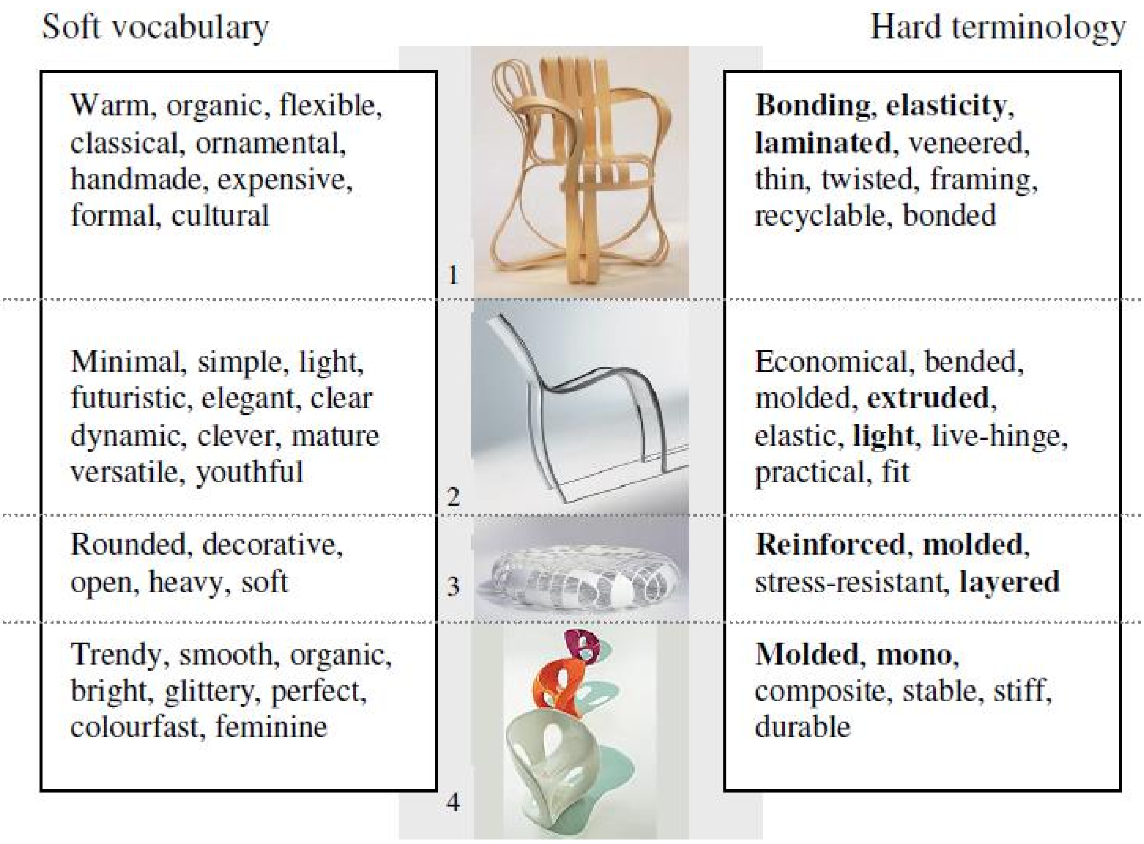

Fig. 8.15. Vocabulary and terminology used by designers and engineers to describe influence of material properties and their shaping techniques. The left column shows the vocabulary used by designers while the right column shows words in bold used by engineers. Source: Anssary (2006)[948]

Even when the support of a sympathetic furniture manufacturer is secured, renewable carbon projects are threatened by the aggressive defence strategies of the petrochemical regime: lobbying policy makers, influencing public opinion and defending favourable technical standards.[949] Despite that formidable resistance, some designers have succeeded in forming a direct relationship with more progressive sectors of the petrochemical industry. In Brazil, manufacturer Tramontina (and their in-house design team) worked closely with local

[948] Anssary, 139.
[949] Smink, Hekkert, and Negro, "Keeping Sustainable Innovation on a Leash?," 95.

petrochemical giant Braskem to develop the *Summa* and *Jet* ranges (fig. 8.16). That partnership resulted in showcase projects for a new post-consumer recycled resin and a bio-based polymer (made form ethane derived from sugar cane). Braskem is unique among the major entrenched petrochemical organisations. Based in Brazil, the company has benefited from government supported development of the biofuel market, generating decades of R&D for the company in processing biomass.[950]

Fig. 8.16. Tramontina manufacture and retail the *Sissi* chair from the *Summa* range (left), developed using post-consumer recycled resin and the *Jet* (right) using Braskem's 'I'm Green' polyethylene made from ethane derived from sugar cane. Source: Tramontina

Petrochemical companies are coming under increasing pressure to improve their sustainability performance across all areas of activity. Andreas Maegerlein reported that in his work as Group Leader of the Creation Center with the Designfabrik team at BASF every

[950] For detailed analysis of the development of the biofuels market in Brazil (and government intervention to support the market) see: Silveira and Johnson, "Navigating the Transition to Sustainable Bioenergy in Sweden and Brazil."

client meeting now includes questions about sustainable plastics.[951] 'It started with the designers, absolutely. But [now] it's, I think every engineer, every company is looking desperately for solutions.'[952] Emeco have enhanced their reputation for sustainable designs by working closely with BASF to develop new recycled materials. This program of material innovation has attracted leading designers such as Starck, Morrison, and Barber& Osgerby to work on Emeco projects. BASF also developed the water-based acrylic resin used by Aisslinger for the *Hemp Chair*, among the best scoring designs included in my study. Designfabrik acts as a hybrid actor, bonded to the existing petrochemical regime but sympathetic to the sustainability problems observed by other actors.[953] These direct interactions between niches and regimes are a key process in the take-off stage of transition.[954]

Material suppliers can be active participants in sharing knowledge, bringing lessons from one project along to the next project. For instance, Shell was involved in most projects with solar photovoltaics in the Netherlands in the late 1990s, speeding up development in that industry.[955] BASF and Braskem appear to be playing similar roles in advancing renewable plastics.[956] By helping to build social networks, material manufacturers can facilitate

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[951] Designfabrik offers design and materials advice to designers, engineers and developers in the early stages of product development. See https://plastics-rubber.basf.com/global/de/performance_polymers/creation_center/designfabrik.html. The division was launched in 2006 in an apparent attempt at revisiting the strategy of knowledge transfer successfully employed by the German plastics industry up until the 1970s. See: Jochen Streb, "Shaping the National System of Inter-Industry Knowledge Exchange: Vertical Integration, Licensing and Repeated Knowledge Transfer in the German Plastics Industry," *Research Policy* 32, no. 6 (June 1, 2003): 1125–40, https://doi.org/10.1016/S0048-7333(02)00114-2.
[952] Isaac, Interview with Andreas Maegerlein, Group Leader Creation Center, BASF.
[953] Smith, "Translating Sustainabilities between Green Niches and Socio-Technical Regimes," 436.
[954] Smith, 427.
[955] Schot and Geels, "Strategic Niche Management and Sustainable Innovation Journeys," 544 The authors report on the work of Van Mierlo for a 2002 PhD at the University of Amsterdam.
[956] In 2008 BASF sponsored Konstantin Grcic to develop the *Myto* chair, showcasing a new fossil polymer, polybutylene terephthalate (PBT).

interactions between relevant stakeholders, and provide access to the necessary resources (people, expertise, and finance) to accelerate transitions.[957]

2. Strategies to accelerate transition

MLP studies have identified strategies that have successfully been implemented to support the adoption of new technologies. I will examine three strategies shown in fig. 8.17: a) hybridisation; b) targeting high growth market segments; and c) multi-technology interaction for their relevance to those interested in promoting the use of renewable plastics.

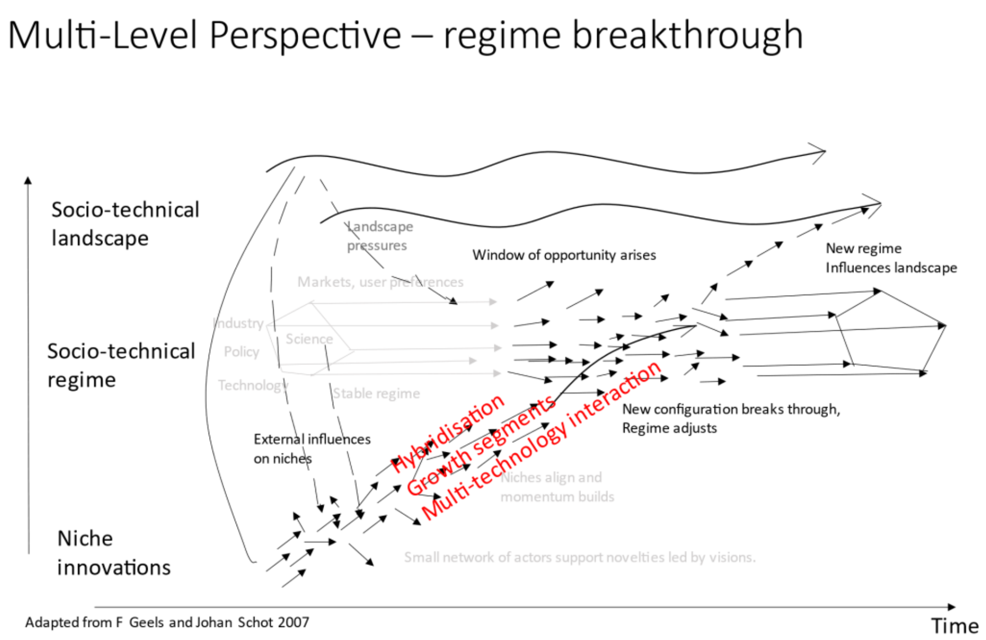

Fig. 8.17. Regime breakthrough is achieved, and the landscape adapts to absorb the new technology. Source: Adapted from Geels and Schot (2008)[958]

[957] Schot and Geels, "Strategic Niche Management and Sustainable Innovation Journeys," 540.
[958] Schot and Geels, 546.

a. Hybridisation

As renewable plastics are an emerging field it can be challenging to find a material with the mechanical specifications required for any given project. Hybridised plastics can offer a solution to this challenge. Hybridisation is a proven mechanism by which a niche innovation can achieve breakthrough to the regime level.[959] As highlighted by Adrian Smith, transition is most easily achieved where new processes or solutions can 'slot into' mainstream practices with minimal disruption.[960] Linking new technologies to established technologies also avoids direct competition between the two and can promote the development of a symbiotic relationship.

There are many examples whereby hybridisation has enabled a new technology to establish a foothold and eventually displace an existing regime. Steam engines were initially added to sailing ships to be used when winds failed, improving their speed, regularity, and reliability. Iron was then used to strengthen wooden hulls to accommodate increasing powerful engines before all metal hulls emerged in the late 1850s.[961] Gas turbines were introduced as an auxiliary device to improve the performance of steam turbines in power stations before gradually becoming the main dominant power source in combined cycle stations.[962]

Hybridisation has already been tested and proven as a very successful strategy for fossil plastics to infiltrate existing regimes. Natural fibres such as wool, cotton, and silk have been largely displaced by synthetic fibres thanks to a growing acceptance of less-expensive hybridised offerings such as poly-cotton, increasingly available since the 1930s. In 2019, 74 million tonnes of synthetic fibres (mainly polyester) were produced and that is projected to

[959] Geels, "Technological Transitions as Evolutionary Reconfiguration Processes," 1271.
[960] Smith, "Translating Sustainabilities between Green Niches and Socio-Technical Regimes," 444–46.
[961] Geels, "Technological Transitions as Evolutionary Reconfiguration Processes," 1268.
[962] Geels, 1272.

increase to 135 million tonnes in 2025.[963] Synthetic fibres now account for two thirds of all fibres produced globally.[964]

Fig. 8.18. Barber & Osgerby's *Tip Ton RE* (2020) made from recycled polypropylene, polyethylene and steel. Source: Vitra

Most recycled plastics available on the market today are essentially hybridised, with virgin polymers added in efforts compensate for any loss in quality caused by mechanical recycling processes. Hybridisation enables recycled polymers to display almost identical mechanical material characterises when compared with their virgin equivalents. Manufacturers and designers are therefore able to use these materials with minimal adjustments to their existing processes. Investments in both time and money to retrain staff and re-tool or recalibrate production facilities are minimised. It is unsurprising, then, that major manufacturers such as IKEA and Vitra have made their first moves into renewable plastics by using recycled materials. IKEA introduced the *Odger* in 2017 made from recycled

[963] https://www.statista.com/statistics/271651/global-production-of-the-chemical-fiber-industry/, February 3, 2022.
[964] European Environment Agency, "Plastics, a Growing Environmental and Climate Concern," 16.

polypropylene mixed with wood, while Vitra released a version of Barber & Osgerby's *Tip Ton Chair* made from recycled polypropylene in 2020 (fig. 8.18).

