Renewable Energy Employment in Australia: Methodology

Prepared for the Clean Energy Council

UTS Institute for Sustainable Futures

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About the authors

The Institute for Sustainable Futures (ISF) is an interdisciplinary research and consulting organisation at the University of Technology Sydney. ISF has been setting global benchmarks since 1997 in helping governments, organisations, businesses and communities achieve change towards sustainable futures.

We utilise a unique combination of skills and perspectives to offer long term sustainable solutions that protect and enhance the environment, human wellbeing and social equity.

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Contents

Please see supplementary document for Appendices 1 – 5

List of figures and tables

Glossary

Abbreviation	Description
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
ARENA	Australian Renewable Energy Agency
BAU	Business As Usual
C&I	Commercial & Industrial
DER	Distributed Energy Resources
EPC	Engineering, Procurement and Construction
OEM	Original Equipment Manufacturer
GW/GWh	Gigawatt / Gigawatt Hours
ISF	Institute for Sustainable Futures
kW/kWh	Kilowatt / Kilowatt Hours
LGC	Large Generation Certificate
NEM	National Electricity Market
MW/MWh	Megawatt /Megawatt Hours
n/a	Not applicable
O&M	Operations & Maintenance
PV	Solar Photovoltaics
SRES	Small-scale Renewable Energy Scheme

1: Introduction

There is limited information on the volume, location and type of jobs in renewable energy in Australia. The international classification frameworks, used by the Australian Bureau of Statistics (ABS) and other national statistical agencies, enable employment within coal mining and fossil fuel power generation to identified but not renewable energy (which is grouped as 'other electricity generation').[1]

The ABS publishes an annual estimate of employment in renewable energy based on secondary and public information sources (e.g. a literature review of employment factors) but does not collect survey data on renewable energy jobs. The nature of the renewable sector means that many jobs may be classified under construction rather than power generation in the periodic Australian census.

Consequently, there is an absence of robust empirical data on employment in renewable energy in Australia. The Clean Energy Council has commissioned the Institute for Sustainable Futures, University of Technology to undertake the first large-scale survey of employment in renewable energy in Australia. This report outlines the detailed methodological basis for the study, in particular the employment factors, in order to allow other interested parties to make calculations.

Scope of the study

This is the first stage of a two-stage project to estimate the number of jobs in renewable energy in Australia The scope of Phase One of the Renewable Energy Employment in Australia includes:.

- Large-scale solar and wind energy;
- On-site solar PV and solar hot water at residential, commercial and industrial sites;
- Hydro generation and storage;
- Battery storage;
- The supply-chain for each of these technologies, which includes manufacturing in Australia and warehousing, sales and distribution for both local and imported technology and products.

Phase Two is planned to estimate the employment in other areas of the renewable energy sector:

- Bio-energy;
- Renewable hydrogen;
- Professional services (government, research and development, consultancies etc);
- Electricity networks construction and operation; and
- Electricity retailing.

The study includes direct jobs (development, construction/installation and operation and maintenance, manufacturing). Some of the indirect jobs associated with the renewable energy industry (professional services, retailing, networks) will be covered in Phase Two.

The study does not include 'induced jobs' (for example, the expenditure of workers employed to build solar or wind farms in regional towns creates employment in accommodation, food, hospitality and other industries).

[1] See Australian Bureau of Statistics (2017), *Employment in Renewable Energy Activities – Explanatory Notes*, for a summary. http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/4631.0Explanatory+Notes12015-16. Accessed September 16 2018.

2: Methodology Overview

The methodology undertaken in this study is consistent with the standard techniques used to estimate renewable energy employment internationally and by the ABS. Simply put, an employment factor (full-time equivalent job-years/megawatt of installed capacity) is derived from the industry surveys and applied to the level of installed capacity (MW) to estimate total employment. The employment factor is reduced over time to reflect productivity improvements.

There are five key steps used in this study to estimate renewable energy employment and identify skill shortages or recruitment issues.

- Step One: Industry surveys to derive employment factors. The surveys are discussed in Section 0.
- Step Two: Calculate employment factors from the survey data, supplemented by literature review where required (see Sections 0 to 0)
- Step Three: Collate three scenarios for renewable energy capacities for the study period, based on the AEMO Integrated System Plan for the National Electricity Market, and Whole of System Plan supplemented by additional research for Western Australia (Section 0)
- Step four: Calculate employment projections for each technology and region based on the capacity projections and the employment factors using an excel model (Section 0)
- Step Five: Calculate the occupational composition of employment using survey data and the volume of employment from the total employment projections (Section 0), and collate details of recruitment experiences and skill shortages from the surveys (Section 0)

The methodology to calculate employment (Step 4) is summarised in

Figure **1**.

Figure 1 Total employment calculation: methodological overview

Manufacturing employment for year	=	MW installed per year	x	Manufacturing employment factor for that year	x	% onshore manufacturing
Construction employment for year	=	MW installed per year	x	Construction employment factor for that year	⁄	Average construction time
Operation and Maintenance jobs	=	Cumulative capacity	x	O&M employment factor for that year		

$$\text{Employment factor for year} = \text{Base year employment factor} \times (1 - \text{average technology decline factor})^{\text{years after base year}}$$

The calculation itself is simple. However, the robustness of the results are entirely dependent on the accuracy of the employment factor. Sections 0 to 0 detail the employment factor derivation, while Section 0 gives some more detail on the employment calculations and the decline factors applied.

For the occupational job estimates, survey data was used to estimate the proportion of total employment accounted for by each of the identified occupations as illustrated in Figure 2.

A weighting was applied to the occupational breakdowns for each project phase based on their share of the employment factor. Construction, for example, is a larger share of total employment so a higher weighting was applied to its occupational mix in calculating the overall occupational composition for each technology.

The relative share of employment for each technology was also reflected in the calculation on the occupational mix for the renewable energy industry as a whole.

Occupational employment was estimated at two levels:

- **Australian and New Zealand Standard Classification of Occupations (ANZSCO), 1-digit**: employment was calculated for six occupational categories – managers, professionals, trades and technicians, clerical and administrative staff, machine operators and drivers, and labourers;[b]
- **Composite profile**: a mix of levels within the ANZSCO based on the concentrations of employment. A 3-digit level job may be used (e.g. electrician) or a 1-digit level (managers) depending on the scale of employment. A composite mix of occupations is used to better illustrate the key job types for the different renewable energy technologies.

Figure 2 Occupational employment calculation overview

Manufacturing = Total manufacturing jobs x Occupational % share of manufacturing employment

Development = Total development jobs x Occupational % share of Development employment

Construction = Total construction jobs x Occupational % share of Construction employment

Operation and Maintenance (O&M) = Total operations and maintenance jobs x Occupation % share of O&M employment

Jobs in occupation = Manufacturing jobs + Construction jobs + O&M jobs

[b] Two categories were excluded on the basis that employment levels were likely to be very low – community services and sales. Data on sales staff was collected amongst managers and professionals.

3: Industry Surveys

Industry surveys were used to collect data for each sector (see Appendices 1 – 5 for copies of the surveys) in order to derive employment factors, the occupational composition of employment and skill shortages and recruitment issues.

Each survey was piloted with a cross-section of business types and then distributed by the Clean Energy Council – and the Australian Industry Group in the case of the supply chain survey – to their members. In the case of the large-scale solar and wind surveys, almost all of the 32 surveys were completed through interviews with ISF to improve data quality.

The surveys collected data on:

- Workforce numbers: the total workforce, renewable energy workforce, the occupational mix, technology, project stage (development, construction etc) and product;
- Business characteristics: business activities, scale of portfolio and technologies;
- Contracting: the breakdown between employees and contractors and the volume of functions that are contracted out to other businesses;
- Skill shortages and recruitment issues: which occupations did the industry experience skill shortages for 2018-19 and the causes for recruitment issues.

Survey respondents covered a very high proportion of the Australian wind power sector, with 87 per cent of capacity during the survey year, and maintaining 74 per cent of Australian installed capacity of wind power. The proportions for utility solar were 46 per cent of installation, with 51 per cent of operations and maintenance. Survey respondents for distributed solar covered about 13 per cent of Australian installation for 2018/19; the lower coverage reflects the large number of small players in the industry. The breakdown for each sector compared to overall Australian installations and cumulative capacity are given in Table 1, while respondents per survey are summarised in

Table **2**.

Disaggregation across the industry and the diversity of business models makes collecting usable data complex, as a single company does not have oversight over the process. As well as technology sectors, we further defined project phases, as shown in Table 3, particularly for the large scale wind and solar surveys. Survey respondents were classified into the phases they operated, as well as the technologies they delivered.

Company business models often include operations across different combinations of these project phases. For example,

- Some companies are pure development operations, some development companies manage the construction and some also own and operate projects;
- The on-site construction phase itself involves many layers of sub-contracting
- Few of the development companies or Original Equipment Manufacturers (OEMs) who oversee and manage construction have data on jobs in the construction phase, and most companies do not have oversight on employment which occurs in their contractor's companies.

