UNIVERSITY OF TECHNOLOGY SYDNEY

Faculty of Engineering and Information Technology

A NEXUS APPROACH TO ENERGY, WATER, AND FOOD SECURITY POLICY MAKING IN INDIA

By

Garima Vats

A dissertation submitted in the fulfilment of the requirement for the degree Doctor of Philosophy

Sydney, Australia

2019

CERTIFICATE OF ORIGINAL AUTHORSHIP

I, Garima Vats, declare that this thesis, is submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the School of Information, Systems, and Modelling under the Faculty of Engineering and Information Technology at the University of Technology Sydney. This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis. This document has not been submitted for qualifications at any other academic institution. This research is supported by the Australian Government Research Training Program.

Production Note:
Signature: Signature removed prior to publication.

Date: 16. 08. 2019

Dedicated to my parents

Acknowledgement

While I was engaged in exploring the concept of ‘nexus’ (the central idea of my thesis), I saw a striking similarity in the last few years of my life to this concept. This thesis examines the interlinkages or ‘nexus’ between energy, water, and food and associated policy trade-offs across different domains. My life in past few years seemed no different, what with the interlinkages in all its facets, and the trade-offs they demanded.

While I was the exploring the concept of energy, water, food nexus from different domains or perspectives, I simultaneously discovered some aspects of my own personality, barely known to me earlier. While examining the policy trade-offs, I recognized the ones real life offers us – either to comfortably survive in your “business-as-usual” or to push your own boundaries and step out of your comfort zone. No words can describe my experience of last few years, however, I can certainly articulate some words to thank those without whom I could not have initiated and completed this journey.

First and foremost, I am most thankful to God for blessing me with favourable circumstances so that I could use the best of my abilities to be where I am today. Most heartfelt and sincere thanks to Professor Deepak Sharma for his immeasurable guidance and support for the completion of this thesis. His philosophical insights and vision about the subject matter, life, and beyond helped me look at things in different light and also shaped me into a better individual. I would also like thank Dr. Ritu Mathur for her continuous support throughout my candidature. My sincere thanks to Mr. Ravindra Bagia for his prompt and invaluable feedback on my work whenever needed. I also take this opportunity to thank Dr. Suwin Sandu for sharing his knowledge on the subject. I would like to extend my thanks to professional editor Hazel Baker, who provided copyediting and proofreading services according to the IPEd guidelines for editing research theses.

I would like to thank my sister Neha and my brother Apoorva for giving me the strength and courage at all times to complete this journey. Special thanks to my friends and colleagues at the University of Technology Sydney, Kristy Mamaril, Avinash Singh, Phuong Nguyen, Dr. Muyi Yang, and Anushree Mistry. Your sharing of the journey’s highs and lows made it so much more enjoyable. I would also like to thank some of my other friends, Ramandeep Kaur, Gaurav Kukreti, Hemraj Nagar, Tushar Saxena, Shegufa Zahedi, and Priyamvada Kayal who kept me motivated and helped me finish in their own capacities.

Lastly, I unreservedly dedicate this thesis to my parents, without whose incessant love and support I would not have been able to reach the final destination.

Table of Contents

List of Figures

List of Tables

List of Appendices

List of Abbreviations

AAY	Antyodaya Anna Yojana
AEZ	Agro-ecological zoning
AoA	Agreement on Agriculture
APDRP	Accelerated Power Development and Reforms Programme
ASP	Activated Sludge Process
BAT	Best Available Technologies
BAU	Business-as-Usual
BCM	Billion Cubic Metres
BPL	Below-poverty-line
BRICS	Brazil, the Russian Federation, India, China, and South Africa
BTS	Base Transceiver Station
CACP	Commission for Agricultural Costs and Prices
CAGR	Compounded Annual Growth Rate
CBM	Coal Bed Methane
CCS	Carbon Capture and Storage
CEA	Central Electricity Authority
CES	Constant elasticity of substitution
CET	Constant Elasticity of Transformation
CGDS	Capital Goods
CGE	Computable General Equilibrium
CHP	Combined Heat and Power
Comtax	Commodity Tax
CPCB	Central Pollution Control Board
CROPWAT	Crop water requirements
CSP	Concentrated Solar Power
DEA	Data Envelopment Analysis
EEFP	Energy Efficiency Financing Platform
EEIO	Environmentally Extended Input-Output
ES	Energy Security
EWF	Energy-water-food
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organisation Statistics
FBEP	Gross factor-based subsidies
FBR	Fast Breeder Reactor
FCV	Fuel cell Vehicle
FDI	Foreign Direct Investment
FEEED	Energy Efficient Economic Development
FS	Food Security
FTRV	Gross Factor Employment Tax Revenue
GDP	Gross Domestic Product
GHG	Green House Gas
GoI	Government of India
GST	Goods and Services Tax

GTAP	Global Trade Analysis Project
IAD	Institutional Analysis and Development
ICDS	Integrated Child Development Services
IESS	Indian Energy Security Scenarios
IGCC	Integrated Gasification Combined Cycle
IIUSE	Intermediate Use
ILO	Indian Labour Organisation
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
INM	Integrated Nutrient Management
INR	Indian Rupees
IO	Input-Output
ISA	International Solar Alliance
ISEP	Net Intermediate Input Subsidies
IWMP	Integrated Watershed Management Program
IWRM	Integrated water resources management
JNNSM	Jawaharlal Nehru National Solar Mission
JNNURM	Jawaharlal Nehru National Urban Renewal Mission
Kgoe	Kilogram of oil equivalent
LEAP	Long Range Energy Alternatives Planning system
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas
LUSET	Land use evaluation tool
LWR	Light Water Reactor
MARKAL	Market and Allocation
MBR	Membrane bio-reactors
MFAREV	Export Tax Equivalent of Multi-Fibres Agreement (MFA) Quota Premia
MLD	Million litres per Day
MMT	Million Metric Tonnes
MNRE	Ministry of Renewable Energy
MNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MoP	Ministry of Power
MOSPI	Ministry of Statistics and Programme Implementation
MoWR	Ministry of Water Resources
MRIO	Multi-Regional Input-Output
MSP	Minimum Support Prices
MSW	Municipal Solid Waste
MTEE	Market Transformation for Energy Efficiency
MuSIASEM	Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism
MW	Mega Watts
NAPCC	National Action Plan on Climate Change
NAS	National Account Statistics
NCAER	National Council of Applied Economic Research
NDC	Nationally Determined Contribution
NEP	National Environment Policy
NHM	National Health Mission

NICRA	National Initiative on Climate Resilient Agriculture
NITI	National Institution for Transforming India
NMEEE	National Mission for Enhanced Energy Efficiency
NMSA	National Mission on Sustainable Agriculture
NPK	Nitrogen-Phosphorus-Potassium
NSGM	National Smart Grid Mission
NSM	National Solar Mission
NSSO	National Sample Survey Organisation
NTPC	National Thermal Power Corporation
NURM	National Urban Renewal Mission
NWM	National Water Mission
NWQSM	National Water Quality Sub-Mission
PAT	Perform, Achieve and Trade
PDS	Public Distribution System
PFA	Power for All
PFCE	Private Final Consumption Expenditure
PFI	Population Foundation of India
PHWR	Pressurised Heavy Water Reactor
PKVY	Paramparagat Krishi Vikas Yojana
PLF	Plant Load Factor
PNG	Piped Natural Gas
PPP	Public-Private Partnership
PV	Photovoltaic
PWHR	Pressurized Heavy Water Reactor
R-APDRP	Restructured Accelerated Power Development and Reforms Programme
RBI	Reserve Bank of India
RGNDWM	Rajiv Gandhi National Drinking Water Mission
RPOs	Renewable Purchase Obligations
SAM	Social Accounting Matrix
SBR	Submerged Bed Reactor
SC	Super Critical
SDG	Sustainable Development Goals
SEEP	Super-Efficient Equipment Programme
SHM	Soil Health Management
SMAF	Sub-Mission on Agroforestry
SPM	Suspended Particulate Matter
SWI	Shannon Weiner Index
T&D	Transmission and Distribution losses
TARIFREV	Tariff Revenue
TFRV, ADV	Ordinary import duty, ad valorem
TPDS	Targeted Public Distribution System
UASB	Upflow Anaerobic Sludge Blanket Reactor
UDAY	Ujwal Discom Assurance Yojana
UIDSSMT	Urban Infrastructure Development Scheme for Small and Medium Towns
UJALA	Unnat Jyoti by Affordable LED for All
UNCED	United Nations Conference on Environment and Development

UNDP	United Nations Development Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations International Children's Emergency Fund
UNU	United Nations University
USC	Ultra-Super Critical
USD	United States Dollar
VDGM	Domestic purchases, by government, at market prices
VDPM	Domestic purchases, by households, at market prices
VST	Margin exports
VXMD	Non-Margin Exports, At Market Prices
WEAP	Water Evaluation and Planning,
WEF	World Economic Forum
WEO	World Energy Outlook
WRI	World Resources Institute
WS	Water Security
WSP	Waste Stabilisation Ponds
WtE	Waste-to-Energy
WTO	World Trade Organization
XTRV	Ordinary Export Tax

Abstract

Prompted by the rising concerns about the security of Energy-Water-Food (EWF) – innate human needs – and premised upon the contention about the siloedness, and hence inadequacy, of current policy approaches to redress EWF security – this research examines the efficacy of EWF nexus-informed policy-approach for redressing EWF security in the context of India – a country whose future prosperity is critically dependent on the provision of adequate quantities of EWF, at affordable prices and by sustainable means. To achieve this objective this research has developed an EWF-extended Input-Output framework (model), supported by flexible production functions to accommodate price-induced input substitution possibilities. This framework is employed in this research to examine the impacts – in terms of selected attributes for EWF security, economic, social and environmental outcomes, over the period 2015-2047 – of (five) alternative policy pathways (scenarios). These scenarios include: Business-as-Usual (BAU), Energy Security (ES), Water Security (WS), Food Security (FS), and EWF-Nexus-oriented (Nexus). Each scenario represents specific policy emphasis (e.g., ES scenario, on improving energy security; WS - water security, FS - food security, and Nexus - joint EWF security). Accordingly, each scenario is supported by a range of emphasis-relevant technologies and strategic measures to achieve its policy objective. The analysis in this research presents a rather insightful array of indications about EWF security, economic, social and environmental outcomes – over the short, medium, and long-term. For example, the ES scenario, while producing best energy security and economic outcomes in the long-term, is likely produce considerably worsened water security throughout the study period; and yield worst environmental outcomes in the short and medium-term. The FS scenario – while producing consistently superior food security outcomes, also produces the best water security outcomes in the short-term, and worst energy security outcomes in all time periods. The WS scenario, while producing considerably improved water security in the long-term, is likely to produce worst economic outcomes throughout the study period. Overall, the Nexus scenario produces the best joint EWF security outcomes, and considerably superior economic, social and environmental outcomes. These insights – especially cross-sectoral (e.g., energy, water, food), cross-domain (security, economic, social, environmental), and temporal (short, medium and long-term) trade-offs – should provide the Indian policy-makers a robust platform for engendering policy debate and making appropriate policy choices for redressing the EWF security challenge, and for other pressing challenges underscored by multiplicity of interdependencies. Therein resides the significance of this research – it is argued.

Chapter 1 Introduction

1.1. Background

Energy, water, and food form the very basis for humanity's existence. Not only are they basic human needs, they also contribute to the development and wellbeing of societies and the effective functioning and flourishing of economies. Prosperity and wellbeing without any of these resources is unimaginable. Yet a large number of people in the world still struggle to meet their basic energy, water, and food needs.

Worldwide, nearly 1.1 billion people lack access to electricity and 2.5 billion people rely on the traditional use of biomass for cooking (IEA 2017). Around 780 million people i.e., approximately one in nine people in the world, lack access to an improved water source. Around 805 million people, i.e., about 11.3 percent of the world's population, are undernourished, with insufficient food to meet the dietary requirements for an active and healthy life. Therefore, security of energy, water, and food water is likely to be a critical challenge for the years to come.

This challenge is more complicated to deal with due to the presence of interlinkages or interdependencies, commonly termed the '*nexus*', between energy, water, and food. With the passage of time and revolutionary transitions – from simple forms of energy like human and animal power to the more advanced forms of energy like electricity and fuel, these resources have become increasingly interdependent. Water is a critical input for different stages of food production as well as for energy extraction, processing, and generation. Similarly, energy is used for the provisioning, distribution, treatment, and disposal of water and is an essential input for the production and processing of food.

Further, demand for energy, water, and food is expected to rise in the future with increasing population, changing consumption patterns, continuing economic growth and developmental pressures. The United Nations projects that the world population will reach 9.8 billion[1] in 2050 (UN 2017, p.12), much of which is expected in under-developed and developing regions. There is also a global transition towards more resource-intensive technologies and diets. Meeting such high demands for energy, water, and food could be a formidable task.

[1] According to the medium-variant projection.

Economic growth and development often accompany exploitation of natural resources and environmental degradation. Climate change is likely to exacerbate the situation further as it affects resource (primarily, energy, water, and food) demand and supply, making the challenge even greater for regions that are already vulnerable to climate change and extreme weather risks. Ensuring EWF security is, therefore, a global concern and continues to be the main agenda for a large number of research groups, policy makers, planners, developmental organisations, think-tanks, advocacy groups and governments all over the world.

Efficacious policy and institutional settings are therefore required to promote multi-sectoral, multi-objective, and multi-stakeholder decision making. However, the design of such policy and institutional settings will need policy frameworks that can provide an insightful perspective on understanding the nexus and the associated trade-offs between EWF security and other developmental objectives.

In the face of ongoing fast-paced development, the inter-relationships between energy, water, and food – called the EWF nexus in this thesis – are of specific concern. Formally, acknowledgement of interactions between resources (originally food and energy) dates back to the 1983 United Nations University (UNU) conference (Sachs and Silk 1990). Subsequently, interlinkages between energy, water, food, and ecosystems were acknowledged in part and also between sub-systems of these resources like electricity and water. Finally, in 2011, the Bonn Conference formally introduced the idea of the EWF nexus and its significance in the development of a 'green economy'[2].

EWF Security and Associated Challenges

In his address to the UN's 66th General Assembly in 2011, the then Secretary-General of the United Nations, Ban Ki-Moon, emphasised the need to find common solutions to address cross-sectoral issues, stating:

> *"We must connect the dots between climate change, water scarcity, energy shortages, global health, food security and women's empowerment. Solutions to one problem*

[2] **Green economy** is defined by UNEP as 'improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities' (Sukhdev *et al*. 2010)

must be solutions for all." Ban Ki-Moon ('We the Peoples' Address to the 66th General Assembly, 2011)

Against this backdrop, the challenge in policy making for energy, water, and food security is twofold (**Error! Reference source not found.**). First, a 'nexus' approach is needed to account for the interlinkages between the Energy (E), Water (W), and Food (F) domains (commonly termed the EWF security nexus) – energy-for-water provisioning, water-for-energy production, and both water and energy as essential inputs for food production. Second, the alignment of EWF security with other development targets needs consideration, that is, to address any trade-offs between energy, water, and food security and the resulting implications for the society, economy, and environment.

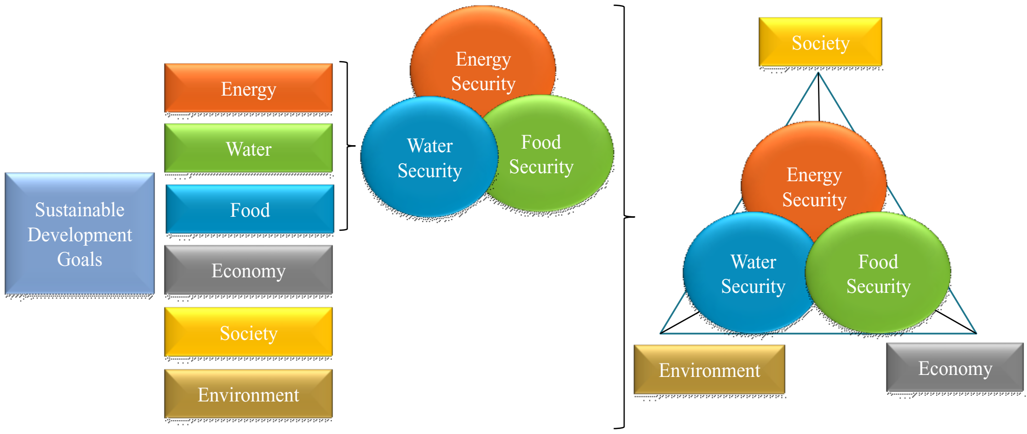


Figure 1-1: SDGs and the EWF Nexus

In addition, EWF securities are context-specific constructs, implying that the attributes defining them evolve with time and vary spatially. Spatial differences in characterising energy, water, and food security arise because of different socio-economic, cultural, or political settings, where concerns related to energy, water, and food vary.

The nexus between energy, water, and food security is of specific concern to developing countries as it is in these countries that the trade-offs between developmental needs, societal, and environmental concerns – against the backdrop of high population growth – are rather critical. This issue is of particular relevance to India because it is one of the fastest growing economies in the world.

India is currently home to almost 18 percent of the world population and by 2024 its population is projected to surpass that of China. The country will need to supply energy, water, food to roughly 320 million additional people between 2015 and 2050 (UN 2017). Further, the rising development in the country (leading to rapidly increasing per capita consumption levels), which could become comparable to India's developed counterparts in the future, and changing consumption patterns, multiplied by the ever-growing population, can lead to a manifold increase in future demand for energy, water, and food.

Such high levels of demand can pose a significant threat to energy, water, and food security; this makes providing equitable, safe and reliable access to basic needs like energy, water, and food one of the top policy priorities for India. Prior to addressing the security challenge, it is imperative to develop an understanding of the particular challenges related to energy, water, and food security in the country. These energy, water, and food security challenges for India are set out in the ensuing paragraphs.

Energy, Water, and Food Security Challenges in India

In 2016 India was ranked the third largest consumer of crude oil and petroleum products in the world after the United States and China (EIA 2018). Per capita primary energy consumption in India rose from 352 kgoe in 1990 to 534 kgoe in 2016-17 (WB 2018a, MoSPI 2018). However, the country does not even appear in the top 10 oil producers, indicating the high import implications to meet the demand (EIA 2018).

New initiatives to boost economic growth, like the Government of India's 'Make-in-India' project, to promote direct foreign investment in the manufacturing sector are highly likely to increase the energy requirements of the country significantly further. Additionally, rural electrification schemes like Deen Dayal Upadhyaya Gram Jyoti Yojana and programmes like '24 X 7 Power for all' to provide reliable and quality power supply will push demand to even higher levels. Specifically, the developmental model for the country rests on a sufficient, continuous, and secure supply of energy. These developmental aspirations, supported by an ever-increasing demand for energy, will require significant transformation of the energy supply complex in the country. This is likely to be a challenging task.

India is already highly reliant on imported energy to meet its demand. In 2016-17, for example, India imported almost 86 percent of its crude oil consumption and nearly 21 and 37 percent of its coal and gas consumption respectively (MoSPI 2018). The country's dependence on imported fossil fuels, i.e., its net energy imports as a percentage of energy use, increased from 8 percent in 1990 to 34.3 percent in 2014 (WB 2018b). The country depends heavily on imported crude oil, mostly from the Middle East. In 2016-17, India was the third largest consumer of crude oil in the world and the second largest crude oil consumer in the Asia-Pacific region after China (MoSPI 2018). These statistics are not just an indication of poor levels of energy security in the country but also of their potential economic consequences.

India has been grappling with the issue of energy poverty for a long time. Energy poverty in a developing country context refers mainly to access to modern energy services and to clean or pollution-free sources of energy for cooking and heating purposes (Brunner *et al*. 2018, p. 304). In 2015, for example, around 780 million people, mostly rural, relied on traditional biomass. The situation in terms of electricity access has improved recently, in that although 239 million people still lacked access, the country has made significant progress, reaching 82 percent of the population in 2016 from only 43 percent in 2000, and is likely to achieve universal electricity access in the early 2020s (IEA 2017).

Energy affordability is also a priority concern within energy security as a result of its direct association with social welfare. Rural households in India spend a higher proportion of their total household budget on energy (~ 6 per cent) as compared to urban households (~ 4 percent), when accounting for all fuels and electricity (Pachauri and Jiang 2008). Given the higher share of inefficient traditional fuels used in rural households, the rural poor often end up paying a higher price per unit of useful energy consumed compared to their urban counterparts (Mathur 2014).

Another social implication associated with lacking access to clean or pollution-free sources of energy for cooking and heating is indoor air pollution, mostly caused by the use of biomass. This is also a cause of increasing morbidity and mortality (Kankaria *et al*. 2014). Aside from energy use, energy supply also has social consequences, in that coal (especially underground coal mining) and nuclear energy production pose safety hazards to those directly employed by these industries as well as those living around coal mines and nuclear energy production facilities. Construction of large hydropower plants often requires massive displacement of population. As a result, there is high public resistance to the building of nuclear and large hydro power plants.

An example is the Kudankulam power plant where the local communities fear radiation risks, nuclear accidents, and effects on marine life and fish catch due to the discharge of water into the sea from the plant. This kind of resistance created by social acceptability issues has the potential to slow down the anticipated pace of development in energy supply.

The energy sector also has a noticeable environmental impact. Net greenhouse gas (GHG) emissions from the energy sector accounted for 58 percent of the total 1727.71 million tons of CO_2 equivalent (eq) emitted in India in year 2007 (MoEF 2010). In the past, coal was (and still is) the dominant fuel for power generation in India, generating in the process large quantities of air pollutants like nitrous and sulphur oxides (NO_x, SO_x), inorganic particles such as fly ash, carbonaceous material (soot), Suspended Particulate Matter (SPM), and other trace gases. High GHG emissions and the release of other pollutants from India's coal and lignite-based thermal power plants can be primarily attributed to the relatively low calorific value and high ash content of Indian coal coupled with inefficient combustion technologies (Mittal *et al*. 2012).

The above discussion suggests the challenges that India faces to meet its growing energy requirements for the development of its economy, while containing adverse impacts on the society and the environment.

India also faces formidable water security challenges. The country has the largest water footprint in the world, a total of 987 Billion Cubic Metres (BCM) per year, which equals 13percent of the global water footprint (Hoekstra & Chapagain 2007, p.43). In addition, a rapidly increasing population, changing consumption patterns, and altering supply due to factors like climate change have caused the per capita availability of water to drop.

Per capita availability of water declined from 1816 cubic metres (m^3) in 2001 to 1545 m^3in 2011 (PIB 2012); this is expected to fall further to 1341 m^3 by 2025 and to 1140 m^3 by 2050 (GoI 2017a), exacerbated by the fact that India is already a water-stressed country (Falkenmark *et al*. 1989). The repercussions of climate change like the melting of glaciers, changes in rainfall patterns, frequent floods and droughts cause additional threats to water supply (Arnell 1999, Arnell 2004, Gosain *et al*. 2006, and Yu *et al*. 2002).

At the same time, India is determined to become a major global economic player. This will be accompanied by rapid urbanisation and population expansion, thus exerting additional pressure on the country's water resources. Water security will therefore be of an enormous concern for India in the years to come. Further, the importance of water in India does not confine itself to just serving basic human needs and driving the economic production processes; water also embraces the religious sentiments of a majority of the population in the country.

Water resources in India are experiencing both quality- and quantity-related issues. There have been many incidents of inter-sectoral and inter-state conflicts over water in the past. Since India is also an agrarian economy, a significant proportion (almost 80 percent) of water is used by the agriculture sector in the country (Sharma *et al.* 2018, p. 9) and therefore the large number of small and marginalised farmers are the most vulnerable to water shortages.

Water stress affects not only crop productivity but also the livelihood of farmers (including many small and marginalised farmers), which leads in turn to social tensions. Between 2001 and 2010, around 6,000 farmers committed suicide in the Vidharbha region of the Indian state of Maharashtra. While several factors contributed to these suicides, scarcity of water for irrigation and lack of irrigation facilities was a major contributing factor (Boyle, 2012).

The situation in the domestic sector is no different. Providing access to adequate and safe drinking water as well as sanitation is crucial. Water supply in urban areas at present varies widely across cities. In a sample of 1400 cities across India, the average per capita supply was only 69 litres per capita per day (lpcd), as opposed to the norm of 135 lpcd (IIHS, 2014). It is also noteworthy that water distribution within cities is not equitable and hardly any city receives a 24×7 supply (WSP, 2014). In 2015, 37 and 72 percent respectively of the urban and rural populations had unimproved sanitation while 10 and 61 percent respectively of the urban and rural populations practised open defecation (UNICEF and WHO 2015).

While urban areas desire a continuous supply of water, a large population of rural India had no access at all to clean and safe drinking water until very recently. In 2015, for example, 54 percent of the urban population and 16 percent of the rural population lacked access to piped water. Although in the same year, 94 percent of the population had access to an improved drinking water source[3], which comprised 93 percent of the rural population and 97 percent of the urban population (UNICEF and WHO 2015). Such high numbers, however, often hide underlying issues, such as low service coverage, high water losses and non-revenue water, inefficient metering, billing and collection and high staffing levels (WSP 2011).

[3] Improved drinking water source has been defined to include piped water on premises (piped household water connection located inside the user's dwelling, plot or yard), and other improved drinking water sources (public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs and rainwater collection).

Water quality issues have also emerged as a major water-related concern in the country. These issues have evolved over the years from being limited mainly to the biological contamination of surface water sources caused by poor sanitation and waste disposal to the more recent addition of chemical pollution of groundwater from such elements as arsenic, fluoride, iron, nitrate, and salts as the major contaminants (GoI 2011). Some of these elements, like arsenic and fluorides, are serious health hazards (Jadhav *et al*. 2015).

Water-related issues also differ between surface and groundwater, which could be attributed to two factors: relatively higher accessibility and replenishment of surface water, and higher stability of groundwater, for instance during periods of drought (OECD 2013; p.6). The latter makes groundwater a preferred source of irrigation. Groundwater and electricity use for agriculture is also highly under-priced, which results in inefficient use of water and encourages a shift towards water-intensive crops. Consequently, irrigation charges do not cover even operating costs, leading to poor maintenance standards that reduces efficiency further (MoWR, 2014, p.6). Therefore, groundwater as a common pool resource needs a better legal and regulatory structure.

The water sector in India is characterised by lack of infrastructure, inadequate treatment facilities, under-recoveries, high subsidies, poor efficiencies, and poor coverage. Private sector investment is still in its nascent stages and the private sector's role is limited to project level than to the sectoral level as a whole (Bhardwaj 2005, WSP 2011). For example, the estimated sewage generation of urban areas in 2015 was 62,000 Million litres per Day (MLD) while the treatment capacity was just 23,277 MLD, i.e., only around one-third of wastewater in urban areas is treated (Singh *et al*. 2017).

Pricing in the urban water sector has received much criticism, including low pricing of urban water in relation to costs incurred, under-pricing resulting in poor service and reduced incentives to expand area coverage of services, and counteracting the prime objective of large-scale subsidisation to make clean water affordable for the poor (Mathur & Thakur 2006).

To support the last criticism, the same authors point out to the evidence that the poor pay more than the non-poor, often two to three times if coping costs are included, and the price subsidy meant for them and built into tariff structures is appropriated by non-poor households. Poor targeting of subsidies on private taps and the lack of private connections further prevent the urban poor from benefiting from water subsidies. The above-mentioned water-related issues in India point to an enormous challenge for the country.

In terms of its food security status, India is a laggard among fast-growing economies. Almost 24 percent of the world's undernourished people live in India. According to the 2014 Global Hunger Index, India ranked 55 among 120 countries in terms of food insecurity (von Grebmer *et al*. 2014). Despite the long-standing subsidised access to food grains made available to the poor in India, the country still has the second-highest estimated number of undernourished people in the world (FAO, IFAD and WFP 2015). India is also home to one of the biggest malnourished populations in the world.

Food insecurity in India is characterised by inadequate calorie intake and under-nutrition, excess intake of dietary energy leading to obesity and related health issues and pervasive micronutrient deficiencies (Narayana 2015). Feeding an adequate diet to such a large population would require extensive growth in the agriculture sector, particularly given the declining net per capita availability of food grains from 186 kg in 1991 to 170 kg in 2015 (GoI 2016a). The changing composition of the food basket, from coarse cereals to superior cereals like rice and wheat, and from vegetarian to animal product-based diets (FAO 2006, Gandhi and Zhou 2014), is likely to significantly increase the demand for both food and animal feed in the years to come.

Ensuring food security for all, for example, is likely to lead to even higher food demand estimates. In the business-as-usual case, total grain demand is projected to increase to 291 Million Metric Tonnes (MMT) by 2025 and to 377 MMT by 2050, including feed demand for grains which is expected to increase manifold, from a mere 8 MMT in 2000 to 38 and 117 MMT by 2025 and 2050, respectively (Amarasinghe *et al*. 2007, p. 22).

To meet the rising food demand, production of food grains in the country rose from 52 MMT in 1951-52 to 252.02 MMT in 2014-15 (GoI 2016a, p. 84). Exports climbed from just over 5 billion US Dollars (USD) in 2003 to more than 39 billion USD in 2013 (USDA 2014).

Driven by the success of the Green Revolution in the 1960s, India has become a net exporter of food. Despite that, the country imports significant quantities of particular grains; its import of pulses, for example, almost doubled in the last decade and is currently estimated to be more than 3 MMT, accounting for around 15–20 per cent of total domestic production (Bhattacharjya *et al.* 2017).

Food claims the highest share of expenditure for urban and rural Indian households[4]; for example, in 2011-12, 38.5 percent of total consumption expenditure in urban households and 48.6 percent of total consumption expenditure in rural households was spent on food (MoSPI 2013). Food affordability is, therefore, a major concern for India.

Futher, the Indian agriculture is characterised by declining crop yields due to various factors such as changing cropping patterns, reducing soil fertility resulting from poor management of agricultural inputs like water, fertilisers, and pesticides. Additional factors compromising the agricultural sector are declining availability of manpower in agriculture due to rural-to-urban migration, small land holdings, low productivity, high domestic consumption, supply-chain losses and constraints, market inefficiencies, low level of processing, and lack of credit and marketing facilities (GoI 2012, Banerjee 2013).

Another critical challenge affecting food security in the county is the operational aspect of food procurement and distribution (Narayanan 2015). The main limitations of the existing Public Distribution System (PDS) run by the Indian government to provide subsidised food grains to the below-poverty-line population are poor coverage, cost ineffectiveness and costliness of the system, high storage losses, low marginal impact, weak targeting, and leakages into the free market (Ahluwalia 1993, Nawani 1994, Radhakrishna *et al.* 1997).

Further, in many cases, lack of infrastructure hinders physical access to food sources. Rural areas lag behind in the transport infrastructure that facilitates public access to markets, particularly accessibility to roads. Whereas national highways and state highways are well maintained, with more than 90 percent surfaced, urban and rural roads are not in good condition. Only 48 percent of rural roads are surfaced (MoSPI 2014). Hence, development of physical infrastructure like road and rail networks is essential for food security.

Food production also causes significant environmental damage. The agriculture sector in India contributes to a sizable amount of carbon emissions, mainly because of the high energy use in agriculture for crop production and processing, rice cultivation, poor management practices such as excessive application of fertilisers and pesticides. The injudicious use of fertilisers, in particular, nitrogen, is one of the fundamental causes of environmental pollution such

[4] For a uniform reference period (URP)

as eutrophication and GHG emissions (Davidson *et al*. 2014). Further, the inefficient use of water causes soil salinity and waterlogging issues.

Excessive applications of nitrogenous fertilisers can result in increased leaching of nitrates into groundwater and more emission losses to the atmosphere. Organic fertilisers represent a priority for Integrated Nutrient Management (INM) (Wu and Ma 2015). Further, Phosphorus (P)—used as a major agricultural nutrient in India—is a potentially scarce resource and the country imports significant amounts of phosphorus fertilisers and almost all the potassium fertilisers it uses as there are no indigenous sources of potash (Keil *et al*. 2018, Kinekar 2011).

Another issue of critical concern concerning food security in India is high post-harvest and storage losses. India suffers costly post-harvest fruit and vegetable losses every year, mainly due to the absence of food processing units, modern cold storage facilities and high post-harvest losses (ET 2013). Large quantities of food grains and horticulture produce go to waste due to a lack of adequate post-harvest facilities like silos, cold storage, and refrigerated transportation facilities.

The country's cold storage facilities are inadequate in their capacity compared to the total production of fruits and vegetables, and most of these cold storage facilities are subject to erratic electricity supply. Road transportation of food and agricultural products is difficult because of the poor state of existing road infrastructure, particularly in rural areas. Further, there is a large number of intermediaries between the farmer and the consumer, which results in high incidence of wastage and loss across the supply chain as well as needless price mark-ups at every stage (Kumar and Basu 2008)

Taking into consideration the challenges mentioned above, the growing population and the possibility of drought, the country's proposition to be self-sufficient in food is undermined (Bhardwaj 2016).

India's rapidly growing economy, urbanisation, technological advancements, industrialisation, emerging consumerism, changes in lifestyle and consumer preferences are all intensifying the pre-existing demands for resources like energy, food and water. The resulting shifts in consumer behaviour and choices can exacerbate environmental impacts. Hence, ensuring the security of food, water and energy for India has a significant bearing on achieving inclusive, equitable and sustainable growth.

Apparent Links Between Energy, Water, and Food

The nexus between energy, water, and food is particularly conspicuous in the Indian agrarian economy because it is heavily reliant on groundwater for agriculture and is one of the highest national groundwater extractors in the world (Gleeson and Wada 2013). In absolute terms, globally, India has the largest area under irrigation from groundwater, followed by China and the USA. In fact, groundwater covers about 70 percent of India's irrigated area and provides about 80 percent of its domestic water (Briscoe and Malik 2006, p.8).

Additionally, India's power sector is highly reliant on water-intensive fuels like coal, nuclear and hydro and is projected to remain so in the future (Chikkatur *et al*. 2009). NCIWRD (1999) projected that water demand by the energy sector in India will increase by about 2.5 times by 2050. At the same time, over half the existing and planned capacity for major power companies, like NTPC, Tata Power and Reliance Infrastructure, is located in areas that are considered to be water-scarce or water-stressed (Sauer *et al*. 2010).

There has been considerable debate in India over growing '*food-versus-fuel*', given its ambitious food and energy security targets. High agriculture water withdrawals have prompted the government to promote water-use efficiency in crop production. This initiative has gained momentum of late, including in the recent speech by the current Prime Minister, Narendra Modi, on the occasion of the 86th foundation day of the Indian Council of Agricultural Research (ICAR). Prime Minister Modi said, 'I am on a new mission of *per drop - more crop*…. With each drop of water saved, we can usher in a new era of progress and prosperity' (NDTV 2016). Lately, the Indian media has also started to highlight the significance of a nexus approach to energy, water, and food security (Kapoor 2017, Srivastava 2017).

Energy, water, and food are also inextricably linked to the environment. Energy production and use in food, water and other sectors is a significant contributor to carbon emissions globally as well as in India. Environmental concerns in India have escalated to unprecedented heights due to uncontrolled urbanisation and industrialisation, leading in turn to the degradation of air and soil quality, to noise pollution, land scarcity and so on, thereby affecting people's quality of life.

India emitted 6.6 percent of global emissions in the year 2014. This share is expected to grow, considering the country's low base of 2.5 tons of emissions per capita, which is just 37 percent of the global average (WRI 2014, Dubash *et al*. 2018). Around two-thirds of emissions originate from the energy sector and within the energy sector, about 77 percent of emissions comes from electricity generation (Chakrabarty 2018).

Environmental protection also includes combating climate change. India is a signatory to several environmental commitments globally, such as the Paris Agreement, and therefore it is imperative for the country to align energy, water, and food policies with ecological sustainability. India's Nationally Determined Contribution (NDC) sets targets for 2030 to lower the emissions intensity of gross domestic product (GDP) by 33 to 35 percent from 2005 levels (PIB 2015).

Other than dealing with the challenge of energy, water, and food security and their intrinsic environmental linkages, India is also grappling with a number of social issues, one leading to the other. These include population explosion, socio-economic disparity, poverty, infant mortality, illiteracy, unemployment, corruption, gender discrimination, urbanisation, health, sanitation and many others. India ranks 131out of the 187 countries on the United Nations Development Programme (UNDP) human development index in 2016 (UN 2016). Human and social development, therefore, needs to keep pace with economic growth for developing nations like India.

This further implies that plans or policies to address the challenge of energy, water, and food security should not conflict with the aims and objectives of social development. This situation therefore calls for a holistic approach in planning and policy making. Driving resource security initiatives without recognising other inter-sectoral, social or economic linkages can also lead to sub-optimal outcomes for the economy, the environment and society. From the discussion above, it is quite evident that there is a complex web of interlinkages between energy, water, and food securities, but that this web also influences a host of other competing factors like society, environment, geopolitics and so on.

This research contends that although the recognition of the interplay between energy, water, food, and other socio-economic domains has been there for quite some time, policies and decisions concerning energy, water, and food security are implemented without due regard to the nexus between these resources and associated economy-wide trade-offs. Further, these interlinkages are complex, and finding redress to the challenge of energy, water, and food security requires a deeper understanding of the nature of the nexus.

The existing literature on the nexus between energy, water, and food in India largely analyses energy, water, and food linkages between only two of these resources (Ghosh 2017, Singh *et al*. 2012, Miller *et al*. 2012, Ghosh *et al*. 2016, Harris *et al*. 2017, Green *et al*. 2018, Hira 2009, Rajagopal 2008). Some studies focus predominantly on the nexus from the perspective of a particular resource, for example, water, and consecutively analyse water use for energy and food production while ignoring the reverse relationships (NCIWRD 1999, Amarsinghe *et al*. 2007). Recently, however, there has been some interest in developing studies that consider all three resources.

Giampetro *et al*. (2013a), for example, explore the EWF nexus in future grain production in the Indian state of Punjab. Ramaswami *et al*. (2017) analyse the EWF nexus in India from an urban perspective, in particular for the capital city Delhi. Notwithstanding the usefulness of these studies for state-level policy guidance, there is limited granular understanding of the EWF nexus from a macro policy perspective.

Ozturk (2015) examines the EWF nexus employing dynamic panel modelling in the BRICS (Brazil, the Russian Federation, India, China, and South Africa) countries using past data. A food security index is the response variable in the model developed in this study, which is composed of three variables—agricultural machinery, land under cereal production, and agricultural value added. The study provides directional indications of relationships between energy, water, and food and concludes that the food security index is affected by energy shortages and inadequate water resources. This assessment, although useful, is insufficient to gain insight into the magnitude of the linkages and a comprehensive picture of the energy-water-food relationships from, say, a water and energy security perspective.

The prime objective of this research, therefore, is to analyse the nature of the nexus between energy, water, and food and its implications on India's society, economy and environment, particularly where evidence of such understanding is limited in the existing stream of literature despite the criticality of energy, water, and food security in the country.

Examination of the EWF nexus in the Indian context presents a special case typically demonstrative of developing economies where developmental goals need to be aligned with sustainability while coping with increasing demand for these resources due to population pressures and changing consumption patterns.

A comprehensive understanding of the nature of the nexus and its implications can support the development of more informed policy choices for attaining energy, water, and food security for India.

1.2. Research Objectives

Against this backdrop, the principal research objective of this research is
'*To examine the interlinkages between energy, water, and food securities, with a view to facilitating a more informed, integrated and comprehensive approach to policy making to redress the energy, water, and food security challenge in India.*'

The primary objective comprises following four sub-objectives:

1. To review the existing framing and methodologies used to examine the energy, water, and food security nexus – and identify a methodological framework to be applied in this research.

2. To develop a broader perspective on the 'security' of energy, water, and food resources in the Indian context.

3. To develop the framework identified in Objective 1 for empirical investigation of the energy, water, and food security nexus to determine the potential trade-offs resulting from alternative scenarios, driven by nexus-based or non-nexus-based security considerations, in order to satisfy future demand for energy, water, and food water.

4. To examine the effectiveness of a nexus approach in guiding policy development for achieving energy, water, and food security in India.

1.3. Research Framework

Figure 1-2 presents the overall framework used for this research. Each component in the framework correlates to the methods applied in the research.

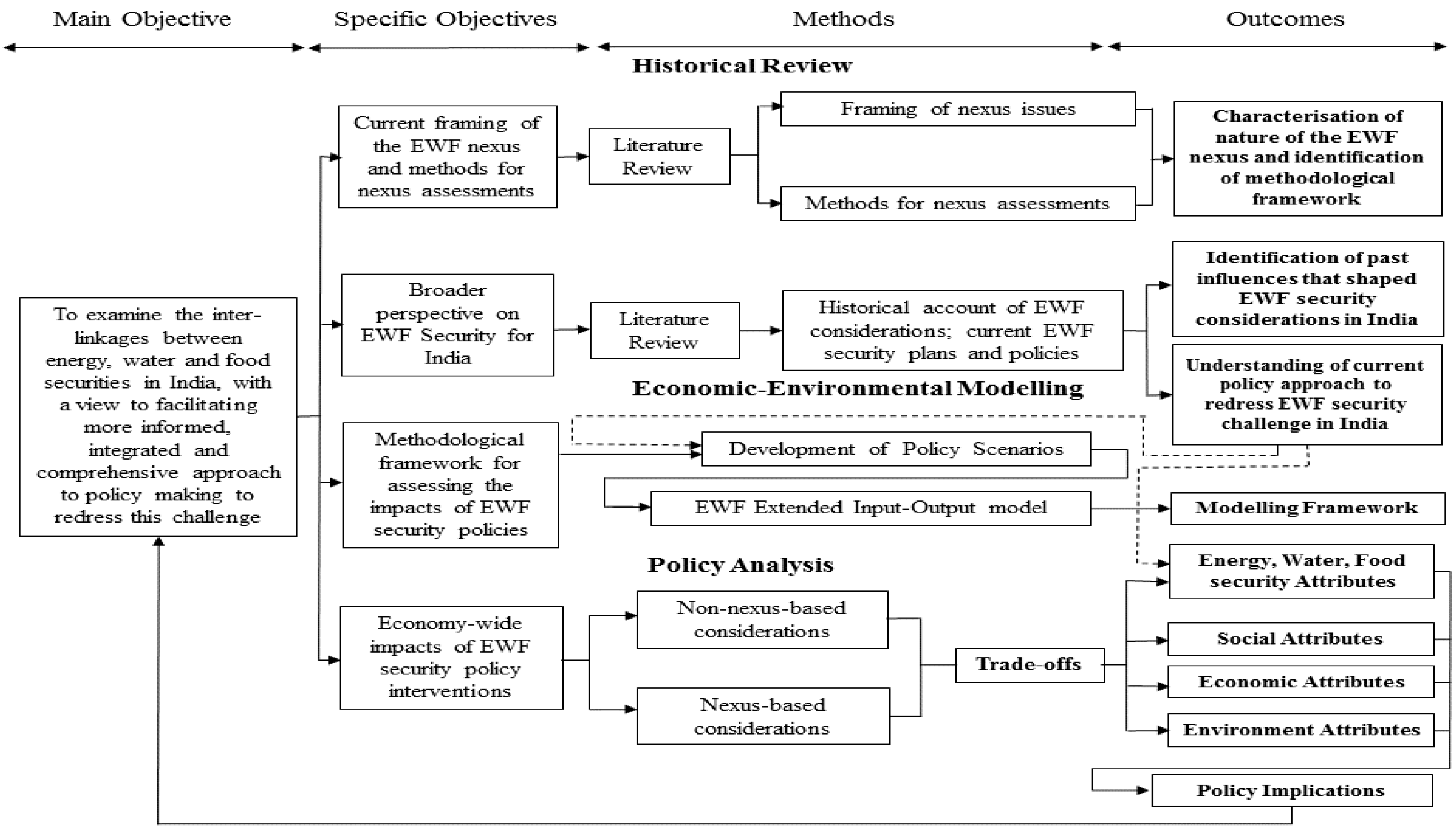


Figure 1-2: Research Framework

1.4. Research Methods

Historical Review

The review is undertaken with a view to understanding the security of energy, water, and food for India that aligns with the second objective of this research. The review is conducted by first examining the origin of security-related concerns, tracing the expansion of security concerns from military to human security; this is further extended to include natural resources like energy, water, and food. The historical review assists in comprehending the energy, water, and food security challenge in India through tracing energy, water, and food considerations from ancient times to the present time.

Current policies and strategies to redress the energy, water, food security challenges are also reviewed. This is followed by the conceptualisation of alternative techno-economic pathways under different security considerations to demonstrate likely future developments, primarily in the energy, water, and food sectors. These reviews are instrumental in the selection of attributes (or indicators) to represent in this research the different kinds of securities (E, W, F), socio-economic and environmental outcomes in the Indian context.

Modelling

The methodological framework used in this research is shown in Figure 1-3. This framework consists of three major components: a) *Scenario development*, b) *Analytical framew*ork, and c) *Impact attributes.* The Input-Output (IO) model is the methodological base chosen for this research, based on an extensive review of methods for assessing the energy, water, and food nexus.

The first component of the framework involves the development of scenarios. The second component is the methodology used to model the impacts of the various scenarios based on nexus and non-nexus considerations. An Energy-Water-Food extended Input-Output model is developed as the analytical base for analysing energy, water, food security policy scenarios. The last component involves selecting attributes to represent different EWF securities, and socio-economic and environmental outcomes for India. Trade-offs between the EWF securities and the social, economic, and environmental outcomes demonstrate the scenario implications.

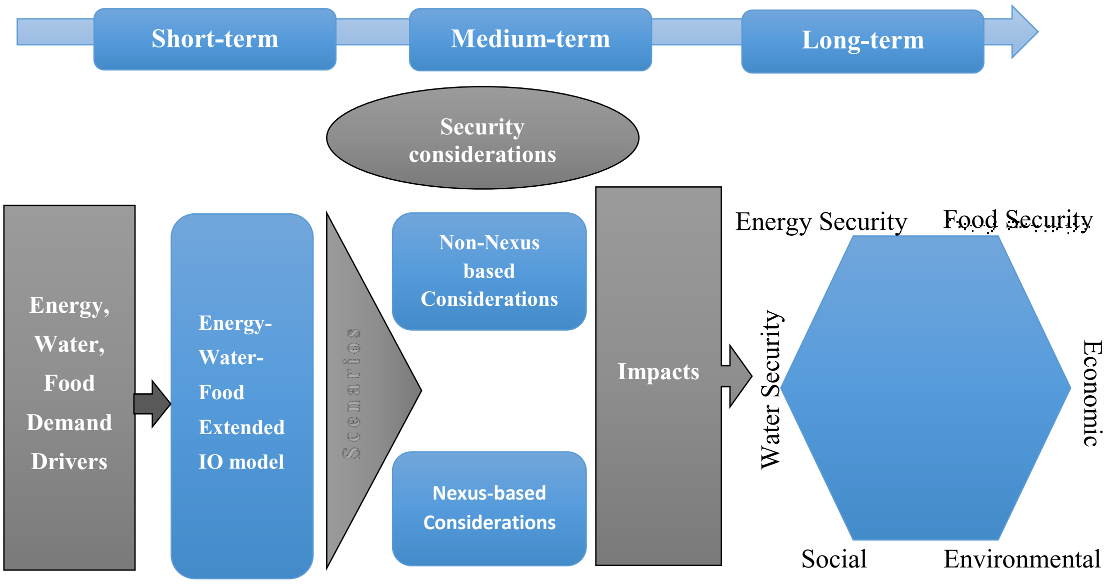


Figure 1-3: Methodological framework

Selection of the methodology involves several steps:

The methods used to assess the EWF nexus assessments are categorised into groups on the basis of base analytical approach employed. The base analytical approaches are grouped into accounting, simulation, optimisation, statistical, participatory and integrated methods.

Six attributes have been used to examine various methods. These are:

a) Domain coverage indicates the extent to which a particular method is capable of analysing the simultaneous influence of multiple domains on the nature of the nexus.
b) Analytical capability: ability to rigorously analyse trade-offs across different domains and comprehensively accommodate, assimilate, and process large amounts of data/information relating to the complex inter-relationships between EWF, including underlying drivers, variables, and assumptions.
c) Context specificity: flexibility in demonstrating the impacts of different contexts (e.g., cultural and traditional perspectives, development philosophies, price effects, market structures, governance arrangements etc.).
d) Temporal flexibility: the ability to analyse trade-offs between securities across different time frames.
e) Methodological transparency: ability to articulate clearly, effectively and transparently model assumptions, analytics, levels of analysis, traceability of relationships among model variables, understanding of data used in the model, understanding of model components at different levels, and understanding of the model as a whole, and

f) Computational simplicity: simplicity of computations, data presentations, representation of results and underlying trade-offs to be comprehensible to policy makers.

Based on this review, an Input-Output (IO) model with modified production functions is selected for this research. This framework allows assessment that is not biased towards any of the resources (energy, water, or food), is rigorous yet straightforward, transparent and allows simultaneous examination of multiple domains of the nexus while capturing context-specific elements of energy, water, and food security. The model is also capable of long-term assessments after some modifications to the methodology.

The IO models represent the economy as a system of interrelated goods and services, expressed in terms of the underlying interdependencies between different economic sectors at disaggregated levels. It therefore captures the national accounts at both aggregate (such as GDP) and disaggregate (such as industry value added) levels. It also captures the trade dependencies through export and import linkages. Hence, it is an effective analytical framework for examining the regional, sub-regional, or national economy-wide impacts of sectoral policies and strategies aimed at redressing the EWF security challenge.

The modelling exercise comprises six stages. The first stage involves the development of baseline information that primarily consists of the base-year IO matrix for India and corresponding sectoral energy, water, food, employment, land, and carbon accounts. The base-year IO matrix is obtained by rebasing the 2011 year matrix to the base year 2015, followed by disaggregation of the IO coefficients to represent the EWF sectors to a fairly disaggregated level to reflect policy, technological, and institutional changes. The EWF sectors are reorganised to follow an order. The second stage involves the determination of the baseline scenario, based on future trajectories of population and macroeconomic variables, and current plans and policies. The third stage involves the implementation of alternative techno-economic scenarios by exogenously changing the IO coefficients.

In the fourth stage, relative changes in energy, water, food, and material prices are estimated in response to changes in the input mix due to technological shifts. The sectoral price effects are evaluated using the IO price model. In the fifth stage, substitution effects in response to changes in energy, water, food, and material prices are analysed. Production functions to investigate the substitution effects between inputs are based on Constant Elasticity of Substitution nested production functions. Substitution possibilities between domestic and imported commodities are analysed using Armington elasticities of substitution. In the sixth and final stage, the economy-wide impacts of nexus and non-nexus-oriented policy options are examined. In addition to energy, water, and food security levels, these include environmental, economic, and social impacts. Trade-offs between the short, medium and long term are also examined.

Policy Analysis

The policy implications of different scenarios, based on nexus and non-nexus considerations, are analysed.

A baseline scenario (also called Business as Usual (BAU) scenario in this research) is created in this research for comparison with alternative cases. The baseline scenario assumes the continuation of prevailing government plans and policies for each of the energy, water, and food sectors. Four alternative scenarios, each underpinned by different EWF security considerations, are examined that are underpinned by different energy, water, and food security considerations. For instance, an energy security scenario assumed particular emphasis on developing an energy secure future for the country while other sectors like water and food progress as per the BAU scenario. Similarly, a water security scenario places specific emphasis on promoting a water secure future, with the food and energy sectors remaining at BAU levels. A comparison of these scenarios is made to ascertain overall security levels achieved from each scenario and the trade-offs associated with each of them in short- to long-term time frames.

1.5. Scope of Research and Data Considerations

This research focuses on India and the broad structure of the sectors in the Indian economy covered in the model is shown in Figure 1-4. The sectoral classification is sourced from the Global Trade Analysis Project (GTAP) database 9.0 for the year 2011(Aguiar *et al.* 2016), which is more recent than the Indian national account statistics where the last IO table published is for the year 2007. The GTAP database is considered a credible source due to the contributions by economists from the National Council of Applied Economic Research (NCAER) in India (Chadha and Tandon 2012).

The original GTAP data with 68 sectors is disaggregated into 93 sectors to suit the purpose and focus of this research, which is primarily on the energy, water, and food sectors of the Indian economy. For instance, coal-based electricity is disaggregated into Sub-critical (Sub-C), Supercritical (SC), Ultra-supercritical (USC), Coal Pre-combustion Carbon Capture and Storage (CCS), and Coal Post-combustion CCS technologies. Gas-based electricity generation is disaggregated into gas-based generation and gas-based CCS. Nuclear-based electricity generation is disaggregated into Pressurised Heavy Water Reactor (PHWR), Light Water Reactor (LWR), and Fast Bed Reactor (FBR) technologies.

Renewable sources of energy used for electricity generation, like hydro, is disaggregated into large and small hydro. Wind-based electricity generation is disaggregated into onshore and offshore generation. Other source-based electricity generation is disaggregated into biomass and waste-based. Solar-based electricity is disaggregated into Photovoltaic (PV), Concentrated Solar Power (CSP), and distributed solar technologies.

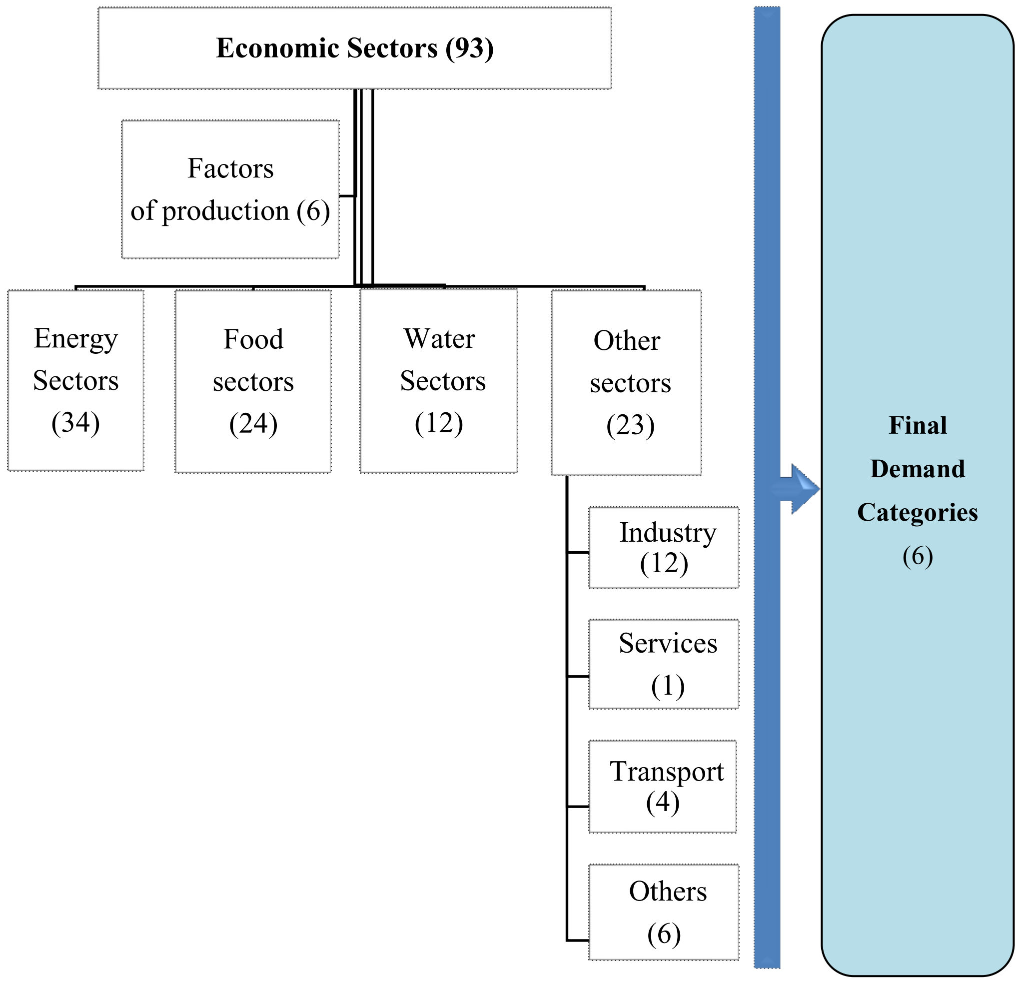


Figure 1-4: Model Coverage

The basis of this disaggregation is to provide a representation of the current and possible future electricity generation technologies in India. The breakdown of sectors is in accordance with the model developed by the leading policy think tank of the Government of India (NITI Aayog), namely, Indian Energy Security Scenarios (IESS) 2047, to analyse different energy security pathways (GoI 2015a).

The energy-intensive sectors mentioned in the IESS 2047 model are highlighted separately in the model used in this research. The chemicals and petrochemicals sector in GTAP is disaggregated in this research into fertilisers, chlor-alkali and other chemical and petrochemicals. Other non-energy-intensive light manufacturing sectors are aggregated to constitute one sector '*Other manufacturing*', while the fertiliser sector is further disaggregated into nitrogen, phosphorous, and potassium fertilisers to analyse the demand for soil nutrients in different scenarios.

The water sector is disaggregated into 12 categories representing water supply and use in different sectors, i.e., municipal water treatment and supply, and wastewater treatment, agriculture (pumping and irrigation), domestic, and industries. The water sectors also include alternative sources of water, such as desalination and treated sewage water (reuse of treated wastewater).

The agricultural sector comprises different food commodities and energy crops. Food commodities are disaggregated to represent differences in food consumption patterns. For instance, the *Other grains* sector is disaggregated into jowar, bajra, maize, and other grains. The fruit and vegetable sectors is disaggregated into roots and tubers, other vegetables, fruits and nuts, and pulses. The cane and beet sector is disaggregated into sugarcane and sugarbeet. Other crops include bio-energy crops like jatropha. An overview of the detailed sectoral disaggregation and model coverage is provided in Chapter 5.

This research develops five scenarios to represent different likely futures for India, namely, Business-as-Usual (BAU), Energy Security (ES), Water Security (WS), Food Security (FS), and Nexus-oriented scenario. These scenarios cover a vast range of policies and technological combinations that are currently being discussed or are considered to be relevant in the Indian context.

The period for analysis in this research is 2015-2047. The base-year IO is obtained by rebasing the 2011-12 IO table for India available from GTAP. The scenario years are chosen to represent the short, medium and long term are 2022 (end of the 13th five-year plan), 2032 (end of the 15th

five-year plan), and 2047 (end of the 18^{th} five-year plan) respectively. The premise behind the choice of these scenario years is their accord with the five-year planning system of India. The year 2047, coincidentally, also marks 100 years of independence of the country.

As mentioned above, this research requires a wide range of data on energy, food, agriculture, water, the economy, and the environment. These data are collected from different published sources and supplemented by communication with experts and professionals working in these sectors of the economy. An overview of the data considerations for each specific objective and further details of the data sources and data preparation for modelling purposes for this research are discussed in **Error! Reference source not found.**.

Table 1-1: Data Considerations for Each Specific Objective

Specific objective (s)	Data requirements	Data Availability	Data Sources	Data Gaps	Strategies to overcome gaps
1	Information on the EWF nexus – Origin, development, current framing, and methods for nexus assessments	Yes	Books, journal articles, reports	Minor	N/A
2	Information on historical events; EWF sector plans and policies in the past and expected future developments	Yes	Books, journal articles, reports, legislation, and policy papers	Minor	N/A
3	a. India IO tables for base year b. GDP growth rates c. Share of urban and rural populations in private consumption d. GDP component shares	Partial	Statistical handbooks, annual statistical reports, and journal articles	No Yes No No	Rebasing 2011 IO Assumptions* Assumptions*
4	a. Population growth rate b. Working age population (in 15-60 the age group) projections c. Employment by sector (skilled and unskilled) d. Labour productivity improvement e. Skill development (%) f. Water – future demand and supply** g. Energy – future demand and supply*** h. Food – calorific values i. Feed conversion ratio j. Seed and waste (%) k. Food demand projections l. Land use m. Carbon emissions	Partial	Statistical handbooks, annual statistical reports, journals articles	Yes Yes No No Partial Partial Yes Yes Yes Yes Partial Partial Yes	 Assumptions* Assumptions* Assumptions* Assumptions* Assumptions* Assumptions* Assumptions*

*The bases for various assumptions are provided in Chapter 5,**Water intensities, technological developments, and efficiency improvements; ***Energy intensities, technological developments, and efficiency improvements

1.6. Significance of the Research

This research is a significant endeavour to analyse the interlinked web of energy, water, and food securities in the Indian context which is an issue of utmost significance not just for India, but globally. While energy, water, and food security are centrally placed in the global and national policy agendas, little is known about the implications of the EWF nexus for the successful implementation of such policies.

This research comprehensively analyses the foundation, nature, and evolution of the EWF nexus in the literature. It then highlights gaps in the existing framing of the nexus, including the treatment of nexus considerations in policy and decision making. Such advancement in knowledge will build stronger foundations for future researchers to address this issue, which is of paramount importance, with policy-relevant solutions.

The methodology used in this research is a significant addition to existing methods used for analysing the EWF nexus as it combines information on energy, water, and food sectors without creating any bias towards any specific resource, and it does so in a computationally transparent manner.

Methodologically, this research exemplifies how the traditional IO approach can be extended to analyse a complex question of much policy significance. This extended approach offers a unique combination of macroeconomic and bio-physical perspectives on the nexus and hence allows different dimensions of the nexus to be covered.

This research is, to the best of this researcher's knowledge, the first most comprehensive assessment of the EWF security nexus for India. The recommendations put forward in this research should benefit the principal planning and policy advisory organisations of the country involved in the development and implementation of short- and long-term energy, water, and food policies. Further, the outputs of this research can benefit a range of other interests, for example, investors, business communities, researchers, governments and the community at large.

1.7. Organisation of the Thesis

This thesis comprises seven chapters.

Chapter 2 comprehensively reviews the evolution of EWF nexus research in the literature, including each of the sub-linkages: energy-water, water-food, and food-energy, both in the Indian and global contexts. The chapter further reviews how the EWF nexus is framed in the existing literature and lists the major limitations of the current framing to redress the EWF security nexus.

Chapter 3 reviews the different methods used in the literature to examine the nexus. This chapter presents the limitations of existing methods for examining the nexus and the policy relevance of these assessments resulting from these methods. The chapter includes some suggestions on how nexus assessments could help strengthen the design of frameworks to guide policy making and how such strengthening could improve policies to redress the challenge. This information provides a basis for the selection of a methodology for this research.

Chapter 4 involves understanding EWF security in the Indian context. It begins by analysing the historical evolution of 'security' in the global context—notably how it expanded from military to energy, water, and food security. Next, understanding of the EWF security challenge in India is enhanced by a brief historical account of EWF considerations in the country. The chapter also reviews current policies in India to redress the EWF security challenge with a view to analysing the current approach to EWF security policy making in India.

Chapter 5 presents the methodological framework for this research along with the three key components, i.e., scenario building, analytical approach, and impact attributes. First, this chapter provides brief scenario storylines, based on current and alternate policy pathways, informed by the discussion in Chapter 4. Next, the chapter describes the methodological base for the analytical approach used in this research, elaborating on its analytical underpinnings and the step-by-step modelling procedure to assess the scenario impacts. The chapter then provides information on some essential modelling aspects, particularly scenario assumption and variables, model calibration and validation, and the key data sources used for modelling and preparation of the framework. Lastly, this chapter presents the selection of the various impact attributes applied in this research to the Indian context to demonstrate the impacts of different scenarios.

Chapter 6 presents the empirical findings resulting from analysis of the different scenarios regarding individual impact attributes for EWF security and social, economic and environmental outcomes, including their trade-offs, in the short, medium, and long term. Further, trade-offs between equally weighted composite EWF securities, social, economic, and environmental outcomes for different scenarios are examined. This analysis is extended to a comparison of the BAU scenario with alternative policy scenarios. This chapter concludes with an analysis of policy implications and provides recommendations based on the results and key findings.

Chapter 7 presents the broad conclusions and contributions of this research, followed by a discussion of its limitations and recommendations for future work.

Figure 1-5 depicts the structure of the thesis in a graphical form.

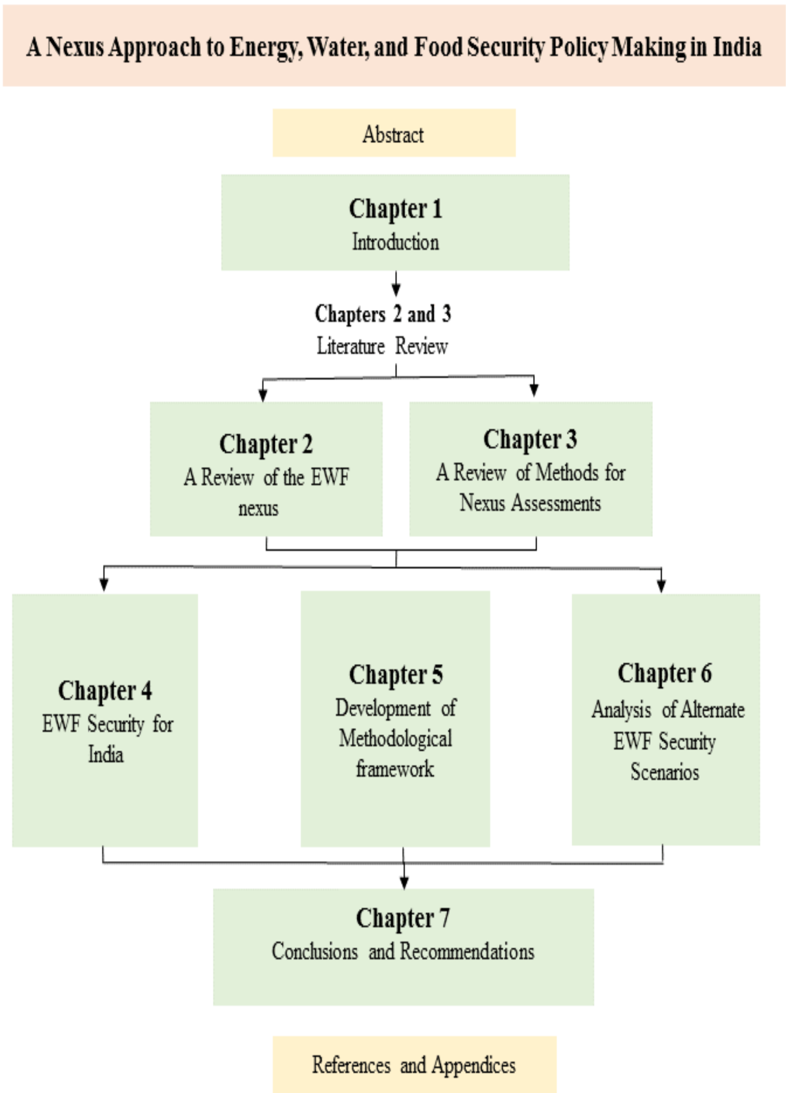


Figure 1-5: Structure of the Thesis

Chapter 2 . A Review of the EWF Nexus

Energy, water, and food are basic human necessities. Demand for them has risen rapidly in recent times, and is likely to rise even faster in the coming times as population growth, industrialisation, urbanisation, and economic prosperity accelerate. By 2050, for example, global demand for energy, water, and food is expected to rise by 61, 55, and 60 percent, respectively (WEC 2013; WWDR 2015; Alexandratos and Bruinsma 2012).

Provisioning the required amounts of these necessities at affordable prices and in sustainable ways, against the backdrop of emerging concerns about climate change and rising inequality, is likely to stretch the limits of human ingenuity to unprecedented levels. Energy-Water-Food (EWF) security – the commonly-used expression to convey the enormity and complexity of this challenge – has consequently emerged as a policy priority across the world. The explicit inclusion of security concerns in the Sustainable Development Goals (SDGs) (Energy – SDG 7, Food – SDG 2, Water – SDG 6) is a testimony to the increasing recognition of the importance of the topic.

The underlying complex nature of interlinkages between energy, water, and food (i.e., the 'nexus'), however, has made the EWF security challenge a complicated issue to understand and redress. A prerequisite accordingly for redressing the WEF security challenge is efficacious policies that acknowledge the criticality and complexity of the nexus and are able to responsibly accommodate (articulate, resolve) diverse nexus related interests.

Considerable commentary has been developed on the EWF nexus in the last decade – more prominently since the Bonn conference of 2011 – recognising the importance of nexus and its inherent complexity. Notwithstanding the usefulness of this commentary, there is still a lack of commonality in understanding the nature of the nexus between energy, water, and food resources. This review will primarily focus on the major motivation/drivers for interest in nexus thinking, and how such thinking is reflected in the framing of the question being investigated.

Previous literature reviews on the EWF nexus have significantly contributed to analysing drivers behind the emergence of nexus thinking, exploration of how 'integration' is understood in the EWF nexus (Al-Saidi and Elagib 2017), and examining the current state of nexus research in terms of global distribution (Endo *et al*. 2015a). The reviews, however, lack an understanding of the drivers behind investigations of the EWF nexus since it has emerged, which in turn shapes the current framing of the EWF nexus, and how it is conceptualised, particularly for guiding EWF security policy making.

The objective of this chapter is therefore to complement and extend the existing knowledge of the EWF security nexus through a comprehensive examination of the key motivations/drivers for interest in nexus thinking and how has such thinking contributed to the framing of nexus, which means how energy, water, and food security issues are framed in the literature for guiding policy formulation, investments, and decision making for EWF security in context of the larger goal of sustainable development.

The review in this chapter is organised as follows: Section 2.1 outlines the evolution of nexus research by focusing on each of the links within the EWF nexus. Section 2.2 develops a panoramic overview of the nature of the nexus. Section 2.3 provides a review of the current framing of the nexus as inferred from the literature and suggests the major limitations of such framing. Section 2.4. provides the summary and key inferences from the chapter.

2.1. Evolution of the EWF Nexus Research

In the context of interlinked resources, the origin of 'nexus' terminology has been described in Chapter 1. It is imperative to understand all the interactions within the nexus in order to present a fully informed analysis of the EWF nexus itself. The interactions within the EWF nexus are divided into three separate linkages that gained recognition much before energy, water, and food were collectively considered as intertwined, namely, energy-water, water-food and energy-food.

2.1.1. Energy-Water

Gleick (1994) delivered the first most comprehensive work on the energy-water nexus. This study included both water needs for energy production through different sources of energy, including renewable and non-renewable, and energy needs for water provisioning, focusing mostly on pumping, distributing and desalinating sea water.

Water withdrawal and consumption for energy production have been assessed by several researchers at the extraction, processing, refining and conversion stages of energy production, namely Babbit and Lindner (2005), Pan *et al*. (2012), Klein and Rubin (2013), Meldrum *et al*.

(2013), Macknick *et al*. (2012), and Delgalo (2012). Primary fuels taken into consideration in the recent literature include biofuels since their emergence as a potentially viable alternative energy source to reduce dependence on oil imports and meet low carbon emission targets. However, there are increasing concerns about the water required for the large-scale implementation of bio-energy (Gerbens-Leenes *et al*. 2009, Gerbens-Leenes *et al*. 2012, Elena and Esther 2010, De Fraiture *et al*. 2008).

Assessing the water requirements for power generation has become popular in the literature since the negative implications of power generation from current and future water shortages have been recognised, as already witnessed in the temporary or permanent shutdown of power plants or, in some cases, delays in the commencement of power projects.

The electricity-water link has been studied either individually or as a component of the energy-water nexus at various spatio-temporal levels. While some studies (Carrillo and Frei 2009, Delgado 2012, Macknick *et al*. 2012, IEA 2012; Keller *et al*. 2010, Mielke *et al*. 2010, Ackerman and Fisher 2013, Fthenakis and Kim 2010, Sattler *et al*. 2012) have recognised, quantified and examined the current state of the linkage between electricity and water, few have forecast the future development of this linkage under various presumed scenarios (Srinivasan *et al*. 2017)

Throughout the literature, water requirement is assessed in terms of both consumption and withdrawals. It is essential to consider water withdrawals due to the unavailability of that water for other users during withdrawal periods. Hence, Macknick *et al*. (2011) acknowledge both water withdrawal and consumption values to be essential indicators for water managers determining the power plant impacts and vulnerabilities associated with water resources.

Concerns about the electricity-water nexus include water allocation issues in hydroelectric power generation. Trade-offs have been analysed under different water availability and allocation scenarios – another popular theme in the energy-water nexus literature. Gjorgiev and Sansavini (2018), for instance, examined water constraints on electricity generation under changing climatic conditions, while Bashir and Elagib (2018) analysed dam operation scenarios to examine trade-offs between water losses and energy generation.

The association of the energy-water link with carbon emissions is popular in the energy-water nexus literature due to the growing implications of the energy-emissions link for water. Carbon-reduction technologies such as CCS further increase demand for water as a consequence of additional fuel use to make up for energy penalties and the demands of the carbon capture system (Ramirez *et al*. 2013, Mielke *et al*. 2010). As a result, some studies have examined the impacts of low carbon technologies on water consumption in power plants, options such as CCS to meet climate objectives (Merschmann *et al*. 2013, Clemmers *et al*. 2013), or switching to cleaner fuels (Grubert *et al*. 2012).

Energy and water dependencies have been studied in various scenarios with varying energy demand trends, power generation fuel mixes, cooling technologies and biofuel production (Kahrl and Roland-Holst 2008, Carrillo and Frei 2009, Siddiqi and Anadon 2011, Gheewala *et al*. 2011, IEA 2012). The World Energy Outlook (WEO) suggested a general trend across all scenarios towards higher water consumption by the energy sector from 2010 to 2035 (IEA 2012).

The literature on energy for water includes municipal water pumping, treatment and distribution, wastewater treatment, recycling and, finally, disposal. Energy sources analysed include electricity (Kenway *et al*. 2008), energy embodied in chemical production, transportation of materials, and operation (Racoviceanu *et al*. 2007). Energy use at the pumping (especially in water deficit regions) and treatment stages is reported to have the highest environmental impact on water systems (Friedrich *et al.* 2007). The energy-water nexus has also been analysed in industries other than electricity, such as the manufacturing industry (Thiede *et al*. 2017).

The energy consequences of water treatment (Racoviceanu *et al*. 2007, Gleick and Cooley 2009), technologies like reverse osmosis (McGinnis and Elimelech 2008), and freshwater conservation like desalination (Semiat 2008) have been analysed in a few studies. Owen (1982), Tillman *et al*. (1998), and Houillon and Jolliet (2005) assessed the life-cycle energy consumption of wastewater treatment. Stokes and Horvath (2006) comprehensively mapped the interactions between all sectors of the economy and identified product and service supply chains.

Groundwater pumping and electricity linkages are prominent in developing nations where agriculture accounts for the lion's share of total water use in the form of irrigation. The irrigation-energy link also embraces a strong societal link for most of the developing countries where agriculture employs a majority of the population. Tushaar Shah, an economist and public

policy specialist, has deeply explored groundwater use through the lens of energy efficiency (Shah 2007), human development (Shah 2006), and policies, institutions, and governance (Mukherji and Shah 2005) at global and national levels (Scott and Shah 2004, Shah *et al*. 2002, Shah 2003, Shah, Giordano and Wang 2004, Shah *et al*. 2008).
The policy and institutional aspects of the energy-water link includes, for example, investigating the impact of a joint carbon and water tax on the power sector (Nanduri and Saavedrea-Antolinez 2013), or interactions between energy policies and water technology development (Liang and Zhang 2011).

To summarise, the literature on energy and water interlinkages includes water use for energy production at different stages of the supply chain for different fuels and technologies, including alternative forms of energy like biofuels. Energy-for-water provisioning includes energy consumption for pumping for irrigation, and different technologies and processes in the municipal water supply chain, such as pumping, distribution, treatment, wastewater treatment, recycling, and disposal. The carbon link with energy and water is a more recent focus in the literature.

Energy and water linkages are prominent in India due to the high dependence of the country on water-intensive fuels, like coal and hydro, in electricity generation. Water pricing in India is still in its nascent stages and the electricity generators therefore lack incentives to save water in the power plants. It is only recently that this link has gained attention due to frequent shutdowns as a result of water shortages and concerns about planned water capacity in India.

The Government of India carried out a comprehensive assessment of water use in a coal-based power generation station (CEA 2012). Srinivasan (2018) projected water withdrawals and consumption under different scenarios for electricity generation in India under various assumptions of economic growth, power plant cooling policies, and electricity CO_2 emissions reductions on water withdrawals and consumption.

Another crucial link being examined recently in India is the energy-water link in biofuel production (Rajagopal 2008). Biofuel production in India is permitted only through non-food crops, moreover on wastelands in the country. *Jatropha curcas*, the primary crop used for bio-diesel production, is drought tolerant, but contrary to common belief, this crop requires less water; in fact, it requires 750–1000 mm water to achieve economic production (Wani 2016).

Energy assessments of municipal and household water and wastewater treatment in the country are mostly recent. While some studies analyse the patterns of water-related electricity consumption at the household level (Ghosh *et al*. 2016), others assess the energy and carbon emissions associated with water provisioning and wastewater treatment (Ghosh 2017, Singh *et al*. 2012; Singh *et al*. 2016, Miller *et al*. 2012).

Examination of energy and groundwater linkages is relatively popular (Gupta 2002, Scott and Shah 2004, Mukherji 2007, Shah *et al*. 2012). Some studies also assess the impact of different options in groundwater irrigation, like water allocation, energy pricing (Kumar 2005), and use of renewable technologies for groundwater pumping and irrigation (Purohit and Kandpal 2005, Kumar and Kandpal 2007).

2.1.2. Water-Food

Briggs and Shantz (1913, 1914) produced one of the earliest and most comprehensive assessments on plant water requirements. There is no dearth of studies recognising the increasing stress on water resources for agricultural or food production, thereby acknowledging a tight relationship between food security and water security. A broad consensus on considering water saving in agriculture as low-hanging fruit for water security, particularly in agriculture-centric economies, led to the emergence of the 'more crop per drop' research paradigm. Merrey (1997) introduced this paradigm in work that included precision irrigation technologies along with water management practices like changes in agricultural practices, the introduction of less water-intensive crop varieties, increasing water-use efficiency of irrigation, and so on.

Another important concept developed in relation to the management of water resources is the water footprint concept, which Hoekstra introduced in 2002 (Hoekstra 2003). The concept was applied to inhabitants of a country and nations as being the cumulative virtual water content of all goods and services consumed by one individual or by all the individuals of one country (Hoekstra and Hung 2002). Several studies have examined the association between national water footprints and virtual water flows in relation to international trade, particularly for crops (Hoekstra and Chapagain 2005), or have compared water footprints with ecological footprints (Hoekstra 2007). Mekonnen and Hoekstra (2014) later developed water footprint benchmark values for a large number of crops grown around the world and the concept is now used at various levels that include products, companies, individual consumers, and nations.

Despite an in-depth knowledge in this regard, large-scale implementation of water saving practices and technologies in food production is minimal. Friedrich and Kassam (2009), Friedrich *et al*. (2009), and Monaghan *et al*. (2013) all identified such barriers as lack of knowledge, expertise, inputs, adequate financial resources, infrastructure, and poor policy support as being responsible for the inability to upscale such practices and technologies or for them to reach the traditional farmers. Hence, new ideas or concepts to prevent water scarcity for food production emerged.

Ren *et al*. (2018) explored linkages of land, food, and water to see how shifts in cultivated crops can prevent overuse of water resources without adversely affecting food supply. Apart from the apparent water-food linkage at the field level, water use for food production, in particular, fresh water for seafood production in aquaculture (given changing dietary patterns) has emerged recently in the literature as a concern (Gephart *et al*. 2017)

Trade of agricultural commodities from water-rich to water-scarce regions has recently emerged as one of the potential solutions to prevent the water crisis from obstructing food security. Although food trade seems to be a globally-agreed solution to addressing water scarcity, it has also been established that local water scarcity is alleviated through the import of agricultural goods to parts of some countries, and intensified through exports from parts of other countries. Therefore, taking into account the indirect and direct effects of policy measures that impact global trade, such as trade liberalisation, trade barriers or agricultural subsidies is advocated (Biewald *et al*. 2014).

There are also arguments in the literature against food trade as a strategy to combat water shortages. Allan (2003), for instance, argued that, for developing countries, the notion of virtual water appears to threaten local farming livelihoods in the importing regions, and thus social linkages need consideration.

Optimal water pricing for irrigation is also a popular suggested measure to promote optimal use of water (Seagraves and Easter 1983, Sampath 1992, Johansson *et al*. 2002). However, it is suggested that pricing alone is not an effective means of encouraging water conservation under current irrigation management institutions, and clearly defined and legally enforceable water rights and responsibilities for water operators and users are needed to support incentives for conserving water and improving irrigation efficiencies (Yang *et al*. 2003).

Further, some studies have contributed to assessing the impact of changing food preferences, due to globalisation or increasing affluence, on water demand for food production. Chartres and Sood (2013), Amarsinghe *et al*. (2007), Odegard and van der Voet (2014), Liu and Savenjie (2008), and Hess *et al*. (2015) have emphasised the stress on water resources due to the changing composition of food baskets. There is wide agreement that a shift to more water-intensive products like meat or from coarse to fine cereals can potentially affect water demand from the food and agriculture sector.