Rather than offer hybridised or fully recycled plastics as separate products, BASF have developed a 'mass-balanced' solution for clients interested in renewable carbon-based materials. Upon request, BASF arrange for the collection or purchase of an equivalent quantity of plastic from the waste stream. The discarded plastic is chemically recycled (treated by pyrolysis) with the resultant oil mixed with traditional fossil inputs and polymerised to produce plastic.[965] The client can then claim the recycled content of the material based on the proportion of feedstock which has been allocated to their product. BASF supply an independent auditor's certificate to support those claims.

Mass balancing is attractive to clients as substantial costs of adapting existing manufacturing processes to match the mechanical characteristic of a different material are avoided. BASF have mixed recycled material with a large quantity of virgin source material meaning that the output is indistinguishable from the equivalent 100% virgin fossil plastic. Clients can potentially claim their product as being made from up to 100% recycled polymer when, in fact, products contain a minimal quantity of recycled ingredients. It can be argued that using pyrolysis derived oil displaces the use of virgin fossil fuels. However, allowing products made from this process to be labelled as made from recycled plastics is contestable. In 2020, BASF only processed 1,000 tonnes of recycled materials, but aims to increase this to 250,000 tonnes by 2025.[966] It is unclear how that method can be adapted to compensate for quality issues as the volume of recycled plastic included in process increases.

[965] See: https://www.basf.com/global/en/who-we-are/sustainability/we-drive-sustainable-solutions/circular-economy/mass-balance-approach/chemcycling.html, accessed February 3, 2022.
[966] DuPont have also joined the Plastics Europe Mass Balance Taskforce to investigate the potential of this approach DuPont, "Thriving Together (Sustainability Report)," 29.

The mass balance approach is relatively complicated to communicate to clients, let alone end-users. Adreas Maegerlein from BASF admitted as much to me in our interview. That complexity could potentially result in marketing messages that simplify or overlook details, misleading consumers, particularly those interested in selecting products based on their environmental credentials. While it can be argued that the actions of the product manufacturer have resulted in an equivalent decrease in demand for virgin fossil plastics, the fact remains that only a small proportion of the material used to make the product is recycled.[967] Consumers are often unknowingly purchasing products containing virgin plastics sourced from fossil-fuels.

Critics argue that chemically transforming plastic into fuel is not recycling; it is just another way to create more fossil fuel to burn.[968] Proponents of recycling highlight that any technology that displaces consumption of virgin fossil oil offers a net gain for the environment. As chemical recycling becomes more prevalent, designers and manufacturers need to stay informed about those debates and question the detail of sustainability claims made by material suppliers.

Bioplastics are also often hybridised with virgin fossil plastics to improve compatibility with existing manufacturing processes and to compensate for any deficiencies in mechanical properties. Even while working with these hybridised materials, pioneering designers and manufacturers have discovered that developing a product takes time and

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[967] In June 2021, Audi announced they had taken the mass balanced approach a step further, successfully producing car parts from recycled mixed plastics using a similar process (with a different material manufacturer) but claim that parts 'could' be manufactured entirely from pyrolysis oil. Closing the material cycle in this way, it is argued, can save valuable resources, energy, and reduce GHG emissions. Although details of the energy required to collect and recycle the plastic waste together with the GHG impacts of consuming the pyrolysis oil to produced new plastics are not detailed. See: https://www.audi-mediacenter.com/en/press-releases/a-new-lease-on-life-recycling-automotive-plastics-14024

[968] Break Free From Plastic, "Missing the Mark: Unveiling Corporate False Solutions to the Plastic Crisis," Break Free From Plastic, accessed February 3, 2022, https://www.breakfreefromplastic.org/missing-the-mark-unveiling-corporate-false-solutions-to-the-plastic-crisis/.

money. While developing the *Kuskoa Bi*, Lizaso was forced to introduce an additional step to the moulding process and modify the base of the chair to accommodate unexpected variance in the performance of the hybridised bioplastic.

Hybridisation is also often a strategy attractive to end-users. By mixing familiar technologies with new the market is given a steppingstone, an opportunity to build confidence in the new, as the resultant products are not radically dissimilar to familiar things. However, adoption is more likely to succeed where distinct consumer benefits are evident to potential purchasers. Blending cotton with polyester produces a breathable, tear-resistant fabric that is less expensive than natural fibres. Car manufacturers are adding features such as lane control or assisted parking to their vehicles demonstrating the convenience of automated driving and building market confidence in the technology. While designers may struggle to identify the consumer benefits of hybridised plastics, as we have already seen, some have showcased the unique aesthetic qualities of these new materials.

b. Multi-technology impacts

Renewable plastics have already branched into other industrial sectors having been primarily developed to meet packaging demands. The automobile industry has been an early adopter of those materials, and manufacturing processes have already been adapted to accommodate them.[969] Bioplastics have been met with enthusiasm by that industry as the use of eco-friendly materials reduced Co2 emissions, helping manufacturers to meet sustainability commitments.[970]

Two of the chairs achieving the highest scores in my ERPR tool, the *Hemp Chair* and *Nobody Chair*, are moulded in one-piece using the same thermo pressing process used to

[969] Hyeon Joo Jeong and Youngjoo Ko, "Analysing the Structure of Bioplastic Knowledge Networks in the Automotive Industry," *International Journal of Technology Management* 82, no. 2 (2020): 136.
[970] For a detailed discussion on bioplastics in the Asian automobile industry see: Jeong and Ko, 133.

form parts for cars, such as removable boot shelves. Compression moulding consumes less energy than injection moulding, the process used to create most of the designs I have examined. The relatively low pressure required by this technique delivers additional benefits: the cost of expensive steel moulds is avoided, enabling smaller production runs to be economically viable. As more bioplastics enter the market this energy saving technology has potential to become increasingly common, particularly among small and mid-range furniture manufacturers.[971] Both the *Hemp Chair* and *Nobody Chair* are stackable, demonstrating that compression moulding opens new horizons for designers to develop stacking chairs without resorting to the traditional solution of cutting holes in the back of the shell.

Other designers have combined multiple innovative technologies in attempts to exceed the benefits that can be achieved by using them individually. Dirk Vander Kooij purchased an industrial robotic arm, retired from the automobile industry, and added an extruder to develop his *Chubby Chair* (fig. 8.19). This interaction of 3D printing and robotics is like the approach adopted by Marcel Garcia for his *Voxel Chair v1.0*. Grcic pointed out to me that the automobile, aeronautical and medical industries already use 3D printing to produce complex components for products and that this approach could be the future of the technology in the furniture industry.[972] Alternatively designers might utilise 3D printing for some components and combine with different manufacturing technologies to create the remainder of the chair.

[971] For very high volumes injection moulding is likely to remain the preferred technology. However, in an increasingly fragmented market it is likely that even large manufacturers will be incentivised to experiment with technologies more suited to smaller runs.
[972] Isaac, Interview with Konstantin Grcic.

Fig. 8.19. *Chubby Chair*, Dirk Vander Kooij, 2012. Source: Studio Dirk Vander Kooij

Experimenting with digital technologies allows the designer (or student) to become more deeply engaged in the production process and has the potential to highlight sustainability issues. In a press interview German industrial designer, Stefan Diez, attributed his own interest in sustainable design to the development of rapid prototyping. Completing his training at a time when 3D printers and computer-controlled manufacturing machines were emerging allowed him to become deeply engaged in the product development process encouraging an appreciation of the resources required to deliver a project.[973] New manufacturing technologies prompt the questioning of long-standing solutions to common design problems. For example, rectilinear ribs are often used to add strength to chairs. Making straight cuts in a mould

[973] Anna Moldenhauer, "Stefan Diez: Circular Design Guidelines," Stylepark, January 29, 2021, https://www.stylepark.com/en/news/stefan-diez-circular-design-guidelines-sustainability.

with a milling machine is an easy (and cost effective) solution when working with injection moulding. With other technologies, where the upfront investment in an expensive high-pressure mould is not required, designers are free to experiment with less-intrusive solutions to enhance the strength of their designs where needed. Structures that occur naturally in our environment provide a variety of models to solve those challenges and the designers working with these new manufacturing technologies are only just beginning to experiment with them.

c. Targeting high-growth market segments

MLP studies have shown that new technologies can transition to the mainstream by identifying and servicing high-growth niche market segments. As the niche market develops, the new technology is propelled with it. But that technology must develop quickly to service growing demands. Geels and Schot observed that steamships benefited from strong growth in the Atlantic passenger market, with historical events such as the potato famine in Ireland and the American gold rush driving demand. The need for faster, more reliable cross Atlantic transfers for people created a new niche market ideally suited to steamships. A premium could be charged for the speed and reliability improvements provided by the new technology, justifying a price premium.[974]

The innovators and early adopters of products made from renewable plastics are most likely to be found among environmentally conscious consumers. Although they might be identified by surveying the market for consumers' beliefs and attitudes, environmentally conscious buyers are difficult to reach as they cannot be accurately targeted using traditional

[974] Frank W. Geels and Johan Schot, "Typology of Sociotechnical Transition Pathways," *Research Policy* 36, no. 3 (April 2007): 410–11, https://doi.org/10.1016/j.respol.2007.01.003.

demographic segmentation when planning marketing activities.[975] Three extensive reviews of relevant academic studies investigated the link between demographics and potential to purchase more sustainable products and found little evidence of a correlation.[976]

All three of those literature reviews, together with the results of original research I have conducted for this dissertation, highlight the challenge of targeting consumers interested in environmentally conscious design. Many consumers often hold negative associations with sustainable products, viewing them as being of lower quality, less aesthetically pleasing, and more expensive.[977] Marketing products to this audience based on their sustainable credentials wastes resources. Given the number of people looking to buy chairs at any time is relatively small (compared with the number of people buying groceries every week, for example), reaching environmentally conscious purchasers with timely and relevant messaging is extremely challenging.

Despite those challenges, some designers and manufacturers have already succeeded in locating discrete market segments with interest in sustainability. Hotels, conference centres, and restaurants were identified by the designers and industry representatives that I have spoken to as early adopters of their renewable carbon creations. Thomas Pedersen reported that within the last two or three years he had noticed increased interest in environmentally friendly products from restaurants and hotels in Europe, keen to signal their

[975] For a summary of the conflicting demographic definitions of sustainable consumers see: Lara F. Horani, "Identification of Target Customers for Sustainable Design," *Journal of Cleaner Production* 274 (November 20, 2020): 2, https://doi.org/10.1016/j.jclepro.2020.123102.

[976] Horani, "Identification of Target Customers for Sustainable Design"; Adamantios Diamantopoulos et al., "Can Socio-Demographics Still Play a Role in Profiling Green Consumers? A Review of the Evidence and an Empirical Investigation," *Journal of Business Research* 56, no. 6 (June 1, 2003): 465–80, https://doi.org/10.1016/S0148-2963(01)00241-7; Yatish Joshi and Zillur Rahman, "Factors Affecting Green Purchase Behaviour and Future Research Directions," *International Strategic Management Review* 3, no. 1 (June 1, 2015): 128–43, https://doi.org/10.1016/j.ism.2015.04.001.