Table 1 Survey coverage – capacity and proportion of Australian industry

	Capacity covered by survey (MW)	2018/19 total capacity (MW) [(1)]	Proportion
Large scale solar construction	1,148	2,547 (installed 2018/19)	45%
Large scale solar O&M	2,063	4,029 (cumulative capacity)	51%
Distributed solar installation	253	1,987 (installed capacity)	13%
Distributed solar O&M	658	7,450 (cumulative capacity)	9%
Wind Farm Construction	1,468	1,688 (installed 2018/19)	87%
Wind Farm O&M	6,331 [(2)]	8,508 (cumulative capacity)	74%
Hydro	7,522 (in operation)	7,700 (cumulative capacity)	97%
Distributed Batteries installation	9.7 (8.2 residential, 1.5 commercial)	Approx. 38.6 MW residential batteries [3]	21% (residential)
Distributed Batteries O&M	35.7	Approx. 122 MW residential batteries [3]	40% (residential)
Solar Water Heating	756 systems (installed 2018/19) 20,800 (cumulative installation)	Approx. 61,700 systems[4]	1% (installation year) 3% (cumulative)

Note 1: the installation and cumulative capacity data for distributed and large scale solar is from the APVI historical postcode data[1]; the installed and cumulative capacity of wind power is from the Clean Energy Council database.
Note 2: Wind O&M coverage includes firms who manage or contract for O&M (4543 MW) and direct contractors who undertake the O&M (1788 MW).
Note 3. Capacity for residential battery installation is estimated from the Clean Energy Regulator data for Small Generation Units including battery storage. The annual installation is the average of 2018 and 2019 number of installations multiplied by the median installation size of 6 kW from the survey responses. Cumulative residential installations are estimated from the cumulative total to the end of 2018 multiplied by the same median size. There was insufficient data on commercial installations to estimate the coverage.
Note 4: estimated from Clean Energy Regulator data for Solar Water Heaters and Heat Pumps.

Table 2 Numbers of respondents per survey

	Number of respondents	Notes
Utility scale solar and wind	32	This includes actual hourly data for employees and contractors provided by: • a wind OEM for the construction of four wind farms totalling 988 MW of capacity; • a solar OEM for the construction of two solar farms totalling 138 MW of capacity. Data for almost all respondents was collected through interviews with follow-up emails to confirm data.
Distributed solar PV	152 with sufficient data	We received 264 responses altogether, of which 152 had sufficient data to consider. Of those, 32 responses were excluded because the company reported less than 30 kW PV installed in the survey year.
Hydro	5	Five companies responded to the survey, covering about 2 GW of hydro in development, and 7.5 GW in operation. As none of the companies had new schemes currently under construction, they answered instead about projects they had planned.
Batteries	47 distributed 8 supply chain	There were 47 responses on battery installations in the distributed solar PV survey. Of these 14 residential and 10 C&I were included in data analysis for installation, and 19 residential and 13 C&I for operations and maintenance. We had 8 responses to the battery supply chain survey.
Solar supply chain	17	The solar industry responses included warehousing, manufacturing, the operations of international companies that sell and distribute imported products and control/monitoring equipment manufacturers and providers.
Wind supply chain	5	The wind industry responses included tower manufacturing, hub assembly, transformer manufacturing, transportation and gearbox repairs.

Table 3: Project phases

Phase	Definition and notes
Development	Development of projects up until financial close
Construction	a. Construction includes the largest proportion of jobs and is the most complex. We defined the following roles, which are calculated separately and then combined to produce a construction employment factor. b. **Engineering Procurement and Construction (EPC) managers**: firms that manage and oversee construction c. **EPC firms:** that undertake (and sub-contract) civil and electrical construction activities **Supply-chain**: warehousing, distribution, transport and installation of technology (i.e. all supply-chain activities except manufacturing)
Manufacturing	We collected data to identify the amount of onshore manufacturing of technology and other inputs
Operation & Maintenance	The operation and maintenance of renewable energy projects following construction or installation, including sales and trading (although we have not included employment in retailers)

4: Solar Employment Factors

Two surveys[c] were used to collect data on employment for large scale solar:

- Projects: the development, construction and operation and maintenance of large solar farms;
- Supply-chain: Australian manufacturing, supply and distribution of solar modules, frames, inverters and other components and power transformers.

Fifteen respondents answered questions on large scale solar projects under development, construction or operation for the 2018-19 financial year. **Table 4** shows:

- the MW covered by these organisations for each phase (i.e. development, construction, and operation and maintenance of solar farms); and
- the weighted average, the average, and the minimum and maximum of the employment factor at each phase. The weighted average was calculated by dividing the total reported employment by the total MW reported for that element (development, under construction, operations and maintenance). Consequently, the calculated employment factor gives a greater weighting to data provided by a respondent with multiple or larger projects than a smaller firm.

We have used the weighted average in subsequent calculations, which tend to be lower than the simple average, presumably reflecting efficiencies of scale.

Table 4 Large scale solar: survey coverage and outcomes

Phase	No of responses	Capacity (MW)	Unit	Weighted average	Average	Max	Min
Development	9	5,078	Job-years/MW	0.03	0.04	0.09	0.01
Construction (management)	2	203	Job-years/MW	0.07	0.20	0.39	0.01
Construction (EPC company)	4	1,148	Job-years/MW	1.59	2.22	3.34	1.33
O&M Manager	5	892	Jobs per MW	0.02	0.02	0.04	0.005
O&M	3	840	Jobs per MW	0.10	0.08	0.12	0.063
Development time	9 (12)	5,191	years		1.74	3.00	0.67
Construction time	6 (10)	1,258	years	1.1	0.95	1.17	0.50
Warehousing	From supply chain survey – aggregate coverage 6.5 GW		Job-years/MW	0.28			
Manufacturing				0.09			

Overall, nine respondents (5 GW in development) responded to questions on employment during the development phase. Four respondents (covering approximately 1.1 GW) answered questions on employment during construction; these respondents accounted for 45 per cent of total large solar

[c] See Appendices 1 and 2 for copies of the surveys.

construction in Australia in 2018-19.[d] One of the respondents provided hourly data for employees and contractors at two solar farms totalling 138 MW for us to calculate directly (instead of an estimate of full-time equivalent employment). Seven respondents answered questions on O&M employment (covering 1.7 GW).In order to calculate the overall development and construction employment per MW, we have added the development, construction management, construction, and warehousing components for an employment factor of 1.25 job-years/MW for development and construction in Table 6.

Table 5 Large-scale solar and wind employment from IRENA (2017) & others

	WIND		**SOLAR PV**		
	Job-years/MW	% of jobs	Job-years/MW	% of jobs	
MANUFACTURING					
Towers	**0.39**	24%			
Cells and modules			**3.05**	70%	
Nacelle and blades	**1.21**	73%			
Monitor & control systems	**0.04**	2.6%			
Inverters			0.73	17%	
Solar trackers & structures			0.61	14%	
Manufacturing total	**1.65**	100%	**4.37**	100%	
CONSTRUCTION & DEVELOPMENT					**Non-IRENA**
Development	0.15	4.7%	0.11	2.8%	
Site selection, feasibility	0.04	1.3%	0.05	1.4%	
Engineering design	0.03	0.8%	0.02	0.6%	
Transport	0.08	2.3%	**0.30**	7.7%	3.1%
Grid connection and cabling	0.55	17%	**0.55**	14%	10%
construction	2.44	74%	**2.87**	73%	
Construction & development total	**3.30**	**100%**	**3.91**	**100%**	
DECOMISSIONING	**0.73**		**0.45**		
	Jobs/MW		Jobs/MW		
O&M	**0.23**	**100%**	**1.18**	**100%**	

Sources for Table 5: International Renewable Energy Agency (2017) [2,3] The solar data point of 3.1% is from Solar Business Services (2010-14)[1], while the 10% for transport and from follow up questions to the utility scale survey.

There were gaps in survey coverage relating to transport, detailed engineering design and the grid connection. Consequently, the survey figure has been adjusted using the percentage share of these elements from other Australian sources and a major international study by the International Renewable Energy Agency (IRENA); key data from the IRENA study and the additional inputs obtained from Australia sources are summarised in Table 5 the percentages used to increase the wind and solar employment factors

[d] Total large solar under construction in 2018-19 was 2504 MW (CEC Renewable Project database, 2019); we have only included the MW covered by the EPC companies (1148 MW) as it is likely there is overlap with the management companies.

are highlighted. The following equation shows how we adjusted the factor from the survey data using the percentage for transport, engineering design, and grid connection:

$$\text{Adjusted employment factor} = \frac{\text{Survey outcome employment factor}}{(1 - \text{engineering design }\% - \text{grid cabling }\% - \text{transport }\%)}$$

The adjusted figure of 2.32 job-years/MW is used for job calculations in this study. As Table 6 illustrates, the employment factor used for this study is lower than international studies but slightly higher than the figure used by the ABS. The ABS also does not include operations & maintenance or manufacturing.

Table 6 Large scale solar: Australian employment per MW (results)

		UNIT	This work	**Comparison with other employment factors**		
				ABS 2019 [2]	Solar Foundation[4]	IRENA 2017 [5]
Construction & development	Survey outcome	Job-years/MW	1.97			
	Adjusted[1]	Job-years/MW	**2.28**	1.8	3.3	3.91
Manufacturing		Job-years/MW	**0.096**	n/a		4.37
O&M		Jobs	**0.11**	n/a		1.18

Note 1 Adjusted for missing elements (detailed design, using the employment data from IRENA 2017[3]; grid connection using data from survey follow up questions so a solar EPC manager; and transport from Solar Business Services (2010-2014).[4]
Note 2 Australian Bureau of Statistics, 2019.[5]
Note 3 Rutovitz, J., Dominish, E. and Downes, J. (2015)[13]
Note 4:The Solar Foundation (2018)[6]
Note 4 International Renewable Energy Agency (2017). [3]
Note 5 This refers to manufacturing and distribution employment occurring in Australia.

Distributed Solar PV Employment Factor

The survey on distributed solar PV was piloted with 5 companies (large and small, residential and commercial and industrial sector), and then distributed by the Clean Energy Council to its membership via their email lists.

We received 264 responses, covering all business sizes. The number of responses was reduced to 152 once surveys without sufficient data to include were eliminated[e].

The remaining 152 responses represented 254 MW of distributed solar installations for 2018/19, approximately 13 per cent of the total installed during the survey year.[f] We excluded responses from just under 7% of these companies, as shown in Table 7, because the total installations reported for the survey year were so low (below 10 kW). Responses for a number of these companies seemed unrealistic, perhaps because solar was only a small proportion of their business; the average system size reported in the residential sector was 6.6 kW so 10kW is less than 2 systems. While this accounted for 7% of companies, it represented less than 1% of employees or installed capacity.