For a holistic understanding, some studies take into account the impact of other influencing factors on the water-food nexus, like land use (Odegard and van der Voet 2014; Das *et al*. 2015), climate (Chartres and Sood 2013, Misra 2014, Hanjra and Qureshi 2010), society (Rosegrant and Ringler 1999), and the economy (Biewald *et al*. 2014, Calzadilla *et al.* 2013). Odegard and van der Voet 2014 stress improving supply-side efficiency to reduce food demand and consequently water demand.

In summary, the water-food nexus literature can be divided into three major themes: a) agricultural misuse and mismanagement of water, for which different strategies have been analysed, including pricing, irrigation technologies, restructuring of water institutions, and so on; b) food trade as a potential option for addressing current and future water shortages, and c) the impact of changing dietary patterns on water resources. The literature suggests that the understanding of water as a limiting factor in food production is not new. The assessment of water and food interlinkages with other factors like energy, environment, land, society, economy, and changing food consumption patterns is, however, a much more recent focus.

Water and food linkages are very prominent in the Indian economy since agriculture is the dominant water user in India. Around 80 percent of all water used in India is consumed in agriculture (Dhavan 2017). Agricultural subsidies have encouraged wasteful use of water for irrigation in India and electricity subsidies, for instance, have been found to be responsible for groundwater overdraft (Badiani and Jessoe 2013).

Studies carried out in the Indian context focus mostly on the water and food security challenge, primarily from water management and demand perspectives while attaining food security (NCIWRD 1999, Kumar 2003, Amarsinghe *et al.* 2007, Hira 2009). Another recent area of study related to the water-food nexus is the water and emission footprints of dietary patterns in India (Harris *et al.* 2017, Green *et al.* 2018).

2.1.3. Energy-Food

Interlinkages between energy and food roughly date back to the 1970s – around the ime of the energy crisis – with speculation about the impact of the energy crisis on food production because of the high dependence of food supply chain on energy resources (Black 1971, Pimental *et al.* 1973). This speculation materialised when one of the primary reasons attributed to the increase in global food prices from 2002 onwards was a steep rise in petroleum prices (Cassman and Liska 2007, Trostle *et al.* 2011).

Much of the earlier work on energy use is on industrialised economies, especially the United States (Leach 1975, Steinhart and Steinhart 1974, Alvani and Chancellor 1977). Further work deliberated about improving energy efficiency and using renewable energy for food production to reduce the consumption of limited fossil fuels (Green 1978). Similarly, organic farming systems were found to be less energy-intensive than conventional farming systems (Dalgaard *et al.* 2001).

A few studies have also explored different factors affecting energy productivity in agriculture over time, like price changes, size of land holdings, technological changes, resource degradation caused by farm management in the form of soil erosion, groundwater depletion, reduced genetic diversity, pest resistance, and so on. Cleveland (1995a) depicted a clear response of farmers to higher energy prices, which resulted in technical and managerial changes that finally improved energy productivity.

The literature covers different forms of energy, like sunlight, human labour, animals, fuel, and electricity. Further, input energy use in agriculture has been classified as direct and indirect (Cleveland 1995b, Kennedy 2000, Singh 2002, Mandal *et al.* 2002, Singh *et al.* 2003, Ozkan *et al.* 2004). Direct energy includes human power, diesel, and electrical energy used in production processes, while indirect energy consists of pesticide and fertilisers. Cao, Xie and Zhen (2010) also took into consideration indirect energy in the form of machinery and biological energy and used the term ‘embodied energy’ to account for both direct and indirect forms of energy used in China’s agriculture sector. Another related concern in the literature is the excessive and unmanaged use of indirect energy like fertilisers and pesticides for food production that leads to land degradation, which in turn affects crop productivity (UNCCD 2013)).

A more recent emerging link between energy and food is biofuel production. Promotion of energy crops, generally called biofuels, is high on the global agenda and this can be attributed to a number of reasons like rising energy prices, increasing concerns about energy security and climate change, the eco-friendly nature of biofuels, and the income expectations of farmers and other investors (von Braun and Pachauri 2006, Kaltschmitt *et al.* 1997). However, this also instigated the 'food-versus-fuel' debate.

Following the rapid rise in food prices from 2005 to 2008, some researchers have assessed biofuel production as a cause for rising food prices. The literature highlights conflicting views in this regard.

Ajanovic (2011) observed no significant impact of biofuel production on feedstock prices. Rathmann *et al.* (2010), Zhang *et al.* (2010) advocated that production of biofuels had contributed to increasing food prices in the short term and indicated no direct long-term price relationship between fuel and agricultural commodity prices. A similar study conducted by Kochaphum *et al.* (2013) revealed that bio-diesel implementation in Thailand had a minimal effect on palm oil price, and the net socio-economic impact was negative.

Conversely, Mueller *et al.* (2011) assessed that biofuel production made a modest (3%-30%) contribution to the increase in commodity food prices observed up to mid-2008 and Mitchell (2008) concluded by citing substantial increase in biofuel production in the US and the EU to be the most crucial factor for the rapid rise in food prices. Also, most of these studies recommended non-food crop-based biofuels, i.e., second and third generation, to mitigate any impact of biofuels on food security.

Additionally, since biofuels are one of the most land-intensive forms of energy production, McDonald *et al.* (2009) make the linkage of land with the energy-food nexus an important issue for deliberation. Fargione *et al.* (2008) and Christopher (2008) advocated that clearing of land in favour of biofuel crops and the consequent loss of forests, peatlands and grasslands would aggravate global warming and climate change. Escobar *et al.* (2009) recommended the establishment of international cooperation, regulations and certification mechanisms for the use of land, and the mitigation of environmental and social impacts caused by biofuel production.

Recognition of the inter-relatedness of food and energy dates way back in the literature. Energy is a useful input in food production. However, there are two major concerns regarding the influence of energy on agriculture (and food): a) excessive use of non-renewable fossil energy and its related consequences on energy security and the environment, and b) replacement of food crops with energy crops. Both of these can possibly lead to an increase in food prices, which would be a threat to food security. As a consequence, energy security can negatively influence food security. Similarly, ensuring food security can also potentially hamper energy security in situations of energy shortages and inefficient energy use.

Energy and food linkages are particularly crucial in the Indian agrarian economy, since agriculture is the primary occupation of the majority of the population. At the time of independence (1947), a majority of the population was engaged in agriculture and post-independence, the agriculture sector was the prime focus of the Indian government for boosting the economy and developing society.

Improvement in farm productivity was highly prioritised during the Green Revolution that commenced in India in the early 1960s. This productivity was achieved by introducing high-yielding varieties, development of minor and major irrigation projects, and promoting the use of fertilisers. Further, there were advancements in the use of modern cultivation technologies (farm mechanisation), agricultural research and development, and farm extension and marketing services. As a result, there were manifold rises in energy consumption in agriculture from that period and to the present (Jha *et al.* 2012). Further, exploitation and misuse of subsidised agricultural inputs like seeds, fertilisers, irrigation, and electricity partly contributed to the sharp increase of energy use in agriculture.

The energy-food link in India has been assessed in existing studies with a view to improving energy productivity of agriculture, for instance, through auditing the energy consumption of cropping patterns or particular crops (Chaudhary *et al.* 2006, Parikh and Ramanathan 1999, Singh *et al.* 2002, Singh *et al.* 2003, Singh *et al.* 2007, Chauhan *et al.* 2006).

Biofuel production is another emerging concern that could potentially create antagonistic connections between food and energy. India currently imports more than 75 percent of its crude oil consumption (Verma 2018). Amidst increasing demand for oil, high import dependency, and concerns surrounding energy security and the environmental impacts of energy use, the country introduced biofuels around the turn of the millennium. The government of India has been making sustained efforts since 2002 to introduce biofuels as a blend in ethanol and diesel to reach a 20 percent ethanol blend and a 5 percent bio-diesel blend by 2030 (National Biofuel Policy 2009 and 2018, National Mission on Bio-diesel 2003, Government of India 2002; 2003).

A few studies have investigated the feasibility and impacts of biofuels on food prices and land use in India. Schaldach, Priess and Alcamo (2011) demonstrated linkages between driving forces (such as population change) and policies (such as biofuel usage) in India that will affect land-use change over the coming decades. Similarly, another study by Rajgopal (2008) examined the implications of India's biofuel policies for food, water, and the poor. Khan *et al.* (2009) mainly focused on bio-diesel prospects from micro-diesel production in India.

2.1.4. Some Further Discussion

Table 2-1 summarises the key themes covered in the literature about different interconnections of energy, water, and food. Understanding the current and potential future development in these interlinkages is essential for producing a fully informed analysis of the EWF nexus.

Table 2-1: Major Themes Covered in the Literature on Energy, Water, and Food Interconnections

Energy, Water, and Food Interconnections	**Key themes covered in the literature**
Energy-Water	• Water consumption of energy generation technologies • Energy consumption of water technologies • Water allocation for energy generation versus other uses • Water consumption for biofuel production
Water-Food	• Water intensity of food crops • Changes in water footprint due to shifts in dietary intake and food trade patterns
Energy-Food	• Energy productivity of food production • Impacts of biofuels on food security

The next section presents a discussion on the nature of EWF nexus

2.2. Nature of the Nexus

The discussion above highlights the different linkages within the EWF nexus. These inter-relationships are both synergistic and antagonistic. The EWF nexus is also vested in multiple domains or dimensions. This research broadly classifies these domains into five categories: physical, economic, social, environmental, and institutional (Figure 2-1).

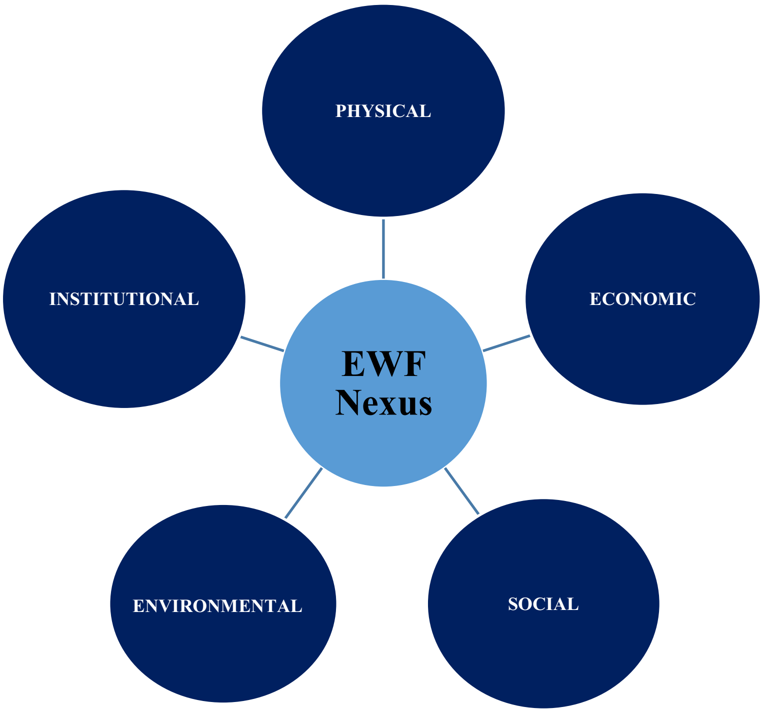


Figure 2-1: EWF Nexus Domains

Table 2-2 provides a brief description of the constitution of different domains of the EWF nexus. The following section presents a discussion on each of the domains.

Table 2-2: Description of Nexus Domains

Domains	Description
Physical	physical flows, technologies, processes, options, practices
Economic	economy-wide implications, supply and production economics, economic efficiencies, valuation, cost and benefits, private, public, and corporate finance, public and private investments
Social	unequal distribution, justice, access, poverty, human rights, social responsibility, safety, affordability, acceptability
Environmental	ecosystem services, carbon emissions, air pollution, land use, soil erosion, etc.
Institutional	institutional analysis, institutional functions, national and international laws, treaties, behaviour, culture/ideology/values/beliefs, decision making process and implementation, structures, functions, processes and organisational traditions, policies, strategies, procedures, political issues like creation of scarcity and inequality, political stability, geopolitics, political support/willingness

2.2.1. The Physical Domain

The physical domain of the EWF nexus broadly covers the understanding of the physical input and output flows of resources, e.g. water for food, water-for-energy production and so on, and the availability, scarcity, and use of physical resources. The physical domain broadly covers the energy, water, food sector technologies, processes, options, and practices, all of which have different energy, water, and emissions intensities.

The energy, water, food sectors are evolving and shifting to new technological innovations with growing demand and developmental consequences on energy, water, and food resources. The water sector, for instance, faced with increasing pollution and scarcity of fresh water, is transitioning to advanced water and wastewater treatment technologies, and even alternative sources of water altogether, like treated wastewater or freshwater derived from seawater with the help of desalination technologies.

Technologies like CCS have been introduced to curb carbon emissions produced by electricity generation from fossil fuels like coal and gas – two of the major sources of carbon emissions globally. However, the water intensity of power plants increases significantly after the deployment of CCS (Mielke *et al.* 2010). Similarly, in the agriculture and food sectors, different pumping and irrigation technologies have different respective energy and water intensities. Different agricultural crops have location-specific water requirements, a function of geographic, climatic, and management factors.

Knowledge of the physical association between resources is usually the first step to comprehending any other aspect regarding the interlinkages between food, water, and energy, and that is why there is better coverage of this aspect in the literature reviewed in comparison to other aspects. However, there is still little understanding of the location-specific quantification of physical linkages, and usage of commonly-established norms is more popular.

Quantification of physical dependence indicates the strength or weakness of the association between resources and thus the vulnerability of one resource in relation to the scarcity of another. It also allows different options, technologies or processes to be weighted in terms of their resource intensities, which could ultimately be helpful in reducing the interdependence of resources on each other. Thus, the knowledge of physical associations becomes vital.

The physical domain has been widely examined in the literature in the form of resource flows, different technologies, processes, and options.

2.2.2. The Economic Domain

The economic domain of the EWF nexus is important in numerous ways and it can be approached from micro and macroeconomic perspectives.

The micro-economic perspective is concerned with understanding the consumer response to changes in policy and market conditions. The pricing of energy, water, and food resources determines the extent of full cost recovery and the internalisation of social and environmental costs. Governments, typically in developing nations, subsidise the energy, water, and food sectors because they are basic human necessities. However, subsidies are a burden on government finances and often have economic consequences. Furthermore, subsidies also promote wasteful use of resources.

The macroeconomic perspective concerns understanding the overall health and functioning of an economy. Economic development is the core of any well-functioning and flourishing society. Macroeconomics explains the inter-relationships between different economic variables like investments, inflation, trade balance, GDP growth, value added, wages, labour, capital financing and investments, and so on. In the context of the EWF nexus, this includes the economy-wide interactions of energy, water, and food. Parameters related to the economic factors of production, like labour, capital, labour intensity, wages, value added, the rate of unemployment, and so on, have also been included in the analysis of EWF security-related interventions (Flammini *et al.* 2014).

Economic analysis can be helpful in assessing the opportunity cost of various management and policy options related to resource use, thereby enabling the fair allocation of resources towards maximising social benefit. Economic analysis also allows valuation of non-tradable natural resources or those that are subsided and whose prices do not reflect their actual cost.

A few studies have focused on the relationship between economic development and resource consumption (Hogan *et al.* 1977; Lee 2005). Some studies (Canning 2011; Markaki *et al.* 2013; Okadera *et al.* 2015) assessed the economy-wide direct and indirect impacts of policy measures intended to address resource security. The economic impacts of climate change on food

(Calzadilla *et al.* 2013), water (Henderson *et al.* 2013), or energy (Edmonds and Reilly 1983) resources have been the emphasis in some other studies.

Investments also play a significant role in the implementation of the nexus approach. Keulertz and Woertz (2015) described financial investment challenges faced by fiscally-constrained Arab countries and suggested some alternative ways of financing green growth to mobilise nexus-related policies, in particular for such crucial sectors as energy, water, and food. In response to future investment in land for agriculture, Bizikova *et al.* (2013) proposed a land investment framework that balances agricultural production and natural capital co-objectives.

Financial risks or opportunities for investors (individual, state, firm, or business) in the EWF sectors can also be analysed. The WEF (2009) highlighted the need to attract more private investment in the water sector given an anticipated shortfall of public funds. This meeting also ushered in a new interest in the business community to examine the vulnerability of their supply chains and corresponding adaptation strategies in case of water scarcity or price rises.

Molle *et al.* (2008) performed financial analysis to develop an incentive-based scheme for an electricity board that would compensate farmers for reducing their irrigation diversions (and hence their water consumption) through better water management or crop cultivation practices. Similarly, Sauer *et al.* (2010) assessed the financial risks of water shortages for electricity generation in power plants situated in Asian countries.

2.2.3. The Environmental Domain

The environmental domain of the nexus broadly covers ecosystem services. There is a two-way interaction between the nexus of EWF resources and the environment. On the one hand, policies directed towards environmental protection can intensify the nexus – for instance, the introduction of carbon capture in power plants to curb carbon emissions almost doubles water consumption (Zhai *et al.* 2011). On the other hand, policies meant to redress the nexus can impact the environment either positively or negatively – for instance, the introduction of energy-efficient or renewable power-based pump-sets to reduce energy consumption in food production will also reduce carbon emissions (Chel and Kaushik 2010).

The environmental domain is understood mostly in terms of the relationship between EWF resources and ecosystem factors like land, emissions, and so on. A few studies assessed how climate change affects food (Rosenzweig 1994) and water (Bates *et al.* 2008) availability. The environment, however, is not explicitly included in the nexus in most studies as a valid player in dealing with resource security and, as Ringler *et al.* (2013) pointed out, even if it was, the environmental sector would not encounter a level playing field.

2.2.4. The Social Domain

Energy, water, and food share an integral bond with society, given that society's consumption patterns and preferences govern the demand for these resources. In addition, the nexus trade-offs affects the society in different ways, for instance, the competition over the use of water for drinking, food production, energy generation, and other uses. Also, some of these sectors are major employers and any structural or technological changes could therefore lead to the loss or creation of jobs.

The social domain in the context of interlinked EWF resources has been covered mostly in powerful rhetoric rather than by quantitative analyses. A few recent studies have emphasised including the social aspect in the decision-making process to empower the local community and increase participation in the decision-making process related to energy, water, and food provisioning. Similarly, local publics have expressed safety concerns about and protested against the construction of nuclear-powered electricity generation facilities as a means to ensure energy security. Political actors have been condemned for taking power away from local people, and social justice is adjured.

The social domain has been touched upon in multiple other ways, like assessing society's hierarchical differentiation of resource consumption (Giampietro et al. 2010), environmental justice or distribution of externalities arising because of the nexus, (Middleton *et al.* 2015; Hellegers *et al.* 2008), environmental racism, environmental sexism, environmental classism (Gaard 2001), and social attributes like safety, acceptability, and affordability.

2.2.5. The Institutional Domain

The institutional aspect of the nexus is, undoubtedly, the most abstract but a very significant one, as it affects the consideration and implementation of all the other domains. The institutional domain is vested in policies, regulations, governance and management structures, and formal-informal institutions. Each of these is discussed in detail in the following paragraphs.

Policies are sets of actions designed to achieve desired outcomes. The meaning of the term 'policy' as interpreted by Cairney (2015), inspired by Hogwood and Gunn (1984, pp.13-19), is as follows: '"Policy" may describe one, or all, of a range of activities, including: a broad statement of intent (we will solve this problem), a set of specific proposals (such as a manifesto), proposals authorised by government and Parliament (such as legislation), proposals backed by resources such as funding and staffing (a policy programme), and the outcomes of decisions. The outcomes may be very different from the original stated intentions.'

Policies are executed with the help of policy instruments, of which there are two kinds: regulatory and economic. Most policies use a combination of these tools and they can be either voluntary or legal. Both kinds are intended to bring about change in behaviour to achieve the desired outcomes of the policy. Regulatory measures are targeted at limiting or controlling behaviour through direct control or incentive-based approaches while economic instruments change or influence behaviour through their impact on market signals.

The term 'regulation' has two different meanings in different contexts. According to one meaning, it is an instrument in policy making, as discussed above. According to the other, it describes a type of regulatory environment, such as types of ownership (privatisation, liberalisation, and so on), organisational setup, legal powers, resourcing of regulating agencies and enforcement of contractual relationships (Lodge and Wegrich, 2012, p. 3).

The term 'governance' as defined by UNESCAP is 'The process of decision-making and the process by which decisions are implemented (or not implemented)' (UN-ESCAP, n.d.). According to the Institute of Chartered Secretaries and Administrators International, governance concerns ensuring that [a program] is run in such a way that it achieves its objectives in an effective and transparent manner' (ICSA n.d., p.2). Incorporation of nexus-based thinking in policies is also recognised as a governance challenge in a few studies.

There is a thin line between governance and management. While the purpose of governance is to establish the right policy and procedures for ensuring that things are done properly, management is about doing things most suitably. In simpler words, governance is concerned with 'doing the right thing', while management is concerned with 'doing things right' (Tricker

1998, p.8.). Management in an organisational sense comes second to governance, bearing in mind that it is mostly concerned with the day-to-day implementation of the strategies, policies, processes, and procedures designed by the governing bodies.

Governance and management issues gained attention in the literature mostly due to the comparison between similar integrated resource management-based paradigms (Benson *et al.* 2015, Muller 2015). The literature suggests that management-related measures were identified to minimise trade-offs and can assist in benefit sharing (Granit *et al.* 2012). Lele *et al.* (2013) emphasised placing the empirical analysis of governance issues at the top of the global agenda. This is because current governance arrangements are characterised by 'lack of strategic clarity, and among stakeholders there is an unequal distribution of power, voice and access to information, resources and the capability to exercise a sound influence which will produce equitable and sustainable outcomes'.

Even though the importance of institutions has been widely recognised for achieving optimal resource security outcomes directed by the policies, only a very few studies (Villamayor-Tomas *et al.* 2015, Hellegers *et al.* 2008, Scott *et al.* 2011, Wang 2009) actually deal with restructuring institutions for these purposes in isolation. Current policy structures and institutions are quite fragmented from the point of view of nexus-based thinking, hence the need to include institutions and decision making in the energy-water nexus arises (Scott *et al.* 2011).

North defines institutions as formal and informal constraints where examples of formal constraints are rules, laws, and a constitution and examples of informal constraints are norms of behaviour, conventions and self-imposed codes of conduct (North 1990, 1991, 1994). Behaviour, in turn, is guided by culture. The behavioural link is one of the potential influencing factors that affect resource demands and hence their interlinkages. Public policy can largely influence behaviours to shift towards sustainable practices through taxes, incentives or soft measures like awareness drives. Marlow *et al.* 2015 compared water, energy, pesticide and fertiliser use for different dietary types in California to recommend sustainable food production methods and reconsideration of agricultural subsidies.

Politics and institutions collectively drive decision making and policy integration. Hence, politics plays a significant role in the successful implementation of the nexus approach. Political motives or willingness are closely associated with the implementation of current or past policies, plans and actions that affect the resource nexus. Political stability is necessary for economic growth and development, which can be credited with boosting investor trust (Verhoven 2015, Matthews and Motta 2015, Sidamor et al. 2016). On the other hand, geopolitics and political issues and disturbances such as the creation of scarcity as a political strategy (Hoff 2011; Allouche *et al.* 2015) also affect the success and implementation of nexus-related policies.

Some examples in the literature that consider the institutional domain include Zilberman *et al.* 2008, where the authors draw attention to the subsequent rise in the cost of flawed institutions like poor distribution systems, water subsidy regimes, and restrictions on water trading against the background of rising energy prices. Villamayor-Tomas *et al.* 2015 suggested the bridging of value chains and institutional analysis to understand the nexus-related issues better. International and national legal institutions have the potential to become the next torchbearers for mobilising the nexus approach. For example, Belinskij 2015 advocated that international water law can be altered to include the EWF nexus.

2.3. Framing of the EWF Nexus

The need for a nexus approach was felt due to some factors, primarily due to intensifying resource linkages due to increasing scarcities, recent resource supply crises, and the failure of siloed resource management strategies (Al-Saidi and Elagib 2017). The concurrent timing of the global food and energy price crises of 2007-08 further fuelled the need for a nexus approach in the EWF security discourse.

Presently, the drivers leading to nexus investigation go far beyond even those noted above; nexus complexity is increasing, variables like society and the environment come into play, and developmental objectives need to keep pace with sustainability. Based on a detailed review of various studies, the major drivers for analysing the EWF nexus can be broadly grouped into five broad categories, namely, physical, economic, social, environmental, and institutional (Figure 2-1 and Table 2-3).

A review of the studies noted in the table suggests that:

1. A large number of studies, aiming to understand the nature of the EWF nexus, are driven by concerns about the **physical availability** of one or other of these resources. This is understandable if the purpose is to evaluate the positioning of a particular resource in the nexus

or to ascertain the benefits of a nexus approach in promoting particular resource security. Even in those studies that focus on individual security, for instance, energy security, the understanding of the nexus emphasises a specific perspective (e.g. sustainability), or a particular question (e.g. social and environmental outcomes of bio-energy and renewables) (Wong 2015, Wong and Pecora 2015, Mirzabaev 2015, Bonsch *et al.* 2016).

The EWF nexus is predominantly framed as water-centric in nature as water security has been considered as central to food and energy security in many studies (Hoff 2011, Allouche *et al.* 2014, Keskinen and Varis 2016). Further, studies driven by water security concerns typically deal with water allocation issues, mostly at basin level. The most commonly examined case is the inter-sectoral competition for water between agriculture and power, caused by misallocation of water leading to water shortages and increased demand (Molle *et al.* 2008, Karlberg *et al.* 2015, Perrone and Hornberger 2015, Keskinen *et al.* 2015, Ethan Wang and Wi 2018).

Table 2-3: Review Summary of Major Drivers in EWF Nexus Literature

MAJOR DRIVERS	REFERENCES
PHYSICAL	
Energy security (7)	Ladanai and Vinterback 2010, Wong and Pecora 2015, Mirzabaev *et al.* 2015, Bonsch *et al.* 2016, Wong 2015, Brouwer *et al.* 2018, Kılkış and Kılkış, 2017
Water security (13)	Siegfried *et al.* 2010, WEF 2011a, Karlberg *et al.* 2015, Perrone and hornberger 2015, Beck and Walker 2013, Vanham 2016, Fasel *et al.* 2016, Smidt *et al.* 2016, Gurdak *et al.* 2017, Cai *et al.* 2018, Kan *et al.* 2016, Yang and Wi 2018, Molle *et al.* 2008, Zhao *et al.* 2018a
Food security (16)	Khan and Hanjra 2009, Mushtaq *et al.* 2009, Al-Ansari *et al.* 2015, Mukuve and Fenner 2015, Chen and Zhang 2015, Fabiola and Dalila 2016, Jeswani *et al.* 2015, Salmoral and Yan 2018, Kibler *et al.* 2018, de Vito *et al.* 2017, Al-Ansari *et al.* 2017, Zhang *et al.* 2017, Ozturk 2015, De Laurentiis *et al.* 2016, Zimmerman *et al.* 2018, Karabulut *et al.* 2018
EWF security (24)	Bazilian *et al.* 2013, Cozzens 2013, Lundy and Bowdish 2014, Vlotman and Ballard 2014, Finley and Seiber 2014, Jarvie *et al.* 2015, Villarroel Walker *et al.* 2014, Hall 2014, Taniguchi *et al.* 2015, Hang *et al.* 2016, Zhang and Vesselinov 2017, Wa'el *et al.* 2017, Haltas *et al.* 2017, Wa'el *et al.* 2018, Belmonte *et al.* 2017, Heard *et al.* 2017, Helmstedt *et al.* 2018, Yao *et al.* 2018, Martinez-Hernandez and Samsatli 2017, Holt *et al.* 2017, Karatayev *et al.* 2017, Räsänen *et al.* 2014, Li *et al.* 2016, Ramaswami *et al.* 2017, Basheer and Elagib 2018
ECONOMIC	
EWF pricing and investments (7)	Zhu *et al.* 2007, Roland-Holst and Heft-Neal 2012, Ringler *et al.* 2016, Gulati *et al.* 2013, WEF 2011b, Siciliano *et al.* 2017, Zilberman *et al.* 2008
Economic impacts of policies (1)	Doukkali and Lejars, 2015
Impacts of economic reforms (1)	Kettalus *et al.* 2014
Financial challenges Corporate risks(2)	Keulertz and Woertz, 2015, Lundy and Bowdish 2014
SOCIAL	
Social justice, societal metabolism, livelihood aspect, social attitudes (8)	Srivastava and Mehta 2014, Allouche *et al.* 2015, Foran 2015, Leese and Meisch 2015, Biggs *et al.* 2015, Middleton *et al.* 2015, Spiegalberg *et al.* 2017, Portney *et al.* 2017a
ENVIRONMENTAL	

Environmental interactions/ecosystem services (11)	Rasul 2014, Carter and Gulati 2014, Conway *et al.* 2015, Karabulut *et al.* 2016, Rasul and Sharma 2015, Howarth and Monasterolo 2017, Zhao *et al.* 2018b, AbdelHady *et al.* 2017, ICIMOD 2012, de Grenade *et al.* 2016, Bell *et al.* 2016
Environmental justice (1)	Ringler *et al.* 2013, Biggs *et al.* 2015, Middleton *et al.* 2015
INSTITUTIONAL	
Regulations, governance management, institutions, politics, decision making (26)	Lele *et al.* 2013, Allouche *et al.* 2014, Halbe *et al.* 2015, Mathews and Motta 2015, Verhoeven 2015, Bromwich 2015, Gain *et al.* 2015, Jobbins *et al.* 2015, Smajgl *et al.* 2016, Guillaume *et al.* 2015, Rasul 2016, Pittock *et al.* 2015, Howarth and Monasterolo 2016, Gallagher *et al.* 2016, Larcom and van Gevelt 2017, Weitz *et al.* 2017, Pahl-Wostl 2017, Abbott *et al.* 2017, Venghaus and Hake 2018, Ziv *et al.* 2018, Artioli *et al.* 2017, Kurian 2017, Hoolohan *et al.* 2017; Garcia and You 2016; Wolfe *et al.* 2016; Portney *et al.* 2017b
Water-related institutions and the EWF nexus (14)	Lawford *et al.* 2013; Bindra *et al.* 2014; Granit *et al.* 2015; Kibaroglu and Gursoy 2015; Keskinen *et al.* 2015; Keskinen *et al.* 2016; Keskinen and Varis 2016; Stein *et al.* 2018; Basheer *et al.* 2018; Benson *et al.* 2015; Muller 2015; Belinskij 2015; Pittock *et al.* 2015; Schmidt and Matthews, 2018
MULTIPLE DRIVERS	
Multi-dimensional nature of resource planning and management (26)	Giampetro *et al.* 2013a; Flammini *et al.* 2014; Daher and Mohtar 2015; Howells *et al.* 2013; Karlberg *et al.* 2015; Keskinen *et al.* 2015; Mayor *et al.* 2015; de Strasser *et al.* 2016; Gondhalekar and Ramsauer 2017; Hake *et al.* 2016; Karan *et al.* 2018; Schlör *et al.* 2018a; Owen *et al.* 2018; Yang *et al.* 2016; Jalilov *et al.* 2018; Jalilov *et al.* 2016; Bergendahl *et al.* 2018, Beiber *et al.* 2018, Liu *et al.* 2017, Martinez-Hernandez *et al.* 2017, White *et al.* 2018, Hoff 2011, Bizikova *et al.* 2013, Bazilian *et al.* 2011, Hermann *et al.* 2012, Schlör *et al.* 2018b

Sustainable food production and consumption are the prime foci of most studies driven by food security considerations. These studies place special emphasis either on resource-intensive agricultural practices (Chen and Zhang 2015, De Laurentiis *et al.* 2016), or on the implications of consumer preferences and behavioural patterns on food consumption and waste (Salmoral and Yan 2018, Kibler *et al.* 2018, De Laurentiis *et al.* 2016, Zimmerman *et al.* 2018). Additionally, assessments of food production systems have been carried out across different geographic scales, e.g.,: (i) global or local food supply chains (Khan and Hanjra 2009, Vlotman and Ballard 2014, Jeswani *et al.* 2015), (ii) national food production sub-systems (Al-Ansari *et al.* 2015), or (iii) at the field level (Mushtaq *et al.* 2009). Some studies are also driven by food security concerns from a human wellbeing perspective (Mukuve and Fenner 2015, Fabiola and Dalila 2016).

Physical availability concerns for energy, water, and food, without any dominant focus on any specific resource, are mostly driven by the socio-economic needs for these resources (Cozzens 2013, Finley and Seiber 2015, Ozturk 2015, Taniguchi *et al.* 2015, Villarroel Walker *et al.* 2014). Some studies also assess the influence of scarcity or poor management of other resources like phosphorus on energy, water, and food securities in light of the nexus between them (Jarvie *et al.* 2015).

2. Studies driven by **economic** concerns typically seek to explore the effects of energy, water, and food provisioning on the costs and prices of these commodities (Gulati *et al.* 2013), particularly on energy prices (Zilberman *et al.* 2008, Zhu *et al.* 2007, Roland-Holst and Heft-Neal 2012, Ringler *et al.* 2016). Some studies examine the economic impacts of changes in energy, water, or food policies; for example, Doukkali and Lejars (2015) examined the impacts of subsidising energy used by agriculture; Kettalus *et al.* (2014) reviewed the impacts of economic and political reforms on EWF security, and Keulertz and Woertz (2015) explored the investment challenges to funding nexus-guided sustainable policies or strategies. Siciliano *et al.* (2017) focused on guiding investors on aspects of resource acquisition, scarcity, and access to promote responsible land investments. Some studies also explore corporate interests for safeguarding operations from energy, water, or food-related risks (Lundy and Bowdish 2014, USCCF 2014).

3. **Social** inclusion, justice, and fair play are key concerns in nexus studies driven by social considerations, e.g., Srivastava and Mehta 2014, Allouche *et al.* 2015, Foran 2015, Middleton *et al.* 2015. These studies seem to imply that the current framing of the nexus

favours fuelling economic growth, and supporting resource-intensive lifestyles of the powerful and rich global masses at the expense of generating negative outcomes for society in terms of unequal access and distribution of energy, water, and food resources as well as for the environment (Ringler *et al.* 2013, Biggs 2015, Middleton *et al.* 2015). Other studies focus on public attitudes (Portney *et al.* 2017a, Spiegalberg *et al.* 2017) and livelihood (Biggs *et al.* 2015) aspects in relation to the nexus.

4. Studies driven by **environmental** or ecosystem concerns primarily focus on a few aspects. These tend to assess the interactions between climate and EWF nexus, for example, the impact of climatic risks on the supply of energy, water, and food resources (Carter and Gulati 2014), ecosystem benefits (Bell *et al.* 2016), co-benefits of the nexus approach (Rasul and Sharma 2016), the influence of climate on EWF nexus (Conway *et al.* 2015), and the role of ecosystem services in the provisioning of energy, water, and food, along with associated benefits on the EWF nexus (Rasul 2014, ICIMOD 2012, and Karabulut *et al.* 2016), especially in the case of river ecosystems (Rasul 2014).

5. Studies driven by **institutional** concerns are mostly dedicated to promoting nexus thinking in planning, policy, and decision making. Implementing the principles of the nexus approach, especially in water governance (at national and trans-boundary basin levels) is a distinguishing concern. The nexus approach has been suggested in some studies as being superior to the integrated water resources management (IWRM) approach in terms of dealing with the complex inter-sectoral nature of basin water governance and management, across national and trans-boundary basins, in order to reconcile the interests of competing users through mechanisms like benefit sharing and multilateral cooperation (Granit *et al.* 2012, UNECE 2015). There is a broad consensus that a nexus-guided approach to basin water management, with its emphasis on resource efficiency and collaborative governance, could be beneficial in addressing geo-strategic issues (Mayor *et al.* 2015, Lawford *et al.* 2013, Keskinen *et al.* 2015, Granit *et al.* 2012).

   Other nexus studies examine the influence of politics on (i) shaping interdependencies between energy, water, and food resources, analysed through the lens of political economy (Mathews and Motta 2015) or political ecology (Bromwich 2015); (ii) implementing nexus principles in real-life policy decisions (Gain *et al.* 2015; Pittock *et al.* 2015); (iii) nexus-guided sustainability innovations (Halbe *et al.* 2015), and (iv) identification and sharing of transferable lessons for effectively managing the nexus in different scalar contexts (Guillaume *et al.* 2015).

Further, some studies emphasise the importance of inter-disciplinary, dynamic, multi-scalar, and multi-stakeholder decision making in regard to the EWF nexus (Garcia and You 2016, Wolfe *et al.* 2016, Kumazawa *et al.* 2016). Allouche *et al.* 2014 stress a nexus approach that promotes a dynamic, democratised, and decentralised approach to decision making for energy, water, or food security. Smajgl *et al.* 2016 suggest a dynamic nexus approach (i.e., that explicitly examines the dynamic relationships and ripple effects in EWF security planning) to guide future investments.

6. **Studies driven by multiple domain considerations** are mostly recent – evidence of the increasing recognition of the multitudinous nature of the nexus. Notwithstanding the importance of other studies in expanding the knowledge in different nexus domains (as discussed above), this group of studies is far more useful as it approaches the nexus from multiple considerations, which is crucial for policy development and decision making.

A review of multiple domain studies suggest that underlying drivers essentially relate to specific emerging issues. Examples of these are the incorporation of nexus approach in planning modern societies (Hake *et al.* 2016, Gondhalekar and Ramsauer 2017, Martin-Hernandez *et al.* 2017, Schlör *et al.* 2018, Bergendahl *et al.* 2018, Liu *et al.* 2017, Bieber *et al.* 2018, Li *et al.* 2016, Karan *et al.* 2018); examination of basin-level trade-offs and the importance of implementing a nexus approach for sub-national, national, and trans-boundary basin governance (Karlberg *et al.* 2015, Jalilov *et al.* 2016, Yang *et al.* 2016, Keskinen *et al.* 2015, Mayor *et al.* 2015, Basheer *et al.* 2018, AbdelHady *et al.* 2017, Jalilov *et al.* 2018); and to develop understanding of the EWF nexus within an economy, or between regional economies (White *et al.* 2018, Owen at al. 2018).

The reviewed literature also includes some case studies that provide assessments of sectoral technical or policy interventions and their wider implications due to the interconnections between energy, water, and food (Giampetro *et al.* 2013a, Howells *et al.* 2013, Flammini *et al.* 2014, Daher and Mohtar 2014). In these studies, however, the objective was not to explicitly examine EWF security-related technological or policy interventions simultaneously. Rather, they focus on a specific sector as the entry point in the nexus and ascertain the resulting impact on other sectors. This emphasis, however, offers a narrow viewpoint of the EWF nexus, especially for the purpose of policy development and decision making.

Even in studies driven by multiple considerations, physical consideration seems to be the dominant driver, followed by combined physical-economic-environmental considerations. It appears that relatively less attention has been paid to social and institutional drivers. Overall, three studies (Giampetro *et al.* 2013a, Flammini *et al.* 2014, Mayor *et al.* 2015) explicitly consider all nexus domains.

Broadly, it appears that even after a steady advancement of the nexus approach in the EWF security literature, there is insufficient knowledge about the trade-offs between the multiple domains of the nexus, in particular the social and institutional domains.

Some key inferences, based on the above discussion, are:

a) Framing of the EWF nexus is predominantly driven by single-domain considerations, focused mostly on the physical/technical aspects. Such framings may appear to be beneficial for addressing the needs of the specific interest groups, but this would be achieved without due consideration of other interests, possibly leaving some questions unanswered or answered mistakenly. In most cases, the framings are backed up by institution-specific agendas, or driven by the risk-aversive and opportunistic outlook of private businesses (Allouche *et al.* 2015), causing the framing as well as the responses to issues vary.

   Consecutively, and when seen in isolation, these studies address the issues in the driving domain very well. However, they ignore the involvement of other stakeholders, like society, the economy, and the environment, which often may have competing objectives (Garcia and You 2016) which cannot be considered in the policy trade-offs by such single-domain studies.

b) There appears to be a resource bias in the literature dealing with nexus assessments. Even in the major nexus conceptualisations, one of the sectors or resource stands pre-eminent above all others, such as food in Ringler *et al.* 2013, water in Hoff 2011, and ecosystems in Bizikova *et al.* 2013. This goes against the very essence of the nexus approach that ideally hinges upon giving equal emphasis to each sector or resource. This sectoral or resource inclination could probably be a reflection of the dominant interests of the stakeholders (groups, organisations) conducting the study. A sector-inclined approach can introduce bias in terms of planning and reduce the willingness of other sectors to participate (Keskinen and Varis 2016).

Sectoral bias in the framing of the EWF nexus is also reflected by the choice of one of the sectors as the entry point (referred to as 'entry point approach' in Smajgl *et al.* 2016) of policy interventions in nexus assessments (e.g. Khan and Hanjra 2009 (food); Mushtaq *et al.* 2009 (food); Ladanai and Vinterback 2010 (energy); Mirzadaev 2015 (energy); Mukuve and Fenner 2015 (food); Perrone and hornberger 2015 (water)).

c) Critical aspects of the nexus, like the socio-political and institutional, are mainly analysed qualitatively because of their intangible nature. Needless to say, though such drivers are not directly suitable for empirical analysis, including some proxies for them in the empirical analysis will provide a good base for developing a comprehensive picture, and will also provide bases for advocating policy actions.

2.4. Summary and Key Inferences

This chapter reviewed the existing framing of the EWF security literature. The review suggests that despite increasing recognition of the importance of the EWF nexus, there appears to be a lack of common vernacular on the topic. The current debate seems to be typified by diverse viewpoints, multiple framings, rhetorical arguments, and confounding streams of terminology and jargon in relation to the nexus. While some diversity in language is understandable because of the multi-dimensional nature of the nexus, a common understanding is still needed, at least on the 'core' concepts of the nexus, in order to facilitate cross-context comparisons.

The physical domain appears to be the dominant driver in most of the studies. Other studies also consider the nexus from the economic and/or environmental domains in conjunction with the physical domain. Apart from their individual coverage, the social and institutional domain have not been explored much in the literature along with the other three domains. Further, a resource bias seems apparent in the literature on nexus assessments. The choice of one of the sectors as an entry point in nexus assessments is also reflective of a sectoral bias in the framing of the EWF nexus.

Broadly, it appears that even after the steady advancement of the nexus approach in the EWF security literature, there is insufficient knowledge about the trade-offs between the multiple domains of the nexus, in particular, the social and institutional domains.

This chapter, therefore, identified the gaps in the current framing of the EWF nexus. The next chapter presents the review of methods for nexus assessments to examine their suitability for guiding EWF security policy development.

Chapter 3 . A Review of Methods for EWF Nexus Assessments

Chapter 2 emphasised on the need for efficacious EWF policies – ones that acknowledge the criticality and complexity of the nexus and are able to responsibly accommodate (articulate, resolve) diverse nexus related interests – as a prerequisite for redressing the EWF security challenge. The chapter also reviewed how the EWF nexus in the current literature is framed, the key motivations/drivers for interest in nexus thinking, and how such thinking has contributed to the framing.

It follows that development of such efficacious policies requires policy frameworks that are supported by appropriate, measurable, indicators and metrics to represent the myriad interdependencies embedded in the nexus, and analytical approaches (methods/models) that inform how various interests will be impacted by alternative policy choices and determine the trade-offs implicit in nexus-based thinking on policy.

Previous literature reviews on EWF nexus assessment methods have contributed significantly to developing analytical methods for use in future nexus assessments (Endo *et al.* 2015b, Albrecht *et al.* 2018). These reviews, however, seem to demonstrate a lack of emphasis on the appropriateness of methods used for nexus assessments, particularly for guiding EWF security policy making. Accordingly, this chapter, while complementing existing reviews on the nexus (Endo *et al.* 2015b, Albrecht *et al.* 2018), provides a basis to extend nexus assessments to augment the policy significance of such assessments.

The prime objective of this chapter is therefore to review the methods used in the literature for nexus assessments. This review focuses particularly on ascertaining the strengths and weaknesses of these methods for nexus assessments to guide EWF security policy making. The review additionally provides some suggestions on how nexus assessments could contribute to strengthening the design of policy frameworks, and how such strengthening could improve policies to redress the security challenge. Finally, this review assists in the selection of an appropriate method for this research.

The review in this chapter is organised as follows: Section 3.1. presents the classification of methods. Section 3.2 presents the criteria against which different methods are reviewed. Section 3.3 summarises the key observations and findings from the review. Section 3.4. presents some further discussion on the review findings. Section 3.5. presents the methodological selection for this research and Section 3.6. summarises the chapter.

3.1. Methods for EWF Nexus Assessment

This section of the paper presents a review of the methods employed in various studies for examining the nature of the EWF nexus. This review focuses particularly on ascertaining the appropriateness of these methods in terms of providing policy-useful insights for promoting EWF security. These methods have been grouped under the following categories: accounting, simulation, optimisation, participatory, statistical and econometric, and integrated – reflecting the essence of the analytical procedures through which insights into the nature of the EWF nexus and underlying trade-offs are developed.

The core principle of accounting-based methods is evaluation and processing of flows at different stages of the system or process under consideration. In regard to the nexus between EWF resources, such methods have been typically used for the accounting of a) physical flows, b) monetary flows, and c) characterisation of EWF systems using quantitative indices.

Applications of accounting-based methods to examine the physical inter-relationships between EWF resources involve examination of input and output flows (Mushtaq *et al.* 2009, Karatayev *et al.* 2017), foot printing (Vanham 2016), supply chain (Vlotman and Ballard 2014), or life cycle analysis (De Laurentiis *et al.* 2016, Salmoral and Yan 2018, Al-Ansari *et al.* 2015).

Monetary accounting typically involves analysis of benefits and costs associated with EWF strategies (Molle *et al.* 2008), or fiscal transactions in the economy in the energy, water, food sectors through specialised methods like Input-Output analysis (Owen *et al.* 2018, Liu *et al.* 2017, White *et al.* 2018) and Social Accounting Matrix (Doukkali and Lejars 2015).

Indicator-based assessments provide a bridge between non-equivalent dimensions of the nexus, like physical, social, economic and so on (Taniguchi *et al.* 2017). This is achieved through selection of indicators for specific dimensions of interest, for each resource at different levels and scales. Often, these indices are then integrated, through a variety of weighing measures, to develop a composite index for each nexus aspect or resource considered (Flammini *et al.* 2014, Hake *et al.* 2016, Schlör *et al.* 2018b, Abbott *et al.* 2017).

Simulation-based methods replicate the behaviour of different variables to predict the impacts of specific changes in conditions. In the nexus assessments, most standalone simulation-based methods are system-based(Hussein *et al.* 2017, Hussein *et al.* 2018) and utilise systems analysis to simulate energy, water, food systems and flows to assess the changes in performance of the system (study area) under different 'what if' scenarios (Abdelhady *et al.* 2017).

Optimisation-based methods are quintessentially used for problems with varied objectives or stakeholders, whereby an optimal solution is arrived at by maximising or minimising the desired objective or any other performance metrics, subject to a given set of constraints. The most commonly examined objective in existing nexus assessments is to minimise cost or maximise net economic benefits (Yang *et al.* 2016, Karan *et al.* 2018). Other objective functions examined include, for instance, minimisation of exergy consumption for meeting local EWF demand in Hang *et al.* (2016). The constraints established in these studies are mostly technical or ecological in nature.

Another variation in optimisation-based methods are economic methods based on optimisation principles, like the Computable General Equilibrium (CGE). Optimisation principles are utilised in this method to find the optimum price that supports equilibrium in demand and supply across a specified set of markets (Wing 2004). This method is frequently used in nexus assessments to examine the economy-wide impacts of energy, water, food interventions at national, regional (Roland-Holst and Heft-Neal 2012), and global levels (Ringler *et al.* 2016).

The core of **participatory methods** is interaction and communication between interest groups or stakeholders. These methods typically utilise participatory inputs to arrive at solutions for nexus-related issues, like the trans-boundary basin conflicts arising as a result of the EWF nexus. Some examples of participatory methods used for redressing nexus-related issues are the Delphi method (Smajgl *et al.* 2016, Foran 2015), interviews, workshops, problem and stakeholder analysis through participatory model-building using casual loop diagrams (Halbe *et al.* 2015), and so on. Participatory methods in this dissertation also refer to some institutional approaches, like the Institutional Analysis and Development (IAD) framework that studies institutionally-mediated action situations where the emphasis is on human interactions or choices that ultimately affect socio-economic and environmental systems (Villamayor-Tomas *et al.* 2015)

Statistical methods, including econometric methods, explore data to discover underlying trends, patterns, and inter-relationships. In the context of nexus, these methods are used to examine EWF interlinkages, factors affecting the nexus, and past trends, and to compare relative EWF efficiencies. Some examples of such methods are regression-based analysis (Gurdak *et al.* 2017, Siegfried *et al.* 2010), dynamic panel modelling (Ozturk 2015), and Data Envelopment Analysis (Li *et al.* 2016).

Integrated methods use a combination of methods backed by principles of accounting, simulation, optimisation, participation, and statistics. Some examples are a combination of hydrological (simulation) and economic models (accounting) in Jalilov *et al.* 2016, Jalilov *et al.* 2018, Basheer *et al.* 2018; energy (accounting) and water (simulation) models in Howells *et al.* 2013, and accounting (value chain analysis) and participatory models (IAD) in Villamayor-Tomas *et al.* 2015.

3.2. Criteria for Review of Methods

The appropriateness of the above methods for providing policy-useful insights is analysed in this paper in terms of the following attributes: domain coverage, analytical capability, context specificity, temporal flexibility, methodological transparency, and computational simplicity. Collectively, these attributes represent the essentials or prerequisites of a robust method aimed at identifying the trade-offs that policymakers might find useful to develop policies aimed at promoting EWF security.

Domain coverage indicates the extent to which a particular method can analyse the simultaneous influence of multiple domains on the nature of the nexus. The domains are classified in this paper as physical, economic, environmental, social, and institutional (as discussed in the previous section). A method with a high domain coverage provides a sound platform for enabling negotiations between different stakeholder groups whose interests may be mirrored in different nexus domains. Such negotiations are essential because policy decisions usually require considerations of economic viability, political suitability, social desirability, institutional simplicity, and public acceptance.

Analytical capability indicates the ability of a method to comprehensively accommodate, assimilate, and process large amounts of data/information relating to the complex inter-relationships between EWF, including underlying drivers, variables, and assumptions. Analytical rigour in nexus assessment methods is needed to handle the complexity and disparity in the nature of different domains of the nexus, the vast interlinkages between the resources and their extensions to society, economy, and the environment.

Context specificity in this dissertation refers to the extent to which a method can consider the impact of different contexts (e.g., cultural and traditional perspectives, development philosophies, price effects, market and institutional structures, governance arrangements, spatial dependencies, technology mix, and so on) on the assessment of the nexus.

Temporal flexibility indicates the ability of the method to analyse trade-offs between securities across different time frames (i.e., short-, medium-, and long-term), an aspect that is particularly significant given the differences in political, policy, planning, and implementation timeframes. Assessments regarding temporal trade-offs in nexus assessments are essential, as they screen out policy actions that purport to be beneficial in the short term, but may not bring long-term benefits. According to Bizikova *et al.* (2013, p12), such trade-offs could '… prevent trading off security today for security tomorrow–pushing externalities to the future.'

Methodological transparency is the ability of a methodology to clearly, effectively, and transparently articulate model assumptions, analytics, levels of analysis, traceability of relationships among model variables, understanding of data used in the model, understanding of model components at different levels, and understanding of the model as a whole (Martinez-Moyano 2012). Transparency is a desirable attribute in methods for effective nexus analysis because policymakers can then see how model(s) in the nexus assessment framework function step by step, and are not merely given the results of the internal machinations of a 'black box' (Patton *et al.* 1993). Transparency also helps explain the degree of detail and disclosure about judgements made during the course of an analysis. Further, methodological transparency is essential as it provides access to the evidence or data used to support research claims, thereby improving the accountability and credibility of results.

Computational simplicity is yet another desirable attribute of a method aiming to analyse EWF policy trade-offs. Specific elements of such simplicity include simplicity of computations, data presentations, representation of results and underlying trade-offs, and comprehensibility to policymakers of the trade-offs under alternative policy interventions. The methods should not be complex or convoluted, as this would make it difficult for policymakers from different sectors to follow the arguments or recommendations.

3.3. Key Observations and Findings

The key observations based on a review of methods (as summarised in Table 3-1), and in terms of the criteria outlined in the preceding discussion, are presented below:

Table 3-1: Review of Analytical Methods for EWF Nexus Assessment

	Methods	Domain Coverage	Analytical Capability	Context Specificity	Temporal Flexibility	Methodological Transparency	Computational Simplicity	References
Accounting	MuSIASEM*	XXX	XXX	XX	X	XX	X	Giampetro *et al.* 2013a
	Index/Indicator-based	XXX	X	X	X	XXX	XXX	Flammini *et al.* 2014, Hake *et al.* 2016, Abbott *et al.* 2017, Schlör *et al.* 2018b, Mushtaq *et al.* 2009, de Vito *et al.* 2017
	Input-Output analysis	XX	XXX	XXX	XX	XXX	XX	Owen *et al.* 2018, Liu *et al.* 2017, White *et al.* 2018
	Social accounting matrix	XX	XXX	XX	X	XXX	XX	Doukkali and Lejars 2015
	Physical flows	X	XX	X	X	XXX	XX	Mukuve and Fenner 2015, Taniguchi *et al.* 2015; Karatyev *et al.* 2017, Kılkış and Kılkış 2017, Khan and Hanjra 2009
	Life-cycle analysis/Foot printing/Supply chain/Virtual resource consumption	X	XXX	X	X	XX	XX	Al-Ansari *et al.* 2015, Ramaswami *et al.* 2017, Vanham 2016, Vlotman and Ballard 2014, Jeswani *et al.* 2015, De Laurentiis *et al.* 2016, Salmoral and Yan 2018
	Economic accounting	X	XX	XX	X	XXX	XX	Perrone and Hornberger 2015; Molle *et al.* 2008
Simulation	Simulation-based approaches	X	XXX	XX	XXX	XX	X	Hussein *et al.* 2017, Hussein *et al.* 2018,Villarroel Walker *et al.* 2014; AbdelHady *et al.* 2017; Räsänen *et al.* 2014, Daher and Mohtar, 2015
Optimisation	Optimisation-based approaches	X	XXX	X	XXX	XX	X	Hang *et al.* 2016; Karan *et al.* 2018; Zhang and Vesselinov 2017, Bonsch *et al.* 2016; Yang *et al.* 2016
	General Equilibrium	X	XXX	XXX	XXX	X	X	Roland-Holst and Heft-Neal, 2012, Ringler *et al.* 2016
Participatory	Delphi Method, Surveys, Interviews, Workshop-based analysis	XX	XX	XXX	X	XXX	XXX	Lawford *et al.* 2013, Foran 2015, Halbe *et al.* 2015, Smajgl *et al.* 2016, Howarth and Monasterolo 2016

Statistical	Statistical and Econometric approaches	X	X	XX	XX	XXX	XXX	Li *et al.* 2016, Siegfried *et al.* 2010, Gurdak *et al.* 2017, Ozturk 2015, Schlör *et al.* 2018a
Integrated	Hydro-economic approaches	XX	XXX	XXX	XXX	XX	X	Jalilov *et al.* 2016, Jalilov *et al.* 2018, Basheer *et al.* 2018
	WEF nexus framework	XXX	XX	XX	X	XXX	XX	Mayor *et al.* 2015
	Trans-boundary River-Basin Nexus Approach	XXX	XX	XX	X	XXX	XX	de Strasser *et al.* 2016
	IMPACT Water **	XXX	XXX	X	XXX	X	XX	Zhu *et al.* 2007
	LEAP-WEAP-AEZ***	XX	XXX	XX	XXX	XX	X	Howells *et al.* 2013
	Hydrological and livelihood analysis	XXX	XXX	XX	XX	XXX	XX	Keskinen *et al.* 2015
	LEAP-WEAP and participatory scenario approach	XXX	XXX	XX	XXX	XX	X	Karlberg *et al.* 2015
	IAD-NAS and Value chain analysis	XXX	XXX	XX	X	XXX	XX	Villamayor-Tomas *et al.* 2015
	Agent-based model, mixed-integer linear optimisation model	XXX	XXX	X	XX	XX	X	Beiber *et al.* 2018
	Synthesis Matrix System	XX	XX	XX	X	XXX	XX	Karabulut *et al.* 2018

X –low, XX– moderate, XXX–high; *MuSIASEM: Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism, **International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT), ***LEAP: Long Range Energy Alternatives Planning system, WEAP: Water Evaluation and Planning, AEZ-Agro-ecological zoning

1. Studies using **accounting-based methods** vary in terms of their coverage of nexus domains; for instance, while some of them (like Al-Ansari *et al.* 2015, Ramaswami *et al.* 2017, Vanham 2016, Vlotman and Ballard 2014, Salmoral and Yan 2018, Khan and Hanjra 2009) examine the nexus from a single-domain perspective (mostly physical, and to a lesser extent economic), others provide reasonably good coverage of nexus domains (Flammini *et al.* 2014, Hake *et al.* 2016, Abbott *et al.* 2017, Schlör *et al.* 2018b).

   The analytical capability of methods with high domain coverage is, however, generally low, as the primary emphasis of methods is to develop physical, socio-economic and ecological profiles (Giampietro *et al.* 2013a), indications and patterns (Flammini *et al.* 2014; Hake *et al.* 2016, Abbott *et al.* 2017, Schlör *et al.* 2018b, Mushtaq *et al.* 2009, de Vito *et al.* 2017). The analytical capability of studies with limited domain coverage is, as expected, generally high, as the assessments are highly detail-oriented, focusing on specific (mostly physical) domains, and using specialised methods like life-cycle assessments (Al-Ansari *et al.* 2015, Salmoral and Yan 2018) and supply chain analysis (Ramaswami *et al.* 2017).

   Some accounting-based methods, like the MuSIASEM approach (in Giampetro *et al.* 2013b), IO analysis (Owen *et al.* 2018, Liu *et al.* 2017, White *et al.* 2018) or SAM (Doukkali and Lejars 2015), although capable of examining different geographic, socio-economic, and political contexts, are characterised by weak analytical bases in their traditional form. While the former does not allow to the capture of monetary or price considerations, the latter two are based mostly around monetary considerations and lack physical considerations that are of particular importance in the case of energy, water, and food resources.

   Further, some accounting-based methods, like IO analysis or SAM, also lack temporal flexibility, particularly for future assessments. This is because they do not allow long-term policy analysis due to the assumption of fixed coefficients or technological structures. The assessments from these methods are often at static points in time (Doukkali and Lejars 2015, White *et al.* 2018) or they explore past inter-relationships (Owen *et al.* 2018). Indicator-based assessments also lack temporal focus as they focus predominantly on benchmarking or comparisons across sectors and scales (Flammini *et al.* 2014, Hake *et al.* 2016).

Accounting-based methods are however generally quite transparent in terms of specifying the assumptions, procedures, and results of the analysis. Most accounting-based methods are reasonably straightforward and comprehensible for use and computation of results.

2. The current application of **simulation-based methods** to analyse the nexus appears to be generally weak in terms of its coverage of nexus domains, focusing as it does mostly on the physical domain (Hussein *et al.* 2018, Villarroel Walker *et al.* 2014, AbdelHady *et al.* 2017). Simulation-based methods, however, generally possess a high degree of analytical rigour and are temporally flexible; some assessments even analyse seasonal variabilities (Hussein *et al.* 2018)

   Methods that possess high domain coverage, like Nexus Assessment 2.0 in Daher and Mohtar (2015), are however weak in terms of specifying the context; this assessment method does not capture future projections of prices, population increase, demand, and resources. Rather, it simulates a static point in time with defined attributes instead of analysing the effects on these profiles of varied influences, for example, price considerations and monetary flows.

   Most simulation-based methods are methodologically transparent in terms of specifying model assumptions, analytics, data, model components, and model structure. These methods are also usually spatially flexible, except a few like Daher and Mohtar 2015, which is mostly applicable only at the national level. However, these methods can get computationally complex, especially when situations with a high number of variables are modelled, in particular, situations that involve consideration of multiple future technologies for various sectors.

3. **Optimisation-based methods** are generally found to be quite analytically rigorous and are generally used for temporal assessments as the prime motivation of such studies is to derive optimal demand and management strategies in a planning context under specified constraints, for which forecasting is critical. Studies employing optimisation-based methods are generally weak in terms of coverage of nexus domains because the emphasis in these methods is on identifying the optimum under a set of constraints, like cost.

   Both the flexibility in replicating context and the methodological transparency of these methods is moderate. For instance, some of the specialised discipline-oriented optimisation-based methods like the CGE models are weak in context building due to the assumption of perfect competition across all sectors in the economy – which is not the case in most developing, and in several sectors of developed economies. Furthermore, these methods are also less transparent and characterised by unexplained causal relationships (Nielson *et al.* 2015) under which traceability of relationships among variables in the model becomes a concern. Some of these shortcomings can, however, be overcome in partial-equilibrium models that illustrate non-market values, however, without a broad capability to model impacts from non-marginal changes in a market (Wellman and Hunt 2016).

Overall, at the computation level, the complexities associated with these methods require substantial data, time, and advanced programming and other analytical skills. Further, optimisation-based methods also restrict decision-makers to experimenting with different options against varied objectives, which is crucial in order to find satisfying solutions to problems without undertaking repeated formal optimisations of the solution (Purshouse and McAlister 2013).

4. **Participatory methods** are highly contextual in nature. The prime motive of these methods is to promote increased involvement of beneficiaries and stakeholders in decision-making processes and this is less likely to be achieved without the inclusion of contextual factors. The participatory inputs project the impact of different contexts that include cultural, traditional, market and behavioural influences, among others. Participatory inputs also give practicality to the recommendations resulting from nexus assessments, thereby offering higher context specificity.

   Participatory methods are however generally found to be weak in ascertaining temporal implications accurately because they lack any analytics to decipher future implications. The popular and well-developed participatory methods, like the Delphi method, are, however, rigorous and transparent.

   Computationally, these methods are usually quite explicit and straightforward. Further, they are moderate in their coverage of different domains due to the social and institutional aspects they take into consideration. However, economic considerations are usually weak in these methods because the focus is on including varied stakeholder interests and not just economic implications.

Moreover, participatory methods are often expert-led, sometimes purely subjective or judgement-based, and their application is often subject to strong influence of personal biases (Misturelli and Heffernan 2003). As a result, the conclusions drawn or policy recommendations made can easily be questioned.

5. **Statistical methods** for nexus assessment generally focus on exploring past trends and inter-relationships, or predicting future trends related to the EWF nexus. Due to such focus and limited applicability, these methods are generally analytically weak for carrying out comprehensive nexus assessments as they are often incapable of accommodating the complex inter-relationships between EWF and their extensions to society, economy, and the environment. These methods are also usually weak in terms of domain coverage, for the same reasons. The methods are however rigorous, transparent, and simple to follow. Furthermore, the methods are quite useful for investigating causal relationships.

6. **Integrated methods**, by and large, permit moderate coverage of nexus domains, primarily attained by integrating of two or more sectoral/discipline-oriented models. As a result, the analytical capability and context specificity of these methods is also improved with additional elements or variables from the involvement of other integrated models.

   The temporal flexibility of these methods varies; for example, integrated methods involving simulation-based methods are generally more flexible in demonstrating temporal effects because they allow future conditions to be replicated and time scales of interest to be specified. Methodological transparency and computational simplicity of integrated methods also varies, depending on the methods used for integration. Broadly, integrated methods involving simulation and optimisation methods like Zhu *et al.* 2007, Howells *et al.* 2013, and Bieber *et al.* 2018 require considerable effort and time. The integration of two methods is also often associated with loss of transparency and ease of computation, particular issues being complexity and validation (Parker *et al.* 2002).

   A significant number of nexus assessments have been carried out at the (national or trans-boundary) basin level, utilising integrated methods that support higher coverage of nexus domains and a combination of hydrological, economic, and participatory approaches (Jalilov *et al.* 2016, Jalilov *et al.* 2018, Mayor *et al.* 2015, Strasser *et al.* 2016, Keskinen *et al.* 2015, Karlberg *et al.* 2015). These assessments are rigorous and context-specific but are very specific to a river-basin environment.

Some broader inferences drawn from the review of methods in Table 3-1 are as follows:

- ***Accounting-based and integrated methods*** *are generally superior in terms of domain coverage. While the former methods are considerably transparent, the latter demonstrate varying (and generally lower) levels of transparency that depends on the kind of methods used for integration.*

  In relation to other aspects, it can be observed that the analytical capabilities of both kinds of methods are comparable. While ***accounting-based methods*** *are computationally simpler,* ***integrated methods*** *are more flexible in representing different contexts and determining temporal trade-offs in nexus assessments.*

- ***Simulation, optimisation, and statistical approaches –*** *in isolation – are generally weak in terms of domain coverage. These approaches are however good in terms of their temporal flexibility. They differ considerably from each other in regards to their analytical capability, transparency, and computational simplicity.*

  The analytical capability of simulation and optimisation-based methods, for example, is generally superior to that of statistical and econometric approaches, especially when dealing with situations typified by a high-dimensional EWF nexus. However, the statistical and econometric approaches are computationally simpler than the simulation and optimisation methods.

  In terms of methodological transparency, statistical methods are better than simulation and optimisation methods owing to the presence of external, potentially verifiable sources, and the transparency intrinsic to these methods (often accompanied by a sensitivity analysis in the case of alternative options). These methods are also characterised by the clarity of their assumptions, the verifiability of their data sources, their coding knowledge, and the decisions made about statistical analysis, all the way to inferences and recommendations (Gelman and Hennig 2017). Transparency, however, is moderate in simulation- and optimisation- based methods as the simulation or optimisation components are often presented as black boxes (Halim and Seck 2011).

- ***Participatory methods*** *used in isolation are weak in terms of temporal coverage. However, when used in conjunction with other methods like accounting, simulation, or optimisation, participatory methods can not only improve the flexibility of visualising temporal trade-offs (across different time frames like short, medium, and long term), but also augment the analytical ability, context specificity, and domain coverage.*

3.4. Discussion

This review helped delineate some broad contours of framework to overcome some of the limitations/shortcomings in the existing frameworks used for nexus assessments if they are to be used to guide policy development.

A prerequisite for frameworks for nexus assessments is to represent a bias-free approach to EWF resources in the nexus. The frameworks should rather offer a collaborative environment in a sectoral bias-free space to cover a diverse range of issues in which context-specific security-related interests of energy, water, and food can be discussed.

The frameworks for EWF nexus assessments should be analytically sound to accommodate the resource interlinkages in different domains and temporally flexible to determine the short-, medium-, and long-term policy impacts. Visualising the trade-offs between nexus domains and across different time periods are key aspects for nexus assessments for guiding policy development. Other important criteria for frameworks for nexus assessments are simplicity of computation and model transparency, all of which are highly relevant if the assessments are to be easily used and understood by policymakers.

At the policy level, particularly macro policy level, the emphasis is on the usefulness of these methods for policy assessments. At the macro level, the understanding of trade-offs, coverage of issues, and domains, and so on are the critical factors. Analytical and computational rigour, important though it may be, is less critical at this stage to obtain a first-order indication of where the major trade-offs may lie. A slightly weaker computational framework is sufficient because at this level, the assessments look mostly at the wider trade-offs. Some of the computational rigour could therefore be sacrificed in favour of the ability of the method to analyse trade-offs. Visualisation of cross-sectoral and cross-domain trade-offs also helps decision-makers develop and explore alternative resource management strategies. Attributes like accuracy and analytical and computational rigour in frameworks are more critical for performing sector-specific assessments or designing actual systems for implementation.

A more policy-relevant analysis could also possibly require development of specialised methods for nexus assessments, or combination or modification of existing methods. It is also suggested that the framework for nexus assessments should strike a balance between technology-rich but limited policy-relevant analysis and relatively less technology-rich but extremely powerful policy-relevant analysis, with valuable insights into the policy trade-offs and economy-wide impacts that could result from pursuing alternative developmental and technological futures.

The review suggests that the usefulness of accounting-based or integrated methods to understand the nature of the nexus, determine impacts, and to identify policy trade-offs could be augmented by including a few more aspects. For example, a nexus assessment framework could use such accounting-based methods as IO analysis or SAM in conjunction with indicator-based tools like Nexus Assessment 1.0 (Flammini *et al.* 2014).

Similarly, the estimates of energy, water, food requirements, derived from integrated methods like WEAP-LEAP, could be used in combination with economic accounting-based methods like IO analysis to examine the economic linkages around consumption and production as well as the economy-wide impacts of different energy, water, food development pathways. Such integration is particularly useful in replicating real-life phenomena like income and price changes. In addition, population and economic growth can be incorporated to determine the role of these drivers. The analysis carried out using these methods is biased neither in favour of any one sector or resource. Lastly, most accounting-based methods are transparent and simple in terms of computation.

While accounting-based economic methods like IO and SAM are useful for nexus analysis, they also have some shortcomings. These include, for example, the inability of these methods to account for non-market interactions such as biomass collection for cooking and heating, or ecological processes such as provisioning of water through the ecosystem. Another shortcoming of these methods, particularly when demonstrating temporal impacts, lies in their limited use for long-term policy analysis; this is because these methods, in their traditional form, cannot analyse structural changes and corresponding price-induced input substitution possibilities.

The first shortcoming can be overcome by linking the economic accounting methods such as the IO and SAM with bio-physical models as appropriate for each policy analysed. Further, sectors in the economic accounting methods can also be aggregated or disaggregated to the desired level of policy intervention, such as technologies, regulatory or market structures, or even institutions. The frameworks so designed specifically capture the nexus linkages affected by the policy measures analysed, thereby enabling the synergies and trade-offs created by those policies to become obvious and therefore to be better understood.

The second limitation can be overcome by constructing a dynamic version of the IO model which enables the model to be used for forecasting. The traditional Leontief IO model is restricted in its ability to analyse structural change due to the fixed proportionality of the input-output coefficients. However, these can be modified to more flexible production systems that are compatible with all possible values of substitution elasticities to analyse structural change and therefore any price-induced input substitution.

Participatory methods are extremely useful and they can be incorporated into such frameworks by encouraging expert and stakeholder participation in the selection of context-specific security attributes for the EWF nexus and indeed any other nexus domains, such as social, economic, and environmental. Such participation can also assist in the development of policy scenarios for energy, water, food and can help overcome the problem of sectoral bias in existing nexus assessments which may have been the case if undertaken by sectoral experts in isolation.

Broadly, the review suggests that specialised methods are required to guide policy development for redressing EWF security. The development of these methods may require some existing methods to be integrated or modified, particularly those based on accounting principles. Other methods can augment nexus assessments by providing additional information as inputs. However, accounting-based methods as the foundation for nexus assessments – particularly to guide policy development – are more suitable. At the macro level, policy making and decision making typically need the issues in question to be free of any sectoral or resource bias, and attention needs to be paid to multiple nexus domains. Further, assessments derived from accounting-based methods are better suited to weighing policy options on the basis of the trade-offs between different nexus domains and over time – a critical precondition for policy and decision making. An additional advantage is that the transparency and ease of computation associated with these methods makes them adaptable and accessible to policymakers, leading to better communication of their findings; this is particularly important considering the diverse range of audiences and the level at which the results need to be communicated.

3.5. Methodological Selection: Input-Output Analysis

In recognition of the diversity and complexity of the EWF security nexus, and the broad contours of the desired framework for EWF security nexus assessments, this research identifies some methods to be somewhat more effective and more comprehensive than others.

As previously stated, the purpose of this research is to examine the nexus approach to EWF security policy making. Hence, a bias-free, rigorous yet straightforward, transparent, multi-domain, and context-flexible method is necessary to assist in policy analysis. On the basis of a detailed review of methodologies and keeping in mind the purpose of this research, an EWF-extended IO-based framework is proposed.

IO models represent the economy as a system of interrelated goods and services, expressed in terms of the underlying interdependencies between different economic sectors at disaggregated levels. This model captures the national accounts at both aggregated (such as GDP) and disaggregated (such as industry value added) levels. It also captures trade dependencies through export and import linkages. Hence, it is an optimal analytical framework for examining the regional, sub-regional, or national economy-wide impacts of sectoral policies and strategies aimed at redressing the EWF security challenge.

The modelling process comprises several steps. The first step is to build the context by identifying context-specific EWF security indicators. The EWF-oriented IO framework can then be constructed to reflect these indicators. A set of scenarios based on nexus or non-nexus considerations can be then applied to the model to assess short- to long-term impacts from various perspectives, for example, technical, social, economic, environmental, or institutional. Trade-offs between different perspectives in the short, medium, and long term can then be examined.

IO offers flexibility in defining context-specific EWF security and other socio-political objectives. The IO framework can be tailored to fit different contexts (in terms of EWF security indicators) by aggregating or disaggregating sectors to the desired level. Lenzen (2011) highlights the sectoral aggregation bias as problematic, since environmentally sensitive sectors are often aggregated in IO data; the author therefore strongly advocates sectoral disaggregation even if it is based on only a small amount of proxy information. The sectors can be disaggregated into technologies, regulatory or market structures, or even institutions.

Notwithstanding the high degree of criticism that the IO model has faced in terms of its functional abilities, most of the criticism have been discredited as misconceptions surrounding the model (Rose 1995). For instance, the IO use of fixed coefficients has been highly criticised due to the underlying assumption about the fixed proportionality of IO coefficients. However, in reality, these coefficients undergo frequent changes due to, for example, innovation, changes in consumer and producer preferences, or policy adjustments (Rose 1984). These changes trigger technological changes which further alter factor inputs.

The fixed proportionality of inputs, however, is valid for only the most basic version of IO. In its most traditional form, IO employs the standard Leontief production function formulation where it is usually assumed that the IO ratios remain fixed in physical terms when relative input prices change. However, the traditional IO model can be extended to more general production systems; the Translog production function and the Constant Elasticity of Substitution (CES) production function, for example, are compatible with all possible values for elasticity of substitution for analysing structural change and correspondingly price-induced input substitution (Milana 2001, Rose 1995, Skolka 1989, Rose and Chen 1991). This flexibility makes the analysis more realistic.

Other limitations of IO mentioned in the literature are the neglect of prices and the supposedly static nature of the model. The former limitation can be overcome by price multiplier analysis, which allows the cost-push inflation of exogenous changes in input cost to be determined (Leontief 1986). The assumed static nature of the model has been overcome by the construction of a dynamic version of the IO model (Leontief 1953, Leontief 1970) which means it can be used for forecasting.

IO is considered mainly a model of production and lacks supply constraints. To overcome this limitation, producer and consumer behaviours are expressed as nested structures, specifically as input usage patterns on the production side of the economy, and as consumption patterns on the demand side of the economy. Further, behavioural equations – expressed in functional forms such as Constant Elasticity of Substitution (CES) and Constant Elasticity of Transformation (CET) that specify relationships within the nested structures – are derived from optimisation.

The model accounts for supply (and demand) constraints by reflecting them in the values for scenario variables.

The procedure described above for taking resource constraints into consideration is in contrast to optimisation models (for example, MARKAL and MESSAGE) whose constraints and boundary conditions are more explicit. An optimisation model is generally technology-rich and the wide range of processes and technologies it includes makes it possible to specify assumptions about resource constraints very explicitly. However, these models provide limited insights that might be relevant to policy making, as they provide few if any meaningful insights into the economy-wide impacts of policy decisions and (therefore) policy trade-offs.

The greatest strength of the modelling framework proposed for this research is the transparency it offers at each step of the modelling process compared to its counterparts, while offering similar capabilities. Each step of the modelling exercise is articulated in a way that the modellers can pin-point the reasoning behind a particular finding. This methodology thus provides a comprehensive yet uncomplicated tool that can be used as a *vade mecum* by the policymakers to evaluate alternative nexus-oriented pathways in policy making.

3.6. Summary and Key Inferences

This chapter develops a comprehensive review of the methods used to analyse the nexus, for guiding policy inquiry into EWF security. This chapter also draws common findings which corroborate the association between the underlying drivers of nexus assessments identified in Chapter 2 and the methods adopted to examine the EWF interlinkages.

This review suggests that despite the popularity and use of nexus thinking for cross-sectoral policy and decision making, the existing frameworks used for nexus assessments are limited in their ability to demonstrate the typical characteristics or attributes that will provide relevant and efficacious policy inputs for EWF security.

A policy-relevant analysis could require a specialised framework to be developed from a method or a combination of methods that will help guide inter-sectoral WEF security policies. Accounting-based and integrated methods for nexus assessments that use diverse knowledge bases and capture stakeholders' interests (and thereby offer greater support for decision making), are found to be more favourable for determining policy outcomes. Overall, while the existing methods for nexus assessments offer promising solutions to complex resource allocation and developmental issues, pertinent selection of a methodology is necessary for an effective and policy-relevant approach.

Lastly, this review suggests broad contours of frameworks for guiding nexus assessments that will support adequate EWF security policy making. A diligent use of such frameworks is likely to result in efficacious nexus assessments, thereby providing better inputs to policy making for EWF security.

In recognition of that, an EWF-extended Input-Output method with flexible production functions was selected as the core methodology for carrying out EWF nexus assessments in this research. Further details on the development of the methodological framework are provided in Chapter 5.

Chapter 4 . Energy, Water, and Food Security for India

The principal objective of this chapter is to develop a broader perspective on energy, water, and food security in the context of India. This involves developing an historical account of EWF security considerations in India and a review of the country's current plans and policies for this issue.

Understanding the past influences affecting considerations of energy, water, and food is essential to understanding the factors that may influence EWF securities in the future. Some of the factors may not link directly to energy, water, and food sectors; probably concern national or global securitisation or development; however, indirectly influence energy, water, and food. An assessment of current policies to attain EWF security in India will be useful to develop the methodological framework for this research, in particular, to conceptualise alternative policy pathways and to select impact attributes for EWF security.

A broader perspective on energy, water, and food in India is developed in three stages. First, the concept of 'security' is reviewed to trace its origin and its transition from military to EWF security. Second, the status of EWF security in India is traced back in time from pre-history to the present day, focusing on EWF considerations during different time periods or key events to understand the present situation of EWF security. Lastly, current policies to attain EWF security are reviewed.

This chapter is divided into three sections: Section 4.1. describes the concept of 'security' and traces its re-conceptualisation from a traditionally military application to energy, water, and food security. Section 4.2. is an historical account of EWF considerations in India in the past and how these considerations transitioned to their present state. This section reviews existing plans and policies for EWF security in India and presents the major findings from that review. Section 4.3. presents a summary of the chapter along with the key inferences.

4.1. Origin of Energy, Water, and Food Securities

4.1.1. The Concept of Security

The word ‘security’ originated from the Latin *securitas*, from *securus* 'free from care'. Security plays a vital role in giving a meaning to life and is the ultimate desire for all living beings, be they human beings or other living organisms. Large populations, both in the past and present, have migrated or sought refuge in other secure or safer places, often giving away their monetary or luxury comforts to achieve that. The Syrian migrant crisis is a classic example of how a security threat to life can lead to mass migration.

Security has also been considered as a value, an instrumental value that is said to be variable due to different psychological states, values to be protected, expectations, and degrees of danger/threat (Hermann 1909). This aptly demonstrates the contextual nature of security. Further, security as a policy objective necessitates answers to the following questions: security for whom? security for which values? how much security? from what threats? by what means?, at what cost?, and in what period? (Baldwin 1997). In the hierarchy of human needs proposed by Maslow, security of physiological needs are placed at the lowest level of the pyramid; this means that in order to transition to higher level needs like creativity, inner potential, and so forth, basic human needs must be met first (Maslow 1943, 1954) (Figure 4-1).

In this regard, Mcleod (2007) states: ‘One must satisfy lower level basic needs before progressing on to meet higher level growth needs. Once these needs have been reasonably satisfied, one may be able to reach the highest level called self-actualisation. Every person is capable and has the desire to move up the hierarchy towards a level of self-actualisation. Unfortunately, progress is often disrupted by a failure to meet lower level needs’. Energy, water, and food security – positioned on the lowest level of the Maslow pyramid – therefore play an important role in the development of societies.