[977] Katherine White, David J. Hardisty, and Rishad Habib, "The Elusive Green Consumer," *Harvard Business Review*, July 1, 2019, np.

commitment to taking action to lessen their environmental impact. The first big order for his *Falk* (made from recycled household plastic waste) came from a hotel who selected the chair as 'it was the best on the market' in terms of design, comfort, price, and especially because of its environmental profile.[978] Purchases by hotels and restaurants are visible signifiers reinforcing the organisations ethical commitment to sustainability and providing them with a point of differentiation to compete in a crowded market. Designers and manufacturers benefit from sales directly and from having their work exposed in public spaces where large numbers of potential customers can see and try out their chairs. Those hotels, restaurants, and conference centres that choose sustainable alternatives help demonstrate that luxury and sustainability are not mutually exclusive. By showcasing sustainable furniture, they act as opinion leaders, contributing toward social norming of renewable carbon products and promoting wider adoption.

Pedersen also highlighted schools as a potential target market, noting that governments are increasingly concerned with integrating sustainability in their purchasing policies. Governments are taking action to mandate the use of recycled materials across all areas of activity. The Australian Government updated its *Sustainable Procurement Guide* in 2020 and suggests preferencing 'furniture and fittings [that] include recycled content and can be recycled at the end of their life'[979] as a strategy to contribute to a departments sustainability targets as specified in the *National Waste Action Plan 2019*.[980] As the focus on

[978] Isaac, Interview with Thomas Pedersen.
[979] Department of Agriculture, Water and the Environment, "Sustainable Procurement Guide" (Canberra: Australian Government, 2020), 18, http://www.environment.gov.au/.
[980] The guide does provide some indicative dollar values to the savings achieved by using recycled materials (including HDPE) but these are restricted to energy and Co2. Full life cycle savings, such as landfill costs avoided are not considered. Importantly, the procurement guide includes a statement reminding purchasing officers that price is not the sole factor when assessing value for money and encouraging consideration of the relevant financial and non-financial costs and benefits, 'including sustainability and whole-of-life costs.' However, little guidance is provided on what is an acceptable premium to pay for more sustainable products

sustainable procurement becomes commonplace in more jurisdictions around the world (and guidelines advance to regulations) governments have the potential to generate significant demand, creating opportunities for designers and manufacturers engaged with developing more sustainable solutions.

Most of the designs that I have analysed were created without reference to a specific target market. I found that designs are more likely to be promoted for their versatility—suitable for both indoor and outdoor use, for example. Seven of the chairs I analysed were designed to allow prospective purchasers to select from a range of bases and shells to tailor the chair for their specific needs. Oki Sato adopted that approach for his *NO2 Recycled* design for Fritz Hansen (fig. 8.20); also offering upholstered or upholstered options in efforts to appeal to niche markets within both the commercial and residential sectors. Offering a wide range of configurations theoretically improves the appeal of the chair (and contributed to Sato's design achieving a high score in my ERPR analysis). However, that approach is also subject to the risk inherent in any compromise—failure to fully satisfy the needs of some, or even all, potential purchasers. While acknowledging these risks it is assumed they are outweighed by the benefits of offering greater variety when scoring these designs in the ERPR tool.

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and services, leaving public servants exposed to justify their decision. Department of Agriculture, Water and the Environment, 38.

The N02 Recycled in a range of configurations

Fig. 8.20. N02 Recycled is available in a range of configurations from Fritz Hansen in an effort to meet the diverse needs of numerous niche markets across both the corporate and residential markets. Source: Fritz Hansen

Surprisingly, only two of the designs included in my analysis appear to have been developed with a particular target audience in mind. *ChairCharlie* was designed as a chair for children, while the *Bell Chair* is specifically aimed at a younger, design conscious audience (20–35-year-olds). Both Grcic and Magis told me that need for the *Bell Chair* needed to be stylish and inexpensive to appeal to that market was explicitly stated in the brief. The articulation of a target market, together with the specification of a target price point, provided a clear direction for the design solution. Backcasting from the retail price determined the allowable production time and the amount of material that could be used. Matching the design to the needs of a specific market is a proven strategy for commercial success. Although launched halfway through the year, Hutschemaekers claimed the *Bell Chair* to be among the top three best-selling designs for Magis in 2020.[981]

The overwhelming majority of designs I have studied (25 out of 32) are only available in a single configuration. Except for *ChairCharlie* and the *Bell Chair*, most designs appear to have been developed for general use rather than tailored to the needs of a particular market niche. Adopting a more targeted approach and meeting the precise needs of a specific group of consumers, embracing consumption within the domain of design, could offer the opportunity to drive the take up of renewable carbon-based chairs. The client is responsible for specifying the target market for their product, but it is in the best interest of the designer to ensure the brief clearly articulates the needs of a promising niche. While the commercial success of any design will be ultimately determined by the market, tailoring designs to satisfy the needs of a specific niche market follows a marketing strategy proven to deliver more predictable results that will accelerate transitions.

While determining a product price is beyond the remit of most designers, their decisions affect costs, which are reflected in retail prices. Renewable plastics (and bioplastics in particular) often cost more than traditional plastics and are likely to for the foreseeable future. Higher retail prices can be expected to stem demand.[982] However, high prices do not necessarily have a negative impact on the uptake of new technology. Higher retail prices imply higher margins for retailers and distributors, incentivising them to carry and promote

[981] Isaac, Interview with Ruben Hutschemaekers, Magis.
[982] See for example: Joshi and Rahman, “Factors Affecting Green Purchase Behaviour and Future Research Directions,” 129 Having reviewed 53 relevant papers the authors found, “It is thus clear that high price negatively influences green purchase intention and behaviour.”

stock. Successful niche experiments will attract interest from competitors in search of higher profits.

Quitllet outlined the issues driving costs, resulting in increased prices for his designs featuring recycled plastics:

> [Working] with a recycled material is a most difficult process. There is much more time to do it and to have it right because there is more mistake pieces that you need to recycle again. And with a higher price and with a less beautiful finish because it's not completely regular, it's nice because I like to know there's this story inside that chair. Every chair is different, because there's a different part of the story inside. Not like the others, which are all the same but you need to put this point of view and say okay, if I want this beautiful chair you have to pay.[983]

In this statement Quitllet acknowledged the role that the aesthetic appeal of the recyclates together with the provenance of the material can play in justifying the price premium to end-users.

For those high-priced products to sell, their environmental credentials must be accepted, valued, preferred even, by consumers. But are buyers prepared to pay more for sustainable designs? Several studies across different jurisdictions consistently identify a sizeable segment of the market prepared to pay more for sustainable designs.[984] Encouragingly, a study undertaken in the Netherlands found consumers particularly willing price premium for products containing recycled ocean plastics.[985] Although the results from these studies are encouraging, they should be treated with caution. Any survey of consumer attitudes only reflects the opinions of participants drawn from a (usually limited) specific geographic location at a particular time and place. Results from a 2019 survey of Dutch

[983] Isaac, Interview with Eugeni Quitllet.
[984] White, Hardisty, and Habib, "The Elusive Green Consumer"; Nova Institute, "Bio-Based Products: Green Premium Prices and Consumer Perception of Different Biomass Feedstocks."
[985] Lise Magnier, Ruth Mugge, and Jan Schoormans, "Turning Ocean Garbage into Products – Consumers' Evaluations of Products Made of Recycled Ocean Plastic," *Journal of Cleaner Production* 215 (April 1, 2019): 84–98, https://doi.org/10.1016/j.jclepro.2018.12.246.

consumers cannot be extrapolated to other markets or other time frames. Low-income markets are unlikely to pay a premium.

The designers who spoke with me held a range of opinions when asked for their view on their ability to charge a premium for sustainable products. Some, including Chiave, found consumers 'willing to spend a bit more for something less disposable, more sustainable.' He then emphasised the need to provide provenance around the material to justify the additional cost.[986] Macadar agreed, saying his customers valued the biodegradability offered by his products and are prepared to pay a premium.[987] Gibson reported a different experience reporting that their customers are not prepared to pay more for sustainability, offering a specific example:

> I'm thinking about the *Ribs Bench*, which was designed by Stefan Lie. When we took it on-board it used to be made out of MDF strips, laminated together. We worked to find a solution without laminates and resin and I don't think anyone cares about them. We like it and I don't think we [would] want to sell it if it wasn't made like that but I don't think that's why people pay premium – they pay for the design and shape and all that.[988]

Grcic reported that attitudes to sustainability had shifted in recent years and is now considered as contributing to the quality of a product and that 'people are very happy to pay a premium.'[989]

Pedersen differentiated between the residential and corporate markets reporting that he found companies are prepared to pay more for recycled materials, but the mass residential market is not.[990] During a site inspection of an IKEA store, Kate Ringvall, the Sustainability Business Partner, expressed her frustration at the reluctance of the display team to use point-of-sale material emphasising the sustainability claims of some products.

[986] Isaac, Interview with Gabriel Chiave.
[987] Isaac, Interview with Victor Macadar.
[988] Isaac, Interview with Sarah Gibson.
[989] Isaac, Interview with Konstantin Grcic.
[990] Isaac, Interview with Thomas Pedersen.

The display team, she said, believe there to be little consumer interest in such messaging and therefore focus their attention elsewhere.[991] Similarly, information about the sustainability credentials of the material used to create the *Odger* is not available on the company's website.[992] This absence is particularly disappointing given IKEA's very public focus on 'sourcing and producing renewable and recycled materials with a positive environmental impact.'[993]

While prices can be compared in absolute terms, the real competitiveness of any product can only be evaluated within the context of its specific market conditions. For example, the *Odger* is available for $99 at IKEA in Australia. While this price is competitive when compared with the other chairs I have analysed, the *Odger* is expensive when compared with other similar chair available from IKEA (with prices starting at around $39 and a wide variety of models available at prices up to $75). If seeking to purchase 6 or 8 dining chairs, the *Odger* effectively commands a significant premium for its sustainable credentials. While the environmental benefits of the design remain unreported, prospective purchasers will remain unaware of the reasons for this price difference and be left without a justification to pay the premium.

Given the complexities around pricing and a lack of data on sales volumes it is difficult to produce quantifiable evidence to evaluate the premium purchasers are prepared to pay for any sustainable product. What is clear is that for renewable carbon products to gain significant market share in any product category end-users must be encouraged to value and be prepared to pay for renewable plastics. The true cost of defuturing, implicit in

[991] Isaac, Interview with Kate Ringvall.
[992] IKEA Australia, "*Odger* Chair," IKEA, accessed February 3, 2022, https://www.ikea.com/au/en/p/odger-chair-anthracite-30457314/.
[993] IKEA, "IKEA People & Planet Positive - Sustainability Strategy," 15.

products made from virgin fossil plastics must be made explicit. In a press interview industrial designer, Stefan Diez claimed that it is the responsible consumer who will finance the development of more environmentally friendly designs that will benefit everyone in the long run.[994] Penna and Geels agree, claiming that mass consumer views on appropriate behaviour change over time add to demand for radically new technologies as their benefits become more widely understood.[995] This emphasises the responsibility of all those involved with the development of chairs, from design to distribution, to encourage prospective purchasers to appreciate the true costs of fossil plastics to both the planet and its people.

The development of marketing messaging is most likely beyond the direct influence of most designers, but detailed information on materials and their environmental benefits needs to be highlighted to those developing the sales narrative. Designers can take the lead and inspire those involved with the promotion of products. In my interview with Grcic, he explained how he worked closely with Magis to develop a separate micro-website specifically to explain the story of the *Bell Chair* (fig. 8.21). Based on examples from the food and fashion industries, Grcic told me that the aim was to fully explain the source of material and the efforts made to optimise production with the aim of improving the environmental credentials of the chair. Grcic worked closely with the marketing team at Magis to finesse both the content and tone of messaging and to ensure copy did not include exaggerated claims. Opportunities for freelance designers to become this deeply involved with marketing are rare, as projects usually end when designs enter production and economic necessity demands the designer moves on to the next project. However, among the chairs included in

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994 See: https://www.stylepark.com/en/news/stefan-diez-circular-design-guidelines-sustainability, accessed February 3, 2022.