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[e] The survey response needed to list both solar employment and installed capacity for the previous year in order to be included in the employment factor calculation.
[f] Based on the reported installations of 1987 MW for distributed PV from the APVI installations by size data from July 2018 to June 2019 (systems up to 5 MW). https://pv-map.apvi.org.au/postcode

Table 7 Analysis of respondents to the distributed solar survey

	Included companies **(installed more than 20 kW in 2018/19)**			Excluded companies **(installed less than 30 kW in 2018/19)**		
	No.	Employees & contractors	MW	No.	Employees & contractors	MW
Micro <5 employees	64	120	16.9	8	8	0.03
SME 5-20 employees	60	409	74.7	2	6	0
Large >20 employees	15	734	162.2	0	0	0
TOTAL	**139**	**1,263**	**254**	**10 (1)**	**14 (1)**	**0.03 (1)**
% of total				7%	0.5%	0.01%

Note 1 The total for excluded companies only sums those excluded from both the residential and C&I analysis. Only 10 company responses were excluded altogether, however the data from 12 companies was excluded from the analysis of residential employment, while 6 companies were excluded from the analysis of C&I employment. The capacity and employees excluded sums the exclusions from both categories.

We undertook analysis of employment by both sector (commercial and industrial or residential) and by business size. The results are summarised in Table 8. In each category, the response presented is weighted according to the MW installed, as we divided the total employment for the included companies by the total MW installed.

To calculate an overall employment factor for distributed solar, the results in each category were used based on the relative market share of commercial and residential sectors in 2018/19 (67% residential).[g,1] Using unweighted employment numbers and MW installed from all the survey respondents would have skewed the result towards commercial installations, which only comprise 33% of the market.

Table 8 Employment per MW for distributed solar by business type (from survey)

	Installation		**Operation & Maintenance**		**Combined**	
	C&I	Residential	C&I	Residential	Installation	O&M
	Job-years/MW				Job-years/MW	Jobs/MW
Micro	3.5	8.5	0.17	0.13	7.2	0.14
SME	4.0	6.4	0.14	0.12	5.8	0.12
Large	4.7	4.4	0.22	0.18	4.5	0.19
OVERALL	**5.6**	**7.5**	**0.19**	**0.15**	**5.1**	**0.16**

[g] The split is calculated from APVI historical postcode data by installation size for Australia; we have taken residential to be anything <14 kW, C&I to be 14kW – 5 MW, and anything over 5 MW to be utility. Total installation recorded for the year is 4.5 GW, with the breakdown on this basis to be residential 1459 MW, C&I 722 MW, and utility 2,547 MW.

Table 9 Distributed solar: Australian employment per MW

	Installation	O&M
Survey outcome for development and construction	5.1	
Transport (Increased overall employment factor by 3.9%)	0.23	-
Wholesalers (Increased overall employment factor by 6.9%)	0.41	
Final employment factor	**5.8**	**0.16**
Manufacturing employment factor (Australian onshore manufacturing only)	**0.15**	

Note: See Table 11 for details and sources of supply chain elements

Table 10 Employment per MW distributed solar – comparison with other studies

	This study	ABS 2019[1]	ISF 2015[2]	Ernst & Young 2017[3]	Solar Foundation 2018 [4]
	Job-years/MW				
Distributed solar	5.8	4.7	13	1 - 6	21 - 38

Note 1 ABS (2019), personal communication[5].The ABS used a figure of 0.03708 per installation, which comes to 4.68 job-years/MW on the basis of the average residential installation of 6kW for 2018 (from the Clean Energy Regulator SGU information)
Note 2 Rutovitz et al,2015 [13]
Note 3 The wide range is for different European countries, from just under 1 in Poland to nearly 6 in Greece and includes downstream jobs, defined as engineering and installation (Ernst and Young, 2017)[7]
Note 4 Solar Foundation, 2018; 21 jobs-years/MW are for commercial, and 39 job-years/MW for residential. The overall factor for the industry is 14 job-years/MW.

The survey did not obtain sufficient data on transport or wholesaling, both important elements of the supply chain for distributed solar PV. As we did not get sufficient survey responses on these elements in the survey, we used data from another Australian survey (Solar Business Services, 2010-2014) to calculate a percentage of employment these elements accounted for and increased the employment factor calculated from our survey accordingly.

While the survey asked respondents to include both subcontractors and employees in all the numbers for employment, it was clear respondents had included subcontractors to differing degrees and that the employment was reported somewhat differently in different survey areas (for example, there tended to be higher employment reported in the detailed occupational questions than in the overall numbers). Where respondents had said we could ask for further information, we clarified which figures were correct, but only 38 per cent had left contact details in their responses. In general, we considered the responses for the detailed occupational questions as most accurate as respondents were listing each different types of workers, so were reminded to include subcontractors.[h]

[h] This also occurred in the large-scale renewable energy surveys which were done through interviews. When the discrepancy was pointed out to respondents, they almost always identified the detailed occupational figures as the correct number, explaining they had overlooked some roles when doing the overall estimate at the beginning of the survey.

Distributed Solar – manufacturing and supply chain

A total of 16 surveys were undertaken with solar and battery storage wholesalers, IT control and monitoring equipment providers and manufacturers. Surveys were undertaken with solar warehouses, offices of international companies responsible for sales and distribution and solar and battery manufacturing. The different elements of the supply chain overlap as warehouses sometimes have manufacturing and manufacturers sometimes have warehousing.

Table 11 Distributed Solar Supply Chain – data from literature

Supply chain element	Data	Source
Transport	3.9% of total employment Equivalent to 0.3 job-years/MW	APVI Intelligence Report (1) This survey
Wholesalers	6.9% of total employment Equivalent to 0.53 job-years/MW	APVI Intelligence Report (1) This survey
Manufacturing & local offices	1.6% of total employment Equivalent to 0.12 job-years/MW	APVI Intelligence Report (1) This survey
Control equipment, monitoring & IT	0.18 job-years/MW Supplying 46% of the Australian market	Industry surveys

Note 1 Nigel Morris (Solar Analytics) provided the data underlying the annual analysis of solar PV employment undertaken for the Australian PV Intelligence Report, 2010 – 2014.[4] Estimates of the proportion of employment were undertaken through industry surveys for the reports. An averaged proportion of employment for the duration of the annual reports was used for wholesalers and manufacturing.

Wholesalers import, store, sell, make and distribute solar technology and components. In the Australian supply chain, there are many international companies with offices for sales and distribution of imported products, and a significant and growing warehouse sector to store and distribute products. There is also a small amounts of manufacturing; for example, inverters and control equipment. Solar warehouses and wholesalers often had small amounts of business in battery storage and many of the same businesses will expand into battery storage as the market develops. There were separate surveys undertaken for the distributed solar supply chain and battery storage. However, in the course of the survey, it became clear that the two sectors are heavily inter-linked at this stage of the industry's development.

In most cases, the sample size was considered insufficient to accurately estimate an employment factor for the distributed solar supply chain. In these cases, the percentage of employment for that element calculated from the APVI *Intelligence report* was applied to the overall employment factor derived for this survey, as detailed in Table 11.

However, data from the 16 surveys was used to produce an estimate on the occupational composition associated with the supply chain which blended together data from wholesalers, manufacturers and control equipment firms. The contribution to the overall estimate of the occupational composition was then weighted based on share of employment factor (see Section 11).

Surveys were undertaken with most of the firms in control equipment, monitoring and data analytics sector. The emergence of IT start-ups in solar PV and battery storage is a new development so the employment factor was added to the manufacturing estimate. This appears to be an area where Australia has a competitive advantage (and firms were considering future export potential) and where a significant and growing proportion of the market sources Australian product.

By way of comparison, Table 12 compares the percentage contribution to employment for different stages of the supply-chain to the US Solar Census. Installation accounts for a relatively high percentage in our study, primarily reflecting a much smaller manufacturing sector. Wholesale trade, distribution and transport is also slightly smaller in our survey relative to the US Solar Census.

Table 12 Distributed Solar Supply Chain – ISF (2020) comparison with US data

Supply chain element	ISF (2020)	US Solar Census
Installation	82.7%	64%
Wholesale trade and distribution	6.6%	12.1%
Transport	3.8%	n/a (included in wholesale trade and distribution)
Control equipment, monitoring & IT	2.1%	n/a
Manufacturing	2.2%	13.9%
Other	n/a	5.4%

5: Wind Power Employment Factors

Seventeen respondents answered questions on wind power employment, with nearly 15 GW of wind in development or under construction. Table 13 shows:

- The volume of MW covered by these companies and in total for the development, construction and operation and maintenance of wind farms, for the supply chain; and
- The weighted average, average, and minimum and maximum of the employment factor at each phase. The weighted average includes weighting the reported employment for that company by the MW they reported for the relevant element of the supply chain (development, under construction, operations and maintenance).

Overall:

- Nine respondents (11 GW in development) responded to questions on employment during the development phase;
- Nine respondents (covering approximately 3.9 GW under construction or construction management) answered questions on employment during construction in either management or delivery roles which accounted for nearly all[i] the wind power under construction in Australia. One respondent provided actual hourly data for employees and contractors for wind farms totalling just under 1 GW;
- Nine respondents answered questions on operation and maintenance employment (covering approximately 1.8 GW[j]).

In order to calculate the overall development and construction employment per MW, we have added the development, construction management, construction, and transport components in Table 13.

This gives the “survey outcome” employment factor of 2.48 job-years/MW for development and construction in Table 14. However, there were gaps in the survey coverage. Consequently, we have adjusted this figure for engineering design and grid connection cabling using the relevant percentage from a major international survey by IRENA (see Table 4):

$$\text{Adjusted employment factor} = \frac{\text{Survey outcome employment factor}}{(1 - \text{engineering design \%} - \text{grid cabling \%})}$$

[i] Total wind under construction in 2018-19 was 1.54 GW (CEC Renewable Project database, 2019); we have only included the MW covered by the EPC construction companies (1468 MW) as there may be overlap with the EPC managers.
[j] We have calculated the coverage by weighting the capacity for O&M management and O&M undertaken by the resultant employment.