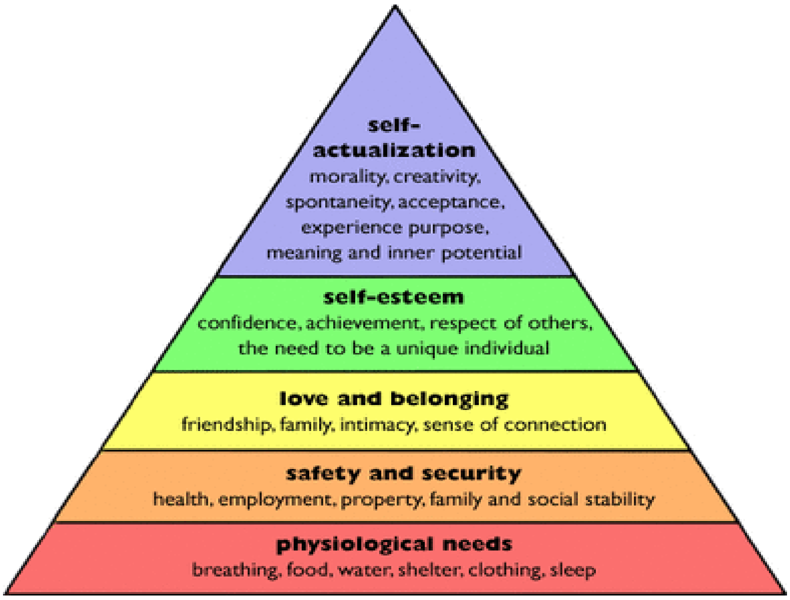


Figure 4-1: Maslow's Hierarchy of Needs

4.1.2. Re-conceptualisation of Security

Traditionalists in the field of security viewed security mostly through military and international politics lenses. Security concerns earlier were somewhat limited to safeguarding territories as well as protecting the interest of citizens of individual nations in international matters. The scale of security conceptualisation was mostly national. Security concerns were limited to threats from military or political disturbances and the quality of life remained largely ignored in the wider security constructs. Security concerns, however, were reconceptualised later.

Re-framing of securitisation since 1990 is attributed to two key developments by Brauch 2006; first, the global contextual change with the end of the Cold War and second, the constructivist approach to social sciences. The former included fundamental changes in international politics, terrorist attacks like September 11, increased attention to global environmental concerns as were put forward in United Nations Conference on Environment and Development (UNCED), also known as the Rio Conference, in 1992 and the World Summit on Sustainable Development (WSSD), also known as the Johannesburg Conference, in 2002, and last but not the least, the risks and threats posed by globalisation. The latter included a paradigm shift from 'positivism' that relies on learning based on empirical evidence to 'constructivism' that relies on learning based on social interaction. The key difference between the two paradigms in their social science approach is that while the positivists compare society with a machine, the constructivists compare it with an organism or an ecosystem (Hwang 1996, Armstrong 2013).

After it was realised that security concerns were much more extensive than had been perceived earlier, two significant changes took place in the re-conceptualisation of security constructs.

First, the scale of appraising security widened, from what used to be mostly national or military to individual (human) and global levels

Global security aims to safeguard mutual survival and safety. Global peace and security require international cooperation, effective trade and sustainable use of resources between states. The states are interdependent, directly or indirectly, more so because of current trends in globalisation that have increased reliance of nations on one another. There is also intense competition between states to develop the most advanced forms of technology and mass communication, and to be self-sufficient or reduce their dependence on other states. Globalisation has been termed as one of the three key propagators to modern threats to peace and security along with modern technology and modern forms of mass communication (Mayanja 2010). Resource scarcity and simultaneous growth in demand are risks or threats to global security as they lead to conflict between nations.

Human security gained recognition as it was realised that most national (as well as global) security goals overlap with the securitisation of human beings. Consequently, informing national policies with societal welfare became the new approach to national security. The UNDP demarcates two major components of human security: ‘freedom from fear’ and ‘freedom from want’, and categorises the threats to human security into seven: economic security, food security, health security, environmental security, personal security, community security, and political security (UNDP, 1994).

Second, the dimensions to demarcate human security also expanded from what used to be traditionally mostly military. For instance, in 1994 the UNDP formally recognised human security as a multi-dimensional concept, and categorised seven elements of human security in its report of that year; these elements were economic security, food security, health security, environmental security, personal security, community security, and political security (UNDP, 1994). Further, Buzan, Wæver and De Wilde (1998) took into consideration five broad aspects of security: military, political, economic, environmental, and societal. Security concerns after that were perceived to be more sectoral, which led to the concept of energy, water, and food security.

The next section attempts to understand historical EWF considerations in India and how the current state of EWF security has been reached.

4.2. EWF Security in India

4.2.1. Brief Historical Account of EWF Considerations

This section presents a historical account of EWF security in India, thereby leading to a better understanding of the current EWF challenges. Chapter 1 described the current challenges in India regarding the three necessities of life – energy, water, and food. It is worthwhile to trace back the historical considerations of EWF to understand the origin and nature of current challenges as well as the past influences on current and future developments in these sectors.

India – also known as the land of saints – traces its origin back to around 9000 BC in Bhimbetka where the earliest traces of human life on the Indian subcontinent were discovered (Mathpal 1985). Since then, India has been a land of several religions and a favourite destination for numerous races, e.g. the Indo-Aryans, Greeks, Scythians, Turks, and others. India has a rich cultural heritage, and the nation has witnessed the birth of some of the world's oldest civilisations and religions.

The history of India spans a transition from prehistoric settlements to the development of urban civilisations; the onset of the Vedic period (when the religious texts that eventually formed the basis of Hinduism and the Sindhian culture were compiled); Ancient India marking the rise of religions like Hinduism, Jainism, and Buddhism, and the Medieval period that witnessed the rise and fall of the large and powerful Rajput, Mughal, and Maratha kingdoms and empires. This marked the beginning of the British colonial era, which ended with India's independence in 1947 (Mcleod 2015).

The rich ancient history reveals how early civilisations in India lived in harmony with nature, utilised natural resources to create means for their livelihood through farming, cattle rearing, spinning, weaving, metalworking and so on. Self-sustenance was the basic premise of living during that period as opposed to the centralised planning prevalent in modern India. Food was grown with the utmost care, without the use of any harmful fertilisers or pesticides, causing least damage to the soil, water, or environment. People in general had limited needs and led a minimalistic lifestyle. This system unintentionally promoted the sustainable use of resources, including energy, water, and food.

The first urban civilisation of the region, i.e. the Indus valley civilisation, is often cited as a legendary example of sophisticated water supply and management, sanitation, and drainage systems (Burian and Edwards 2002). In the absence of water infrastructure, most of the early civilisations flourished along the banks of rivers so that people, plants and animals could access the water they needed to survive. As a result, rivers such as the Yamuna and Ganga were revered, as suggested in many of the religious texts written during the Vedic period, including the Vedas. The emotions attached to the rivers exist to date.

Religious texts from the Vedic and Ancient periods suggest a sense of ecological awareness, with nature, ecological, and environment-related concerns apparently embedded in their teachings. The example given below implies the attitude that this culture was supposed to have towards the environment. Ancient Vedic prayers in Hinduism directed to Earth, Sun, Wind, Water, and Space – also referred to as 'Panchbhoothas' – are a testimony to the tradition's ecological awareness (Chandran 2015).

'Om dyauh śāntir antariksam śāntih prithvi śāntih āpah śāntih osadhayah śāntih' – Yajur Veda 36.17 {Unto Heaven be Peace, Unto the Sky and the Earth be Peace, Peace be unto the Water, Unto the Herbs and Trees be Peace}.

Likewise, *Manusmriti* – an ancient legal text – prohibits pollution of lakes and rivers and threatens severe punishment to offenders. Arthashastra (an ancient book on statecraft, economic policy, and military strategy) prescribes various punishments for cutting trees, damaging forests, and killing animals. The *Puranas* applaud planting of trees as a religiously commendable act. Ancient religious texts like the *Bhagavata Purana*, a famous Hindu scripture, makes a metaphor of nature as a teacher that teaches forbearance and patience for humanity to learn and practice humility (Klostermaier 2007). The *Charak Samhita* (ancient Indian texts on traditional medicine) provides information on the use of water to maintain its purity (Skandhan *et al.* 2011).

Similarly, Jainism advocated *Ahimsa* – not harming anyone or anything – as its first and highest directive. Buddhism conveyed ecological sensitivity through stories about earlier incarnations of the Buddha (*Jatakas)* in various animals. Buddhism provides knowledge to attain full control over such normal human tendencies as greed, hatred, and delusion, themselves often regarded as the roots of the ecological crisis (Hewage 1982, p. 105).

The encouragement of vegetarianism by several major religions in Asia (including Hinduism in India) is believed to be backed by environmental agendas and religion played a role in sensitising people about overconsumption and materialism. Several religious teachings, like *Dharma* (Human Actions), *Moksha* (Liberation), *Karma* (Human Actions), *Shanti* (Peace), and *Daan-Punya* (Charity) aim to sensitise people to be less greedy and materialistic, and more respectful, peaceful, and giving towards society and nature. These teachings are meant to discourage wasteful use of resources, encourage their fair distribution and prevent wars, which are the cause of so much ecological devastation (Skolimowski 1989).

The medieval period in India is also suggestive of ecological sensitivity towards nature, including energy and water. Settlements in medieval India, including the Rajput and Mughal clans, demonstrated the use of such sustainable design techniques as water conservation structures at a time when such technology was almost non-existent elsewhere (Zuberi 2017). Several Mughal kings were environmentalists, which seems to reflect the Islamic environmental philosophy. Energy, water, food considerations are also embedded in the texts from the Islamic religion. One example is as follows:

> *Imam Sadiq: There is no joy in life unless three things are available: clean fresh air, abundant pure water, and fertile land.* ~ Bihaar al-Anwaar, Volume 75, p. 234 (In Shomali 2008)

The early nineteenth century, which marked the end of the Maratha Empire, followed by complete British control over India until independence in 1947, saw the British seizure of Indian forests, primarily for its timber, which the British needed for military purposes, for Royal Navy ships, and for construction and expansion of roads and railways. Large landowners also encouraged the conversion of forests to agriculture to generate revenue and meet the tax demands of colonial administrators (Rosen 2000).

During the colonial period, agriculture was dominated by human and animal labour and was the primary occupation in the country. Crop yields were quite low and the country also experienced major famines during that period. Reallocation of millions of acres of agricultural land for export crops instead of domestic subsistence crops, and the exorbitant taxes levied by the British further increased the vulnerability of Indians to food shortages (Davis 2001). The introduction of large-scale irrigation systems and construction of canals under British control also washed away the traditional wisdom on rainwater harvesting (Pacey and Cullis 1986, Agarwal and Narain 1997, Rohde 2018).

The management of natural resources in the country was relatively better in the latter half of the 19th century, the highlight being the beginning of organised forest management. However, the ulterior motive of such initiatives seemed to be a steady supply of timber products to Britain. The British also introduced some environmental regulations and acts in India during this period ((Budholai).

The Public Distribution System (PDS) was initiated in India during World War II to counter food shortages. Post-Independence, the agriculture sector in India was the prime focus of the Indian government to boost the economy and develop society because farming was the primary occupation in the country. After the partition in 1947, the country was left with 82 per cent of the total population of pre-partition, undivided India, but with only 69 per cent of the land that had previously been under rice, 65 per cent the land that had previously been the land that had previously been under wheat and 75 per cent under all cereals (Kaur and Sharma 2012). This unequal distribution of resources led to food shortages in the country, and these food shortages gave impetus to the existing PDS.

The poor state of Indian agriculture further intensified the food shortages. The farming process was still mostly reliant on traditional, i.e., human and animal forms of energy, and animal products as manure. Productivity was low and India had to resort to importing food grains from different parts of the world. The famines of 1966 made the situation even worse. This scenario marked the onset of the Green Revolution.

The Agricultural Prices Commission, now known as the Commission for Agricultural Costs and Prices (CACP), was set up in January 1965 to provide price protection to the farmers against sharp falls in market prices and to enhance domestic agricultural production. The commission fixes Minimum Support Prices (MSP) for major crops every year to insure a minimum price is paid to farmers for their produce (Acharya 1997).

The decade that ran from 1961 to 1971 saw a record high rate of increase in population (MoSPI 2011), one of the prime factors affecting the demand for energy, water, and food. The possible reasons suggested for this high population growth rate were a negligible focus on education during the British rule, which caused high illiteracy, poverty, poor nutrition, high infant mortality rates, and utilisation of children as productive assets (family labour) in agriculture by marginalised small farmers (Maddison 1971, Rahman 2004).

The Green Revolution improved income levels and nutritional intake, increased life expectancy, and reduced infant mortality rates. However, poverty and hunger persisted despite the success of the Green Revolution and the fact that India became a food grain exporter. Several factors contributed to this, including a focus of the Green Revolution on favourable areas, inequitable land distribution, insecure ownership and tenancy rights, poorly developed input, credit, and output markets, policy discrimination against small farm holders (such as subsidies for crops or mechanisation), and scale bias in research and extension (Hazell 2003, Pingali 2012).

The Green Revolution aimed to improve agricultural yields through the introduction of subsidies on agricultural inputs like seeds, fertilisers, irrigation, and electricity to protect the interests of marginalised farmers. Although the agricultural situation improved by the 1970s, the subsidies prevailed as these had become part of political manifestos and were exploited by political parties as a campaign tool. Similarly, power subsidies became a routine political instrument, particularly in the dominant agricultural states of India (Dubash 2007, Badiani *et al.* 2012). As a result, over-exploitation of energy (in the form of electricity and fertilisers) and water for food production continued.

Long before the climate change debates began, Mahatma Gandhi, regarded as India's Father of the Nation, sensitised the public regarding the need to protect the environment for the benefit of current and future generations. The Gandhian philosophy urged people not to blindly follow western practices that may be unsuitable for the Indian environment. One of the popular statements made by Mahatma Gandhi in this regard was:

> *The earth, the air, the land and the water are not an inheritance from our forefathers but on loan from our children.* ~ Mohandas Karamchand Gandhi

During the 1970s and 1980s, education levels improved and the population growth rate started to decline due to such factors as improved literacy rates and increased access to contraceptives (Jain 1985). The 1970s was also marked by the beginning of environment protection legislation in India, catalysed by the United Nations Conference on the Human Environment (also known as the Stockholm Conference) in 1972.

Several pieces of environmental legislation were passed during the 1970s and 1980s, including the *Water (Prevention and Control of Pollution) Act 1974,* the *Air (Prevention and Control of Pollution) Act 1981*, and the *Wildlife (Protection) Act 1972*, and the constitution of the Central Pollution Control Board (CPCB) was set up in 1974. The *Environment Protection Act* was passed in 1986 in the wake of the Bhopal gas tragedy – an industrial gas leak disaster at the Union Carbide India Limited (UCIL) pesticide plant in the Indian city of Bhopal – and the National Forest Policy was also adopted later in 1988.

In the 42nd Amendment to the Indian Constitution in 1976, Article 48-A was added to the Directive Principles of State Policy and Article 51-A was added to the Fundamental Duties (sections of the Constitution of India that prescribe the fundamental obligations of the states to its citizens and the duties and the rights of the citizens to the state). These articles imposed responsibility on the state to protect and improve the environment and safeguard the forests and wildlife of the country; they also directed Indian citizens to protect and improve the natural environment, including forests, lakes, rivers, and wildlife, and to have compassion for living creatures as a fundamental duty (Ramakrishna 1984, p.912).

In 1991, India made a historical move by liberalising the economy in an effort to make it more market-oriented and expand private and foreign investment. This was attained by introducing numerous changes in the country's regulatory policies, such as reducing import tariffs, deregulating markets, and reducing taxes (Ahluwalia, 2002). India's economic reforms are widely believed to have been successful in accelerating growth and reducing poverty (Ahluwalia and Little 2012). However, some researchers also believe that the reforms widened the income gap and caused greater inequality.

The World Trade Organization (WTO) Agreement on Agriculture (AoA) that came into force in 1995 was a significant step towards reforming agricultural trade between WTO member countries and making it fairer and more competitive. India’s long-established public distribution system also went through reforms in 1992 and 1997 aimed at restructuring and strengthening the system, and targeting the poorest sections of the society as its key beneficiaries.

The next decade was characterised by the development of sectoral policies and legislation like the National Agriculture Policy 2000, the *Electricity Act 2003*, the National Population Policy 2000, and the National Water Policy 2002 to improve the sectors' performance, coordination, and management. A National Environment Policy introduced in 2006 built upon existing policies to extend the coverage of environmental management and protection and fill in the gaps (GoI 2006).

The period between 2004-05 and 2011-12 saw a marked rise in the middle-class population; in other words, the number of people spending between US$2 and US$10 per capita per day that doubled in size in this period, amounting to nearly half of India's population (Krishnan and Hatekar 2017). Urbanisation and rising incomes are generally associated with an increase in demand for necessities like energy, water, food more so in developing countries (FAO, WFP, and IFAD 2012).

Despite the PDS reforms, improvement in education levels, economic growth, and other progress and developments in the country, India's position in terms of food security outcomes, like undernutrition and malnutrition, was still quite poor. Hence, the *National Food Security Act* was passed in 2013 to supply highly-subsidised food grains to a majority of Indian population. Under the provisions of this Act, *Priority* households are entitled to 5 kg of foodgrains per person per month, and *Antyodaya* households ("eligible households") to 35 kg per household per month. The combined coverage of priority and Antyodaya households extends up to 75% of the rural population and up to 50% of the urban population (Narayanan 2014). Further, in 2015, the WTO members (including India) addressed the high trade barriers distorting agricultural trade by eliminating export subsidies (Bartels 2016).

While such measures can potentially lead to an increase in domestic agricultural production for consumption and exports, they are also likely to put further strain on resources like energy (electricity, diesel, and fertilisers), water, and land, the primary inputs of agricultural production. Therefore, in such case nexus between energy, water, food becomes even more important to address.

Energy, water, food nexus-related issues have started to become more evident globally, including in India, in the past decade and there are seemingly more inter-sectoral issues. The year 2007-08 witnessed global food inflation (Headley and Fan 2008). The factors identified as contributing to this inflation included increased demand, decreased supply, and increased production costs driven by higher energy and fertiliser costs (Muellar *et al.* 2011). Food inflation affected food prices in India and the energy-food link gained attention globally.

Indian states like Punjab and Haryana – the hotspots of the Green Revolution – are experiencing falling water tables and facing severe groundwater shortages (Singh 2009), and pumping water from deeper aquifers consumes more energy in these states.

Thermal power plants are also experiencing water shortages in India. An assessment by World Resources Institute (WRI) in 2018 found that freshwater consumption by Indian thermal utilities increased by 43 percent from 2011 to 2016 and the country lost about 14 terawatt-hours of thermal power generation due to water shortages in 2016 (Luo *et al.* 2018).

Water allocation between agriculture and power sectors, particularly in water-stressed regions, has emerged as a rising concern. This situation is compounded by the fact that among all India's freshwater-cooled thermal utilities, 39 percent of the capacity is installed in high water-stress regions, and 79 percent of new capacity will be built in areas that are already water-scarce or water-stressed (Luo *et al.* 2018, Sauer *et al.* 2010)

Meeting continually increasing demand for energy, water, and food in the context of the damage caused by long-prevailing and distortionary agricultural subsidies, specifically the mismanagement of land, water, and energy, makes the redress of EWF security a difficult task.

Some of the schemes launched by state governments are attempting to address these interlinkages; for instance, the Jyotirgram Yojana[5] in 2006 physically separated domestic and agriculture electricity supply to better control pricing and accessibility while facilitating co-management of groundwater and electricity (Shah and Verma 2008). Similarly, the Government of Punjab passed the *Punjab Preservation of Subsoil Water Act 2009* to slow groundwater depletion (Singh 2009). Likewise, the Environment (Protection) Rules lays down water consumption limits in existing and newly-installed power plants in the country (MoEF 2015).

However, at the national policy and planning level, there is less understanding and redressal of such trade-offs. Current policies are targeted towards meeting energy, water, food demands

---

5 Jyotigram Yojana is an initiative of the Government of Gujarat to ensure availability of 24-hour three-phase quality power supply to rural areas of the state and to supply power to farmers residing in scattered farm houses through feeders having specially designed transformers.

through supply and demand management options. However, these options are not developed from a nexus perspective and EWF security policy making is still siloed.

This section presented a brief historical overview of EWF-related considerations in India. The discussion highlighted that recognition of EWF security challenge is not a recent phenomenon in the country – even the earliest civilisations in India took cognisance of the EWF security challenge. The ancient texts hinted at an understanding of this challenge in the foreseeable future. However, some unsustainable rituals and beliefs crept into religious practices over time that affected the natural resources of the country over time. The values of customary and community norms also diminished considerably over time with the development of statutory instruments, and the public lost its sense of ownership of the need to protect natural resources (Kumar 2018).

In summary, recognition of EWF insecurity is not new to India. The urgency of this problem has increased manifold over time with increasing demand for energy, water, and food due to urbanisation, changing consumption patterns with globalisation, improvement in income levels, economic growth, and climate change implications, all of which continue to stress EWF resources. Over time, the approach to make adequate provision for energy, water, and food has evolved from a self-driven, self-sustenance, and participatory approach to the current government-led planning and policy approach. Against the above background, the existing energy, water and food security policies are discussed in the next section.

4.2.2. EWF Security for India: Current Policies Pathway

EWF security-related issues in India have already been discussed in Chapter 1. Some of the significant EWF security measures are vested in one of the most extensive national environmental programs, namely, the National Action Plan on Climate Change (NAPCC), implemented by India in response to its Nationally Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC) under the Paris Agreement.

The NAPCC includes eight national missions implemented in the specific areas of solar energy, enhanced energy efficiency, sustainable habitat, water, sustaining the Himalayan ecosystem, green India, sustainable agriculture, and strategic knowledge for climate change (Pandve 2009).

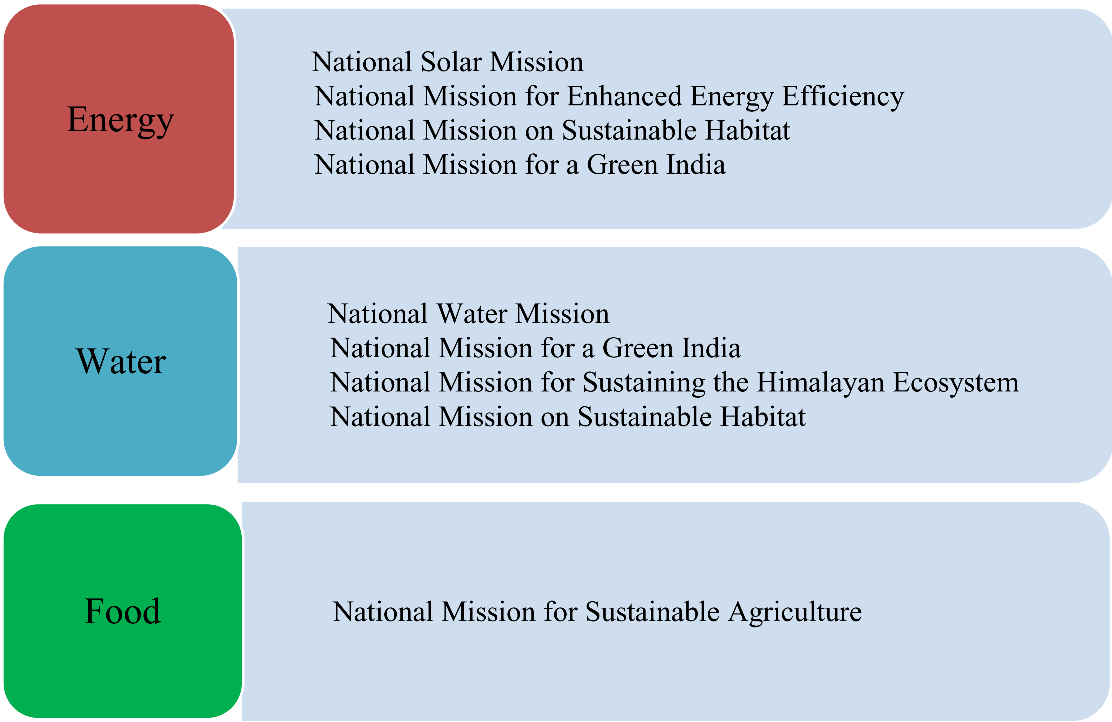


Figure 4-2: National Missions under NAPCC Contributing to EWF Security

Almost four of the eight missions as planned in the NAPCC are dedicated to ensuring a sustainable supply of energy through energy conservation, promotion of renewable sources of energy and reduction of energy use through practices like afforestation.

Three out of the eight missions in the NAPCC directly or indirectly contribute to improving water security in the country. The National Water Mission is focused on improving the efficiency of water use, biodiversity conservation and protection of the Himalayan ecosystem, which is a primary water source in the country. The National Mission for a 'Green India' focusing on afforestation will also indirectly help in improvement of water yields. (Farley *et al.* 2005, Sahin and Hall 1996)

The National Mission on Sustainable Agriculture contributes to food security, its mission being to enhance agricultural productivity, particularly in rain-fed areas, focusing on integrated farming, water-use efficiency, soil health management, and synergising resource conservation (GoI 2014a).

Current Policies in Energy Sector

Table 4-1 presents a summary of demand-side energy security initiatives.

Table 4-1: Key Existing Demand-side Energy Security Policies

Segment	Focus	Initiatives
Domestic transport	Energy demand reduction	Promotion of rail transport, planning of activity centres, development of smart cities based on smart transportation
	Electric mobility	National Electric Mobility Mission Plan: promotion of electric vehicles
Freight transport	Logistics, infrastructure, and planning	dedicated freight corridors, faster train speeds
Cooking	Access, cooking fuel, and efficiency:	Transition towards cleaner fuels and more efficient technologies
Domestic and commercial	Energy access to domestic consumers	Power for All (PFA) Initiative: uninterrupted supply of quality power to existing consumers and electricity access to all unconnected consumers
	Awareness and distribution of energy-efficient appliances	Market Transformation for Energy Efficiency (MTEE)* ● Unnat Jyoti by Affordable LEDs for All (UJALA) ● Super-Efficient Equipment Programme (SEEP)
Building	Residential and commercial building energy saving	Energy conservation building codes (ECBC)
Industry	Improve industrial energy efficiency	Perform, Achieve and Trade (PAT) Scheme*
Agriculture	pumping fuel, Fuel efficiency for pumping and mechanisation, irrigation technology	Replacement of diesel pumps with electric and solar, efficiency pump-sets and tractors, promotion of micro-irrigation technologies
Telecom	Fuel used for operation of base transceiver station (BTS)	Replacement of diesel with renewables like solar and wind
Financing and investment	Energy efficiency	Financial institutions to invest in energy efficiency projects and programs: Energy Efficiency Financing Platform (EEFP)*
Financing and investment	Energy efficiency	Fiscal instruments to leverage financing for energy efficiency: Framework for Energy Efficient Economic Development (FEEED)*

*Programs under the National Mission for Enhanced Energy Efficiency (NMEEE)

On the demand side, the energy security initiatives primarily target demand reduction, efficiency improvement, and fuel switching. The following discussion describes each of the sectoral policy interventions.

Table 4-2 summarises the supply-side energy security initiatives.

Table 4-2: Key Existing Supply-Side Energy Security Policies

Segment	Focus	Initiatives
Electricity	Development of clean and renewable energy sources for power generation	Strategic Plan For New And Renewable Energy Sector: upscale and mainstream the use of new and renewable energy sources like solar, biomass, waste-to-energy, small hydropower, solar, wind
Transport	Clean and renewable energy for transportation	National Biofuel Policy: promotion of biofuel blending
Electricity	Boost contribution of renewable energy sources	National Tariff Policy: Renewable Purchase Obligations (RPOs)
	Promoting installations of rooftop solar	Rooftop solar programme
	Facilitate offshore wind power generation	National Offshore Wind Energy Policy
	Promote solar power	National Solar Mission; International Solar Alliance (ISA)
Coal, gas, oil	Domestic production	Improvement in coal mineability and recovery of oil and gas
Coal- and gas-based electricity generation	Carbon emission reduction	Carbon Capture and Storage(CCS) technology
Energy losses	Reduction of T&D losses	Integrated Power Development Scheme (IPDS)
	Reduction of T&D losses	Restructured-Accelerated Power Development and Reforms Programme (R-APDRP)
	Reduction of T&D losses	Deen Dayal Upadhyaya Gram Jyoti Yojna Scheme (DDUGJY)
		UDAY (Ujwal Discom Assurance Yojana) Scheme
		National Smart Grid Mission (NSGM)
Investment and financing	Capacity expansion	Make-in-India: 100% Foreign Direct Investment (FDI) is allowed under the automatic route in the power sector (except atomic energy)
Governance	Effective transfer of subsidies	Direct Bank Transfer Scheme – direct transfer of subsidies into beneficiary's bank account

*Programs under National Mission for Enhanced Efficiency (NMEE)

The increased use of indigenous renewable resources is expected to reduce India's dependence on expensive imported fossil fuels as well as reduce carbon emissions. As a result, there is a planned transition towards clean energy, primarily nuclear and renewables, in the energy mix. The Ministry of Renewable Energy (MNRE) is dedicated to developing and deploying new and renewable energy to supplement the energy requirements of the country. Renewable sources of energy promoted in the country are solar, small and large hydro, onshore and offshore wind power, small hydropower, waste-based energy, and bio-energy. In 2018, India set ambitious renewable energy targets of 175 GW by 2022, which includes 100 GW of solar power, 60 GW of wind power, 10 GW of waste-to-energy power and 5 GW of small hydropower (CEA 2018).

The Jawaharlal Nehru National Solar Mission (JNNSM), also known as the National Solar Mission (a part of the NAPCC), targeted to promote the use of solar power through grid-connected and distributed solar PV and CSP and the government is working towards harnessing solar power. The International Solar Alliance (ISA), initiated by India, was launched in 2015 to unite solar resource-rich countries. In 2018, the government also announced a national wind-solar hybrid policy.

The National Policy on Hydropower Development, introduced by the Ministry of Power (MoP) in 1998, primarily focuses on accelerating hydropower development in India and undertaking measures to exploitation the vast hydroelectric potential in the country.

The role of bio-energy as an energy source is also considered crucial for energy security because of the environmental and economic benefits offered by biomass-based energy generation. The components that presently make up bio-energy production in India are agricultural residue, forest residue, sugarcane molasses-based bio-ethanol, Jatropha bio-diesel and biogas.

Another focus of government is on blending transportation fuels with biofuels. India mandated oil companies to blend 5 percent of ethanol with petrol in 2016 and the country's aviation sector has begun experimenting with biofuels. The Government of India initiated mandated biofuel blending programs from 2003 under its National Biofuels Mission and its National Policy on Biofuels 2009. These programs specify blending of biofuels with fossil fuels in a time-bound and phased manner across India. More recently, to succeed the existing policy from 2009, a new policy 'National Policy on Biofuels was announced in 2018 with the goal to increase the blending percentages in both bio-diesel and bio-ethanol to an indicative target of 20 percent of ethanol in petrol and 5 percent blending of bio-diesel in diesel by 2030 (GoI 2018a).

Feedstocks identified in this policy are biomass such as those that are sugar-based, like sugar cane, sugar beet, and sweet sorghum; starch-based such as corn, cassava, rotten potatoes, and algae, and cellulose materials such as bagasse, wood waste, agricultural and forestry residues. Other renewable resources include industrial waste for production of ethanol and non-edible oilseed crops like Jatropha and Pongamia, acid oil, used cooking oil or animal fat and bio-oil from trees for bio-diesel production. Wastelands are also envisaged as pivotal for the production of biomass for lignocellulosic fuel conversion. Third generation algae-based biofuels are considered a potential option for blending with transportation fuel.

Municipal waste is also envisioned as a potential energy source for India, both in urban and rural areas, as it holds enormous potential in terms of the useful energy it could yield in various ways, such as electricity, biogas, and thermal energy. The Ministry of Urban Development, as well as urban local bodies (ULBs) across the country, also focuses on municipal solid waste (MSW) -based waste-to-energy (WtE) projects.

Currently, Pressurized Heavy Water Reactors (PHWR), which use natural uranium, account for almost all of the present installed nuclear-based electricity generation capacity. Uptake of new nuclear technologies, like Light Water Reactor (LWR) and Fast Breeder Reactor (FBR), is planned for future capacity expansion.

Domestic production of coal is affected by the extent of available proven coal reserves in the country and their mineability. Some improvement in mineability is expected due to technological improvement. Coal is expected to continue play an important role in the power sector despite the high push for renewables, as electricity from conventional fuels such as coal will provide a buffer against the fluctuations as experienced in the case of renewables, thereby stabilizing the grid (BCG-CII, 2017).

Efficiencies and the plant load factor (PLF) for coal-based power plants are anticipated to improve. New technology development and deployment will take place in coal-based power generation. New installations of sub-critical technology power plant stopped after 2017 as per current government plans (Ministry of Power 2012). Ultra-Super Critical Coal (USC) and Integrated Gasification Combined Cycle (IGCC) technologies will be commercialised in future to generate power from coal at much higher efficiencies.

Domestic oil production is envisaged to improve with some upcoming Enhanced Oil Recovery / Improved Oil Recovery (IOR/EOR) schemes. Additionally, oil or gas discoveries that are at various stages of approval/appraisal for extraction are anticipated to start production, thus enhancing domestic production. This recovery factor is expected to improve slightly. The availability of gas in the country is likely to be augmented by unconventional sources of natural gas like Coalbed methane (CBM) and shale gas. Some improvement in the gas recovery factor is also expected.

Given that the energy sector is a major contributor to emissions in India, CCS technology is being considered as a critical greenhouse gas reduction solution to curb carbon emissions from fossil-fuel-based energy generation. However, since it is a nascent technology, deployment is expected to progress slowly.

Transmission and distribution losses in India are among the highest in the world. With the objective to reduce distribution losses and strengthen the distribution sector, the Government of India, together with the Ministry of Power, has launched several programs, such as the Accelerated Power Development and Reforms Programme (APDRP), the Restructured Accelerated Power Development and Reforms Programme (R-APDRP), the National Smart Grid Mission, and others.

Energy as a fundamental need for both rich and poor was highly subsidised for a very long time. These subsidies are continuing for Liquefied Petroleum Gas (LPG) and kerosene pricing, given their usefulness for cooking and lighting purposes in the poorest sections of the society. The efficacy of subsidisation is improved by directly transferring the subsidies into the beneficiary's bank account, such as the Direct Bank Transfer Scheme in the case of the LPG fuel subsidy.

Additionally, the energy sector needs a much higher level of investment for sustained growth. Any shortfalls in energy supply can impede sustainable economic growth. Therefore, the government is encouraging both private sector participation and foreign direct investment through initiatives like Make-in-India, where 100 percent FDI is allowed under the automatic route in the power sector (except in the case of atomic energy). Promotion of domestic private investment is expected to attract foreign investment and vice-versa (Ndikumana and Verick 2007).

Current Policies in the Water Sector

Table 4-3 summarises key water security initiatives.

Table 4-3: Key Existing Water Security Policies

Segment	Focus Area	Initiatives
Domestic and industrial	Water conservation, recycling, and efficiency improvements	Increased water-use efficiency by 20%; Efficient labelling of water appliances and fixtures; adoption of water-neutral or water-positive technologies; water recycling and reuse; ensuring effective management of water resources*
Agriculture	Regulation of water use	Regulation of power tariffs for irrigation
Domestic	Development of alternative water sources	Water needs of urban areas met through recycling of wastewater and those of coastal cities through technologies like desalination*
Domestic, agriculture and industry	Water conservation	Promoting groundwater recharge*
Water supply	Rural water supply – access and adequacy	Rajiv Gandhi National Drinking Water Mission (RGNDWM): providing every person in rural India with adequate safe piped water supply for drinking, cooking and other basic domestic needs on a sustainable basis
Water supply	Rural drinking water quality	National Rural Water Quality Monitoring and Surveillance Programme: improving rural water quality
Sanitation	Rural sanitation	*Swachh Bharat Abhiyaan*: promoting general cleanliness and improved sanitation coverage and facilities, particularly in rural India
Water supply	Urban water supply and sanitation	Jawaharlal Nehru National Urban Renewal Mission (JNNURM): providing of basic services to urban poor, including water supply and sanitation
Water supply and sanitation	Urban water infrastructure: small and medium towns	Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT): improving urban infrastructure for small and medium towns, including water supply and sanitation
Water supply and sanitation	Urban water infrastructure	National Urban Renewal Mission (NURM): developing infrastructure services
Water quality	Water quality (rural and urban)	National Water Quality Sub-Mission (NWQSM) – Improving water quality
Sanitation	Urban sanitation	National Urban Sanitation Policy: transforming urban India into community-driven, totally sanitised (open defecation-free), healthy and liveable cities and towns
Water quality	River pollution	*Namami Gange* – National Mission for Clean Ganga: cleaning the River Ganges

*Program under the National Water Mission (NWM)

Globally India lags far behind in terms of its water-use efficiencies in all water-consuming sectors like irrigation, industry, and power plants. As a result, there is ample scope for efficiency improvements in India. The Ministry of Water Resources (MoWR) has provided estimates of current and full achievable water efficiencies in different sectors, as shown in Table 4-4 below.

Table 4-4: Current and fully achievable sectoral water efficiencies in India

Water-use sectors	Current level of efficiency	Full achievable efficiency
Irrigation		
Surface water	30	60
Ground water	55	75
Drinking water		
Urban water	60	90
Rural water	70	90
Industries	80	95

Source: Adapted from MoWR 2014

In response to the high water-use inefficiencies in India, the government has planned numerous interventions in different sectors of the economy. One of the key objectives stated in the National Water Mission is to improve water-use efficiency by 20 percent.

The efficiency improvement in the *agriculture sector* is planned through the increased use of water-efficient irrigation technologies (drip and sprinkler technologies) and the lining of irrigation canals. The mission additionally focuses on power tariffs for irrigation to promote judicious use of water in irrigation. Finally, the 'More crop per drop' initiative, a component of the Pradhan Mantri Krishi Sinchai Yojana, aims to improve water-use productivity of Indian agriculture.

Industries are encouraged to improve water efficiency through promoting and incentivising the adoption of water-neutral or water-positive technologies, promoting the uptake of water-efficient technologies as a part of corporate social responsibility initiatives, and reuse of treated effluents.

Efficiency improvement measures in *the domestic sector* comprise technical and managerial options. These are efficiency improvement of urban water supply systems, mandatory water audits, eco-labelling of water-efficient appliances and fixtures, and promotion of water-efficient technologies. Other measures to reduce freshwater consumption in the domestic sector include promoting the use of alternative water sources like recycled wastewater in urban areas and desalinated water, preferably in coastal cities.

Other goals of the National Water Mission are to assess the impact of climate change on water resources and to promote basin-level integrated water resources management to help in water conservation, minimise waste and ensure the equitable distribution of water both across and within states. Development of policies guided by the principles of integrated water resource management are expected to help in coping with rainfall and river-flow variability at the basin level.

Another major government priority in the water sector is the provisioning of a safe, adequate and sustainable drinking water supply to the entire population. To this end, the Government of India has launched rural and urban water supply programs to improve the quantity and quality of water coverage in both urban and rural areas.

The government is also working proactively on the extent, quantity, and quality of water coverage in rural areas. The National Drinking Water Mission, established in 1986 and renamed as the Rajiv Gandhi National Drinking Water Mission in 1991, aims to improve coverage and access to improved services in rural areas. The 12th five year plan (2012-2017) has increased the target of safe piped drinking rural water supply from 40 litres per capita per day (lpcd) to 55 lpcd, while the ultimate goal is to supply 70 lpcd (MoDWS 2013).

The NWQSM recently initiated by the Ministry of Drinking Water and Sanitation under the National Rural Drinking Water Programme addresses the urgent need to provide clean drinking water, particularly in arsenic- and fluoride-affected rural habitations. The National Rural Water Quality Monitoring and Surveillance Programme focuses on monitoring water quality in rural areas to ensure its sustainability on a long-term basis.

Clean India *(Swachh Bharat)*, an initiative launched by the Government of India to promote general cleanliness and improved sanitation facilities in rural and remote areas in India, attracted huge national attention and improved public awareness of the importance of more hygienic practices. The prime motive of this campaign is to make India open defecation-free and put this forward as a large contribution to universal sanitation coverage (Adapa 2018).

In urban areas, the provisioning of water supply, sanitation services and infrastructure is a part of the JNNURM, the NURM and the UIDSSMT. Through the National Urban Sanitation Policy launched in 2008, the government aims to achieve total sanitisation in cities, characterised by being open-defecation free, by the safe collection and treatment of all wastewater generated, and by the elimination of manual scavenging of solid waste and its collection and safe disposal.

Lastly, river water pollution is one of the critical long-standing issues in India. One of the largest river cleansing programs is the National Mission for Clean Ganga; this aims to remediate pollution and rejuvenate the river through a river-basin approach that promotes inter-sectoral coordination of the comprehensive planning and management required. The program also includes maintaining minimum ecological flows in the River Ganga to ensure water quality and environmentally-sustainable development. The program's mission includes cleaning up the river, setting up wastewater treatment plants, and conservation.

Water pricing is still at nascent stages in India and is currently characterised by a subsidised price structure. However, most water policies, including the most recent – National Water Policy 2012 – advocates for a fair water pricing structure to be in place to reduce over-exploitation of the country's scarce freshwater resources. India is currently seeking a rational and pragmatic regulatory water pricing structure that enables full recovery of operations and maintenance costs and reflects the value of water (CWC 2017). Revenue realisation and creation of disincentives for wastages will enable water conservation and reliable delivery and services in the water sector.

Current Policies in the Agriculture and Food Sector

Table 4-5 summarises the key food security policy initiatives in India.

On the demand side, the government is giving high priority to the health and nutritional wellbeing of its people, given the wide prevalence of malnutrition and undernutrition in the country. These initiatives include the National Health Mission () launched in 2013 and simultaneous action on a wide range of determinants of health, such as water, sanitation, education, nutrition, and social and gender equality, both in urban and rural areas. Subsidised food grains and initiatives like the Integrated Child Development Services (ICDS) and the Mid-day Meal Programme contribute to this goal. The National Nutrition Mission focuses on social and behavioural change to ensure awareness about health and nutrition.

The *National Food Security Act 2013* (also called the *Right to Food Act*) was formulated to ensure access to adequate quantities and quality food at affordable prices. It enables up to 75 percent of the rural population and up to 50 percent of the urban population to receive subsidised food grains under the Targeted Public Distribution System (TPDS), thus covering between them about two-thirds of the total population (PIB 2013a).

Sustainable agricultural development is a precursor to food security for India. The national mission on sustainable agriculture under the NAPCC prescribes a focus on crucial dimensions encompassing Indian agriculture, namely, 'Improved crop seeds, livestock and fish cultures', 'Water-use efficiency', 'Pest management', 'Improved farm practices', 'Nutrient management', 'Agricultural insurance', 'Credit support', 'Markets', 'Access to information' and 'Livelihood diversification' (PIB 2013b).

Table 4-5: Key Existing Food Security Policies

Segment	Focus area	Policy interventions
Domestic	Food and nutrition	Antyodaya Anna Yojana (AAY): reduce hunger among poorest segments of below-poverty-line (BPL) population
	Food and nutrition	*National Food Security Act* (also *Right to Food Act*): ensure access to adequate quantity of quality food at affordable prices to enable people to live a life with dignity; distribute subsidised food grains under TPDS
	Public health (rural and urban)	NHM: take action on wide range of health determinants such as water, sanitation, education, nutrition, and social and gender equality
	Food and nutrition	ICDS: provide food, preschool education, and primary health care to children under 6 years of age and their mothers
	Nutritional status of children	Mid-Day Meal Programme: improve nutritional status of children
	Social and behavioural change	National Nutrition Mission: ensure awareness of health and nutritional behaviour among beneficiaries
Agriculture	Agricultural yields, water-use efficiency and soil quality	National Mission on Sustainable Agriculture (NMSA), under NAPCC: enhance agricultural productivity, particularly in rain-fed areas, focusing on integrated farming, water-use efficiency, soil health management and synergising resource conservation
	Soil quality	Soil Health Management (SHM)*: raise farm output levels and promote judicious use of fertilisers
	Organic farming	Paramparagat Krishi Vikas Yojana (PKVY): Organic farming value chain development for North Eastern Region*: promote organic farming
	Agro-forestry	Sub-Mission on Agro-forestry (SMAF)*: development of agro-forestry
	Agricultural productivity	Neeranchal National Watershed Project: integrated watershed management

	Climate-sensitive agriculture	National Initiative on Climate Resilient Agriculture (NICRA): make agriculture climate resilient
	Irrigation coverage	Pradhan Mantri Krishi Sinchai Yojana – 'Har Khet Ko Pani': extend irrigation coverage
	Irrigation efficiency	Pradhan Mantri Krishi Sinchai Yojana 'More crop per drop': promote micro-irrigation techniques such as sprinkler and drip irrigation
Financial	Farmers welfare	Pradhan Mantri Fasal Bima Yojana Insurance for farmers in cases of crop failure; Doubling Farmers Income Initiative
Financial	Farmers welfare	Commission for Agricultural Costs and Prices (CACP): assurance of a remunerative and stable price in the interest of farmers
Governance	Effective transfer of subsidies	Digitisation of ration cards, digitisation of agricultural marketing, leveraging the Aadhaar (national identification document) for authenticated delivery of benefits and an online grievance redressal mechanism
Financing and investment	Food supply chain, including processing and storage	Make-In-India – 100% FDI is permitted under automatic route in food processing industries; 100% FDI allowed through government approval route for trading, including through e-commerce, in respect of food products manufactured or produced in India; promotion of public private partnership(PPP) in the establishment of mega food parks

*Programs under the National Mission on Sustainable Agriculture (NMSA)

A prospering farm sector is a prerequisite for sustainable agricultural production. The Government of India has launched quite a few initiatives to protect farmers' interests and reduce the disincentives that could potentially drive the farming community away from agriculture. These initiatives are Minimum Support Prices (MSP), whereby a minimum crop price is set by the government to insure agricultural producers against any sharp fall in farm prices, Pradhan Mantri Fasal Bima Yojana, a revamped crop insurance program to double farming income by 2022, and others.

Other initiatives to improve farm productivity and judicious use of agricultural inputs are, for example, Pradhan Mantri Krishi Sinchai Yojana, the primary aim of which is to extend the coverage of irrigation and improve agricultural water-use productivity; the Soil Health Management scheme, designed to improve soil health by promoting efficient use of fertilisers; the Neeranchal National Watershed Project to support the Integrated Watershed Management Program (IWMP) to improve incremental conservation outcomes and agricultural yields, and the adoption of more effective processes and technologies.

Sustainable agricultural practices, like organic farming, and the development of agro-forestry, are promoted through numerous schemes like the Paramparagat Krishi Vikas Yojana and the

Sub-Mission on Agroforestry. Further, the National Initiative on Climate Resilient Agriculture (NICRA) aims to redress the climate vulnerability of the agriculture sector.

The operational aspects of food procurement and distribution (Narayanan 2015) are currently addressed through various governance reforms that are being undertaken to improve the effectiveness of food security programs. These include digitisation of ration cards, digitisation of agricultural marketing, leveraging *Aadhaar* for authenticated delivery of benefits and an online grievance redressal mechanism.

The Indian food and agriculture sector experiences high post-harvest and storage losses. The country's low levels of cold storage facilities also result in a high incidence of wastage and loss across the supply chain (Kumar and Basu 2008). Increases in the level of food processing and the development of mega food parks are considered potential strategies to address these issues.

Growth in the food processing industry is expected to increase farm gate prices, reduce wastage, ensure value added, promote crop diversification, generate more employment and increase export earnings (FICCI 2010). Mega food parks provide modern infrastructure for food processing along the value chain from farm to the market, including the development of processing infrastructure near the farm, transportation, logistics and centralised processing centres. Mega food parks are expected to realise increased revenue for farmers, create high-quality processing infrastructure, reduce wastage, build capacity for producers and processors, and create an efficient supply chain along with significant direct and indirect employment generation.

The government has created economic incentives under the Make-In-India initiative to ensure a greater flow of credit and attract private and foreign investment in the sector. It is increasingly incentivising private sector companies to introduce technological and business model innovations to increase value chain efficiency.

The development of supply chain-related infrastructure like cold storage, abattoirs and food parks is also a sectoral priority. The establishment of food parks is a unique opportunity for entrepreneurs, including foreign investors, to enter the Indian food processing sector. To boost investment, 100 percent FDI is permitted in the automatic route for most food products and several agricultural activities. The government is also taking initiatives to encourage the export of agricultural products through various measures and incentives.

This section involved a discussion on current policies in the EWF and agriculture sectors. The next section is a discussion on the findings from the review of current plans and policies.

Current Policies: Review Findings

This section presents some of the key observations regarding current policies in the energy, water, and food (and agriculture) sectors. Energy security policies in India are primarily focused on energy and environmental issues like air pollution and climate change. Water security policies in India are focused on water quantity and quality issues and improving sanitation practices in the country. Food security policies are centred on eradicating undernutrition and malnutrition, and improving crop yields to maintain self-sufficiency of food in the face of rising food demand.

a) From the above review of current policies, it is evident that, in general, energy security draws more attention from policymakers in the country than do water and food security. A possible reason is that energy security also reflects some form of strategic intent due to the country's heavy dependence on imports associated with geopolitical risks. The dependence on energy imports also means that energy security has economic implications. As a result, and as is also evident from the review, energy security is underpinned by a greater focus and by more extensive and explicit plans and policies.

b) Some degree of nexus consideration is evident in the existing policies, mostly in the energy sector. An example of this is the prohibition on building any new sub-critical technology-based power plants. However, these policy initiatives, including the recent huge push to add solar power to the energy mix and the promotion of electric vehicles, seem to be primarily driven by carbon-reduction commitments and rising air pollution levels.

d) Some recent governmental initiatives, like the Jyotigram Yojana (an initiative of the Government of Gujarat), suggest a nexus approach to EWF security. However, so far, initiatives like these have been implemented mostly at state level. Overall, the macro-level EWF policy discourse seems to be single-sectored and siloed.

Siloed approaches or pathways to EWF security policy making have often been cited as the root cause of ineffective policies to redress the EWF security challenge. Alternative pathways based on EWF nexus considerations offer policy makers a departure from such siloed approaches.

The next section presents the chapter summary and discussion.

4.3. Summary and Key Inferences

This chapter summarised how the concept of 'security' expanded over time from its focus on military to human security (including security of energy, water, and food). Further, the chapter discussed the historical and cultural influences on energy, water and food security considerations in India, and traced their impact over time that led to the existing state of energy, water, and food in the country.

This chapter also reviewed the current policies and strategies used in the country to redress EWF insecurities. Some key inferences drawn from the review are:

a. The historical account revealed a deeper understanding of the importance of energy, water, and food, and a precautionary outlook towards EWF security in the country. Various internal and global socio-political influences and factors caused India to deviate from its earlier, sustainable ways of thinking and behaviour, and arrive at its present state wherein the insecurities of food, energy, and water have become pronounced and urgent.
b. Overall, the current policies seemed to be more sector inclined and isolated.
c. Policies in the water and food sectors are not as clearly defined and extensive as they are in the energy sector.
d. Some recent governmental initiatives suggestive of a nexus approach to EWF security are mostly at state level. Overall, the macro-level EWF policy discourse seems to be siloed.

Lastly, based on the historical account and current policy considerations for EWF security, this chapter established the need to explore alternative likely future pathways to attain EWF security in India. Such alternative pathways form the basis for the scenarios that will be developed to examine the policy implications of redressing EWF security concerns. The next chapter provides a detailed description and development of different elements of the methodological framework used in this research.

Chapter 5 . Development of Methodological Framework

The methodological framework used for this research, also described in Chapter 1, consists of three major components: a) *scenario development* – to develop different scenarios for examination, b) *analytical framew*ork – to set up the base for analysing the scenarios with details of some essential aspects of scenario modelling, like scenario assumptions and variables, model validation and calibration, key data sources and modelling preparation., and c) *impact attributes* – to select attributes used in this research to examine the EWF, socio-economic, and environmental impacts for different policy scenarios in the Indian context.

This chapter is divided into four sections. Section 5.1. summarises the scenario storylines used in this research. Section 5.2. contains a detailed description of the analytical approach, including its analytical underpinnings, followed by an elaborated step-by-step modelling procedure for development of the analytical framework to assess the scenario impacts. Section 5.3. provides information on some important modelling aspects, like key scenario assumptions and variables, calibration and validation and key data sources used for modelling and preparation of the framework. Section 5.4. presents the selection of impact attributes to be used in this research for demonstrating scenario results.

5.1. Scenario Development

The storylines used to develop the scenarios in this research were guided by the alternative EWF security pathways conceptualised in Chapter 4. A summary is presented below:

Business-as-Usual (BAU) Scenario

The BAU scenario assumes the continuation of the current trends, policies, and planned investments in each of the energy, water, and food/agriculture sectors.

For the energy sector, this implies planned improvement in energy efficiency across sectors, an increase in the share of renewable energy in the electricity mix and biofuel production in accordance with planned policies.

The BAU scenario in the context of water assumes improvement in water efficiency across sectors in line with planned targets and continuing trends. This scenario additionally assumes a moderate improvement in domestic and industrial wastewater treatment capacity. Improvement in piped water coverage is assumed to follow past trends. Wastewater treatment in urban areas is assumed to follow a more centralised model, which is also a continuation of past trends. Wastewater treatment in rural areas is mostly assumed to be carried out through decentralised natural technologies across all scenarios.

Food consumption trends are based on past trends and the available knowledge of changing food patterns. Crop productivity and areas under irrigation are also assumed to increase moderately in the future. Similarly, food production-related parameters, like feed conversion ratio, nutrient management, seed and waste of total consumption, are also assumed to improve moderately.

Energy Security (ES) Scenario

The energy security scenario envisages greater emphasis on ensuring a sustainable energy supply in the country through various means, such as efficiency improvement, promotion of renewables, and enhancing domestic production. On the supply side, this scenario sees the promotion of centralised, conventional, large-scale technologies like coal, nuclear and large hydro to meet energy demand. Additionally, there are interventions to improve the efficiency of energy production, such as deployment of new and efficient coal-based power technologies like the Supercritical, Ultra-supercritical and IGCC. Bio-energy for power generation and production of transportation fuel (first, second, and third generation biofuels) is promoted aggressively.

This scenario assumes dedicated efforts towards reducing dependence on imported fossil fuels like coal, oil, and gas by enhancing domestic production and diversifying the fuels in the energy mix to improve energy resilience. Energy losses are prevented to a great extent by aggressively reducing transmission and distribution losses to reach global benchmark levels. Reliability of the energy system is enhanced by improving the storage capacity and reliability of the grid.

On the demand side, there is a stronger focus on improving end-use energy efficiency. Better transport planning and management is assumed for reduction in domestic passenger transport energy demand. Rural energy transition from traditional biomass towards cleaner and modern fuels, like LPG and Piped Natural Gas (PNG), is facilitated by enhancing energy equity. Water and food sector interventions, however, follow similar trends to the baseline (or BAU) scenario trends.

Water Security (WS) Scenario

The emphasis on water security in this scenario includes ensuring proper sanitation and hygiene to counter the negative effects of poor sanitation on water security.

On the supply side, the country will resort in this scenario to alternative sources of water like desalination and treated sewage water to augment fresh water resources. There is increased penetration of advanced wastewater technologies like membrane bio-reactors (MBR) and sequencing batch reactors (SBR), together with traditional large-scale wastewater treatment technologies like the Activated Sludge Process (ASP) for domestic wastewater treatment. Piped water coverage and levels of wastewater treatment are assumed to improve significantly compared to the baseline scenario. On the demand side, water-use efficiency across sectors is improved to maximum attainable levels. Food and energy sector interventions follow existing patterns in the baseline scenario.

Food Security (FS) Scenario

By making food security a priority, this scenario seeks on the demand side to eradicate undernourishment and malnutrition by educating the public masses about diet diversification and by improving access to food. On the supply side, this scenario achieves reduces food imports, improves soil fertility through more efficient application of fertilisers and pesticides, better nutrient management, investment in high-yielding crop varieties, practising intensive farming, and increasing the agricultural areas under irrigation. Greater efforts are made towards reducing seed and waste, feed conversion losses. Biofuels are not highly promoted in the energy mix to avoid any adverse outcomes on food security. The water and energy sector interventions follow the baseline scenario.

EWF Nexus (Nexus) Scenario

In this scenario, nexus-guided strategies and solutions are implemented to attain EWF security, using multiple and diverse EWF designs that decentralise, democratise, and facilitate social and environmental justice (Allouche *et al.* 2015).

Recognising the EWF nexus, this scenario considers the application of small-scale technologies. For example, inefficient and water-intensive fossil fuel power plants would be selectively replaced by small-scale, distributed, renewable electricity generation technologies that also consume much less water. This emphasis on decentralised and distributed renewable technologies, it is argued, is also an attractive proposition for improving energy access and democratised decision making. Other examples are renewable energy-based agricultural pump-sets, renewable energy-based generators in the telecom sector, rooftop solar, solar cookers, and so on. Biofuels are not highly promoted in this scenario due to their conflicting nature with food security.

In this scenario, water security would be achieved by greater use of less energy-intensive and decentralised wastewater treatment technologies like waste stabilisation ponds (WSPs). The use of alternative but energy-intensive water sources like desalinated water would be discouraged because of their risk to energy security. In attaining the goal of food security, this scenario would replace energy-intensive chemical fertilisers with organic fertilisers, and would also manage the application of soil nutrients. The sectoral interventions describe above would remain primarily the same as in the individual resource security scenarios and would be implemented in this scenario simultaneously.

Table 5-1 summarizes the storylines of the five scenarios.

Table 5-1: Summary of scenario storylines

		BAU	ES	WS	FS	Nexus
Energy	Demand	• Planned improvement in energy efficiency across sectors • Cooking fuel transition from traditional to modern and cleaner fuels in line with existing policies	• High demand-side energy efficiency improvements • Rapid transition in cooking/heating from traditional biomass towards cleaner and modern fuels, like electricity, LPG and PNG with higher focus on electricity and PNG.	Same as BAU scenario	Same as the BAU scenario	• High demand-side energy efficiency improvements • Rural energy transition in cooking from traditional biomass towards cleaner and modern fuels, like LPG and PNG
	Supply	• Planned improvement in recovery factors for oil and gas and coal mineability • Planned improvement in efficiencies of coal-based power generation, planned increase in renewable energy and biofuel production • Planned level of deployment of CCS technology • Planned level of biofuel production	• Strong focus on reducing import dependency through higher domestic energy production and renewables • Higher improvement in recovery factors for oil and gas and coal mineability • High biofuel production • Promotion of centralized conventional large-scale technologies like coal, nuclear and large hydro • High Deployment of CCS technology • Higher level of improvement in efficiencies of coal-based power generation	Same as BAU scenario	Same as BAU scenario	• Strong focus on reducing import dependency through higher domestic energy production and renewables-particular focus on decentralized and distributed energy sources • Higher improvement in recovery factors for oil and gas and coal mineability • Only planned level of biofuel production • Particular focus on decentralised and distributed energy sources • Only planned level of deployment of CCS technology • Planned level of improvement in efficiencies of coal-based power generation

Water	Demand	• Planned or moderate improvement in water efficiencies across sectors	Same as BAU scenario	• Maximum attainable demand-side water efficiency improvements across different sectors	Same as BAU scenario	• Maximum attainable demand-side water efficiency improvements across different sectors
	Supply	• Moderate improvement in share of alternate water sources, like desalinated and treated sewage water, in water supply • Predominant use of traditional large-scale wastewater treatment technologies • Moderate improvements in piped water coverage and level of wastewater treatment in domestic and industrial sectors	Same as BAU scenario	• Higher share of alternate water sources, like desalinated and treated sewage water, in water supply • Advanced wastewater technologies in conjugation with traditional large-scale wastewater treatment technologies • Significant improvement in piped water coverage and level of wastewater treatment in domestic and industrial sectors	Same as BAU scenario	• Significant improvement in piped water coverage and level of wastewater treatment in domestic and industrial sectors • Greater use of less energy intensive and decentralised wastewater treatment technologies like waste stabilisation ponds • Moderate improvement in share of alternative but energy intensive water sources like desalinated water and higher improvement in share of treated sewage water
Food and agriculture	Demand	• Continuation of existing food consumption patterns: Grain-dominated diets	Same as BAU scenario	Same as the BAU scenario	• Transition towards diversified dietary patterns to achieve better health and nutrition outcomes	Same as FS scenario
	Supply	• Moderate improvement in crop yields, area under irrigation, feed conversion ratio, seed and waste rates • Planned improvement in management of soil nutrients	Same as BAU scenario	Same as BAU scenario	• High improvement in crop yields, higher increase in area under irrigation, reduced seed and wastage rates, improved feed conversion ratios • Higher use of chemical fertilisers, better soil nutrient management	• High improvement in crop yields, higher increase in area under irrigation, reduced seed and wastage rates, improved feed conversion ratios • Higher use of fertilisers, better soil-nutrient management • Use of organic fertilisers in place of chemical fertilisers

5.2. Analytical Framework

The methodological framework used in this research, as described in Chapter 1, consists of three major components: a) scenario building, b) analytical approach, and c) impact attributes. Development of an analytical base to examine these scenarios is presented below.

Analytical Approach: IO Analysis

The core methodology applied in this research centres on the development and application of an *Energy Water Food-oriented Input-Output model*. The Input-Output (IO) model is a quantitative economic model that represents the economy as a system of interrelated goods and services, and expresses the underlying interdependencies as monetary transactions between different economic sectors at disaggregated levels. The model was conceptualised by Wassily Leontief in 1936 (Leontief 1936) building on the foundations of François Quesnay's 'tableau économique' created in 1758 (Quesnay, 1758). Leontief won the Nobel Prize in Economic Sciences in 1973 for his contribution to IO analysis.

Originally expressed in monetary units, the model is currently expressed in both physical and monetary units. This advancement happened over time as environmental concerns gained prominence and industrial ecologists, environmental scientists, and engineers sought to analyse the direct and indirect economy-wide and environmental impacts of technology and policy changes (Duchin and Steenge 2007).

A panoramic overview of an IO model is provided in Table 5-2. In this model, the technology structure of a particular sector is presented in columns under INTERMEDIATE DEMAND, which comprises technical coefficients (A), import coefficients (D), and primary factors coefficients (F). The technical coefficients (A) represent the proportion of inputs required from other domestic sectors for each unit of production of that particular sector. The import coefficients (D) denote the proportion of inputs from sectors located in a foreign country per unit of production of a sector. The primary factor coefficients (F) describe the unit production costs (or value added) of a particular sector in terms of the payment for primary factors of production, including indirect taxes and subsidies.

The FINAL DEMAND column in this model consists of household consumption, government expenditure, investment and exports. Each of the first three demand categories describes the share of the commodity required to meet final domestic demand. This demand is considered to be sourced from domestic production (final use coefficients B) and imports (import coefficients E). The last category (i.e., exports) describes the share of a domestically-produced commodity that is exported (export coefficients C).

This model thus captures the national accounts at both aggregate (such as GDP) and disaggregate (such as industry value added) levels. Through the international trade (i.e., export and import) linkages captured in matrices C, D and E, it also captures the trade dependencies. The model is driven by final demand and can compute the implications of change in the final demand of one sector based not only on the output of that sector but also on the output of the other sectors. This ability to capture indirect effects has earned acclaim and is one of the prime reasons for the model's popularity. The model, therefore, is an extremely useful analytical framework for examining the EWF security nexus.

Table 5-2: Basic Layout of an IO Table

<table>
<tr><th colspan="3" rowspan="2"></th><th colspan="4">INTERMEDIATE DEMAND</th><th colspan="4">FINAL DEMAND</th></tr>
<tr><th>Food</th><th>Energy</th><th>Water</th><th>Others</th><th>Household Consumption</th><th>Government Expenditure</th><th>Investment</th><th>Export</th></tr>
<tr><td rowspan="8">SECTOR/COMMODITIES</td><td rowspan="4">Domestic</td><td>Food</td><td colspan="4" rowspan="4">A</td><td colspan="3" rowspan="4">B</td><td rowspan="4">C</td></tr>
<tr><td>Energy</td></tr>
<tr><td>Water</td></tr>
<tr><td>Other</td></tr>
<tr><td rowspan="4">Imports</td><td>Food</td><td colspan="4" rowspan="4">D</td><td colspan="3" rowspan="4">E</td><td rowspan="4"></td></tr>
<tr><td>Energy</td></tr>
<tr><td>Water</td></tr>
<tr><td>Other</td></tr>
<tr><td colspan="2" rowspan="2">VALUE ADDED</td><td>Primary factors</td><td colspan="4" rowspan="2">F</td><td colspan="3" rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Indirect taxes and subsidies</td></tr>
</table>

Additionally, the model developed for this research is a variation of environmentally extended Input Output (EEIO) models used for environmental accounting, primarily to analyse material inputs for economic growth; the difference in the model developed for this research is that it focuses specifically on energy, water, and food.

The analysis employs a six-step modelling procedure. A schematic diagram of the overall procedure used to analyse the scenarios in this research is shown in Figure 5-1. This procedure is underpinned by the modelling approach presented above. It essentially comprises six steps, as follows:

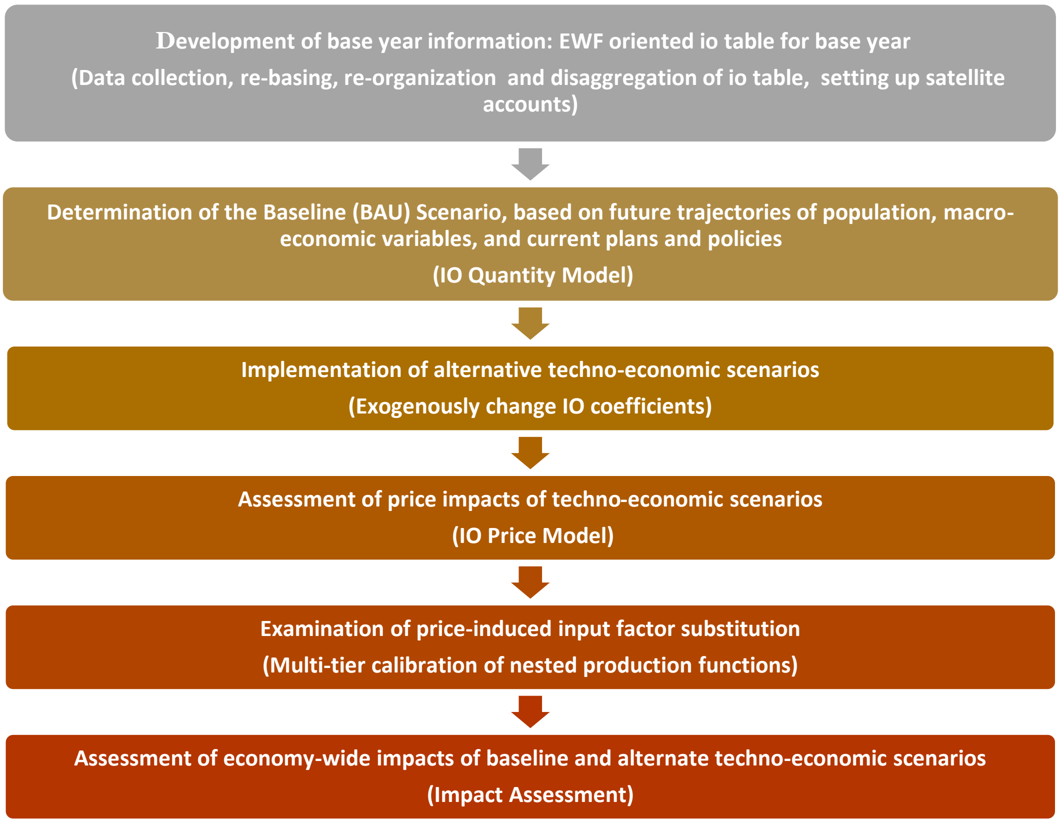


Figure 5-1: Steps involved in the modelling procedure

5.2.1. Development of Base-Year Information

The first step in the modelling procedure necessitated the development of base-year information for modelling the EWF security scenarios; this primarily involves the development of an EWF-oriented IO table for the base year in this research of 2015. This information is further used to demonstrate the implementation of technological changes in the model in the second and third steps.

This research focuses on the Indian economy. The base IO model employed in this research is adapted from the GTAP databases because GTAP IO tables for various countries are available in a consistent industry-classification format. There are several reasons for not using the national accounts published by India's Ministry of Statistics and Programme Implementation (MoSPI). First, the GTAP has more recent economic account information – the latest accounts available from the MoSPI are for 2007-08 while the latest GTAP information is for 2011-12. Second, the GTAP disaggregates the value added component into the different factors of production, namely, land, labour (skilled and unskilled), capital, and natural resources, some of which are not available in the national accounts. Third, the GTAP data for India contains contributions by economists from India's NCAER. It can therefore can be considered a credible source.

GTAP 9 database with the reference year 2011-12 is used for this research, in particular, because the GTAP power database – an extension of the GTAP 9 database – disaggregates the power sector (Peters 2016a, Aguiar *et al.* 2016).

The GTAP 9 database provides the IO monetary transaction matrix for 140 regions worldwide, 57 commodities, and 8 factors of production, for three base years (2004, 2007, and 2011) while the GTAP power database disaggregates the electricity sector into transmission and distribution, nuclear, coal, gas, hydroelectric, wind, oil, solar, and other. Gas, oil, and hydroelectricity are further differentiated into base and peak loads; however, for this research, these were aggregated. Figure 5-2 shows the basic layout of an IO table in GTAP.

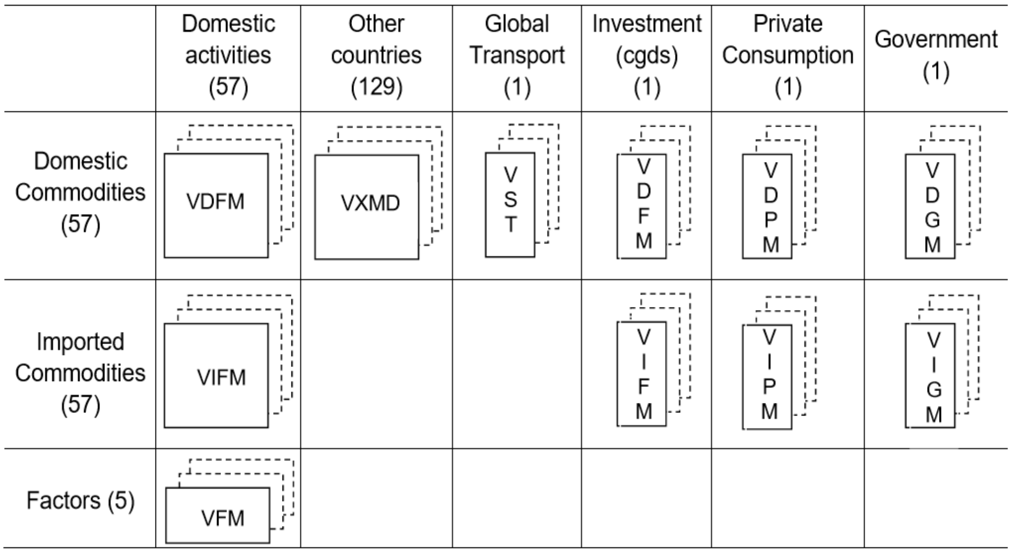


Figure 5-2: Basic Layout of an IO table structure in GTAP (Walmsley et al. 2012)

As can be seen in Figure 5-2, the GTAP data is arranged in different files as different components of GDP, such as factor inputs, taxes, subsidies, import, exports tariffs, and so on. The files containing the 2011 data are extracted from the GTAP database. The 68 sectors and 8 factors of production from the GTAP power database are collapsed into 49 sectors and 5 factors of production (Appendix A). The relevant files are then arranged in the form of an IO table, and the GDP from both expenditure and factor approaches is matched to validate the IO table used in the model. The information is provided in Table 5-3.

Table 5-3: Estimation of India GDP 2011-12 from GTAP: Factor and Expenditure Approach

	Factor approach (million US$)	Expenditure approach (million US$)
GDP factor prices	1758445.702	1758445.323
GDP market prices	1880101.103	1880101.103

Where,

Market price GDP by expenditure approach = CGDS + CGDS tax + VDPM + VDPM tax + VDGM + VDGM tax + VST + MFAREV + XTRV + VXMD + TARIFREV – Imports,

Market price GDP by income approach = Land + Unskilled labour + Skilled labour + Capital+ NatRes+ FTRV + FBEP + ISEP (dom and imp) + Output tax + CGDS tax + VGDM tax + VDPM tax + IIUSE comtax (domestic and imported) + TFRV, ADV,

Factor price GDP by expenditure approach = CGDS+ VDPM+ VDGM +VST+VXMD– Imports, and

Factor price GDP by income approach = Land+ Unskilled labour+ Skilled labour + Capital+ NatRes+ FTRV + FBEP + ISEP (domestic and imported) + Output tax.

The IO matrix obtained for the 2011 market prices is used as the base for this research. The output of each sector is estimated to obtain the IO coefficient matrix, which is then disaggregated into 93 sectors. The purpose of disaggregation is to avoid aggregation errors, which are particularly relevant to environmental impact analysis due to aggregation bias that can result in underestimating or overestimating impacts (Lenzen 2011), which in turn arise mostly from the large differences in resource-use intensities of different sectors and technologies. Lenzen (2011) substantiates this by giving an example of aggregating a rice and wheat sector into one grain growing sector which may lead to under/overestimation of water-use intensity because of the difference in water required per unit output of each sector. Lenzen (2011) concludes that results are more accurate when economic data is disaggregated as opposed to aggregating environmental data.

Such disaggregation of the IO table enables detailed analyses to be made at the technological and sectoral levels. These analyses include, for example, assessment of the impact that a policy targeted at one sector is likely to have on the broader economy through underlying sectoral interdependencies.

Table 5-4: Model Coverage

Energy sectors (34)	Food Sectors (24)	Water Sectors (12)	Factors of Production (5)
Energy resource extraction	*Paddy*	*Water pumping – diesel-based*	
Coal mining	*Wheat*	*Water pumping – electricity*	Skilled labour
Crude oil exploration	*Jowar*	*based*	Unskilled labour
Natural gas production	*Bajra*	*Water pumping – solar-based*	Capital
Other mining	*Maize*	*Conventional irrigation*	Land
	Other grains	*Efficient irrigation*	Natural resources[6]
Non-electric	*Roots and tubers*	*Highly efficient irrigation*	
energy supply	*Other vegetables*	*Municipal and industrial water*	**Final Demand (6)**
Petroleum refining	*Fruits*	*supply/treatment*	Private
LPG	*Pulses*	*Sea water desalination*	Consumption (rural)
Kerosene	*Oilseeds*	*Centralised ASP*	Private
Petrol	*Sugarcane*	*Decentralised WSP*	consumption (urban)
Diesel	*Sugarbeet*	*Decentralised MBR*	Government
Naphtha	*Other crops*	*Treated sewage water*	Expenditure
Fuel oil	*Other animal*		Investment
Other petroleum	*products*	**Other sectors (23)**	Exports
products and coke	*Milk*	*Cotton*	Imports
Gas distribution	*Cattle meat*	*Jute*	
	Other meat	*Cattle*	
Electricity supply	*Vegetable oil*	*Wool*	
Electricity T &D	*Milk products*	*Forestry*	
Coal sub-critical	*Processed rice*	*Fishing*	
Coal super-critical	*Sugar*	***Industry (12)***	
Coal ultra-supercritical	*Fish*	*Nitrogen fertilisers*	
Coal IGCC	*Other preserved*	*Phosphorus fertilisers*	
Coal pre-CCS	*food*	*Potassium fertilisers*	
Coal post-CCS		*Chlor-alkali*	
Gas power plants		*Textiles*	
Gas CCS		*Paper*	
Nuclear PWHR		*Nonmetal*	
Nuclear LWR		*Iron and steel*	
Nuclear FBR		*Non-ferrous*	
Large hydro		Other manufacturing	
Small hydro		Other chemical and	
Wind onshore		Petrochemicals	
Wind offshore		Construction	
Oil power		***Services (1)***	
Biomass to electricity		**Transport (4)**	
Waste to electricity		Road transport	
Solar PV		Rail transport	
Solar CSP		Air transport	
Solar distributed		Water transport	

Table 5-4 presents the list of sectors, commodities, primary production factors, and final demand categories for the IO model developed in this research. The 93-sector matrix provides a high level of commodity/sectoral disaggregation, especially for the EWF sectors.

[6] Non-producible natural resource inputs like Coal, oil, natural gas, minerals, fisheries and forestry (Hertel *et al.* 2016)

The disaggregation or aggregation of sectors is performed in accordance with the focus of the research, i.e., the nexus between energy, water, and food security. Industries that might have greater influence on the nexus, for example, those that are energy- or water-intensive, are disaggregated to better represent the nexus. Similarly, crops were disaggregated on the basis of either their importance in achieving food security or their possible influence on the nexus because they are water- or energy-intensive. Sectors less relevant individually to the EWF nexus, like different kinds of services, were aggregated.

India's Energy Security Scenarios model (GoI 2015a) developed by the Planning Commission of India is used as a reference to decide the level of energy sector disaggregation (into energy-producing and energy-consuming sectors) in the model. In the power sector, electricity generated using various fuels is further disaggregated into the respective fuel technologies in accordance with the IESS 2047 classifications (GoI 2015a).

Similarly, the water sector is disaggregated to represent sectoral water consumption and water supply technologies. This disaggregation broadly represents the stages of water provisioning, i.e., pumping, treatment, supply, use, and wastewater treatment. The disaggregation also represents sectoral water usage (broadly, agriculture, municipal and industrial water supply) and technologies within sectoral water usage (like pumping, irrigation, and wastewater treatment technologies). Lastly, alternative sources of water like desalination and treated sewage water are also represented in the water sector disaggregation.

Water use for agriculture is further divided into pumping and irrigation technologies, keeping in mind the differences in energy and water use in both these processes. Energy used for irrigation depends on its source (ground water or surface water), pump efficiency, and the type of fuel used to run the pump (diesel, electricity, or solar). Water used for irrigation is classified by the type of irrigation technology used. These technologies can be conventional (flood irrigation), efficient (sprinkler irrigation), or highly efficient (drip technology).

It is assumed that municipal water treatment in India, typically a sequence of alum addition, coagulation, flocculation, sedimentation, filtration and disinfection by chlorination, is likely to see little change in the schemes or technologies currently used. For centralised domestic wastewater treatment, advanced technologies like SBR and MBR are expected to become large scale in future; however, if wastewater treatment becomes decentralised in future, MBR technology would be the preferable technology. Currently, physico-chemical processes and ASP are the preferred treatments for industrial water. With stricter environmental regulations for industrial wastewater disposal, however, SBR technology with physicochemical at the primary level is expected to be the preferred choice for industrial water treatment in the future (Kansal 2017, pers. comm., 24 January, 2017).

Water recycling or use of treated sewage water are not yet widespread in India, although they are gaining momentum in cities like Delhi when water crises arise. In this research, treated sewage water refers to the water derived from conventional wastewater treatment plants that is further treated for applications that allow the use of low-quality water, more likely in commercial and industrial establishments.

The agriculture and food commodities sectors have been disaggregated to represent variations in broad food consumption patterns and in crops or processes that are water-and energy-intensive. The classification of food and non-food crops is broadly in alignment with Amarsinghe *et al.* (2007). Water-intensive non-food crops like cotton have been disaggregated from the fibre crops sector.

Industries have been disaggregated primarily to represent the energy-intensive industries as specified in IESS 2047. However, many of these industries, like pulp and paper, textiles, and fertilisers, are also water-intensive. To enable this representation, the chemical and petrochemical sector is disaggregated into fertilisers, chlor-alkali, and other chemicals and petrochemicals and the fertiliser industry disaggregated further into nitrogenous, phosphorus and potassium categories to represent their respective roles in food security.

The procedure followed for disaggregation is different for different sectors, depending on data availability and the type of information available. These disaggregation procedures involved different bases, such as cost-production normalisation, cost normalisation, share of value of output, and production share. Since IO is a monetary accounting system, cost-production or cost normalisation were the preferred methods for disaggregation.

An example of disaggregation – say, the capital cost coefficient for coal-based power generation technologies – is described here. The original GTAP coefficients were normalised on the basis of information on capital cost per MW for different technologies (available from IESS 2047) to obtain new coefficients for the newly-disaggregated sectors representing different coal-based technologies. The capital cost coefficient of the aggregated sector is normalised against the average of these capital costs. Similarly, the coal input coefficient of each technology is normalised according to their respective heat rates. Finally, the EWF sectors were re-arranged in order to be placed next to each other.

Rebasing the IO Table

While the latest available IO table from GTAP for this research is for 2011-12, the base year of the research is 2015-16. To obtain the IO table for 2015-16, the 2011-12 is therefore rebased as follows. It is assumed that the technological structures in different sectors underwent no significant change during 2011 and 2015. The GDP estimates for the year 2015-16 in billion INR 2011 prices were taken from the Reserve Bank of India (RBI) Statistics (RBI 2017).These components were used to obtain the IO transaction matrix for 2015-16.

Setting up of Satellite Accounts

The macroeconomic accounts for 2015-16 were obtained after rebasing. In addition to the economic account (as above), other accounts (such as energy, water, food, land, emissions, and employment), referred to as ‘satellite’ accounts in this research, were developed corresponding to the sectoral classification in this research.