995 Caetano C. R. Penna and Frank W. Geels, “Climate Change and the Slow Reorientation of the American Car Industry (1979–2012): An Application and Extension of the Dialectic Issue LifeCycle (DILC) Model,” *Research Policy* 44, no. 5 (June 1, 2015): 1031, https://doi.org/10.1016/j.respol.2014.11.010.

my study Grcic and Magis set the standard for what can be achieved by collaboration between the designer and the manufacturer.

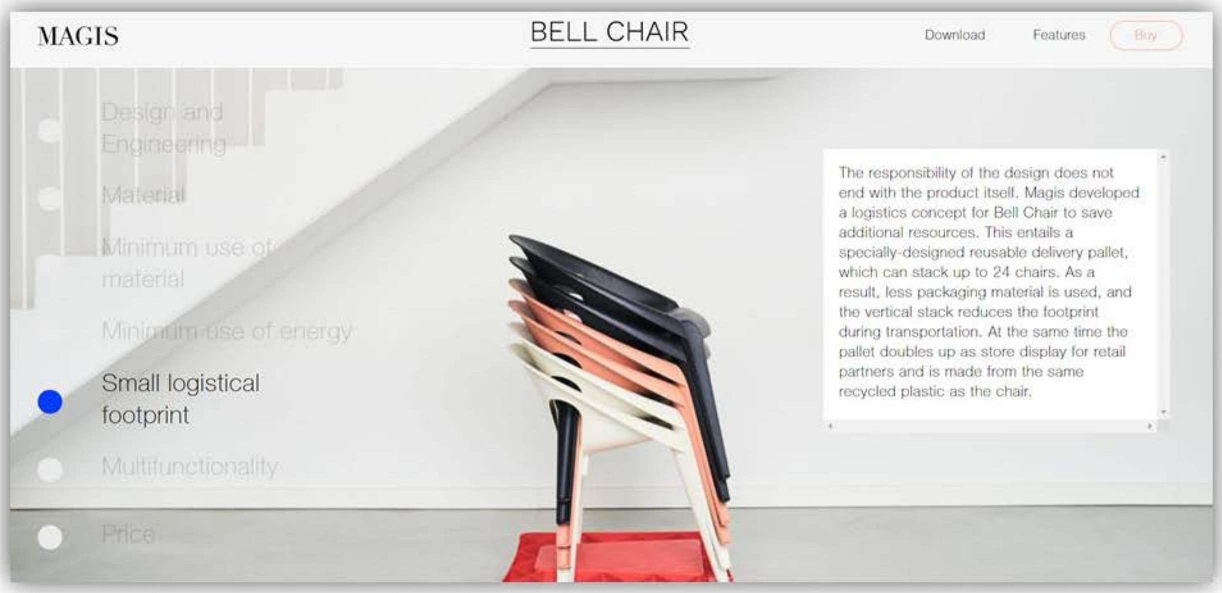

Fig. 8.21. The *Bell Chair* micro-site by Magis. Source: bell-chair.com[996]

In efforts to imbue a product with personality to encourage an emotional connection with end-users, marketing and advertising teams can attempt to instil a sense of history or design heritage. Story telling around provenance is a strategy often featured in the sales narrative for products made from traditional materials. For example, 'handmade from sustainably sourced oak from the USA.' Alternatively, the craft skills used during construction might be emphasised: 'handcrafted using sheep wool and traditional techniques.'[997]

[996] Magis, "Bell Chair," accessed February 3, 2022, https://bell-chair.com/.
[997] 'Think of wood. It is a natural material with a grain that has a surface texture, pattern, color, and feel that other materials do not have. It is tactile –it is perceived as warmer than many other materials, and seemingly softer. It is associated with characteristic sounds and smells. It has a tradition; it carries associations of craftsmanship. And it ages well, acquiring additional character with time; objects made of wood are valued more highly when they are old than when they are new.' Ashby and Johnson, "The Art of Materials Selection," 31.

During our interview Australian designer, Trent Jansen, explained the commercial pressures that he has experienced to provide detailed information about the materials he uses:

> My gallerist constantly asks me about the provenance of the materials that I'm working with. "Where's this from? Who made it?" She wants selling points... That's something that sort of adds to her narrative and something that her audiences are interested in. I don't think unless the project was about innovation in plastic or using plastic in a in some kind of really interesting [she would be interested]. She never asked me, "Where did the plastic feet come from? What's the provenance of plastic?"[998]

Jansen's comments highlight the important role for designers in highlighting the provenance of material to other actors involved with a project. Where fossil plastics are used as the primary material, those considerations are usually irrelevant. Although Jansen does not work with plastics as a primary material, he recognised the potential for provenance to be relevant for those designers working with these materials. Renewable plastics can differentiate themselves from fossil plastics by celebrating the ingredients they are made from.

When we encounter antiques, they contain the essence of their former lives and experiences and, designer and academic Nick Grant, argues that recycled materials also develop and gather importance through their extended lives.[999] He goes on to suggest that the recycling process can form part 'of the articulated language and sophisticated narration that becomes embodied in the final object.'[1000] He argues that materials themselves have agency and offer the ability to mediate the message of a more sustainable society.[1001] Use of recycled material can act as a reminder of the collective value and responsibility implicit in managing our materials.[1002] Magis attempt to leverage those associations by promoting the

[998] Isaac, Interview with Trent Jansen.
[999] Nick Grant, "Mediating Matters," in *Routledge Handbook of Sustainable Product Design* (Abingdon, Oxon; New York, NY: Routledge, Taylor & Francis Group, 2017), 225.
[1000] Grant, 227.
[1001] Grant, 234.
[1002] Grant, 233.

fact that the material for the *Bell Chair* comes from waste generated by their own furniture production and from the local car industry as part of a detailed narrative around the sustainable properties of their design.[1003]

Fig. 8.22. Provenance of material used for his *Coastal Furniture* as explained by the designer. 'The seaweed roofs on the island Læsø (Denmark) has been the key inspiration source. The shell for the lounge chair is made of 100% biodegradable seaweed composite... The material consists of eelgrass and carrageenan. Eelgrass grows naturally near the coastline only to be collected when washed ashore. Carrageenan is extracted from certain red algae.' Source: Nikolaj Thrane Carlsen

Designer Nikolaj Carlsen offers extensive information on the historical use of the seaweed composite used for his *Coastal Furniture* chair, to emphasise its proven durability. In the process Carlsen creates a story focusing the potential purchaser on the environmental benefit of the product and instilling an emotional connection with the chair (fig. 8.22).[1004]

[1003] See: https://bell-chair.com
[1004] See: http://tangform.com

Fig. 8.23. Vondom promote their *Coastal Furniture* series highlighting the link between plastic retrieved from the Mediterranean Sea. Source: Vondom

The emotional response to the ocean plastic crisis is being used to construct powerful marketing narratives in deliberate attempts to position products as a solution for the ocean plastics crisis. For example, the Vondom website (fig. 8.23) promotes the *Coastal Furniture* series of designs claiming:

> The soft white tone is the result of our work closely with companies specialised in the collection and recovery of plastics from the Baleraric Islands and Ibiza. Subsequently and

> together with transforming companies, we managed to convert these resources into quality new material, recycled plastic with a natural tone.[1005]

The accuracy of any story told around provenance depends on who wrote it and how thoroughly any third-party claims have been investigated. Examples where chairs are marketed as being made from 'ocean plastics' provide illustrations of many dubious claims being made by some manufacturers (unlike Vondom). Unsubstantiated or misleading claims can destroy trust when they are discovered, negatively affecting attitudes to sustainable eco-design more generally. Indeed, several studies conclude that the use of eco-labels is already of limited value as trust has been destroyed following the introduction of a plethora of systems designed to indicate the environmental profile of products.[1006] While many of these schemes were developed by organisations with a bona fide interest in promoting sustainable purchasing, others merely represent greenwashing attempts by manufacturers. The quantity and complexity of these systems (and the dubious claims made by some users) has left consumers confused and sceptical.

More generally, provenance narratives can help to create a bond between the user and the product. With storytelling designed to evoke the ghost of the material's previous life, purchasers are encouraged to take pride in their environmental credentials earned by acquiring the products. The history of the material has added meaning to the product. A 'circle of virtue' can be enhanced when a consumer can configure a sense of the material

[1005] Vondom website, accessed February 3, 2022, https://www.vondom.com/vondom-revolution/

[1006] For a review of the eight voluntary eco-labelling schemes in use by the furniture industry in the EU plus six more from surrounding countries see: Els Van Den Broeck, "The EU Furniture Market Situation and a Possible Furniture Products Initiative," *CEPS* (blog), April 14, 2015, https://www.ceps.eu/ceps-publications/eu-furniture-market-situation-and-possible-furniture-products-initiative/. For a more focused discussion of the confusion this causes see Donatello et al., "Are the Existing EU Ecolabel Criteria for Furniture Products Too Complex?"

being returned to them.[1007] Designers can author authenticity by physically embodying recycling activities in products, creating a more ethical interpretation of the material being used.[1008] Dutch designer Dirk Vander Kooij, who recycles the insides of refrigerators to make his *Chubby Chair*, agreed with this, claiming not be primarily motivated by sustainability concerns he chooses to use this material as 'the best thing about recycled plastic is it has history.'[1009]

Working with recycled plastics creates the opportunity to focus attention on the downstream impacts of the material and promote the circular economy. On the other hand, bioplastics offer the potential to highlight the upstream impacts of fossil-plastic production. Design academic Ann Thorpe observes that few eco-design approaches get the opportunity to link consumers to the upstream social and environmental consequences of making products, suggesting that: 'many designers are as distant as consumers from these upstream effects.'[1010] Focusing on upstream impacts offers designers and marketers the opportunity to differentiate bioplastic products from both virgin and recycled plastics.

The bioplastic properties of the chairs I have studied tend to be promoted using basic facts. For instance, Braskem highlight that the bioplastic they supplied to Tramontina for use in the *Jet* series of chairs result in the capture of 3 tonnes of Co2 per metric ton produced.[1011] A Lot of Brasil emphasise the regenerative properties of the trees used to make Rashid's *Siamese Chair*.[1012] There is potential for designers and manufacturers to develop stories to

[1007] Grant, "Mediating Matters," 226.
[1008] Grant, 225.
[1009] Karen Day, "An Interview with Dirk Vander Kooij," COOL HUNTING®, March 28, 2011, https://coolhunting.com/design/dirk/.
[1010] Thorpe, "Design's Role in Sustainable Consumption," 7.
[1011] See: https://www.braskem.com.br/braskem-news-detail/braskems-green-plastic-now-in-chairs-released-by-tramontina, accessed February 3, 2022.
[1012] See: http://media.designerpages.com/2016/10/siamese-chair-by-karim-rashid-for-a-lot-of-brasil/, accessed February 3, 2022.

explain the provenance of the bioplastics they are working with. Emotionally-engaging narratives can be constructed to highlight supply chain differences and the cascading environmental benefits of purchasing products made from these materials. Bioplastics developed from second generation (or above) sources and processed using sustainable energy have far superior environmental impacts when compared with fossil plastics.

Investigations of the provenance of fossil plastics can also be used to reinforce the selection of renewable plastics by emphasising the omnipresent unmaking concealed within fossil plastics. James Marriott and Mika Minio-Paluello used a performative strategy to illustrate the environmental impact of everyday materials during a conference paper where they offered attendees a carton of ice-cream on arrival.[1013] After the ice-cream had been consumed, the authors began to explain the destructive 'pre-life' of the plastic used to make the container, tracing:

> The passage of that material from oil-bearing rocks, through drilling rigs, pipelines, terminals, depots, refineries, factories, distribution centres and shops, to homes…Examin[ing] the impacts – both ecological and social – of that passage.'[1014]

While acknowledging that it is impossible to know the precise source of the materials used to make the carton that Mario and Minio-Paluello describe as the most likely scenario. Oil extracted in Azerbaijan is transported by pipeline and sea to a processing plant in Germany and to the ice-cream factory in the UK. In detailing the journey, we are confronted with some alarming details about the activities and employment practices of those involved with the industry. The authors conclude by highlighting that the true costs of disruption and violence caused by the extraction of fossil fuels remains largely invisible to the end user.