Table 13 Wind farms: survey coverage and outcomes

Phase	No of responses	Capacity (MW)	Unit	Weighted average	Average	Min	Max
Development	9	11,122	Job-years/MW	0.13	0.18	0.02	0.43
Construction (management)	5	2,247	Job-years/MW	0.24	0.29	0.07	0.63
Construction (EPC company)	4	1,468	Job-years/MW	1.99	1.40	0.13	2.00
Manufacturing	5 [1,2]	2,100	Job-years/MW	0.47			
O&M - Manager	4	4,543	Jobs per MW	0.07	0.06	0.010	0.10
O&M	5	1,788	Jobs per MW	0.14	0.13	0.09	0.16
Development time	10	n/a	years	5.0	5.10	1.00	10.00
Construction time	8	n/a	years	1.8	1.60	0.75	2.50

Note 1: a survey was also conducted with a major wind farm transport firm. Disaggregated data is not reported here for reasons of confidentiality, so the employment factor for wind transport is included in the construction employment factor. There are also transportation companies that specialise in transformers, but no surveys were able to be conducted so this is not included.
Note 2: MW are for the entire supply chain survey.

The adjusted figure of 2.84 job-years/MW is used for job calculations in this study. **Table** 14 also shows the comparison with employment factors from other studies. The employment factor for construction and installation from survey responses in this study is lower than international studies – note the employment factor in the ISF study in 2015 was based on a literature review of international studies – but significantly higher than the ABS employment factor.

Table 14 Wind power: Australian employment per MW (results)

<table>
<tr><th colspan="2" rowspan="2"></th><th rowspan="2">Unit</th><th rowspan="2">This Survey</th><th colspan="3">Comparison with other work</th></tr>
<tr><th>ABS 2019 [2]</th><th>ISF 2015 [3]</th><th>IRENA 2017 [4]</th></tr>
<tr><td rowspan="2">Construction & development</td><td>Survey outcome</td><td>Job-years/MW</td><td>2.34</td><td></td><td></td><td></td></tr>
<tr><td>Adjusted[1]</td><td>Job-years/MW</td><td>2.84</td><td>1.2</td><td>3.2</td><td>3.30</td></tr>
<tr><td colspan="2">Manufacturing [5]</td><td>Job-years/MW</td><td>0.38</td><td>0.093</td><td>0.3</td><td>0.23</td></tr>
<tr><td colspan="2">O&M [6]</td><td>Jobs</td><td>0.22</td><td></td><td>4.7</td><td>1.65</td></tr>
</table>

Note 1 Adjusted for missing elements (detailed design and grid connection, using the employment data from IRENA 2017)[2].
Note 2 Australian Bureau of Statistics, 2019 [5]
Note 3 Rutovitz, J., Dominish, E. and Downes, J. (2015)[13]
Note 4 International Renewable Energy Agency (2017)[2]
Note 5 This refers to manufacturing employment occurring in Australia
Note 6 The O&M employment factor includes a small element of manufacturing for gear box repair, which assumes that 10% of installed capacity has a gear box repair each year.

Wind – manufacturing and supply chain

The wind farm supply chain in Australia is not extensive with only a small number of firms. The surveys aimed to discover the amount of employment associated with a particular element of the supply chain, and the proportion of Australian construction which sourced those elements onshore.

Surveys were conducted with the major firms, including tower manufacturing, hub assembly, equipment transport, transformer manufacturing and gearbox repair (note that gear box repair is included in the employment factor for operations and maintenance, not in this element). In most but not all cases the survey respondents provided detailed information on sourcing of local inputs in the Australian wind farm sector. Respondents to the utility scale survey also provided data on the proportion of each element sourced onshore.

The calculated employment factor for wind manufacturing is a blended average of these respondents; employment factors cannot be provided for each of the supply-chain elements in order to preserve confidentiality as there is only a small number of suppliers. The employment factor was multiplied by survey data on local sourcing to derive an employment factor for onshore manufacturing.

Table 15 shows the calculated proportion of each element sourced onshore; we have applied these percentages to the employment factors for each element in order to arrive at the overall onshore wind manufacturing employment factor of 0.38 job-years/MW.

Table 15 Proportion of supply chain elements sourced on shore

	% sourced onshore
Towers	14%
Blades	0%
Nacelles	0%
Inverters	0%
Grid connection/ cabling	71%
Control systems	12%
Concrete	100%
Transport Equipment	65%

Note: although respondents reported 12% of control system equipment sourced onshore, we were not able to derive an employment factor for this element

In the case of electrical cabling and concrete, data on the percentage of capital expenditure on these inputs was provided by a respondent that was constructing four wind farms (almost 1 GW of capacity) during 2018/19. Employment ratios were calculated using data for employment and industry turnover averaged over the past five years for Electric Cable and Wire Manufacturing and Ready Mixed Concrete Manufacturing. The number of FTE jobs was then calculated using the total capital expenditure for wind farms in Australia[8]. Lastly, an employment factor was calculated by dividing the employment by the installed capacity.

For construction materials, an employment factor of 0.13 job-years/MW was calculated and for electrical cable manufacturing an employment factor of 0.06 job-years /MW was calculated.

6: Hydro Employment Factors

A survey was used to collect data on employment for pumped hydro, covering current and projected employment. A great deal of new build hydro is being planned at present in Australia, although little is underway, so respondents were about a planned project, and could answer for two projects if they wished. See Appendix 5 for a copy of the survey.

Six respondents answered questions on hydro employment. Table 16 shows the volume of MW covered by these organisations, and the specific capacity for planned projects used to derive the employment factors.

Overall, six respondents (2.4 GW in development) responded to questions on employment during the development phase. Two respondents (covering approximately 2.2 GW) answered questions on employment during construction. Five respondents answered questions on employment post construction (covering approximately 3 GW).

The survey resulted in a construction/ development employment factor for pumped hydro of 7.2 job-years/MW, somewhat lower than the international figure, noting that it is difficult to find international studies which distinguish between hydro and pumped hydro.

Phase	No. of responses	Capacity by responses (MW)	Unit	Weighted Average	Min	Max
Development	5	2,463	Job-years/MW	**0.34**	0.12	0.53
Construction	2	2,250	Job-years/MW	6.86	6.64	12.93
O&M	4	2.563	Jobs/MW	**0.08**	0.05	0.56
Development time	5 (1)	2,400	years	**3.8**	2	5
Construction time	6	4,650	years	**4.5**	3.5	6
Capacity covered by respondents (2)	7	7,522	-	**-**	-	-

Note 1: a ramp-up time of 6 months is included for pumped hydro, so that job-years are spread over 5.5 years.
Note 2: The survey focus was on pumped hydro, so only the planned pumped hydro projects are summed in the for development, construction, et cetera.

Table 16 Pumped hydro employment factors: comparison with other studies

		This work	ABS 2016 [11]	ISF 2015 [13]	Navigant/ NREL 2017 [9, 10]
HYDRO					
Construction & development	Job-years/MW	**n/a**	n/a	7.4	8.7
O&M	Jobs/MW	**0.14**	0.14	0.2	0.25
PUMPED HYDRO					
Construction & development	Job-years/MW	**7.2**	n/a	n/a	17.2
O&M	Jobs/MW	**0.08**	n/a	n/a	0.12

We used ABS data for employment to derive the employment factor for operations and maintenance on conventional hydro. There were 1,112 people employed in 2017, for a hydro generation capacity of 7,983 MW, resulting in an O&M employment factor of 0.14 jobs/MW.[11,12] We used a manufacturing employment factor of 3.5 job-years/MW and a construction employment factor of 7.4 job-years/MW for conventional hydro generation from previous work[13]; however, all the new build currently planned is pumped hydro so the construction factor for conventional is not relevant.

There was not sufficient data from the supply chain survey to calculation manufacturing employment for pumped hydro, so we have used international figures and assumed that 20% will occur onshore to allow for steel, cabling, and construction materials.

7: Batteries Employment Factors

Two surveys were used to collect data on employment for batteries:

- Distributed batteries: responses from the distributed solar survey
- Battery projects and supply-chain: the development, construction and operation and maintenance of battery installations, and the Australian manufacturing, supply and distribution of batteries.

See Appendix 2 for a copy of the distributed solar survey (which includes batteries), and Appendix 4 for a copy of the battery supply chain.

The distributed solar survey had 47 responses that included battery installation and information on both installed capacity and employment (noting that without this information we could not include the responses in the employment factor analysis).

All 28 responses on commercial battery installation were included in the analysis. However, a high proportion of residential battery installers reported very few installations. We have taken a conservative approach, and excluded data for residential batteries where respondents had done less than 5 residential battery installations during the previous financial year.

This left 29 included respondents for residential battery installations (16 excluded). While a high proportion of responses were excluded (36%), they accounted for only 3% of the residential battery capacity installed (3.1% of the residential batteries installed, 2.6% of total batteries installed). We used the same exclusion for residential O&M, which left 36 responses. We had 10 responses for C&I installation and 13 responses for C&I O&M.

The battery supply chain survey had 11 responses - 8 responses once incomplete answers were eliminated, including manufacturers (3) and importers/distributors (4) and utility construction (1). Table 18 shows:

- the MW covered by these organisations for each phase (i.e., installation, manufacturing and operation and maintenance of battery systems); and
- the weighted average, the employment factor at each phase.
- The final employment factors used in the jobs analysis.

We did not have sufficient data to derive an employment factor for utility battery development, as there are few completed utility scale projects yet in Australia. We therefore used the distributed C&I installation factor as the closest proxy. For the distributed installation factor, we used the combined factor from the residential and C&I data. We have used the operations and maintenance data from the distributed survey for distributed batteries, and the data from manufacturers for the utility scale batteries.