The satellite accounts, presented in Appendix B, were developed using several sources, including annual statistical publications from different ministries and national organisations. They allowed a sector-wise estimation of energy, water, emissions, land, employment, and agriculture production and distribution in the economy. Since the sectoral disaggregation is quite comprehensive, some assumptions were made in case some data is not available. The data sources used to create these accounts are discussed in detail in Section 5.4.3.b.

5.2.2. Determination of Baseline Scenario

The base IO table can be transformed into IO coefficients matrices that underpin the model. An overview of these matrices is shown in Figure 5-3.

In this coefficients structure, the technology structure of a particular sector is presented under columns denoted Intermediate demand, which comprises technical coefficients (a_{ij}), import coefficients (C_{mj}), and primary factors coefficients (C_{vj}). The technical coefficients represent the proportion of inputs required from other domestic sectors for each unit of production of a particular sector. The import coefficients describe the proportion of inputs from sectors located in a foreign country for one unit of production in a sector. The primary factor coefficients describe the unit production costs of a particular sector in terms of (a) the payment for primary factors of production (or value added) and (b) taxes. The Final demand column in this model (typically consisting of household consumption, government expenditure, investment, and exports) are considered to be sourced from domestic production (final use coefficients b_{ik}) and imports (import coefficients d_{mk}).

[D]	Intermediate demand	Final demand (F)	
Domestic production sectors	a_{ij} [A]	b_{ik} [B]	X_i
Import sectors	c_{mj}	d_{mk}	M_m
Factors of production	c_{vj}	d_{vk}	V_v
	X_j	F_k	

Figure 5-3: Overview of IO coefficients table

Assuming the Leontief fixed-proportion production function, the inputs to a particular intermediate sector can be expressed by the linear relations:

$$z_{ij} = a_{ij} \cdot X_j; \; m_{mj} = c_{mj} \cdot X_j \text{ and } v_{vj} = c_{vj} \cdot X_j \qquad \textbf{(1)}$$

where

z_{ij}: output of sector i used by sector j,

m_{mj}: import from foreign sector m used by domestic sector j,

v_{vj}: factor v used by sector j, and

X_j: total output of sector j.

Similarly, the sources of final demand can be determined by the linear relations:

$$f_{ik} = b_{ik} \cdot F_k;\ m_{mk} = d_{mk} \cdot F_k \text{ and } v_{vk} = d_{vk} \cdot F_k \qquad \textbf{(2)}$$

where

f_{ik}: output of sector i used by final demand k,

m_{mk}: import from foreign sector m used by final demand k,

v_{vk}: factor v paid by final demand k, and

F_k: total final demand k.

The relationships in both equations capture the national accounts at both aggregate and disaggregate levels. For example, GDP can be determined either from an income approach (i.e., ∑Vv) or an expenditure approach (i.e., ∑Fk - ∑Mm), the sectoral output can be determined from Xi, and so on.

Further, equations 1 and 2 form the basis of determining the baseline scenario in the model. That is, information from the base-year IO table is needed to develop the IO table forecasts for any future year (t). This necessitates future assumptions about macroeconomic conditions, particularly economic growth and contribution to this growth by various final demand categories (i.e., F_{kt}).

The starting point is to calculate the total final demand for year t for each row of the IO table. Total final demand includes a total final demand that would be fulfilled by domestic production sectors (F_{it}), a total final demand that would be fulfilled by import sectors (F_{mt}), and total tax paid by final demand sectors (F_{vt}), which can be determined from equations 3 and 4.

$$F_i^t = B^s \cdot F'^t_k \qquad \textbf{(3)}$$

$$F_{m+v}^t = D^s \cdot F'^t_k \qquad \textbf{(4)}$$

where B and D are the coefficients matrices for the base year 's'.

The outcomes from equations 3 and 4 are then used to estimate total sectoral output (X_i), total imports (Mm), and total factors of production, including taxes (V_v) for year t, by using the following IO identity:

$$X_i^t = \left(I - A^s\right)^{-1} \cdot F_i^t \tag{5}$$

$$M_m^t + V_v^t = \left[C^s \cdot \left(I - A^s\right)^{-1} \cdot B^s + D^s\right] \cdot F'^t_k \tag{6}$$

Finally, the individual components in the IO table (including z_{ij}, m_{mj}, v_{vj}, f_{ik}, m_{mk} and v_{vk}) can be estimated using the linear relationship similar to equation 7:

$$z_{ij}^t = a_{ij}^s \cdot X_j^t \tag{7}$$

where, $X_j = X'_i$.

Intensity Vectors

Intensity vectors (such as energy, water, food, land, emissions and employment) are developed using the satellite accounts prepared in the first step to correspond with the sectoral classifications in this research. The mathematical formulation shown below is for estimating energy demand in the economy. A similar principle is applied to develop estimates of other satellite accounts.

To begin, let E_{fi} be the energy of type f consumed by production sector i. From the above, the total output (X_i) of production sector i goes to satisfy intermediate and final demands. Therefore, the energy intensity of sector i - denoted by e_{fi} - can be expressed as:

$$e_{fi} = E_{fi}/x_J \tag{8}$$

This expression can be written in a matrix notation as:

$$e = E.X^{-1} \tag{9}$$

where
e: matrix of energy intensities (e.g., toe per US$), and
E: matrix of total energy use (toe).
From equation 9, the energy requirements for the production sectors can be represented as:

$$E = e.X \tag{10}$$

By substituting total output (X) from equation 5 into equation 10, the sectoral energy requirement for year t can be estimated by:

$$E_{fi}^{t} = e_{fi}^{s}\left(I - A^{s}\right)^{-1} \cdot F_{i}^{t} \quad \textbf{(11)}$$

The term e. [I – A]-1 in equation 11 also represents the sectoral energy intensities for the baseline scenario.

5.2.3. Implementation of Technological Change

In the next step, the IO technical coefficients of the columns representing specific technologies were exogenously adjusted. To implement this, the IO coefficients were exogenously changed. In each column, as shown in Figure 5-3, the IO coefficients describe the input intensities used in a production process, in terms of both intermediate and primary factor inputs. This information is useful for designing future technology scenarios.

This adjustment took into account a suite of EWF-related measures that were implemented in other scenarios. For example, energy efficiency improvements in industries is demonstrated by reducing the energy input coefficients (i.e., a_{ij}, where i refers to energy sectors). Since improving energy efficiency entails capital, reduction in energy coefficients is compensated for by increases in capital coefficients.

Adjusting technical coefficients is widely used to examine the impacts of changes in energy technologies in IO frameworks (Gowdy and Miller 1968, Just 1974, Faber *et al.* 2007). Several CGE modellers apply the same principle to introduce technological shock in their models (Matthews *et al.* 2003, Asafu-Adjaye and Wianwiwat 2012, Nasseri and Konan 2012). The magnitude (scale) of adjustments in the technical coefficients are generally based on scenario assumptions. The assumptions and values of the scenario drivers used to adjust the technical coefficients in this research are discussed in more detail in Section 5.3.2.

5.2.4. Assessment of Price Impacts of Techno-economic Scenarios

This stage demonstrates how a shock in one sector (or a change in technology, process, or practice) can affect the rest of the economy. Policy changes induce changes in the input mix of various production sectors through technological or regulatory measures. Consequently, the price of sectoral outputs can change. This implies, for instance, in the case of energy efficiency improvements, that every unit of output requires less energy input, resulting in a decrease in production cost, and thus decrease in output prices.

This type of sectoral price effects from technological change is estimated using the standard Leontief IO price model. The changes in sectoral prices can be determined from equation 12:

$$P_i = [I - A']-1.C_j' \quad \textbf{(12)}$$

where C_j is the sum of factors of production and imports for each sector j.

To assess the price impact, the base-year price level first needs to be calculated. When applying base-year IO coefficients to Equation 12, a vector of base-year prices for all sectors will be equal to one because in this approach prices normalise. The base IO data comprises only value (price x quantity) flows. This approach translates value data into price and quantity data by normalising the initial (base) prices in the model into 1.

The coefficients for each column in the IO model are thus interpreted as the quantity of input per unit monetary value of produced output, instead of the value of the input. The same method is typically applied in CGE models as it considerably reduces the information required to develop a model database, without losing the ability of the model to generate meaningful results (Burfisher 2011).

Next, the new sectoral prices in year t are determined by new technical coefficients, which are updated exogenously in the previous stage, as shown in equation 13.

$$P_t = [I - A'_t]-1.\ C'_t \quad \textbf{(13)}$$

where

P_t: vector of new sectoral price levels;

At: matrix of IO technical coefficients, adjusted for new energy technology; and

Ct: matrix of primary factor (and import) coefficients for year t.

This would give the index of changes in sectoral prices, compared to the base year:

$$\frac{P`}{P} = \frac{P_t - P_s}{P_s} \qquad \textbf{(14)}$$

5.2.5. Examination of Price-Induced Input Factor Substitution

The changes in sectoral prices (described in Section 5.3.4.) will induce substitution among factor inputs. The traditional IO model does not provide justifiable mechanisms for evaluating the impacts of changes in technology due to the underlying assumption about the fixed proportionality of input-output coefficients (shown as matrices A-F in Figure 5-3) and would assume perfect complementarity between factor inputs through the use of the Leontief fixed-proportion production function, thus ignoring substitution possibilities.

In reality, these coefficients are likely to undergo continual changes due to, for example, innovation, changes in consumer and producer preferences, or policy adjustments (Rose 1984). The change in coefficients would impact input prices and hence would prompt changes in technology through changes in factor inputs. Therefore, if one is to assess how changes in the supply-demand patterns would alter producer preferences and other adjustments in the economy, one must make the IO coefficients responsive to price changes.

This is achieved in this research by selectively (due to the partially regulated nature of the Indian economy) replacing the Leontief production function with more flexible production functions. These substitution possibilities were realised in this research by introducing flexible CES and Armington production functions into the standard IO model. The use of these functions allows for input factor substitutions in response to policy adjustments, an approach that imparts much-needed realism into the analyses undertaken in this research.

The procedure used to introduce a flexible production function into this research is similar to one typically employed in Computable General Equilibrium (CGE) models. It assumes a nested structure for IO coefficients, a particular functional form, assumes (or determines, if sufficient data are available) the values for elasticities of substitution, and calculates each tier in the nested structure to obtain the values for an updated IO table.

The substitution possibilities are introduced in the IO model in terms of elasticities of substitution, which can then be used to modify the IO coefficients (Rose 1984).

A simplified nested structure is shown in Figure 5-4. This IO coefficient structure consists of two nests (or tiers). The first tier shows that a final output of a particular sector is produced according to a nested Leontief function, using intermediate and factor inputs. The second tier shows intermediate inputs sourced from domestic production and imports, according to the Armington production function that represents the elasticity of substitution between products of different countries (Armington 1969).

In the first tier, a Leontief production function (zero elasticity of substitution) represents final output (Xj) as:

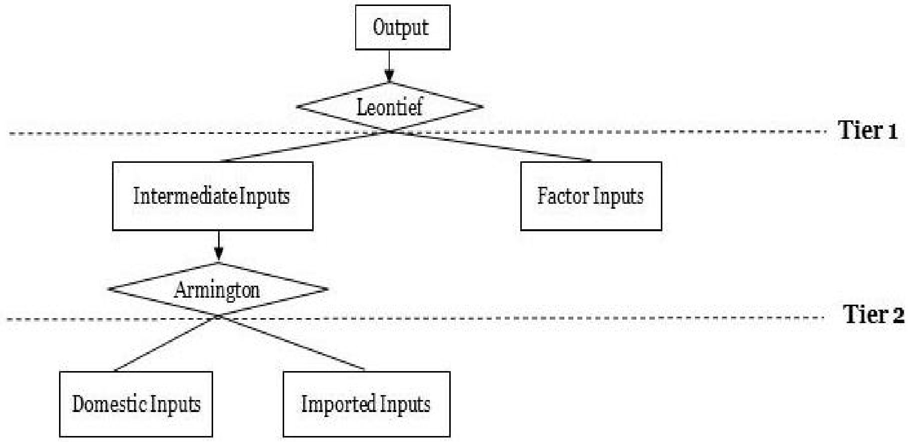


Figure 5-4: Typical nesting structure of IO coefficients

$$X_j = \min\left[\frac{h_{ij}}{\alpha_{ij}}, \frac{v_{vj}}{c_{vj}}\right] \qquad \textbf{(15)}$$

where

h: intermediate inputs, which include inputs from domestic sector (z_{ij}) and import sector (m_{mj}); and

α: coefficients for intermediate inputs, which comprises a_{ij} and c_{mj}.

Since the elasticity of substitution in this function is zero, changes in price will have no effect on the choice of inputs used. Thus, the amount of intermediate inputs can be determined from the formula that is similar to equation 7, i.e.,

$$h_{ij} = \alpha_{ij} \cdot X_j$$
$$v_{vj} = c_{vj} \cdot X_j \qquad \textbf{(16)}$$

In the second tier, intermediate inputs are provided by flexible domestically-produced and importable inputs through a CES production nest as:

$$h_j = \left[a_{ij} \cdot z_{ij}^{\frac{\sigma-1}{\sigma}} + c_{mj} \cdot m_{mj}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \quad \textbf{(17)}$$

where σ is the elasticity of substitution between z_{ij} and m_{mj}.

Equation 17 can also be shown as an input demand function:

$$z_{ij} = 1^{\sigma-1} \cdot a_{ij} \cdot \left(\frac{p_j}{p_{ij}} \right)^{\sigma} \cdot h_j$$

$$m_{mj} = 1^{\sigma-1} \cdot c_{mj} \cdot \left(\frac{p_j}{p_{mj}} \right)^{\sigma} \cdot h_j \quad \textbf{(18)}$$

where

h_j: total intermediate inputs used in sector j;

p_j: unit costs of total intermediate inputs used in sector j;

p_{ij}: unit costs of domestically-produced intermediate inputs i used in sector j; and

p_{ij}: unit costs of importable intermediate inputs m used in sector j.

Using equation 18 instead of equation 17 thus allows substitution to be captured within the IO framework. To update IO table for the future year that resulted from technological change (changes in IO coefficient in stage 2), equations 16 and 18 can be used, depending on the type of production functions assumed in the nested structure.

Nested Elasticity Structures

The nesting structure of IO coefficients assumed for sectors in this research is much more complicated than in Figure 5-4. The substitution possibilities between various input factors for both the demand-side and supply-side analyses were included in this research.

The analysis for the demand side, presented in Figure 5-5, focuses on final demand, or the consumption end, of the society in which four groups of consumers (or utility maximisers, in economic terms) were included, namely, household, government, investment, and export sectors.

These sectors collectively maximise the national welfare through their optimally-selected combinations of consumer products – food, energy, water, and other like services. These consumer products branch out further into higher levels of user-specified sub-categories, which commonly end at the selected combination of domestically acquired and imported products, as shown in Figure 5-5. Food products consumed by urban and rural households are divided into six main categories: grains, fruits and vegetables, milk and milk products, poultry, fish and other meat, oils and fats, and other miscellaneous food products.

The analysis allows substitution between the key grains of rice and wheat consumed in India, followed by their substitution with other grains. Further, there is a provision of substitution within animal meat in light of a strong religion based meat preference in India. Energy fuels for private consumption are further divided into electricity and other fuels, which are then broken up into coal, charcoal, coke, kerosene, petrol, diesel, oil, CNG, PNG, and combustible renewables (mainly biomass). Electricity is separated into centralised electricity and distributed solar. Fossil fuels are obtainable from both within and outside the country, whereas combustible renewables are provided by local suppliers.

The household sector consumes these energy products together with an optimally chosen bundle of food and other products. In the water sector, there is provision for substitution between freshwater and alternative sources, like desalinated water and recycled and treated sewage water. A similar categorisation is applied to the other three final demand categories, i.e. government, investment, and exports.

The demand-side analysis focuses on sectoral consumption activities at national level, where an aggregated view is more favourable than a detailed one. Accordingly, the top tiers of consumer products, i.e. food, energy and others, are assumed to be non-substitutable and therefore the Leontief production function characterises the choice of product-mix made by each consumer group at this level. As the activity tree branches further downwards, where a detailed analysis on the impacts of technology-related decisions is required, the selection of the same-level product-mix takes into account substitution possibilities and is characterised by CES and Armington production functions.

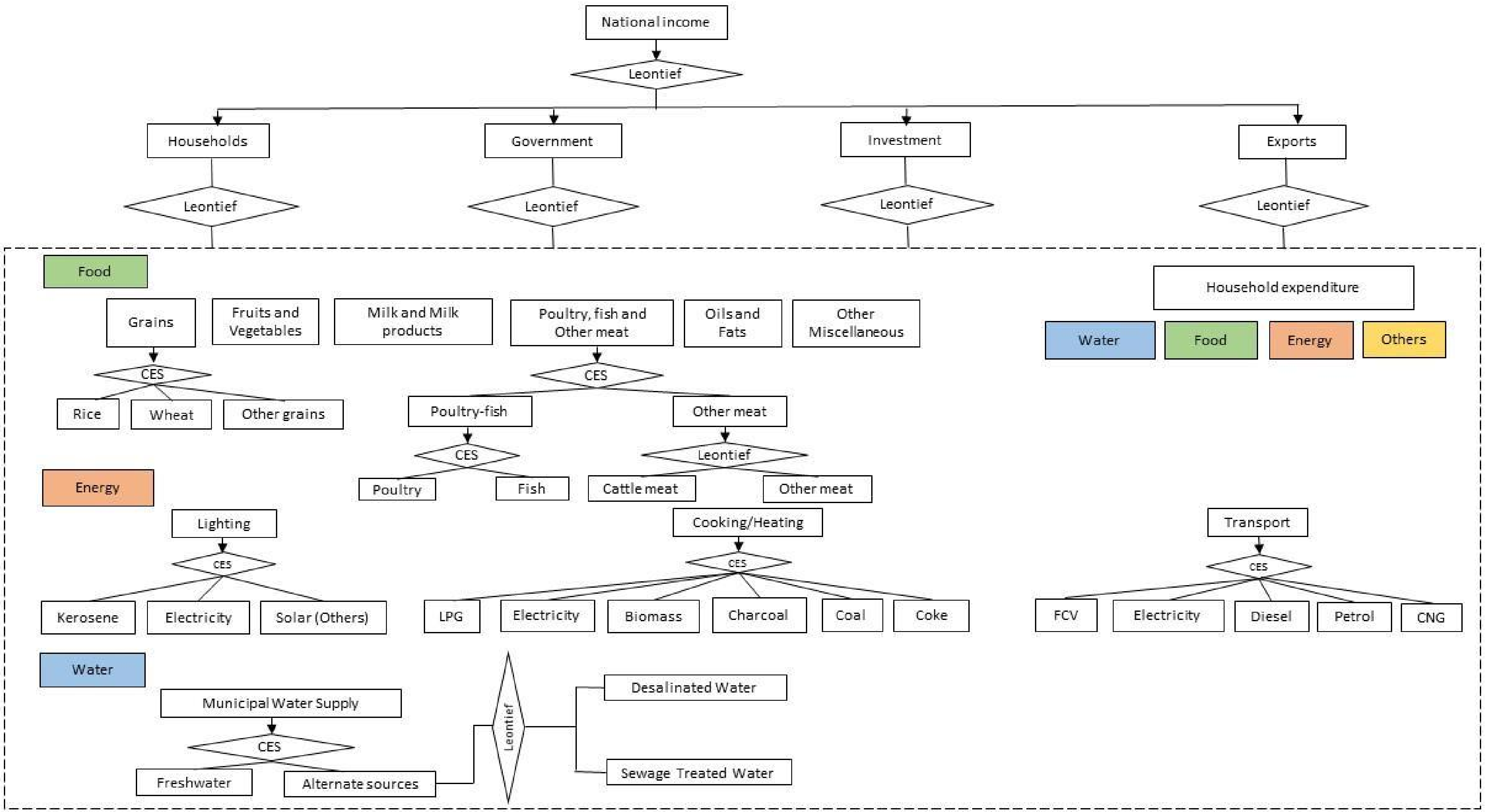


Figure 5-5: Nesting Structure for Demand Side

The supply-side analyses focus on the production end of the society where optimal technology bundles are chosen by the producers (or production sectors) to produce energy, water, food, and other products to meet final demand from the consumption end. In this research, producers' input structures were classified into six broad categories: agriculture; electricity generation, petroleum refining and mining; energy-intensive industries; other industries and services; transport, and water. This chapter provides only the nested elasticity structure of the Final demand and Electricity supply sectors. Nested elasticity structures for other sectors are provided in Appendix C**.**

The electricity sector in this model is divided into 21 technologies comprising fossil and non-fossil-based technologies used for electricity generation (Figure 5-6). Nine of these are polluting and the rest are non-polluting, thus allowing substitution between fuels used for electricity generation. Distributed solar is the only decentralised electricity generation technology. A CES-nested structure nests polluting and non-polluting fuels. This substitution between polluting and non-polluting fuel is demonstrated in nested production structure of all sectors that use electricity.

Nested CES structures used to represent the electricity sector, petroleum refining, and the mining, transport, and energy-intensive industries differ from other sectors by separability assumptions in their K (capital), L (labour) E (energy) function, allowing direct substitution between capital and energy in these sectors (KE-L). Non-energy inputs were assumed in this research to be non-substitutable. Therefore, the choice of these non-energy input mixes used for each technology is characterised by Leontief production function. However, the petrol and diesel sectors demonstrate substitution possibilities between crude oil and biofuels. There is also substitution between and within sugar-based and other bio-feedstocks for production of bio-ethanol and bio-diesel.

This approach is similar to the one used in Timilsina and Shreshtha (2006), except that the capital and fuel substitutions are allowed in other energy-intensive sectors like mining, petroleum refining, and transport. As a result, the KE-L nesting form has been assumed for energy-intensive sectors like industries, transport, and electricity generation while KL-E is assumed to be the preferred form for non-energy-intensive sectors.

Accounting for such substitution possibility is very important in a country like India where industry, the power sector and transport contribute to a very significant proportion of emissions. In 2007, the energy sector alone emitted 1100 million tons of CO_2 eq, of which 719 million tons of CO_2 eq came from electricity generation and 142 million tons of CO_2 eq from the transport sector (MoEF 2010).

This research characterises water-capital substitution in electricity generation technologies as a CES combination of water and the capital-fuel mix. Such consideration of water substitution and other production inputs to accommodate changing scarcities of water is taken into account in Grebenstein and Field (1979) and in Babin *et al.* (1982). This substitution is also accounted for in some sectors that are both water- and energy-intensive, such as mining and petroleum refining. The water supply to these sectors is represented as a nested CES function between fresh water and alternative sources of water like desalination and treated sewage water.

The food production sector is characterised as a CES combination of factor inputs as follows: 1) key inputs (land-natural resources-energy-capital-labour-water-fertilisers), and 2) other intermediate inputs. For both mix, each input is further broken up into a CES combination of relevant sub-categories. Other intermediate inputs are assumed to be non-substitutable. The choice of these material inputs mixes, therefore, is characterised by a Leontief production function.

The key inputs (land-natural resources-energy-capital-labour-water-fertilisers) are grouped into four CES bundles: 1) natural resources-land-water, 2) capital-labour, 3) energy, and 4) fertilisers. The inputs in the natural resources-land-water bundle are assumed to be non-substitutable. Capital and labour are in a nested CES function. In the energy bundle, the inputs are broken down into electricity and petroleum product (essentially diesel) inputs and other energy inputs. Electricity use in the agriculture sector is further divided into centralised electricity supply and decentralised electricity supply like wind- or solar-based water pumping for irrigation. Other energy inputs are assumed to be non-substitutable, hence the choice of a non-energy input mix is characterised by a Leontief production function.

Lastly, in the fertiliser bundle, there is a nested structure of Nitrogen, Phosphorus, and Potassium (NPK) fertilisers. In India, nitrogen is mostly produced locally, while large proportions of potassium and phosphorous are imported. Any fluctuation in international prices usually leads to the replacement of nitrogen with potassium and phosphorus. Hence, this research divides the fertiliser bundle into nitrogen and a P-K bundle with a nested CES function. There is a further substitution between P and K fertilisers. This substitution is demonstrated in the nested production structure of any crop using fertilisers.

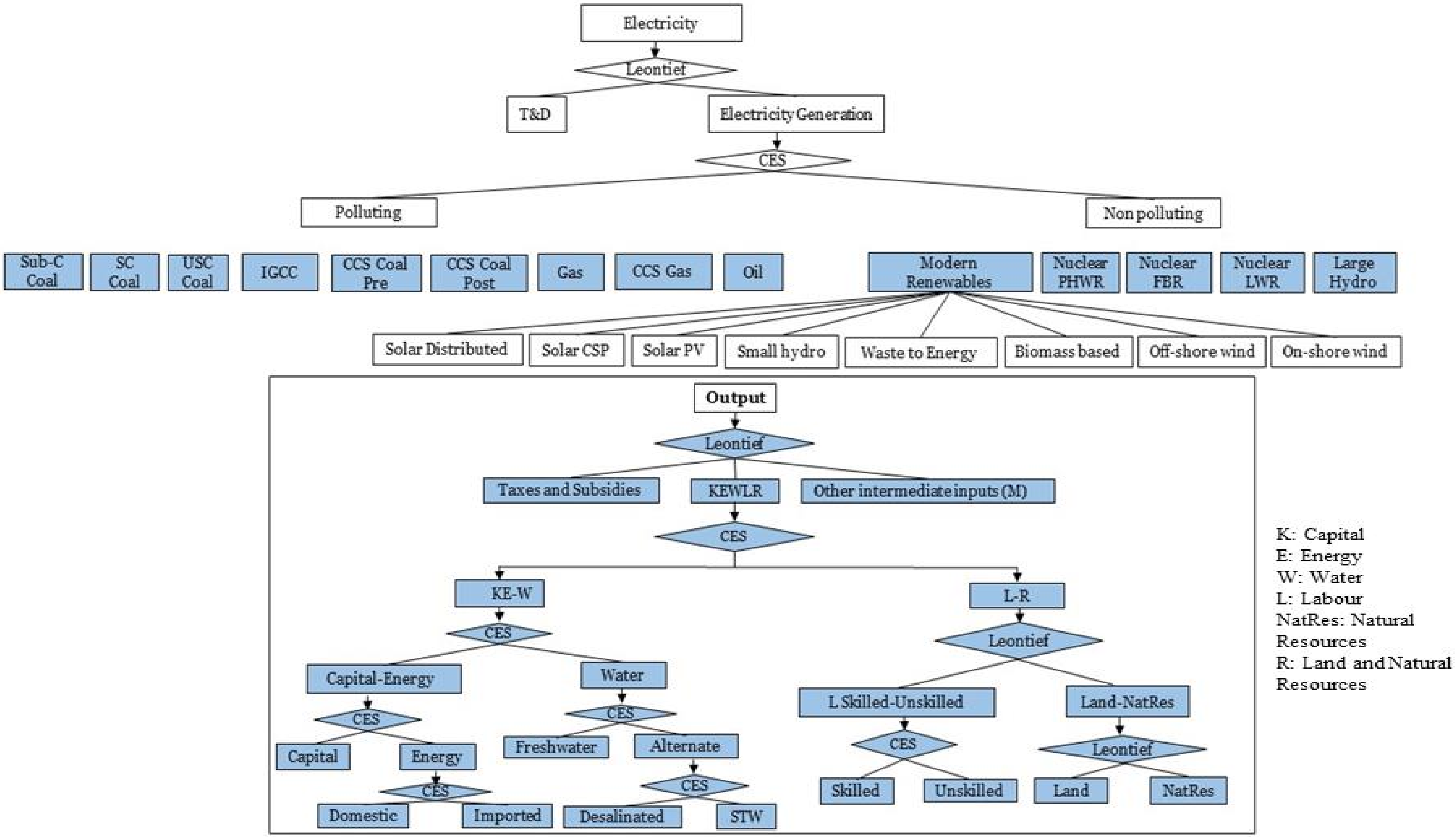


Figure 5-6: Nested Structure for Electricity Generation, Petroleum Refining and Mining Sectors

5.2.6. Assessment of the Economy-wide Impacts of Technological Change

The macroeconomic impacts of technological change were analysed in the final step of the modelling procedure. In particular, the new IO (as developed in the previous stage using equations 16 and 18) formed the basis on which to calculate the updated economic accounts. The results (such as GDP and sectoral output) were then compared with those developed in the first stage for the base year, using equation 7. The difference shows any economic impact of technological change.

Further, similar to the first stage, the updated IO table in the fourth stage is used as a basis to develop other satellite accounts, including energy, water, food, land, emissions and employment. Again, the difference between these results and those estimated in the first (base year) stage shows any impacts on energy, water, food, emissions, and employment.

The macroeconomic impacts of energy, water, and food-related policy changes were analysed next. These impacts include, for example, energy demand, water demand, food demand, economic growth, land use, and employment. The new IO structure (as developed in the previous step), as well as changes in sectoral prices across alternative scenarios, would lead to changes in GDP, employment, energy consumption, water consumption, food consumption, land use, and so on. The changes in these parameters brought about by the alternative policies were then compared with the parameters obtained under the BAU scenario.

5.3. EWF Extended IO Model

5.3.1. Scenario Assumptions

The EWF extended IO modelling is carried out for five scenarios, namely business-as-usual (BAU), energy security (ES), water security (WS), food security (FS), and nexus-oriented (Nexus). The period under consideration in this research is 2015-2047, divided into three time frames to represent the short (2022), medium (2032), and long (2047) term. The year 2047 also marks 100 years of independence for India and it will be crucial to explore its journey of recovery from nearly 200 years of British colonisation and its development after a century of independence to become one of the largest economies in the world.

The first step in scenario building is to identify the key drivers affecting demand for energy, water, and food. There are numerous drivers that govern the demand for these resources, including different lifestyles to cultures, income levels, prices, demographics, etc. However, at the macro level, there are the few major influencers of food, water, and energy demand that are common to all scenarios, namely, population and economic growth. In the ensuing paragraphs, each of these is discussed in detail.

Population

India is the second most populated country in the world and likely to exceed the most populated country – China – by the year 2024 (UN 2017). There is vast literature on population projections for India based on different assumptions on fertility rates, mortality rates, migration, and so on. These projections get revised from time to time and a few recent projections were examined to compare and identify the most realistic one for this research. This research employs the projections on population growth and share of working population in total population carried out by the Population Foundation of India (PFI) (PFI 2007). The PFI is the nodal agency for population-related studies in India and its projections are more country-specific and therefore, in the opinion of this researcher, more realistic. The PFI projected the population of India for two scenarios, called Scenario A and Scenario B. Scenario A assumes a total fertility rate of 2.1, while Scenario B assumes it to be 1.85. Scenario B is chosen for this research on the assumption that improvements in literacy and awareness levels would slow down the growth in population. The same source is also used to provide estimates on the working population, i.e., the population aged between 14 and 64 as a percentage of the total population.

Economy

Gross Domestic Product (GDP)

The literature provides various projections of GDP growth for India, both short and long term, by different organisations.

Since this research uses the IESS 2047 model as a base for energy sector developments, wherein the model uses GDP as a driver to arrive at energy demand estimates, this research also uses the growth rate estimates assumed in the IESS 2047 model. The model is developed by the NITI Aayog, the central planning agency in the country, hence it is a credible source. In particular, a

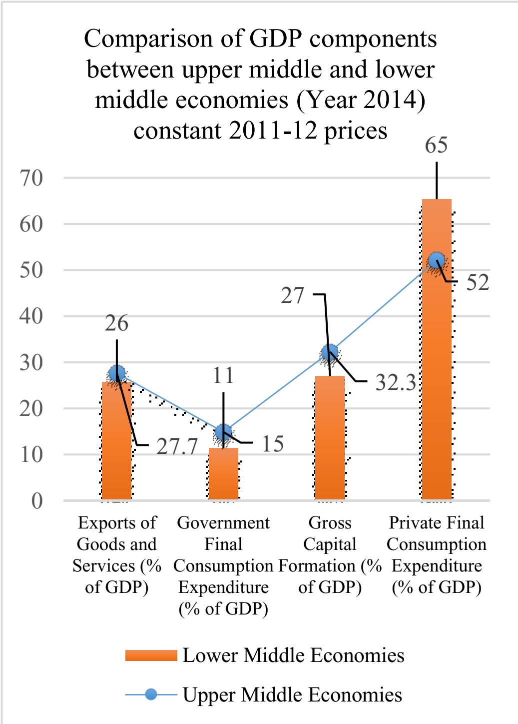
GDP with a compounded annual growth rate (CAGR) of 7.4 percent from 2012 to 2047 is assumed to be constant for all scenarios, given India's rapid economic development.

Sources of Economic Growth

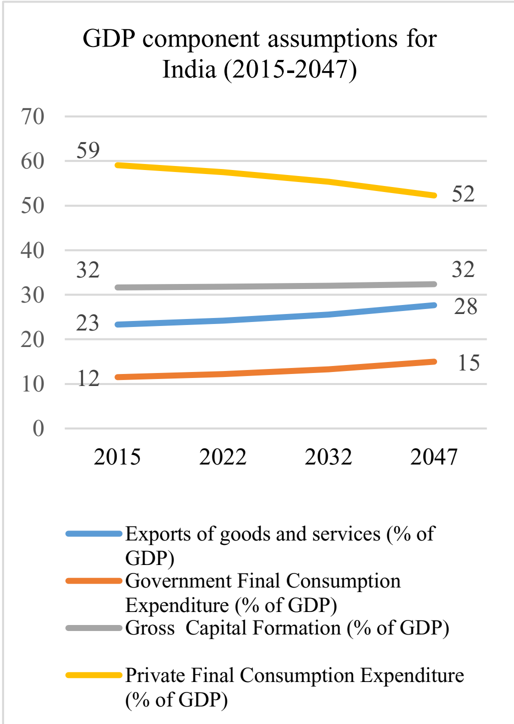
The Indian economy is one of the fastest growing economies in the world. Since the economic reforms of 1991, the economy has grown at an unprecedented average annual rate of almost 7 per cent from 1993–1994 to 2011–2012. Between 2004– 2005 and 2011–2012 the rate of growth was high as 8.3 per cent (Aggarwal 2018 p.70). GDP growth has averaged 7.3 per cent for the period 2014-15 to 2017-18, the highest among the major economies of the world (GoI 2018b). Private Final Consumption Expenditure (PFCE), Government Final Consumption Expenditure (GFCE), Gross Capital Formation (GCF), and Exports (X) are four demand-side drivers of economic growth. In 2015, based on constant 2011-12 prices, the contributions of private consumption, gross government expenditure, gross capital formation and exports to GDP were 56, 10, 36, and 21 percent respectively (RBI 2017).

According to the World Bank's income classification, India is a lower-middle-income country with a gross national income per capita of current US$1800 in 2017 (WB 2017). In the absence of long-term forecasts for the components of GDP, this research assumes that India will transition economically from a lower-middle-income to an upper-middle-income country according to World Bank classification by 2047. Consequently, the latest 2014-15 share of components (PFCE, GFCE, GFCF, and export and import of goods and services) from the World Development Indicators (WDI) dataset (WB 2016) for upper middle economies is assumed to be the share that will manifest in the Indian economy by 2047.

It can be inferred from Figure 5-7 that upper-middle-income economies have a higher share of government expenditure, of gross capital formation and of exports in their total GDP compared to lower-middle-income economies. However, the difference in GDP composition of these two income categories is the lower level of private or household consumption expenditure for upper-middle-income economies which is balanced by increased share of exports, government expenditure and capital formation in GDP as the economy progresses.



(a)



(b)

Figure 5-7: Comparison of GDP Components between Upper middle and Lower middle economies (a); GDP Component Assumptions for India (2015-2047) (b)

Share of Urban and Rural Economy in Private Consumption

Currently, the share of the rural and urban economies in private consumption is 54 and 46 percent respectively (CRISIL 2016). Due to the absence of any available forecasts for this parameter, these proportions were assumed in this research to be equal by 2047, a common assumption in all the scenarios. Rural consumption is expected to increase in coming years with incomes rise thanks to rural welfare and employment generation schemes like the *Mahatma Gandhi National Rural Employment Guarantee Act 2006* (MGNREGA), the National Rural Livelihood mission, and others. However, this assumption also takes into account a simultaneous reduction in the rural population as a percentage of the total population (GoI 2017b).

Economic Structure

The Indian economy is typically classified into three key sectors, Agriculture and allied, Industry and Services. The latest available information on the shares of these sectors in the GDP, as used in this research, is for the year 2013-14. In 2013-14, the shares of these sectors in GDP were 13.94, 26.13, and 59.93 percent respectively (CSO 2014). The assumption about growth in the share of each sector in GDP, to the year 2047, is taken from WWF-TERI (2013). According to this report, the share of the agriculture sector in the aggregate GDP is expected to decline to 6 per cent, while the industry and services sectors will rise to 34 per cent and 60 per cent respectively by 2051. These two data sets have been used to interpolate the sectoral shares for the time-periods analysed in this research (Figure 5-8).

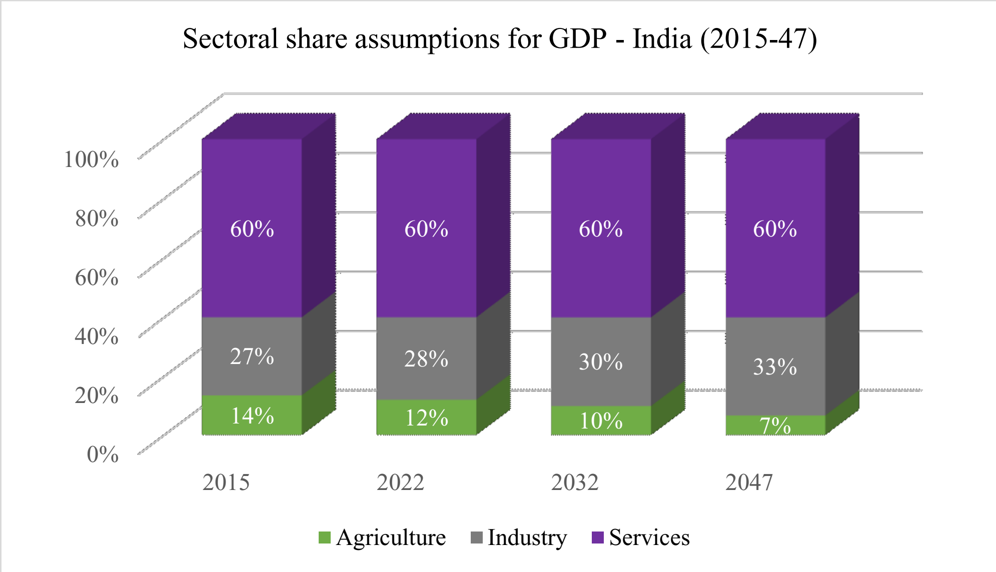


Figure 5-8: Modelling Assumptions on GDP sectoral shares- India (2015-47)

Other common assumptions are:

(1) labour productivity is assumed to improve at an annual rate of 5 percent throughout the modelling period.

(2) N, P, and K fertiliser use efficiency is assumed to be 60, 50 and 70 percent respectively by the end of modelling period from current levels[7].

(3) due to the lack of any reliable estimates on rural wastewater treatment capacity and technologies, it is assumed that currently rural wastewater treatment is virtually non-existent at present and in future will be carried out mostly through decentralised natural wastewater treatment technologies. This assumption is valid given the fewer land constraints for these technologies in rural areas.

(4) that growth in area under micro irrigation is shared equally between drip and sprinkler irrigation.

(5) that open defecation will have been completely eliminated in both rural and urban areas by 2030, as planned under India's SDGs.

(6) electricity over-generation is avoided in all scenarios developed through the IESS 2047 model.

(7) that electricity imports will be at the same level across all scenarios.

[7] The current N, P, and K fertilizer use efficiencies are 40, 20, and 50 percent respectively (Umesha et al. 2017)

(8) that imports will continue to grow at a moderate pace of 5 GW from the 13th Plan (2017-2022) up to 2037 and will remain at that level thereafter.

To avoid over-generation of electricity, some of the variables had to be kept constant as per the planned policies and no major improvement in those sectors is examined. Improvements in industrial efficiency are assumed to grow at the same level as planned in the current policies across all scenarios. The assumption regarding industrial energy efficiency improvements is that the designated consumers (DCs) in the Perform, Achieve, and Trade (PAT) scheme will achieve the best possible efficiency in every sub-sector. The units not covered under PAT are expected to improve their energy efficiency, which is 10 percent of the PAT target; the remaining sub-sectors are expected to improve their energy efficiency of at the rate of around 5.5 percent compounded annual growth rate.

Domestic passenger mode of transport (road: 83 percent, rail: 15 percent, air: 2 percent) is assumed to be the same across scenarios as per current policies. The share of road and rail in domestic freight transport is assumed to be 36 percent and 64 percent respectively. Domestic freight transport demand is assumed to be 13540 billion ton-kilometres by the end of modelling period. Penetration of electric vehicles in passenger transport in different modes like bus, car, two-wheelers, three-wheelers, taxi and rail is assumed to be 10, 33, 19, 35, 42, and 52 percent respectively by the end of modelling period. The share of electric rail for freight transport by 2047 is assumed to be 70 percent.

Residential floor space in urban areas is assumed to be 20 percent under high rise, 66 percent under horizontal development, and 14 percent under affordable housing by the end of modelling period. In the residential lighting sector, the penetration of different lighting appliances like bulb, tube light, CFL, and LED is assumed to reach 7.5, 17.5, 40, and 35 percent respectively by 2047.

5.3.2. Scenario Variables

Table 5-5 summarises the values assumed for each of the scenario variables in this research.

The IESS 2047 model developed by the NITI Aayog is used as the platform to generate the energy sector scenarios in this research. The values for the scenario variables for current policies and departures from current policies in energy sector are adapted from the IESS, 2047 model developed by the NITI Aayog (GoI 2015a). Some of the variables in Table 5-5 are not directly used in the model but are the variables governing energy demand in the model. Energy demand estimates resulting from these variables are used in the model developed in this research. Similar calculations were done for water and food demand for use in the model developed for this research. Some new policies, like the Electric Mobility plan, and much faster penetration of renewable energy, particularly solar-based electricity generation in the energy mix, as specified in the National Electricity Plan, 2018 (CEA 2018) are considered in the BAU scenario. Although the IESS model used in this research allows one to consider the National Electricity Plan targets, the maximum penetration of electric vehicles allowed in the IESS model is less than those targeted in the National Electricity Plan.

The IESS model downloaded for this research is the version updated on the 21st September, 2016. The model has undergone some minor revisions since then but these were not considered in this research.

Table 5-5: Values Assumed for Scenario Variables by the End of the Modelling Period across the Different Scenarios

SECTOR	SCENARIO VARIABLES	BAU	ES	WS	FS	NEXUS
ENERGY FOR TRANSPORT	Domestic passenger transport demand per capita(passenger km)	16,803	15,186	16,803	16,803	16,803
ENERGY DEMAND FOR COOKING	Rural cooking fuel mix (LPG %; electricity %; PNG %; biogas %; biomass %)	42; 26; 3; 9; 20	38; 5; 38;15; 4	42; 26; 3; 9; 20	42; 26; 3; 9; 20	38; 5; 38;15; 4
	Urban cooking fuel mix (electricity %; PNG %; LPG %)	18; 40; 42	20; 55; 25	18; 40; 42	18; 40; 42	20; 55; 25
BUILDINGS	Commercial – technology penetration level scenario (high %, medium%, low %)	30, 50, 20	50, 40, 10	30, 50, 20	30, 50, 20	50, 40, 10
AGRICULTURE	Energy demand from irrigation (TWh)	723	723	549	723	549
	Diesel demand from mechanisation (TWh)	193	193	145	193	145
	Choice of fuel for irrigation (electricity %; diesel %; solar %)	85; 11; 4	85; 11;4	85; 11; 4	85; 11; 4	75 ;0; 25
DIESEL IN TELECOM	Towers with diesel generators (Rural %; Urban %)	54; 54	54; 54	54; 54	54; 54	0; 21
RENEWABLE ENERGY	Solar PV (installed capacity, GW; Generation, TWh)	479; 865	479; 865	479; 865	479; 865	479; 865
	Solar CSP (installed capacity, GW; generation, TWh)	46; 181	46; 181	46; 181	46; 181	90; 357
	Onshore wind power (installed capacity, GW; generation, TWh)	202; 495	202; 495	202; 495	202; 495	270; 666
	Offshore wind power (installed capacity, GW; generation, TWh)	20; 64	20; 64	20; 64	20; 64	20; 64
	Small hydroelectric power (installed capacity, GW; generation, TWh)	15; 58	15, 58	15; 58	15; 58	30; 115
	Distributed solar PV (grid-connected TWh, off-grid generation* TWh, solar water heater TWh)	439;37;17	439; 37; 17	439;37;17	439;37;17	439; 130; 49
NUCLEAR	Power generation installed capacity, GW; generation, TWh	26, 183	45, 316	26; 183	26; 183	26; 183

SECTOR	SCENARIO VARIABLES	BAU	ES	WS	FS	NEXUS
	Nuclear power technology shares in % (PWHR; LWR; FBR)	55; 40; 5	47; 46; 7	55; 40; 5	55; 40; 5	55; 40; 5
LARGE HYDRO POWER STATIONS	Power stations (installed capacity, GW; generation, TWh)	75; 263	105, 368	75; 263	75; 263	75; 263
	Pumped hydro schemes installation	Pumped hydro schemes under construction are completed	Pumped hydro schemes under survey and investigation are completed	Pumped hydro schemes under construction are completed	Pumped hydro schemes under construction are completed	Pumped hydro schemes under construction are completed
BIO-ENERGY	Bio-energy split % (cooking; power generation; liquid fuel for transport and others)	25; 27; 15; 33	0; 29; 38; 33	25; 27;15 ;33	30; 25; 13; 32	30; 25; 13; 32
	Total first- and second-generation biofuels (mtoe/year)	8.1	52	8.1	8.1	8.1
	Total first-generation (sugarcane and sugar beet) ethanol from sugar crops (mtoe/year)	0.6	1.26	0.6	0.6	0.6
	Jatropha/Pongamia bio-diesel production (mtoe/year)	1.8	9	1.8	1.8	1.8
	Ligno-cellulosic liquid fuels from agri-residue and wasteland biomass production (mtoe/year)	5.7	42	5.7	5.7	5.7
	Algae biofuel production (micro-algal; macro-algal biofuel) (mtoe/year)	2.6; 0.11	107; 6	2.6; 0.11	2.6; 0.11	2.6; 0.11
ENERGY FROM WASTE	Segregated rural and urban organic MSW (%)	20; 25	20; 25	20; 25	20; 25	60; 75
	Biogas (rural, urban), mtoe	0.28; 0.36	0.28; 0.36	0.28; 0.36	0.28; 0.36	0.83; 1.09
	Installed power generation capacity (MW)	3500	3500	3500	3500	5850
	Segregated urban combustibles used as a fuel (%) and energy generation (mtoe) for use in CHP applications	18; 0.002	18; 0.002	18; 0.002	18; 0.002	30; 0.008
GAS	Domestic gas production – recovery factor (%); production (BCM)	60; 137	70; 171	60; 137	60; 137	70; 171
	Gas power stations (installed capacity, GW; generation, TWh)	50; 198	50; 198	50; 198	50; 198	50; 198
COAL	Domestic coal production (MTPA)	1163	1602	1163	1163	1602
	Coal-based power technology generation TWh, technology Shares % (Sub-C; SC; USC; IGCC)	2134; 0, 10, 40, 50	2196; 0, 5, 30, 65	2134; 0, 10, 40, 50	2134; 0, 10, 40, 50	2134; 0, 10, 40, 50

SECTOR	SCENARIO VARIABLES	BAU	ES	WS	FS	NEXUS
OIL	Domestic oil production – recovery factor (%); production (MTPA)	30; 59	40; 78	30 ; 59	30; 59	40; 78
	Carbon capture and storage (CCS), GW and generation (TWh)	35; 185	90; 475	35; 185	35; 185	35; 185
	T&D losses (%)	10	7	10	10	10
WATER SECTOR	Surface water conveyance efficiency (%)	50	50	55	50	55
	Ground water conveyance efficiency (%)	65	65	70	65	70
	Proportion of area under irrigation (macro; micro)	144; 10	144;10	187; 20	144; 10	187; 20
	Industrial water efficiency improvement from 2015 levels (%)	10	10	20	10	20
	Power generation water efficiency improvements 2015 levels (coal sub C%, large hydro%, others %)	20; 5; 10	20; 5; 10	25; 5; 15	20; 5;10	25; 5; 15
	Desalination – installed capacity (MLD); volume (BCM)	54491; 18	54491; 18	96007; 31	54491; 18	54491; 18
	Treated sewage water – domestic sewage recycled (%); volume (BCM)	10; 2.7	10; 2.7	15; 4.5	10; 2.7	10; 4.5
	Domestic water consumption – rural and urban (LPCD)	55; 135	55; 135	55; 122	55; 135	55; 122
	Water supply losses and leakages – rural and urban (%)	80; 75	80; 75	90 both	80; 75	90 both
	Piped water coverage – rural and urban (%)	29; 63	29; 63	50; 80	29; 63	50; 80
	Wastewater treatment coverage – rural and urban (%)	20; 70	20; 70	50; 100	20; 70	50; 100
	Proportion of wastewater technologies - urban (% centralised; % decentralised natural; % decentralised advanced)	85; 10; 5	85; 10; 5	60; 10; 30	85; 10; 5	60; 10; 30
	Industrial wastewater treatment capacity (% of wastewater treated)	80	80	80	80	80
FOOD	Rural and urban food consumption patterns**	Continuation of past trends in food consumption	Continuation of past trends in food consumption	Continuation of past trends in food consumption	Focus on improved health and	Focus on improved health and

SECTOR	SCENARIO VARIABLES	BAU	ES	WS	FS	NEXUS
					nutritional intake***	nutritional intake***
YIELD	Yield improvement**	Moderate improvement	Moderate improvement	Moderate improvement	High Improvement	High Improvement
SEED AND WASTE	Improvement in seed and waste rates as a percent of total consumption**	Moderate improvement	Moderate improvement	Moderate improvement	10 % more than BAU levels	10 % more than BAU levels
FEED	Improvement in feed conversion ratio (Kg/1000 Kcal)**	Moderate improvement	Moderate improvement	Moderate improvement	10 % more than BAU levels	10 % more than BAU levels
TRANSPORT INVESTMENTS	Investment in road and rail transport (as % of GDP)	3.7	3.7	3.7	5	5
FERTILISERS	NPK ratio					
	N	6.5	6.5	6.5	4	4
	P	2	2	2	2	2
	K	1	1	1	1	1
	NPK from organic sources (MMT)	10	10	10	10	15
	NPK from chemical sources (MMT)	33	33	33	33	28
PROPORTIONS OF CHEMICAL AND ORGANIC FERTILISERS	Chemical fertilisers (%)	0.77	0.77	0.77	0.77	0.65
	Organic fertilisers (%)	0.23	0.23	0.23	0.23	0.35

*Solar pump-sets and Telecom;**For crop-wise detailed values, refer to Appendix D; *** Lower cereal consumption, higher consumption of pulses, poultry and meat, significant increase in consumption of fruits and vegetables, milk and milk products

5.3.3. Model Calibration and Validation

The construction of the disaggregated EWF-oriented IO table requires data from multiple secondary sources, as described in the above sections. Since the original IO database has been disaggregated to fit into the proposed EWF IO-based framework, it is also necessary to check whether the IO structure could continue to represent the macroeconomic situation of the Indian economy for the year 2015-16. This is achieved through model calibration and model validation (Table 5-6 and Table 5-7). The model calibration is performed by comparing the value of output pre and post-disaggregation. A negligible error, i.e. 0.02 percent, between the pre- and post-disaggregated value of output is observed. Further, the error observed between the post-disaggregated value of output and the actual value of output for India for the year 2015 in 2011 INR obtained from the National Account Statistics (NAS) published by the Government of India (MoSPI 2017a) is less than 5 percent.

There are no equivalent statistical tests to assess the validity of long-term IO analysis when the economic structure changes drastically. It is also difficult to recreate past economic structure and conditions to assess the validity of the model. Instead, the accuracy of the model – and therefore its results – is determined by how accurately it represents the economy at any given time.

The model is, therefore, validated for the short term by testing its performance in estimating macroeconomic parameters. Model rebasing is used to validate the model for vital macroeconomic indicators. The macroeconomic parameters obtained after rebasing the newly-disaggregated IO table for the year 2015-16 are compared with the officially available data for the macroeconomic indicators of the Indian economy for the year 2015-16. Since in the rebasing process the final consumption expenditure, government expenditure, investment, and exports had already been specified to obtain the IO for year 2015-16, it will be important to examine the discrepancies in imports that is determined by the model. The error observed between actual and model- determined imports is around 6 percent. This ensures that the disaggregated IO is not only a balanced data set, but it represents the current macroeconomic situation of the economy for the year being estimated.

Additionally, this research utilises data from the best available sources, for example, energy, water, and food sector-related information is obtained from reliable national and international sources. Wherever information was unavailable, especially for the future technological developments in the water sector, the researcher sought opinions from experts or used proxies from comparable national data.

Table 5-6: Model Calibration

	Value of output (2015-16), actual	Value of output (2015-16), pre-disaggregation	Value of output (2015-16), post-disaggregation (model predicted)
Billion INR, 2011 prices	225266	214274	214311

Table 5-7: Model Validation

	GDP (2015-16); actual	GDP (2015-16); Model run for rebasing to the base year
Billion INR, 2011 prices	113502	106594

5.3.4. Key Data Sources and Preparation

There are three critical stages when external data has been sourced for this research. These are IO disaggregation, Satellite accounts, and Elasticities of substitution.

IO Disaggregation

The main sources for disaggregation of the energy sector data are IESS 2047 (GoI 2015a) and National Energy Statistics (MoPNG 2015; MoSPI 2017b).

This research incorporates several electricity generation technologies. The cost structures of different electricity generation technologies are incorporated in the model in terms of technical coefficients, in matrices A, D and F. The GTAP power database represents the entire range of electricity generation technologies in terms of fuel – thus making analysis of technological substitutions/transformations difficult. This issue is addressed in this research by disaggregating the individual fuel-based electricity generation sector to represent a range of electricity generation technologies. This is an established and widely-applied approach to address this issue, see, for example, Gay and Proops 1993, Proops *et. al* 1993, and Timilsina and Shrestha 2006.

The annual fixed and variable costs of various technologies are taken from IESS 2047 and these estimates are used to differentiate the technical coefficients (i.e., cost structures) of various technologies. Similarly, the heat rates of different fossil fuel-based technologies like coal has been used to modify coal input into each technology. These modifications depicts the differences in the efficiencies of the various technologies. The main data sources used to disaggregate the crop coefficients are the Cost of Cultivation Surveys published by the Directorate of Economics and Statistics, Ministry of Agriculture (DESAg) (GoI 2013)

Cost estimates for irrigation water pumping technologies are also taken from IESS 2047. Cost and energy-use estimates for water and wastewater treatment technologies are taken from multiple sources (Wintgens et al. 2016, GoI 2015a). The private consumption coefficients are disaggregated into rural and urban private coefficients using the NSSO 2011-12 results about household consumption from a recent survey (NSSO 2014a). The 93 sector- disaggregated coefficient matrix is provided in Appendix E.

Satellite Accounts

The energy accounts developed for the model in this research include fuel-wise energy supply (domestic and imported) and demand. They include computation of energy for water and food. The energy accounts for the base year (2015) are largely sourced from IESS 2047. The sectoral classification in IESS 2047 is quite different from the IO model. The national statistics for petroleum and natural gas and some proxies are used to disaggregate to obtain the energy demand for specific sectors in the IO model. Wherever information for the base year was not available, the mid-point of the base year (2011) and first scenario year (2017) from IESS 2047 is assumed to be base year information. Information on the energy intensities required for various water supply options, including wastewater treatment and recycling, is taken from multiple sources (Semiat 2008, Singh et al. 2016, Bennett et al. 2010, GoI 2015a). This information generated the energy-water link in the model.

Water accounts developed for the model used in this research are composed of sector-wise water demand, which included blue water (ground and surface water), green water, treated grey water, and desalinated and treated sewage water used by different industries. These uses included water for energy, food and fuel crops. The values for green and blue water withdrawals per unit of crop produce for different crops were taken from Bogra 2017 (water-food link). The values in this research are for the year 2004. However, for use in the base year, the values were adjusted for improvement in surface and groundwater irrigation efficiencies using the information from NCIWRD 1999, which also provides information on water use for different industries per unit of product, in particular for water-intensive industries.

Spang *et al.* 2014 provided a basis for the water-for-energy aspect in the energy-water nexus in the IO model at a detailed, technological level. Specifically, it provided information on water intensities required in various energy technologies. Information from various sources has been used to generate unit estimates for energy-for-water provisioning at different stages, technologies, and processes.

Food supply accounts were largely prepared from the FAO's Food Balance-2013-14 and the NSS's 68th round (survey) on household consumption of various goods and services in India (FAO 2013, NSSO 2014a). Food accounts were generated in the form of a food balance equation, where supply is total production minus seed and waste, feed demand, food manufacturing, exports plus imports, and stock balances and the demand side is human consumption and non-food uses. Food calorie factors are used to calculate the base year's calorie consumption. Information on the calorific values of food commodities is derived from FAO (2011-12) food consumption data and data on population to obtain calories/capita/day for different foods.

The FAO estimates were higher than those obtained from the national statistical surveys as the FAO data included losses of edible food and nutrients in the household, e.g. during storage, in preparation and cooking, as plate-waste or as quantities fed to domestic animals and pets or thrown away (FAO, n. d.). As a result, the amount of food consumed may be lower than the quantity shown in the food balance sheet. However, since FAOSTAT provided more recent data than the national surveys and is also much more extensive in providing data on the other categories like feed demand, seed and waste, food manufacturing, and so on, this was a preferable source for developing food accounts. In terms of individual commodities, data on calorie intake by rural and urban population is developed after making some adjustments for food losses at consumption level. These adjustments were made on the basis of calorie share from different categories of food like cereals, roots and tubers, fruits and vegetables, oils, meat, milk, and eggs (NSSO 2014b).

In terms of the individual sectors, land statistics are prepared using information from IESS 2047 and MoSPI annual agricultural and horticultural yearbooks (GoI 2015a, MoSPI 2016, Vanitha *et* *al.* 2013). Land under coal mining is not a part of the IESS 2047 land calculations, and the estimates are therefore taken from Garg (n.d.). According to Garg (n.d.), in 2013-14, the total land under coal production constituted 75, 934 ha of forested land, and 204, 248 ha of non-forested land. These estimates served as a proxy for 2015-16 in the base-year land accounts. Forested land is not considered in the analysis. The chemical and bio-fertiliser statistics are taken from the annual publication published by the Ministry of Chemicals and Fertilisers (GoI 2015b)

The information on sectoral employment is taken from latest Indian Labour Organisation (ILO) information (ILO 2013) for the year 2011. The statistics provide employment figures for organised labour in factories by industry groups. Disaggregation of employment by crop is done on the basis of labour intensity for the different crops (GoI 2013, Sharma and Prakash 2011). Fuel-related employment factors are taken from Rutovitz and Harris (2012). Information on employment in the unorganised sector is sourced from GoI (2016b, p. 17). The disaggregation of labour into skilled and unskilled is based on the assumption that organised labour is mostly skilled and unorganised labour is mostly unskilled.

Since data on labour use in water technologies was not available, it is assumed that a majority (~98%) of the population employed in water supply and treatment is employed in the conventional municipal water treatment sector and rest in the desalination sector. Similarly, disaggregation of the population employed in wastewater treatment and reuse is based on the assumption that most (roughly 85 percent) of the population is employed in centralised wastewater treatment. Decentralised natural wastewater treatment technologies like WSP are assumed to be more labour (particularly unskilled) intensive than decentralised energy-intensive technologies and treating sewage water (Hophmayer-Tokich, S., 2010). As a result, labour employed in these technologies is assumed to be distributed accordingly.

Carbon emission factors from IESS 2047 have been used to calculate the carbon emissions from the energy accounts. The factors used to develop the satellite accounts for energy, water, food, land, emissions, and employment (with their respective sources) are provided in Appendix F. These values are collectively used to create base-year energy, water, and food accounts.

Elasticities of Substitution

The elasticity of substitution governs how the relative expenditure on goods or factor inputs changes as relative prices change. An elasticity of substitution value of less than one implies commodities as gross complements and an elasticity of substitution value of more than one implies commodities to be gross substitutes.

Sources for the elasticity of substitution are more readily available for the production side. Several assumptions have been made regarding elasticities of substitution on the demand side. Some examples used in the literature, for instance, Papageorgiou *et al.* (2013), evaluate elasticity of substitution between clean and polluting energy inputs to be around 2 for the electricity generating sector and close to 3 for the non-energy industries. Likewise, Behar (2010) estimated the elasticity of substitution between skilled and unskilled labour in developing countries to be around 2.

Different values for capital and labour substitution have been assumed for both the short and long term. A single elasticity of substitution may confuse short- and long-term scenarios, because that elasticity may increase with the period being analysed. In the short term, substitution is limited by existing capacity (no capital expansion); however, moving to the long-term equilibrium as capacity is replaced, only operational considerations constrain perfect substitution (Peters 2016b).

Some assumptions regarding elasticity of substitution are made in reference to the socio-political and institutional contexts of this research. For example, the elasticity of substitution between municipal water supply and treated sewage water for domestic uses is assumed to be zero in anticipation of the low public acceptance of treated sewage water in India. Similarly, the elasticity of substitution between poultry meat like chicken and other meat (like beef or pork) is assumed to be negligible due to religious factors. Likewise, due to a lack of reliable data, substitution elasticities between different fertiliser nutrients (NPK) are assumed to be 0.5 (Bartelings *et al.* n.d).

Values and sources used for supply- and demand-side elasticities of substitution with respective sources are provided in Appendix G.

5.3.5. Additional Discussion on the Methodological Framework

Some specific provisions or adjustments made in the modelling exercise are discussed below.

Treatment of resource constraints

The modelling approach considers resource constraints in the model and scenario assumptions. The model employed in this research is quite similar to the widely-used general equilibrium models. Producer and consumer behaviours are accordingly expressed in this model in the form of *nested* structures, specifically in terms of input usage patterns for the production-side of the economy, and consumption patterns for the demand side of the economy.

Further, the behavioural equations are expressed in functional forms that specify relationships within the nested structures in the model, such as CES and CET. The nested CET and the closely-related CES functions for crop production incorporate land supply curves to reflect whether more land is utilised. Consequently, rent will increase to account for land scarcity. In response to these changing resource rents, the behavioural equations focus on resource allocation to achieve assumed levels of economic and population growth. This approach to consider resource constraints is well established and widely practised (Gurgel *et al*. 2008, Gurgel *et al*. 2016, Verburg *et al*. 2008).

Further, it is acknowledged that, in reality, markets may not work properly in developing countries, including India. Accordingly, the modelling (as described above) may not account sufficiently for resource constraints. This research therefore also incorporates supply and demand constraints in the scenarios.

The Armington model assumes two stages of substitution between domestically-produced and imported goods. The first stage is the allocation of expenditure on each good between domestic and imported varieties, and the second stage is the allocation of expenditure on imports among competing national suppliers (Jomini *et al*. 2009). In this research, the other national suppliers are grouped into one, and elasticity between imports from different sources is therefore not considered. However, if the elasticity of substitution between imported and exported coal is high, more coal will be imported.

Treatment of proportionality between monetary and physical flows

Environmentally extended IO (EEIO) models often assume a proportionality between monetary and physical flows (Lenzen 2000, Dias *et al*. 2014). The monetary flows can increase disproportionately relative to physical flows or vice-versa due to various factors. This is particularly true for countries with low incomes where, for instance, economic growth may not induce a substantial increase in particular sectors like agriculture, residential, etc. in energy content terms, even if there is an increase in the value of sectoral energy services (Adams and Miovic 1968, Burke and Zsuzsanna 2016). In the short term, these changes are assumed to be insignificant.

This aspect is accounted for in this research by modification of the intensity vectors. The bases for such modifications are: a) elasticity of supply and demand to GDP growth, b) a change in capital and operating costs, or simply an increase or decrease in the real costs of production, or c) the introduction of effective pricing in poorly-priced resources like water.

5.4. Impact Attributes

The first chapter of this thesis contained a detailed description of EWF security challenges in India. Chapter 4 supplemented this information with historical and cultural influences on energy, water, and food security considerations in India, and existing strategies to redress this challenge. In alignment with both of these discussions, impact attributes have been chosen in this research to reflect the EWF security aspirations of India and relevant social, economic, and environmental outcomes (Figure 5-9).

While some of the chosen attributes are widely used in the literature on energy, water, or food security assessments, others have been designed specifically for this research – to capture specific social, institutional, and environmental domains relevant to the EWF nexus in the Indian context (also see Appendix H).

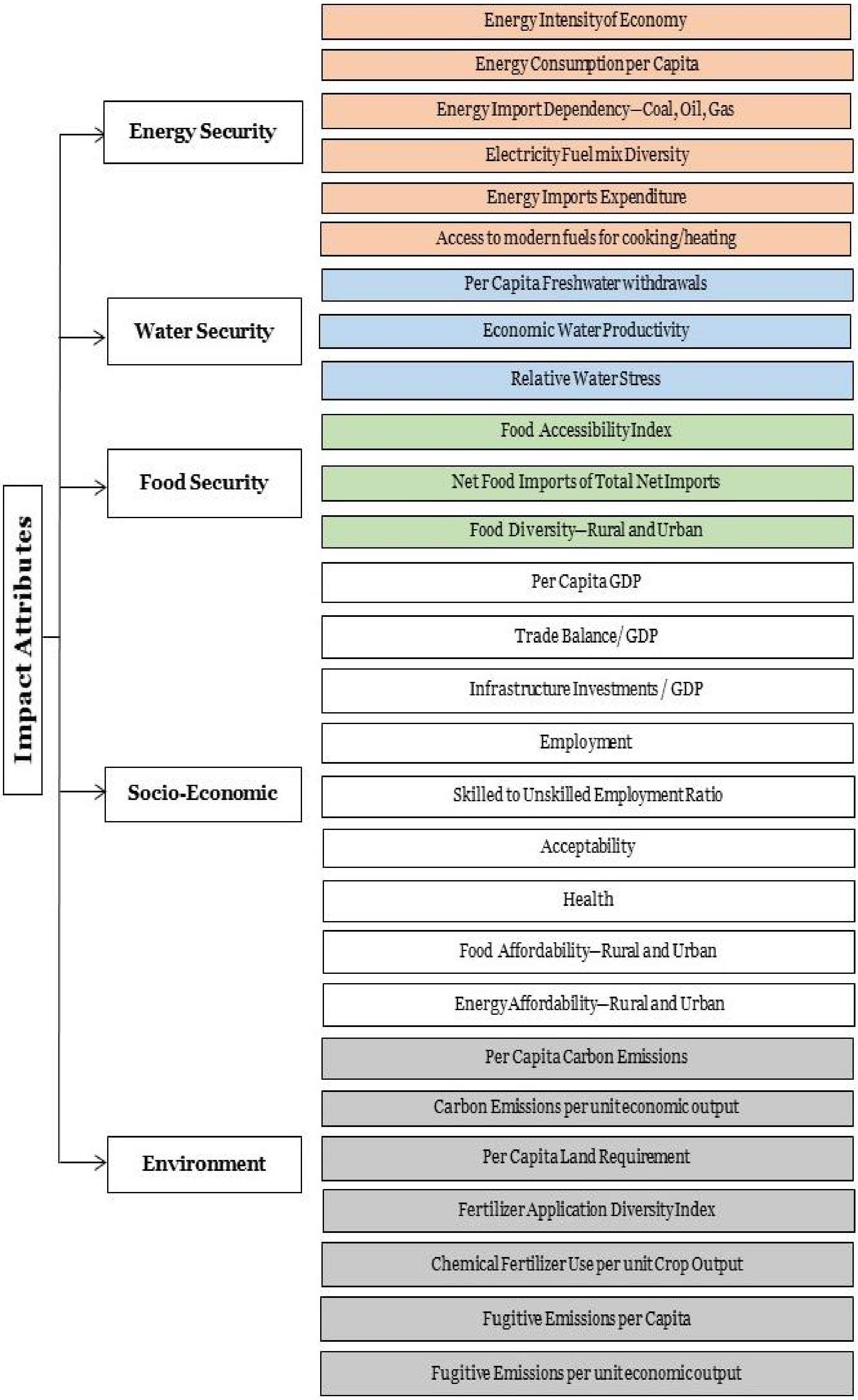


Figure 5-9: EWF, Socio-economic and Environmental Attributes for India

Energy intensity of the economy is expressed in this research as megawatt hours of energy used per rupee generated in the economy as the gross domestic product for a particular year. This indicator is a measure of the energy intensiveness of an economy. A lower energy intensity of economy represents better outcomes for energy security.

Per capita energy consumption *is* expressed in this research as kilowatt-hours (KWh) of energy consumed per person in a given year. This indicator demonstrates the energy-use levels and patterns of a society. Although a certain level of energy consumption is indicative of social and economic development, in view of the adverse impacts of energy generation on natural resources and the environment, energy efficiency and conservation measures are implemented to reduce per capita demand for energy along with continuing socio-economic development. Therefore, a lower per capita energy demand indicates better outcomes for energy security.

Energy-import dependency (coal, oil, and gas) is expressed in this research as energy imports as a percentage of total domestic production and imports. This research examines India's import dependency for primary fossil energy fuels, i.e., coal, oil, and gas. This indicator is represented in this research as energy imports of a particular energy fuel as a percentage of total use of the same energy fuel in a given year. A lower value means a country can manage its energy imports in case of political or economic disruption, thus suggesting improved energy security. A lower import dependency indicates better energy security outcomes.

Electricity fuel mix diversity is expressed in this research as the degree of diversification in the fuel mix used in electricity generation and this diversity characterises the resilience of the electricity system. A higher fuel diversity in the electricity fuel mix implies better resilience to any technical, economic, or geopolitical disruption. This indicator is evaluated by use of the Shannon Weiner Index (SWI), which ranges from 0 to 2. Higher values of the index suggest greater diversity and consequently better energy security outcomes. This index – primarily developed for evaluating diversity in biological species – is chosen because it has been applied widely in past studies pertaining to energy security.

Energy (food) imports expenditure is represented in this research as a value of net energy imports, expressed as a percentage of total net imports in a given year. It indicates a country's reliance on balance of payments for energy (food) imports. This attribute demonstrates national energy (food) affordability from a macroeconomic level, thus signifying the economic burden of energy (food) imports. A lower value for this attribute is suggestive of better energy (food) security outcomes. The *value of net food imports of total net imports* is expressed similarly.

Access to modern energy for cooking/heating is represented in this research as the percentage of population using modern and cleaner sources of energy for cooking and heating purposes, like LPG, PNG, solar, and electricity. This attribute is a representation of equity as well as the technology aspect of energy security. A higher value of this attribute signifies improved household access to modern energy services and therefore better energy security.

Per capita fresh water withdrawals is evaluated in this research as cubic metres of water withdrawals per person for a particular year. This attribute portrays the population pressure on water demand. A lower value of per capita water withdrawals indicates better outcomes for water security.

Relative water stress is represented in this research as the percentage of fresh water withdrawn to meet water demand compared to total renewable water resources. It reflects the water demand pressures faced by a country relative to its water supplies. Total renewable water resources available in the country are assumed to be the same across all scenarios. India's total renewable fresh water resources (including both surface water and ground water resources) are estimated at 1911 BCM (FAO 2016). A higher value of this attribute implies worsened water security outcomes.

Water productivity of economy is evaluated in this research as a ratio of constant 2011 GDP to cubic metres of total water use in the economy for a particular year. This attribute is a measure of the water intensiveness of the economy. A lower value of economic water productivity signifies better outcomes for water security.

Food accessibility is expressed in this research as the ratio of value of crop output to transportation sector output. This attribute is derived from FAO food security indicators, where road density is considered a measure of better access to food and therefore higher food security (FAO 2018). Food accessibility reflects the adequacy of transportation services for better access to food. This attribute of food security provides information on physical access to markets, typically defined in terms of the proportion of road networks to the country's land area. A higher value of this attribute represents better outcomes for food security.

Food diversity for rural and urban populations is evaluated in this research using the Shannon Weiner Index (SWI) for dietary diversity**.** The attribute characterises the nutritional food security status of the individuals and is associated with a balanced and nutritious diet. A higher value of this index represents better food security outcomes.

Although per capita calorie consumption is also a widely-used attribute to demonstrate food security outcomes, is not used for this research. The reason for this is that many nutritional problems are not necessarily the result of a lack of calories, but rather a lack of diet quality, particularly in developing countries like India, where diets are composed mostly of starchy staples like rice and wheat, include few animal products, and are high in fats and sugars (Ruel 2003). As well, this attribute has been shown to be positively related to dietary diversity, which is used in this study (Hoddinott 1999, Hoddinott and Yohannes 2002).

Per capita GDP is expressed as the economic output generated per person in the economy for a given year. Sustained economic growth, measured as growth in economic output (GDP) is one of the global key policy priorities. However, an increasing GDP could be misleading for countries with high population growth, like India. Therefore, per capita GDP is a better proxy for standard of living of a nation's citizens.

Although median per capita income is regarded as the best proxy for standard of living, the estimation of median per capita income requires regular, expensive, and time-consuming household surveys. In addition, medians are harder to determine than per capita averages (Kopf 2018). A higher value of per capita GDP signifies better economic outcomes.

Trade balance is expressed in this research as the proportion of net exports i.e., the difference between exports and imports, to total economic output generated in the economy in a given year. This attribute is a measure of a country's economic competitiveness at a national level. A higher value of trade balance to economic output is indicative of better economic outcomes.

Infrastructure investments are expressed in this research as the proportion of investments in key infrastructure, like energy, water, agriculture, and transport, to the total economic output for a given year. A higher value of this attribute suggests better economic outcomes.

Increased infrastructure investment is an essential driver of economic growth. This relationship has been understood widely in the literature, and it has been established that delivery of services like water, sanitation, transportation, and energy directly benefit households, can dramatically improve their welfare and contribute to their productivity. Further, infrastructure-related services lower production costs, expand market opportunities that positively affect competitiveness and production and lead to economic growth (Snieska and Simkunaite 2009).

Employment as a percentage of working population is represented as employment opportunities generated in the economy as a proportion of population in the working age group (i.e., 16-64). Job creation is often a critical factor affecting the choice of future policies as it affects people directly and has much more extensive social implications. Therefore, a higher value of this attribute suggests better social outcomes.

Policy and technological interventions that promote employment generation are particularly favourable for highly populated economies. India has the largest youth population in the world, and the youth are more vulnerable to unemployment. This attribute, also often referred to as the *labour participation rate* (e.g. in Kakinaka and Miyamoto 2012) is very commonly used to understand employment and economy dynamics.

Skilled-to-Unskilled employment ratio provides a measure of skilled work opportunities generated in the economy as a proportion of unskilled job opportunities.

The Indian government recently initiated dedicated efforts towards skill development, given the meagre percentage of the skilled population in total workforce. The National Skill Development Initiative is expected to improve skills and knowledge through nationally- and internationally-recognised qualifications for Indians to gain access to decent employment, higher incomes, improved social welfare, and to ensure India's competitiveness in the global market (Goel and Vijay 2017This attribute to reflect the level of skilled job creation has been used in several studies, for example, in Lee and Schluter, 1999 (referred to as skill intensity ratio). A higher value of this attribute indicates better social outcomes.

Acceptability (share of nuclear and large hydro) is expressed as the share of nuclear and hydro in the energy mix. Energy fuels like nuclear and hydro face resistance from the local community right from proposal stages. Such projects cause 'Not In My Backyard' type of reactions and raise distributional and environmental justice questions, implying that while the power generated from these projects may get transmitted far away to serve the urban agglomerations, people in the neighbourhood suffer the local consequences of the construction and operation of the power project. Acceptability, therefore, is indicative of distributive social justice and a higher value of this attribute indicates worsened social outcomes.

Health (air, drinking water, sanitation, and nutrition-related impacts) is expressed in this research as a composite index indicating health outcomes of clean air, improved water sources and sanitation facilities, and diversified diet. These health-related aspects are influenced by EWF security policies. Health is directly related to social welfare, therefore, a higher value of the health composite index indicates better social outcomes.

Energy (food) affordability is expressed in terms of the proportion of total household expenditure (as a proxy of income) spent on energy (food). Food affordability is measured in this research as the proportion of household expenditure on staple foods, namely rice, wheat, pulses, and roots and tubers. Household expenditure on staple food is particularly sensitive to food price fluctuations (INDDEX Project 2018).

Energy affordability is expressed as household expenditure on energy-related needs. Energy-related expenditure accounts for a significant proportion of household incomes in many developing countries (Alcon *et al.* 2016). Considering the basic need for food and energy, their affordability becomes an important social aspect. Water pricing is still at very nascent stages in India and therefore is not part of the social outcomes.

While energy (food affordability) is usually a part of energy (food) security assessments, the resulting affordability outcomes in this research are also influenced by the EWF nexus. Furthermore, the expenditure on energy or food affects the expenditure on other services and therefore, energy (food) affordability attributes are part of the social domain in this research. A lower value of this attribute indicates better social outcomes.

Carbon emissions per unit of economic output are represented in this research as kilograms of carbon emitted per unit (rupee) of economic output generated in the economy in a given year. Rises in anthropogenic carbon emissions are widely claimed to be responsible for recent climate change. This attribute provides an indication of the influences between carbon emissions and economic growth. The carbon emissions used in this attribute are only energy-use related emissions. A lower value of this attribute indicates lower environmental implications of economic growth.

Per capita carbon emissions are represented in this research as metric tonnes of carbon emissions per person in an economy. This attribute is indicative of the influence of population on the intensity of carbon emissions generated in an economy. The carbon emissions used in this attribute are energy-use emissions only. The lower value of this attribute indicates better environmental outcomes.

Per capita land requirement represents land required in million hectares per person in the country and shows the implications of economic development, population growth and growth in EWF demand on land resources. A lower value of this attribute indicates better environmental outcomes.

Agriculture uses almost 60 percent of the land area in India (WB 2015).There are land disputes over the use of land for industry, urban development or agriculture purposes, which is particularly evident since the development of the Special Economic Zone (Levien 2012). In addition, promotion of biofuels has often sparked debates over their land requirements. This aspect is of particular concern in this research given the high population density of India and the significant dependence of the rural population on land resources for their livelihood (Ravindranath *et al*. 2011).

Fertiliser application diversity index represents the diversification in use of fertilisers as soil nutrients. Soil nutrition management greatly affects soil quality. Historically, overuse of urea has resulted into a skewed NPK ratio in the country, for example, the NPK ratio in 2014-15 was 6.7: 2.4:1 while the broadly recommended ratio is around 4:2:1 (GoI 2015b, Gulati and Banerjee 2015). Therefore, the Shannon Weiner Diversity index is used as an indicative to demonstrate the level of diversity in the use of fertilisers. A higher value of this attribute indicates better soil quality and therefore better environmental outcomes.

Chemical Fertiliser use per unit of crop output is represented in this research as the use of chemical fertilisers per unit value of crop output, in tonnes per billion rupees, for a given year. This attribute is used to monitor the environmental damage caused by excessive use of chemical fertilisers, which also has implications on soil and water quality. A higher value of this attribute therefore represents better soil and water quality and improvement in environmental outcomes.

Per capita fugitive emissions represent fugitive emissions, in kilograms, generated from provisioning of energy, water, and food per person in the economy in a given year. Fugitive emissions from the energy sector in this research refer to the non-energy use emissions from mining, processing, storage, and transportation of coal, oil, and natural gas. Fugitive emissions from the water sector in this research are the on-site emissions from a wastewater treatment plant into atmosphere due to biological degradation of organic matter into carbon dioxide and/or methane and nitrous oxide from nitrogen fraction subsequently removed from sewage sludge (Singh et al. 2016). Fugitive emissions in the agriculture sector in this research refer to the greenhouse gas emissions excluding energy emissions from irrigation (pumping) and mechanisation (tractors). The resulting emissions arise mainly from management practices at the farm level. This attribute highlights the link between population growth and emissions. A lower value of this attribute indicates lower environmental implications of population growth.

Fugitive emissions per unit of economic output represents the fugitive emissions, in kilograms, from provisioning of energy, water, and food per unit economic output, in 2011 prices. A lower value of this attribute indicates lower environmental implications of economic growth.

5.5. Summary and Key Inferences

The objectives of this chapter were: i) to develop a methodological framework based on an IO model with modified production functions to analyse the impact of EWF security policy scenarios on the broader economy, and ii) to describe the sources of data as well as the methodology used in this research to transform raw data into a form that could be employed in this methodology.

The methodological framework developed in this research comprised six steps: 1) the base-year information for the model was developed, 2) the baseline scenario model was developed using information on future population and economic growth trajectories, current plans and policies, 3) technological change was implemented by exogenously changing the IO coefficients, 4) price impacts due to change in technologies were assessed, 5) price-induced input factor substitution was examined using multi-tier calibration of nested production functions, and 6) based on the new IO coefficients, the economy-wide impacts of EWF security policy scenarios were assessed.