[1013] James Marriott and Mika Minio-Paluello, "Where Does This Stuff Come from? Oil, Plastic and the Distribution of Violence," in *Accumulation: The Material Politics of Plastic* (London: New York: Routledge, Taylor & Francis Group, 2013), 171–83.

[1014] Marriott and Minio-Paluello, 172.

With gas from shale activities in the USA becoming an ever-greater source for plastics (even for Europe) it is incumbent on those using these materials (and products subsequently made from those materials) to familiarise themselves with their 'brutish origins' and the consequences of the environmental racism caused by their creation.[1015] However, the different feedstocks used to create fossil-based plastics are often ignored by those promoting plastic products. The chemical composition of polypropylene (or any specific plastic for that matter) remains unchanged and is usually treated as homogeneous regardless of the feedstock source. The environmental impacts of their creation vary depending on the source of the feedstock. Investigation of the provenance of fossil plastics remains a rich and unexplored territory to discourage the use of the material. For instance, China still relies primarily on coal to produce plastic. When used as a feedstock for plastic or to generate the energy required to process it, coal creates the largest Co2 emissions compared to the alternative fossil feedstocks.[1016] This environmental impact remains a hidden cost of often the lowest-priced plastics, and deserves consideration by designers, manufacturers, and consumers alike.

Publicising the negative upstream impacts of fossil plastics can highlight the conceptually and geographically distant costs of irresponsible consumption and undermine the incumbent regime. By revealing the source of materials they work with, and telling the story of their creation, designers and manufacturers are uniquely placed to promote the adoption of renewable plastics. The main challenge here is to communicate this information in a simple, trustworthy, and effective format.[1017] Successfully communicating direct

[1015] Fisher refers to the brutish origin of plastics in: Fisher, "Fashioning Plastics," 126.
[1016] Bennett, "Implications of Climate Change for the Petrochemical Industry," 331.
[1017] Caution should be used here as studies have shown consumers are confused by and lack trust in eco-labels Joshi and Rahman, "Factors Affecting Green Purchase Behaviour and Future Research Directions," 138.

consumer effectiveness has been demonstrated to positively correlate with green purchase intentions.[1018]

Fig. 8.24. Forest Management Certification (left) indicates timber used in a product has been sustainably sourced. Renewable carbon logo developed by the Nova Institute has potential to be used by the furniture industry to signal the use of plastics that meet sustainable criteria. Source: FSC and Nova Institute

Individual designers or manufacturers might consider the role of educating consumers about the upstream impacts caused by the creation of fossil plastics as beyond their remit. However, many manufacturers already use Forest Management Certification to reassure consumer of the origins of their timbers. A similar opportunity exists when renewable plastics are used with the Nova Institute making one suggestion for an equivalent symbol of endorsement (fig. 8.24).

d. Timing

The speed with which the transition to renewable plastics occurs within the furniture industry depends on the actions of large-scale furniture manufacturers. Timing is everything for the major manufacturers: If they wait too long, they risk losing market share; if they go too soon, the risks are equally high. Kartell has already paid a heavy price for attempting to gain a first

[1018] Joshi and Rahman, 137.

mover advantage with second generation bioplastics. Philippe Starck told to me that he is working with Kartell to transform the company from its dependence on fossil plastics to a 'smart materials company.'[1019] He went on to explain that Kartell will work with bioplastics, plywood, and other materials made with 'human intelligence' in efforts to develop more sustainable products. Those statements represent a demonstration of the potential powerful agency held by organisations in guiding sustainable transitions when setting strategy. While designers are unlikely to hold much influence over the strategic policy settings of a furniture manufacturer, Starck's comments illustrate the important role that designers can played in both guiding and delivering sustainability commitments.

Starck's *AI Chair* (2019) was Kartell*'s* first attempt at incorporating recycled plastic into its repertoire, but the company has yet to include a bioplastic chair in its catalogue. Kartell did develop a prototype for a bioplastic chair in 2018 (*Bio Chair* by Antonio Citterio, see fig. 8.25) using a polyhydroxyalkanoate (PHA), but this version of the design failed to make it into production.[1020] The following year, a bioplastic version of its *Componibili* storage system was released, using the same PHA derived from 'non-GMO agricultural waste not intended for the food chain.'[1021]

[1019] Isaac, Interview with Philippe Starck.
[1020] Kartell released Citterio's design in recycled plastic in 2021.
[1021] The bio version of the *Componibili* is available from Kartell in the UK (as at December 2021), although priced at a 48% premium to the standard version. See: https://www.Kartell.com/GB/best-sellers/componibili-bio/05970?variantName=x_colorVariant&variantValue=PA, accessed February 3, 2022.

Fig. 8.25. *Bio Chair* by Antonio Citterio for Kartell (prototype only), 2018. Source: Kartell

This pivot from fossil plastics was probably motivated by falling sales rather than concern for the environment, with company revenue estimated at 83 million euros in 2019 down from a high of 107 million in 2016 (a 22% decrease).[1022] Kartell, with a product catalogue consisting almost entirely of plastic products, is probably the furniture manufacturer most exposed to changing attitudes towards plastic. As one of the designers I interviewed observed:

[1022] See: https://www.statista.com/statistics/977696/sales-value-of-furniture-company-felofin-spa/, accessed February 3, 2022.

> Now everyone has realised that bioplastics are the new way forward. If you are going to continue to produce polycarbonate [products], people aren't going to buy that in a couple of years, if not by next year. Companies like Kartell must seriously be considering their business plan by now. Most other companies probably have a more diverse base of products.[1023]

In December 2017, Kartell (through its parent company *Felofin*) backed its strategy to embrace renewable plastics with a ten million euro investment to acquire 2% of an Italian manufacturer, Bio-on, who claimed to be the first industrial-scale producer of PHAs.[1024] Bio-on became the original supplier of PHAs to Kartell (and Unilever) and went on to be named the best bioplastic company of the year by a leading industry trade magazine in 2019.[1025] The announcement of the deal signalled a potentially productive alliance between an incumbent in the furniture industry and a new entrant to bioplastics, which could accelerate Kartell*'s* transition plans. At the end of that same year, Bio-on became involved in a financial scandal, following the publication of an unfavourable report from a financial analyst in Israel (who is accused of shorting the stock).[1026] The chairman and CEO of Bio-on was briefly arrested, with the company declared bankrupt at the end of 2019.[1027] While the company has been repeatedly (and so far, unsuccessfully) offered for sale it appears unlikely that Kartell will recover any of its investment.[1028]

Kartell*'s* experience to date illustrates the risks associated with experimenting with embryonic technologies. No guarantees can be given that such ambitious technical reorientations will succeed. Or, as Peen and Geels put it, 'the possibility of 'betting on the

[1023] Designer interviewed for this study – identity available on request.
[1024] See: https://www.globenewswire.com/news-release/2017/12/20/1266757/0/en/Kartell-enters-Bio-on-to-help-develop-new-technologies.html, accessed February 3, 2022.
[1025] See: https://bioplasticsnews.com/2019/09/03/best-bioplastic-company-2019-award/, accessed February 3, 2022.
[1026] "Italy's Bio-on Shares Hit Hard on Allegations of Accounting Flaws," *Reuters*, July 25, 2019, https://www.reuters.com/article/us-italy-bioon-idUSKCN1UK1M9.
[1027] See: https://www.bioplasticsmagazine.com/en/news/meldungen/20200101Bio-on-officially-declared-bankrupt.php, accessed February 3, 2022.
[1028] Having been twice offered for auction with a starting price of 100 million euros the auction was relaunched with a starting price of 50 million euros in September 2021, just 10% of the value implied by the Kartell purchase.

wrong horse' makes green reorientation a risky process with long-term strategic ramifications.'[1029] Kartell*'s* experience also illustrates that investing resources in technologies undermining powerful regimes can be risky.

While Kartell*'s* attempt to reposition is commendable they face another challenge. Since opening for business in 1949, the Kartell brand is synonymous with fossil plastics. For the company to successfully reposition itself as a 'smart materials company' it must succeed in convincing the market that the new brand image is genuine. Few studies on the impact of brand image on consumers' green purchase behaviour have been undertaken.[1030] However, aligning the Kartell brand with sustainability is likely to be challenging.

Given the investment of time and capital required to adapt, it is more logical for large furniture manufacturers to adopt a reconfiguration strategy.[1031] This includes selecting and adopting symbiotic components from new technologies and making minor adjustments to established business practices to accommodate them.[1032] That approach maximises the potential to defend market share, while minimising the risks from working with relatively untested technologies.[1033] Kartell*'s* recent experiment with recycled plastics (the *AI Chair*) is more aligned to this shadow-track strategy.[1034] Both Vitra and IKEA have also introduced chairs made from recycled plastic, but neither has yet produced a bioplastic design. Whether

[1029] Penna and Geels, "Climate Change and the Slow Reorientation of the American Car Industry (1979–2012)," 1029.
[1030] Joshi and Rahman, "Factors Affecting Green Purchase Behaviour and Future Research Directions," 134.
[1031] Geels and Schot, "Typology of Sociotechnical Transition Pathways."
[1032] Geels and Schot.
[1033] Geels and Schot, 410; Allard van Mossel, Frank J. van Rijnsoever, and Marko P. Hekkert, "Navigators through the Storm: A Review of Organization Theories and the Behavior of Incumbent Firms during Transitions," *Environmental Innovation and Societal Transitions* 26 (March 1, 2018): 57, https://doi.org/10.1016/j.eist.2017.07.001; Smink, Hekkert, and Negro, "Keeping Sustainable Innovation on a Leash?," 88.
[1034] "Shadow-track strategy" is defined as, "developing new technologies in line with sustainability requirements while continuing their regular business practices." Gaziulusoy, "System Innovation for Sustainability," 3.

these innovations represent the beginnings of the transition to renewable carbon materials by these major manufacturers or are merely designed to reduce tension among critics or avoid the imposition of further environmental regulations remains to be seen.[1035] Regardless, other large manufacturers are more likely to similarly explore less expensive and less risky opportunities that are compatible with existing investments when diversifying into a new niche. Adaptive diversification, a less disruptive hedging strategy, allows current business activities to continue as usual while experimenting with promising innovations.[1036]

Apart from Kartell, only one other furniture manufacturer included in my study has made a stated commitment to transition away from fossil plastic. IKEA aim to 'begin to phase out virgin fossil plastic from the IKEA product range, a focus that will continue towards 2030.'[1037] Although commendable, it should be noted that this statement makes no firm commitment to reducing the use of virgin polymers. It is a disappointing departure from IKEA's 2020 sustainability goals (2012, revised 2014) that committed to 'all plastic material used in our home furnishing products will be 100% renewable and/or recycled' by August 2020.[1038] At the time of submitting this dissertation (February 2022) the IKEA catalogue featured only one chair made from renewable plastics. IKEA, together with all the major established manufacturers, risk losing market share if consumer sentiment in favour of renewable plastics accelerates faster than their transition plans.

[1035] Diaz et al., "Green Tides in Brittany," 67.
[1036] van Mossel, van Rijnsoever, and Hekkert, "Navigators through the Storm," 57.
[1037] IKEA, "IKEA People & Planet Positive - Sustainability Strategy," 15.
[1038] IKEA, "People & Planet Positive IKEA Group Sustainability Strategy for 2020," August 2020, 14.

3. Conclusion

Tony Fry argues that driven by a deterministic economic imperative, design serves an instrumental mode of making that brings things into being without knowing what the consequences will be.[1039] As the environmental emergency accelerates, failing to consider the consequences of design is becoming increasingly unacceptable— and particularly so for designers and manufacturers working with fossil plastics. Environmental pressures are likely to focus on the petrochemical industry as climate impact from the energy and transport regimes are lessened, thanks to increased use of renewables and electrification. Renewable plastics are an essential element of the solution to the climate emergency threatening the planet.