We found the combined employment factor for installation of distributed batteries to be 5.2 job-years/MW installed for installation, which is equivalent to 7.4 person days on average for a residential system. This goes down to 5.4 days if only companies who have installed more than 10 systems are included, probably reflecting the early stage of this industry. However, the sharp decline rate expected for battery may adjust for this over time.

Table 17 Battery employment: survey outcomes by business size and sector

	Installation		Operation & Maintenance		Combined	
	C&I	Residential	C&I	Residential	Installation	O&M
	Job-years/MW		Jobs/MW		Job-years/MW	Jobs/MW
Micro	8.4	1.0	1.23	0.08	1.3	0.08
SME	3.6	10.5	1.74	0.46	7.4	0.43
Large	7.6	5.7	0.96	0.29	5.8	0.28
Overall	**4.7**	**5.3**	**1.4**	**0.30**	**5.2**	**0.29**

Table 18 Battery employment: survey coverage and outcomes

	No. of responses	Coverage (MW)	Weighted Average Job-years/MW
DISTRIBUTED SURVEY RESULTS			
Distributed installation - Residential	29	8.2	**5.2**
Distributed installation – C&I	10	1.4	**4.7**
Distributed O&M – residential	36	36	**0.29**
Distributed O&M – C&I	13	1.2	**1.4**
SUPPLY CHAIN SURVEY RESULTS			
Wholesale	1	25	**0.4**
Manufacturing (1)	2	4.7	**6.6**
Maintenance (2)	1		**1.2**
FINAL EMPLOYMENT FACTORS (DISTRIBUTED BATTERIES)			
DISTRIBUTED INSTALLATION (including wholesale)	**39**	**9.7**	**5.6**
DISTRIBUTED OPERATIONS AND MAINTENACE	**49**	**33.6**	**0.29 jobs/MW**

Note 1. We have used this as the overall manufacturing figure for both utility and distributed battery manufacturing, and assumed that 5% of battery manufacturing occurs onshore.
Note 2. We have used the maintenance figure obtained from the supply chain survey for the utility batteries, and the O&M figure here for distributed batteries.

8: Employment Factors – All Technologies

The employment factors used in all the projections are summarised in **Table** 20.

The majority have been derived using data from the surveys conducted for this work, there are a small number which are from previous work and/ or from other sources.

The overall manufacturing employment factors are for comparison, as the relevant factor for Australian projections is the employment which occurs onshore. However, the overall figure gives some indication of how this could be improved if requirements for local content were increased.

Table 19 Employment factors – all technologies

	Construction/ installation	Manufacturing	Australian manufacturing	Operations & maintenance
	Job-years/MW			Jobs/MW
Wind	2.8 (1)	1.7 (3)	0.377 (1)	0.22 (1)
Utility Solar	2.3 (1)	4.4 (3)	0.092 (1)	0.11 (1)
Rooftop PV	5.8 (1)	4.4 (3)	0.153 (1)	0.16 (1)
Utility batteries	4.7 (1)	6.6 (1)	0.331 (4)	1.20 (1)
Distributed batteries	5.6 (1)	6.6 (1)	0.331 (4)	0.29 (1)
Hydro	7.4 (2)	3.5 (2)	0.699 (5)	0.14 (1)
Pumped hydro	7.2 (1)	3.5 (2)	0.699 (5)	0.08 (1)
	Job-years/ system			
Solar water heating	0.015 (1)	n/a	0.0021 (6)	-

Note 1: Factor derived in this study
Note 2: Factor from previous work, Rutovitz et al, 2015 [13]
Note 3: Factor from IRENA, 2017 [2,3]
Note 4: Assumed that 5% of overall manufacturing for batteries will occur onshore.
Note 5: Assumed that 20% of overall manufacturing for hydro will occur onshore.
Note 6: Australian Bureau of Statistics, 2019 (Personal communication, November 2019)

9: The Renewable Electricity Scenarios

Renewable energy is forecast to grow under all scenarios used by the system operators for the National Electricity Market (Australian Energy Market Operator) and the South-West Interconnected System in Western Australia.

NEM Scenarios[k]:

Three of the scenarios[l] in AEMO's Integrated System Plan[14,15] were used for projecting the growth of renewable energy in the NEM:

- **Central scenario**: the pace of transition is determined by market forces under current federal and state government policies (i.e. a business-as-usual scenario)
- **Step change**: both consumer-led and technology-led transitions occur in the midst of aggressive global decarbonisation and strong infrastructure commitments.
- **High Distributed Energy Resource**: higher growth in rooftop solar, battery storage and demand-side flexibility.

In all three cases the optimal development path scenario was used. The NPV of the three scenarios are relatively close: the Step Change scenario has an NPV 6% above the Central Scenario, while the High DER scenario has an NPV 8% lower than the Central Scenario. However the emissions profile of the scenarios are very different, with the Step Change having cumulative emissions 40% less than the Central Scenario, while the High DER has cumulative emissions only 2% lower than the Central scenario.

Note that job calculations in 2020 and 2021 are highly sensitive to gap between the current capacity and the first scenario year, 2020/21, particularly for distributed solar and batteries as the capacity increase is so great, particularly in the High DER scenario, and the employment factor is relatively high. Increasing capacity linearly from the last data point (2018/19) to the first scenario year, by averaging the two values, would be the most straightforward approach for each individual scenario. However, as 2019/20 is almost over it is not reasonable for there to be markedly different capacities (or job numbers) between the three scenarios. We have therefore modified the AEMO scenarios as follows:

- Distributed PV: we first calculated the average capacity in each scenario if the increase was linear, and then averaged the three results to obtain the capacity for 2019/20. We have set this as the capacity for 2019/20 *in all three scenarios.*
- Distributed batteries: we have taken the average value between the Step Change and the Central scenario to set the capacity of distributed batteries in 2019/20, and then increased the batteries over two years, to reach ISP levels in 2022.
- Distributed batteries: in the High DER scenario only, we have then increased capacity to meet the ISP scenario level in 2021/22 over the two years 2019/20 and 2020/21, as the large spike in capacity to reach the ISP 2021/22 level, and with it the spike in job numbers, seems a modelling artefact rather than reflecting what would happen under the High DER scenario.

WA Scenarios:

The Government of Western Australia is currently developing a Whole of System Plan (WSP) for the South West Interconnected System (SWIS). The four scenarios are:

- Techtopia: technological change places downward pressure on energy costs
- Groundhog day: renewables thrive, but reliance on the network remains high
- Cast Away: leaving the grid with muted economic growth
- Double Bubble: booming economy with limited global action on climate change.

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[k] Note the NEM includes QLD, NSW, ACT, VIC, SA, TAS
[l] There are five scenarios in total. In addition to the three used for this study, there is a 'slow change' and a 'fast change' scenario. Various sensitivities are applied to each scenario to determine an optimum development path for each.

These do not correspond well to the AEMO scenarios, and modelling is only complete on the distributed renewable generation. The characteristics of the WA WSP and the NEM ISP are shown in Table 21.

In the absence of the WSP modelling being complete we have used the WSP modelling for DER in the SWIS, as shown in Table 22, and have used assumptions on the proportion of potential projects which will go ahead in each of the three scenarios.

Table 20 WA Whole of System Plan and NEM ISP scenario characteristics

	Electricity Demand	De-Carbonisation	UTILITY RE	Rooftop PV	Distributed Batteries
SWIS SCENARIOS					
Cast Away	Low	Low	Low	Medium	High
Groundhog day	Medium	High	Medium	High	Highest
Techtopia	Medium	High	High	Low	Low
Double Bubble	High	Low	High	Low	Low
AEMO SCENARIOS					
Central	Medium	Medium	Medium	Medium	Low
High DER	Medium	Medium	Medium	Very high	High
Step Change	high	high	High	High	Medium

Note 1 Low on grid DER, but high decentralisation

Table 21 Mapping WA scenario to the ISP scenarios

	South West Interconnected System		PIlbara and the Goldfields	
ISP scenario	**Utility**	**DER**	**Utility**	**DER**
Central	50% of proposed projects go ahead	Rooftop PV: Cast Away Distributed Batteries: Techtopia Utility Batteries: Techtopia	10% of proposed projects go ahead	n/a
High DER	20% of proposed projects go ahead	Rooftop PV: Groundhog Day Distributed Batteries: Groundhog Day Utility Batteries: Techtopia	50% of proposed projects go ahead	n/a
Step Change	All proposed projects go ahead	Rooftop PV: Groundhog Day Distributed Batteries: Techtopia Utility Batteries: Double Bubble	100% of proposed projects go ahead	n/a

For the employment modelling it is assumed that 50%, 10%, and 100% of proposed utility scale projects go ahead in the SWIS under the Central, High DER, and Step Change scenarios respectively. The potential projects for the SWIS are sourced from the WSP assumptions workbook supplemented by the Clean Energy Regulator database and a renewable energy project database maintained by the CEC and listed in Appendix 6. [16,17,18]

Renewable projects in the PIlbara and Goldfields areas are not routinely reported by AEMO, as they are not connected to the SWIS, and are likely to see development over the next decade in all scenarios. We have sourced a list of potential projects via web research, from the CEC project database and the Clean Energy Regulator database. For the PIlbara projects, we have assumed only 10 per cent go ahead in the Central scenario, with 30 per cent in the High DER and 100 per cent in the Step Change scenario. The projects and sources are listed in Appendix 7.

10: Employment Calculations

Calculating the employment from the renewable energy scenario for any year uses this basic equation for construction and development; for operations and maintenance the cumulative installations are multiplied by the job factor in jobs per MW:

Construction employment for year	=	MW installed per year (MW)	x	Construction employment factor for that year (job-years/MW)	⁄	Average construction time (years)

The employment factor for the year is the employment factor from your base year reduced by decline in technology cost.