The impacts of the different scenarios are classified into six security categories: energy, water, food, social, economic, and environmental. The attributes used in this research to demonstrate each of the categories in the Indian context were described later in this chapter. The resulting impact from the BAU and alternative scenarios are discussed in the next chapter.

Chapter 6 . Analysis of Alternative EWF Security Scenarios

Chapter 5 contained a detailed description of the methodological framework employed in this research to analyse the EWF security impacts and associated trade-offs involved in the alternative techno-economic developmental pathways considered in this research. This chapter presents the empirical estimates of the impacts and trade-offs obtained from the application of this method. As noted in Chapter 2, the interactions between energy, water, and food impact multiple domains, including economic, societal, and environmental.

This chapter consists of four sections. Section 6.1 presents the results and findings for each of the attributes used in this research to represent EWF security, socio-economic and environmental outcomes. This section also includes an assessment of trade-offs between EWF securities and the social, economic, and environmental outcomes in the short, medium, and long terms. The analysis is further extended to collective EWF securities, to socio-economic and environmental trade-offs and to compare the BAU scenario with the alternative policy scenarios. Section 6.2 presents the policy implications and recommendations based on the results and key findings. Section 6.3 comprises further discussion based on the findings and Section 6.4. presents the summary and discussion.

6.1. Empirical Findings

This section provides an assessment of EWF security in terms of the key attributes for the five scenarios, namely, Business-as-Usual (BAU), Energy Security-oriented scenario (ES), Water Security-oriented scenario (WS), Food Security-oriented scenario (FS), and Nexus-oriented (Nexus).

6.1.1. Energy Security

Energy Intensity of Economy

Figure 6-1 shows the variations in the energy intensities of the Indian economy over the modelling period across different scenarios.

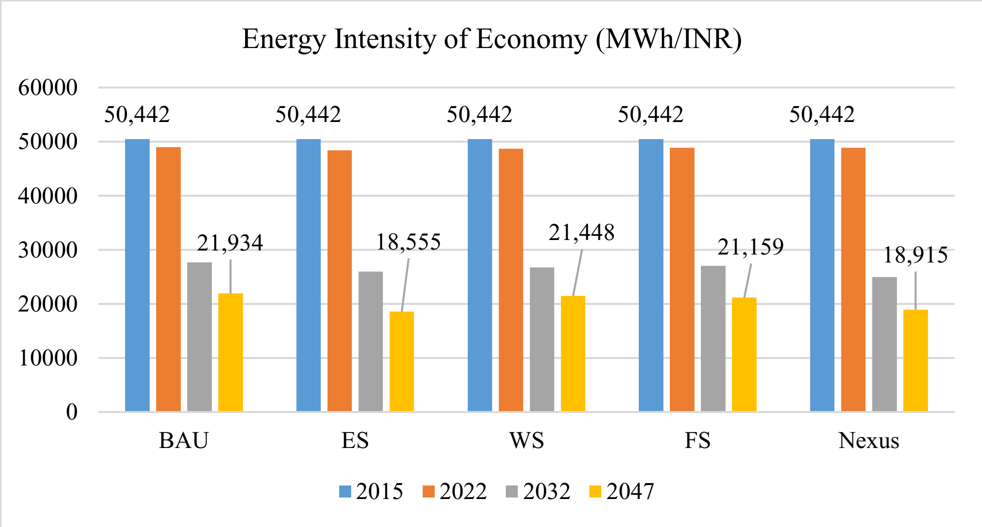


Figure 6-1: Model Estimates of Energy Intensity of India (2015-47) across scenarios

Energy intensity is estimated in this research as the ratio of total energy consumed and total economic output for a given year. It is noticed that energy intensity of the Indian economy will reduce from the current level (50,442 MWh/INR) in all scenarios over the modelling period. The ES scenario yields the lowest energy intensity for 2047, i.e., 18,555 MWh/INR, as a result of marked improvements in energy efficiency. The Nexus scenario obtains the next lowest energy intensity (18915 MWh/INR) – 361 MWh/INR higher than the ES scenario.

The Nexus scenario assumes implementation of efficiency improvement strategies and high economic output (the highest among all scenarios in the short, medium, and long term). The BAU scenario shows the least improvement in energy intensity; it decreases to only 0.44 times of the base-year energy intensity, compared to a decrease of 0.37 in the ES scenario and 0.38 in the Nexus scenario.

Per Capita Energy Consumption

Figure 6-2 shows the changes in per capita energy consumption in India over time for the different scenarios. Energy consumption in this research is expressed in Kilowatt hours (kWh).

The per capita energy consumption is expected to increase over the study period from its current (2015) level (4263 KWh) in all scenarios. The BAU scenario yields the highest increase, growing at a compounded annual growth rate of 3.59 percent over the study period, followed by the FS and WS scenarios, which yield increases of around 3.51 percent and 3.53 percent respectively. The lowest growth rate in per capita energy consumption is expected in the ES scenario (3.08 percent) approximately 15 percent lower than the BAU scenario), followed by the Nexus scenario (3.16), which is only marginally higher than the ES scenario but around 12 percent lower than the BAU scenario.

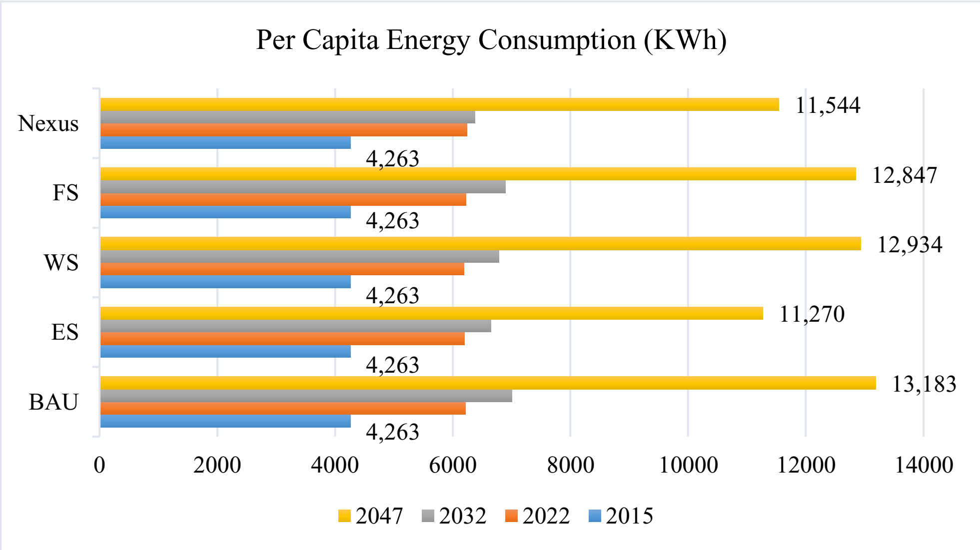


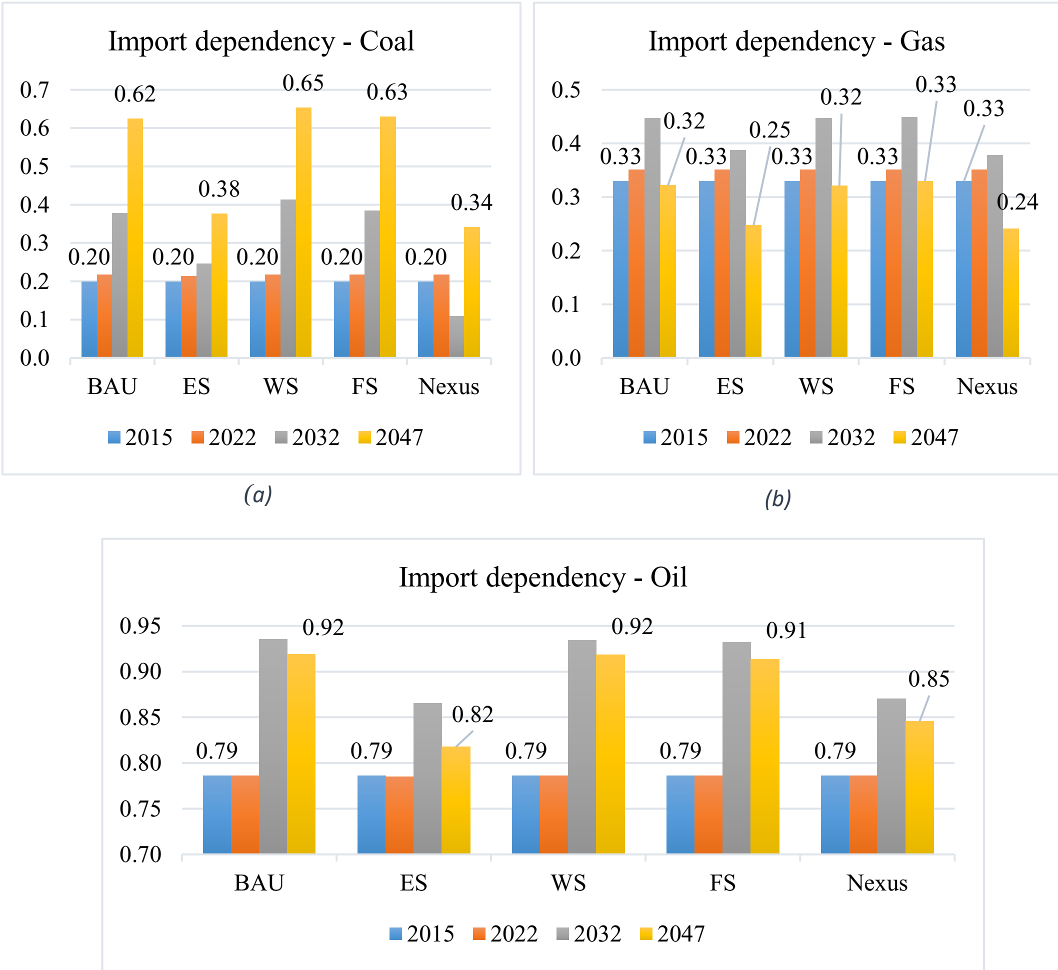
Figure 6-2: Model Estimates of Per Capita Energy Consumption (2015-47) across scenarios

The low growth in per capita energy consumption in the ES and Nexus scenarios can be attributed to demand-side energy efficiency improvements and fuel-switch measures in different sectors of the economy. Per capita energy consumption in the Nexus scenario, although low due to the implementation of energy efficiency measures, is still slightly higher than the ES scenario due to lower penetration of high-efficiency coal technologies in power generation, higher domestic passenger transport energy demand relative to the ES scenario where better urban planning and transport demand management is assumed, and higher domestic crop production in the country as part of food security ambitions.

Energy-Import Dependency: Coal, Gas, Oil

Figure 6-3 shows the patterns in import dependency for primary energy fuels, i.e., coal, gas and oil, for the different scenarios over the modelling period.

It can be observed that while dependency on coal and oil imports is expected to increase in all scenarios by the end of modelling period compared to the base year, gas import dependency declines in the long term. Overall, by the end of the modelling period, the Nexus scenario shows the lowest dependency on imported coal and gas, while the ES scenario shows the lowest dependency on imported oil. Details of these trends are as follows:



(c)

Figure 6-3: Model Estimates of Import Dependency of (a) Coal, (b) Gas, and (c) Oil

In the long term (2047), high dependency on coal imports is expected in the BAU, FS, and WS scenarios, reflecting India's high demand for coal as the dominant fuel for electricity generation in these three scenarios. In the long term, the Nexus scenario shows the lowest increase in coal import dependency (34 percent), followed by the ES scenario (38 percent) compared with 20 percent in the base year. The lower coal dependencies shown in the ES and Nexus scenarios are based on an assumption of significant improvements in mineability[8] and a reduced share of coal in the energy mix. As a result, in these scenarios, demand for coal and hence coal imports fall, a

[8] Ratio of techno-economically extractable reserves to proved reserves

result that is distinctly apparent in the medium term. Against this, growth in proven reserves declines with time as most of the reserves will have been explored and coal import dependency consequently increases in the long term; however, it remains lower than in the other scenarios in the long term.

There are other reasons behind the higher reduction in coal import dependency in the Nexus scenario compared to the ES scenario despite the lower improvement in efficiency of coal based power generation. These are a greater share of renewable electricity generation, greater efficiency improvements at various stages of crop production, water efficiency improvements, particularly for irrigation, and choice of less energy-intensive technologies for wastewater treatment. These interventions reduce electricity demand and consequently the demand for coal.

Oil and gas import dependency trends are characterised by a rise in the medium term, followed by a decline in the long term. This pattern in oil and gas import dependency in the medium term is a result of higher net consumption of oil and gas relative to the increase in domestic production of oil and gas, which will increase in the long term from improved recovery rates.

In the long term, the ES scenario shows the lowest oil import dependency (82 percent), followed by the Nexus scenario (85 percent). The Nexus scenario is more import dependent due to the lower share of biofuels in the energy mix to prevent any negative impact on food security. The BAU, FS, and WS scenarios show almost similar levels of oil dependency by the end of the modelling period.

The Nexus scenario shows the least gas import dependency (24%), followed by the ES scenario (25%). This can be explained by some of the assumptions they contain; for example, the ES and Nexus scenarios emphasise enhanced domestic production of gas. Further, the Nexus scenario has the lowest demand for gas and therefore the lowest import dependency. This accords with the scenario’s use of bio-fertilisers instead of chemical fertilisers, which require large quantities of natural gas. The BAU, WS, and FS scenarios show almost similar levels of gas import dependency.

In general, the coal, oil, and gas import dependencies in the ES and Nexus scenarios are lower than those in the other scenarios as a result of the improved mineability of coal and higher recovery factors for oil and gas.

Electricity Fuel-mix Diversity

Figure 6-4 shows the patterns of fuel mix diversity in the electricity generation fuel mix in India across different scenarios over the modelling period.

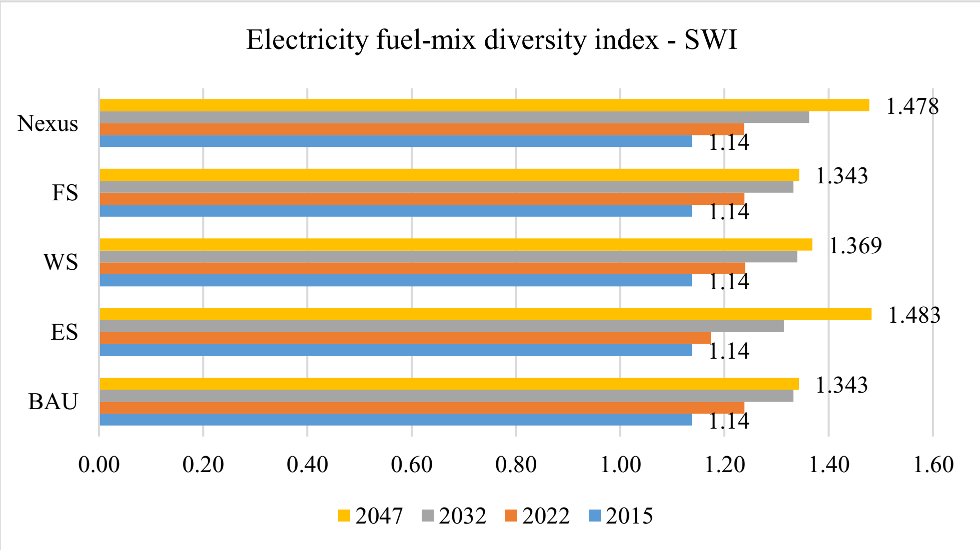


Figure 6-4: Model Estimates of Fuel Diversity for Electricity Generation (2015-47) across scenarios

Fuel diversity, as measured by the Shannon-Weiner Index (SWI), increases over the modelling period in all scenarios. The fuel diversity for electricity generation is highest in the ES scenario, with a SWI of 1.483 – slightly higher than the Nexus scenario (SWI of 1.478).

This suggests a slightly higher focus on renewables (both grid-connected and distributed), like solar, in the Nexus scenario compared to the ES scenario, which focuses both on renewables and fossil-based electricity generation, hence shows greater diversity in the fuels used for electricity generation. Such considerations ultimately reduce diversity in the electricity mix for the Nexus scenario, which also signifies low reliability and resilience of the system in case of disruption. Further, renewables have been often criticised for their intermittent nature and lack of reliability (Hart *et al*. 2012, Hart and Jacobson 2012, Perez-Arriaga and Batlle 2012, Zhou *et al*. 2016).

Energy Imports Expenditure

Figure 6-5 shows the patterns of energy imports expenditure (i.e. expenditure on net energy imports as a proportion of total net imports, expressed in percentage terms) for India across the different scenarios over the modelling period.

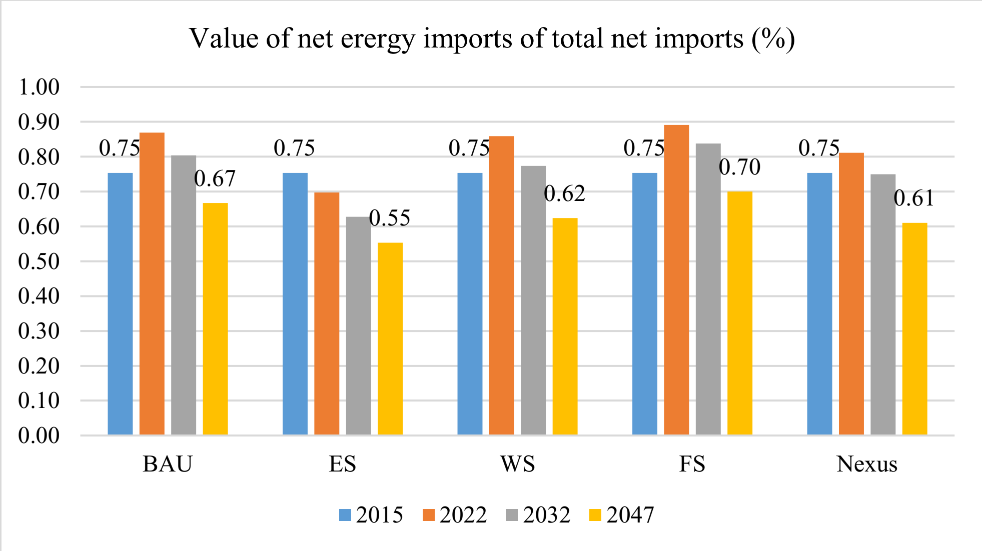


Figure 6-5: Model Estimates of Value of net energy imports of total net imports (%) (2015-47) across scenarios

The share of expenditure on net energy imports in total net imports is observed to decline in all scenarios. Although total net imports and net energy imports both increase over time in all scenarios, the rate of increase in total net imports exceeds that of the net energy imports.

The maximum decline is observed in the ES scenario, from 75 percent in the base year to 55 percent in 2047. This is followed by the Nexus scenario, where the percentage share of net energy imports in total net imports falls to 61 percent by the end of the modelling period. The steep declines in these two scenarios are due to low levels of net energy imports.

The smallest decline (72 percent) is observed in the BAU scenario, reflecting the highest net energy imports of all the scenarios by the end of modelling period. The lowest net energy imports are expected for the ES scenario followed by the Nexus scenario, reflecting the reduction in energy imports in that scenario due to the promotion of biofuels in the energy mix.

Access to Modern Energy Fuels for Cooking/Heating Purposes

Figure 6-6 shows the trends in household access to modern cooking fuels in percentage terms for India over the modelling period.

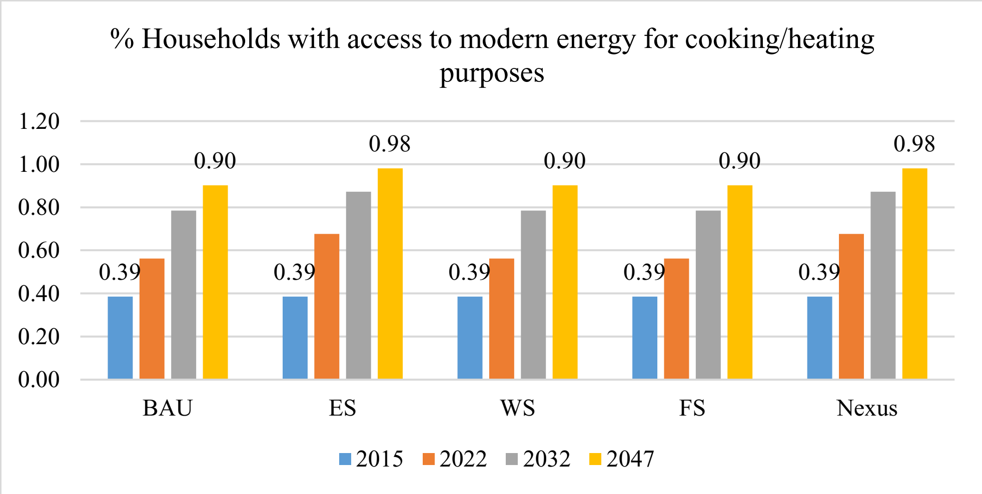


Figure 6-6: Model Estimates of Households with access to modern cooking/heating fuels (%) (2015-47) across scenarios

This attributue represents access to energy in the country and is unique for being both a scenario driver and an indicator of energy security. Access to electricity for lighting is not used as an attribute in this research as all scenarios assume early fulfilment of targets related to grid connectivity. However, an increase in penetration of different kinds of electric appliances and devices is a consideration for estimating energy demand in the scenarios. Greater access to modern and cleaner cooking fuels in rural and urban households is assumed in the ES and Nexus scenarios, which is evident and self-explanatory in the results for this attribute.

6.1.2. Water Security

Per Capita Freshwater Withdrawals

Figure 6-7 shows the trends in freshwater withdrawals per capita (m^3) for India across different scenarios over the modelling period.

Per capita freshwater withdrawals in the base year (2015) were around 680 cubic metres. These withdrawals in 2047, relative to the base year, increase in the BAU and ES scenarios and decrease in the WS, FS, and Nexus scenarios. The maximum reduction in freshwater withdrawals is observed in the Nexus scenario, followed by the WS and FS scenarios. The growth in population is faster than the growth in water withdrawals in the WS, FS, and Nexus scenarios.

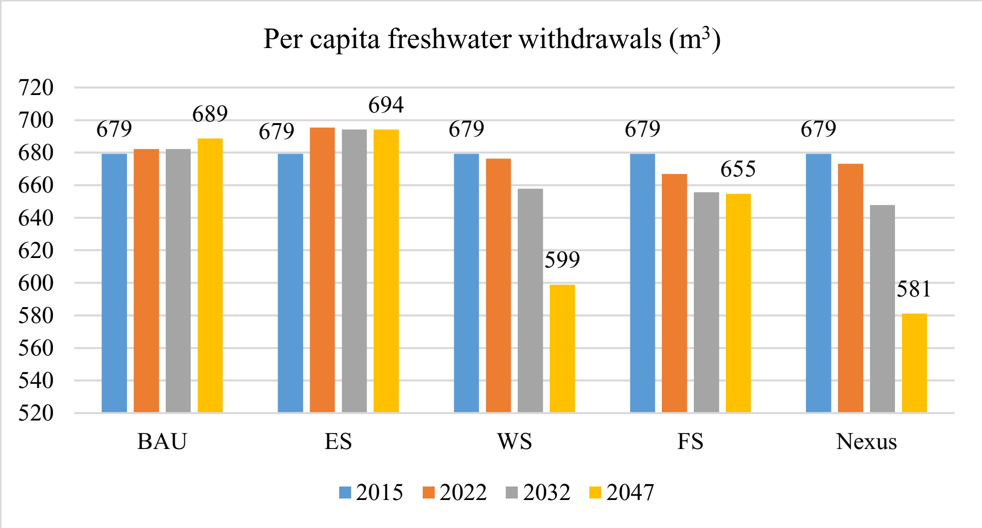


Figure 6-7: Model Estimates of Freshwater Withdrawals per Capita (m^3) (2015-47) across scenarios

Per capita freshwater withdrawals show the greatest reduction in the Nexus scenario in the long term (581 cubic metres), due to the simultaneous introduction of less water-intensive renewables, like distributed solar, transition towards less water-intensive diets, and improvements in water efficiencies across different sectors. Water consumption in the energy sector in the long term is lowest in the Nexus scenario – close to 33 BCM against the highest value of 50 BCM in the ES scenario.

The high reduction in per capita freshwater withdrawals (599 cubic metres) in the WS scenario is a result of improved water efficiencies across various sectors. The main reason behind the reduction in water withdrawals per capita in the FS scenario in the absence of any aggressive water efficiency measures is dietary shifts towards less water-intensive crops.

Both the BAU and ES scenarios show high per capita withdrawals of fresh water. This is due to several reasons: a) high fresh water withdrawals in the agriculture sector due to dietary patterns dominated by water-intensive cereals crops projected to continue for the future, b) lack of aggressive efforts to improve sectoral water efficiencies in both scenarios, and c) absence of determined efforts to introduce alternative sources of water.

The similarity in BAU and ES water withdrawals can be explained by the current transition of energy mix towards less water-intensive solar-based electricity generation. Water withdrawals in the ES scenario are minimally higher than the BAU scenario in spite of the aggressive promotion of biofuels due to the use of wastelands for biofuel generation. This small margin of difference could be attributed to energy security aspirations.

Although the ES scenario involves a transition towards efficient, clean and less water-intensive technologies like efficient coal-based technologies, biofuels, and renewables, it also introduces water-intensive technologies like CCS, nuclear, and large hydro, which raises fresh water withdrawals to levels higher than in the BAU scenario.

Water Productivity of Economy

Figure 6-8 shows the trends in economic water productivity, measured as a ratio of economic output (constant 2011 GDP) and total water use (cubic metres). This water use includes alternative sources of water in addition to freshwater resources.

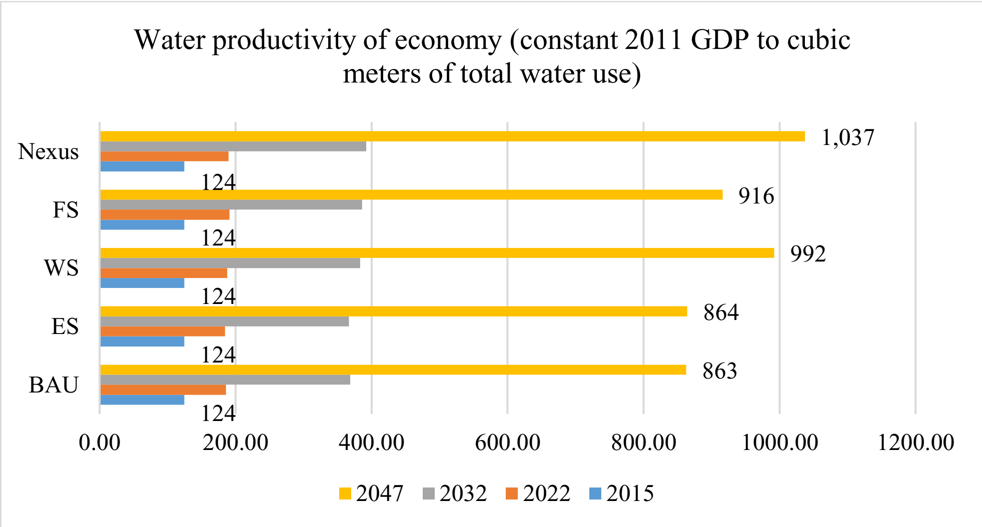


Figure 6-8: Model Estimates of Water productivity in constant 2011 GDP/m3 of total water use (2015-47) across scenarios

Figure 6-8 shows that water productivity increases in all scenarios; it is highest in the Nexus scenario, followed by the WS scenario, and lowest in the BAU scenario. Such trends are due to the lowest in water demand in the Nexus scenario by the end of the modelling period, whereas the highest water demand is experienced in the BAU scenario. Economic output (GDP) is higher in the Nexus scenario than in the BAU scenario. Therefore, water productivity is highest in the Nexus scenario, or, in other words, the highest economic output per unit of water use is produced in the Nexus scenario, and the least is in the BAU scenario.

Relative Water Stress

Figure 6-9 shows the trends in relative water stress, expressed in percentage terms, for India across different scenarios over the modelling period.

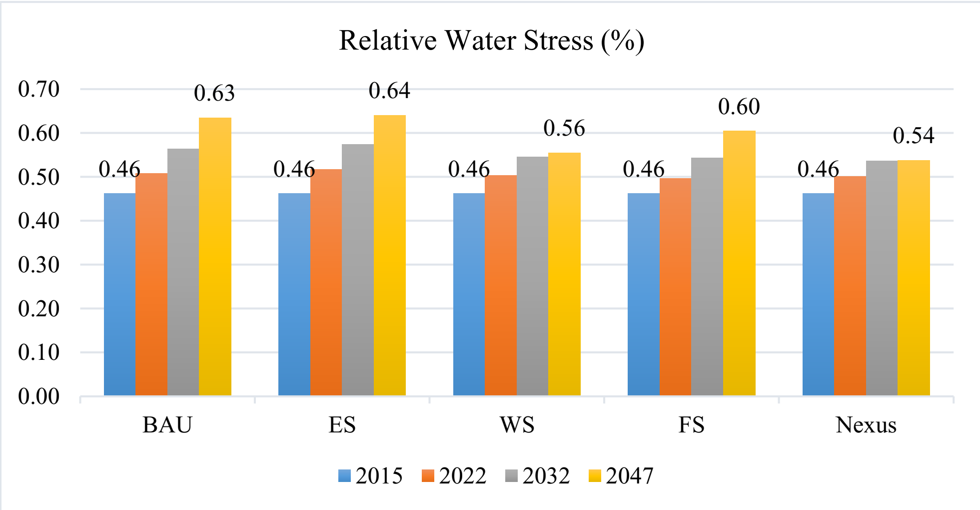


Figure 6-9: Model Estimates of Relative Water Stress in percentage terms (2015-47) across scenarios

Relative water stress is calculated in this research as the ratio of freshwater withdrawals to total renewable water resources. The figures show that relative water stress increases in all scenarios during the modelling period. The highest increase is observed in the ES scenario, closely followed by the BAU scenario. This is in line with the trends observed in total freshwater withdrawals, due to the common scenario assumptions about total renewable water resources (1911 BCM). Freshwater withdrawals and consequently relative water stress grow the least in the Nexus scenario, followed by the WS scenario.

6.1.3. Food Security

Food Accessibility Index

Figure 6-10 shows the trends in the food accessibility index in India across different scenarios over the modelling period. Food accessibility is expressed in this research as transport services available for each unit of food and agriculture sector output produced. Better transport services imply better physical access to food.

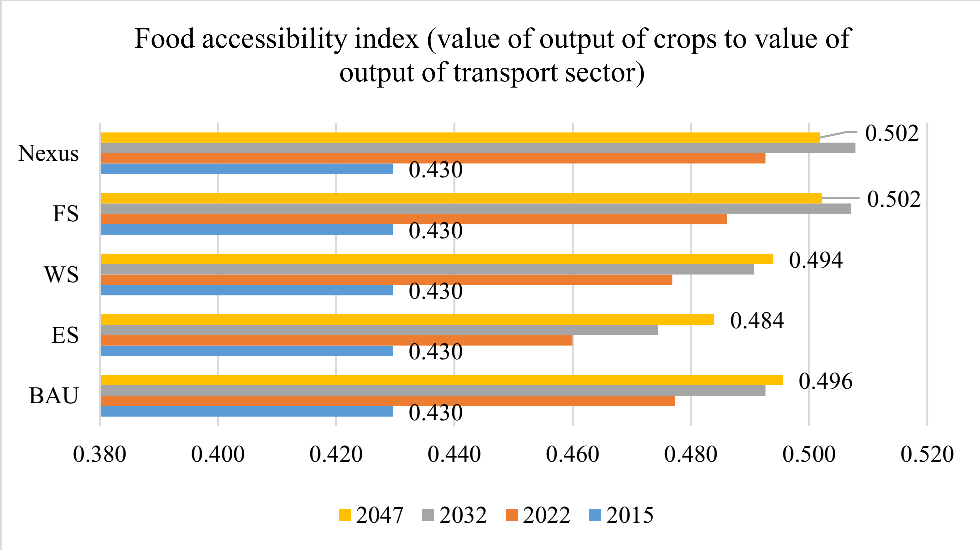


Figure 6-10: Model Estimates of Food Accessibility Index (2015-47) for India across scenarios

Despite the reduction in the food accessibility index from the medium to the long term in the FS and Nexus scenarios, they show the greatest long-term improvements in food accessibility, demonstrating the impact of improved transportation infrastructure in improving access to food. The least improvement in food accessibility is expected in the ES scenario, because it cannot keep pace with the very high (the highest of all the scenarios) food and agriculture sector output resulting from the additional output from biofuel crops.

Food Import Expenditure

Figure 6-11 shows patterns in food import expenditure, i.e. net food imports as a percentage of total net imports in India across the different scenarios over the modelling period.

The negative sign for net food imports indicates that India will continue to be a net exporter of food in the future in all the scenarios. The highest food exports as a percentage of total net imports can be seen in the ES scenario. These high food exports are possible in the ES scenario for two reasons: the first is because it focuses less on food security in India; the second is because it has the lowest value of total net imports of all the scenarios, precisely because of its greater self-sufficiency in energy supply. The Nexus scenario exhibits the lowest food exports, which is consistent with the scenario assumption of attaining self-sufficiency in energy, water, and food.

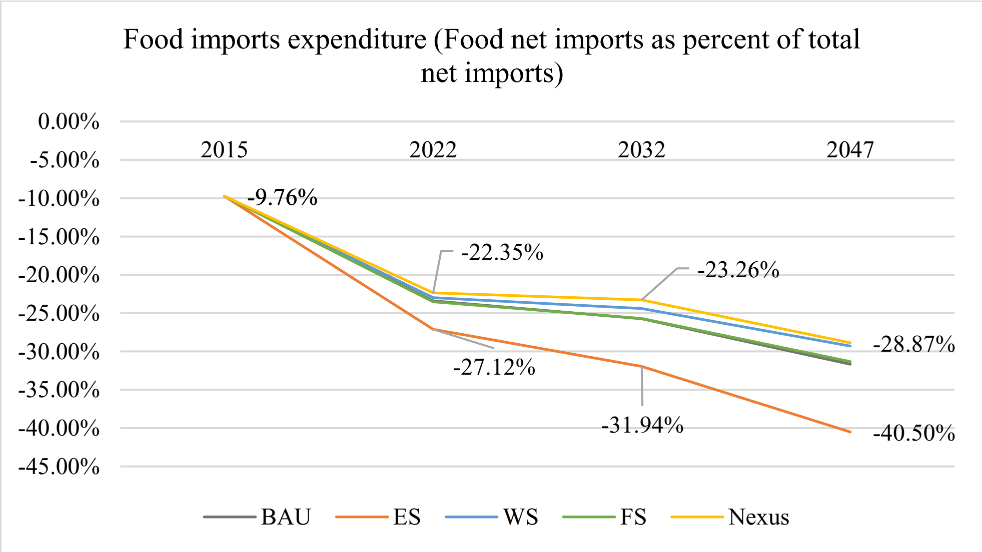


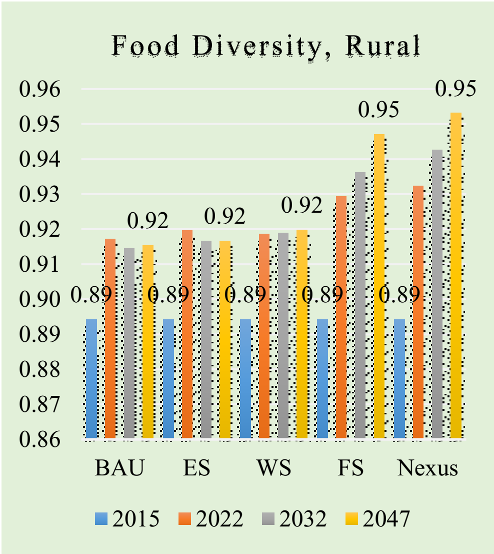
Figure 6-11: Model Estimates of Food Net Imports as % of Total Net Imports (2015-47) across Scenarios

Food Diversity: Rural and Urban

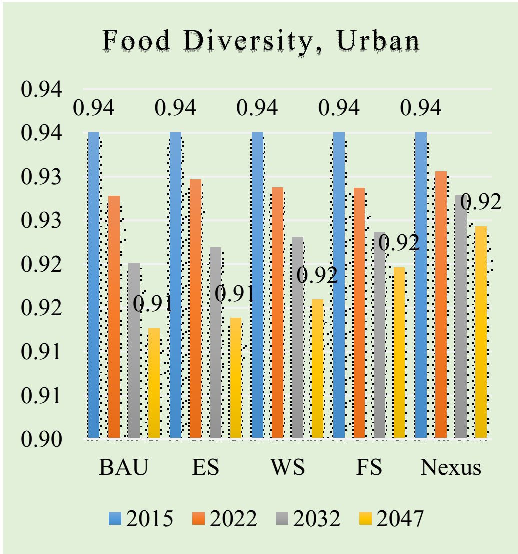
Figure 6-12 shows food diversity trends in rural and urban India across the different scenarios over the modelling period. Food diversity in this research is estimated using the Shannon Weiner Diversity index for calorie contribution from three different kinds of food sources. These are grain crops, non-grain crops (sugar, fruits and vegetables, oil-crops), and animal products. High food diversity indicates improved food security outcomes.

Food diversity is seen to be increasing for the rural population while decreasing for the urban population across all the scenarios. The highest rise in food diversity for the rural population is observed in the Nexus scenario, followed by the FS scenario. Results from the BAU, ES, and WS scenarios show that increases in rural food diversity by the end of the study period (2047) will still be lower than urban food diversity in the base year (2015).

For the urban population, the lowest decline in food diversity by the end of the modelling period is observed in the Nexus scenario, followed by the FS scenario. It can also be deduced from the results that none of the scenarios show urban food diversity to fall below the current levels of rural food diversity. The worst food diversity is observed in the BAU scenario, for both the urban and rural populations. These results accord with the assumption of a transition from a cereals-dominated to a diversified diet.



(a)



(b)

Figure 6-12: Model Estimates of Rural (a) and Urban (b) Food Diversity Index (2015-47) across Scenarios

By the end of the modelling period, rural food diversity in every scenario is slightly better than its urban counterparts. This shift could be explained by the increased focus of the urban population on non-grain crops and animal products, while the rural population gradually diversifies from a primarily grains-dominated diet to one composed of increasing quantities of non-grain crops and animal products. As a result, the composition of the rural diet retains grains even after the transition to animal products and non-grains, while the calorie contribution from grains in the urban population reduces to a greater extent, resulting in a reduction in food diversity.

6.1.4. EWF Security: Trends and Trade-offs

The previous section presented an assessment of the impacts of different scenarios in terms of EWF security-related attributes for India. This section synthesises these assessments and extends the analysis to provide a more comprehensive policy perspective. Specifically, it examines the trade-offs that may arise between policies that aim to achieve different and often conflicting objectives in the five scenarios developed in this research. The policy implications of these scenarios are also discussed thereafter.

The examination of policy trade-offs is undertaken in this section in terms of composite indices, reflecting the three dimensions of security, namely, energy, water, and food. Each composite index indicates the overall outcome of a particular security dimension. For example, the composite energy security index is calculated as the mean of energy security attributes, namely, energy intensity of the economy, per capita energy demand, energy diversity, energy-import dependency, energy-import expenditure, and energy access to modern fuels for cooking. These attributes are normalised and then scaled from 0-100, where 100 represents the most favourable outcome, and 0 the least favourable. Indicators where a higher value indicates a more favourable outcome are normalised as follows:

$$x = \frac{[x - Min(x)]}{[Max(x) - Min(x)]}$$

where Min(x) and Max(x) are the lowest and highest values for any given indicator. For attributes where high values indicate unfavourable outcomes (for example, energy/food import dependencies, water stress), the normalisation function takes the form:

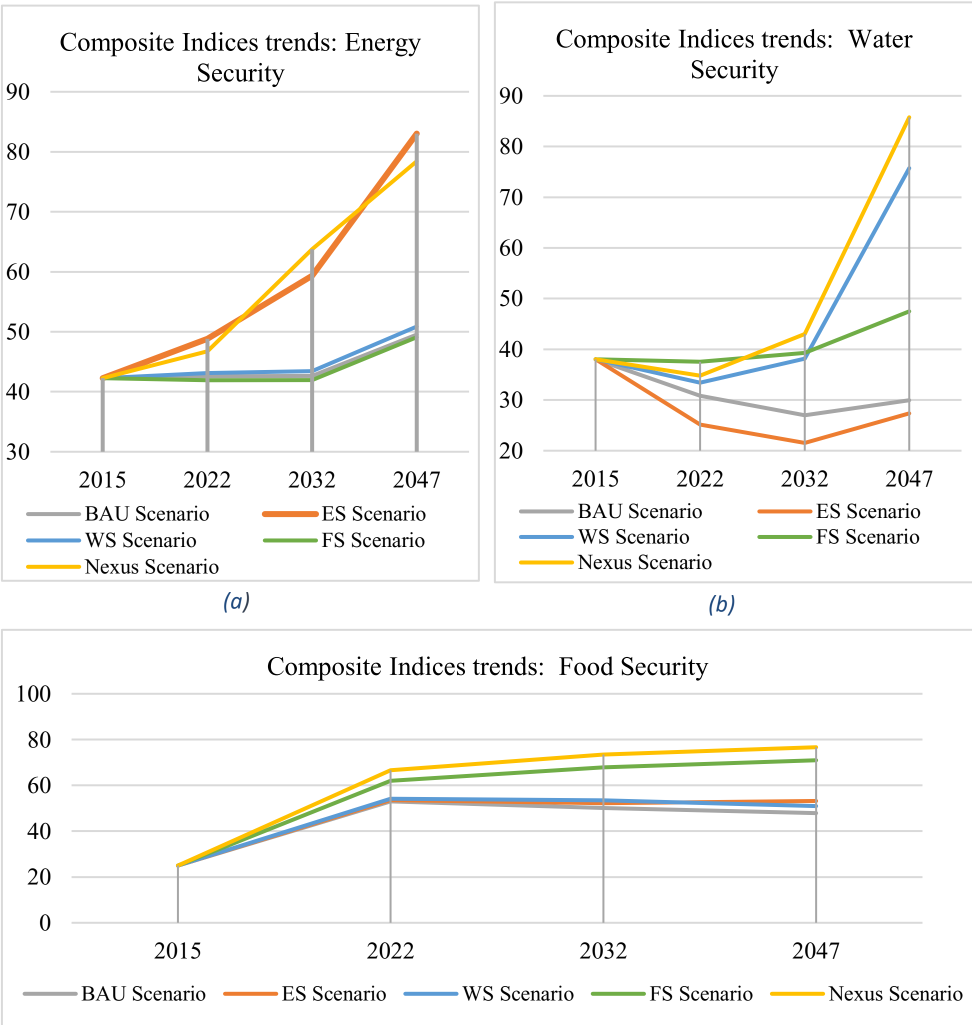
$$x = \frac{[x - Max(x)]}{[Max(x) - Min(x)]}$$

This formulation of indices enables analysis of trade-offs between outcomes of different kinds of securities like energy, water, and food.

In addition, as highlighted in Chapter 2, EWF securities vary across temporal scales and it is essential to consider how plans and policies are likely to impact the levels of EWF securities over time and ascertain any associated temporal trade-offs between these securities (Bizikova *et al*. 2013, Endo 2015).

Figure 6-13 (a-c) presents the trends in EWF composite security indices for the various scenarios for the base year (2015) and for the three scenario periods, i.e., 2022 (short term), 2032 (medium term), and 2047 (long term).

Some key findings from Figure 6-13 are:



(a) *(b)*

(c)

Figure 6-13: Composite Indices for (a) Energy Security, (b) Water Security, and (c) Food Security

Energy Security

a. Energy security improves from base-year levels long term in all scenarios, with particularly high improvement in ES and Nexus scenarios compared to the other scenarios by the end of the study period. The FS scenario shows the lowest level of energy security in the short term, and is slightly reduced from energy security levels in the base year (2015).

b. In the short term, the highest improvement in energy security over the base year happens in the ES scenario, and the lowest in the FS scenario, where energy security declines only marginally. In the medium term, energy security improves most in the Nexus scenario, which also shows the highest level of energy security in the medium term. The FS scenario produces the worst energy security scenario in the medium term.

c. In the long term, the ES and Nexus scenarios produce distinctly high energy security outcomes. Energy security is highest in the ES scenario, which shows the greatest improvement in energy security in the long term, followed by the Nexus scenario; the least is in the BAU scenario. Long term, the FS scenario shows the lowest level of energy security. The BAU and WS scenarios produce energy security outcomes close to those of the FS scenario.

Water Security

a. Water security improves over the base-year levels in all scenarios except BAU and ES by the end of the modelling period.
b. In the short term, water security declines in all scenarios from base-year level. The decline is least in the FS scenario, followed by the Nexus scenario, and the highest is in the ES scenario.
c. In the medium term, water security declines in the BAU and ES scenarios. The highest level of water security is attained in the Nexus scenario.
d. All scenarios show improvement in water security through the medium to long term, with the greatest improvement in the Nexus scenario. The Nexus scenario also shows the best final outcome for water security in the long term, while the ES scenario not only shows the lowest water security, it is worse than the base year.

Food Security

a. Food security improves in all scenarios, with high improvement in the FS and Nexus scenarios compared to the other scenarios by the end of study period.

b. In the short term, the highest improvement over the base year occurs in the Nexus scenario, followed by the FS scenario, while the BAU, ES, and WS scenarios show lower but similar levels of improvements in food security.
c. Food security decreases slightly from the medium to long term in the BAU, ES, and WS scenarios, while it increases in the Nexus and FS scenarios by almost similar levels, though slightly higher in the Nexus scenario.

d. Food security reduces slightly from the medium to long term in the BAU and WS scenarios. The highest (and almost equal) food security improvement during this period is observed in the Nexus and FS scenarios. Long term, the BAU and Nexus scenarios respectively produce the worst and best food security outcomes.

The reasons for these varying rates of EWF security outcomes across scenarios and across time reside in the complex interplay of underlying attributes. The patterns of EWF security attributes as shown in Figures 6-13(a-c) provide an overview of the influence of such interplay. Some key observations are as follows:

The FS scenario shows the lowest levels of energy security in all time frames. The ES scenario produces the best energy security outcomes in the short and long term, while the Nexus scenario shows the best energy security energy outcomes in the medium term.

- The underlying reasons for lowest level of energy security in the FS scenario are high per capita energy consumption without commensurate energy efficiency improvements, high value of net energy imports in total net imports and particularly high import dependencies, particularly for gas and coal. Further, the FS scenario shows the highest share of net energy imports in total net imports in the short term and the highest gas import dependency in the medium term.

- The ES scenario, on the other hand, produces the best outcomes for several energy security attributes in the long term, for example, least energy intensity per unit economic output, maximum electricity fuel diversity index, lowest share of net energy imports in total net imports, and highest access to modern cooking fuels. In the short term, the ES scenario leads to the lowest oil import dependency.

- Overall, the Nexus scenario shows the lowest gas import dependency in the long term and the least coal import dependency in the medium term. Per capita energy consumption increases throughout the modelling period in all scenarios, with a similar increment in the short term for all scenarios. A distinctly high increment in per capita energy consumption in the medium and long term is seen in the Nexus and ES scenarios respectively.

Water security declines in all scenarios in the short term; however, the reduction is least in the FS scenario.

- The short-term decline in water security in all scenarios is caused by increased water stress and per capita freshwater withdrawals, accompanied by a slow improvement in water productivity per unit economic output in this period. The least decline is seen in the FS scenario, which shows the least increase in relative water stress and the highest reduction in per capita freshwater withdrawals.

Water security is lowest in the ES scenario in all time periods and highest in the Nexus scenario in the medium- and long-term time frames.

- The primary underlying factors are high relative water stress and high freshwater withdrawals per capita. The ES scenario causes the highest relative water stress in the long term as compared to other scenarios throughout the modelling period. This scenario also has the highest freshwater withdrawals in all time periods.

- In contrast, the Nexus scenario shows the best outcomes for water productivity and per capita freshwater withdrawals across the modelling period. Relative water stress decreases continually in all scenarios throughout the study period; the lowest value is observed in the short term in FS scenario and in the medium and long term in the Nexus scenario.

Food security is lowest in the BAU scenario and highest in the Nexus scenario in all time frames.

- The underlying reasons responsible for low levels of food security in this scenario are a high share of net food imports in total net imports and low levels of urban as well as rural food diversity. Urban food diversity worsens from base-year levels in all the scenarios, with the least reduction observed in the Nexus scenario in each period.

- The Nexus scenario shows highest accessibility of food in the medium term and lowest rural food diversity in the long term across all scenarios over the study period, while the ES scenario shows the highest share of net food imports in total net imports in the long term. The share of net food imports in total net imports attribute is one of the primary reasons why the ES scenario shows greater improvement in food security than the BAU scenario, despite the trade-offs between energy and food security.

EWF Trade-offs

Short-term

Figure 6-14 demonstrates the short-term EWF securities trade-offs for different scenarios. Note that values closer to the origin represent worse security outcomes.

Energy security outcomes for all scenarios are least pronounced in the short term. The highest energy security is seen in the ES scenario, the least in the FS scenario. The best short-term water security outcomes are in the FS scenario, the worst in the ES scenario. Food security outcomes are more pronounced in the short term, with the highest improvement in food security in the Nexus scenario, and the least in the BAU scenario.

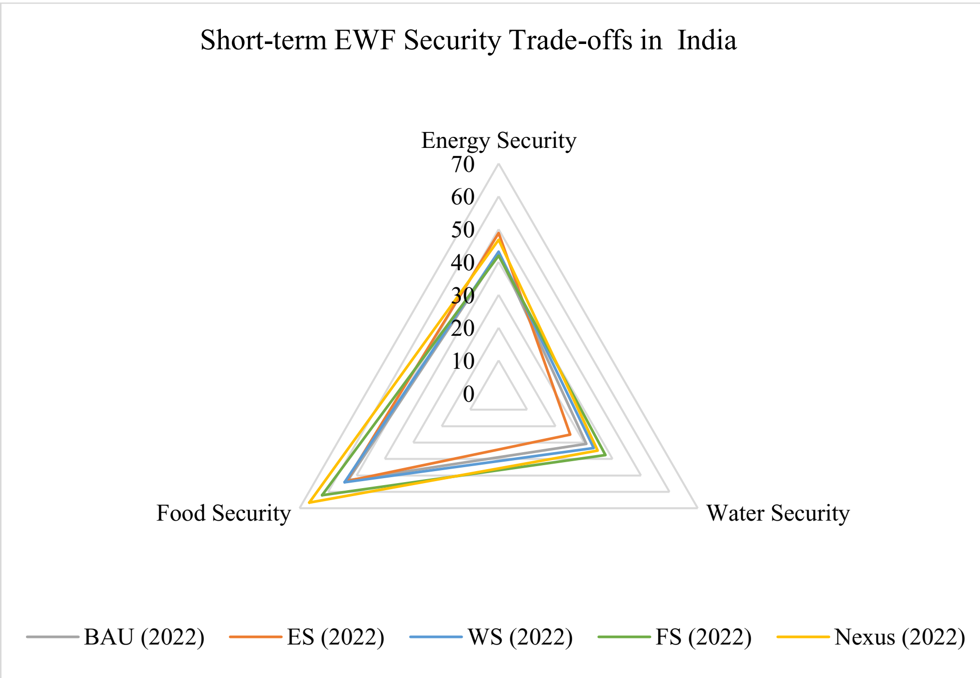


Figure 6-14: Model Estimates of Short-term Trade-offs between EWF Securities in India

Some of the trade-offs observed in the short term are: a) high energy security in the ES scenario at the expense of water security, which deteriorates from base-year levels, (b) one of the smallest improvements in the ES scenario, which suggests energy and food security trade-offs and c) high food security in the FS scenario, associated with a decline in energy and water securities from base-year levels.

Medium-Term

Figure 6-15 shows medium-term security impacts for the different scenarios. The medium-term trade-offs are more pronounced than the short-term trade-offs.

The Nexus scenario shows the most positive outcomes for EWF security in the medium term. The worst outcomes for energy security are seen in the FS scenario, while the worst outcomes for water and food security are seen in the ES and BAU scenarios respectively.

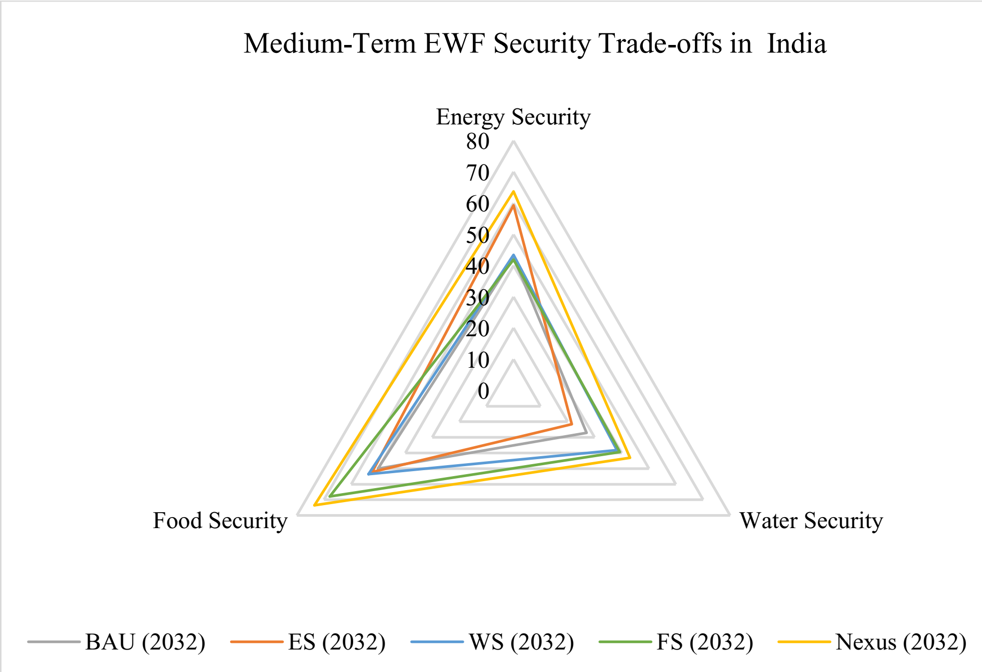


Figure 6-15: Model Estimates of Medium-term trade-offs between EWF Securities in India

The distinctive trade-offs in the medium term are: a) in the ES scenario, where energy security is achieved without commensurate improvement in food security, and deterioration in water security, and b) in the FS scenario, where improvement in food security is associated with deterioration in energy security and little improvement in water security.

Long Term

Figure 6-16 shows the long-term security impacts of different scenarios. As can be observed, EWF trade-offs are most prominent in the long term. Energy security shows the most improved outcomes in the ES scenario while the Nexus scenario shows the best outcomes for water and food security. Long-term energy security is rather high in the Nexus scenario.

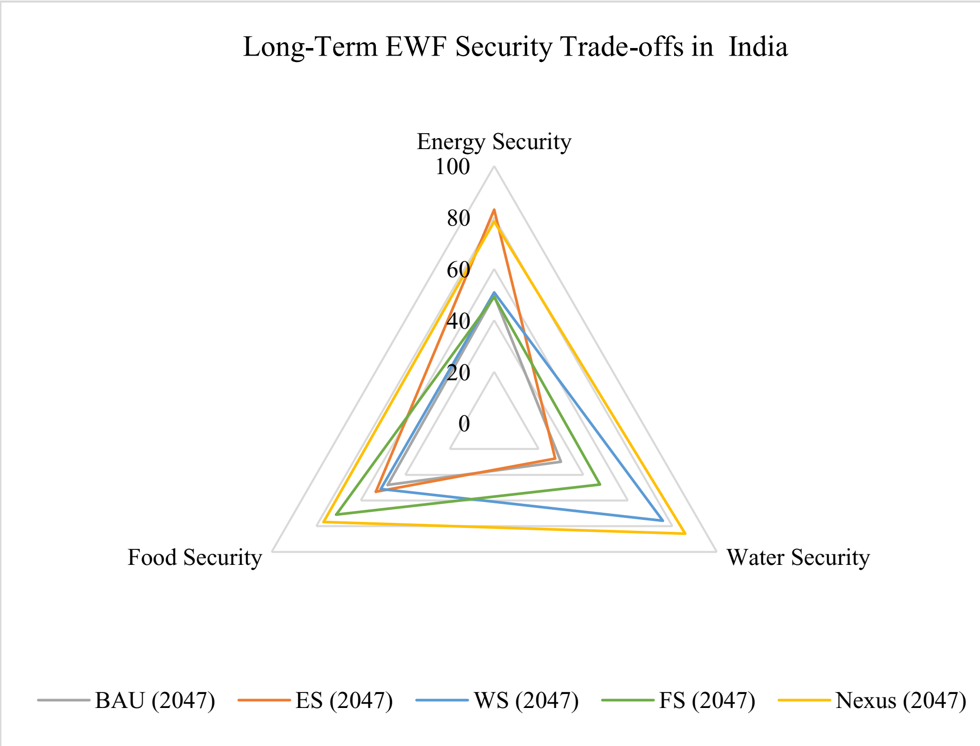


Figure 6-16: Model Estimates of Long-term Trade-offs between EWF Securities in India

The most significant trade-offs observed in Figure 6-16 are: a) although the ES scenario shows the most improved energy security outcomes, improvements in water and food security outcomes are among the lowest; b) while the FS scenario shows considerable improvement in food security, it seems to pose water and energy security risks, and c) the WS scenario shows significantly improved water security outcomes, however, there is little improvement in energy and food security outcomes. Food security deteriorates moderately during the medium to long term in this scenario.

6.1.5. Economic Outcomes

GDP Per Capita

Figure 6-17 presents estimates for GDP per capita for India (in billion INR, 2011 prices) in the short, medium, and long term, i.e., the end of 13th, 15th, and 18th five-year-plan periods, for all scenarios.

The base year (2015) estimate of GDP per capita for India was INR 84,511. In all scenarios, India's GDP in 2011 real terms is expected to grow almost ten-fold over the 32 years to the end of the 18th plan period (2047). The highest GDP is observed in the Nexus scenario, with a compounded annual growth rate of 7.38 percent during this period. This is followed in terms of GDP growth in order by the ES, FS, and WS scenarios. The BAU scenario has the least economic gains during this period, with a compounded annual growth rate of 7.33 percent. The same correspondence is observed in the growth of GDP per capita due to common population growth assumptions for all the scenarios. The lowest and highest growth in GDP per capita is observed in the BAU and Nexus scenarios, with a compounded annual growth rate of 6.37 percent and 6.32 respectively.

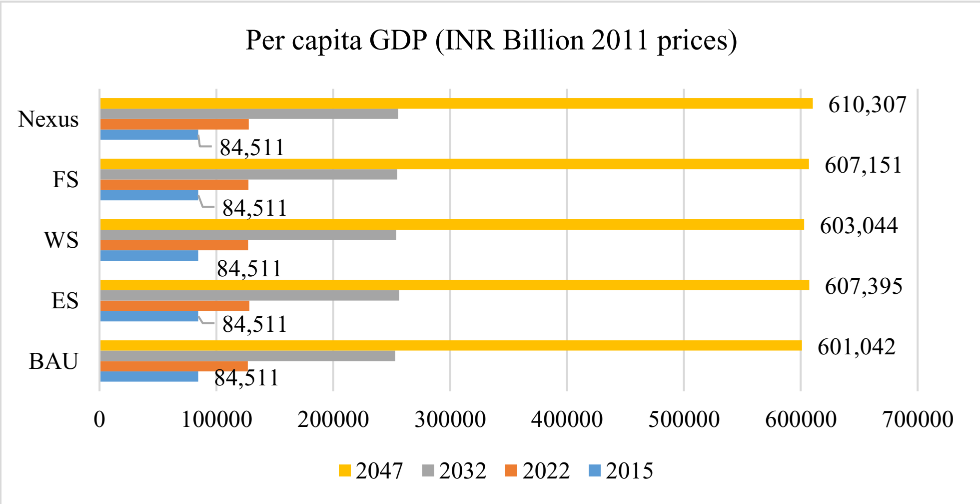


Figure 6-17: Modelling Estimates for GDP per capita for India, 2015-47

A further breakdown of the GDP is presented in Table 6-1 to facilitate a better understanding of the reasoning behind the growth patterns.

Table 6-1: Component-wise GDP India for 2015 and 2047

Billion INR, 2011 prices	2015	2047				
		BAU	ES	WS	FS	Nexus
Private consumption	63011	585669	585241	589040	593489	597485
Government expenditure	11270	154552	154544	154546	154558	154551
Investment	41352	336321	336443	336423	336256	336540
Exports	23777	275707	275270	275258	275732	274860
Imports	32817	327970	316392	327576	325346	323367
GDP	106594	1024279	1035106	1027690	1034690	1040069

Source: Author's estimates based on modelling undertaken in this research

The highest increment in private consumption by the end of the modelling period is seen in the Nexus scenario, thus contributing to a higher GDP. Investments also are highest in the Nexus scenario, while government expenditure is highest in the FS scenario. Exports and imports are highest in the FS and BAU scenarios respectively. While exports are lowest in the Nexus scenario, imports are the lowest in the ES scenario.

The specificities of each scenario are well represented in these results. For example, although biofuels are not promoted much in the Nexus scenario (to avoid any negative impact on food security), India's energy imports in the Nexus scenario still compare closely to the ES scenario. This is because the Nexus scenario aims to promote effective utilisation of India's domestic energy resources which is also why the exports are also the lowest in this scenario. Similarly, the ES scenario entails the lowest imports, which is in accord with the emphasis on reducing energy imports and focus on biofuels to attain self-sufficiency, given that energy imports occupy a significant share of total imports.

It can be noticed that that GDP estimates in this research do not exhibit considerable difference despite scenario assumptions like reduction in energy import dependence in ES and Nexus scenarios. While this assumption, for instance, in the ES scenario reduces the energy and net energy imports by 14 and 35 percent respectively relative to BAU scenario, this reduction with respect to the total imports makes it much less significant as the imports arise mainly from the non-energy industries (particularly manufacturing, non-ferrous metals, chemicals and petrochemicals) and services sectors. As a result, the total imports in the ES scenario turn out to be only 4 percent less than the BAU scenario. Initiatives, like Make-in-India, to boost the manufacturing sector in the country could affect these estimates, which however is not in the current scope of this research.

Trade Balance to GDP

Figure 6-18 shows the trade balance as a proportion of GDP for different scenarios across the study period.

Overall, imports exceed exports in all scenarios and in all time periods. The ES and WS scenarios show the best and worst economic outcomes respectively in the long-term trade balance. The ES scenario shows the highest (most positive) trade balance of all the scenarios, followed by Nexus scenario, while the WS scenario shows the lowest and most negative trade balance. However, trade deficit as a percentage of GDP follows a slightly different trend, i.e., it is lowest in the ES scenario and highest in the BAU scenario. This is due to the higher GDP attained in the WS scenario compared to the BAU scenario long term. International trade in goods and services (exports plus imports) was estimated in 2015 to be almost 57 trillion INR in 2011 value, with imports exceeding exports by approximately 9 trillion INR. This trade deficit is around 8 percent of the GDP.

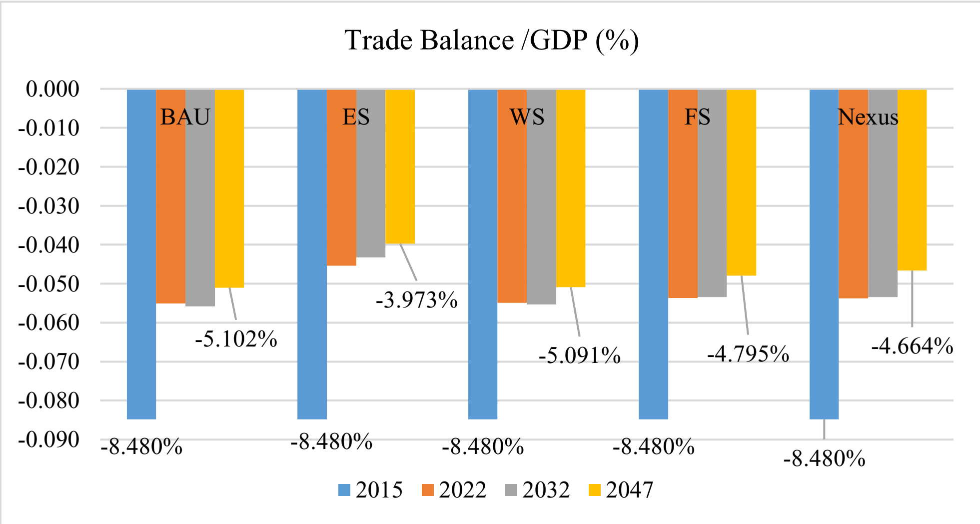


Figure 6-18: Modelling estimates for Trade Balance per unit of economic output for India (2015-47)

Total trade is expected to grow most (i.e. about 604 trillion INR) by 2047 in the BAU scenario, followed by the WS and FS scenarios. The lowest volume of trade is expected in the ES scenario (around 592 trillion INR in 2047), with total imports expected to grow faster than total exports. The trade deficit in this scenario is expected to be around INR 41 trillion, i.e., 3.97 percent of GDP in 2047. In the BAU scenario, total imports are expected to grow much faster than total exports. As a result, the country's trade deficit in this scenario is expected to reach around 52 Trillion INR, i.e., 5.1 percent of GDP, by mid-century.

Infrastructure Investments to GDP

Figure 6-19 shows the trends in infrastructure investment as a percentage of GDP for the various scenarios.

The ES scenario shows the highest infrastructure investments in proportion to GDP for the year 2047, followed by the Nexus scenario. The percentage increase in these scenarios over the base year is around 132 and 114 percent respectively. The WS scenario requires relatively fewer investments, hence the infrastructure investment to GDP ratio increased by 102 percent during this period. The BAU and FS scenarios require an almost similar level of growth in infrastructure investment as a proportion of GDP, i.e., around 108 percent.

Overall, the investment requirements trend as follows: the ES scenario has the highest investment requirements (124 trillion 2011 INR), followed by the Nexus and FS scenarios (about 114 and 111 trillion INR respectively). A possible explanation for these results is the high infrastructure cost of large-scale energy technologies, particularly electricity generation and higher levels of domestic energy production. Infrastructure requirements are least for the WS scenario, followed by the BAU scenario, around 17 and 14 trillion less respectively than the ES scenario.

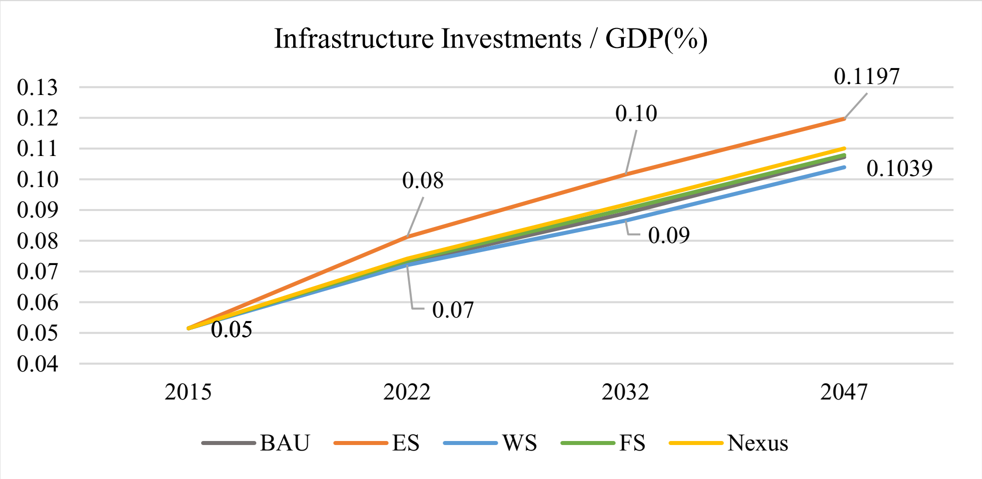


Figure 6-19: Modelling estimates for Infrastructure Investment/GDP for India (2015-47)

The Nexus scenario, in addition to a higher level of domestic energy production, requires high investment in new renewable energy capacity (grid-connected and distributed), in water and wastewater infrastructure, and in the transport sector for better food distribution.

The FS scenario requires additional investment in the transport sector to ensure better distribution of food commodities. It requires more such investment compared to the WS scenario as it demands more energy for higher levels of food production, and it shows low improvement in energy efficiency.

The ES scenario requires the highest investment in the energy sector compared to the other scenarios. This is followed by Nexus and BAU scenarios. The Nexus scenario also has higher investment requirements in the energy sector as a result of higher domestic energy production. The BAU scenario, in addition to continued investment in infrastructure-intensive centralised technologies, also requires more energy, and therefore, more investment due to relatively fewer improvements in energy efficiency.

The ES scenario requires significant investments (~23 trillion INR) in the electricity sector, followed by the BAU scenario. The WS scenario requires much less investment (~18 trillion INR) compared to these scenarios; this could be attributed to its small share of capital-intensive thermal and nuclear power plants and lower electricity requirement for water provisioning in different sectors, precisely because of its improved water efficiencies.

The WS and Nexus scenarios require significantly high investment in the water sector. In general, the size of water sector investment in relation to total investment is quite low in every scenario; energy sector investments usually dominate the total investment picture.

6.1.6. Social Outcomes

Employment as a Percentage of the Working Population

Figure 6-20 shows the observed trends in employment generated (as a percentage of the working population) in the different scenarios.

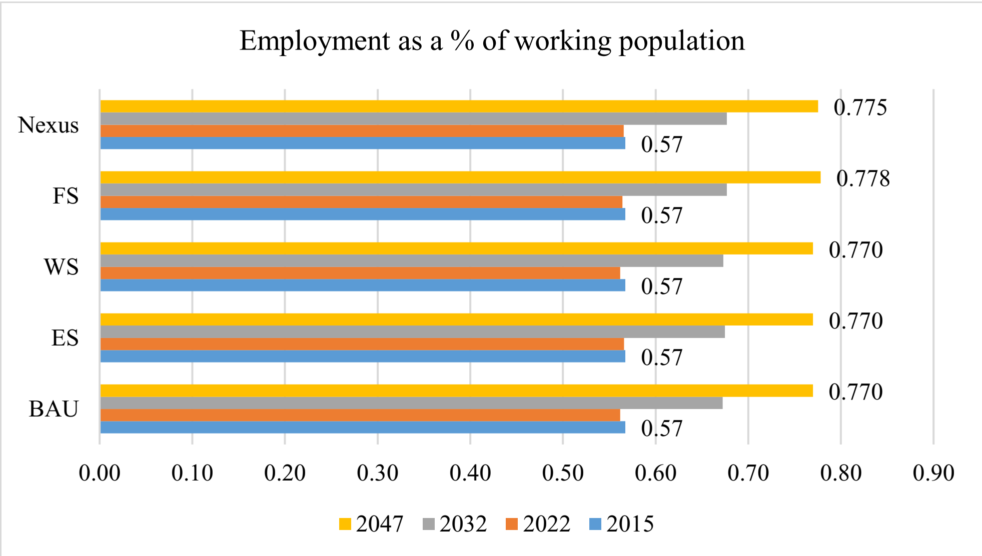


Figure 6-20: Modelling estimates for employment as a percent of working population for India (2015-47)

The figure shows that employment generation as a percentage of working population deteriorates slightly in the short term for all scenarios and increases thereafter. However, the lowest reductions are observed in the ES and Nexus scenarios. The reduction of this attribute in the short term is a result of relatively high population growth in comparison with the increase in employment opportunities.

The results further show that the highest increase in long-term employment will take place in the FS scenario (884 million), followed by the Nexus scenario (881 million) from the base-year level of 466 million. Since the projections of the working population are common across scenarios, employment generation follows the same trend.

In the long term, the highest increase in agriculture and food sector jobs takes place in the FS scenario, closely followed by the Nexus scenario. The FS and Nexus scenarios lead to distinctly higher job creation as a result of the high focus on food security improvement along with the dietary transition from cereals towards more labour-intensive crops like fruits and vegetables (Raju *et al*. 2015).

Transport sector jobs are also highest in the FS scenario, closely followed by the Nexus scenario, this being a result of higher levels of food distribution owing to improved and enlarged transportation networks. Higher distribution levels of food-related commodities is an indication of the improved food access achieved by increasing transportation investment in these scenarios.

Industrial and commercial job creation is highest in the BAU scenario, while energy sector jobs are highest in the ES scenario, followed by the Nexus scenario. The greatest number of job opportunities in the water sector is in the WS scenario.

A comparison of employment in different sectors across the various scenarios suggests that although employment opportunities do not differ much from one scenario to another, there are considerable contrasts from one sector to another; for example, in the long term (2047), the FS scenario is expected to generate an 15 million more jobs in the agriculture sector than the BAU scenario. Likewise, the ES scenario will generate around 270 thousand more jobs in the energy sector than the BAU scenario would generate. Around 43 thousand additional jobs will be created in the water sector in the WS scenario compared to the BAU scenario.

The Nexus scenario shows a considerable rise in EWF sector jobs compared to the BAU scenario and is also second highest in terms of the number of jobs created in all the scenarios in the long term.

Skilled-to-Unskilled Employment Ratio

Figure 6-21 shows the trends in skilled-to-unskilled employment ratios across different scenarios.

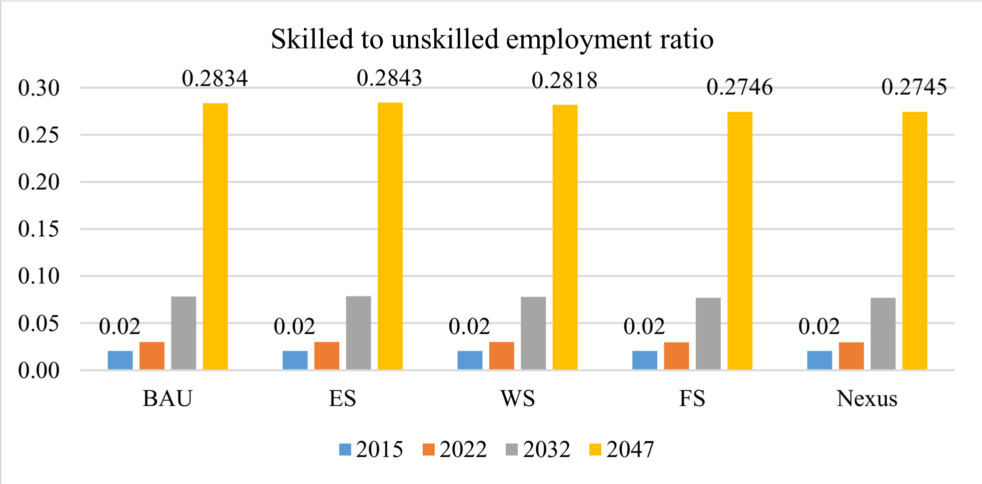


Figure 6-21: Modelling estimates for Skilled-to-Unskilled ratio for India (2015-47)

The highest skilled-to-unskilled employment ratio is observed in the ES scenario, followed by the BAU scenario. The ES scenario envisages development in skill-intensive technologies like nuclear, large hydro, high-efficiency coal-based technologies, solar, and so on. The BAU scenario lags not far behind because of it strong focus on renewables, particularly solar technologies, in the current policy set up, which is likely to create higher demand for skilled labour.

The FS scenario shows the least demand for skilled jobs, relative to unskilled jobs, by the end of the modelling period. Although the scenarios do not vary drastically regarding generation of skilled jobs, the ES scenario is expected to generate the highest number of skilled jobs, around 194 million in 2047 alone, i.e., 184 million more jobs than in the base year. The Nexus scenario generates around 4 million fewer skilled jobs (i.e., about 2 percent) than the ES scenario, primarily due to food security aspirations and the type of technologies implemented in this scenario.

Overall, the FS scenario is expected to generate the most unskilled job opportunities, around 455 million, by the end of the modelling period, from 248 million in the base year. Both the BAU and ES scenarios lag by roughly 16 million unskilled jobs compared to the FS scenario. The FS and ES scenarios are likely to generate the highest and lowest number of unskilled jobs respectively by the end of the study period.

The results are congruent with the tendency of the skilled-to-unskilled labour ratio to fall as output shifts from manufacturing towards primary production, particularly in developing economies (Wood and Ridao-Cano 1999).

Acceptability

Figure 6-22 shows the status of social acceptance for the various scenarios.
Social acceptability is expressed in this research as the share of nuclear and large hydro in the energy mix.

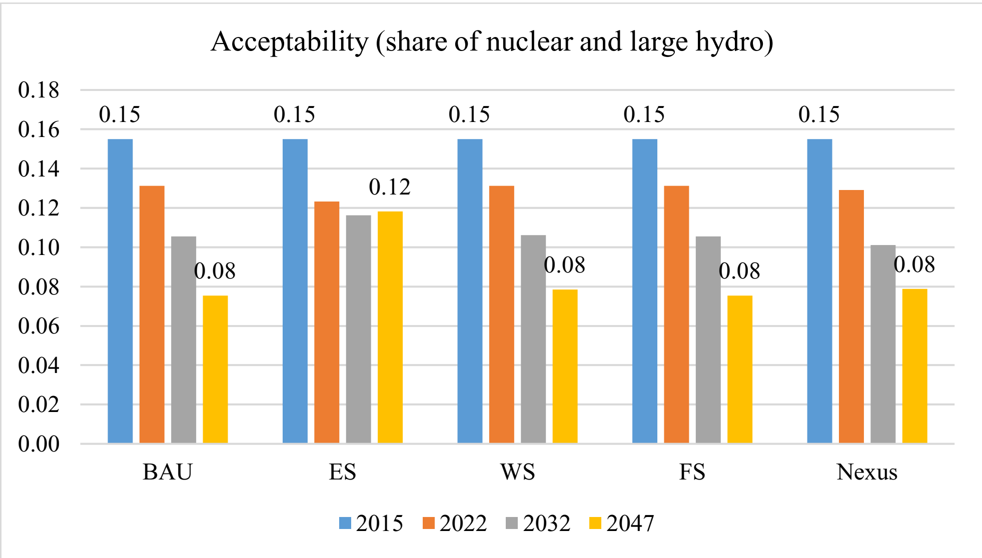


Figure 6-22: Modelling Estimates for Acceptability for India (2015-47)

The ES scenario shows the least improvement in acceptability outcomes among all the scenarios. The other scenarios are fairly similar in their levels of improved social acceptance. This is consonant with their respective scenario assumptions, whereas the ES scenario attains energy security through conventional large-scale technologies that include nuclear and large hydro.

Health

Figure 6-23 shows the health outcomes for various scenarios, health outcomes in this research being a combination of air, drinking water and sanitation, and nutrition-related impacts. The share of polluting fuels in the energy mix is a proxy for energy-related health impacts. Similarly, piped water coverage and proper sanitation facilities are the proxies for water-related health impacts. Dietary diversity is a proxy for food-related health outcomes. The modelling results show that the best health outcomes are experienced in the Nexus scenario, followed by the WS scenario. The BAU scenario shows the worst health outcomes.

Regarding food-related health impact measured in terms of nutritional status, the Nexus scenario shows the best outcomes, followed by the FS scenario. Regarding drinking water and sanitation, the Nexus and WS scenarios produce the best water-related health outcomes. Regarding energy-related health outcomes (measured as the share of non-polluting fuels in the energy mix, including nuclear), the ES scenario produces the best outcomes, followed by the Nexus scenario. The high share of biofuels and nuclear energy in the energy mix, along with the high penetration of renewables in the energy mix, makes the ES scenario produce the best health outcomes in terms of energy-related health impacts.