This chapter examined the strategies available to designers to accelerate the transition to renewable plastics in the furniture industry, through an analysis of tactics adopted by successful innovators. Designers make or contribute toward decisions that directly impact our environment every day. While the ultimate decision on the type of material to be used will be beyond their remit for many projects, designers can reduce environmental impacts by minimising the quantity of material needed for their design. Designers can influence the final form of a design together with many of the attributes that contribute to the aesthetic appeal of their creations. Many renewable plastics have different characteristics when compared with virgin fossil plastics: They often look and feel different and process unique mechanical properties. In many cases, working with these relatively new materials opens new horizons for designers prepared to experiment with novel forms, colours, and textures made possible by renewable carbon. Even more possibilities become

[1039] Fry, *Design Futuring*, 26.

available when designers are prepared to move away from injection moulding and experiment with new digital manufacturing technologies or with more established manufacturing technologies borrowed from other industries. Combining multi-technological solutions is a proven strategy to accelerate transitions generally and the success of pioneering designers discussed in this chapter demonstrate that this approach can succeeded in accelerating the uptake of renewable plastics.

Hybridisation offers a proven pathway for designers and manufacturers to minimise the costs of transition, as established manufacturing processes can remain unchanged. While purists may question hybridisation as an acceptable solution from an environmental perspective, the reality is that most recycled plastics available are already hybridised. Virgin fossil plastics are commonly combined with recycled plastics to help maintain structural integrity. However, the petrochemical regime's reliance on the mass-balance approach to recycling (where minimal amounts of recyclates are included in materials certified as being recycled) will undoubtedly become a focus of ongoing debate. Hybridisation is also a popular strategy to imbue bioplastics with the strength often needed for consumer goods. While hybridisation affects the end-of-life prospects for a product, including any biomass in the material reduces the amount of fossil fuel needed for its creation, the environmental priority for products designed for long term use.

When investigating renewable carbon materials designers can familiarise themselves with the story of their creation. Recycled plastics carry the history of their previous lives, while bioplastics are derived from an increasing variety of feedstocks, each with their own story, allowing engaging marketing narratives to be constructed. Those factors differentiate renewable plastics from fossil plastics that can only be created through extractivism and exploitation. By educating marketing teams on the provenance of materials, designers can introduce a unique differentiator for renewable plastics in sales and marketing collateral.

Designers can play an important role in tailoring their products for the specific needs of market segments most likely to be willing to pay a premium for more sustainable chairs. While the complexities of identifying and targeting environmentally conscious consumers as a discreet market are acknowledged, strategies to target potentially lucrative niche markets such as hotels, restaurants, and conference centres are already being explored. Designers who succeed in getting their chairs into these public spaces also benefited from exposure to (and trial by) high numbers of visitors. Targeting niche markets with potential for significant growth is a proven strategy to accelerate transitions. In coming years, governments (at all levels) can be expected to update and revise purchasing guidelines, with increasing emphasis given to the importance of sustainability considerations, particularly encouraging the use of recycled materials. When such changes occur, renewable carbon-based products, including chairs, will benefit from significantly increased demand, rewarding innovative manufacturers.

While the focus of this chapter is the role of the designer, an examination of their agency in the network of actors involved with all aspects of production is required to understand how regime change can occur. Establishing networks of like-minded actors, exploring and sharing experiences from individual niche experiments are essential. However, even the development of a single design involves many actors. A number of the successful designs included in my study were created by designers with links to manufacturers secured through the development of personal relations with senior level personnel within those organisations. Actors are likely to find it challenging to secure support from material manufacturers, particularly when those suppliers have vested interests in fossil fuel extractivist activities. Those large incumbents usually own their own feedstocks—switching to raw materials supplied by third parties risks diminishing their control of supply chains.[1040] Despite those barriers there are exceptions to be found, with some material manufacturers embracing (or at least experimenting) with transitional technologies (for example, Braskem) and these are joined by large petrochemical organisations which are not directly owned by those involved with the extraction of fossil fuels (for example, BASF which has also pursued a dualistic approach). Developing relationships with key suppliers such as these, who are prepared to reconfigure their business to adapt to the new feedstocks, will provide access to expertise developed from the real-life experiences of other pioneering clients. Indeed, fostering close relationships between entities operating on all three levels of the MLP model is the most productive way to accelerate change, as a process of co-evolution and mutual adaptation is enabled.[1041]

Finally, the recent experience of Kartell*'s* failed investment in a bioplastic manufacturer illustrates the financial risks in backing new, commercially unproven technologies. Competing large-scale manufacturers have been more cautious in their approach, launching limited designs made using recycled plastics and relying on a wait and see approach, particularly with bioplastics. Many smaller manufacturers are introducing new designs featuring either recycled plastics or bioplastics and this trend is expected to continue for the foreseeable future. With major manufacturers unlikely to surrender market share, their transition into renewable plastics can be expected to accelerate in the coming years. However, the transition is not guaranteed, as it depends on multiple factors including

[1040] Bennett, "Using Past Transitions to Inform Scenarios for the Future of Renewable Raw Materials in the UK," 106.
[1041] Schot and Geels, "Strategic Niche Management and Sustainable Innovation Journeys," 547.

mainstream consumer acceptance of renewable plastics and the co-evolution of the petrochemical regime to accommodate renewable feedstocks. Both designers and manufacturers have the agency to influence this outcome by promoting the update of renewable plastics.

Conclusion

Are you really sure that this world needs another plastic chair?[1042]

During an interview with BASF's Andreas Maegerlein, I was surprised to hear him suggest that this question should be asked of every designer proposing another plastic chair. He went on to admit his company is coming under increasing pressure from clients and governments alike to provide solutions to the plastics issue, predicting:

> There is a big change coming because, people will not accept the materials [plastics] as they were anymore… companies are now seeing that they have to act before their products will be… taken from the market due to restrictions coming from politics. They have to find solutions… It's a stupid idea to tell people to use less of our products but actually, that is the way you need to think.[1043]

While I found Maegerlein's comments surprising, they are also encouraging, with a representative from a prominent member of the entrenched petrochemical regime admitting that their industry is being affected by disruptions in their operating environment and that they are actively seeking to adapt their business in response. Maegerlein's comments are particularly welcome as I have found a general lack of commitment to sustainability among furniture manufacturers.

The operating environment for both the petrochemical and fossil fuel regimes continue to be affected by disruptions like the impact of the China Sword policy, banning the import of mixed plastic waste. The issue of ocean plastics has remained in the public discourse, heightened by the realisation that an estimated 6 billion face masks are being dumped in our oceans every month because of our response to COVID-19.[1044] The landscape for the entire fossil fuels regime is also facing disruption. As at the end of June 2021, nearly 2,000 jurisdictions across 34 countries—representing over 1 billion citizens—had declared a

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[1042] Isaac, Interview with Andreas Maegerlein, Group Leader Creation Center, BASF.
[1043] Isaac.
[1044] Based on the average 4% of annual plastic production that ends up in our oceans and the estimated 129 billion facemasks being disposed of every month. Xu and Ren, "Preventing Masks from Becoming the next Plastic Problem."

climate emergency.[1045] As more people accept the science of climate change it is inevitable that all extractivist activities will be held increasingly accountable for the damage they are inflicting on our environment. Pressure for change aimed at both the petrochemical and fossil-fuel regimes will intensify. Multi-level perspective (MLP) theory predicts that significant disruptions such as these can create an opportunity for new technologies to challenge the entrenched regime.[1046]

Despite those favourable conditions transitions take decades.[1047] Enormous investment in mechanical, chemical/advanced recycling infrastructure is needed, together with the research and development required to produce bioplastics at industrial scale.[1048] However, supply (and the investment required) will not increase unless matched or exceeded by demand. The purpose of my study has been to identify practical actor-specific tasks that supportive designers and manufacturers can undertake to accelerate this transition.

This dissertation examined how shifting environmental concerns have affected the development of the plastic chair market. During the second half of the twentieth century, the interests of environmentally-conscious designers and industry were aligned. By focusing on reducing the amount of energy and/or materials needed to make products, including chairs,

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[1045] See: https://climateemergencydeclaration.org/climate-emergency-declarations-cover-15-million-citizens/

[1046] As I write this conclusion, in the final quarter of 2021, prices for all fossil fuels are spiralling as the northern hemisphere enters winter and the global economy attempts to recover momentum lost throughout the COVID-19 crisis. With prices for fossil plastics at near record highs, renewable plastics are a more attractive financial proposition. As the price of virgin fossil feedstocks increase the petrochemical industry is effectively incentivised to boost recovery rates by investing in pyrolysis and emerging advanced recycling technologies. Similarly, the price differential between biomass and fossil fuels is eroding, helping to stimulate investment in developing these and higher generation feedstocks (such as Co2) to create alternative plastics. Ironically, OPEC's short-sighted focus on maximising profits by restricting supply, might well hasten the demise of the entire fossil regime.

[1047] Geels, "Ontologies, Socio-Technical Transitions (to Sustainability), and the Multi-Level Perspective," 495; Markard, Raven, and Truffer, "Sustainability Transitions," 956; Elzen, Geels, and Green, *System Innovation and the Transition to Sustainability*, 108.

[1048] However, as Escobar observes, transitioning to a post extractivist framework does not, 'endorse a view of untouched nature, nor a ban on all mining or larger-scale agriculture, but rather the significant transformation of these activities so as to minimize their environmental and cultural impact.' The future for plastics is unlikely to be idealistic but consist of a patchwork of solutions, with the incumbent petrochemical regime adapting to take a significant role as pioneered by BASF and Braskem.

both the environmental impacts and the cost of production were reduced. As detailed in Chapter1, those dematerialisation efforts were initially rewarding but continued growth in demand quickly outweighed the diminishing returns achieved. In the twenty-first century, renewable plastics promise to enable us to enjoy the many benefits offered by polymers while reducing the environmental devastation caused by their creation and disposal. Plastics are often combined with other materials when manufacturing products, making it challenging to accurately calculate their environmental impacts. In response, I developed a simplified eco-audit tool (ERPR) to facilitate a comparison between designs using only the very limited data commonly available from manufacturers (Chapters 4 and 5). An online version of this tool has been developed to support actors involved with the creation of plastic chairs and guide them toward more sustainable solutions while they work. The eco-audit tool was successful in identifying interventions that could be made at the product level. However, my main interest is in examining how the knowledge gained from successful experiments with renewable plastics can be scaled-out and scaled-up to drive change at the socio-technical level.

Promoting the use of renewable plastics is important as it is the only short-term activity that can reduce the GHGs emitted during their production, as shown in Chapter 3. Consumer durables is a particularly attractive niche for material manufacturers, as potential profit margins are significantly greater from supplying the higher quality, long lasting materials demanded by this sector. A small decrease in the demand for virgin fossil plastics has the potential to cause significant disruption to the fossil regime as shown in Chapter 3.[1049] The regime's dependence on a niche market (plastics) to drive growth is also its greatest weakness. Designers and manufactures can exploit this vulnerability, reducing the

[1049] Carbon Tracker Initiative, "The Future's Not in Plastics," 6.

compound annual growth rate (CAGR) for plastic demand to 1% (from 4%) will be sufficient to cause significant disruption to business plans of the petrochemical industry market according to Carbon Tracker.[1050] The significance of a relatively small change in demand for fossil plastics highlights the importance of hybridisation as a strategy to advance the uptake of renewable plastics. While not a perfect solution, hybridisation allows current work practices to continue and results in a relative reduction in demand for fossil fuels. If a quarter of the virgin fossil plastic used to make consumer durables is replaced with renewable plastics this would be sufficient to deliver the destabilising reduction in demand identified by Carbon Tracker. My study demonstrates that designers and furniture manufacturers are in a very powerful position to effect real change and accelerate the transition away from our dependence on finite fossil resources.

One of the main innovations of my research is to include consideration of the appeal of a product while evaluating its environmental impact. A 'sustainable' product only delivers an environmental benefit if it is purchased in preference to a less sustainable alternative (discussed in Chapter 4). For a product to sell it must appeal to end-users, the role of design is key here. Tailoring products to meet the needs of a well-defined target audience is a proven strategy more likely to succeed according to marketing theory. Further, MLP posits identification of potential high-growth niche markets as a proven strategy to accelerate transitions (as shown in Chapter 8). More rigorous attention to researching and satisfying the requirements of environmentally aware niche markets could lower the financial risks of developing a new design while accelerating the transition toward renewable plastics. However, the common practice of hiring external design consultants is not conducive to

[1050] Carbon Tracker Initiative, 21.

investment in market research, as both the client and the consultant are likely to view the provision and cost of these services as the responsibility of the other party.