Decline factors

Renewable energy technologies are still experiencing significant cost declines. While there may not be an exact correspondence with employment creation, it is likely that employment broadly declines in line with overall cost reductions. Note that this does not imply that wages decline, but the time taken to install (or manufacture, or maintain) each MW goes down alongside the cost.

For example, one of the major drivers of the decline in wind technology cost is the size of the turbine, which have gone from around 0.5 MW per turbine to closer to 3 MW in the last two decades. The employment created per MW will have an associated decline; while there will be additional work to install the larger turbine, it will certainly not be six times as great.

As determining the exact relationship between overall cost decline and employment is not possible or subject to assumptions, we have instead applied the cost decline to the calculated employment factors. So the employment factor for a particular year is equal to the base year factor multiplied by the percentage cost decline since the base year.

We have calculated an average annual decline factor from the AEMO cost projections for each technology and scenario for which costs are available. We note that the declines are grater in those scenarios which install more renewable capacity, so for example, there is an average cost decline for wind energy in the Step Change scenario of 1.4% per year between 2020 and 2035, compared to a decline of 0.8% in the Central or High DER scenario. We assume that this decline also applies to the job creation per MW.

The average annual decline is calculated by comparing the technology cost in scenario year with the cost in the base year (in this case, 2020):

$$Annual\ decline\ factor = 1 - \left(\frac{technology\ cost\ (yr\ x)}{Technology\ cost\ (base\ yr)}\right)^{1/(\text{year x} - \text{base year})}$$

This is then used to calculate an employment factor for each year:

$$Employment\ factor\ (yr\ x) = Employment\ factor\ (base\ yr)\ \text{x}\ (1 - ADF)^{(yr\ x\ -\ base\ yr)}$$

Table 22 gives the calculated average annual decline factor at 2025, 2030, and 2035. The 2025 figure is used from 2020-2025, the 2030 figure for 2026 – 2030, and the 2035 figure up until 2035.

Table 22 Average annual decline factors by scenario and technology

	2020 – 2025			2020 – 2030			2020 – 2035		
	Central	Step Change	High DER	Central	Step Change	High DER	Central	Step Change	High DER
Wind	0.9%	1.9%	0.9%	0.8%	1.8%	0.8%	0.8%	1.4%	0.8%
Utility Solar	6.3%	6.5%	5.4%	4.9%	5.7%	4.5%	3.9%	4.3%	3.6%
Rooftop PV	6.3%	6.5%	5.4%	4.9%	5.7%	4.5%	3.7%	3.7%	3.7%
Utility batteries	4.4%	4.1%	2.8%	3.7%	3.3%	3.1%	2.5%	2.2%	2.2%
Distributed batteries	4.4%	4.1%	2.8%	3.7%	3.3%	3.1%	4.3%	4.3%	4.3%
Pumped hydro	0.1%	0.3%	0.1%	0.1%	0.2%	0.1%	0.1%	0.2%	0.1%
Solar water heating									
Wind repowering	0.9%	1.9%	0.9%	0.8%	1.8%	0.8%	0.8%	1.4%	0.8%
Solar repowering	6.3%	6.5%	5.4%	4.9%	5.7%	4.5%	3.9%	4.3%	3.6%

Factors calculated from AEMO cost trajectories for technologies, 2020 – 2035 except for rooftop PV and distributed batteries, which are sourced from Appendix Table B.1 of GenCost 2019-20[19], the cost trajectory for rooftop solar and for batteries balance of system.

Table 23 Proportion of 2020 cost at 2035

	Proportion of 2020 cost at 2035		
	Central	Step Change	High DER
Wind	87%	74%	87%
Utility Solar	38%	37%	44%
Rooftop PV	41%	41%	41%
Utility batteries	51%	54%	66%
Distributed batteries	46%	46%	46%
Pumped hydro	98%	96%	99%
Solar water heating			
Wind repowering	87%	74%	87%
Solar repowering	38%	37%	44%

As AEMO do not include cost trajectories for either rooftop PV or distributed batteries, we have taken these from CSIRO's GenCost 2019 – 20 preliminary results.[19] We have used the Central Scenario for all three cases, which may underestimate the decline in the High DER scenario. Table 22 shows the proportion of the 2020 cost in each scenario at 2035; the employment factors will be reduced the same amount, so employment creation per MW of wind power, for example, will be 87% of the employment creation per MW in 2020.

Regional percentage

In the large-scale wind and solar surveys, companies were asked to estimate the proportion of jobs that were sourced 'local' to the project (defined as within 100 kilometres). For the job estimates, our interest was on the portion of jobs that could be locally or regionally located for future projects. For distributed solar, it was assumed that all the installation and maintenance jobs could be local and regional.

Based on the survey and discussions with companies, the assumptions on the percentage split for particular occupations (Table 25) were used to determine the proportion of jobs sourced locally or regionally (i.e. outside capital cities). For example, it's assumed that 70 per cent of construction managers would be based regionally, to be within reach of the projects they are managing. The same split is assumed for wind and solar.

The assumed regional proportion per occupation is then applied to the composite split for that development phase to arrive at the overall regional percentage for each technology. For example, this results in an overall figure of 69 per cent of construction employment in solar farms that could occur regionally.

The regional split for hydro was from the survey responses, with a weighted average result that construction is taken as 84 per cent regional and operations and maintenance is 93 per cent regional.

We have assumed that 50 per cent of onshore manufacturing occurs in regional areas, which is likely to be an underestimate (the majority of respondents to the supply chain survey were located in regional areas).

Table 24 Regional percentage per technology (wind and solar)

		Wind farms		Solar farms	
	Assumed regional %	% of total	Regional %	% of total	Regional %
DEVELOPMENT	0%		0%		0%
CONSTRUCTION					
Construction managers	70%	9%	6%	7%	5%
Electrical engineers	40%	6%	3%	2%	1%
Health and Safety	75%	5%	4%	3%	3%
Civil engineers	40%	5%	2%	4%	2%
Community engagement	0%	1%	0%	0%	0%
Logistics	50%	5%	2%	2%	1%
Site administrators	100%	3%	3%	5%	5%
Electrical trades	90%	11%	10%	16%	14%
Mechanical Trades	90%	7%	6%	7%	6%
Other Trades & technicians	90%	6%	5%	0%	0%
Drivers, Machine Operators & Labourers	100%	26%	26%	32%	32%
OVERALL % REGIONAL EMPLOYMENT: CONSTRUCTION			**67%**		**69%**
OPERATIONS & MAINTENANCE					
Operations manager	50%	11%	6%	15%	7%
community engagement	100%	2%	2%		
health & safety	75%	4%	3%	2%	1.4%
Electrical trades/ technicians	100%	40%	40%	31%	31%
Scada trades/ technicians				2%	2%
Mechanical trades/ technicians	100%	23%	23%	12%	12%
Labourers/ landscapers/ panel cleaners	-	-	-	1%	1%
OVERALL % REGIONAL EMPLOYMENT: OPERATIONS AND MAINTENANCE			**73.3%**		**54.6%**

Note: occupations where we assume 0% regional are not listed, so the "% of total" does not add up to 100%

11: Occupational Employment Calculations

There were three key steps to the occupational employment calculations:

- Industry surveys;
- Weighting of survey responses to calculate the occupational composition for each technology;
- Calculation of occupational employment by technology under the Step Change scenario to estimate the occupational composition across the renewable energy industry.

Industry Surveys

Survey data was used to calculate the occupational composition of employment across all of the renewable energy technologies. Survey respondents were asked the number of full-time equivalent workers for each of the major 1-digit occupational categories and then for a more detailed list of occupations within each of these categories. **Table 25** provides the list of jobs included in the survey.

Table 25 Jobs included in the surveys by 1-digit category

1-Digit Category	OCCUPATIONS INCLUDED	
Managers	Executive and General Manager HR, Finance & Business administration managers Construction/project managers	Transport & logistics managers Site managers Operations/asset managers Other managers
Professionals	Civil engineers Electrical engineers Scada/telecommunications engineers Mechanical engineers Grid engineers Health and Safety Professionals Community engagement Environment assessment professionals Legal and planning professionals Finance & accounting professionals	Sales & marketing professionals Human resource professionals Transport & logistics IT professionals Surveyors Land Developers GIS Solar PV Designer Other professionals
Trades and Technicians	Site supervisors Civil engineering technicians Electricians Electrical technician support SCADA technician support Control Room Operators Other technicians Metal trades	Mechanical trades Mechanical technicians Carpenters Plumbers Electricians Telecommunications trades Power plant/control room operators Other trades
Administrative	Secretaries and clerical staff Accounting clerks & book-keepers	Project controller Office managers and contract administrators

1-Digit Category	OCCUPATIONS INCLUDED	
Machine Operators and Drivers	Crane and hoist operators Earthmoving, grader operators Forklift operators	Truck Drivers (large solar and wind) Drivers (distributed solar PV) Other drivers & machine operators
Labourers	Concreters Riggers Dogmen Scaffolders Security guards	Electrical trade assistants Mechanical trade assistants/labourers Civil trade assistants/labourers Landscape gardeners Other labourers

Table 26 Weighting of occupational employment by sector and category

Sector	Sub-categories	Weighting
Large-scale wind	Development	4.4%
	Transport	4%
	Construction	73.5%
	Operations & Maintenance	6.2%
	Supply-chain	11.3%
Large-scale solar	Development	2.9%
	Transport	3.5%
	Construction	89%
	Operations & Maintenance	5.3%
	Supply-chain	n/a
Distributed Solar	Residential (installation)	68.7%
	Commercial & Industrial (installation)	17.1%
	Wholesalers	6.6%
	Manufacturing	1.5%
	Software/control equipment	2.2%
	Transport	3.8%
Hydro	Development & Construction (including major refurbishments)	69%
	Operation and Maintenance	31%

Note 1: the occupational composition for distributed solar was used for battery storage. There is significant overlap between the supply chains and battery storage is still too new to determine an occupational composition as many firms have small levels of battery storage activity in addition to their solar PV activity.
Note 2: survey data was insufficient to estimate occupational composition for large-scale solar supply chain.