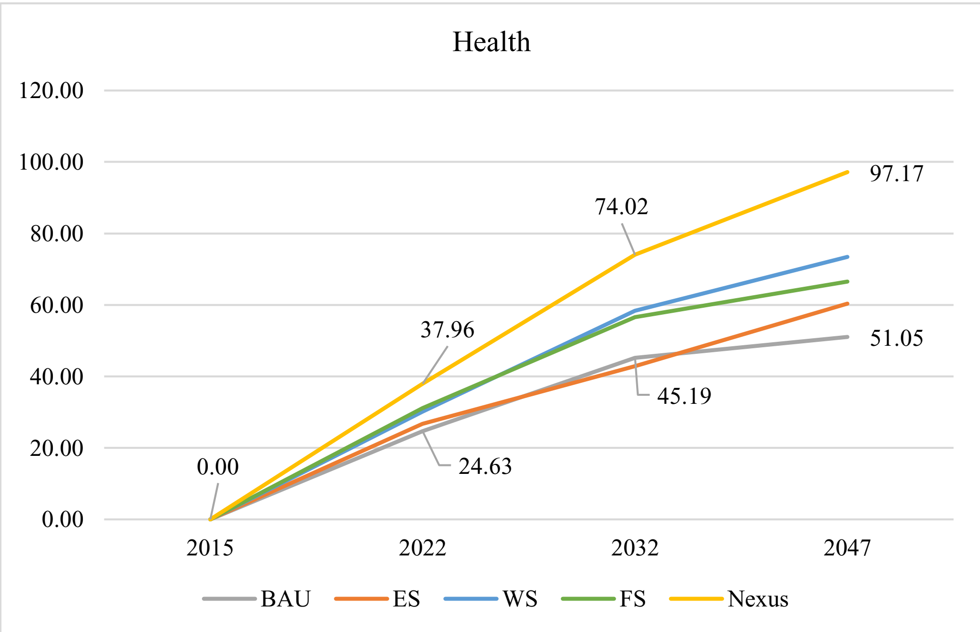
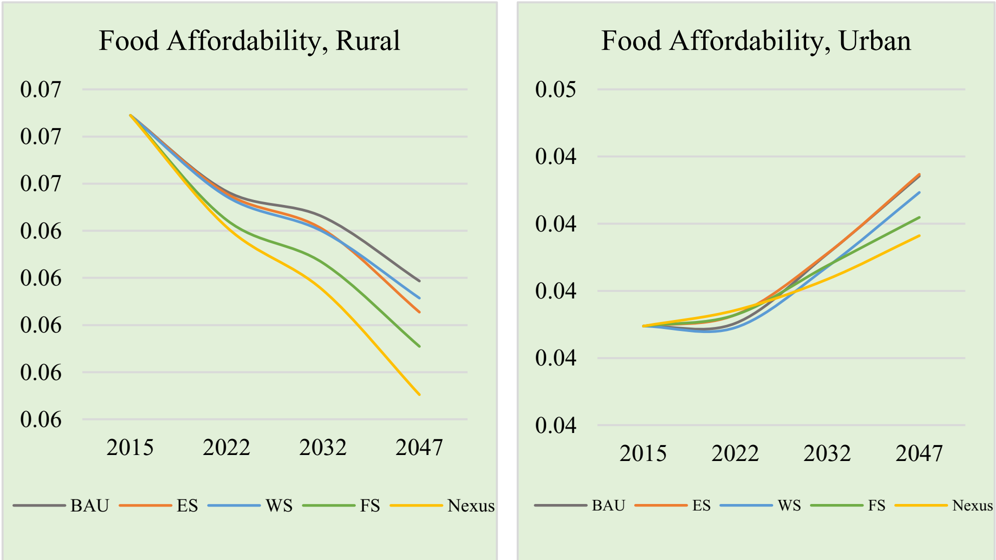


Figure 6-23: Modelling estimates for Health Outcomes for India (2015-47)

Food Affordability: Rural and Urban

Figures 6-24 (a) and 6-24 (b) present food (staple foods, namely rice, wheat, pulses, and roots and tubers) affordability patterns in rural and urban India, across different scenarios, over the modelling period.



(a) (b)

Figure 6-24: Modelling estimates for Rural (a) and Urban (b) Food Affordability for India (2015-47)

The trends in household affordability (as a proxy of share in income expenditure) show that rural expenditure on staple food is declining. The highest reduction in rural food (staples) expenditure occurs in the Nexus scenario, followed by the FS scenario. Rural food expenditure decreases in the Nexus and FS scenarios by 17 and 14 percent respectively from the base year to the end of study period. The lowest percentage reduction in food expenditure happens in the BAU scenario (10 percent), which is close to the ES and WS scenarios (12 and 11 percent respectively).

In the base year, expenditure on staple food in rural areas is higher in comparison to its urban counterparts. This is in contrast to food diversity, which is higher for the urban population. With economic development and rises in rural incomes, along with increased awareness of the nutritional aspects of food, rural food expenditure increases, showing in particular a drastic shift from staples to high-value food commodities like fruits and vegetables and milk and milk products, by the end of study period. As a result, rural expenditure on staples reduces over time.

The results also indicate the opposite trend for the urban population, i.e., an increase in expenditure on staple food. The increase in staple food expenditure in urban areas indicates a rise in consumption of food grains in an already more diversified diet compared to rural areas, particularly pulses, a major protein source for a large vegetarian Indian population. The Nexus scenario shows the least increment (7 percent) in staple food expenditure as it assumes increased dietary contribution from other foods, like fruits and vegetables, from the base year to the end of the modelling period. It is closely followed by the FS scenario (9 percent). The BAU scenario shows the highest increase in staple food expenditure, approximately 13 percent.

Energy Affordability: Rural and Urban

Figures 6-25(a) and 6-25(b) show energy affordability patterns in rural and urban India across different scenarios over the modelling period

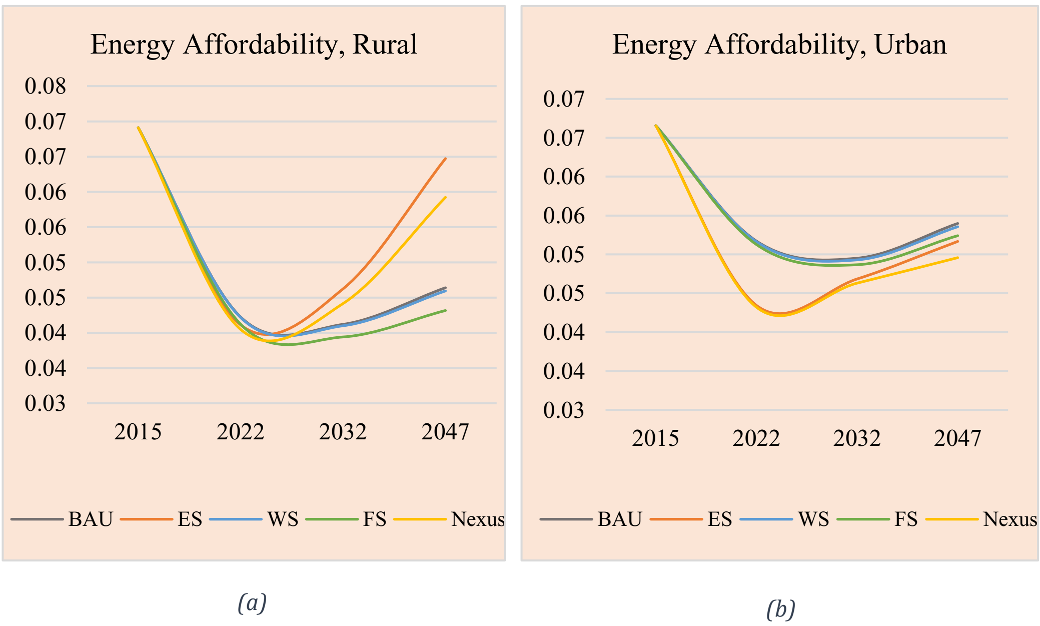


Figure 6-25: Modelling estimates for Rural (a) and Urban (b) Energy Affordability for India (2015-47)

The energy expenditure (or affordability) in rural India shows the highest decline in the FS scenario, from around 7 percent in 2015 to 4.32 percent in 2047. The lowest decline takes place in the ES scenario, to 6.47 %, by the end of the modelling period. The energy expenditures in all scenarios decrease first and then increase, with the highest and lowest increases taking place respectively in the ES and FS scenarios.

For the rural population, energy demand rises faster in the ES and Nexus scenarios because of rural programs that increase access to electricity (like the Rajiv Gandhi Grameen Vidyutikaran

Yojana), to LPG (Rajiv Gandhi Gramin LPG Vitaran Yojana for LPG), and to improved cook stoves.

Rural household demand for electricity and piped natural gas increases by 2047, however, in the short term, the increase in income is higher than the increase in energy demand. Therefore, energy affordability improves in the short term. In the medium and long term, increases in rural income slow down but energy demand continues to increase as energy access improves, hence the rise in energy expenditure as a percentage of total expenditure, or in other words, a decline in affordability

Also in the ES and Nexus scenarios, there is a high rate of transition from low-priced biomass to high-priced energy cooking fuels, resulting in increases in rural energy expenditure. However, the penetration of Best Available Technologies (BAT) and high-efficiency appliances is limited due to high upfront costs and limited institutional support in rural areas (GoI 2014b).

For the urban population, in the short term, increased incomes result in increased energy demand. In the long term, however, energy demand stagnates, and even falls in some scenarios like ES and Nexus, due to the penetration of energy-efficient technologies. The ES scenario has higher biofuel generation whereas the Nexus scenario envisages more distributed energy generation and therefore reduced energy transmission and distribution losses, both leading to reduced energy cost.

The analysis further shows that energy is likely to be more affordable in the future, particularly for the urban population. Energy expenditure as a proportion of total urban expenditure shows the highest decline in the Nexus scenario, down from 6.6 percent in the base year to 4.96 percent in 2047 (a 26 percent decline), and the least decline in the BAU scenario, to 5.4 percent (19 percent lower than the base year). The ES scenario also shows a considerable decline in energy expenditure in urban India (22 percent from the base year).

6.1.7. Environment

Per Capita Carbon Emissions

Figure 6-26 shows the trends in per capita carbon emissions across different scenarios for the modelling period 2015-2047.

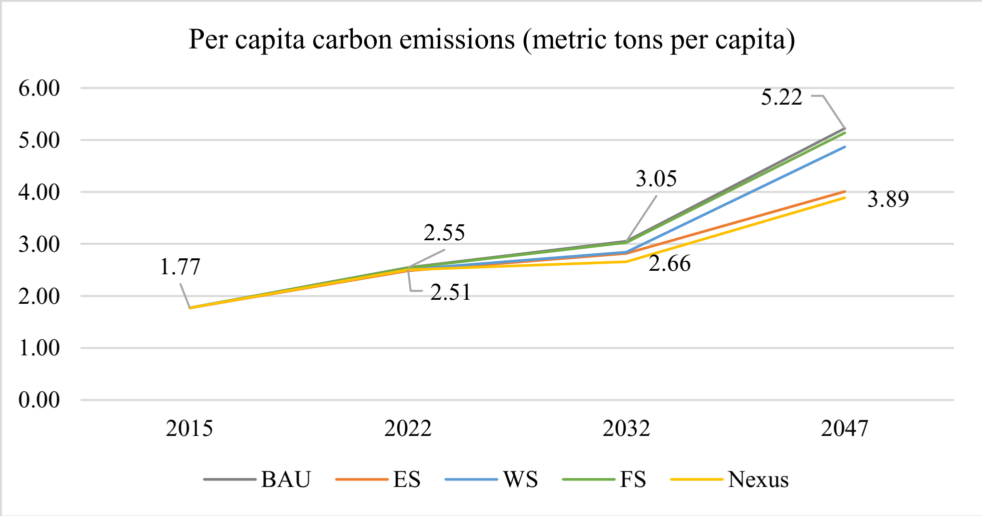


Figure 6-26: Modelling estimates of Per capita Carbon Emissions for India (2015-47)

The figure shows that, in the long term, the lowest per capita carbon emissions result in the Nexus scenario while the highest lie in the BAU scenario. Per capita carbon emissions increase by 2.19 times in the Nexus scenario from the base year to the end of the study period. Emissions in the ES scenario increase by 2.26 times. The highest growth is observed in the BAU scenario (2.94 times). Note that these emissions include only emissions from energy combustion. Since the population estimates are the same across the scenarios, carbon emissions are also expected to show the same order as absolute emissions.

Carbon Emissions per Unit of Economic Output

Figure 6-27 shows the trend in carbon emissions (in kg) per unit of economic output (GDP in INR 2011 prices) across the different scenarios for the modelling period 2015-2047.

The carbon intensity of economic output is seen to decline in all the scenarios over the modelling period with the rapid economic growth. The results show that in the long term, the lowest emissions per unit of economic output are observed in the Nexus scenario, followed by the ES scenario. The highest carbon emissions per unit economic output in the long term are observed in the BAU scenario.

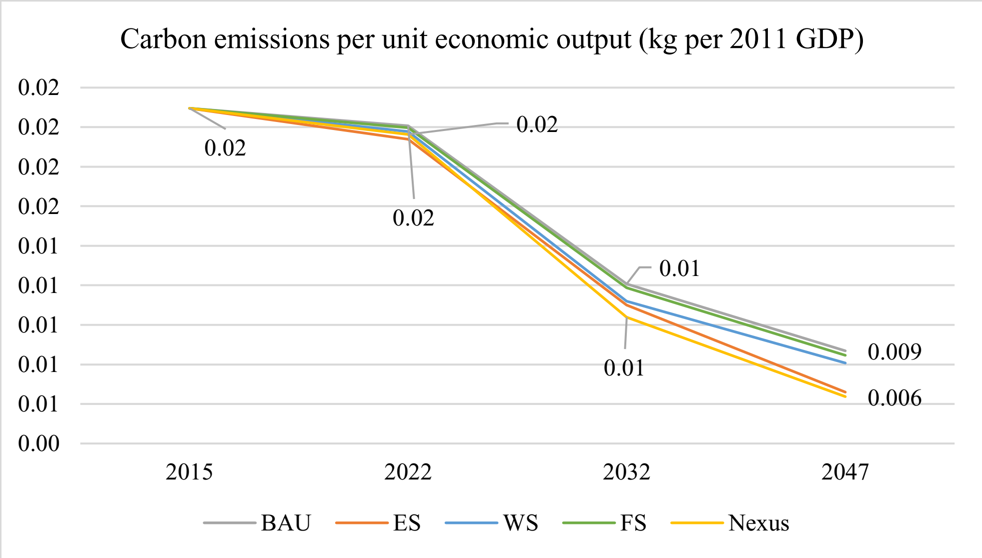


Figure 6-27: Modelling estimates of Carbon Emissions per unit economic output for India (2015-47)

GDP grows most in the Nexus scenario over the modelling period, followed by ES and FS scenarios, but growth in emissions is highest in the BAU scenario. As a result, carbon emissions per unit of economic output are highest in the BAU scenario by the end of modelling period, almost 36 percent more than the minimum value in the Nexus scenario. In the BAU scenario, high carbon emissions can be attributed to less focus on efficiency improvements in the EWF sectors, and low promotion of cleaner fuels in the energy mix.

Per Capita Land Requirement

Figure 6-28 shows the trends in per capita land requirement, expressed in terms of hectares (ha) per person.

It is observed that per capita land requirement increases over the modelling period, with the ES scenario experiencing the highest land requirements per capita, from 0.121 ha per person in the base year to 0.143 ha per person in 2047. This is followed by the Nexus scenario requirement of 0.140 ha per person.

A closer examination of the long-term land requirements for the EWF sectors in the various scenarios suggests the highest land requirement from the food and agriculture sector manifests in the ES scenario. This is primarily due to high biofuel production and increased penetration of large-scale electricity generating technologies and low improvement in crop yields.

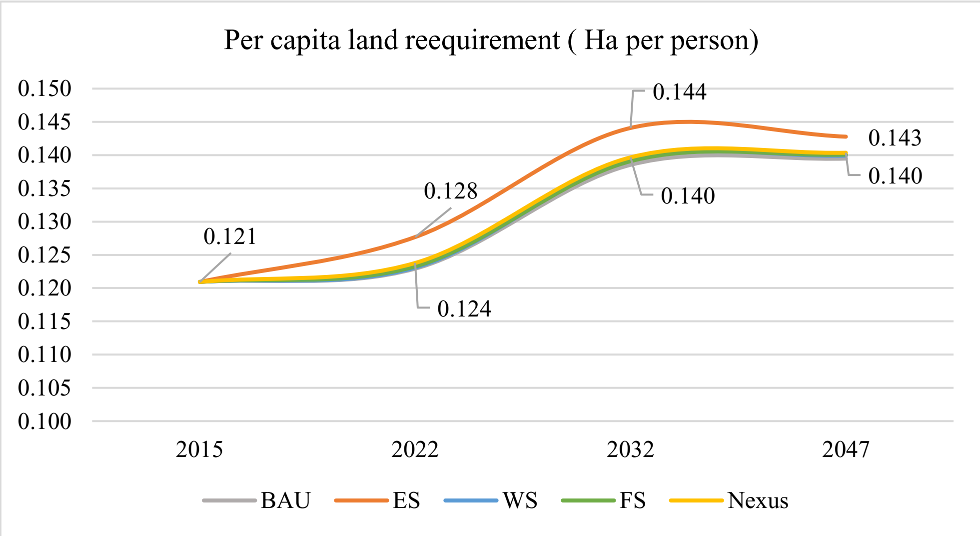


Figure 6-28: Modelling Estimates of Land requirement per capita for India (2015-47)

The Nexus scenario, closely followed by the ES scenario, demonstrates high land requirements from the energy sector due to higher penetration of land-intensive renewables. The water sector creates similarly high land requirements in this scenario because of the higher penetration of land-intensive decentralised wastewater technologies.

Fertiliser Application Diversity Index

Figure 6-29 shows the diversity trends in fertiliser nutrient application through the Shannon–Wiener Index (SWI) across the different scenarios for the modelling period 2015-2047

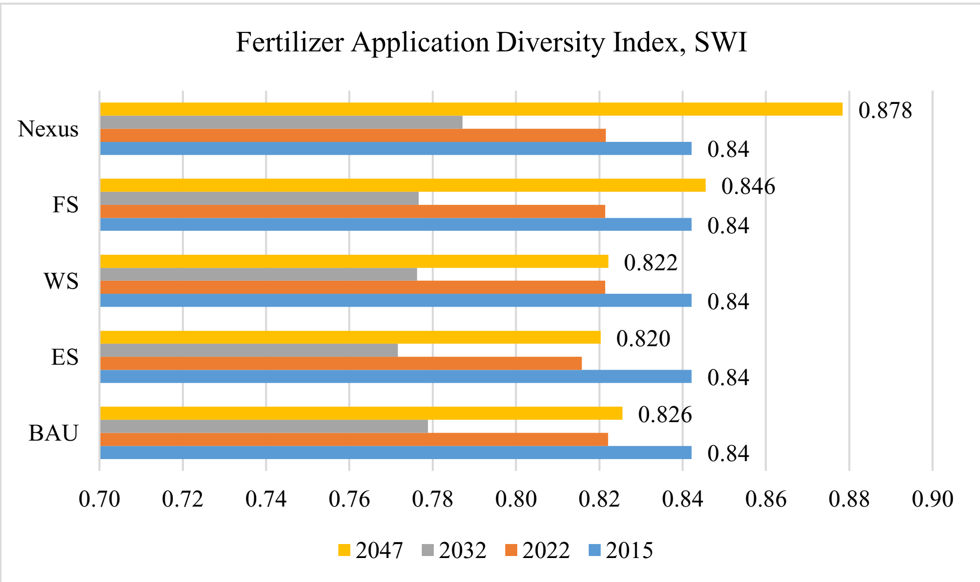


Figure 6-29: Modelling Estimates of Diversity Index for NPK Fertiliser Application for India (2015-47)

In line with the assumption of better-managed application of fertilisers, the Nexus and FS scenarios show improved SWI indices; the other scenarios show worsened SWI indices. The improvement in the SWI index in the Nexus scenario is higher (0.878) than the FS (0.846) scenario; the SWI for 2015 is 0.84.

Chemical Fertiliser Use per Unit of Crop Output

Figure 6-30 shows trends in the use of chemical fertilisers (in tonnes) per 2011 INR billion of crop output, across different scenarios.

The figure shows that fertiliser use per unit of crop output decreases over the modelling period, mainly due to improvements in fertiliser use efficiency and high increase in crop output. Fertiliser use per unit of crop output decreases the most (almost 55 percent) over the base year in the Nexus scenario, and by almost 54 percent in the FS scenario. The decline in fertiliser consumption can be attributed to the changes in dietary habits in the FS and Nexus scenarios, from high to low fertiliser using crops.

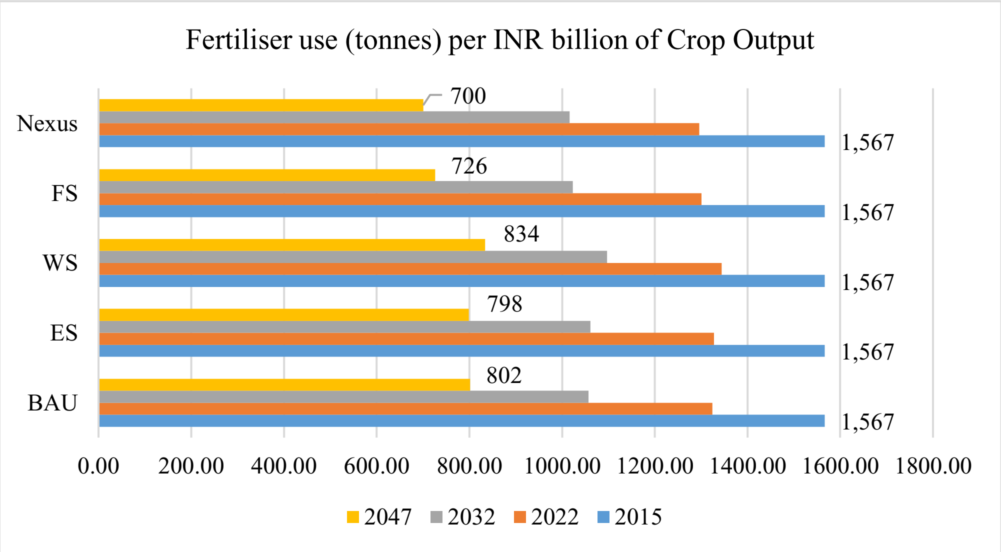


Figure 6-30: Modelling estimates of Fertiliser use in Tonnes per Billion Rupees of Crop Output for India (2015-47)

Per Capita Fugitive Emissions

Figure 6-31 shows trends in per capita fugitive emissions across the different scenarios.

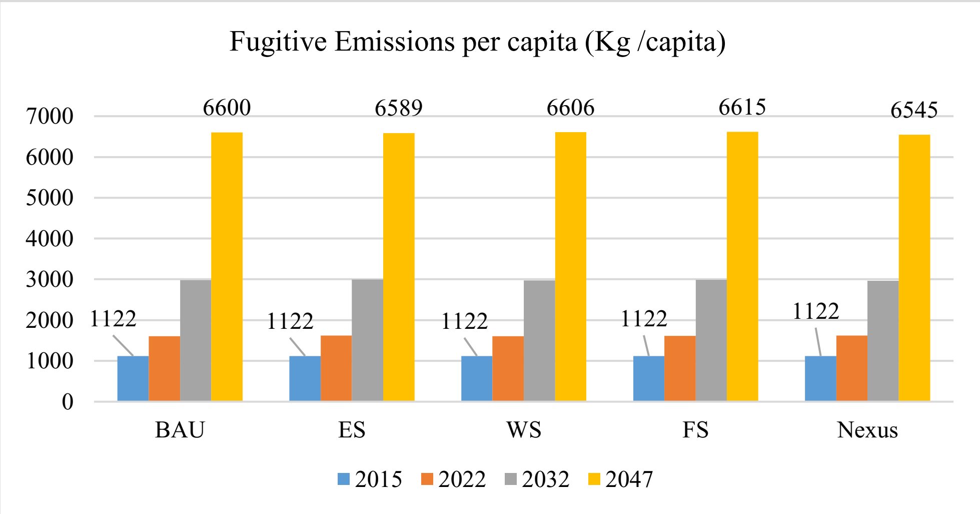


Figure 6-31: Modelling estimates of per capita fugitive Emissions for India (2015-47)

A closer examination of fugitive emissions from the energy, water, and food sectors in the long term suggests highest fugitive emissions from the food and agriculture sectors in the FS scenario due to higher level of agriculture production, higher use of chemical fertilizers, and higher consumption of milk and poultry products. Likewise, fugitive emissions from the energy sector are the highest in the BAU scenario due to relatively lower efficiency improvements and higher share of fossil fuels in the energy mix. Fugitive emissions from the water sector are the highest in WS scenario owing to higher level of wastewater treatment in this scenario.
The per capita fugitive emissions increase from 1122 kg in the base year is highest in the FS scenario (6615 kg) and least in the Nexus scenario (6545 kg). Since the population growth assumptions are common to all scenarios, this attribute follows the same patterns as total fugitive emissions from energy, water, and food.

Fugitive Emissions per Unit of Economic Output

Figure 6-32 shows trends in the use of fugitive emissions (in kilograms) per unit of economic output across the different scenarios.

Fugitive emissions per unit of economic output are expected to reduce over the modelling period 2015-47. The highest fugitive emissions per unit economic output in the long term are obtained in the BAU scenario, followed by the FS scenario; the fewest are in the Nexus scenario.

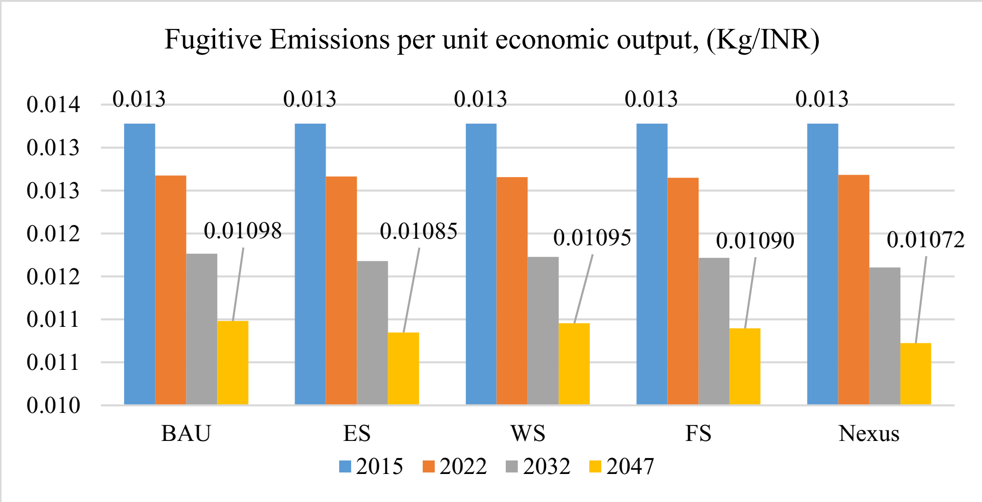


Figure 6-32: Modelling estimates of Fugitive Emissions per unit economic output for India (2015-47)

Overall, fugitive emissions are highest in the FS scenario, closely followed by the ES scenario. The lowest fugitive emissions are observed in the Nexus scenario. Economic growth over the modelling period is highest in the Nexus scenario, followed by the ES and FS scenarios. Consequently, the highest decline in fugitive emissions per unit of economic output is observed in the Nexus scenario, followed by the ES and FS scenarios.

6.1.8. Socio-Economic, Environmental: Trends and Trade-offs

This section examines the trends in the overall social, economic, and environmental composite indices, resulting in different EWF security policy scenarios obtained by averaging the normalised scores for the respective attributes. The composite indices are calculated in the same manner as for EWF security. Social, economic, and environmental indices are calculated as the average of corresponding indicators.

Figure 6-33 (a-c) shows social, economic, and environmental outcomes for various scenarios. These outcomes are expressed in terms of composite indices.

It can be inferred that economic, social, and environmental outcomes improve by varying degrees across the scenarios and across the three time frames.

Economic Outcomes

a. Economic outcomes improve considerably and consistently in all scenarios from base year to long term, with the ES and WS scenarios showing the best and worst outcomes respectively in all time periods. Economic outcomes in the other scenarios do increase consistently over time, albeit at different and slower rates than in the ES scenario.

b. The short- and medium-term improvements are the highest and lowest in the ES and WS scenarios respectively.

In the long term, the ES scenario shows the slowest improvements in economic outcomes, while the Nexus scenario shows the fastest improvement.

Social Outcomes

a. Social outcomes improve consistently in all scenarios, with the Nexus scenario showing the best outcomes in all three time periods.

b. In the short term, however, the most significant improvement in social outcomes happens in the Nexus scenario and the smallest in the BAU scenario.

c. In the medium term, while social outcomes improve most in the FS scenario, the smallest improvement takes place in the ES scenario. The longer term improvement remains sluggish in the ES scenario while the FS scenario exhibits the fastest growth.

d. Overall, long-term social outcomes are best in the Nexus scenario and worst in the ES scenario.

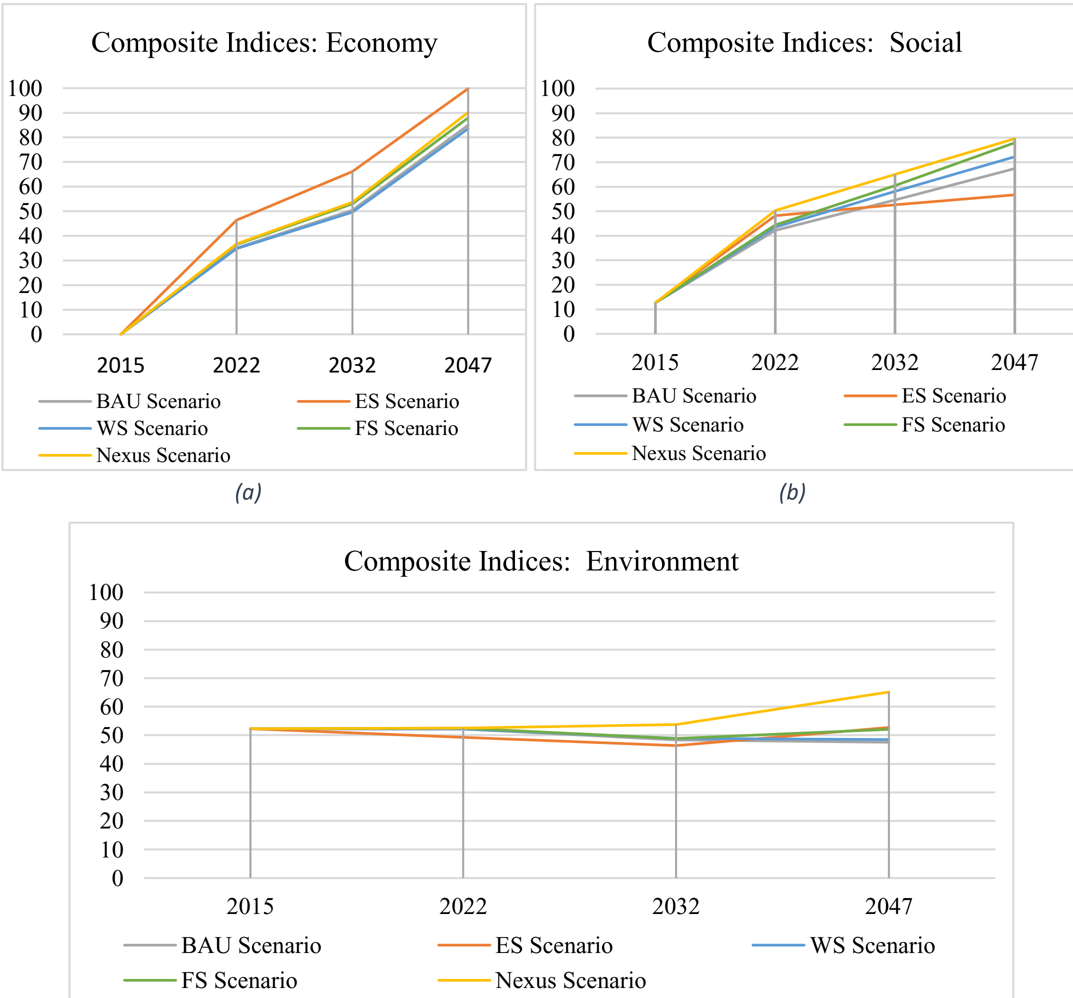
Environmental Outcomes

a. Environmental outcomes deteriorate from base year to long term in the BAU, WS, and FS scenarios. Only the Nexus scenario shows a distinct improvement over the base year.

b. In the short term, the Nexus scenario shows the most improved outcomes, and the ES scenario the least.

c. The medium- and long-term improvements are highest in the Nexus and lowest in the ES scenarios. Overall, the Nexus scenario shows the best environmental outcomes in both the medium and long term. While the worst environmental outcomes in the medium term are experienced in ES scenario, long-term environmental outcomes are associated with the BAU scenario.

d. Long-term improvement of environmental outcomes follows the same trend as in the medium term, i.e., lowest and highest for BAU and Nexus scenarios respectively. These scenarios also produce the worst and best environmental outcomes in the long term.



(c)

Figure 6-33: Modelling Estimates of Composite Economic (a), Social (b), and Environmental (c) Outcomes

The reasons for these varying rates of economic, social, and environmental outcomes across scenarios and across time reside in the complex interplay of underlying attributes and their interlinkages with EWF security attributes. Figures 6-33 provide an overview of the influence of such interplay. Some observations are as follows:

- ***Economic outcomes are observed to be the best and worst in the ES and WS scenarios respectively in all time periods.***

  Economic outcomes improve for all scenarios over the study period. However, the ES scenario records a more favourable trade balance than the other scenarios, primarily due to reduced energy imports with higher levels of domestic energy production and higher infrastructure investments (mostly in large-scale energy generation technologies, domestic energy production, transmission and distribution networks).

  The WS scenario shows the most negative trade balance among all scenarios owing to the highest imports of all scenarios due to less focus in this scenario on ensuring domestic availability of energy and food as part of energy and food security objectives. Further, this scenario registers a relatively slower GDP growth, which is only marginally higher than the lowest GDP growth seen in the BAU scenario. This results in the lowest proportion of trade balance in GDP. Additionally, this scenario requires the least infrastructure investment compared to the other scenarios in all the time periods.

  The Nexus scenario also shows high economic outcomes, second only to the highest economic outcomes in the ES scenario. The ES scenario produces the highest economic output as it requires reasonably high infrastructure investments and sees reduced energy imports, leading to a more favourable trade balance. However, since the Nexus scenario does not favour biofuel production, oil imports do not fall as much as in the ES scenario. Further, the technological mix envisaged in the Nexus scenario does not incur as much investment as in the ES scenario, like large-scale electricity generation technologies.

- ***The Nexus scenario produces the best social outcomes in the short term, while the BAU scenario produces the worst. Social outcomes in the medium and long term are best and worst in the Nexus and ES scenarios respectively.***

  In the short term, the Nexus scenario shows appreciable improvement in social attributes like rural food affordability, rural and urban energy affordability, acceptability, and health. While employment deteriorates slightly from the base year levels in short term in all scenarios, highest deterioration takes place in the BAU scenario.

In the medium term, the Nexus scenario shows consistent improvement in social attributes while the ES scenario replaces the BAU scenario in producing the least improvement in social outcomes. This is because of the lower acceptability in this scenario caused by a rapid rise in the share of nuclear and large hydro in the energy mix in the medium term.

The Nexus scenario continues to show most improved social outcomes even in the long term, with highest improvement in rural food affordability and health – both attributes are superior to outcomes in all other scenarios over the study period. The ES scenario also progresses social outcomes, particularly in terms of generating skilled employment and urban energy affordability. However, this scenario shows the worst outcomes for urban food affordability in the long term, accompanied by low acceptability and rural energy affordability.

- ***The Nexus scenario shows the best environmental outcomes in all time periods. The ES scenario results in the worst environment outcomes in the short and medium term. The worst long-term environment outcomes are observed in the BAU scenario.***

Environmental outcomes deteriorate from the short to the long term in all, except the Nexus and ES scenarios**.** In the ES scenario, environmental outcomes initially deteriorate through the medium term but long term they improve beyond base-year levels.

In the short term, the Nexus scenario shows the most favourable outcomes for most attributes except per capita land requirement, which is the best and worst in the BAU and ES scenarios respectively. The ES scenario also shows the lowest diversity in fertiliser nutrient application; as a result, it shows the worst environmental outcomes in the short term.

In the medium term, the ES scenario produces the worst outcomes over the study period for per capita land requirement as well as in fertiliser nutrient application diversity.

In the long term, while the ES scenario shows improvement in these attributes, however, the BAU scenario produces the worst outcomes for per capita carbon emissions (combustion) and per capita fugitive emissions. The Nexus scenario, on the other hand, shows the best outcomes for carbon intensity per unit of economic output, fertiliser nutrient application diversity, fertiliser output per unit of crop output, and fugitive emissions per unit economic output over the study period.

Next, the trade-offs between different kinds of securities in different scenarios and their respective outcomes for the economy, society and environment are discussed together. These trade-offs are observed in the short, medium, and long term.

6.1.9. Overall Trade-offs

Figure 6-34 shows the trade-offs between different kinds of securities, namely, energy security, water security, food security, social, economic and environmental outcomes, for India in the short term.

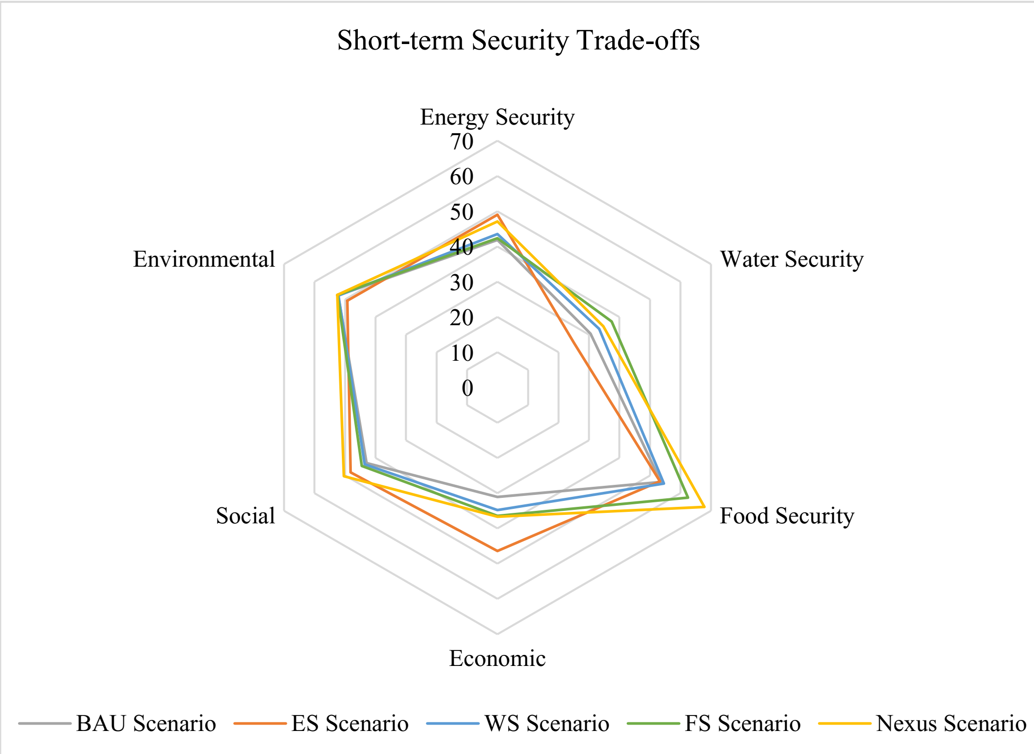


Figure 6-34: Short term Socio-Economic, Environmental, and EWF Security Trade-offs for India

In the short-term, the contrasts in terms of various outcomes (economic, social, environmental, and EWF security) are rather insignificant. Water security deteriorates from the base year in every scenario in the short term, but least in the FS scenario.

Overall, the BAU and ES scenarios produce the most inferior outcomes in the short term – the BAU scenario for food security and social outcomes, and ES scenario for water security and environmental outcomes. The FS and WS scenarios produce the least favourable outcomes for energy security and economy respectively.

The ES scenario shows maximum improvement in energy and economic outcomes. Such improvements are however associated with reduced water security and weak social outcomes in the short term. The Nexus scenario, however, produces the best short-term improvement in food security, social, and environmental outcomes. The reasoning behind such trends are explained in detail in Section 6.1.4. and Section 6.1.9.

Figure 6-35 shows the trade-offs between different kinds of securities and corresponding social, economic, and environmental outcomes in the medium term.

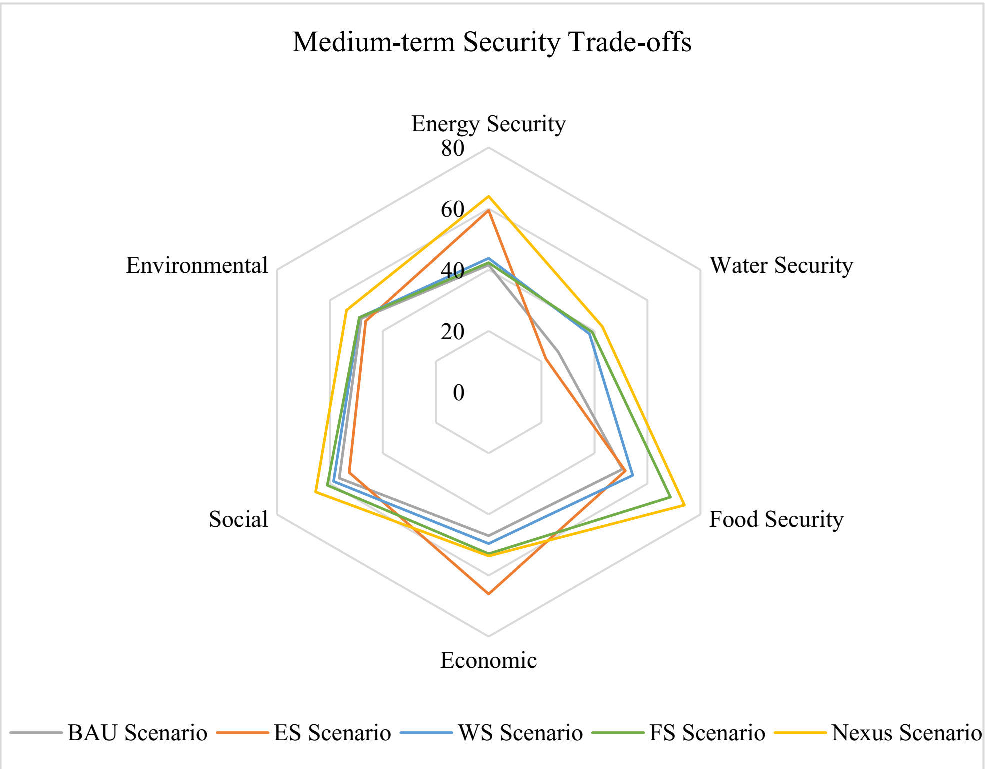


Figure 6-35: Medium-term Socio-Economic, Environmental, and EWF Security Trade-offs for India

The BAU and ES scenarios produce the most inferior outcomes again in the medium term – the BAU scenario for food security, and ES scenario for water security, social, and environmental outcomes. The FS and WS scenarios continue to produce the least favourable outcomes for energy security and economy respectively.

In the medium-term, the ES scenario produces the best energy security outcomes but this results in considerably inferior water security, food security, and social outcomes. Also, in the medium term, the ES scenario produces the most impressive improvements in economic outcomes. However, this comes at the expense of precariously negative water security, and considerably negative social and environmental outcomes. This aspect is critically important for an essentially agrarian economy where the imperative to provide adequate water. India, being a developing nation, the ongoing rapid economic growth also needs alignment with social and environmental sustainability.

The Nexus scenario provides the best overall outcomes in terms of improved EWF security, environmental, and social outcomes. However, it produces rather inferior economic outcomes. The reasoning behind such trends are explained in detail in Section 6.1.4. and Section 6.1.9.

Figure 6-36 shows the trade-offs between different kinds of securities and corresponding social, economic, and environmental outcomes in the long term for India.

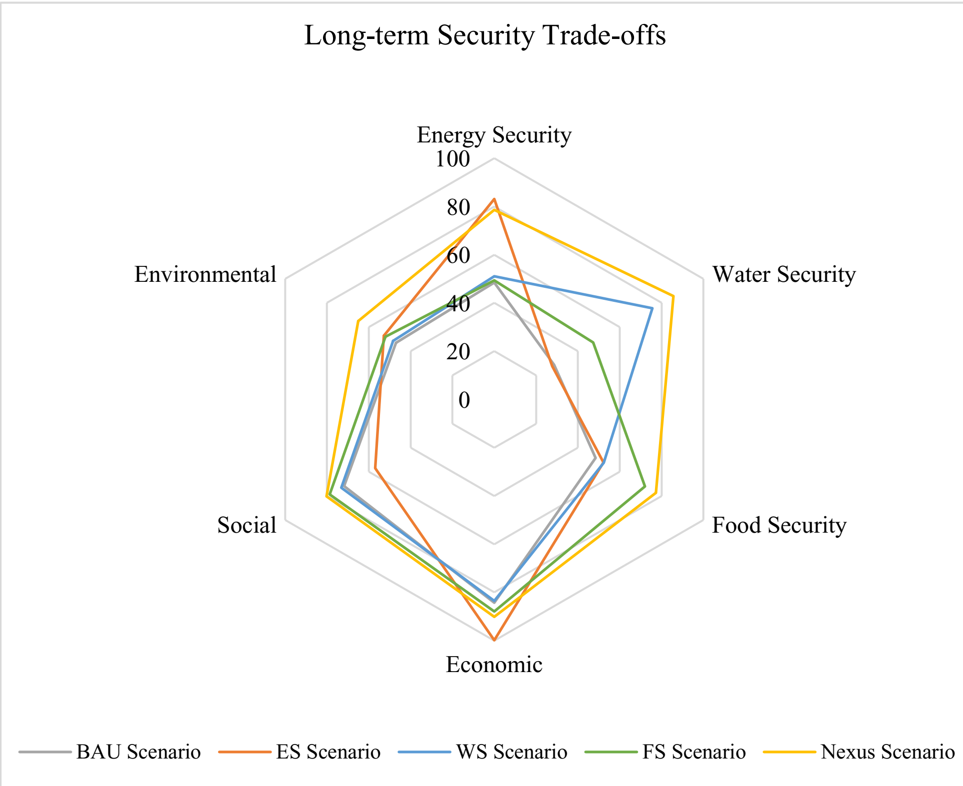


Figure 6-36: Long-term Socio-Economic, Environmental, and EWF Security Trade-offs for India

It is evident from Figure 6-36 that the trade-offs are most evident in the long term. In the long term, the Nexus scenario produces the most favourable water security, food security, social, and environmental outcomes. The ES scenario produces the best energy security and economic outcomes, but worryingly inferior water security and social outcomes. The BAU scenario produces significantly adverse environmental and food security outcomes. The reasoning behind such trends are explained in detail in Section 6.1.4. and Section 6.1.9.

Collective EWF Security Trade-offs

This section examines the trade-offs among the collective EWF security and social, economic, and environmental outcomes. The estimates of collective EWF security outcomes are obtained by weighing the composite scores of individual EWF security equally. Figure 6-37 (a-e) shows the collective EWF security, socio-economic-environmental trade-offs for the various scenarios.

The EWF composite security increases consistently in all scenarios over the entire study period, except in the BAU scenario, where EWF composite security increases in the short term, decreases in the medium term and increases marginally in the long term. The fall in EWF composite securities in the medium term in BAU scenario is caused by water and food security, both of which decrease in the medium term. The detailed reasoning behind such trends is provided in Section 6.1.4.

Overall, however, composite EWF security in the long term for all scenarios are higher than the base year, short, and medium terms. The Nexus scenario results in markedly highest EWF composite security, in comparison with the other scenarios. The BAU scenarios shows the least improvement in EWF composite security over the modelling period. Overall, the Nexus scenario shows a fine balance in terms of attaining EWF security and socio-economic-environmental objectives.

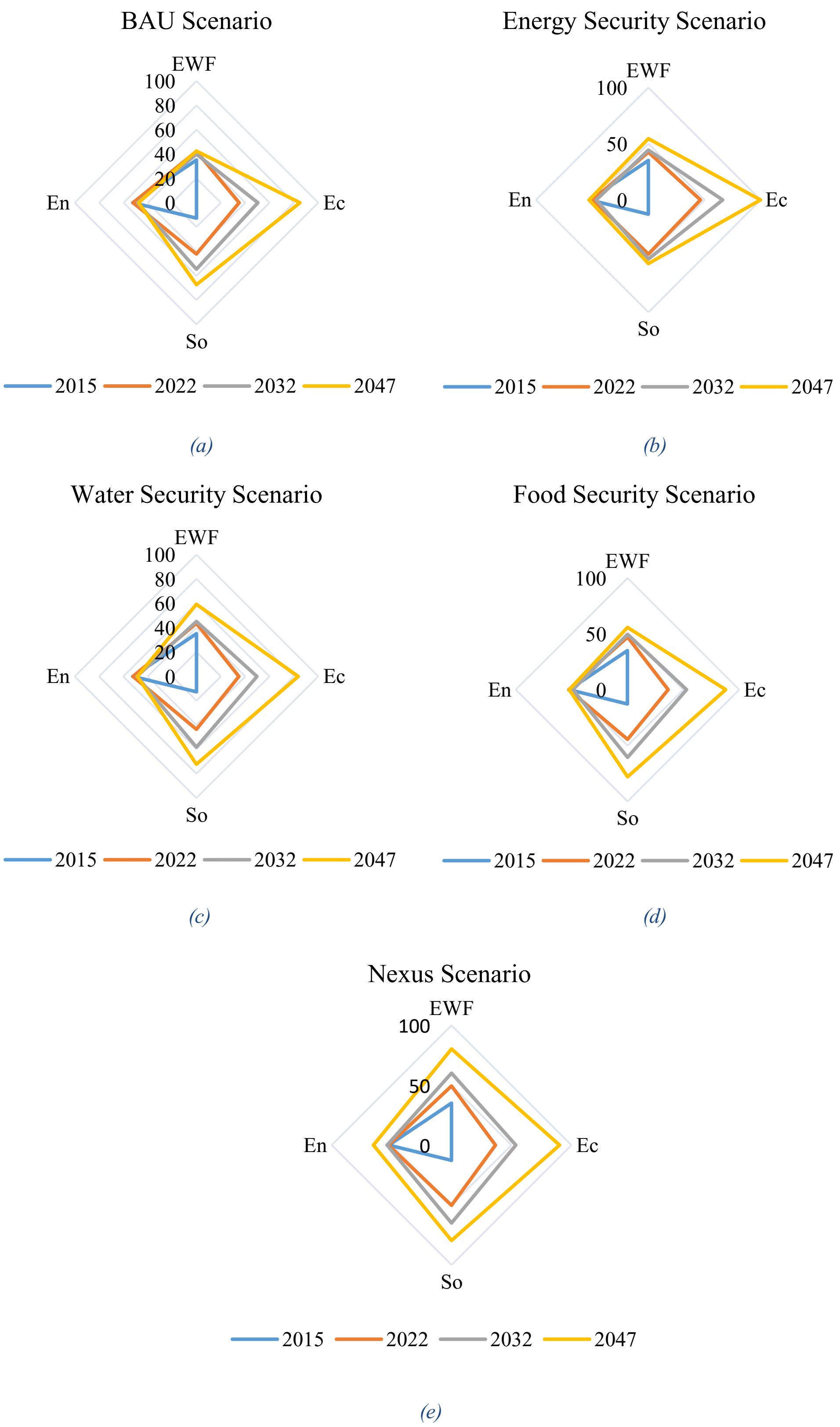


Figure 6-37: Collective EWF security, socio-economic-environmental trade-offs in various scenarios

6.1.10. Alternative Policy Scenarios versus the BAU Scenario

This section compares the outcomes of the BAU scenario and the alternative policy scenarios developed in this research, short, medium, and long term.

Table 6-2 illustrates EWF security, socio-economic, and environmental outcomes for the alternatives to the BAU scenario. Deviations from the BAU scenario have been estimated from the normalised values of each of the attributes to allow a consistent and fair comparison of attributes with different units and measures. The deviation in different attributes are calculated in percentage terms and are categorised into 11 groups. The positive values suggest a positive impact, while the negative values suggest negative impacts. The broad categories are: no impact (0 percent), slight positive or negative impact (1-10 percent variation), low positive or negative impact (10 to 25 percent), moderate positive or negative impact (25 to 50 percent), high positive or negative impact (50 to 90 percent), very high positive or negative impact (90 to 100 percent). The ranges for measuring the impacts have been adapted from AICPA (2012).

The results show that the Nexus scenario yields the highest number of notable improvements (more than 50 percent) compared to the BAU scenario. All these improvements in the Nexus scenario occur in the long term and for the following attributes: coal import dependency, relative water stress, per capita fresh water withdrawals, and rural and urban food diversity. The most notable improvement in the Nexus scenario over the BAU scenario is for per capita fresh water withdrawals.

Only the ES scenario shows some notable improvement in the short and long term; however, the most notable long-term improvement in this scenario is limited to energy security attributes only, i.e., reduction in energy imports expenditure. Likewise, long-term notable improvements in the FS and WS scenarios are limited to water and food security attributes respectively. The notable improvement in the FS scenario in the long term is in the diversification of rural diet, while for WS scenario is in freshwater withdrawals per person.

Table 6-2: EWF Security, Socio-Economic and Environmental outcomes for alternative policy scenarios, in comparison with the Business-as-Usual (BAU) scenario

		SHORT-TERM				MEDIUM TERM				LONG TERM			
	ATTRIBUTES	ES	WS	FS	NEXUS	ES	WS	FS	NEXUS	ES	WS	FS	NEXUS
ENERGY SECURITY	ENERGY INTENSITY												
	PER CAPITA ENERGY CONSUMPTION												
	COAL IMPORT DEPENDENCY												
	OIL IMPORT DEPENDENCY												
	GAS IMPORT DEPENDENCY												
	ELECTRICITY GENERATION: FUEL DIVERSITY INDEX												
	VALUE OF NET ENERGY IMPORTS OF TOTAL NET IMPORTS												
	ACCESS TO MODERN COOKING FUELS												
WATER SECURITY	RELATIVE WATER STRESS												
	WATER PRODUCTIVITY												
	PER CAPITA FRESH WATER WITHDRAWALS												
FOOD SECURITY	FOOD ACCESSIBILITY												
	FOOD NET IMPORTS AS % OF TOTAL NET IMPORTS												
	RURAL FOOD DIVERSITY												
	URBAN FOOD DIVERSITY												
ECONOMY	PER CAPITA GDP												
	TRADE BALANCE / GDP												
	INFRASTRUCTURE INVESTMENTS / GDP												
SOCIAL	EMPLOYMENT												
	RURAL FOOD AFFORDABILITY												
	URBAN FOOD AFFORDABILITY												
	RURAL ENERGY AFFORDABILITY												
	URBAN ENERGY AFFORDABILITY												
	ACCEPTABILITY												
	HEALTH												
	SKILLED EMPLOYMENT												
ENVIRONMENT	PER CAPITA CARBON EMISSIONS												
	CARBON EMISSIONS PER UNIT ECONOMIC OUTPUT												
	PER CAPITA LAND REQUIREMENT												
	FERTILISER NUTRIENT APPLICATION DIVERSITY												
	FERTILISER USE PER UNIT OF CROP OUTPUT												
	PER CAPITA FUGITIVE EMISSIONS												
	FUGITIVE EMISSIONS PER UNIT ECONOMIC OUTPUT												

VERY HIGH POSITIVE IMPACT (90-100%)	HIGH POSITIVE IMPACT (50-90%)	MODERATE POSITIVE IMPACT (25 to 50 %)	LOW POSITIVE IMPACT (10 to 25 %)	SLIGHT POSITIVE IMPACT (0-10%)	NO IMPACT (0%)	SLIGHT NEGATIVE IMPACT (0 to -10%)	LOW NEGATIVE IMPACT (-10 to -25%)	MODERATE NEGATIVE IMPACT (-25 to -50 %)	HIGH NEGATIVE IMPACT (-50 to -90 %)	VERY HIGH NEGATIVE IMPACT (-90 to -100 %)

Further, to quantify the performance of the alternative policy scenarios against the BAU scenario, a scoring index is created (Table 6-3). This index assigns minus five points (-5) to outcomes with very high negative impact, minus four points (-4) to outcomes with high negative impact, minus three points (-3) to outcomes with moderate negative impact, minus two points (-2) to outcomes with low impact significant worsening, minus one points (-1) to slight negative impact compared to BAU scenario outcomes, zero point to outcomes the same as the BAU scenario, one point (+1) to outcomes with slight positive impact, two points (+2) to outcomes with low positive impact, three points (+3) to outcomes with moderate positive impact, four points (+4) to outcomes with high positive impact and five points (+5) to outcomes with very high positive impact compared to the BAU scenario outcomes.

Table 6-3: Quantification of Security Outcomes compared to the BAU Scenario

Impact	Points Assigned
Very High Positive Impact	5
High Positive Impact	4
Moderate Positive Impact	3
Low Positive Impact	2
Slight Positive Impact	1
No Impact	0
Slight Negative Impact	-1
Low Negative Impact	-2
Moderate Negative Impact	-3
High Negative Impact	-4
Very High Negative Impact	-5

Some of the key observations obtained after quantifying the security outcomes with respect to the BAU scenario from the heat map in Table 6-3 are organised, first, according to each of the scenarios for each of the impact attributes and second, by time periods. Considering the maximum and minimum attainable values for each of the attributes, i.e., plus or minus five (+5 to -5), one could estimate the maximum improvement and worsening scores for each kind of security. This led to the following scores: energy security (-40 to +40), water security (-15 to +15), food security (-20 to +20), economic security (+15 to -15), social security (+40 to -40) and environmental security (+35 to -35). Correspondingly, the improvement or deterioration relative to the BAU scenario could be ascertained in percentage terms. This section concludes with some findings from the overall aggregated scores for these scenarios.

Note that the findings from the results obtained after the scoring may differ slightly from the findings above due to the cancellation of some positive and negative impacts in some scenarios. Such cancellation, however, could also be useful in obtaining a better indication of the security impacts of the different scenarios; in such a case, a scenario showing moderate improvement in almost all attributes is better than one with high improvement in some attributes and high deterioration in others.

A comparison of the alternative scenarios with the BAU scenario for each of the securities is discussed in detail below.

Energy Security

Figure 6-38 presents the short-, medium-, and long-term outcomes of energy security for different scenarios compared to the BAU scenario.

In the short term, energy security shows highest improvement in the ES scenario (over the BAU scenario), owing to highest gains from value of net energy imports of total net imports, per capita energy consumption, and coal import dependency.

However, in the medium term, energy security improvements in the Nexus scenario, compared to the BAU scenario, surpass those in the ES scenario with better fuel diversity in electricity generation and lower coal import dependency, although value of net energy imports of total net imports is still lowest in the ES scenario. Reduction in oil imports, over the BAU scenario, is of the same level in both the ES and Nexus scenarios in the medium term.

In the long term, energy security again shows highest improvement over the BAU scenario with most favourable gains observed for energy intensity, oil import dependency, and value of net energy imports of total net imports, while coal import dependency is still lowest in the Nexus scenario. Although the Nexus scenario also assumes high domestic oil production, it still lags in oil import dependency improvements as compared to the ES scenario due to its less focus on biofuel production. The reasoning behind such trends are explained in detail for each of the energy security attributes in Section 6.1.1.

These findings imply that the influence of biofuels, in terms of increased oil import dependency, in the ES scenario is noticeably prominent only in the long term due to the slow development of biofuels in India. The additional reduction in demand for imported coal in the Nexus scenario, in comparison with the ES scenario, is caused by higher reduction in electricity demand in this scenario arising from greater energy efficiency improvements at various stages of crop production, water efficiency improvements, particularly for irrigation, and choice of less energy-intensive technologies for wastewater treatment. The reduced electricity demand results in reduced coal consumption and therefore less coal imports.

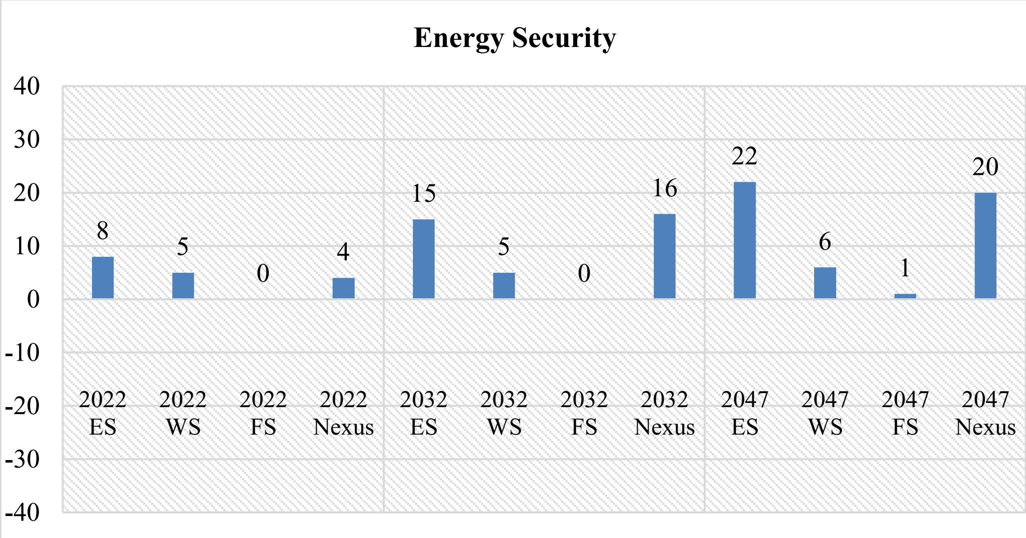


Figure 6-38: Energy security outcomes in the alternatives scenarios compared to the BAU scenario in short, medium and long term

From the scoring index shown in Table 6-3, the greatest improvement in all energy security attributes relative to the BAU scenario can attain a maximum +40 points and the greatest deterioration a minimum -40 points. From the analysis in this research, the maximum attainable energy security improvement is 20 percent in the short term and 55 percent in the long term in the ES scenario while 40 percent improvement in the Nexus scenario in the medium term.

Water Security

Figure 6-39 presents the short-, medium-, and long-term outcomes of water security for the alternative scenarios compared to the BAU scenario.

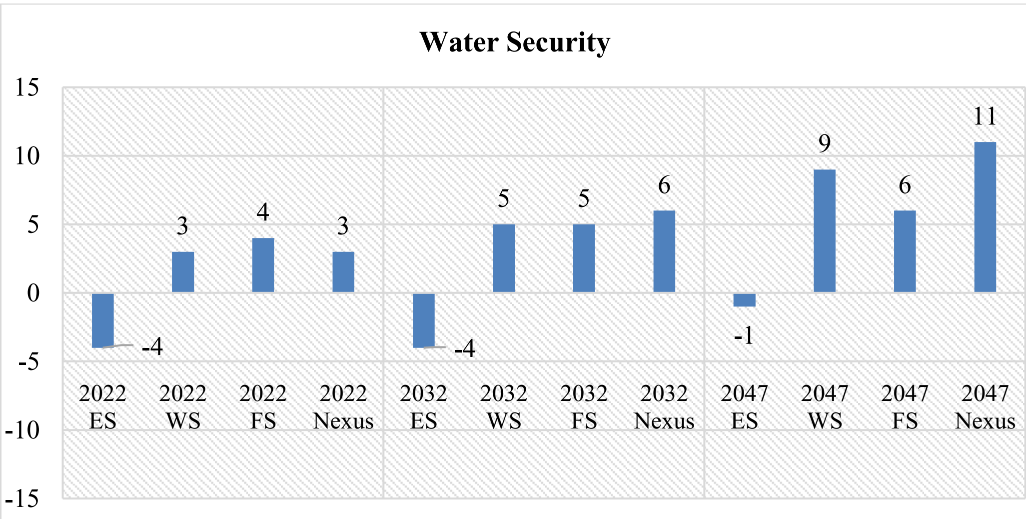


Figure 6-39: Water security outcomes in the alternative scenarios compared to the BAU scenario in short, medium and long term

The Nexus scenario shows the highest improvement in water security outcomes compared to the BAU scenario in the medium and long term, largely owing to distinct improvement in per capita freshwater withdrawals and relative water stress outcomes – even better than the WS scenario where water security is the prime focus. Such outcomes are a result of simultaneous introduction of less water-intensive renewables, like distributed solar, transition towards less water intensive diets, and improvements in water efficiencies across different sectors in the Nexus scenario.

However, the FS scenario shows the greatest improvement in water security compared to the BAU scenario in the short term with its assumption about shifting of dietary focus from water intensive grain crops to less water intensive non-grain crops and low biofuel penetration in the energy mix that collectively leads to most positive outcomes for per capita freshwater withdrawals over the BAU scenario.

The ES scenario shows worse water security outcomes compared to the BAU scenario in the short, medium, and long term with high share of centralized water-intensive modes of energy generation; water security improves in this scenario in the long term but still remains lower than that of the BAU scenario. The improvement in water security in the long term takes place on account of better water productivity of the economy that mainly results from the generation of high economic output in the scenario. Detailed reasoning behind such trends are provided for each of the water security attributes in Section 6.1.2.

The Nexus scenario realises 40 and 73 percent improvements in the maximum attainable water security in the medium and long term respectively, and the FS scenario an improvement of 27 percent in the short term. The ES scenario shows worsened water security outcomes comparison to the BAU scenario, i.e., 27 percent in the short and medium term, but this reduces to 7 percent in the long term.

Food Security

Figure 6-40 presents the short-, medium-, and long-term outcomes of food security for the alternative scenarios compared to the BAU scenario. The figure shows that in the short term, food security attains equal highest level of improvement in the FS and Nexus scenarios; in the medium and long term, the Nexus scenario scores the highest level of food security primarily owing to better rural and urban food diversity in the Nexus scenario.

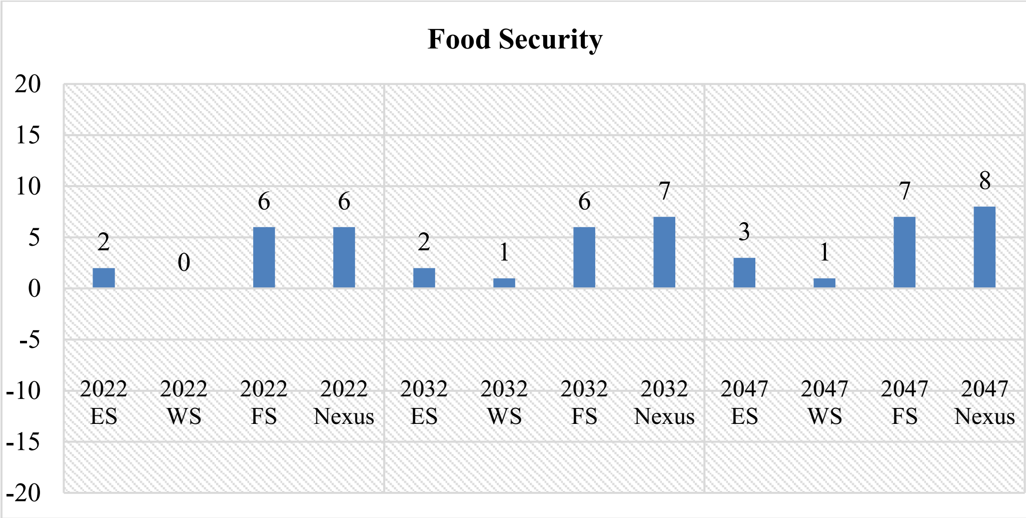


Figure 6-40: Food Security Outcomes in the Alternative Scenarios Compared to the BAU Scenario in the Short, Medium and Long Term

The WS scenario shows an almost identical level of food security as the BAU scenario in the short term; this improves slightly in the medium and long term due to some improvement in levels of rural and urban food diversity despite the absence of any significant dietary transitions but it still remains the lowest of the alternative scenarios across all time frames. The detailed reasoning behind trends in food security attributes is provided in Section 6.1.3.

The Nexus scenario achieves 30, 35, and 40 percent of maximum attainable food security improvement, in the short, medium, and long term respectively, while the FS scenario achieves 30 percent in the short term.

Economy

Figure 6-41 presents the short-, medium-, and long-term economic outcomes for the alternative scenarios compared to the BAU scenario.

The economic outcomes in all the alternative scenarios are higher than the BAU scenario across all time periods. The ES scenario consistently produces the best economic outcomes compared to the BAU scenario with prominently positive outcomes for trade balance with reduction in energy imports and high investments in energy infrastructure needed in this scenario. The improvement remained high and steady during the entire modelling period, slightly higher in the medium and long term. None of the alternative scenarios produced economic outcomes worse than the BAU scenario in any of the time periods. The detailed reasoning behind trends in economic outcomes is provided in Section 6.1.4.

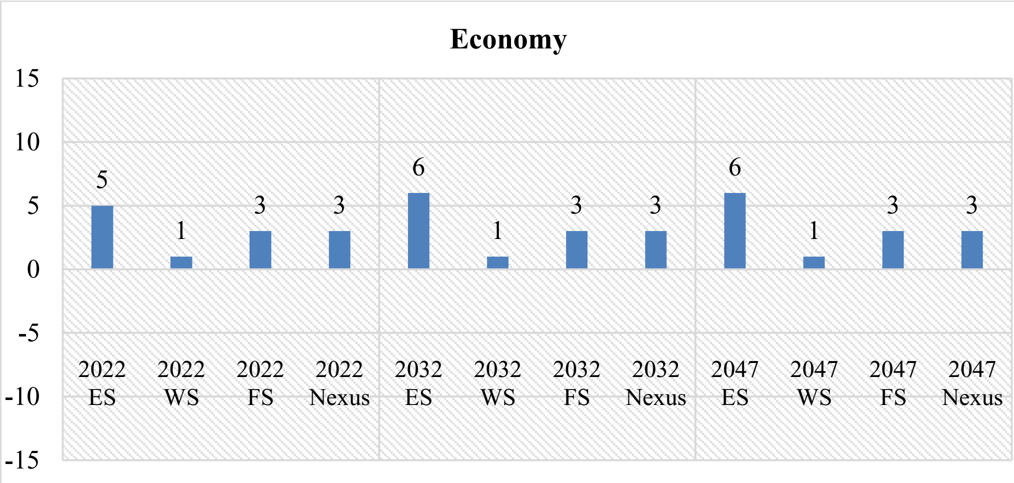


Figure 6-41: Economic outcomes in the alternative scenarios compared to the BAU scenario in the short, medium, and long term

The ES scenario achieved 33, 40, and 40 percent of maximum attainable economic improvement, in the short, medium, and long term respectively. The WS scenario shows the lowest level of economic improvement (7 percent of the highest attainable economic improvement) over the BAU scenario and it remained steady across all time frames. The Nexus scenario shows a constant economic improvement of 20 percent over the BAU scenario in all time periods.

Social

Figure 6-42 presents the short-, medium-, and long-term social outcomes for the alternative scenarios compared to the BAU scenarios.

The social outcomes in the ES and Nexus scenario show the highest equal improvement over those of the BAU scenario in the short term. Both of these scenarios show high improvement in urban energy affordability in the short term. In the medium term, the Nexus scenario produces the best social outcomes with superior health outcomes, urban energy affordability, and rural and urban food affordability.

The FS scenario shows the greatest improvement in the long term, followed by the Nexus scenario. The Nexus scenario lags behind largely due to the decline in rural energy affordability. The ES scenario shows high improvement in social outcomes compared to the BAU scenario in the short term, but this declines sharply declines over the medium and long term to below that of the BAU scenario primarily due to decline in rural energy affordability and acceptability levels. Further details on trends in social outcomes are provided in Section 6.1.5.

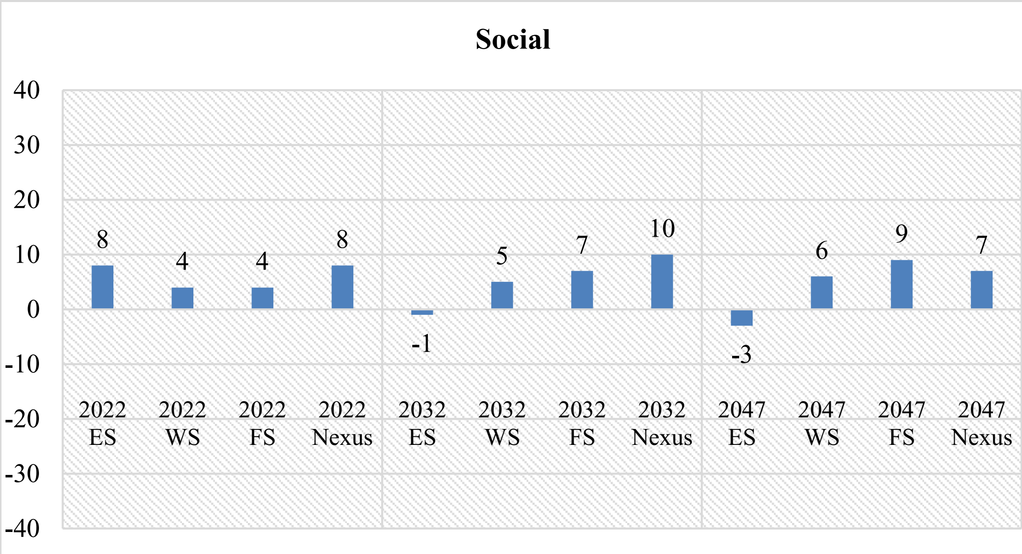


Figure 6-42: Social security outcomes in the alternative scenarios compared to the BAU scenario in the short, medium and long term

The Nexus scenario achieves 20, 25, and 18 percent of maximum attainable social improvement in the short, medium, and long term respectively. The ES scenario maximum deteriorates to 3 percent in the medium term and to 8 percent in the long term.

Environment

Figure 6-43 presents the short-, medium-, and long-term environmental outcomes of energy security for the alternative scenarios compared to the BAU scenario.

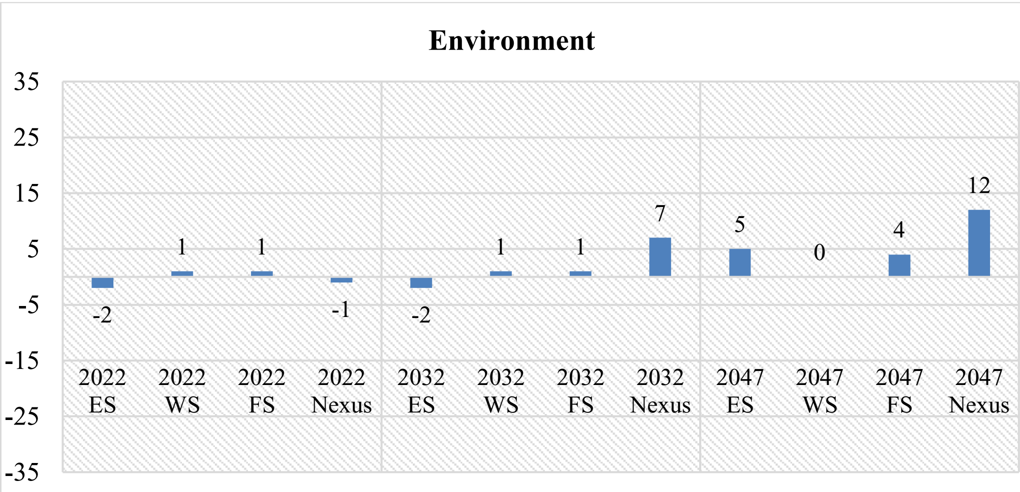


Figure 6-43: Environmental outcomes in the alternative scenarios compared to the BAU scenario in the short, medium and long term

In the short term, the FS and WS scenarios are the only scenarios to show small equal improvement over the BAU scenario. Other than similar level of improvements observed in all alternative scenarios over the BAU scenario in per capita carbon emissions and carbon emissions per unit economic output, the WS scenario also shows slightly lower per capita fugitive emissions and fugitive emissions per unit economic output than the BAU scenario. The FS scenario, in the short term, shows better outcomes for use of chemical fertilizer use per unit crop output relative to the BAU scenario in the short term. Both FS and WS scenarios show lower fugitive emissions per unit economic output than the BAU scenario.

In the medium term, the Nexus scenario shows the best outcomes for environment relative to the BAU scenario with considerable improvement over the BAU for each environmental attributes except land requirement. Higher improvements are observed for per capita carbon emissions and carbon emissions per unit economic output.
In the long term, Nexus scenario clearly stands out with high improvement in per capita carbon emissions and fertilizer application diversity index. Land requirement in the Nexus scenario still remains higher than the BAU levels. Further details on trends in environmental outcomes are provided in Section 6.1.6.

The Nexus scenario shows considerable improvement over the BAU scenario in the medium and long term, i.e., 14 and 29 percent of maximum attainable improvement in environmental outcomes respectively in comparison with the BAU scenario.

Aggregated Security Outcomes

Figure 6-44 presents the short-, medium-, and long-term aggregated security outcomes of energy security for the alternative scenarios compared to the BAU scenario.
It can be inferred from the figure that all alternative scenarios result in higher aggregated security outcomes than the BAU scenario. The Nexus and WS scenarios demonstrate the highest and lowest aggregated security outcomes respectively across all time periods. The Nexus scenario achieves 13, 28 and 36 percent of maximum attainable improvement compared to the BAU scenario in the short, medium, and long term respectively. The minimum improvement observed in the WS scenario is 5, 9, and 13 percent in the short, medium and long term respectively.

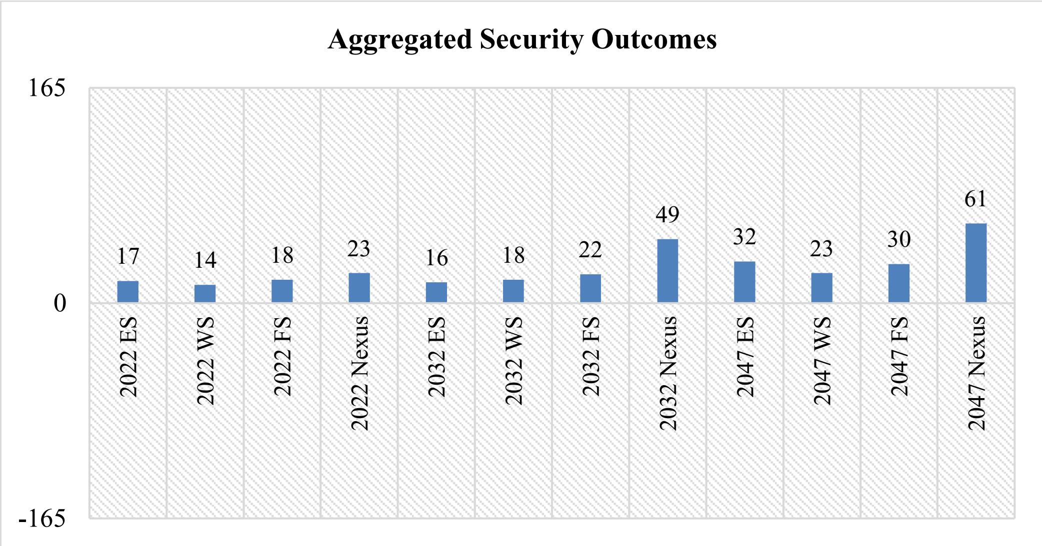


Figure 6-44: Aggregated security outcomes in alternative scenarios compared to the BAU scenario in short, medium and long term

The next section presents the summary of the chapter and draws the main conclusions from the results findings.

6.2. Policy Implications and Recommendations

The discussion in the previous sections illustrates the nature of trade-offs that the country policymakers might like to consider while developing sectoral (EWF) economic, social, and environmental policies for India. The following examples should substantiate this statement.

a) ***The analysis demonstrates increasingly pronounced trade-offs from short-to-long term.***

The research findings suggest that the trade-offs between securities will become more apparent with time and therefore establishes the significance of a far-sighted approach to policy making. The analysis suggests that any trade-offs between the current policies scenario (BAU) and alternative scenarios will be more prominent in the long term. Similarly, the co-benefits will also be realised more effectively in the long term.

b) ***Continuation of current policy trends will exacerbate water security and environment-related risks in India by 2047.***

The continuation of current policy trends, as represented by the BAU in this research, shows reduced water security and worsened state of environment by the end of study period compared to the base-year levels. Water security in the BAU scenario is expected to deteriorate as a result of less focus on improvement in water efficiencies, higher consumption of water-intensive cereals, high water consumption from fossil-based electricity generation, particularly coal, and so on. As a result, the relative water stress in the country will increase according to this research from 46 percent in the base year to 63 percent in 2047. Likewise, per capita water withdrawals will rise from 679 in the base year to 688 cubic metres in 2047.