Renewable plastics may appear visually distinct from virgin fossil plastics and feel different to the touch. Colour choices are usually restricted and often muted and clichéd. Working within the constraints of these limitations confronts designers with both their main challenge and the best opportunity to effect change. Appealing or desirable products are more likely to sell, where this avoids the purchase of a less sustainable product a real environmental benefit has been delivered. Different strategies have already been developed by designers working with renewable plastics to overcome any perceived sensory deficiencies as discussed in Chapter 5. These pioneering designers provide a glimpse of the new horizons awaiting further investigation by those choosing to work with renewable plastics.

The responsibility of the designer to consider sustainability has received attention from many academics and practitioners since Victor Papanek proposed the profession be held accountable for its impacts. More recently, designer and academic Rachel Egenhoefer bluntly stated:

> If product design lays the basis for the formation of materials, objects, services and systems, then the product designer's influence over the sustainability of production and consumption is nothing short of pivotal.[1051]

Design academic Vicky Lofthouse is among an increasing number of voices going further:

> Designers need to take responsibility for what they agree to design and say 'no' to designing nonsensical products that society really does not need.[1052]

[1051] Rachel Beth Egenhoefer, *Routledge Handbook of Sustainable Product Design* (Abingdon, Oxon; New York, NY: Routledge, Taylor & Francis Group, 2019), 99.
[1052] Egenhoefer, 113.

Tony Fry argues that once the defuturing caused by the existing regime is exposed to failure to act 'is to commit oneself to remaining unknowingly within the anthropocentric and productivist structures of unsustainability.'[1053] Such demands are easy to make by those on fixed salaries but harder to implement by those managing studios with responsibilities to employees and their families whose livelihoods are dependent on continued commercial success.

Taking a more practical approach, Stefan Diez updated a checklist (see table 9.1) originally developed by Dieter Rams in 1976 as a guide to 'good' design, with a focus on sustainability and this serves as a concise summary of the actions that require consideration from those creating another plastic chair (or any consumer durable). Many of the topics listed in that table were addressed in Chapter 5. Numbered lists risk being interpreted as suggesting a hierarchy, with topics most worthy of attention appearing at the top. Diez did not specify if this was his intent, certainly all the items on the list are worthy of consideration. However, when designing plastic chairs (or any consumer durable primarily made from plastic) a sub-set of items on this list require urgent attention. In fact, the last item on the list ('a good product is as little product as possible'), is the most important consideration for all plastic products that do not consume power during use. The energy consumed in creating the material from fossil fuels or renewable organic sources will cause the biggest environmental impact (see Chapter 4). Minimising the use of materials delivers GHG reductions during manufacture, transportation, and end-of-life (addressing item 5 on Diez's list). Efforts to reduce both the amount of material and energy required to manufacture a chair can benefit from the decades of experience in dematerialisation detailed in Chapter 1.

[1053] Fry, *Defuturing*, 126.

Circular Design Guidelines by Stefan Diez

An update on Dieter Rams 10 guidelines for good design developed in 1976

1. A good product remains useful for a long time.
Design it in such a way that it can adapt to changing requirements and thus remain relevant for longer.

2. A good product is repairable.
Use the kind of materials where signs of wear do not diminish the product's value. Construct it in such a way that components with a shorter life cycle can be replaced by the customers themselves.

3. Can the product be designed as a system?
Then, system modules or assemblies can be continually advanced and optimized by the manufacturer in line with technical progress. A good product can be updated and remains on the market for a long time.

4. Use materials that originate from a material cycle or that are renewable.
The materials used should not evaporate or rub off during use and should in general not be toxic. The materials used should be self-explanatory and easily separable from one another. A recycling point should be easily accessible to the last user.

5. As little energy as possible should be used in the manufacture, use and recycling of the product.
Consider the consumption of energy and resources over the entire lifecycle of the product. In the case of products for everyday use, a high level of effort in production can be more than offset by daily savings. Keep the energy input for recycling in focus.

6. Design the product so that it can be transported in a space-saving way.
It can be packed in a compact fashion during production, for transport to the customer, for moving, for repair, and for recycling. The packaging provides reliable protection for the product against damage. Transport should generally be kept as short as possible.

7. A good product is innovative and fascinating.
It may be complex, but never complicated. And it rewards its user with a real benefit. Products should be coherent and honest throughout, speak for themselves, and enable a resonant relationship with their users.

8. A good product is used by many.
It can potentially be rented, shared and returned. Could the product, or a substantial part of it, remain the property of the manufacturer, who sells only its use? Maintenance and repair would then be part of the manufacturer's promise.

9. The production, maintenance & recycling processes employ people in a fulfilling and demanding way.
Good products are made in countries that ensure equal treatment for minorities and guarantee freedom of speech. The health of workers is protected. Workers are employed according to their skills and receive fair pay.

10. A good product is as little product as possible.
It consists of as little material as necessary or has even been replaced by a (digital) service.

Table 9.1. Stefan Diez's update of Deiter Rams guidelines for circular design. Source: Stylepark [1054]

[1054] Moldenhauer, "Stefan Diez."

After exhausting attempts to reduce the quantity of plastic required designers should focus their efforts on avoiding the use of virgin fossil plastics completely (item 4 on Diez's list in table 9.1). With a wide and constantly increasingly, range of recycled plastics and bioplastics available the chance of finding the right choice for the task at hand continually improves. Renewable carbon materials offer no obvious consumer benefits compared with fossil plastics. In fact, perceived disadvantages are more common, especially the aesthetic limitations that afflict many renewable plastics. Exposing the damaging origins of fossil plastics is a strategy that could grow demand for renewable plastics more generally and increase their use in consumer durables. Designers should adjust their focus from 'truth to materials' to declaring the truth about materials. End-users must be alerted to the destructive consequences of their purchase decisions.

The rich provenance of renewable plastics offers significant potential for those involved with the promotion of products (discussed in Chapter 8 and addressing item 7 on Diez's list). Initiating and maintaining a closer relationship with marketing to develop those narratives is made challenging by the fact many designers are often employed on a contract basis, quickly moving on to the next project once a design enters production. The *Bell Chair* project sets the gold standard here, as shown in Chapter 5. The consultant designer (Grcic) worked closely with the marketing department at Magis to construct a narrative to explain where the material had come from, its history, and the environmental benefit of using it. In the final analysis, the success and speed of any transition is determined at the micro-level by the individual attitudes, motivations, and purchase decisions of consumers. Designers can work with manufacturers to nudge these decisions through a tighter focus on developing the marketing narrative.

Switching to renewable energy could reduce the GHG emissions created during the production of fossil plastic by up to 62% in 2050, far greater than could be achieved by switching feedstock to renewable carbon sources.[1055] Details of energy sources used to manufacture plastics are not commonly declared. However, just by raising queries about energy sources designers and manufacturers are signalling the existence of a potentially lucrative market segment, while adding pressure to material manufacturers to consider this aspect of their GHG impacts. Driving this change is particularly important as several factors (including the low-price of fossil fuels, battery technology, and the investment required) mean that switching to renewable energy is a long-term project.[1056] Change is beginning to happen; some material suppliers already use some renewable power.[1057]

Furniture manufacturers and their suppliers should also be encouraged to increase their use of renewable energy. Only seven of the 46 companies I reviewed for my study (15%) reported a commitment to sourcing some or all of their energy needs from renewable sources (Chapter 4). The final decision on energy supply rests with the entity consuming (and paying for) the resource. Designers can attempt to influence those decisions by evangelising the significant environmental and potential economic and marketing advantages achievable by switching to renewables.

[1055] Zheng and Suh, "Strategies to Reduce the Global Carbon Footprint of Plastics | Nature Climate Change," 375.
[1056] Pires da Mata Costa et al., "Capture and Reuse of Carbon Dioxide (CO2) for a Plastics Circular Economy," 6.
[1057] BASF has multiple projects to reduce emissions including electrification, renewable energy, and plastic recycling, among others. Pires da Mata Costa et al., "Capture and Reuse of Carbon Dioxide (CO2) for a Plastics Circular Economy." Evonik launched a version of nylon12, made using renewable energy in Germany and reducing GHG emissions by 40%. "Cracker of the Future" is an initiative of a consortium, including BASF, Borealis, BP, LyondellBasell, SABIC, and Total aiming to electrify steam crackers, replacing the use of fossil fuels by renewable electricity with a demonstrations plant due to become operational in 2023. See https://www.thechemicalengineer.com/news/greener-chemicals-steam-cracking-could-go-electric-by-2023/, accessed February 3, 2022.

This dissertation provides a methodology for designers to embrace a more sustainable approach to the design of plastic products, but it is also a call to arms for urgent action to mitigate the most devastating impact of the climate emergency. As detailed above, the designer's priorities are to reduce their use of plastic (or any other material for that matter), then, where plastics are still needed, avoid fossil plastics all together by using renewable plastics, promote the provenance of the material, and evangelise for both the material and for the use of renewable energy during production.

This dissertation has shown that the cultural reception of plastic is malleable and constantly reinterpreted. Plastics are often admired for their formability and low cost, the ideal expression of the material age. They are often revered as a scientific miracle, the enabling driving force behind consumerism, perpetuating the illusion of endless material progress. Plastics are both venerated and derided for their disposability, malleability, and homogeneity, simultaneously creating a utopian abundance of affordable consumer goods and a profusion of ephemeral waste. However, poorly made plastic products have often been met with disdain, especially when the material has been used inappropriately as a cheap substitute for natural materials.

Our cultural interpretation of plastic has been guided by product designers, interior designers, set designers, and graphic designers. In the early 1990s, Manzini recognised the main challenge facing designers working with plastics is to shift the focus of consumer attention from quantity to quality.[1058] These same professions need to take the lead in showcasing renewable plastics as the most sustainable and logical choice—an essential

[1058] Ezio Manzini, "Plastics and the Challenge of Quality," *Unpublished*, 1992, 5, https://www.changedesign.org/Resources/Manzini/Manuscripts.htm.

component of our response to the environmental emergency in the age of the Anthropocene.

A single solution to the plastic problem does not exist. Even within the category of renewable plastics, and particularly among bioplastics, it is challenging to identify the most sustainable solution. MLP studies demonstrate this is not unusual for an emerging industry, there are multiple possible transition pathways and, as the notion of sustainability remains contested, different actors will disagree about the most desirable innovations and transition pathways.[1059] Many blind alleys must be explored before the main direction is agreed upon and it can be expected that even then solutions will be distributed rather than hierarchical.

The choice of renewable plastic will be partly determined by their availability, which will vary by region reflecting local conditions. This regional variation in feedstock availability is reflected in the United Nations Environment Programme, which calls for technology to be adopted when it is compatible with the environment and society in which it is used.[1060] This recognises that nations or regions must find their own way of combining technological change with local conditions. While this approach sounds logical it is challenging to accommodate in a globalised world addicted to the economies of scale delivered by homogenous mass production.

Combining multiple technologies is a proven strategy to accelerate transitions as shown by MLP studies and discussed in Chapter 8. This study found that specifying renewable plastics alone is not sufficient to optimise a design for sustainability. The most successful designs identified by the environmentally responsible product rating

[1059] Köhler et al., “An Agenda for Sustainability Transitions Research,” 3.
[1060] Holtz, Brugnach, and Pahl-Wostl, “Specifying ‘Regime’ — A Framework for Defining and Describing Regimes in Transition Research.”

(ERPR) tool, embrace the advances in dematerialisation achieved during the first 70 years of plastic chairs (and described in Chapter 1). Designers were often prepared to consider manufacturing technologies both new and old. Some of the chairs with the least environmental impacts were developed using traditional low-pressure compression moulding and not more recent technologies. This is an encouraging finding as compression moulding is more widely accessible due to the lower upfront investment needed. The process itself operates at lower temperatures, and when combined with the lower operating pressures, reduces energy demands when compared with injection moulding. Even small organisations operating in tiny or markets can experiment with renewable plastics using these manufacturing technologies.