Weighting of Survey Data: Calculation of Occupational Employment Share for each Technology

The survey data was used to estimate the proportion of total employment comprised by each occupation for each of the technologies through two steps:

- The percentage of total employment for each occupation by project phase (large-scale renewable energy) and sub-sector in the case of distributed solar (commercial & industrial vs residential);

- The occupational share for each project phase was weighted based on the proportion of the total employment factor and then added together for the overall technology result to ensure their contribution reflected overall employment.

Table 27 details the sub-categories and the weightings

Figure 3 Renewable energy technologies, occupational composition, 1-digit (%)

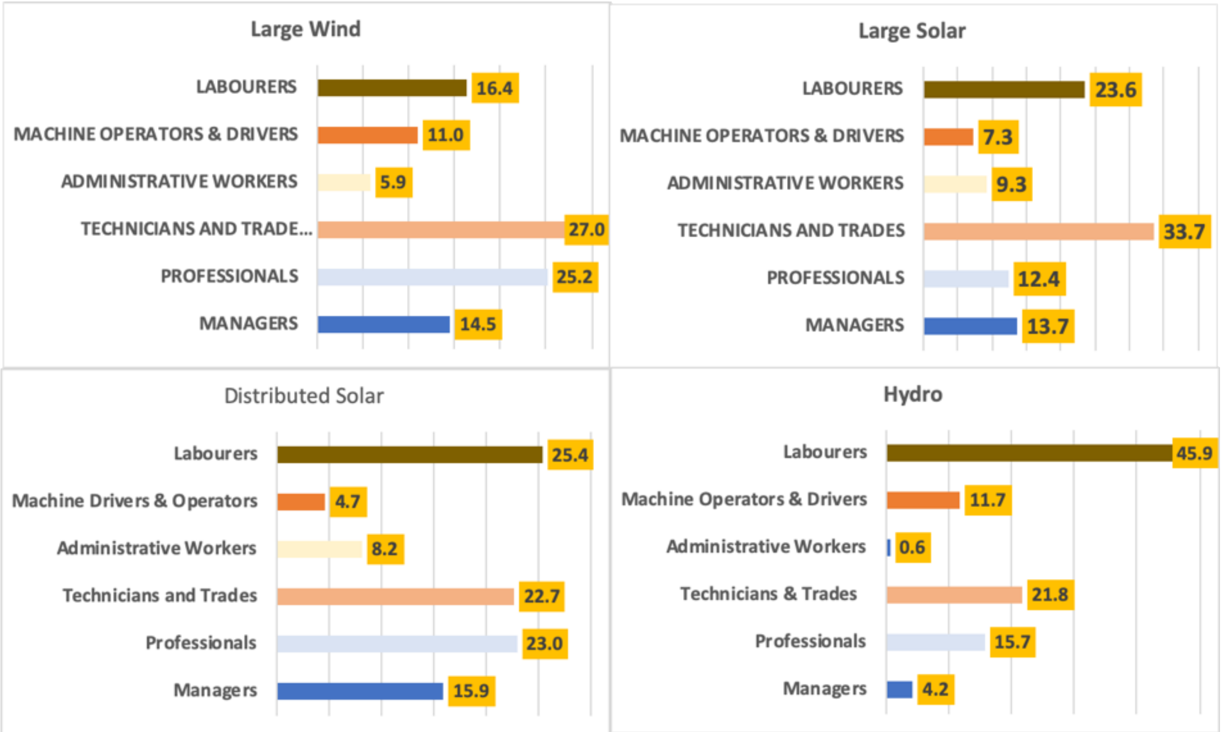
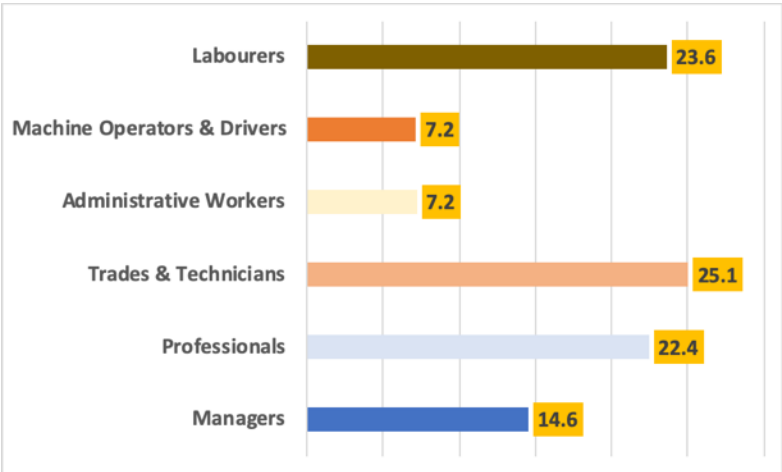


Figure 4 All Renewable energy, occupational composition, 1-digit (%)



Note: The label 'managers' is frequently applied to professional jobs, even if they are not managing staff. Whilst efforts were made to adjust for this and to inform respondents that only staff managing other staff should be considered managers, it is highly likely the proportion of managers is over-stated and the proportion of professionals is under-stated.

Figure 3 contains the occupational mix for each of the four technologies that was produced. A decision was made to group occupations based on alignment of work and the volume of employment to generate 'composite' results instead of presenting results for 2-digit, 3-digit and 4-digit level occupations under the

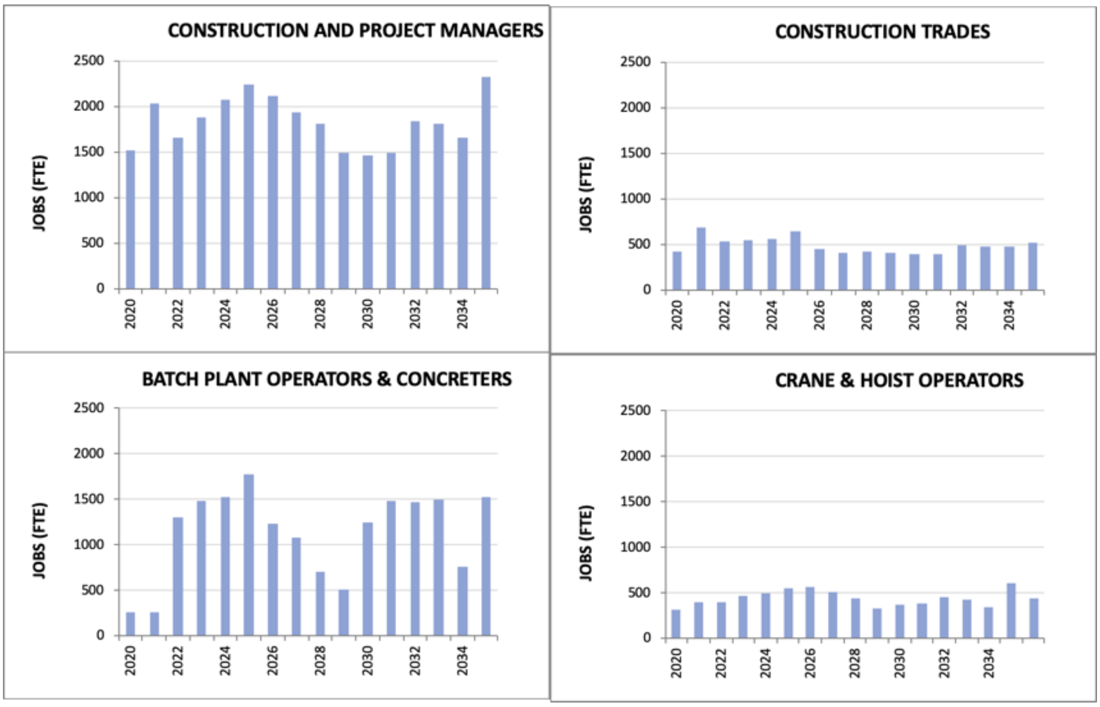
ANZSCO. In general, the aim was to produce a set of results that would be meaningful for readers and therefore the 'composite' results is a mix of 2, 3 and 4-digit level occupations.

The occupational shares were then applied to the employment generated for each technology under the Step Change scenario. The occupational shares across the renewable energy industry is an average of employment for each occupation from 2020-2035.

At an aggregate level, it is assumed that rising labour productivity over time will reduce the labour intensity (i.e. less FTE/MW) using decline factors based on AEMO's cost projections. No assumptions have been made on changes to relative labour intensity between occupations over time.

Variations in occupational employment over time therefore reflect AEMOs forecasts for growth in different technologies as the shares by technology are fixed. For example, Figure 5 illustrates how concreter demand is driven by the forecast for new build wind farms and hydro/pumped hydro so its employment profile is much peakier than construction and project managers which are required across technologies.

Figure 5 Employment for selected construction occupations, 2020-2035



12: Skill Shortages & Recruitment Issues

The skill shortage analysis is based on data from the surveys on recruitment issues and skill shortages, combined with the occupational employment mix projections. The questions on recruitment were aligned with the classification system used by the Department of Small Business to develop its list of skill shortages.

Organisations were asked to classify the level of difficulty for recruiting occupations over the past 12 months into one of the three ratings:

- **Low Difficulty:** Able to find the workers needed in Australia within 4 weeks or less
- **Medium Difficulty:** Able to find the workers needed in Australia within 5 - 8 weeks
- **High Difficulty:** Unable to find workers needed in Australia within 2 months

Respondents were instructed the time period applies to search (i.e. doesn't mean physical placement which may take longer due to notice requirements etc).