Regarding environmental outcomes, the BAU scenario shows a continuous increase in per capita carbon emissions from 1.77 metric tonnes in the base year to 5.22 metric tonnes by the end of the modelling period as a result of continuing dominant role of fossil fuels in the energy mix, less energy-efficient use of energy across sectors and energy-intensive agriculture and food production processes. Per capita fugitive emissions and land use also show a rising trend in this scenario, thereby contributing to the deterioration of environmental outcomes if current policies and trends continue.

c) ***Continuation of current policies trends shows least favourable food security outcomes compared to the alternative scenarios in all time periods.***

The execution of current policies, as assumed in the BAU scenario, does result in improved food security outcomes. However, in comparison with the food security improvement in alternative scenarios, the BAU scenario seems to be the least favourable. The attributes of food security largely responsible for such low-level improvements are food diversity and a high share of net food imports in total net imports.

d) ***Prioritising energy security – following a conventional, large-scale centralised approach to energy generation, along with deployment of carbon-reduction technologies – is highly likely to cause water security risks.***

The analysis shows that giving priority to energy security in India is likely to worsen its water security. The continuation of a centralised approach to energy generation, with an emphasis on large-scale technologies like coal, nuclear, land arge hydro, is likely to cause increased levels of stress on water resources. Further, promotion of carbon-neutral but water-intensive energy options like biofuels and Carbon Capture and Storage (CCS), is likely to aggravate water stress. The analysis, therefore, demonstrates worst water security outcomes in all time periods in the ES scenario compared to the other alternative scenarios.

e) ***Prioritising water security can slow economic growth.***

The analysis shows that the WS scenario produces the worst economic outcomes in all time periods. It is slightly lower than even the BAU scenario, primarily because it requires the least infrastructure investment, and therefore the smallest share of infrastructure investment in GDP.

f) ***Water security deteriorates in the short term in all scenarios.***

The analysis shows that water security is expected to deteriorate in every scenario in the short term. This finding results from increases in relative water stress and per capita freshwater withdrawals. This finding seems likely in light of the grave water situation in the country. In the medium and long term, water security follows different (better or worse) trends in different scenarios which are explained in detail in Section 6.1.4.

g) ***A dedicated focus on food security can be detrimental to energy security.***

The analysis shows FS scenario producing the worst energy security outcomes across all time periods. The energy security pattern in the FS scenario is characterised by slight reductions in the short and medium terms from base-year level, followed by a rise in the long term. The results corroborate energy and food interlinkages, which means higher food production will necessitate higher levels of energy in terms of fertilisers, machinery, and irrigation; in the FS scenario, these are not accompanied by energy supply and demand-side improvements.

h) ***Influence of biofuels (as an energy security intervention) on food security.***

The ES scenario (with biofuels) shows low levels of improvement in food security outcomes, but the least improvement is shown in the BAU scenario. This is an unexpected finding and a central topic of ongoing discussion in all the debates on 'fuel vs food'. A closer examination suggests that the adverse effect on food security obtained by improving energy security through biofuels (mainly first and second generation) is overshadowed by the least expenditure on food imports in this scenario. This means that the reduction in energy imports into the country in this scenario can enhance the capacity of the country to import food crops in economic terms. However, if this attribute is not considered, the ES scenario produces the worst outcomes for food security across all time periods.

i) ***The Indian economy grows most in the ES scenario, however, with associated trade-offs.***

The ES scenario produces the best economic outcomes across all time periods. However, this economic progress is accompanied by poor food, water, and social outcomes. While this scenario results in the highest improvement in trade balance for the country due to reduced energy imports and the best outcomes for infrastructure investments to develop large-scale centralised energy infrastructure required for the scenario, it also leads to highest relative water stress, water withdrawals, land requirement, imbalance in fertiliser application, and lowest urban food affordability and public acceptability, in different time periods when compared against all other scenarios over the modelling period. Further, the ES scenario also leads to low energy affordability, food diversity, and accessibility. The reasoning behind each of these trends are explained in detail in Section 6.1.

j) Social outcomes improve least in the BAU and ES scenarios.

The analysis in this research shows that, in general, the BAU and ES scenario show the lowest improvements in social outcomes. The underlying social attributes responsible for the slow improvements in social outcomes in these scenarios are poor levels of food and nutritional diversity, poor health outcomes relative to other scenarios (particularly the BAU scenario), and low levels of acceptability (specifically in the ES scenario). The ES scenario further records a higher share of rural income expenditure on energy, distinctly higher in the medium and long term.

k) Environmental impact of the ES scenario seems counter-intuitive.

The focus of the ES scenario is to address energy-related issues and mitigate the environmental consequences linked with production and use of energy. For the latter, this scenario assumes a high share of clean fuels like renewables, nuclear, and biofuels in the energy mix. Further, this scenario also assumes improvement in domestic energy production, efficiencies in coal-based power generation in the country and deployment of technologies like CCS to reduce carbon emissions.

Despite the measures implemented in this scenario, its environmental outcomes are the worst in the short and medium term, counter to expectations. In fact, the environmental outcomes deteriorate from base-year levels in the short and medium term, and improve over the base year only in the long term.

The interventions mentioned above in the ES scenario show superior outcomes regarding combustion-related emissions. However, the reason for the poor environmental performance of this scenario is increased land requirements demanded by the incorporation of higher land-intensive options like renewables and biofuels into the energy mix. Further, the enhanced levels of domestic energy production (coal, gas, oil) lead to rises in fugitive emissions. In addition, this scenario does not assume any determined efforts in soil-nutriment management or reduction in the use of chemical fertilisers.

l) Food security and socio-economic outcomes improve by the end of the study period in all scenarios, however, with associated trade-offs.

The results show that food security, social, and economic outcomes improve by the end of the modelling period in all the alternative scenarios compared to the base levels. Some scenarios may indicate a decline in these securities in the short and medium term, however, these three outcomes certainly improve over the base-year levels by the long term.
The level of improvements in the long term in food, social, and economic outcomes, however, varies and is often associated with trade-offs with other security outcomes in some scenarios, as discussed previously in this chapter.

m) Nexus scenario energy security improvements are substantial but lower than in the ES scenario.

The Nexus scenario is driven by concurrent considerations for EWF security in the country. Energy security is marginally higher in the Nexus scenario than in the ES scenario in the medium term but lower in the short and long term.

An examination of underlying attributes shows that medium-term fuel diversity in the Nexus scenario is significantly better than in the ES scenario. Import dependencies on primary energy fuels like coal and gas, are also relatively higher in this scenario than the ES scenario. In the medium term, however, the Nexus scenario produces better or equivalent outcomes for each attribute of energy security relative to the ES scenario, except for the share of net energy imports in total net imports, and in oil import dependency. The dominant focus on the development of biofuels in the ES scenario is the underlying factor for lower energy imports and oil import dependencies.

In the short term, the ES scenario yields the lowest share of net energy imports in total net imports over the study period, while in the long term, the ES scenario produces the most favourable outcomes for economic energy intensity, share of renewables in the energy mix, fuel diversity in electricity generation, and share of net energy imports in total net imports. As a result, the ES scenario short and long-term energy security outcomes are somewhat better than those in the Nexus scenario.

n) Water security and food security outcomes are higher in the Nexus scenario than in the respective sectoral security scenarios, i.e., WS and FS scenarios, across all time periods.

The results show that the Nexus scenario is better than the WS scenario in terms of water security outcomes. Likewise, in terms of food security, the Nexus scenario yields better outcomes than the FS scenario. The most favourable water security outcomes result from an integrated approach to EWF security in the Nexus scenario. For example, high integration of renewables in the energy mix along with energy and water efficiency improvements, dietary transition from water-intensive cereals to less water-intensive crops, collectively contribute to lower water requirements in this scenario.

The Nexus scenario produces better food security-related outcomes than the FS scenario as a result of its better food diversity compared to the FS scenario; this likely results from the higher incomes in the Nexus scenario. Collectively, these findings reinforce further the benefits of a Nexus approach to EWF security policy making.

o) The Nexus scenario suggests relatively weaker economic outcomes for India

The economic outcomes in the Nexus scenario are slightly better than in the BAU scenario but slightly lower than in the ES scenario. It is true that economic growth is an important policy priority for India. However, the Nexus scenario is likely to achieve a similar level of economic growth as the current policies or BAU scenario, with the advantage that at the same time it effectively redresses the EWF security challenge.

p) The social, environmental, and food security outcomes in the Nexus scenario provide more significant benefits than in any other scenario.

In the short term, the Nexus scenario shows apparent improvement in social attributes like rural food affordability, rural and urban energy affordability, acceptability, and health. In the medium term, the Nexus scenario shows consistent improvement in social attributes. It maintains most improved social outcomes even in the long term, with highest improvement in rural food affordability and health, superior in both attributes to the outcomes in all the other scenarios over the study period.

In the short term, the Nexus scenario shows the most favourable outcomes for most attributes except per capita land requirement. In the medium term, the Nexus scenario shows continuous improvement in environmental attributes. In the long term, the Nexus scenario yields best outcomes for carbon intensity per unit of economic output, fertiliser nutrient application diversity, fertiliser output per unit of crop output, and fugitive emissions per unit of economic output over the study period.

q) While all scenarios overall yield better security outcomes than the BAU scenario, the outcomes of the Nexus scenario are significantly superior.

As the detailed analysis in the research shows, while some alternative scenarios may be slightly better than the Nexus scenario in some specific factors, the Nexus scenario yields superior performance overall. It leads to considerably improved energy, water, food, social, and environmental outcomes. The improvement in economic outcomes, however, is rather modest in this scenario. Overall, the Nexus scenario seems to be the most desirable for improving EWF security outcomes in India, while at the same time providing superior socio-economic and environmental outcomes.

Separate isolated approaches that focusing on one resource or another have not yielded superior outcomes overall. Success using these isolated approaches has usually been at the security expense of one or other resource. It is this researcher’s contention that an integrated approach, as suggested by this research, is essential to effectively redress the EWF security challenge.

However, the practicality and successful implementation of the Nexus scenario hinges upon a few factors and conditions:

a. The Nexus scenario will require the electricity sector to undergo significant transformations, such as increased uptake of renewable energy technologies like wind, small hydro, and waste-to-energy generation.
b. The successful integration of highly decentralised and distributed renewable energy technologies (like solar pumps for irrigation, solar water heaters, solar in telecom) rests on the following conditions: i) cost-effectiveness of energy generation and storage technologies, ii) feedstock access and availability for waste and biomass-based electricity generation, iii) infrastructure availability, particularly for electric vehicles.
c. Similarly, the successful integration of micro-irrigation technologies is dependent on the profitability of micro-irrigation technologies.
d. The Nexus scenario is land-intensive due to the type of technologies it assumes, including renewables and decentralised, less energy-intensive wastewater options. Land constraints can potentially limit the practicality and successful implementation of the Nexus scenario.

e. A decentralised approach to wastewater treatment is dependent on land availability, so should be largely promoted in rural areas where land is not much of a constraint.
f. Overcoming institutional and behavioural constraints or cultural barriers to shift to a less grain-dominated diet is imperative to the practicability of the Nexus scenario.
g. Horticulture development is critical to ensuring food diversity, nutritional security, poverty alleviation, and rural and economic development. Therefore, emphasis on research and development in horticulture is critical to the practical implementation and securing of benefits foreseen in this scenario (also see, Weinberger and Lumpkin 2007).

6.3. Some Further Discussion

The insights into policy trade-offs at the macro level (as discussed above) could be useful for designing specific sectoral and even sub-sectoral policies. For this, however, the analysis will need to be complemented by the analysis of the underlying trends in the EWF security, social, economic, and environmental attributes at sectoral and sub-sectoral levels.

Some examples are presented below:

a) Import dependencies of fuels

Overall, the Nexus and ES scenarios yield superior outcomes for energy security. However, the patterns in import dependencies of primary fuels (coal, gas, and oil) vary in these scenarios. The import dependency for oil is higher in the Nexus scenario but lower for coal and gas. These differences arise because of the assumption underpinning these scenarios, as described under energy security outcomes in Section 6-1.

b) Electricity fuel diversity mix

Similar to the import dependencies of primary fuels, fuel diversity in electricity generation varies between the ES and Nexus scenarios. Fuel diversity in electricity generation is higher in the ES scenario and lower in the Nexus scenario because of the presence of high renewables. A comparatively lower fuel diversity in the Nexus scenario reflects lesser robustness in the electricity sector against any interruptions or issues pertaining to any of the energy sources (also see, Grubb *et al*. 2006).

c) Gross Domestic Product (GDP)

GDP – the most popular measure of economic progress – in the Nexus and FS scenarios competes with the ES scenario in the short and medium term while the Nexus scenario leads in long-term GDP growth against other scenarios.

In the Nexus scenario, the growth in output of agricultural commodities is characterised by food demand and therefore dietary patterns. High dietary diversification, particularly in the Nexus and FS scenarios, in favour of fruits and vegetables, provides higher returns relative to other crops and therefore results in higher farmers' income, rural development and poverty alleviation, higher levels of consumption, and corresponding improvement in economic output (also see, Chand *et al*. 2008, Singh *et al*. 2015). Further, the reduction in energy imports in the Nexus scenario contributes to the highest GDP growth compared to the other scenarios. .

d) Short-term decline in employment-to-population ratio

The results show that all scenarios can expect to see a marginal decline in the employment-to-population ratio in the short term. This decline is a result of faster rate of increase in working population to that of employment generation. This seems to be a serious concern for the country and therefore needs immediate attention. Rising unemployment reported recently substantiates this finding. Although there are numerous underlying factors that affect unemployment, some inferences can still be drawn (EPW 2018, Mehrotra and Parida 2018).

e) Shift in sectoral employment

Employment generation in absolute terms across the different scenarios in this research does not show vast differences, particularly in the BAU, ES, and WS scenarios. The Nexus and FS scenarios show higher job creation, resulting mostly from the increased focus on food security in these scenarios, as well as the dietary shift from less to more labour-intensive crops.

Further, there are sectoral shifts in job creation in different scenarios, depending on the underlying assumptions in each of the scenarios, as discussed under social outcomes in Section 6-1. Consideration of sectoral job creation and transitions is important for guiding sectoral and sub-sectoral policies.

f) Skilled versus unskilled job creation

As the country grows and experiences significant growth in the youth population looking for jobs, job creation will become a critical policy priority for the nation. The FS scenario shows the highest increase in job opportunities (mostly unskilled) by 2047, strong agriculture sector growth being the primary driver for job creation. At the same time, skill development is an emerging priority of the country as evidenced by such initiatives as the National Skill Development Mission. In this respect, the ES scenario would be favourable as it shows the highest skilled job creation.

The ES scenario is likely to experience the most substantial growth in terms of skilled job creation, and these improvements would not entail any appreciable job losses. The positive impact of generating skilled jobs can be realised only by ensuring a sufficient supply of skilled labour, which in the Indian context will necessitate concerted efforts in skill development.

As an agrarian economy where a dominant portion of the working population is employed in unorganised and unskilled jobs, India would still require the creation of jobs that do not need a high level of skill. A more balanced situation in these two kinds of employment generation can be seen in the Nexus and FS scenarios.

g) Emission reduction in the alternative scenarios

The combustion and fugitive emissions from different sectors of the economy can be reduced to a great extent in the ES and Nexus scenarios. However, the differences in fugitive emissions between the different scenarios is quite low. The smallest reduction in combustion emissions in the long term takes place in the BAU scenario, in fugitive emissions in the FS scenario.

The above-mentioned examples suggest the need for a careful examination of trends in the underlying impact attributes for their usefulness as inputs in sub-sectoral or other related policies.

This research offers Indian policy makers a choice as to which pathway they should take. This choice will, of course, depend on the policy makers' policy priorities, be they improved economic outcomes and energy security, or enhanced EWF securities along with improved social and environmental conditions. If the former (i.e., improved economy and energy security), then policies that underpin the ES scenario should be followed. In that case the country should be prepared to live with increased water and food insecurity, and social risks. However, if there is a preference for much improved EWF securities, social, and environmental outcomes, plans and policies that are underpinned by the Nexus-oriented scenario should be implemented.

6.4. Summary and Key Inferences

This chapter examined the EWF security, socio-economic, environmental impacts of alternative EWF security policy scenarios. The impacts are examined in terms of individual attributes representing EWF securities, social, economic, and environmental outcomes of various scenarios, over the short-, medium-, and long-term. Also examined in this Chapter are trade-offs in terms of composite indices for various individual attributes. Further, EWF securities are also collectively analysed to visualise the trade-offs with other socio-economic and environmental outcomes. Finally, a comparison of the BAU scenario with the alternative scenarios is made to ascertain the improvement or worsening of different kinds of securities.

A summary of major conclusions is as follows:

The worst outcomes for energy security are consistently generated in the FS scenario over the study period. The most favourable outcomes in the short and medium term are seen in the Nexus scenario, and in the long term in the ES scenario. The ES scenario shows the worst outcomes for water security over the study period. The most favourable outcomes are seen in the FS scenario in the short term, and in the Nexus scenario in the medium and long term. The BAU and Nexus scenarios consistently generate least and most favourable outcomes respectively for food security over the study period.

The WS and ES scenarios produce the least and most favourable economic outcomes in the short, medium, and long term respectively. The worst social outcomes in the short term are generated in the BAU scenario, in the medium and long term in the ES scenario. The Nexus scenario results in the best social outcomes across all time periods; it also produces the most favourable environmental outcomes across all time periods. The least favourable environmental outcomes in the short and medium term are generated in the ES scenario while the least favourable environmental outcomes in the long term are generated in the BAU scenario.

Overall, the Nexus scenario seems to be the most desirable to improve energy, water, food security outcomes in India while at the same time achieving superior socio-economic and environmental outcomes. The Nexus scenario also produces the highest collective EWF security outcomes in comparison with other scenarios.

A comparison of alternative scenarios with the BAU scenario depicts all scenarios to be better than the BAU scenario in terms of aggregated security outcomes (EWF securities, social, economic, and environmental) in all time periods, with maximum improvement is observed in the Nexus scenario. Overall, the Nexus scenario achieves 13, 28 and 36 percent improvement over the BAU scenario in the short, medium, and long term respectively. The minimum improvement is observed in the WS scenario – 5, 9, and 13 percent in the short, medium and long term respectively.

The Nexus scenario yields the most noteworthy improvements (more than 50 percent) over the BAU scenario, all of which occur in the long term and for the following attributes: coal import dependency, relative water stress, per capita fresh water withdrawals, and rural and urban food diversity.

Finally, this chapter has highlighted some key policy inferences from the results and added further discussion on some of the individual impact attributes potentially relevant as policy inputs at sub-sectoral levels.

The next chapter presents the conclusions and recommendations for further research.

Chapter 7 . Conclusions and Recommendations

This chapter is a synthesis of notable findings and contributions from the thesis to assist with the development of EWF security policies. The chapter also outlines the limitations of this research, and potential areas for further research. Section 7.1. presents the summary and major conclusions from this research, including key contributions in relation to guiding policy and decision making for EWF security. Section 7.2. provides the limitations of this research and recommends prospective areas for further research.

7.1. Summary and Conclusions

Chapter 1 highlighted the criticality of the EWF security challenge in the Indian context that prompted the need for undertaking this research. This research specifically examined the usefulness of a nexus approach to EWF security planning and policymaking in India. The primary objective of this research was to examine the interlinkages between EWF securities with a view to facilitating a more informed, integrated and comprehensive approach to policy making to redress the EWF security challenge in India.

This objective has been achieved in this thesis through four sub-objectives:

The first sub-objective involved reviewing the existing framing and methods used to examine the EWF security nexus.

The purpose was to identify gaps in the current framing of the EWF nexus, and to ascertain the strengths and weaknesses of existing methods for nexus assessments, particularly to guide EWF security policymaking.

This research broadly classifies the EWF nexus domains into five categories: physical, economic, social, environmental, and institutional. The findings from the review of the current EWF nexus suggested that the framing was predominantly driven by a limited sub-set of nexus domains, mostly physical or technical. The nexus conceptualisations were also found to be characterised by a resource bias that revealed a narrow sectoral outlook.

The social and institutional domains of the nexus have received relatively little attention in the existing literature. Moreover, much of the work on analysing social and institutional domains in the literature is qualitative, and lacks empirical considerations that (even in proxy form) could be useful in developing a comprehensive picture that would provide more relevant inputs to policy making.

The methods for nexus assessments were reviewed in terms of the following attributes: domain coverage, analytical capability, context specificity, temporal flexibility, methodological transparency, and computational simplicity. The findings from this review suggest that the existing methods are limited in their ability to provide useful inputs to EWF security policy making.

One of the reasons for this is that the existing methods do not balance the key attributes that are essential for such policy making, which means while some existing methods are individually strong in that they possess a few of these attributes, these attributes are themselves often either compromised or in conflict with other attributes, thereby limiting their usefulness in terms of policy making. Finally, the review provided some recommendations to strengthen the design of frameworks for nexus assessments.

Development of specialised frameworks was recommended to perform nexus assessments for a policy-relevant analysis to guide inter-sectoral WEF security policies. These specialised frameworks could be developed from a method or a combination of methods. Accounting-based and integrated methods for nexus assessments that use diverse knowledge bases and capture stakeholders' interests (and thereby offer greater support for decision making), were found to be more favourable for drawing policy outcomes.

Overall, while the existing methods for nexus assessments were seen to offer promising solutions to complex resource allocation and developmental issues, an effective and policy-relevant approach necessitates development of specific methods. The suggestions based on the review finally resulted in the selection of a method for this research.

An EWF extended IO model with flexible production functions was selected as the methodology for this research because the ability of IO-based methods to display the attributes mentioned above was found to be particularly appropriate for this research.

The second sub-objective was to develop a broader perspective on the security of EWF resources in the Indian context. This involved developing an historical account of EWF considerations in India and a review of current EWF security plans and policies.

The purpose of this objective was to understand the historical influences on EWF considerations that led to the current state of EWF security in the country. A review of current polices was carried out to help determine the current approach of redressing the EWF security challenge in India.

The findings from the historical account revealed a transition in the EWF security considerations in the country from an implicit understanding of the significance of energy, water, and food in the past to the prevailing overexploitation of these resources, and the resulting insecurities in respect of these resources. These changes in attitudes were driven by various internal and global socio-political influences and factors.

The review of current policies also revealed a sector-oriented and siloed approach to policy making and a more explicit and extensive focus on energy sector policies than on water and food. Some nexus considerations evident in the existing policies are unintended and seem to be primarily driven by rising air pollution levels and hence carbon-reduction commitments in the country. Some recent nexus-guided policy development at state level was observed; however, overall, the macro-level EWF policy discourses seem to remain siloed. The findings in this research offer policymakers the opportunity to explore alternative approaches to EWF security policy making.

The third sub-objective was to develop the framework identified in Objective 1 for empirical investigation of the EWF security nexus to determine the potential trade-offs resulting from the various scenarios, driven by nexus or non-nexus-based security considerations, in order to satisfy future demand for energy, water, and food.

This objective was achieved through the development of an Energy-Water-Food extended Input-Output model with flexible production functions to understand the impact of current and alternative EWF security policy pathways and their associated social, economic, and environmental outcomes, using a scenario-based approach.

The fourth and last sub-objective of this research was to examine the effectiveness of a nexus approach in guiding policy development to achieve EWF security in India.

Four alternative scenarios to the current policies scenario (represented as the BAU scenario in this research) were examined. The four alternative scenarios portray different EWF security policy considerations, either nexus or non-nexus-based. They include three non-nexus-oriented scenarios: energy security (ES), water security (WS), and food security (FS), and one EWF nexus-oriented scenario (Nexus).

The ES, WS, and FS scenarios each focus exclusively on the security considerations of an individual resource, i.e., energy, water, and food, while the Nexus scenario focuses on the mutual interdependencies of these resources.

The five scenarios developed in this research, including the BAU scenario, examined different EWF security policy pathways in the country from short, medium, and long-term perspectives. The base year of the research was 2015 and the years 2022, 2032, and 2047 were chosen to mark the short, medium, and long term respectively.

The major findings from the scenario-based modelling are as follows:

a) The worst outcomes for **energy security** were consistently generated in the FS scenario over the study period. The most favourable outcomes in the short and medium term are seen in the Nexus scenario, and in the ES scenario in the long term. The ES scenario shows the worst outcomes for **water security** over the study period. The FS scenario produced the most favourable outcomes in the short term, while the Nexus scenario produced the most favourable outcomes in the medium and long term. The BAU scenarios consistently generated the least favourable outcomes for **food security** over the modelling period and the Nexus scenarios generated the most favourable outcomes.

b) The WS and ES scenarios produced the least and most favourable **economic outcomes** respectively in the short, medium, and long term. The worst social outcomes were generated in the BAU scenario in the short term, and in the ES scenario in the medium and long term. The Nexus scenario produced the best social outcomes in all time periods. The Nexus scenario also produced most favourable environmental outcomes across all time periods. The least favourable **environmental outcomes** in the short and medium term were generated in the ES scenario while the worst environmental outcomes in the long term were generated in the BAU scenario.

c) **Overall**, the **Nexus scenario** seems to be the **most effective** in improving EWF security outcomes in India, at the same time achieving much superior socio-economic and environmental outcomes.

The collective energy-water-food security outcomes are also the highest and markedly high in the Nexus scenario, in comparison with other scenarios. A comparison between the alternative scenarios and the BAU scenario shows that every alternative scenarios is better than the BAU scenario in terms of aggregated security outcomes (EWF, social, economic, and environmental securities) in all time periods, with the maximum improvement in the Nexus scenario.

The Nexus scenario yields noteworthy improvements (more than 50 percent) over the BAU scenario (in the long term) for the following attributes: coal import dependency, relative water stress, per capita fresh water withdrawals, and rural and urban food diversity.

Overall, the Nexus scenario achieves 13, 28 and 36 percent improvement over the BAU scenario in the short, medium, and long term respectively. The minimum improvement is observed in the WS scenario – 5, 9, and 13 percent in the short, medium and long term respectively.

The findings that the Nexus-based scenario provides better policy outcomes overall reinforces the need for an integrated planning approach to resolving the EWF security challenge.

Research Contribution

In addressing the research question – *whether and to what extent a nexus approach to energy, water, food security is effective in redressing the security challenge* – the major contributions of this research are as follows:

a) One of the key contributions of this research is advanced knowledge on the research question analysed. Through a literature synthesis, this research reveals the gaps in the current framing of the nexus and the limitations of existing methodologies to guide policy formulation for augmenting EWF security – two areas which are critical to making better policy choices.

b) Further, this research creates a novel and fresh perspective on the nexus approach to facilitate the analysis of EWF security policy measures through the development of a nexus-oriented scenario in which EWF security policies, strategies, and even technologies are guided by principles of a nexus approach.

c) The methodological contribution of this research is the development of a framework that unites the multiple physical, social, economic, institutional, and environmental domains into a single nexus framework with no bias on any particular resource. Simultaneously, it examines associated trade-offs in the short, medium and long term for each of the different EWF security policy options.

d) The framework used in this research is pragmatic and analytically rigorous, yet transparent and computationally simple. It is also context-specific to demonstrate the socio-political nuances that affect or are affected by EWF outcomes in different contexts.

e) The EWF linkages are intrinsically embedded in the IO framework through the monetary interactions between different sectors. The consideration of physical flows is an extension to the traditional methodology, and is a common feature in an environmentally extended IO analysis (Miller and Blair 2009). In addition, this research disaggregated the EWF sectors to detailed technological levels and aggregated sectors that had little relation to EWF sectors to produce a nuanced analysis of EWF security interventions.

   Through an indicator-based analysis of different policy scenarios, this research indicates directional trends in the subjective and complex areas of social and institutional dimensions of the EWF security nexus, like acceptability and the health outcomes resulting from EWF security.

f) This research contributes to practice by providing a lens through which Indian policy makers can make better informed decisions about EWF security by incorporating the direction and extent of trade-offs that extend considerations beyond existing practices. The research indicates how policymakers can probe and understand various policy scenarios directed towards EWF security regarding their impacts in different nexus domains.

g) This research suggests that while all nexus and non-nexus consideration based scenarios yield better performance than the BAU scenario, it is the Nexus scenario that demonstrates significant improvement in energy, water, food, social, and environmental outcomes compared to the BAU scenario. The Nexus scenario seems in general to be better than all the other scenarios it as produces better EWF security outcomes; it also produces improvements in social, economic and environmental outcomes, unlike the other scenarios that demonstrate distinct trade-offs.

h) The recommendations derived from this research may benefit the key planning agencies involved in short and long-term development and implementation of EWF security policies in India. Further, the outputs produced from this research can also benefit investors, business communities, researchers, governments and the community at large.

i) This research is one of the first to comprehensively examine the nexus between energy, water and food securities, particularly in the Indian context. This has been achieved through the development of an EWF-oriented IO framework that also incorporated social, economic, and environment securities into a cohesive framework. The whole process was time-consuming and required certain approximations to be made. As a result, there are certain limitations and scope for further improvements. The key limitations of this research and recommendations for further research in the future are presented in the next section.

7.2. Limitations and Recommendations for Further Research

The key limitations of this research can be broadly grouped into theoretical and data-related segments. The theoretical limitations include the following:

a) The model used in this research is an open economy model. The flexible production function approach used to model the security scenarios enabled the model to take into account the impact of prices in the level and structure of final demand and the impact of input prices on single intermediate inputs.

However, a theoretical limitation of the model used in this research was its inability to take into account the impact of import prices on imported and domestic demand, and the impact of these prices on the level and structure of final demand, which implies that global goods and services prices are assumed to be constant – an advantage offered in a fully closed IO model. It is therefore recommended to assess the changes in household expenditure resulting from changes in household income caused by direct and indirect effects in an economy using a closed IO model (Grady and Muller 1986).

b) This research used a top-down modelling approach to understand the nexus between energy, water, and food. The analysis could be complemented by a combination of spatial bio-physical models, like a combination of energy, agriculture, land use and hydrological models can be linked to guide the top-down model used in this research.

   This will also assist in reducing the degree of uncertainty associated with spatial differences in EWF intensities, such as the use of national averages for crop water requirements to estimate water demand in food production. Another suggestion to overcome the spatial discrepancies in EWF intensities is to carry out this modelling exercise at a state level, using the Multi-Regional Input-Output (MRIO) approach. The MRIO approach can provide additional insights into inter-state trade influences.

c) The results obtained regarding physical parameters, for example, water, energy, land, and so on, from the scenario modelling should not be regarded as forecasts, as these are purely indicative. The accuracy of these results may be hampered due to the assumption of linearity between monetary and environmental flows.

d) This research has relied primarily on secondary information available in the public domain from diverse sources that included various national, international, and sectoral planning and developmental agencies. The data so obtained also required additional preparation and and assumptions were made when and where data was not available for the research framework. The research contribution here is the development of a prototype of the kind of data required for nexus studies in the Indian context.

It would be highly beneficial if a centralised system of data collection could be established to reduce the time and effort involved in this aspect of the research. Additionally, such a data bank would help guide the data requirements for future nexus studies, which are likely to become more and more prevalent over time.

Some of the key data-related limitations experienced in this research were:

a) Lack of data regarding skilled and unskilled labour in different sectors of the economy, energy and employment factors for water technologies.

b) This research assumed similar intensities of parameters like energy, water, emissions, land per unit economic output for currently non-existing sectors (due to several reasons like these are upcoming future technologies) in the IO table created for this research to that of similar existing sectors as these sectors have data on gross economic outputs and corresponding energy, emissions, water, land, etc. Such assumptions contribute to some uncertainties in the research.

c) Other sources of uncertainty that are not specific to this research but may have affected the results are the sampling and reporting errors in primary data source (e. g. (e. g. Lenzen *et al*. 2004a, Rosado and Ferrão 2009, Wiedmann 20*09*).

Some other recommendations beyond the current scope of this research include the following:

a) This research examined different techno-economic and environmental policy perspectives on EWF security that are also the dominant perspectives in the current policy making process. Other perspectives, for example, social and institutional, should also be examined in detail.

   One example of a social perspective on policy making is an examination of the livelihood and gender implications of EWF security policies; another is livelihood and gender-responsive policy and planning to redress EWF security. Energy, water and food have wider livelihood and gender-related implications, especially in the developing context, where there equity issues (Crow and Sultana 2002, Coles and Wallace 2005, O'Reilly 2006, Truelove 2011, Köhlin 2011). Gender considerations are essential in developing countries as in these countries women spend more time and energy in provisioning energy, water, and food and they also play a key role in nutritional food security (Smith 2003, Wang *et al*. 2014).

   Poverty and unequal distribution of income in India are long-standing social issues. Income can be a significant factor in the consumption of energy, water, and food. Households can be disaggregated into income classes to study potential impacts of sectoral reforms on welfare, and the impact of change in income on energy, water, and food can be explored (Hussein *et al*. 2017).

   The impact of institutional and governance changes on EWF sectors should also be examined. This research took place during a time of significant governance reforms in India under the National Democratic Alliance-led government. Major reforms include the implementation of GST, greater liberalisation of India's Foreign Direct Investments (FDIs), the creation of a national identification system (Aadhar Card), the launch of the Pradhan Mantri Jan Dhan Yojana (PMJDY) – a financial inclusion program, and the Direct Benefit

Transfer program – transfer of subsidies directly to the people through their bank accounts and the Make-in-India initiative to boost the local manufacturing sector. It would be useful to examine such political, institutional, and governance aspects and their impact on the implementation of EWF security policies.

The impact of removing central and state regulations affecting the movement, storage, processing, and marketing of EWF commodities that serve as disincentives for private investment can be understood. Similarly, reducing the role of government by deregulating procurement, storage and distribution of food grains through the Public Distribution System (PDS) can be analysed.

In the energy sector, the impacts of greater liberalisation, private sector participation, institutional restructuring, deregulation, decentralisation, improvement in marketing efficiencies, and so on could be studied. Likewise, the impacts on the nexus of introducing competition through private sector participation in water supply and wastewater treatment can be understood.

Food grains and fossil fuels like kerosene and LPG have historically been subsidised in India while water pricing is still in its nascent stages (Gangopadhyay *et al*. 2005). As a part of restructuring the regulatory structure of these sectors, one could examine the physical and economic consequences of reducing these subsidies at various levels.

Apart from examining the role of formal institutions, it is important to understand the influence of informal institutions like religion, faith, ethics, belief-systems, spirituality, or philosophy in shaping people's attitudes towards energy, water, and food. These informal institutions in a country like India are highly instrumental in bringing about more sustainable consumption patterns.

b) Another recommendation for further research is to include recently announced new policies or amendments in existing EWF policies in future assessments. Some of the examples are the National Biofuels Policy 2018 and the proposed amendments in 2018 to the National Tariff Policy. This research considered EWF security policies in the base year of 2015. Future research could examine the trade-offs after the incorporation of new policies or modifications to existing policies.

c) The model developed for this research is a single-region IO table, that is, it assumed identical environmental intensities associated with domestically-produced and imported goods. This shortcoming could be overcome by employing multi-region IO (MRIO) tables and different impact intensities for imported goods (Davis and Caldeira 2010, Lenzen *et al*. 2004b, Su and Ang 2014, Wiebe *et al*. 2012, Wiedmann 2009).

   Further, the model for this research treats countries other than India as a single region. Global goods and services prices are also assumed to be constant. However, understanding the drivers of many environmental problems, including EWF insecurities, requires an understanding of the global supply chain (Andrew and Peters 2013). Consequently, an MRIO table could be employed to perform international trade analysis and the impacts of import/export price shocks (Kratena 2005).

d) The model developed in this research is an open Leontief model in which final (non-input) demand is exogenously specified for the product for each industry and which supplies a primary input, like labour, not produced by the industries themselves. This working of the open model is in contrast to a closed model where labour and consumption demand are included in the inter-industry transaction table, hence considered as another industry, is called a closed Leontief model (Piratsteh and Karimi 2005).

   Hence, it is recommended that changes in household expenditure resulting from changes in household income caused by direct and indirect effects in an economy using a closed IO model be assessed (Grady and Muller 1986). In the open model used in this research, any increase in household income generated in the process of production is not assumed to be re-spent, whereas in the closed model, additional income is assumed to be either spent on goods and services or taxes, or to be saved in accordance with average past proportions (Grady and Muller 1986).

e) The climatic dimension – in the EWF framework– considered in this research is primarily the carbon emissions from energy, water, food provisioning resulting from the various techno-economic pathways as envisaged in different scenarios. The resulting impacts from the emissions are contained in the environmental attributes as per capita carbon emissions and carbon emissions per unit economic output. The assessment in this research, however, does not include climate change impacts on availability and demand for energy, water, food resources. Inclusion of such impacts would necessitate soft-linking more elaborated and advanced energy, water, food modelling tools with climatic components to capture EWF nexus in a more detailed and complex manner.

In conclusion, the overarching objective of this thesis was to evaluate the usefulness of a nexus approach in guiding EWF security policies. Through the discussion of the findings, this objective has been demonstrated to have been met. This research suggests that energy, water, and food security issues in the context of India can be more effectively redressed using a nexus-based approach.

Appendices

Appendix A: Details of sectorial reclassification and the new IO matrix with 49 sectors and 5 factors of production

Table A: Sectoral Reclassification

Original Sectoral Classification (n=68)	New Sectoral Classification (n=49)
1 Paddy	1 Paddy
2 Wheat	2 Wheat
3 Other grains	3 Other grains
4 Vegetables and Fruits	4 Vegetables and Fruits
5 Oilseeds	5 Oilseeds
6 Cane & beet	6 Cane & beet
7 Plant Fibres	7 Plant Fibres
8 Other crops	8 Other crops
9 Cattle	9 Cattle
10 Other animal products	10 Other animal products
11 Milk	11 Milk
12 Wool	19 Cattle meat
13 Forestry	20 Other meat
14 Fishing	21 Vegetable Oils
15 Coal	22 Milk products
16 Oil	23 Processed rice
17 Gas	24 Sugar
18 Other mining	25 Other preserved food
19 Cattle Meat	12 Wool
20 Other meat	13 Forestry
21 Vegetable Oils	14 Fishing
22 Milk products	26 Other manufacturing
23 Processed Rice	30 Chemical Rubber Products
24 Sugar	27 Textiles
25 Other food	28 Paper
26 Beverages and Tobacco products	31 Non-Metallic Minerals
27 Textiles	32 Iron & Steel
28 Wearing Apparel	33 Non-Ferrous Metals
29 Leather	15 Coal mining
30 Lumber	16 Oil Extraction
31 Paper & Paper Products	17 Gas Extraction
32 Petroleum & Coke	18 Other Mining
33 Chemical Rubber Products	29 Petroleum & Coke
34 Non-Metallic Minerals	34 T&D
35 Iron & Steel	35 Nuclear
36 Non-Ferrous Metals	36 Coal
37 Fabricated Metal Products	37 Gas power

Original Sectoral Classification (n=68)	New Sectoral Classification (n=49)
38 Motor vehicles and parts	38 Wind
39 Other Transport Equipment	39 Hydro
40 Electronic Equipment	40 Oil power
41 Other Machinery & Equipment	41 Other power
42 Other Manufacturing	42 Solar
43 T & D	43 Gas Distribution
44 Nuclear Base Load	44 Water
45 Coal Base Load	45 Construction
46 Gas Base Load	46 Services
47 Wind Base Load	47 Land transport
48 Hydro Base Load	48 Air transport
49 Oil Base Load	49 Water transport
50 Other Base Load	
51 Gas Peaking	
52 Hydro Peaking	
53 Oil Peaking	
54 Solar Peaking	
55 Gas Distribution	
56 Water	
57 Construction	
58 Trade	
59 Other Transport	
60 Water transport	
61 Air transport	
62 Communications: post and telecommunications	
63 Other Financial Intermediation	
64 Insurance	
65 Other Business Services	
66 Recreation & Other Services	
67 Other Services (Government)	
68 Dwellings	

Source: Aguiar et al. 2016

Table B: Factors of Production Reclassification

Original Factors of production Classification (n=8)	New Factors of Production Classification (n=5)
1: Land	1 Land
2 officials and managers	2 Skilled Labour
3 technicians	3Unskilled Labour
4 clerks	4 Capital
5 service/shop workers	5 Natural Resources
6 agricultural and unskilled workers	
7 Natural Resources	
8 Capital	

Source: Aguiar et al. 2016

Table C: IO Matrix (n=49) in current US Million dollars (Post sectoral re-arrangement)

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**19**
Domestic	1	20	5	0	2	0	0	0	38	7	7	0	0
	2	2	76	0	16	0	0	0	140	3	3	2	1
	3	0	1	22	0	0	0	0	7	12	12	2	0
	4	2	30	1	262	0	0	0	30	10	10	21	0
	5	0	2	0	3	92	0	0	5	0	0	0	0
	6	0	0	0	0	0	124	0	6	0	0	7	1
	7	0	0	0	0	0	0	153	2	0	0	0	0
	8	0	1	0	2	0	0	0	331	254	266	325	0
	9	165	31	81	141	117	19	80	127	1	0	1	45
	10	7	1	12	6	8	0	6	6	0	0	1	0
	11	0	1	1	1	0	0	0	0	0	0	3	0
	19	0	0	0	0	0	0	0	0	0	0	0	5
	20	0	0	0	0	0	0	0	0	0	0	0	0
	21	0	0	0	1	0	0	0	0	17	30	38	0
	22	0	0	0	0	0	0	0	0	0	0	0	0
	23	0	9	0	4	0	0	0	67	0	0	0	0
	24	0	1	0	1	0	0	0	0	0	0	0	0
	25	1	1	0	1	0	0	0	1	1	14	5	0
	12	0	0	0	0	0	0	0	0	0	0	0	0
	13	0	0	0	0	0	0	0	0	0	0	1	0
	14	0	0	0	0	0	0	0	0	0	0	0	13
	26	1	11	1	14	1	1	1	6	1	1	1	5
	30	27	189	40	67	74	50	64	225	2	1	2	11
	27	2	9	0	2	0	0	0	10	1	0	19	1
	28	0	0	0	1	0	0	0	0	0	0	0	6
	31	0	0	0	0	0	0	0	0	0	0	0	1
	32	0	0	0	0	0	0	0	0	0	0	0	0
	33	0	0	0	0	0	0	0	0	0	0	0	0

		1	2	3	4	5	6	7	8	9	10	11	19
	15	0	0	0	0	0	0	0	0	0	0	0	0
	16	0	0	0	0	0	0	0	0	0	0	0	0
	17	0	0	0	0	0	0	0	0	0	0	0	0
	18	0	0	0	0	0	0	0	0	0	0	0	0
	29	19	74	35	76	47	15	23	72	0	0	0	1
	34	12	81	5	23	13	11	10	40	0	0	0	1
	35	1	10	1	3	2	1	1	5	0	0	0	0
	36	26	172	10	49	27	24	21	84	1	0	0	2
	37	8	53	3	15	8	7	6	26	0	0	0	1
	38	1	9	1	2	1	1	1	4	0	0	0	0
	39	5	33	2	9	5	5	4	16	0	0	0	0
	40	3	20	1	6	3	3	2	10	0	0	0	0
	41	1	8	1	2	1	1	1	4	0	0	0	0
	42	0	1	0	0	0	0	0	0	0	0	0	0
	43	0	0	0	0	0	0	0	0	0	0	0	0
	44	0	0	0	0	0	0	0	0	0	0	0	0
	45	4	31	6	11	7	1	5	21	1	0	0	5
	46	19	118	15	107	40	24	18	85	209	113	227	81
	47	12	57	15	32	22	12	17	63	50	27	53	30
	48	1	5	0	1	1	0	0	2	0	0	0	1
	49	0	0	0	1	0	0	0	1	5	3	5	0
Imported	1	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	1	0	11	0	0	0	1	0	0	1	3
	5	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	3	3	4	0
	9	0	0	0	0	0	0	0	0	0	0	0	0

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**19**
	10	0	0	0	0	0	0	0	0	0	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	0
	19	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	0	0	0
	21	0	0	0	0	0	0	0	0	14	24	31	0
	22	0	0	0	0	0	0	0	0	0	0	0	0
	23	0	0	0	0	0	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0	0	0	0	0
	12	0	0	0	0	0	0	0	1	0	0	0	0
	13	0	0	0	0	0	0	0	0	0	0	0	0
	14	0	0	0	0	0	0	0	0	0	0	0	0
	26	2	3	0	1	0	0	0	1	0	0	0	2
	30	19	39	8	14	15	10	13	46	0	0	0	2
	27	0	0	0	0	0	0	0	1	0	0	1	0
	28	0	0	0	0	0	0	0	0	0	0	0	1
	31	0	0	0	0	0	0	0	0	0	0	0	0
	32	0	0	0	0	0	0	0	0	0	0	0	0
	33	0	0	0	0	0	0	0	0	0	0	0	0
	15	0	0	0	0	0	0	0	0	0	0	0	0
	16	0	0	0	0	0	0	0	0	0	0	0	0
	17	0	0	0	0	0	0	0	0	0	0	0	0
	18	0	0	0	0	0	0	0	0	0	0	0	0
	29	4	4	2	5	3	1	2	4	0	0	0	0
	34	0	0	0	0	0	0	0	0	0	0	0	0
	35	0	0	0	0	0	0	0	0	0	0	0	0
	36	0	0	0	0	0	0	0	0	0	0	0	0
	37	0	0	0	0	0	0	0	0	0	0	0	0
	38	0	0	0	0	0	0	0	0	0	0	0	0
	39	0	0	0	0	0	0	0	0	0	0	0	0

		1	2	3	4	5	6	7	8	9	10	11	19
	40	0	0	0	0	0	0	0	0	0	0	0	0
	41	0	0	0	0	0	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	0	0	0	0	0
	43	0	0	0	0	0	0	0	0	0	0	0	0
	44	0	0	0	0	0	0	0	0	0	0	0	0
	45	0	0	0	0	0	0	0	0	0	0	0	0
	46	1	1	1	3	1	1	1	3	0	0	0	2
	47	1	1	0	1	0	0	0	1	0	0	1	0
	48	0	0	0	0	0	0	0	1	0	0	0	0
	49	0	0	0	0	0	0	0	0	2	1	3	0
Factors of Production	50	530	334	198	1850	494	272	314	1168	161	317	1345	0
	51	456	287	170	1592	426	234	270	1005	139	273	1158	34
	52	2	1	1	6	2	1	1	4	1	1	4	6
	53	217	137	81	757	202	111	128	478	66	130	550	18
	54	0	0	0	0	0	0	0	0	0	0	0	0
	55	1	0	0	48	2	0	0	18	0	1	2	0
	56	0	0	0	0	0	0	0	0	0	0	0	0
	57	0	18	-7	-9	-6	1	-1	0	0	0	0	0
	58	-78	-419	-17	-16	-24	-89	-128	-370	27	34	34	11
	59	1497	1413	707	5147	1601	841	1019	3796	989	1275	3852	295

Source: GTAP 9.0 database (Aguiar et al. 2016)

Table C: IO Matrix (n=49) in current US Million dollars (Post sectoral re-arrangement) Contd.

		20	21	22	23	24	25	12	13	14	26	30
Domestic	1	0	0	0	1127	0	0	3	0	0	1	1
	2	0	1	5	9	0	992	1	0	0	2	2
	3	0	1	0	0	0	39	5	0	0	2	1
	4	0	5	2	11	2	644	4	0	0	38	10
	5	0	703	0	1	0	67	0	0	0	2	154
	6	0	0	6	0	537	8	0	0	0	14	5

		20	21	22	23	24	25	12	13	14	26	30
	7	0	6	0	0	0	0	0	0	0	10	3
	8	0	36	0	0	1	152	103	0	0	93	123
	9	0	0	0	16	0	0	0	0	0	30	8
	10	59	1	0	38	0	0	0	0	0	70	19
	11	0	1	397	0	1	0	0	0	0	4	5
	19	0	0	0	1	0	9	0	0	0	1	3
	20	1	0	0	0	0	2	0	0	0	0	2
	21	0	97	0	0	0	84	6	0	0	1	15
	22	0	0	174	1	0	13	0	0	0	1	4
	23	0	1	0	142	0	137	0	0	0	2	1
	24	0	1	0	0	25	154	0	0	0	130	14
	25	0	5	24	7	1	94	0	0	3	126	29
	12	0	0	0	3	0	0	0	0	0	5	1
	13	0	0	1	0	0	1	0	1	0	234	8
	14	1	0	66	0	0	55	0	0	12	1	1
	26	0	8	28	14	32	23	1	8	15	4771	196
	30	1	48	53	260	10	44	1	2	2	1100	2320
	27	0	1	5	17	1	4	0	1	28	474	52
	28	0	4	31	1	5	26	0	1	0	121	51
	31	0	0	5	0	0	5	0	0	0	87	9
	32	0	0	0	0	0	0	0	0	1	2028	29
	33	0	0	0	0	0	0	0	0	0	622	15
	15	0	0	0	0	0	0	0	0	0	10	13
	16	0	0	0	0	0	0	0	0	0	0	0
	17	0	0	0	0	0	0	0	0	0	6	78
	18	0	0	0	0	0	0	0	0	0	87	15
	29	0	1	3	11	1	2	0	17	68	90	861
	34	0	1	5	13	1	4	0	1	0	166	107
	35	0	0	1	2	0	1	0	0	0	19	13
	36	0	3	11	27	2	9	0	2	0	352	228

		20	21	22	23	24	25	12	13	14	26	30
	37	0	1	3	8	1	3	0	1	0	109	70
	38	0	0	1	1	0	0	0	0	0	18	11
	39	0	1	2	5	0	2	0	0	0	67	43
	40	0	0	1	3	0	1	0	0	0	42	27
	41	0	0	1	1	0	0	0	0	0	17	11
	42	0	0	0	0	0	0	0	0	0	1	1
	43	0	1	1	3	1	1	0	0	0	15	36
	44	0	0	0	0	0	0	0	0	0	8	3
	45	0	1	27	43	18	22	0	9	0	260	41
	46	4	222	406	185	289	335	93	24	12	4141	887
	47	2	30	151	111	17	124	22	28	12	1186	381
	48	0	6	6	7	0	5	0	0	1	22	9
	49	0	1	2	0	0	2	2	0	0	42	12
Imported	1	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	21	0	0	26	0	0	0	3	1
	5	0	3	0	0	0	0	0	0	0	0	1
	6	0	0	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	1	0	0	6	12
	9	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	1	0
	11	0	0	0	0	0	0	0	0	0	0	0
	19	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	0	0
	21	0	77	0	0	0	55	5	0	0	1	11
	22	0	0	3	0	0	0	0	0	0	0	0
	23	0	0	0	0	0	0	0	0	0	0	0
	24	0	0	0	0	0	2	0	0	0	1	0

		20	21	22	23	24	25	12	13	14	26	30
	25	0	0	0	0	0	4	0	0	0	1	0
	12	0	0	0	1	0	1	0	0	0	2	0
	13	0	0	0	0	0	0	0	0	0	29	1
	14	0	0	1	0	0	1	0	0	0	0	0
	26	0	4	13	5	23	12	1	2	21	1775	64
	30	0	20	22	39	3	20	1	0	1	487	1646
	27	0	0	0	1	0	0	0	0	2	41	4
	28	0	1	10	0	2	9	0	0	0	39	16
	31	0	0	1	0	0	1	0	0	0	13	1
	32	0	0	0	0	0	0	0	0	0	404	6
	33	0	1	1	0	0	1	0	0	0	2282	56
	15	0	1	1	0	0	1	0	0	0	17	21
	16	0	0	0	0	0	0	0	0	0	0	0
	17	0	0	0	0	0	0	0	0	0	14	171
	18	0	0	1	0	0	1	0	0	0	319	70
	29	0	0	0	1	0	0	0	1	4	8	59
	34	0	0	0	0	0	0	0	0	0	0	0
	35	0	0	0	0	0	0	0	0	0	0	0
	36	0	0	0	0	0	0	0	0	0	0	0
	37	0	0	0	0	0	0	0	0	0	0	0
	38	0	0	0	0	0	0	0	0	0	0	0
	39	0	0	0	0	0	0	0	0	0	0	0
	40	0	0	0	0	0	0	0	0	0	0	0
	41	0	0	0	0	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	0	0	0	0
	43	0	0	0	0	0	0	0	0	0	0	0
	44	0	0	0	0	0	0	0	0	0	0	0
	45	0	0	0	0	0	0	0	0	0	2	0
	46	0	4	19	3	6	18	0	5	1	356	56
	47	0	1	3	1	0	2	1	1	0	18	7

		20	21	22	23	24	25	12	13	14	26	30
	48	0	1	1	0	0	1	0	0	2	4	0
	49	0	0	1	0	0	1	1	0	0	16	5
Factors of production	50	0	0	0	0	0	0	29	0	0	0	0
	51	4	51	197	567	85	437	25	443	224	3508	630
	52	1	9	34	99	15	76	0	2	1	610	110
	53	2	177	78	300	82	168	12	349	271	3337	1466
	54	0	0	0	0	0	0	0	72	241	0	0
	55	0	350	7	1	5	16	1	7	1	530	238
	56	0	0	0	0	0	0	0	0	0	0	0
	57	0	0	1	3	0	2	0	-4	-18	47	-214
	58	3	28	73	-154	78	156	9	0	-2	487	232
	59	81	1914	1906	2933	1250	4073	329	983	940	30889	11030

Source: GTAP 9.0 database (Aguiar et al. 2016)

Table C: IO Matrix (n=49) in current US Million dollars (Post sectoral re-arrangement) Contd.

		27	28	31	32	33	15	16	17	18	29	34	35	36	37	38	39	40
Domestic	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	5	1	8	1	0	1	0
	7	633	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	2	6	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

		27	**28**	**31**	**32**	**33**	**15**	**16**	**17**	**18**	**29**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	25	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	12	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	13	0	58	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26	113	32	42	134	52	27	64	4	20	8	98	12	156	10	9	28	8
	30	319	95	104	33	37	25	23	3	29	73	10	1	16	1	1	3	1
	27	746	4	9	1	1	0	0	0	0	1	0	0	1	0	0	0	0
	28	24	297	21	2	2	1	0	0	1	2	7	1	11	1	1	2	1
	31	1	1	191	9	1	0	18	1	3	1	0	0	0	0	0	0	0
	32	1	2	9	484	25	0	0	0	1	0	1	0	2	0	0	0	0
	33	0	1	1	189	75	0	0	0	6	1	1	0	1	0	0	0	0
	15	2	4	40	68	2	0	0	0	1	11	0	0	466	0	0	0	0
	16	0	0	0	0	0	0	0	0	0	1260	0	0	0	0	0	0	0
	17	0	0	2	5	1	0	0	0	1	4	0	0	0	69	0	0	0
	18	0	0	110	82	50	0	0	0	5	0	0	0	0	0	0	0	0
	29	38	13	321	278	18	0	0	0	92	2252	8	0	0	326	0	0	236
	34	18	27	40	81	60	0	0	0	23	0	20	3	69	9	2	9	2
	35	2	3	5	9	7	0	0	0	3	0	2	0	8	1	0	1	0
	36	38	58	85	172	127	0	0	0	49	0	42	7	146	18	4	20	4
	37	12	18	26	53	39	0	0	0	15	0	13	2	45	6	1	6	1
	38	2	3	4	9	6	0	0	0	2	0	2	0	7	1	0	1	0
	39	7	11	16	33	24	0	0	0	9	0	8	1	28	3	1	4	1
	40	4	7	10	20	15	0	0	0	6	0	5	1	17	2	0	2	0
	41	2	3	4	8	6	0	0	0	2	0	2	0	7	1	0	1	0
	42	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	43	1	5	9	2	1	0	39	1	3	56	0	0	0	173	0	0	0
	44	1	0	0	0	0	0	0	0	0	0	3	0	4	0	0	1	0

		27	**28**	**31**	**32**	**33**	**15**	**16**	**17**	**18**	**29**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
	45	53	15	119	6	4	2	76	2	12	1	29	4	46	3	3	8	2
	46	772	124	279	648	137	20	66	4	63	201	342	32	398	26	24	70	21
	47	423	88	190	287	72	17	23	2	25	124	119	22	139	18	17	49	14
	48	2	1	7	11	3	0	0	0	0	4	0	0	23	0	0	0	0
	49	5	5	1	1	0	0	0	0	0	1	1	0	2	0	0	0	0
Imported	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	7	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	13	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26	72	10	10	36	19	13	38	2	7	5	31	4	50	3	3	9	3
	30	235	50	39	18	23	10	10	1	13	43	5	1	8	1	0	1	0
	27	61	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	28	8	87	7	1	1	0	0	0	0	1	1	0	2	0	0	0	0

		27	28	31	32	33	15	16	17	18	29	34	35	36	37	38	39	40
	31	0	0	17	1	0	0	3	0	0	0	0	0	0	0	0	0	0
	32	0	0	2	61	5	0	0	0	0	0	0	0	0	0	0	0	0
	33	1	2	5	689	277	0	0	0	20	2	2	0	3	0	0	1	0
	15	4	6	65	111	3	1	0	0	1	81	0	0	761	0	0	0	0
	16	0	0	0	0	0	0	0	0	0	7061	0	0	0	0	0	0	0
	17	0	0	4	10	2	0	0	0	1	12	0	0	0	152	0	0	0
	18	1	1	175	25	73	0	0	0	8	1	0	0	0	0	0	0	0
	29	3	1	28	25	2	0	0	0	6	182	1	0	0	42	0	0	31
	34	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	35	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	36	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	37	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	39	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	40	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	43	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0
	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	45	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	46	52	8	8	10	7	1	10	1	5	13	12	1	11	1	1	2	1
	47	8	2	3	2	1	0	0	0	0	1	1	0	1	0	0	0	0
	48	1	0	3	1	0	0	0	0	1	1	0	0	2	0	0	0	0
	49	2	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Factors of Production	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	51	565	212	246	292	53	81	173	23	237	36	114	7	94	6	5	17	5
	52	98	37	43	51	9	7	16	2	22	6	290	36	186	19	17	37	15
	53	568	133	554	841	181	174	370	48	507	580	401	46	574	29	74	369	10
	54	0	0	0	0	0	136	319	35	93	0	0	0	0	0	0	0	0
	55	30	26	15	45	351	156	1	55	98	1374	-115	-13	-244	-76	-12	-46	-29

		27	28	31	32	33	15	16	17	18	29	34	35	36	37	38	39	40
	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	57	-3	7	-84	-64	22	0	0	0	-14	0	8	1	-68	-81	1	4	-21
	58	163	22	51	77	22	4	9	0	7	40	-95	-11	-240	-38	-8	-48	-8
	59	5145	1487	3016	4987	1774	676	1263	185	1411	13442	1362	159	2888	892	145	547	341

Source: GTAP 9.0 database (Aguiar et al. 2016)

Table C: IO Matrix (n=49) in current US Million dollars (Post sectoral re-arrangement) Contd.

		41	42	43	44	45	46	47	48	49
Domestic	1	0	0	0	0	0	56	0	0	0
	2	0	0	0	0	0	79	0	0	0
	3	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	302	1	0	0
	5	0	0	0	0	0	9	0	0	0
	6	0	0	0	0	0	3	0	0	0
	7	0	0	0	0	0	3	0	0	0
	8	0	0	0	0	201	216	194	1	0
	9	0	0	0	0	4	55	0	0	0
	10	0	0	0	0	10	130	0	0	0
	11	0	0	0	0	0	109	0	0	0
	19	0	0	0	0	0	22	0	0	0
	20	0	0	0	0	0	14	0	0	0
	21	0	0	0	0	0	81	2	0	0
	22	0	0	0	0	0	24	0	0	0
	23	0	0	0	0	0	98	0	0	0
	24	0	0	0	0	0	65	0	0	0
	25	0	0	0	0	0	191	0	0	0
	12	0	0	0	0	1	10	0	0	0
	13	0	0	0	0	85	4	0	0	0
	14	0	0	0	0	0	3	0	0	0

	26	9	0	1	2	2220	959	863	66	28
	30	1	0	1	1	271	583	416	129	54
	27	0	0	0	0	22	25	42	1	0
	28	1	0	0	1	16	257	94	1	1
	31	0	0	0	0	2289	5	13	0	0
	32	0	0	0	0	1130	27	0	0	0
	33	0	0	0	0	0	6	0	0	0
	15	0	0	0	0	1	10	0	0	0
	16	0	0	2	0	0	0	0	0	0
	17	0	0	1	0	0	0	0	0	0
	18	0	0	0	0	149	1	0	0	0
	29	26	0	0	0	70	252	2728	33	49
	34	1	0	0	5	14	200	29	1	0
	35	0	0	0	1	2	23	3	0	0
	36	3	0	0	10	29	425	61	1	1
	37	1	0	0	3	9	131	19	0	0
	38	0	0	0	1	1	21	3	0	0
	39	1	0	0	2	6	81	12	0	0
	40	0	0	0	1	3	50	7	0	0
	41	0	0	0	0	1	21	3	0	0
	42	0	0	0	0	0	1	0	0	0
	43	0	0	79	0	1	11	28	1	0
	44	0	0	0	39	45	19	4	16	1
	45	3	0	4	28	555	611	239	16	13
	46	23	1	38	22	2948	4674	1995	144	48
	47	16	1	9	2	1196	1203	565	53	28
	48	0	0	0	0	28	12	35	1	1
	49	0	0	0	0	9	55	14	0	0
Imported	1	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0

	4	0	0	0	0	0	14	0	0	0
	5	0	0	0	0	0	0	0	0	0
	6	0	0	0	0	0	0	0	0	0
	7	0	0	0	0	0	0	0	0	0
	8	0	0	0	0	3	3	3	0	0
	9	0	0	0	0	0	0	0	0	0
	10	0	0	0	0	0	0	0	0	0
	11	0	0	0	0	0	0	0	0	0
	19	0	0	0	0	0	1	0	0	0
	20	0	0	0	0	0	1	0	0	0
	21	0	0	0	0	0	44	2	0	0
	22	0	0	0	0	0	0	0	0	0
	23	0	0	0	0	0	0	0	0	0
	24	0	0	0	0	0	1	0	0	0
	25	0	0	0	0	0	3	0	0	0
	12	0	0	0	0	0	1	0	0	0
	13	0	0	0	0	10	1	0	0	0
	14	0	0	0	0	0	0	0	0	0
	26	3	0	0	1	276	322	228	81	3
	30	0	0	1	1	85	101	62	38	12
	27	0	0	0	0	1	2	4	0	0
	28	0	0	0	0	3	43	18	0	0
	31	0	0	0	0	128	1	2	0	0
	32	0	0	0	0	256	5	0	0	0
	33	0	0	1	0	1	20	0	0	0
	15	0	0	0	0	1	16	1	0	0
	16	0	0	0	0	0	0	0	0	0
	17	0	0	1	0	0	0	0	0	0
	18	0	0	0	0	1112	2	0	0	0
	29	3	0	0	0	7	20	157	2	3
	34	0	0	0	0	0	0	0	0	0

	35	0	0	0	0	0	0	0	0	0
	36	0	0	0	0	0	0	0	0	0
	37	0	0	0	0	0	0	0	0	0
	38	0	0	0	0	0	0	0	0	0
	39	0	0	0	0	0	0	0	0	0
	40	0	0	0	0	0	0	0	0	0
	41	0	0	0	0	0	0	0	0	0
	42	0	0	0	0	0	0	0	0	0
	43	0	0	0	0	0	0	0	0	0
	44	0	0	0	0	0	0	0	0	0
	45	0	0	0	0	10	5	0	0	0
	46	1	0	3	4	74	805	238	23	13
	47	0	0	0	0	21	22	8	1	1
	48	0	0	0	0	6	9	21	10	1
	49	0	0	0	0	2	28	10	0	0
Factors of Production	50	0	0	0	0	0	0	0	0	0
	51	5	0	4	30	5091	5799	2972	458	120
	52	11	0	10	72	2365	16218	597	92	24
	53	47	6	305	85	1462	21358	1894	293	77
	54	0	0	0	0	0	0	0	0	0
	55	-12	-1	43	0	5	25	3	0	0
	56	0	0	0	0	0	0	0	0	0
	57	-2	0	0	2	-13	22	-701	-9	-13
	58	-6	0	2	2	204	117	-23	30	2
	59	142	9	506	313	22456	56105	14267	1504	493

Source: GTAP 9.0 database (Aguiar et al. 2016)

Table C: IO Matrix (n=49) in current US Million dollars (Post sectoral re-arrangement) Contd.

		INV	PC	GOV	VST	Exports	Value of Output	Final Demand
Dome	1	0	213	1	0	16	1497	230

		INV	PC	GOV	VST	Exports	Value of Output	Final Demand
	2	0	60	9	0	8	1413	77
	3	0	530	0	0	71	707	602
	4	0	3557	4	0	201	5147	3763
	5	0	462	0	0	98	1601	560
	6	0	111	0	0	0	841	112
	7	0	0	0	0	205	1019	205
	8	0	1214	30	0	240	3796	1484
	9	4	63	1	0	1	989	69
	10	55	823	10	0	14	1275	902
	11	0	3292	30	0	6	3852	3327
	19	0	86	2	0	165	295	254
	20	0	55	1	0	4	81	60
	21	0	923	0	0	617	1914	1541
	22	0	1635	34	0	20	1906	1689
	23	0	2231	9	0	231	2933	2471
	24	0	741	0	0	117	1250	858
	25	0	3062	64	0	437	4073	3562
	12	18	267	3	0	3	329	291
	13	0	562	0	0	23	983	585
	14	0	774	0	0	12	940	786
	26	10617	3242	299	0	6625	30889	20782
	30	318	1169	161	0	2558	11030	4206
	27	14	2329	58	0	1262	5145	3664
	28	0	268	119	0	110	1487	497
	31	107	82	0	0	185	3016	374
	32	630	0	0	0	617	4987	1246
	33	185	0	0	0	670	1774	855
	15	0	5	0	0	41	676	47
	16	0	0	0	0	1	1263	1
	17	0	0	0	0	18	185	18

		INV	PC	GOV	VST	Exports	Value of Output	Final Demand
	18	0	0	0	0	910	1411	910
	29	0	2022	0	0	3262	13442	5285
	34	0	252	0	0	0	1362	252
	35	0	29	0	0	0	159	30
	36	0	534	0	0	0	2888	534
	37	0	165	0	0	0	892	165
	38	0	27	0	0	0	145	27
	39	0	101	0	0	0	547	101
	40	0	63	0	0	0	341	63
	41	0	26	0	0	0	142	26
	42	0	2	0	0	0	9	2
	43	0	37	0	0	0	506	37
	44	0	50	117	0	0	313	168
	45	19435	27	567	0	60	22456	20090
	46	1470	20648	9016	0	4199	56105	35332
	47	930	5345	268	11	555	14267	7110
	48	12	178	4	981	131	1504	1307
	49	113	100	19	5	81	493	319
Imported	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	1	0	0	0	1	1
	4	0	194	0	0	0	277	194
	5	0	1	0	0	0	6	1
	6	0	0	0	0	0	0	0
	7	0	0	0	0	0	18	0
	8	0	16	0	0	0	57	16
	9	0	0	0	0	0	1	0
	10	1	6	0	0	0	8	7
	11	0	0	0	0	0	0	0
	19	0	1	0	0	0	1	1

		INV	PC	GOV	VST	Exports	Value of Output	Final Demand
	20	0	1	0	0	0	2	1
	21	0	633	0	0	0	899	633
	22	0	18	1	0	0	23	20
	23	0	0	0	0	0	0	0
	24	0	10	0	0	0	13	10
	25	0	48	1	0	0	59	49
	12	1	12	0	0	0	21	13
	13	0	69	0	0	0	117	69
	14	0	7	0	0	0	8	7
	26	3634	458	84	0	0	7335	4176
	30	45	121	25	0	0	3358	191
	27	1	218	5	0	0	345	225
	28	0	45	18	0	0	315	63
	31	17	13	0	0	0	200	31
	32	123	0	0	0	0	862	123
	33	706	0	0	0	0	4072	706
	15	0	9	0	0	0	1099	9
	16	0	0	0	0	0	7062	0
	17	0	1	0	0	0	371	1
	18	0	0	0	0	0	1789	0
	29	0	172	0	0	0	783	172
	34	0	1	0	0	0	5	1
	35	0	1	0	0	0	3	1
	36	0	1	0	0	0	4	1
	37	0	1	0	0	0	5	1
	38	0	0	0	0	0	1	0
	39	0	1	0	0	0	3	1
	40	0	0	0	0	0	2	0
	41	0	0	0	0	0	1	0
	42	0	0	0	0	0	0	0

		INV	PC	GOV	VST	Exports	Value of Output	Final Demand
	43	0	1	0	0	0	5	1
	44	0	0	2	0	0	2	2
	45	39	0	0	0	0	71	39
	46	349	474	168	0	0	2775	990
	47	13	105	4	0	0	235	122
	48	0	117	1	0	0	186	119
	49	0	179	1	0	0	260	180
Factors of Production	50	0	0	0	0	0	7011	0
	51	0	0	0	0	0	28859	0
	52	0	0	0	0	0	21264	0
	53	0	0	0	0	0	40106	0
	54	0	0	0	0	0	896	0
	55	0	0	0	0	0	2908	0
	56	0	0	0	0	0	0	0
	57	-34	-564	-9	0	0	-583	-607
	58	2481	2150	121	0	0	4903	4753
	59	41352	63011	11270	997	23777	214274	0

Source: GTAP 9.0 database (Aguiar et al. 2016)

Appendix B: Satellite Accounts

Table D: Energy (TWh)

	Supply Side	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Domestic	Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Agriculture / Biomass	146.0	124.3	16.7	23.0	33.7	4.6	0.0	0.0	58.2	17.0	46.3	104.0	0.0	72.0	3.7	0.0	0.0	11.6	0.0	0.0
	Solar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Oil and Petroleum products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0
	Electricity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Imported	Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Agriculture/ biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Solar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Oil and Petroleum products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Electricity Oversupply imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	146.0	124.3	16.7	23.0	33.7	4.6	0.0	0.0	58.2	17.0	46.3	108.4	0.0	72.0	3.7	0.6	0.0	11.6	0.0	0.0

Source: Author's calculations

Table D: Energy (TWh) Contd.

	Supply Side	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Domestic	Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Agriculture / Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	400.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Solar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Oil and Petroleum products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Electricity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Imported	Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Agriculture/ biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Solar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Oil and Petroleum products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Electricity Oversupply imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	400.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Author’s calculations

Table D: Energy (TWh) Contd.

	Supply Side	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Domestic	Gas	0.0	0.0	0.0	410.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Nuclear	0.0	0.0	0.0	0.0	138.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Coal	0.0	3057.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Agriculture / Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Solar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Oil and Petroleum products	0.0	0.0	461.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Electricity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	259.6	39.5	7.0	1.8	791.4	92.2	0.0	0.0
Imported	Gas	0.0	0.0	0.0	202.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Coal	0.0	760.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Agriculture/ biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Solar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Oil and Petroleum products	0.0	0.0	1717.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Electricity Oversupply imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	0.0	3818.0	2178.9	612.5	138.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Author's calculations

Table D: Energy (TWh) Contd.

	Supply Side	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
Domestic	Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hydro	0.0	0.0	0.0	0.0	0.0	0.0	157.8	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Wind	0.0	0.0	0.0	0.0	48.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.0	0.0	0.0

	Agriculture / Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Solar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.4	1.9	2.6	0.0
	Oil and Petroleum products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Electricity	0.0	0.0	112.6	0.0	48.0	0.0	157.8	16.0	15.0	35.7	0.8	7.4	1.9	2.6	0.0
Imported	Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Agriculture/ biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Solar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Oil and Petroleum products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Electricity Oversupply imports	0.0	0.0	0.0	0.0	0.0	0.0	-111.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	0.0	0.0	0.0	0.0	48.0	0.0	46.2	16.0	0.0	0.0	3.1	7.4	1.9	2.6	0.0

Source: Author's calculations

Table D: Energy (TWh) Contd.

	Supply Side	**76**	**77**	**78**	**79**	**80**	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**
Domestic	Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Agriculture / Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Solar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Oil and Petroleum products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Electricity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Imported	Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Nuclear	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Waste	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Agriculture/ biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Solar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Oil and Petroleum products	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Electricity Oversupply imports	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Author's calculations

Table D: Energy (TWh) Contd.

Water intensity (BCM)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Ground Water	155.2	77.4	0.3	0.2	2.4	0.1	0.8	10.9	23.5	1.4	1.9	52.0	0.0	12.8	0.0	0.0	0.0	0.0	0.0	0.0
Surface Water	182.2	90.8	0.3	0.2	2.8	0.1	0.9	12.7	27.6	1.6	2.2	61.0	0.0	15.0	0.0	0.0	2.6	0.0	0.0	0.0
Green water	106.4	0.5	35.6	34.6	34.0	0.5	0.0	0.0	0.0	54.6	50.7	5.2	0.0	28.0	0.0	0.0	0.0	0.0	0.0	0.0
Grey water released	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grey water treated	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Desalinated water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Treated sewage water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Author's calculations

Table D: Energy (TWh) Contd.

21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.7	0.4	0.7
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.5	1.7	0.9	1.6
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.5	1.7	0.9	1.6
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Author's calculations

Table D: Energy (TWh) Contd.

41	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.2	0.0	7.7	0.7	0.0	0.0
0.0	0.9	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	2.4	0.4	0.1	18.0	1.7	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Author's calculations

Table D: Energy (TWh) Contd.

61	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**	**76**	**77**	**78**	**79**	**80**
0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	3.5	0.0	0.0	0.0	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Author's calculations

Table D: Energy (TWh) Contd

81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.9	15.5	0.0	0.0	0.0	399.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	15.5	0.0	0.0	0.0	458.3
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	350.1
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.0	23.2	0.0	0.0	0.0	57.1
0.0	0.0	0.0	6.8	0.7	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.5
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.5
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: Author's calculations

Table E: Labour (persons) Contd.

Labour	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Skilled	13064	4390	1307	751	2068	719	880	3826	6490	3151	4028	3710	0	4281	453
Unskilled	65206990	21912879	6525294	3750441	10322984	3588164	4392396	19095121	32393485	15726689	20103960	18519325	1239	21366400	2263340
Total	65220054	21917269	6526601	3751192	10325053	3588883	4393276	19098946	32399975	15729840	20107988	18523035	1240	21370680	2263794

Source: Author's calculations

Table E: Labour (persons) Contd.

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
233125	290	4291	7764	4428	510	40912	23292	3254	113888	8350	373335	13137	88	0
483312	602	8897	16096	9181	1058	84819	48288	6746	236112	17312	773993	27236	182	933124
716437	892	13189	23860	13609	1568	125731	71580	10000	350000	25662	1147328	40373	270	933124

Source: Author's calculations

Table E: Labour (persons) Contd.

31	32	33	34	35	36	37	38	39	40	41	42	43	44	45

1202164	87296	27021	0	1181	377371	473159	75087	279932	240683	122829	125934	293	34	68156
11792313	180982	56019	0	2447	782360	7480947	155668	580351	498980	254647	261084	607	70	141300
12994477	268279	83039	0	3628	1159731	7954106	230755	860283	739663	377476	387018	900	104	209456

Source: Author’s calculations

Table E: Labour (persons) Contd.

46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
42	1	4878	9795	2094	5865	2005	1743	2364	419	105	18154	2115	0	0
87	3	10113	20308	4342	12159	4156	3614	4901	869	217	37637	4384	0	0
128	4	14992	30103	6436	18024	6161	5357	7266	1288	322	55792	6498	0	0

Source: Author’s calculations

Table E: Labour (persons) Contd.

61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
0	0	37	0	6528	0	17730	14011	0	10040	1188	1750	0	0	2692
0	0	76	0	13534	0	36758	29047	0	20815	2463	3628	0	0	5580
0	0	113	0	20062	0	54489	43058	0	30855	3651	5377	0	0	8272

Source: Author’s calculations

Table E: Labour (persons) Contd.

76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	Total
0	0	0	0	0	0	7902	203	2300	189	135	27	1905	5231971	6019	63	146	1040	9312377
0	0	0	0	0	0	16383	420	4768	559	280	56	44003949	141906477	152866	130	304	2155	456306482
0	0	0	0	0	0	24285	623	7068	748	416	83	44005854	147138449	158885	193	450	3195	465618859

Source: Author’s calculations

Table F: Land (Mha)

Sector	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Land, Mha	30.93	21.72	3.69	4.96	6.64	1.72	1.59	6.33	4.43	16.20	18.39	3.55	0.00	9.23	0.55

Source: Author's calculations

Table F: Land (Mha) Contd.

16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
11.66	10.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Author's calculations

Table F: Land (Mha) Contd.

31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00

Source: Author's calculations

Table F: Land (Mha) Contd.

46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.03	0.00	0.00	0.00

Source: Author's calculations

Table F: Land (Mha) Contd.

61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
0.00	0.00	0.00	0.00	0.30	0.00	0.04	0.01	0.00	0.02	0.00	0.02	0.00	0.00	0.00

Source: Author's calculations

Table F: Land (Mha) Contd.

76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	Total
0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	153

Source: Author's calculations

Table G: Agriculture Production (MMT)

Commodities	Production	Imp.	Exp.	Feed	Food manufacturing	Seed and Waste
	MMT	MMT	MMT	MMT	MMT	MMT
Paddy	100	0	0	0	86	6
Wheat	89	0	5	1	0	9
Jowar	6	1	0	0	0	1
Bajra	10	2	0	0	0	1
Maize	21	3	0	14	0	3
Other grains	5	0	3	0	0	0
Roots and Tubers	50	1	1	0	0	9
Other Vegetables	117	1	8	0	0	6
Fruits	79	1	3	0	0	11
Pulses	18	3	0	1	0	1
Oilseeds	31	0	1	1	20	1
Sugarcane	352	0	0	3	299	0
Sugar beet	0	0	0	0	0	0
Cotton	5	0	0	0	0	0
Other animal products(poultry)	8	0	0	0	0	0
milk + milk products	156	2	0	0	46	0
Cattle meat	3	0	2	0	0	0
Other meat	0	3	0	0	0	0
Vegetable oil	9	9	0	0	0	0
Processed rice	86	0	5	0	0	0
sugar	31	1	3	0	0	0
fish	18	0	11	0	0	0
Other crops	22	25	42	0	0	0
Miscellaneous (other preserved food)	19	1	1	0	0	0

Source: Author's calculations

Table H: Food (MMT)

Food Commodities	Urban	Rural	Non-food
	MMT	MMT	MMT
Paddy	2	6	0
Wheat	23	51	0
Jowar	1	5	0
Bajra	2	9	0
Maize	1	7	0
Other grains	0	1	0
Roots and Tubers	11	28	0
Other Vegetables	36	66	0
Fruits	28	37	0
Pulses	7	13	0
Oilseeds	3	6	0
Sugarcane	4	8	38
Sugar beet	0	0	0
Cotton	1	3	0
Other animal product (poultry)	3	5	0
milk + milk products	41	71	0
Cattle meat	1	1	0
Other meat	1	2	0
Vegetable oil	4	7	6
Processed rice	22	59	0
sugar	8	17	3
fish	2	5	0
Other crops	2	3	0
Miscellaneous (other preserved food)	7	12	0
	210	421	

Source: Author's calculations

Table I: Carbon and Fugitive emissions (MT)

CO_2 (MT) - Energy Supply (Energy Fugitive Emissions)																				
Domestic	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Imported																				
Oil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CO_2 (MT) - Energy demand																				
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Coal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.7	0.3
Gas (Unpiped + piped)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Petroleum products	9.1	5.6	0.6	0.8	1.2	0.3	0.3	1.3	1.3	2.7	3.1	1.9	0.0	1.9	0.1	1.5	0.0	0.0	4.8	0.3
biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electricity, grid connected	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	9.1	5.6	0.6	0.8	1.2	0.3	0.3	1.3	1.3	2.7	3.1	1.9	0.0	1.9	0.1	1.5	0.0	0.0	8.8	0.6

Source: Author's calculations

Table I: Carbon and Fugitive emissions (MT) Contd.

CO_2 (MT) - Energy Supply																			
21	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CO_2 (MT) - Energy demand																			
0.1	1.8	1.8	2.8	1.2	0.4	3.4	0.3	0.0	0.0	26.3	11.5	3.6	0.0	0.8	8.4	2.6	32.8	75.1	206.3
0.0	0.2	0.2	0.3	0.1	0.0	0.4	0.0	0.0	0.0	2.7	0.0	0.0	0.0	0.2	0.9	0.1	0.2	0.0	8.8
0.1	2.3	2.3	3.6	1.5	0.5	4.4	0.4	0.0	0.0	33.7	8.5	2.6	0.0	0.1	11.3	0.7	1.1	3.2	11.9
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.2	4.3	4.2	6.7	2.8	0.9	8.2	0.7	0.0	0.0	62.7	19.9	6.2	0.0	1.1	20.6	3.4	34.1	78.3	227.0

Source: Author's calculations

Table I: Carbon and Fugitive emissions (MT) Contd.

CO_2 (MT) - Energy Supply																			
41	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**
0.0	0.0	0.1	0.0	0.0	0.4	0.3	1.2	3.4	0.6	0.4	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

0.0	0.0	0.0	13.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.2	0.0	0.0	1.4	1.0	4.5	12.7	2.3	1.4	6.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	6.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CO_2 (MT) - Energy demand																			
12.3	0.5	1.1	0.2	1.2	0.6	1.0	0.9	4.6	1.0	2.8	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.5	0.1	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.5	0.7	1.4	0.2	1.6	0.8	1.3	1.1	5.9	1.3	3.6	1.2	0.0	0.1	0.0	0.0	2.9	0.3	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	843.5	80.9	0.0	0.0
12.8	21.2	2.9	19.9	2.9	3.2	3.7	7.8	27.1	5.3	8.4	10.6	0.0	0.1	0.0	0.0	846.4	81.3	0.0	0.0

Source: Author’s calculations

Table I: Carbon and Fugitive emissions (MT) Contd.

CO_2 (MT) - Energy Supply														
61	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.4
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.5
CO_2 (MT) - Energy demand														

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.6
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	38.4	0.0	0.0	0.0	0.0	0.0	16.3	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	39.4	0.0	0.0	0.0	0.0	0.0	16.3	0.2	0.0	0.0	0.0	0.0	124.0

Source: Author's calculations

Table I: Carbon and Fugitive emissions (MT) Contd.