Applying the ERPR also found that increasing circularity by using recycled plastics is currently more likely to deliver chairs with superior environmental performance. Many of the bioplastic chairs included in this study failed to achieve above average ERPR scores (Chapter 5). However, recycling alone cannot provide the solution to the plastics crisis, with bioplastics offering the only alternative to our continued dependency on fossil fuels. Future experimentation should not be deterred by the disappointing scores awarded to the bioplastic chairs included in this study, as perfection cannot be achieved without applied research. Early attempts at incorporating bioplastics into consumer durables are useful to alert material manufacturers to issues that require addressing to satisfy the demands on designers. Experimentation and learning by doing is an essential part of transition. Niche accumulation is the very process of networking and learning from the experiments undertaken by innovators in the industry over the past 15 years. Only by examining them can the most 'promising next steps' be identified.[1061] Transitioning to a more sustainable long-term solution requires designers and manufacturers to continue their experiments with bioplastics to reduce our dependence on fossil fuels while retaining the unique benefits of plastics.

While large and mid-tier manufacturers remain predominantly locked-in by previous investments and pre-existing supply arrangements, designers interested in working with innovative materials are more likely to find support from smaller furniture manufacturers with a strong commitment to sustainability, combined with the ambition, networks, and financial resources needed to support innovation. While that checklist may appear formidable, suitably qualified organisations do exist with many of the designs included in this study developed by organisations that match these criteria. Since 2019, Vitra*,* Fritz Hansen*,* and Kartell have all introduced chairs made from recycled plastics and (Chapter 8) Kartell have experimented with bioplastics. With these major market leaders entering the market it is likely that many others will be prompted to experiment with renewable plastics, increasingly motivated by the fear of missing out as the market evolves.

A constantly growing and increasingly urbanised global population will demand more manufacturing to support ever higher levels of consumption, delivering sustained growth for the linear capitalist economy at the continued expense of our environment. The MLP model has been criticised for being representative of the neo-liberal system 'in which scarcity is (mis)assumed to be observed in the market and the environment is seen as an endless resource and waste sink open for exploitation by our socio-technical system.'[1062] My study, and the MLP theory I have adopted could be criticised for focusing on the meso level and

[1061] Elzen, *System Innovation and the Transition to Sustainability Theory, Evidence and Policy*, 290.
[1062] Gaziulusoy, "System Innovation for Sustainability," 110.

failing to offer solutions at the macro level. Transitioning to renewable carbon materials alone will not solve the overarching problem. In fact, replacing fossil fuels with renewable plastic can be criticised as solutionism.[1063] While addressing the urgent need to reduce environmental impacts the solution continues to support the prevalent unsustainable systems of production and consumption. The macro-scale challenge of altering these systems remains. Recycling can be labelled an example of 'environmental technologies' that 'totally buys into technology's inscribed discourse of a solutions-based model of progress.'[1064] However, recycling plastic is an essential requirement of developing a circular economy that many scholars agree is preferable to the prevailing linear system. Providing guidance at the functional level provides direction, simplifying decision for designers in their day-to-day work with plastics. Dramatically increasing the use of recycled plastics will act as a contestation, stimulating debate around consumption and spotlighting the benefits of a circular economy. Increasing the use of renewable feedstocks displaces demand for non-renewables.[1065] Encouraging designers to work with renewable plastics is likely to focus attention on the long-term sustainability challenges facing the entrenched petrochemical regime.

Additional research is required to assess the relevance of the ERPR tool to designers and other actors involved with the development of consumer durables. A methodological innovation of this study, the ERPR online tool was initially developed to compare the environmental impacts of the chairs included I selected for analysis. But the tool can also be

[1063] Morozov introduced the term solutionism to describe the flawed idea that every social problem has a technological fix. Evgeny Morozov, *To Save Everything, Click Here: Technology, Solutionism and the Urge to Fix Problems That Don't Exist* (London: Allen Lane, 2013).
[1064] Fry, *Defuturing*, 212.
[1065] Fry identifies six guidelines for more designers including: remakes existing objects or structures by re-forming their life cycle, to give an extended life, multiple lives or a short life with a total recovery of valuable material, or complete biodegradability and advance renewables to replace a non-renewable Fry, 222.

used to assist designers to make choices that reduce the environmental impact of their products. The first iteration of ERPR is specifically tailored to support decisions relevant to chairs, but it can be easily adapted for other categories of consumer durables where the main material is plastic. Additional investigation is needed to establish the effectiveness of this tool as a method for driving sustainable design among those involved with the development of chairs and other consumer durables.

Further research is required to understand how the information gaps identified by this study can be addressed. Product designers are not environmental scientists, but they do have the expertise and experience to be actively involved with the material selection process and advocate for renewable plastics. Designers can identify appropriate sustainable materials and ensure their mechanical properties are fit for purpose and explain their environmental benefits to clients. Keeping informed of new materials is challenging. Good industry contacts are required to maintain awareness of local developments and supply issues. Designers I interviewed for this study reported difficulty in accessing timely and accurate information on renewable carbon materials and their availability. No commonly referenced sources were cited with participants frequently resorting to ad hoc methods to find relevant information and details of suppliers (Chapter 7). These findings are consistent with reports of a general lack of 'clear and useful' information on how to address sustainable design.[1066] Explicit communication opportunities and effective implementation of technological communication are key to the distribution of knowledge.[1067] There are opportunities for universities to partner with industry actors to address the information needs of designers.

[1066] Egenhoefer, *Routledge Handbook of Sustainable Product Design*, 121.
[1067] Pier Paolo Patrucco, "The Emergence of Technology Systems: Knowledge Production and Distribution in the Case of the Emilian Plastics District," *Cambridge Journal of Economics* 29, no. 1 (January 1, 2005): 37, https://doi.org/10.1093/cje/bei011.

No common mechanisms for designers to share experiences or gain knowledge from other pioneering actors were identified. Many renewable plastics lack an established track record to demonstrate their durability, strength, or other attributes required for a proposed task. Designers need to work with both material manufacturers and furniture makers and rely on their own enquiries to satisfy themselves that a material is suitable. More technical research is required to provide independently verifiable data on the mechanical properties of new renewable plastics to support designers in assessing their relevance for a specific task. Universities could play a leading role in addressing and filling these information gaps, potentially establishing communities of practice to facilitate and encourage the dissemination of relevant information between designers and manufacturers.

With the global population forecast to increase throughout this century, the demand for chairs will grow. Constantly changing cultural, social, economic, and technological conditions will ensure a continuous stream of new designs whether or not the world really needs another plastic chair. Designers, materials manufacturers, furniture makers, and end-users must all accept their responsibility to preference or demand renewable plastics.

This dissertation adds to a growing body of research which increases pressure on design to take a central role in delivering solutions to environmental and social problems. The way that products and services are designed will play a deterministic role in the success of our response to the climate emergency. With up to 90% of a product's environmental impact fixed during the design stage responsibility falls heavily on industrial designers.[1068] This study has shown that the agency of the designer is often limited; even internationally acclaimed designers are most often engaged on a project basis, with future employment

[1068] Elizabeth Resnick, ed., *The Social Design Reader*, First Edition (London New York Oxford New Delhi Sydney: Bloomsbury Visual Arts, 2019), 26.

dependent on client satisfaction. The structure of those relationships tends to diminish the agency of the designer—if a freelance consultant fails to agree with the client (who is often also the entrepreneur) they can be replaced. Despite those limitations, designers are uniquely placed to showcase and drive cultural acceptance, or even preference, for the unique attributes of renewable plastics, promoting their use in consumer durables. While it is often easier to continue using familiar material and manufacturing technologies it is becoming increasingly clear that fossil plastics are taking us along a pathway to self-destruction. Increasing the use of renewable plastics in consumer goods guides us to a pathway leading to a more sustainable future, where materials are either reused or biodegrade at the end of their life.

The fossil regime is expanding production of fossil plastics in efforts to sustain profit growth despite weaker demand for oil. This reliance on a niche market is a risky strategy; just a small reduction in the growth in demand for virgin fossil plastics will have a devastating impact on the projected profits of the entrenched regime. Designers are in a powerful position to influence our fate. As this thesis has argued, design can and should be a futuring agent of change, playing an essential role in shaping a more sustainable future.[1069]

[1069] Fry, *Defuturing*, xxvi.

Appendices

Appendix 1- Example questionnaire:

Design for the environmental emergency:
Plastic chairs as a case study for the transition to low-carbon product design

Note: The questionnaire was tailored for each research participant (not all questions were asked of all participants). The majority of interviews were conducted with industrial designers and these would commence with specific questions relating to their most recent design using renewable carbon-based plastics and then lead into more generic questions focusing on sustainability issues.

Today I want to ask you about the ** chair. Then I have some more general questions with a focus on sustainability.

DESIGN PROCESS

Can you tell me how the project came about?

Can you remember what the original inspiration for your design was?

What process did you follow in developing your design for production?

PROMPT: How did the design first develop – through sketches in a notebook or using CAD?

If computer mentioned: How do you use the computer – *PROMPT* do you develop sketches, three dimensional models etc.

How did the design develop though the use of models or prototypes?

Thinking about the selection of materials, can you tell me who was involved and who made the final decision on choice of materials the final choice?

At what stage did you decide to make your design from plastic?

What other materials (if any) were considered and why were they rejected?

Can you tell me what factors influenced the material selection process, who was involved and what were the main considerations?

Were you concerned about the environmental credentials of the plastic used to develop your design and did they influence material selection?

How did the design evolve when prototypes of the design started to be developed?

The material used for this project is relatively new. Do you remember how you first heard about this material?

How did you develop an understanding of how the material would perform in real life – e.g., will it be hardwearing and have the material strength needed? – how were these concerns satisfied?

What do you see as the main benefits offered by this new plastic/technology?

The material used for this project has different aesthetics (feel/limited colour choices) than traditional plastics – how did you accommodate this in the design and do you think this has impacted the commercial success of the design?

More generally what sources of information do you use when looking for new materials or for technical specifications about them?

About how long did it take from your first design concepts for the design to getting the chair launched on the market?

Once the chair moved to the manufacturing stage can you remember any problems or issues you had to overcome?

Were there aspects of the design that performed better or worse than you expected?

How about the material specifically – were there any surprises in how this behaved during the manufacturing process or in terms of its performance?

How did you decide which manufacturer(s) to approach to develop your design?

Have you worked with the manufacturer before and can you tell me how this relationship come about?

Was your manufacturer concerned about the environmental credentials materials of the proposed to be used?

Was your manufacturer concerned about the environmental credentials of the proposed manufacturing technology?

What impact did the manufacturer have on the development of your design?

MARKET

In recent years there has been increased focus on the environmental impacts of manufactured goods, with a particular emphasis on plastics. Have you noticed any shift in consumer attitude or demands as a result of this focus?

How has this impacted your work?

Do you think the market is really moving? – is there a noticeable increase in demand for more environmentally friendly products or are the press keener on the issue than the public?

Do you think consumers are prepared to pay for products with good environmental credentials?

How do you monitor market trends?

Prompt: What sources of information do you rely on to keep abreast of what is affecting demand?

What role (if any) do you see product designers taking in driving demand for more sustainable materials and production techniques?

In your work with [manufacturer] you have experimented with a variety of materials and technologies – who usually initiates discussion about working with new technologies or materials?

Do you have any plans to work with bioplastics – i.e., plastics made from renewable organic material?

We talked earlier about some of the issues around experimenting with new materials – how can designers be sure bioplastics are fit for purpose and how will they will wear after 20 years of use?

Do you see this as a major barrier preventing their widespread use in consumer durables?

Have you noticed any changed in attitudes from manufacturers – are they more interested in the environmental impacts of products or is this not a significant factor in their thinking?

FUTURE PLANS

Are there any existing plastics or technologies that you are aware of that you would like to use to experiment with?

Are there any new plastics or technologies under development that you are particularly interested in experimenting with?

New technologies (3D printing, AI and robotics) offer potential environmental benefits as they can minimise the amount of material needed to develop a design – do you think this is an important attribute of these technologies and will it affect their take up?

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