For occupations where medium or high difficulty had been experienced, the respondent was asked to classify the cause(s) based on 6 categories (multiple responses were permitted):

- Not enough candidates with the right qualifications/ licenses;
- Not enough candidates with general experience;
- Not enough candidates with specific experience in renewable energy projects;
- Suitable candidates but they wanted higher pay;
- Difficulty attracting suitable candidates for projects in regional or remote locations;
- Suitable candidates but they wanted longer-term employment.

In the course of the surveys, respondents were also asked to identify any other workforce, skills or recruitment issues. Some of the additional information or barriers identified by respondents is also included. Respondents were asked separately for information on each state in which they reported recruitment.

Appendices 1–5: Utility renewable energy surveys

Appendix 1 Utility renewable energy survey

Appendix 2 Distributed solar energy survey (includes Batteries and Solar Water Heating)

Appendix 3 Supply chain survey

Appendix 4 Batteries supply chain survey

Appendix 5 Hydropower survey

Please see supplementary document for Appendices 1 – 5

Appendix 6: SWIS renewable projects included in scenarios

Projects with identified commissioning years

Power station	Type	Year	MW	
Greenough River Solar (extension)	Solar	2020	30	Note 1
Merredin	Solar	2020	100	Note 1
Warradarge	Wind	2020	180	Note 1
Yandin	Wind	2020	214.2	Note 1

Proposed projects (no identified commissioning year)

Power station	Participant	Type	MW	
Sunrise Energy Group	Boonanarring Solar Farm	Solar	4.0	Note 2
Carnegie Clean Energy	Kemerton Solar Farm	Solar	10.0	Note 2
Moonies Hill Energy	Flat Rocks Solar Farm	Solar	10.0	Note 2
Hadouken	Collie Solar Farm	Solar	20.0	Note 2
Carnegie Clean Energy	Mungari Solar Farm	Solar	100.0	Note 2
South Energy	Benger Solar farm	Solar	100	Note 2
Byford Solar Project	WestGen	Solar	30	Note 3
Kalbarri Microgrid Project		Solar	5	Note 3
Solar total			**279**	
Fremantle Wind Farm Team	Fremantle Wind Farm	Wind	9.6	Note 2
AMRCCE	Augusta Margaret River Renewable Energy Project	Wind	10.0	Note 2
Kondinin Energy	Kondinin Wind and Solar Farm	Wind	50.0	Note 2
Moonies Hill Energy	Flat Rocks Wind Farm	Wind	130.0	Note 2
Wind total			**199.6**	

Note 1 Appendix A Whole of System Plan Data and Assumptions Workbook, 29 Nov 2019. Government of WA. https://www.wa.gov.au/organisation/energy-policy-wa/energy-transformation-strategy

Note 2 CEC project database

Note 3 Clean Energy Regulator noted as probable

Projects are assumed to be commissioned between 2022 and 2027, with an even amount of capacity added each year between these dates.

In the Central scenario, 50% of the total proposed solar and total proposed wind is commissioned during this time; while in the High DER there is 20% and in the Step Change 100% is commissioned.

Appendix 7: PIlbara and Goldfields proposed projects included in scenarios

Projects for the PIlbara and Goldfields areas

Name	Participant	Type	Year	MW	Location	Source
Marble Bar	Horizon Power	Solar	2010	0.3	Pilbara	Note 1
Nullagine	Horizon Power	Solar	2010	0.3	Pilbara	Note 1
Karratha Airport	Karratha Airport	Solar	2016	1	Pilbara	Note 2
Chichester	Alinta	Solar	2020	60	Pilbara	Note 3
Port Hedland	Pilbara Solar	Solar	2021	10	Pilbara	Note 4
AREH	CWP Renewables	Solar	n/a	3,500	Pilbara	Note 5
Granny Smith Mine Solar		Solar	n/a	7.3	Goldfields	Note 6
Zenith Energy Solar Project		Solar	n/a	6	Goldfields	Note 6
TOTAL SOLAR				**3,584.95**		
AREH	CWP Renewables	Wind	n/a	7,500	Pilbara	Note 5
Agnew Gold Mine wind project		Wind	n/a	19	Goldfields	Note 6
TOTAL WIND				**7,519**		
Newman battery	Alinta	Storage	2017	35	Pilbara	Note 7

Note 1 ABB website, http://www.abb.com/cawp/seitp202/38567a1472ea578fc1257e8a0030a70d.aspx

Note 2 Arena projects. Karratha Airport Solar Plant https://arena.gov.au/projects/karratha-airport-solar-plant/

Note 3 Renew Economy, 7 June 2019. Alinta plans 60MW solar farm to slash energy costs for Pilbara mining giants. https://reneweconomy.com.au/alinta-plans-60mw-solar-farm-to-slash-energy-costs-for-pilbara-mining-giants-36470/

Note 4 Personal communication, Geoff James, Pilbara Solar (2019)

Note 5 Asian Renewable Energy Hub Press Release, 8 October 2018. https://asianrehub.com/wp-content/uploads/2018/10/AREH-Media-Release-8-October-2018.pdf

Note 6 Clean Energy Regulator (committed projects) Clean Energy Regulator. Data as at 31/12/2018. http://www.cleanenergyregulator.gov.au/RET/About-the-Renewable-Energy-Target/Large-scale-Renewable-Energy-Target-market-data/large-scale-renewable-energy-target-supply-data

Note 7 Renew Economy, 12 August 2019. Alinta sees sub 5-year payback for unsubsidised big battery at Newman. https://reneweconomy.com.au/alinta-sees-sub-5-year-payback-for-unsubsidised-big-battery-at-newman-78605/

Projects are assumed to be commissioned between 2022 and 2030, with an even amount of capacity added each year between these dates. In the Central scenario, 10% of the total proposed solar and total proposed wind is commissioned during this time; while in the High DER there is 50% and in the Step Change 100% is commissioned. No rooftop PV is included for the PIlbara as this is likely to be a small amount compared to the very large utility scale generators that are planned.

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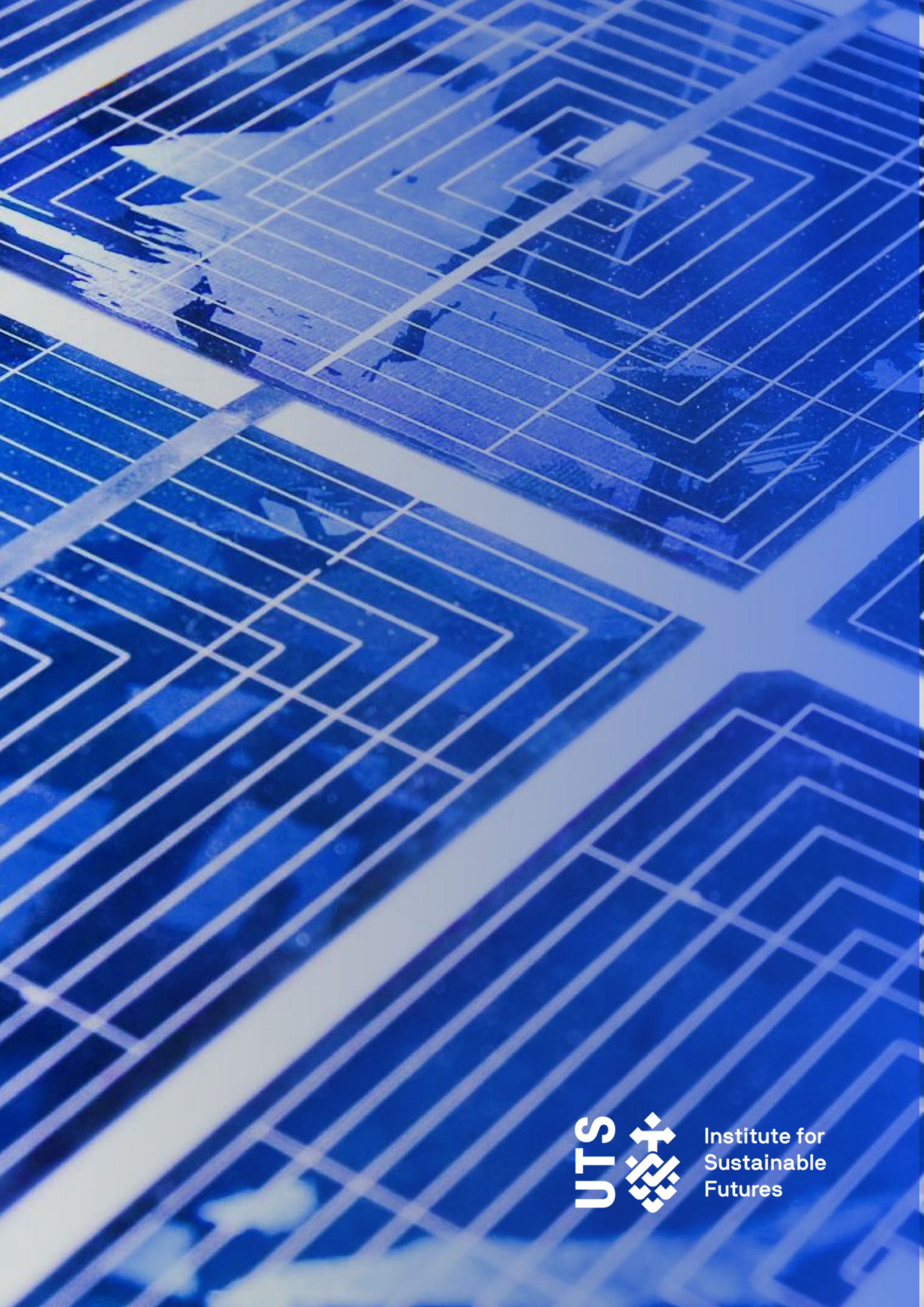
[19] Graham, P., Hayward, J., Foster J., and Havas, L. (2019) GenCost 2019-20: preliminary results for stakeholder review. Draft for review. December 2019. Appendix. Table B.1 Current and projected generation technology capital costs under the Central scenario.



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