CO_2 (MT) - Energy Supply																								
76	**77**	**78**	**79**	**80**	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**Tot.**
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	95.5
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.9
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	47.0
CO_2 (MT) - Energy demand																								
0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	18.1	0.0	0.0	0.0	0.0	0.0	0.0	0.9	1.9	0.0	0.0	0.0	432
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9	0.0	2.0	0.0	0.0	0.0	0.0	0.1	1.8	0.0	0.0	0.0	22.0
0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	23.2	21.0	193	7.9	7.4	0.0	0.0	28	71.6	0.0	0.0	0.0	503
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	266	31.8	0.0	0.0	0.0	298
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	979
0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.1	0.0	0.0	0.0	43.2	21.0	196	7.9	7.4	0.0	0.0	295	107	0.0	0.0	0.0	2434

Table I: Carbon and Fugitive emissions (MT) Contd.

Fugitive emissions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Food related emissions (MT)	549	29	3	4	0	2	11	20	8	10	11	31	0	0	0	0	0	20	364	151	1	0	0	0	0	0	0	0	0	0
Water related emissions (MT)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Energy related emissions (MT)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: Author's calculations

Table I: Carbon and Fugitive emissions (MT) Contd.

31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	20	0	20	0	2	1	6	16	3	2	8	0	0	0	0	0	0	0	0	0	0	0

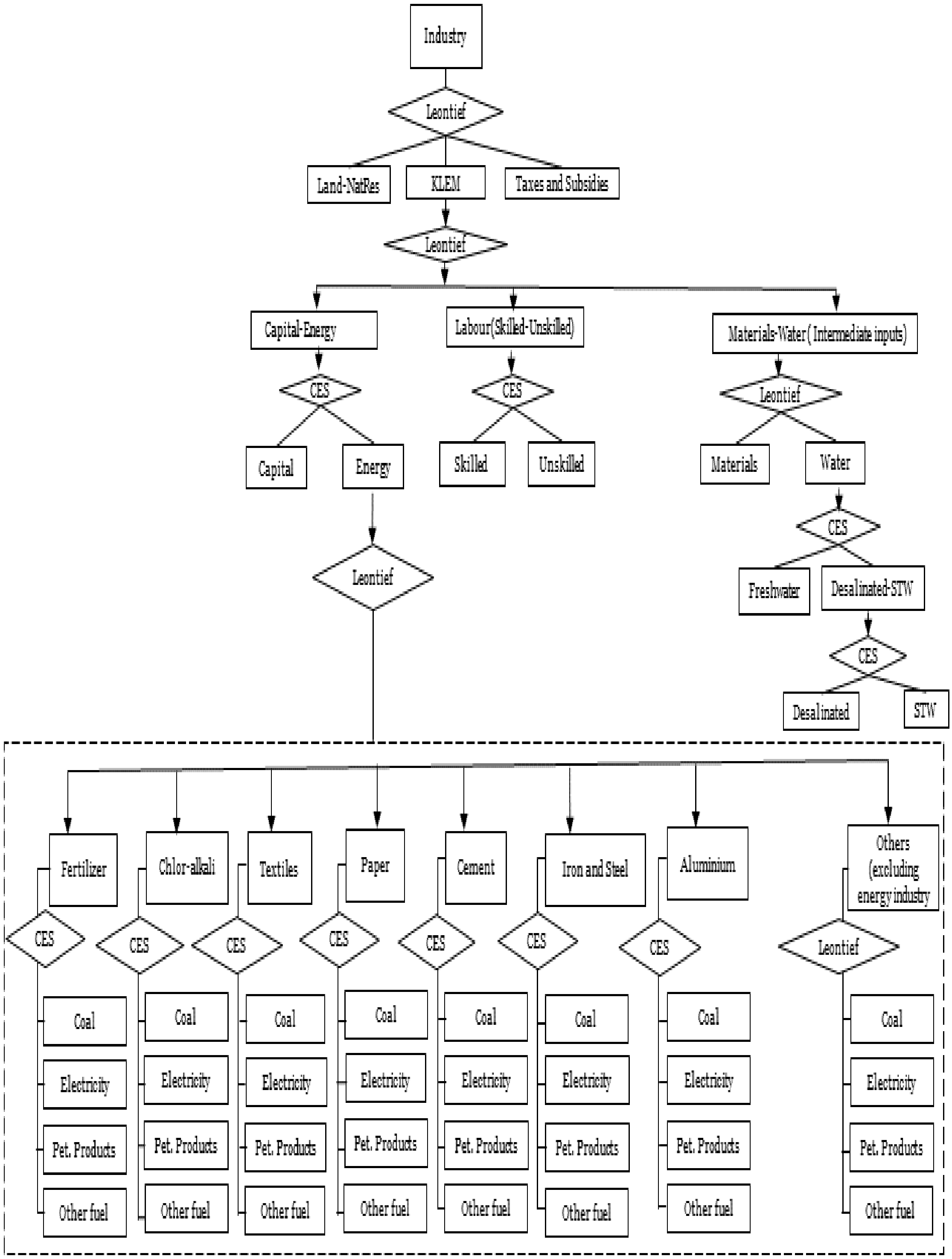
Source: Author's calculations

Table I: Carbon and Fugitive emissions (MT) Contd.

64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	123	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Source: Author's calculations

Appendix C: Nested elasticity structures



Where K-Capital, L-Labour (Skilled and Unskilled), E- Energy, M-Material

Figure A: Nested elasticity structure of Energy Intensive Industries

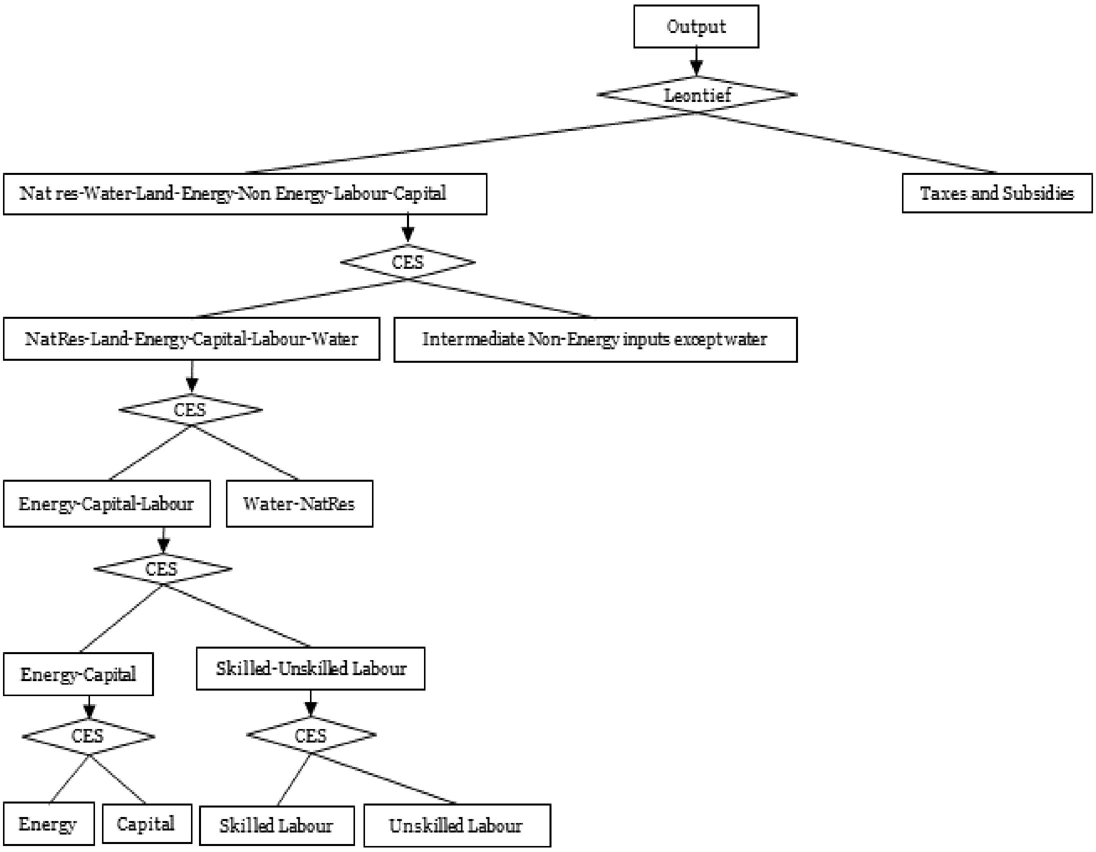


Figure B: Nested Elasticity Structure of Water sector

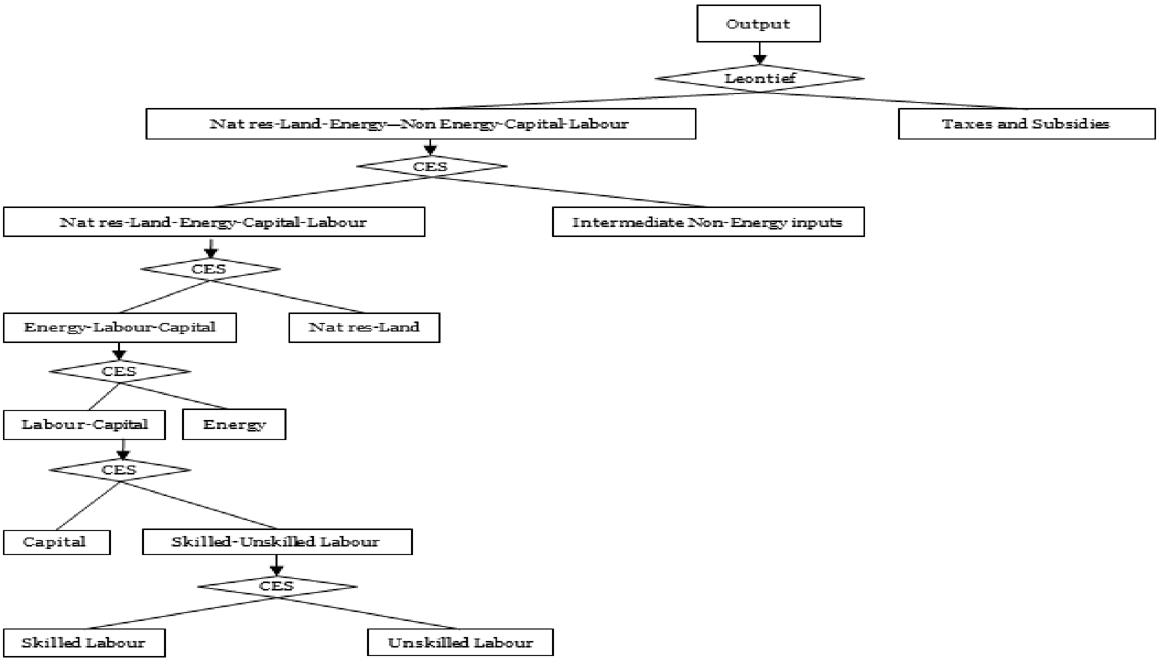


Figure C: Nested Elasticity Structure of Other Industries and Services

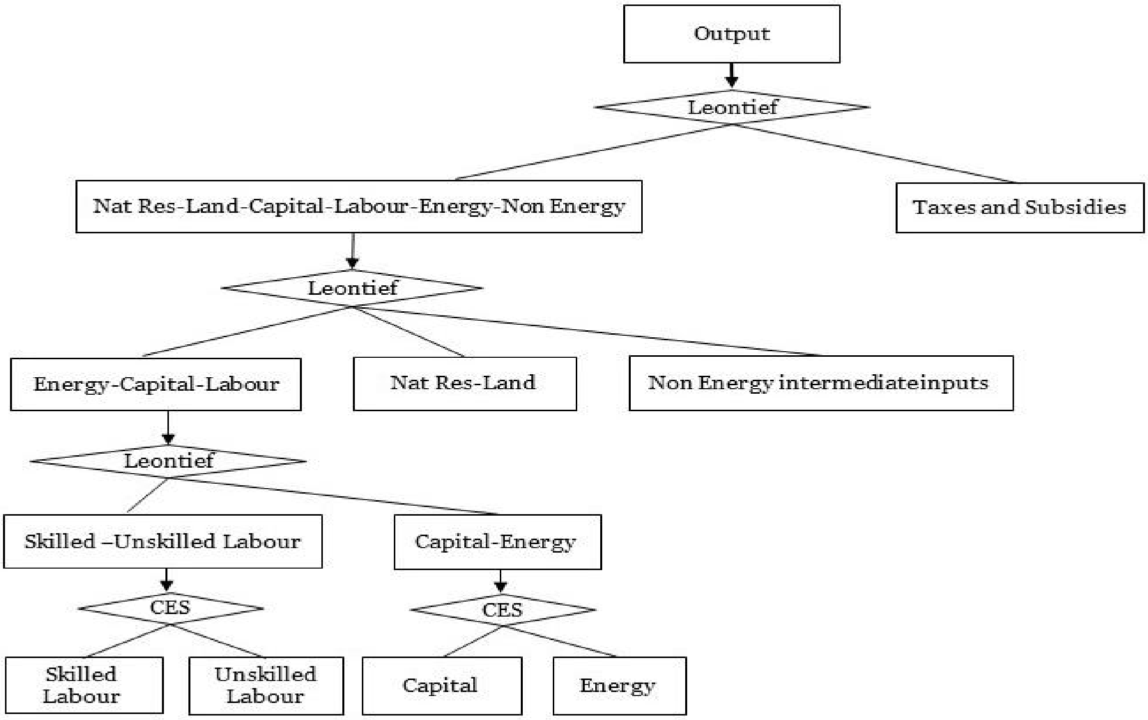


Figure D.: Nested Elasticity Structure of Transport Sector

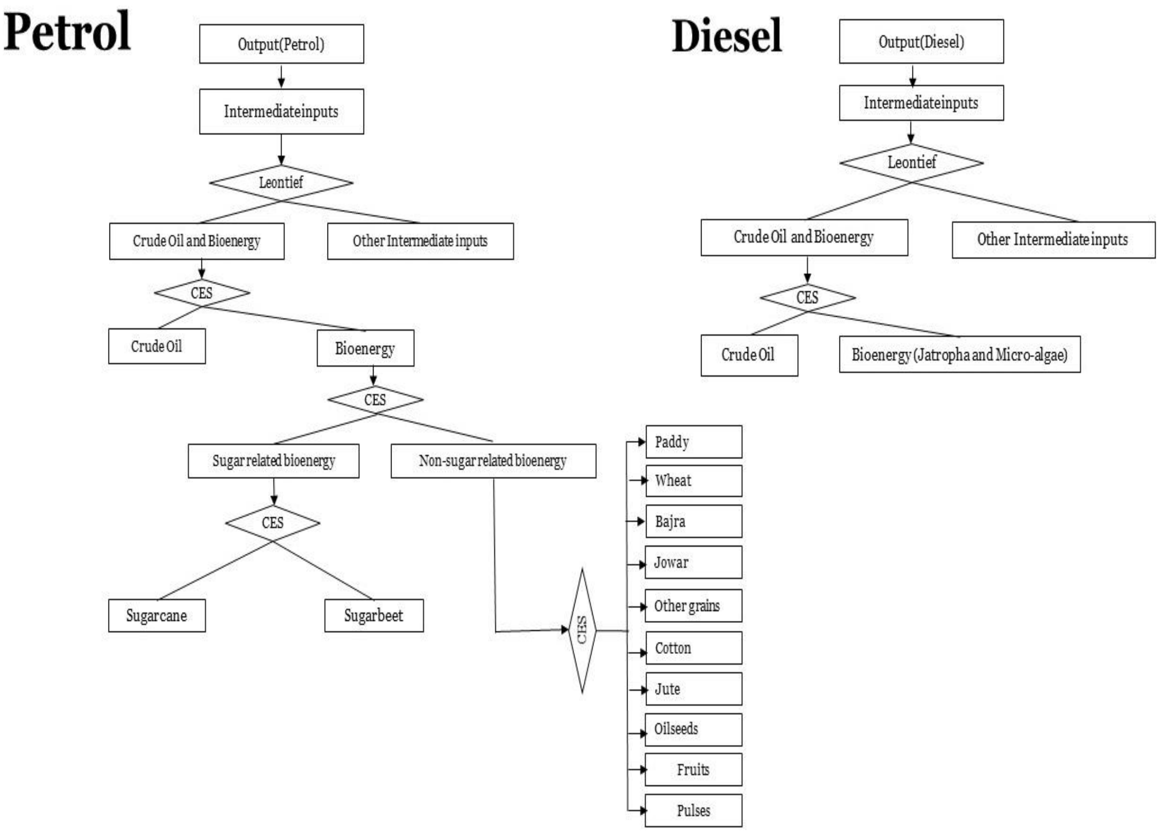


Figure E. Nested Elasticity Structure of Input Substitution in Petrol and Diesel sectors

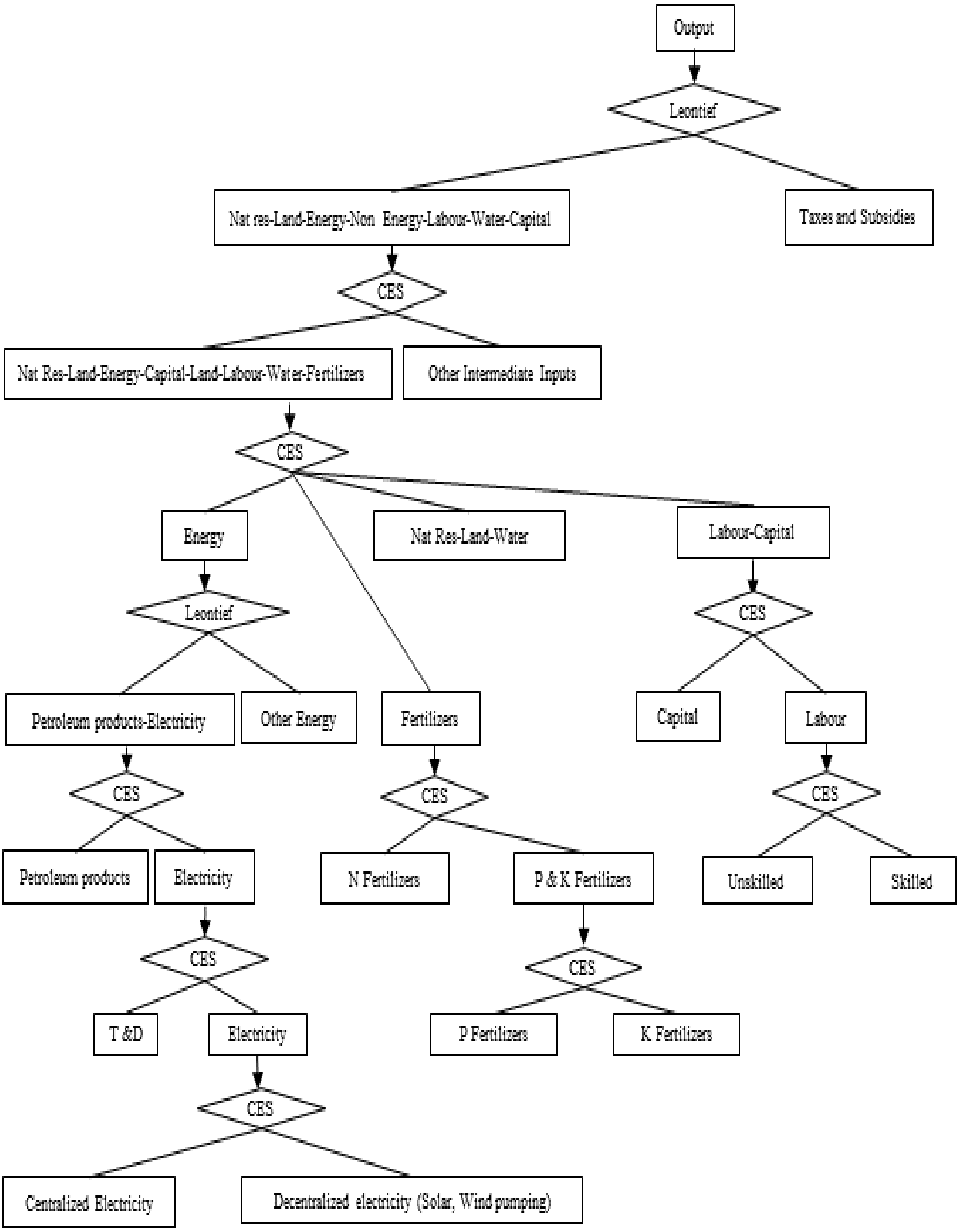


Figure F. Nested Elasticity Structure of Crop Production Sectors

Appendix D: Crop-wise details on Agriculture and food sector scenario variables

Table J: Assumed values for food demand in Kg/capita/year (BAU, ES, and WS Scenarios)

Commodities	Urban (kg/capita/year)				Rural (kg/capita/year)			
	2015	2022	2032	2047	2015	2022	2032	2047
Paddy	4.81	5.01	5.31	5.75	6.88	6.81	6.72	6.57
Wheat	57.89	59.32	61.35	64.39	59.26	60.41	62.05	64.51
Jowar	3.70	3.92	4.23	4.71	5.49	5.87	6.42	7.24
Bajra	3.75	3.58	3.33	2.97	10.48	10.14	9.66	8.94
Maize	1.28	1.42	1.63	1.94	8.50	8.60	8.74	8.96
Other Grains	0.96	1.37	1.95	2.82	1.14	1.65	2.38	3.48
Roots and Tubers	26.76	28.41	30.76	34.29	32.96	32.97	32.98	33.00
Other Vegetables	90.44	88.35	85.37	80.89	76.66	77.33	78.28	79.71
Fruits	70.55	65.44	58.14	47.19	43.30	42.64	41.70	40.28
Pulses	16.53	16.83	17.25	17.87	14.71	14.97	15.34	15.89
Oilseeds	6.44	6.44	6.44	6.44	6.44	6.44	6.44	6.44
Sugarcane	9.81	9.81	9.81	9.81	9.81	9.81	9.81	9.81
Sugar beet	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cotton	3.62	3.66	3.68	3.78	3.42	3.50	3.54	3.77
Other crops	0.01	0.02	0.02	0.04	0.01	0.01	0.02	0.04
Other animal products (poultry)	7.19	7.35	7.58	7.93	5.54	5.83	6.25	6.87
milk	98.62	98.25	97.72	96.93	80.01	80.46	81.10	82.07
Cattle meat	1.31	1.20	1.18	1.14	0.96	0.89	0.87	0.85
Other meat	2.60	2.72	2.78	2.85	1.90	2.00	2.06	2.13
Vegetable oil	10.53	10.92	11.51	12.44	8.54	9.27	10.43	12.44
Milk products	3.29	3.28	3.26	3.23	2.67	2.68	2.70	2.74
Processed rice	54.49	56.82	60.16	65.16	68.88	68.19	67.22	65.75
sugar	21.06	22.36	24.23	27.04	19.23	20.92	21.89	26.97
fish	5.19	5.35	5.58	5.93	5.43	5.55	5.71	5.95
Other preserved food	0.05	0.06	0.10	0.15	0.04	0.05	0.10	0.15

Table K: Assumed values for crop yield in tonnes/ha (BAU, ES, and WS Scenarios)

Crops	2015	2022	2032	2047
Rice	2.1	2.3	2.6	3.1
Wheat	2.9	3.2	3.7	4.5
Jowar	1	1	1.1	1.1
Bajra	1.3	1.4	1.5	1.5
Maize	2.2	2.5	2.9	3.7
Coarse Cereals	1.6	1.8	1.8	1.9
Roots and tubers	22.1	22.2	22.3	22.5
Other vegetables	13	13.1	13.3	13.5
Fruits	12.6	13.4	14.7	16.5
Pulses	0.7	0.8	0.9	1
Oilseeds	1.1	1.3	1.6	2.2
Sugarcane	69.9	70.5	71	72

Sugarbeet	58	58	58	58
Cotton*	0.5	0.5	0.5	0.5

Source: Derived from Amarsinghe et al. (2007)

Table L: Assumed values for area under crops in Million Hectares (BAU, ES, and WS Scenarios)

Crops	2015	2022	2032	2047
Rice	43.9	44.4	45	46
Wheat	30.8	30	28.8	27
Jowar	5.2	4.9	4.4	3.6
Bajra	7	6.6	5.8	4.8
Maize	9.4	11.1	13.5	17
Coarse Cereals	2.4	2.3	2	1.7
Roots and tubers	2.3	2.5	2.7	3
Other vegetables	9	9.4	9.9	10.7
Fruits	6.3	6.7	7.2	8
Pulses	23	22.3	21.4	20
Oilseeds	26.1	28.9	32.8	38.7
Sugarcane	5	5	5	5
Sugar beet	0	0	0	0
Cotton	13.1	13.3	13.6	14

Source: Derived from Amarsinghe et al. (2007)

Table M: Assumed values for Irrigated Area in Million Hectares (BAU, ES, and WS Scenarios)

Crops	2015	2022	2032	2047
Rice	25.6	26.1	26.7	27.6
Wheat	28.8	28.3	27.4	26.2
Jowar	0.5	0.5	0.6	0.8
Bajra	0.7	0.7	0.8	1.1
Maize	2.4	2.9	3.8	5.1
Coarse Cereals	0.5	0.5	0.6	0.8
Roots and tubers	2.3	2.5	2.7	3
Other vegetables	9	9.4	9.9	10.7
Fruits	6.3	6.7	7.2	8
Pulses	4.3	4.4	0	4.4
Oilseeds	7.4	8.5	10	12.4
Sugarcane	4.8	4.8	4.8	4.9
Sugar beet	0	0	0	0
Cotton	4.5	4.7	5.1	5.6

Source: Derived from Amarsinghe et al. (2007)

Table O: Assumed values for feed Conversion Ratio in Kg/1000 Kcal (BAU, ES, and WS Scenarios)

Feed conversion ratio (kg/1000 kcal)	2015	2022	2032	2047
Rice	0.003	0.003	0.003	0.002
Wheat	0.009	0.009	0.008	0.007
Maize	0.139	0.182	0.270	0.486
Jowar	0.004	0.003	0.002	0.002

Bajra	0.004	0.003	0.002	0.002
Other (cereals)	0.004	0.003	0.002	0.002
Pulses	0.011	0.009	0.007	0.005
Oilseeds equivalent	0.008	0.007	0.006	0.004
Oilseeds	0.008	0.007	0.006	0.004
Oil	0.003	0.002	0.002	0.001
sugarcane	0.033	0.027	0.021	0.014

Source: Derived from Amarsinghe et al. (2008)

Table P: Assumed seed and waste rates as % of total consumption (BAU, ES, and WS Scenarios)

Crops	2015	2022	2032	2047
Rice	6.2	6	5.9	5.9
Wheat	10.6	10.1	9.4	8.5
Maize	12.4	10.8	8.7	6.4
Jowar	9.7	9.7	9.7	9.7
Bajra	9.7	9.7	9.7	9.7
Other (cereals)	9.7	9.7	9.7	9.7
Pulses	6.8	6.1	5.9	5.9
Oilseeds equivalent	12.7	12.7	12.7	12.7
Oilseeds	12.7	12.7	12.7	12.7
Oil	0	0	0	0
Roots and Tubers	19.2	19.2	19.2	19.2
Vegetables	6	5.6	5.2	4.6
Sugar (raw equivalent)	0	0	0	0
sugarcane	0.4	0.4	0.4	0.4
Sugarbeet	0	0	0	0
sugar	0	0	0	0
Fruits	14	14	14	14
Cotton*	5	5	5	5

Source: Derived from Amarsinghe et al. (2008), *Assumed

Table Q: Assumed food demand in kg/capita/year (FS and Nexus Scenarios)

	Urban (kg/capita/year)				Rural (kg/capita/year)			
	2015	2022	2032	2047	2015	2022	2032	2047
Paddy	4.81	4.95	5.09	5.28	6.88	6.58	6.30	5.88
Wheat	57.89	56.98	56.16	54.92	59.26	57.92	56.70	54.88
Jowar	3.70	4.04	4.36	4.83	5.49	6.09	6.64	7.45
Bajra	3.75	3.48	3.24	2.88	10.48	9.95	9.47	8.75
Maize	1.28	2.76	4.11	6.13	8.50	7.71	7.00	5.93
Other Grains	0.96	1.60	2.18	3.06	1.14	1.94	2.68	3.77
Roots and Tubers	26.76	29.35	31.71	35.24	32.96	33.60	34.19	35.06
Other Vegetables	90.44	93.44	96.17	100.27	76.66	83.99	90.66	100.67
Fruits	70.55	71.95	73.22	75.13	43.30	53.26	62.32	75.91
Pulses	16.53	19.19	21.61	25.24	14.71	17.94	20.88	25.29
Oilseeds	6.44	6.44	6.44	6.44	6.44	6.44	6.44	6.44
Sugarcane	9.81	9.81	9.81	9.81	9.81	9.81	9.81	9.81

Sugar beet	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cotton	3.62	3.68	3.70	3.81	3.42	3.54	3.59	3.81
Other crops	0.01	0.01	0.02	0.03	0.01	0.01	0.02	0.03
Other animal products (poultry)	7.19	7.44	7.67	8.02	5.54	6.31	7.01	8.07
Milk	98.62	101.08	103.32	106.68	80.01	88.32	95.88	107.21
Cattle meat	1.31	1.20	1.18	1.14	0.96	0.89	0.87	0.86
Other meat	2.60	2.73	2.79	2.86	1.90	2.02	2.07	2.15
Vegetable oil	10.64	11.22	12.11	13.59	8.63	9.53	10.98	13.59
Milk products	3.29	3.37	3.44	3.56	2.67	2.94	3.20	3.57
Processed rice	54.49	56.13	57.63	59.88	68.88	65.80	63.01	58.82
Sugar	21.06	23.11	24.98	27.79	19.23	21.89	22.86	27.94
Fish	5.19	5.44	5.67	6.02	5.43	5.61	5.77	6.02
Other preserved food	0.05	0.05	0.08	0.13	0.04	0.04	0.08	0.13

Table R: Assumed feed conversion ratio in kg/1000 Kcal (FS and Nexus Scenarios)

Feed conversion ratio (kg/1000 kcal)	**2015**	**2022**	**2032**	**2047**
Rice	0.003	0.003	0.003	0.002
Wheat	0.010	0.009	0.008	0.007
Maize	0.131	0.168	0.239	0.406
Jowar	0.004	0.003	0.003	0.002
Bajra	0.004	0.003	0.003	0.002
Others (cereals)	0.004	0.003	0.003	0.002
Pulses	0.011	0.009	0.008	0.006
Oil Crops equivalent	0.008	0.007	0.006	0.005
Oilseeds	0.008	0.007	0.006	0.005
Oil	0.003	0.002	0.002	0.002
Sugarcane	0.035	0.029	0.023	0.016

Table S: Assumed crop yields in tonnes/ha (FS and Nexus Scenarios)

Crops	**2015**	**2022**	**2032**	**2047**
Rice	2.1	2.5	3.1	4.1
Wheat	2.9	3.4	4.3	5.9
Jowar	1.0	1.1	1.3	1.5
Bajra	1.3	1.5	1.7	2.0
Maize	2.2	2.7	3.4	4.8
Coarse Cereals	1.6	1.9	2.1	2.5
Roots and tubers	20.7	21.6	22.9	25.0
Other vegetables	13.0	13.4	14.1	15.0
Fruits	12.6	14.5	15.3	16.5
Pulses	0.7	0.8	1.0	1.3
Oilseeds	1.1	1.4	1.8	2.5
Sugarcane	69.9	70.5	71.0	72.0
Sugarbeet	58.0	58.0	58.0	58.0
Cotton	0.5	0.6	0.9	1.3

Table T: Assumed Irrigated Area in Million hectares (FS and Nexus Scenarios)

Crops	2015	2022	2032	2047
Rice	25.6	26.4	27.8	29.9
Wheat	28.8	28.5	27.8	26.7
Jowar	0.5	0.6	0.8	1.1
Bajra	0.7	0.8	1.0	1.5
Maize	2.5	3.2	4.4	6.8
Coarse Cereals	0.5	0.6	0.7	1.0
Roots and tubers	2.3	2.5	2.7	3.0
Other vegetables	9.0	9.4	9.9	10.7
Fruits	6.3	6.7	7.2	8.0
Pulses	4.3	4.5	0.0	5.0
Oilseeds	7.4	8.6	10.4	13.5
Sugarcane	4.8	4.8	4.8	4.9
Sugarbeet	0.0	0.0	0.0	0.0
Cotton	4.5	5.2	6.3	8.4

Table U: Assumed seed and waste rates as % of total consumption (FS and Nexus Scenarios)

Seeds and waste (% of total consumption)	2015	2022	2032	2047
Rice	5.9	5.5	5.3	5.3
Wheat	9.9	9.2	8.5	7.6
Maize	11.7	9.8	7.9	5.7
Jowar	9.1	8.8	8.7	8.7
Bajra	9.1	8.8	8.7	8.7
Others (cereals)	9.1	8.8	8.7	8.7
Pulses	6.3	5.6	5.3	5.3
Oil Crops equivalent	11.9	11.6	11.4	11.4
Oilseeds	11.9	11.6	11.4	11.4
Roots and Tubers	18.0	17.5	17.3	17.3
Vegetables	5.6	5.1	4.7	4.1
Sugar (raw equivalent)	0.0	0.0	0.0	0.0
Sugarcane	0.4	0.4	0.4	0.4
Fruits	13.1	12.8	12.6	12.6
Cotton (assumed as 5 %)	5.0	5.0	5.0	5.0

Appendix E: Final Disaggregated Coefficient Matrix

Table V: Disaggregated coefficient matrix (93 Sectors, 5 Factors of production, 6 Final demand categories)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.01	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.11	0.02	0.13	0.09	0.12	0.11	0.01	0.03	0.03	0.05	0.07	0.02	0.02	0.10	0.06
18	0.00	0.00	0.00	0.03	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.01	0.10	0.04	0.03	0.06	0.04	0.01	0.01	0.01	0.01	0.03	0.04	0.04	0.05	0.04
33	0.00	0.03	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.01
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
37	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	0.01	0.05	0.04	0.07	0.04	0.05	0.01	0.01	0.01	0.02	0.03	0.02	0.02	0.03	0.02
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
53	0.01	0.06	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
54	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57	0.02	0.11	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.02	0.01
58	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63	0.01	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	0.00	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
89	0.01	0.08	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.02
90	0.00	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
91	0.00	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
33	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
94	0.35	0.24	0.24	0.30	0.30	0.28	0.35	0.36	0.36	0.37	0.31	0.32	0.32	0.20	0.41
95	0.30	0.20	0.30	0.21	0.22	0.24	0.30	0.31	0.31	0.32	0.27	0.28	0.28	0.28	0.25
96	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	-0.04	0.00	0.00	0.00	0.00	0.00
97	0.14	0.10	0.15	0.12	0.07	0.11	0.12	0.15	0.15	0.17	0.13	0.13	0.13	0.06	0.19
98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
99	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
101	0.00	0.01	-0.01	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
102	-0.05	-0.3	-0.02	-0.02	-0.02	-0.02	0.00	0.00	0.00	0.00	-0.02	-0.11	-0.11	-0.13	-0.13

Source: Author’s Estimates

Table V: Disaggregated coefficient matrix (93 Sectors, 5 Factors of production, 6 Final demand categories) Contd.

	16	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
1	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.01	0.00	0.00
2	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00
10	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.37	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.09	0.26	0.21	0.08	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.04	0.31	0.00	0.00
17	0.03	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.73	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.02	0.02	0.01	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.03	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.04	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
27	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.08	0.02	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.04	0.01	0.00	0.03	0.00	0.00	0.05	0.00	0.00	0.00	0.01
31	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.03	0.02	0.01	0.00	0.01	0.02
32	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
33	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.04	0.01	0.03	0.03	0.09	0.01	0.03	0.01	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.03
38	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.07
52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
53	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.00	0.00
58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	16	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.00	0.01	0.00
89	0.02	0.21	0.09	0.06	0.27	0.05	0.12	0.21	0.06	0.23	0.33	0.08	0.28	0.02	0.01
90	0.01	0.03	0.01	0.01	0.06	0.01	0.01	0.05	0.02	0.01	0.07	0.02	0.04	0.02	0.01
91	0.01	0.02	0.01	0.01	0.04	0.01	0.01	0.03	0.02	0.01	0.05	0.01	0.03	0.01	0.01
92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
93	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
101	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
102	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Author’s Estimates

Table V: Disaggregated coefficient matrix (93 Sectors, 5 Factors of production, 6 Final demand categories) Contd.

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
14	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.15	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.03	0.03	0.04	0.05	0.02	0.01
32	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.21	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.04	0.00	0.00	0.00	0.00	0.21	0.06	0.06	0.03	0.01	0.02	0.04	0.02	0.02	0.02
37	0.02	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.01	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.01	0.00	0.00
40	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.01	0.00	0.00	0.00	0.00
41	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	0.00	0.03	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.03	0.00	0.00	0.00	0.00
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.06
50	0.00	0.00	0.01	0.01	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00
52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.05	0.00	0.00	0.00	0.00	0.00
53	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.01	0.02	0.03	0.00	0.00	0.00	0.02

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57	0.01	0.00	0.00	0.00	0.00	0.02	0.01	0.03	0.03	0.03	0.06	0.00	0.00	0.00	0.03
58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.02	0.00	0.00	0.00	0.01
64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.01
68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.04	0.00	0.00	0.00	0.06	0.01	0.01
89	0.13	0.08	0.08	0.08	0.08	0.08	0.15	0.08	0.09	0.13	0.08	0.03	0.05	0.02	0.04
90	0.02	0.02	0.02	0.02	0.02	0.02	0.05	0.03	0.04	0.03	0.02	0.01	0.01	0.01	0.01
91	0.02	0.01	0.01	0.01	0.01	0.01	0.03	0.02	0.03	0.02	0.02	0.01	0.01	0.01	0.01
92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
101	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
102	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Author's Estimates

Table V: Disaggregated coefficient matrix (93 Sectors, 5 Factors of production, 6 Final demand categories) Contd.

	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.08	0.08	0.08	0.05	0.05	0.05	0.05
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.11	0.10	0.09
43	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02
54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.04	0.04	0.04	0.05	0.05	0.05	0.05
58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02
64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
89	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.25	0.20	0.20	0.20	0.14	0.14	0.14	0.14
90	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.08	0.08	0.08	0.03	0.03	0.03	0.03
91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.06	0.06	0.06	0.02	0.02	0.02	0.02
92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01
93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
101	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
102	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Author’s Estimates

Table V: Disaggregated coefficient matrix (93 Sectors, 5 Factors of production, 6 Final demand categories) Contd.

	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.05	0.05	0.01	0.01	0.06	0.06	0.05	0.05	0.02	0.06	0.06	0.05	0.05	0.05	0.00
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	0.15	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75
44	0.00	0.00	0.06	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51	0.00	0.00	0.37	0.37	0.00	0.00	0.00	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00
52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
53	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00
54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57	0.05	0.05	0.02	0.02	0.02	0.02	0.03	0.03	0.01	0.02	0.02	0.01	0.01	0.01	0.00
58	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.00	0.00	0.00	0.00

	61	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67	0.01	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.19	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	61	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	0.02	0.02	0.00	0.00	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01
89	0.14	0.14	0.03	0.03	0.17	0.05	0.13	0.13	0.06	0.16	0.16	0.12	0.12	0.12	0.08
90	0.03	0.03	0.01	0.01	0.07	0.03	0.05	0.05	0.02	0.07	0.07	0.05	0.05	0.05	0.01
91	0.02	0.02	0.01	0.01	0.05	0.02	0.04	0.04	0.02	0.05	0.05	0.03	0.03	0.03	0.01
92	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
101	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
102	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Author's Estimates

Table V: Disaggregated coefficient matrix (93 Sectors, 5 Factors of production, 6 Final demand categories) Contd.

	76	**77**	**78**	**79**	**80**	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
31	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.10	0.02	0.06
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03
37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00
40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00

41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
53	0.00	0.04	0.00	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.01	0.02	0.00	0.00	0.00
54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57	0.00	0.09	0.00	0.00	0.00	0.00	0.03	0.08	0.01	0.00	0.01	0.04	0.00	0.01	0.00
58	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63	0.00	0.03	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.02	0.00	0.00	0.00
64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67	0.00	0.02	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.00
68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77	0.00	0.00	0.00	0.10	0.10	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.08	0.01	0.04	0.00	0.00	0.00	0.00

83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.02	0.01	0.02
89	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.13	0.08	0.14
90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.01	0.02
91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.01	0.02
92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
101	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
102	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Author's Estimates

Table V: Disaggregated coefficient matrix (93 Sectors, 5 Factors of production, 6 Final demand categories) Contd.

	91	92	93	CGDS/ I	Rural	Urban	VDGM/ G	VST	VXMD
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.04	0.03	0.00	0.00	0.01
9	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	0.01	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.01
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.06	0.05	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.03
23	0.00	0.00	0.00	0.00	0.02	0.03	0.00	0.00	0.00

	91	92	93	CGDS/ I	Rural	Urban	VDGM/ G	VST	VXMD
24	0.00	0.00	0.00	0.00	0.05	0.03	0.00	0.00	0.01
25	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.05	0.05	0.01	0.00	0.02
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
31	0.06	0.04	0.06	0.26	0.06	0.05	0.03	0.00	0.28
32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
36	0.03	0.09	0.11	0.00	0.02	0.02	0.00	0.00	0.11
37	0.00	0.00	0.00	0.00	0.04	0.04	0.01	0.00	0.05
38	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
40	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.03
41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
46	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
47	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00
48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04

	91	92	93	CGDS/ I	Rural	Urban	VDGM/ G	VST	VXMD
49	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
51	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.01
52	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.02
53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00
58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	91	92	93	CGDS/ I	Rural	Urban	VDGM/ G	VST	VXMD
74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
78	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00
83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
84	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
88	0.02	0.01	0.03	0.47	0.00	0.00	0.05	0.00	0.00
89	0.14	0.10	0.10	0.04	0.23	0.36	0.80	0.00	0.18
90	0.02	0.02	0.03	0.01	0.08	0.07	0.01	0.01	0.01
91	0.02	0.01	0.02	0.01	0.01	0.02	0.01	0.00	0.01
92	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.98	0.01
93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

	91	92	93	CGDS/ I	Rural	Urban	VDGM/ G	VST	VXMD
99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
101	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
102	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: Author's Estimates

1. paddy
2. Wheat
3.Jowar
4. Bajra
5. Maize
6. Other Grains
7. Roots and Tubers
8. Other Vegetables
9. Fruits
10. Pulses
11. Oilseeds
12. Sugarcane
13. Sugar beet
14. Cotton
15. Jute
16. other crops
17. Cattle
18. Other animal products (poultry)
19. milk
20. cattle meat
21. other meat
22. Vegetable oils
23. milk products
24. Processed rice
25. sugar
26. fish
27. Other preserved food
28. wool
29. forestry
30. fishing

52. Other pet products and coke
53. T & D
54. PWHR
55. LWR
56. FBR
57. Coal subcritical
58. coal super critical
59. coal Ultra supercritical
60. coal IGCC
61. CCS coal pre
62. CCS coal post
63. Gas power gen
64. CCS gas
65. On-shore wind
66. Offshore wind
67. Large hydro
68. Small hydro
69. Oil power
70. Biomass based
71. Waste to electricity
72. Solar PV
73. Solar CSP
74. Solar distributed
75. gas distribution
76. GW pumping diesel
77. GW pumping electric
78. GW pumping solar
79. Conventional Irrigation (Flood)
80. Efficient Irrigation (Sprinkler)
81. Highly Efficient Irrigation (Drip)

31. Other manufacturing	82. Municipal and industrial Water supply/treatment
32. Nitrogen Fertilizers	83. Sea water desalination
33. Phosphorus Fertilizer	84. Centralized ASP
34. K Fertilizers	85. De-centralized WSP
35. Chlor-alkali	86. Decentralized MBR
36. Other chemical and Petrochemicals	87. Treated sewage water
37. textiles	88. Construction
38. paper	89. services
39. non metal	90. Road transport
40. iron and steel	91. Rail transport
41. nonferrous	92. Air transport
42. coal mining	93. Water transport
43.oil extraction	94: land
44. gas extraction	95: Unskilled Labour
45. other mining	96: Skilled Labour
46. LPG	97: Capital
47. Kerosene	98: Natural Resources
48. Petrol	99: FTRV
49. Diesel	100: FBEP
50. Naphtha	101: ISEP
51. Fuel oil	102: Output tax

Appendix F: Sources for development of satellite accounts

Table W: Water intensities of energy fuels

Water intensities of energy fuels	Unit	Values
Nuclear		
PHWR	m^3/MWh	86.025
LWR	m3/MWh	86.025
FBR	m3/MWh	86.025
Coal		
Sub C	m^3/MWh	32.862
Super C	m^3/MWh	27.267
USC	m^3/MWh	27.267
IGCC	m^3/MWh	1.476
CCS pre coal	m^3/MWh	3.768
CCS post coal	m^3/MWh	3.768
Gas		
Gas Power Stations	m^3/MWh	45.270
CCS gas	m^3/MWh	1.878
Wind		
Onshore Wind	m^3/MWh	0.000
Offshore Wind	m^3/MWh	0.000
Hydro		
Large Hydro Power Generation	m^3/MWh	17.000
Small Hydro	m^3/MWh	0.000
Oil power	m3/MWh	0.000
Others		
Biomass Based Electricity& Biogas	m^3/MWh	1.306
Waste to Electricity	m^3/MWh	0.000
Solar		
Solar PV	m^3/MWh	0.098
Solar CSP	m^3/MWh	1.546
Distributed Solar PV (grid connected)	m^3/MWh	0.000
Other Energy fuels		
Oil Production*	m^3/KWh	0.0003168
Coal mining*	m^3/KWh	
Coal Surface*	m^3/KWh	0.0004464
Coal underground*	m^3/KWh	0.0004464
Gas Mining*	m^3/KWh	0.0001
Oil and Petroleum products imports for refining*	m^3/KWh	0.0001332

Source: Derived from Macknick et al. (2011) and *Spang et al. (2014)

Table X: Water intensities of industrial products

Water use per unit product		2011
Iron and Steel	m^3/ton	22.00
Pulp and paper	m^3/ton	192.50
Textile	m^3/ton	209.17
Fertilizer	m^3/MT	6.60
Cement	m^3/ton	5.50
Chlor alkali	m^3/ton	5.50
Aluminium	m^3/ton	5.51

Source: NCIWRD (1999)

Table Y: Water intensities of agriculture and food crops

	Blue water	Green Water
	m^3/tonne	m^3/tonne
Rice	4302.0	3877.0
Wheat	1792.0	235.0
Maize	608.0	2577.0
Jowar	681.0	8398.0
Bajra	304.0	4515.0
Others (cereals)	128.6	167.6
Pulses	695.0	4418.0
Oil Crops equivalent	660.0	2592.3
Roots and Tubers	31.7	391.3
Vegetables	187.0	174.0
Sugar (raw equivalent)	305.0	31.0
Fruits	598.0	556.0
Cotton	6538.0	13213.0
Sugarbeet*	103	177
Sweet Sorghum*	2342	6366
Jatropha*	15812	8141

Source: Bogra (2017), *Gerbens-Leenes et al. (2008)

Table Z: Dietary intake of rural and urban population in India; Year 2015

	Dietary norms			Kcal/ person/ day	Kcal/ person/ day	Protein (gms)	Protein (gms)	Fat (gms)	Fat (gms)
	Kcal/ Kg.	Protein (gm)	Fats (gms)	Urban	Rural	Urban	Rural	Urban	Rural
Paddy	3608	68	8	44	58	1	1	0	0
Wheat	3100	91	14	457	428	14	15	2	2
Jowar	3209	95	35	31	46	1	1	0	1
Bajra	3099	90	35	30	84	1	3	0	1
Maize	2961	74	37	10	59	0	2	0	1
Other grains	2542	65	11	6	8	0	0	0	0
Roots and Tubers	706	13	1	52	64	1	1	0	0

Other Vegetables	253	13	2	44	32	3	3	0	0
Fruits	466	6	3	63	33	1	1	1	0
Pulses	3438	205	29	140	125	9	8	1	1
Oilseeds	2032	27	195	36	36	0	0	3	3
Sugarcane	296	1	2	8	8	0	0	0	0
Sugar beet	296	1	2	0	0	0	0	0	0
Cotton	0	0	0	0	0	0	0	0	0
Other animal products (poultry)	1277	114	88	24	19	2	2	2	1
milk + milk products	814	34	55	182	184	10	8	15	12
Cattle meat	1378	136	91	5	4	0	0	0	0
Other meat	2010	141	169	14	10	1	1	1	1
Vegetable oil	8813	0	999	254	206	0	0	29	23
Processed rice	3608	68	8	501	579	10	13	1	2
sugar	3533	1	0	204	186	0	0	0	0
fish	633	110	23	9	9	2	2	0	0
Other crops	2460	95	92	31	23	1	1	1	1
Miscellaneous (other preserved food)	2461	2	0	126	93	0	0	0	0
Total				2270	2294	59	61	59	51

Source: Derived from FAOSTAT (2011-12) and population from PFI (2007)

Table AA: Skilled and Unskilled employment in India, Year 2015

Employment	Persons
Skilled	9312377
Unskilled	456306482
Total	465618859

Sources: Derived from ILO (2013-14), GoI (2013), Sharma and Prakash (2011), Rutovitz and Harris (2012), GoI (2016b)

Table AB: Land Accounts; Year 2015

	Mha
Land (for energy, water, and food provisioning*)	153

*excluding rivers, oceans, lakes, and forests

Sources: Energy - GoI 2015a, Garg n.d., Water - MoUD 2012, CMWSSB 2012, Food - GoI 2016a

Table AC: Combustion emission factors

Combustion emissions factors	Per TWh		
Fuel	CO_2 (Mt)	CH_4 (Mt CO2e)	N_2O (Mt CO2e)
Coal	0.347096774	0.001019645	0.003074761
Petroleum Products	0.26672399	0.00033207	0.004798911
Natural gas	0.198947368	0.000398787	0.000428915

Source: GoI, 2015a

Table AD: Fugitive emissions (year 2015)

Sector	MT
Energy	2402.268
Food	1248.863
Water	0.173098

Source: Energy – GoI 2015a, Water – Singh and Kansal 2018, Food – Vetter et al. 2017

Appendix G: Assumed values and sources for elasticities of substitution

Table AE: Assumed values of elasticities of substitution for Private Consumption

Food and Energy-Water-Others	0
Others and Energy-Water	0
Energy and Water	0
Energy	
Petrol-Diesel-Coal-Charcoal-Kerosene-Biomass and CNG-LPG-PNG-FCV-Electric-Solar distributed	2.00
LPG-PNG-CNG and FCV-Electric-Solar distributed	0.50
PNG-CNG and LPG	0.50
PNG and CNG	0.00
FCV and Electric-solar distributed	1.00
Electric and Solar distributed	1.00
Petrol-Diesel and Coal-Charcoal-Kerosene-Biomass	0.00
Petrol and Diesel	0.00
Coal-Charcoal and Biomass-kerosene	1.00
Coal and Charcoal	1.00
Biomass and Kerosene	1.00
Food	
Grains (Rice, Wheat, Other grains) and Other food (F&V + Oil + pulses+ milk+ meat)	1.00
Rice-Wheat and Maize-Jowar-Bajra-Other grains	0.50
Rice-Processed rice and Wheat	1.00
Maize and Jowar-Bajra-Other grains	1.00
Jowar-Bajra and Othergrains	1.00
Jowar and Bajra	1.00
Pulses-Milk-Meat-Milk prod and Oil and F&V, sugar, cane and beet, other crops , other preserved	0.50
Pulses-Milk and Poultry-Cattle meat-Other meat-Fish	0.50
Poultry-Fish and Other meat-cattle meat	0.00
Poultry and Fish	0.50
Other meat and Cattle meat	0.50
Pulses and Milk and Milk products	2.00
Milk and Milk products	1.00
Processed rice and Paddy	0.00
Water	
Municipal water and Desalinated water	1.00

Table AF: Values for elasticities of substitution between domestic and imported commodities

Domestic and Imported	**Armington Elasticities**
1. paddy	5.050
2. Wheat	4.450
3.Jowar	1.300

4. Bajra	1.300
5. Maize	1.300
6. Other Grains	1.300
7. Roots and Tubers	1.850
8. Other Vegetables	1.850
9. Fruits	1.850
10. Pulses	1.850
11. Oilseeds	2.450
12. Sugarcane	2.700
13. Sugar beet	2.700
14. Cotton	2.500
15. Jute	2.500
16. other crops	3.250
17. Cattle	2.000
18. Other animal products	1.300
19. milk	3.650
20. cattle meat	3.850
21. other meat	4.400
22. Vegetable oil	3.300
23. milk products	3.650
24. Processed rice	2.600
25. sugar	2.700
26. fish	2.000
27. Other preserved food	2.000
28. wool	6.450
29. forestry	2.500
30. fishing	1.250
31. Other manufacturing	3.630
32. Nitrogen Fertilizers	3.300
33. Phosphorus Fertilizer	3.300
34. K Fertilisers	3.300
35. Chlor-alkali	3.300
36. Other chemical and Petrochemicals	3.300
37. textiles	3.750
38. paper	2.950
39. non-metal	2.900
40. iron and steel	2.950
41. nonferrous	4.200
42. coal mining	3.050
43.oil extraction	5.200
44. gas extraction	17.200
45. Other mining	0.900
46. LPG	2.100

47. Kerosene	2.100
48. Petrol	2.100
49. Diesel	2.100
50. Naphtha	2.100
51. Fuel oil	2.100
52. Other pet products and coke	2.100
53. T & D	2.800
54. PWHR	2.800
55. LWR	2.800
56. FBR	2.800
57. Coal subcritical	2.800
58. coal super critical	2.800
59. coal Ultra Supercritical	2.800
60. coal IGCC	2.800
61. CCS coal pre	2.800
62. CCS coal post	2.800
63. Gas power gen	2.800
64. CCS gas	2.800
65. On-shore wind	2.800
66. Offshore wind	2.800
67. Large hydro	2.800
68. Small hydro	2.800
69. Oil power	2.800
70. Biomass based	2.800
71. Waste to electricity	2.800
72. Solar PV	2.800
73. Solar CSP	2.800
74. Solar distributed	2.800
75. gas distribution	2.800
76. GW pumping diesel	2.800
77. GW pumping electric	2.800
78. GW pumping solar	2.800
79. Conventional Irrigation (Flood)	2.800
80. Efficient Irrigation (Sprinkler)	2.800
81. Highly Efficient Irrigation (Drip)	2.800
82. Municipal and industrial Water supply/treatment	2.800
83. Sea water desalination	2.800
84. Centralized ASP	2.800
85. De-centralized WSP	2.800
86. De-centralized MBR	2.800
87. Treated sewage water	2.800

88. Construction	1.900
89. services	1.900
90. Road transport	1.900
91. Rail transport	1.900
92. Air transport	1.900
93. Water transport	1.900

Source: GTAP Database 9.0 (Aguiar *et al.* 2016)

Table AG: Values for Capital and Labour Substitution (short and long term)

Sectors	Short term[1](K-L)*	Long term[2] (K-L)**
1. paddy	0.305	1.14
2. Wheat	0.305	1.14
3.Jowar	0.305	1.14
4. Bajra	0.305	1.14
5. Maize	0.305	1.14
6. Other Grains	0.305	1.14
7. Roots and Tubers	0.305	1.14
8. Other Vegetables	0.305	1.14
9. Fruits	0.305	1.14
10. Pulses	0.305	1.14
11. Oilseeds	0.305	1.14
12. Sugarcane	0.305	1.14
13. Sugar beet	0.305	1.14
14. Cotton	0.305	1.14
15. Jute	0.305	1.14
16. other crops	0.305	1.14
17. Cattle	0.305	1.14
18. Other animal products	0.565	0.71
19. milk	0.565	0.71
20. cattle meat	0.565	0.71
21. other meat	0.565	0.71
22. Veg oil	0.565	0.71
23. milk products	0.565	0.71
24. Processed rice	0.565	0.71
25. sugar	0.565	0.71
26. fish	0.565	0.71
27. Other preserved food	0.565	0.71
28. wool	0.565	0.71
29. forestry	0.305	0.67
30. fishing	0.305	0.34
31. Other manufacturing	0.565	0.71

32. Nitrogen Fertilizers	0.565	0.71
33. Phosphorus Fertilizer	0.565	0.71
34. K Fertilizers	0.565	0.71
35. Chlor-alkali	0.565	0.71
36. Other chemical and Petrochemicals	0.565	0.71
37. textiles	0.565	0.71
38. paper	0.565	0.71
39. Non-metal	0.565	0.71
40. Iron & steel	0.565	0.71
41. nonferrous	0.565	0.71
42. Coal mining	0.565	0.36
43.Oilext	0.565	0.36
44. Gas extraction	0.565	0.36
45. other mining	0.565	0.36
46. LPG	0.64	1.3*
47. Kerosene	0.64	1.3*
48. Petrol	0.64	1.3*
49. Diesel	0.64	1.3*
50. Naphtha	0.64	1.3*
51. Fuel oil	0.64	1.3*
52. Other pet products and coke	0.64	1.3*
53. T & D	0.64	1.22
54. PWHR	0.64	1.22
55. LWR	0.64	1.22
56. FBR	0.64	1.22
57. Coal subcritical	0.64	1.22
58. coal super critical	0.64	1.22
59. coal Ultra supercritical	0.64	1.22
60. coal IGCC	0.64	1.22
61. CCS coal pre	0.64	1.22
62. CCS coal post	0.64	1.22
63. Gas power generation	0.64	1.22
64. CCS gas	0.64	1.22
65. On-shore wind	0.64	1.22
66. Offshore wind	0.64	1.22
67. Large hydro	0.64	1.22
68. Small hydro	0.64	1.22
69. Oilpower	0.64	1.22
D70. Biomass based	0.64	1.22
71. Waste to electricity	0.64	1.22
72. Solar PV	0.64	1.22
73. Solar CSP	0.64	1.22

74. Solar distributed	0.64	1.22
75. Gas distribution	0.64	1.22
76. GW pumping diesel	0.565	0.71
77. GW pumping electric	0.565	0.71
78. GW pumping solar	0.565	0.71
79. Conventional Irrigation	0.51	1.22
80. Efficient Irrigation	0.565	0.71
81. Highly Efficient Irrigation	0.565	0.71
82. Municipal Water supply	0.51	1.22
83. Sea water desalination	0.51	1.22
84. Centralized ASP	0.51	1.22
85. De-centralized WSP	0.51	1.22
86. De-centralized MBR	0.51	1.22
87. Treated Sewage Water	0.51	1.22
88. Construction	0.565	0.28
89. services	0.6	1.15*
90. Road transport	0.6	1.15*
91. Rail transport	0.6	1.15*
92. Air transport	0.6	1.15*
93. Water transport	0.6	1.15*

Sources: [1]Assumed values for year 2022, [2]Assumed values for year 2032 and 2047,*Fragiadakis *et al*. 2012;** Goldar *et al*. 2014 (Note that averages have been used wherever ranges are provided)

Table AH: Elasticity of Substitution between capital and labour in Major sectors (short term)

	Short Run Range		**Average**
Agriculture	0.14	0.47	0.3
Mining, Quarrying, and manufacturing	0.42	0.71	0.6
Energy	0.53	0.75	0.6
Market services	0.34	0.86	0.6
Non Market services	0.09	0.93	0.5

Source: Fragiadakis et al. (2012)

Table AI: Elasticities of substitution between capital and labour

Sectors	**Long Run**
Agriculture, Including Livestock	1.14
Forestry & Logging	0.67
Fishing	0.34
Mining & Quarrying	0.36
Manufacturing	0.71
Electricity, Gas & Water Supply	1.22
Construction	0.28
Energy*	1.3

Market Services*	1.15

Source: *Fragiadakis *et al.* (2012), Goldar *et al.* (2014)

Table AJ: Elasticities of substitution between sugar and non-sugar feedstocks for ethanol production

	Elasticities of Substitution	
	Petrol	Diesel
Crude Oil and bio-crops	1	1
Sugar and non-sugar inputs	5	5
Sugarcane-sugarbeet	50	50
Paddy-other biomass	5	5
Wheat-other biomass	5	5
Jowar-other biomass	5	5
Bajra-Other biomass	5	5
Maize-Other biomass	5	5
Other Grains-Other biomass	5	5
Fruits-Other biomass	5	5
Pulses-Other biomass	5	5
Oilsds-Other biomass	5	5
Cotton and Jute	5	5
Jute and other crops	5	5

Source: Adapted from Brouwer and Joshi 2016

Table AK: Substitution elasticities between Capital, Energy, and Labour in different industries

KE-L	
Chemical	0.34
Other non-metallic mineral	0.21
Iron & Steel	0
Electrical equipment	0.33
Transport	0.47
Construction	0.94
K-E	
Chemical	0.04
Other Non-metallic Mineral	0.35
Electrical equipment	0.25
Transport	0.45
Construction	0.11

Source: Okagawa and Ban (2008)

Table AL: Elasticities of substitution between energy fuels in energy intensive industries

Allen partial elasticity of substitutions (AES)	Non-ferrous metal	Cement	Chemical (without Fertilizer and Pesticide)	Fertilizer and Pesticide	Iron and Steel	Pulp and Paper	Textile

Coal-Electricity	-0.42	0.51	1.98	6.17	1.07	1.97	-1.14
Coal petroleum products	3.93	3.37	3.01	3.81	1.44	0.84	1.02
Coal-Other fuel*	-1.27	-6.57	-9.21	-3.18	0.14	-5.46	2.99
Electricity-Petroleum product	0.88	0.92	0.95	0.98	1.04	1.06	1.01
Electricity-Other fuel*	1.07	1.09	0.96	0.82	0.72	0.65	1.14
Petroleum Product-Other fuel*	3.67	13.91	2.36	0.92	-5.35	0.09	4.58

*Other fuel is assumed as gas in this research

Source: Dasgupta et al. 2017

Other elasticity sources and assumptions are:

- Elasticity of Substitution between skilled and unskilled workers is assumed to be 2 (Behar 2010).
- Substitution elasticities between different fertiliser nutrients (NPK) are assumed to be 0.5 (Bartelings *et al.* n.d).
- Elasticity between freshwater and desalinated water is assumed to be 1 (substitutable) for all users.
- Elasticity between freshwater and treated sewage water is assumed to be zero (non-substitutable) for domestic users and is assumed to be 1 (substitutable) for industrial users.
- Elasticity between treated sewage water and desalinated freshwater and treated sewage water is assumed to be zero (non-substitutable) for domestic users.
- Capital-labour substitution is assumed to be unity and short-run substitution between this composite and fossil fuels is found to be close to zero (Papageorgiou *et al.* 2013), hence assumed to be 0.1 in this research.
- Elasticity estimates between clean and dirty inputs are assumed to be around 2 for the electricity generating sector and close to 3 for the non-energy industries (Papageorgiou *et al.* 2013)
- The elasticity of substitution between the irrigated land endowment and the agricultural water composite (R-W) is 0.05 (Koopman et al. 2017).

Appendix H: Energy, water, and food security attributes chosen for this research

Table AM: Details on Impact attributes chosen for this research

Attribute	Description	Unit	Relevance	Directional Impact	Literature sourced or derived (L); Developed solely for the research (D	Literature	Dimension/Aspect
Energy Intensity of Economy	Energy used per unit economic output	MWh/INR	Measure of energy intensiveness of an economy	A reduction in estimates of energy intensity of economy represents better outcomes for energy security	L	IAEA/IEA 2001, Vera and Langlois 2007, Kruyt et al. 2009, Martchamadol and Kumar 2012, Kemmler and Spreng 2007, Sreenivas and Iyer 2014	Economic aspect of energy availability
Per Capita Energy consumption	Energy consumed per person	KWh/capita	Energy use levels and patterns of a society	A reduction in per capita energy demand indicates better outcomes for energy security.	L	IAEA/IEA 2001, UNDESA 2001, Vera and Langlois 2007, Kruyt et al. 2009, Martchamadol and Kumar 2012	Physical aspect of energy availability
Energy Import Dependency (Coal, Oil, and Gas)	Energy imports as a percentage of total energy use	%	Resilience to any possible geo-political disruption	Lower value indicates better energy security outcomes	L	Vera and Langlois, 2007, Kruyt et al. 2009, IAEA/IEA 2001	Physical aspect of energy availability
Electricity Fuel-mix Diversity	Diversity in fuel-mix in electricity generation	Unit-less: Shannon Weiner Index (SWI), Range (0-2)	Resilience of the electricity system to any technical, economic, or geopolitical disruption	Higher values of the index suggests greater diversity and consequently better energy security outcomes	M	Grubb et al. 2006, Kruyt et al. 2009, Le Coq and Paltseva 2009, Sovakool and Mukherjee 2011,	Physical aspect of energy availability

Attribute	Description	Unit	Relevance	Directional Impact	Literature sourced or derived (L); Developed solely for the research (D	Literature	Dimension/Aspect
						Martchamadol and Kumar 2012	
Energy (Food) Imports Expenditure	Value of net energy imports as a percentage of total net imports	%	Economic burden of energy (food) imports	A decline in value obtained for this attribute is suggestive of better energy (food) security outcomes	L	Kruyt et al. 2009	Economic affordability of energy
Access to modern energy for cooking/heating	Percentage of population using modern and cleaner sources of energy for cooking and heating purposes	%	Access to modern energy services	A higher value of this attribute signifies improved household energy access to modern energy services and therefore better energy security.	L	UNSDSN 2015	Energy accessibility
Relative Water Stress	Percentage of freshwater withdrawn to meet water demand to total renewable water resources	%	Water demand pressures faced by a country relative to its water supplies	A higher value of this attribute implies worsened water security outcomes.	L	Alcamo et al. 1999	Physical aspect of water availability
Water Productivity of Economy	Ratio of economic output to total water use in the economy	2011 INR/m^3	Water intensiveness of the economy	A reduction in values of economic water productivity signifies better outcomes for water security	L	WB 2016	Economic aspect of water availability
Per Capita Freshwater withdrawals	Water withdrawals per person	m^3/capita	Population pressure on water demand	A reduction in values for per capita water withdrawals indicates better outcomes for water security.	L	WB 2016	Physical aspect of water availability

Attribute	Description	Unit	Relevance	Directional Impact	Literature sourced or derived (L); Developed solely for the research (D	Literature	Dimension/Aspect
Food Accessibility Index	Ratio of value of crop output to transportation sector output	Unit-less	Adequacy of transportation services for better access to food	A higher value of this attribute represents better outcomes for food security	D		Food accessibility
Food Diversity	Dietary Diversity of rural and urban population	Unit-less: Shannon Weiner Index (SWI), Range (0-2)	Characterizes the nutritional food security status of the individuals. It is associated with a balanced and nutritious diet.	A higher value of this index represents better food security outcomes.	L	FAO 2018	Food nutritional availability
GDP per capita	Economic output generated per person	2011 INR	Country's standard of living	A higher value of per capita gross domestic product signifies better economic outcomes	L	WB 2016	Economic sustainability
Trade-Balance as a percentage of GDP	Proportion of net exports to total economic output generated in the economy	%	Measure of Economic competitiveness of a country	A higher value of trade-balance to economic output is indicative of better economic outcomes	L	OECD 2010	Economic sustainability
Infrastructure investments as a percentage of GDP	Proportion of investments in key infrastructure, like energy, water, agriculture, and transport, to the total economic output	%	Regarded as a driver of economic growth	A higher value of this attribute suggests better economic outcomes.	L		Economic sustainability
Employment as a percentage of working population	Employment opportunities generated in the economy as a proportion of population in the working age group	%	Measure of social welfare	A higher value of this attribute suggests better social outcomes.	L		Social Sustainability

Attribute	Description	Unit	Relevance	Directional Impact	Literature sourced or derived (L); Developed solely for the research (D	Literature	Dimension/Aspect
Skilled to Unskilled Employment Ratio	Ratio of skilled employment to unskilled employment	Unit-less	Access to decent employment, higher incomes, improved social welfare, and ensure India's competitiveness in the global market	A higher value of this attribute indicates better social outcomes	L	Lee and Schluter 1999	Social Sustainability
Acceptability	Share of nuclear and hydro in the energy mix	%	Measure of distributive social justice	A higher value of this attribute indicates worsened social outcomes.	D		Social Sustainability
Health	Composite index indicating health outcomes of clean air, improved water sources and sanitation facilities, and diversified diet	Unit-less	Measure of Social well-being	A higher value of health composite index indicates better social outcomes	D		Social Sustainability
Food (Energy) Affordability	Proportion of total household expenditure (as a proxy of income) spent on staple food	%	Measure of Social welfare; expenditure on energy, water, food also affects expenditure on other services	A lower value of this attribute indicates better social outcomes	L	Vera and Langlois, 2007	Food (Energy) social Affordability
Carbon Combustion Emissions per unit Economic Output	Carbon emissions per unit of economic output generated in the economy	Kg/2011 INR	Indicative of the influences between carbon emissions and economic growth	Lower value of this attribute indicates lower environmental implications of economic growth	L	Vera and Langlois, 2007, Martchamadol and Kumar 2012	Environmental Sustainability
Per Capita Carbon Combustion Emissions	Carbon emissions per person	Metric tonnes per capita	Indicative of the influence of population on the intensity of carbon emission generated in an economy	Lower value of this attribute indicates lower environmental implications of population growth.	L	Martchamadol and Kumar 2012	Environmental Sustainability
Per Capita Land Utilization	Land resources utilized per person	million hectares per capita	Implications of economic development,	Lower value of this attribute indicates	L	van Vuuren and Smeets 2000	

Attribute	Description	Unit	Relevance	Directional Impact	Literature sourced or derived (L); Developed solely for the research (D	Literature	Dimension/Aspect
			population growth and growth in energy, water, food demand on land resources	better environmental outcomes			Environmental Sustainability
Fertilizer application diversity index	Diversification in use of fertilizers as soil nutrients (NPK)	Unit-less: Shannon Weiner Index (SWI), Range (0-2)	Captures the influence of soil nutrition management levels influences the soil quality	Higher value of this attribute indicates better soil quality and therefore better environmental outcomes	D		Environmental Sustainability
Fertilizer Use per unit Crop Output	Quantity of chemical fertilizers used per unit value of crop output	Tonnes per billion 2011 INR	Environmental damage (Soil and water) caused by excessive use of chemical fertilizers	Higher value of this attribute represents improved environmental outcomes	D		Environmental Sustainability
Fugitive Carbon Emissions per unit Economic Output	Fugitive emissions from provisioning of energy, water, and food per unit economic output	Kg/2011 INR	Indicative of the influences between fugitive emissions and economic growth	Lower value of this attribute indicates lower environmental implications of economic growth	L		Environmental Sustainability
Per Capita Fugitive Carbon Emissions	Fugitive emissions, in kilograms, generated per person	Kg/capita	Signifies the population growth and fugitive emissions link	Lower value of this attribute indicates lower environmental implications of population growth	L		Environmental Sustainability

Bibliography

Abbott, M., Bazilian, M., Egel, D. and Willis, H.H., 2017. Examining the food–energy–water and conflict nexus. *Current Opinion in Chemical Engineering*, 18, pp.55-60. https://doi.org/10.1016/j.coche.2017.10.002

AbdelHady, R.S., Fahmy, H.S. and Pacini, N., 2017. Valuing of Wadi El-Rayan ecosystem through water–food–energy nexus approach. *Ecohydrology & Hydrobiology*, 17(4), pp.247-253. https://doi.org/10.1016/j.ecohyd.2017.07.001

Acharya, S.S., 1997. Agricultural price policy and development: Some facts and emerging issues, *Indian Journal of Agricultural Economics*, 52(1): 1-47.

Ackerman, F., Fisher, J., 2013. Is there a water–energy nexus in electricity generation? Long-term scenarios for the western United States, *Energy Policy*, 59, 235–241

Adams, F.G. and Miovic, P., 1968. On relative fuel efficiency and the output elasticity of energy consumption in Western Europe. *The Journal of Industrial Economics*, pp.41-56.

Adapa, S., 2018. Indian smart cities and cleaner production initiatives–Integrated framework and recommendations. *Journal of Cleaner Production*, 172, pp.3351-3366.

Agarwal, A. and Narain, S. eds., 1997. Dying Wisdom: Rise, fall and potential of India's traditional water harvesting systems. Centre for Science and Environment.

Aggarwal, A., 2018. Economic Growth, Structural Change and Productive Employment Linkages in India: Did Market Transition Matter?. *South Asia Economic Journal*, 19(1), pp.64-85.

Aguiar, A., Narayanan, B. and McDougall, R., 2016. An overview of the GTAP 9 data base. *Journal of Global Economic Analysis*, 1(1), pp.181-208.

Ahluwalia, D., 1993. Public Distribution of Food in India: Coverage, Targeting and Leakages. *Food Policy*, 18 (1): 33-54.

Ahluwalia, I.J. and Little, I.M.D., 2012. India's economic reforms and development: Essays for Manmohan Singh. Oxford University Press.

Ahluwalia, M.S., 2002. Economic reforms in India since 1991: Has gradualism worked?. *Journal of Economic perspectives*, 16(3), pp.67-88.

AIPCA (American Institute of Certified Public Accountants), 2012. CGMA Tools: How to communicate risks using a heat map. viewed online 15 August 2018 https://web.actuaries.ie/sites/default/files/erm-resources/communicate-risks-using-heat-map.pdf

Ajanovic, A., 2011. Biofuels versus food production: does biofuels production increase food prices?. *Energy*, 36(4), 2070-2076

Al-Ansari, T., Korre, A., Nie, Z. and Shah, N., 2015. Development of a life cycle assessment tool for the assessment of food production systems within the energy, water and food nexus. *Sustainable Production and Consumption*, 2, pp.52-66. https://doi.org/10.1016/j.spc.2015.07.005

Al-Ansari, T., Korre, A., Nie, Z. and Shah, N., 2017. Integration of greenhouse gas control technologies within the energy, water and food nexus to enhance the environmental performance of food production systems. *Journal of Cleaner Production*, 162, pp.1592-1606. https://doi.org/10.1016/j.jclepro.2017.06.097

Albrecht, T., Crootof, A. and Scott, C., 2017. Trends in the development of water-energy-food nexus methods. In XVI World Water Congress, International Water Resources Association, Cancun, Mexico.

Alcamo J., Henrichs T., Roesch T., 1999, Global modelling and scenario analysis for the World Commission on Water for the 21st Century. University of Kassel, Centre for Environmental Systems Research, Germany

Alexandratos, N. and J. Bruinsma, 2012. World agriculture towards 2030/2050: the 2012 revision. ESA Working paper No. 12-03. Rome, FAO.

Alkon, M., Harish, S.P. and Urpelainen, J., 2016. Household energy access and expenditure in developing countries: Evidence from India, 1987–2010. Energy for Sustainable Development, 35, pp.25-34.

Allan, J.A., 2003. 'Virtual water — the water, food, and trade nexus: useful concept or misleading metaphor?', *Water International*, 28(1):pp 4–11.

Allouche, J., Middleton, C. & Gyawali, D., 2015. Technical veil, hidden politics: Interrogating the power linkages behind the nexus. *Water Alternatives*, 8(May 2013), pp.610–626.

Allouche, J., Middleton, C. and Gyawali, D., 2014. Nexus Nirvana or Nexus Nullity? A dynamic approach to security and sustainability in the water-energy-food nexus. In STEPS Working Paper no. 63, STEPS Centre, Institute of Development Studies. University of Sussex Brington.

Al-Saidi, M., & Elagib, N. A., 2017. Towards understanding the integrative approach of the water, energy and food nexus. *Science of The Total Environment*, 574, 1131-1139. https://doi.org/10.1016/j.scitotenv.2016.09.046

Alvani, P.K. and Chancellor, W.J., 1977. Energy requirements for wheat production and use in California. Transactions of ASAE 20, 429–37

Amarasinghe, U. A., Shah, T., & Singh, O. P., 2007. Changing consumption patterns: Implications on food and water demand in India (Vol. 119). IWMI.

Amarasinghe, U. A., Shah, T., Turral, H., Anand, B. K., 2007. India's water future to 2025-2050: Business-as-usual scenario and deviations. Colombo, Sri Lanka: International Water Management Institute. 47p. (IWMI Research Report 123)

Amarsinghe, U. A., and Singh, O. P., 2008. 'Changing consumption patterns of India: Implications on future food demand', in Amarsinghe, U. A., Shah, T., Malik, R.P.S., (Eds.) 2008. India's Water Future: Scenarios and Issues. Colombo, Sri Lanka: International Water Management Institute.

Andrew, R.M. and Peters, G.P., 2013. A multi-region input–output table based on the global trade analysis project database (GTAP-MRIO). *Economic Systems Research*, 25(1), pp.99-121.

Armington, P.S., 1969. A theory of demand for products distinguished by place of production. IMF Staff Papers, 16, 159–178.

Armstrong, J., 2013. Positivism and Constructivism. In: Improving International Capacity Development. Palgrave Macmillan, London

Arnell, N.W., 1999. Climate change and global water resources. *Global Environmental Change*, 9(1), pp. S31-S49

Arnell, N.W., 2004. Climate change and global water resources: SRES emissions and socio-economic scenarios. *Global Environmental Change*, 14 (1), pp. 31–52

Artioli, F., Acuto, M. and Mcarthur, J., 2017. The water-energy-food nexus: An integration agenda and implications for urban governance. *Political Geography*, 61, pp.215-223. https://doi.org/10.1016/j.polgeo.2017.08.009.

Asafu-Adjaye, J. and Wianwiwat, S., 2012. A CGE approach to the analysis of biofuels for promoting energy self sufficiency and security policy in Thailand-Methodology. *Procedia engineering*, 49, pp.357-372.

Babbitt, C. W., & Lindner, A. S., 2005. A life cycle inventory of coal used for electricity production in Florida. *Journal of Cleaner Production*, 13(9), 903-912

Babin, F.G., Willis, C.E. and Allen, P.G., 1982. Estimation of substitution possibilities between water and other production inputs. *American Journal of Agricultural Economics*, 64(1), pp.148-151

Badiani, R. and Jessoe, K., 2013. The impact of electricity subsidies on groundwater extraction and agricultural production. Working paper, University of California at Davis.

Badiani, R., Jessoe, K.K. and Plant, S., 2012. Development and the environment: the implications of agricultural electricity subsidies in India. *The Journal of Environment & Development*, 21(2), pp.244-262.

Baldwin, D.A., 1997. The concept of security. *Review of international studies*, 23(1), pp.5-26.

Banerjee, R., 2013. Agricultural transformation and food security in India: Lessons for Southeast Asia. *Journal of Resources, Energy and Development*, 10(1), pp.11-24.

Bartelings, H., Kavallari, A., van Meijl, H. and von Lampe, M., n. d. Estimating the impact of fertilizer support policies: A CGE approach, viewed online 14 July 2017 https://www.gtap.agecon.purdue.edu/resources/download/8287.pdf

Bartels, L., 2016. The Relationship between the WTO Agreement on Agriculture and the SCM Agreement: An Analysis of Hierarchy Rules in the WTO Legal System, *Journal of World Trade*, 50(1), 7–20.

Basheer, M., & Elagib, N. A., 2018. Sensitivity of Water-Energy Nexus to dam operation: A Water-Energy Productivity concept. *Science of The Total Environment*, 616, 918-926.

Basheer, M., Wheeler, K.G., Ribbe, L., Majdalawi, M., Abdo, G. and Zagona, E.A., 2018. Quantifying and evaluating the impacts of cooperation in transboundary river basins on the Water-Energy-Food nexus: The Blue Nile Basin. *Science of the Total Environment*, 630, pp.1309-1323.
https://doi.org/10.1016/j.scitotenv.2018.02.249

Bates, B., Kundzewicz, Z. W., Wu, S., & Palutikof, J., 2008. Climate change and water. Intergovernmental Panel on Climate Change (IPCC).

Bazilian, M., Davis, R., T. Pienkos, P. and Arent, D., 2013. The energy-water-food nexus through the lens of algal systems. *Industrial Biotechnology*, 9(4), pp.158-162. https://doi.org/10.1089/ind.2013.1579

Bazilian, M., Rogner, H., Howells, M., Hermann, S., Arent, D., Gielen, D., Steduto, P., Mueller, A., Komor, P., Tol, R.S. and Yumkella, K.K., 2011. Considering the energy, water and food nexus: Towards an integrated modelling approach. *Energy Policy*, 39(12), pp.7896-7906. https://doi.org/10.1016/j.enpol.2011.09.039

BCG (Boston Consulting Group) and CII (Confederation of Indian Industries), 2017. Future of Coal- Based Power Generation in India, viewed online 12 September 2018 http://www.ciienergyconclave.com/download/BCGCII_Report_2017.pdf

Beck, M.B. and Walker, R.V., 2013. On water security, sustainability, and the water-food-energy-climate nexus. *Frontiers of Environmental Science & Engineering*, 7(5), pp.626-639. https://doi.org/10.1007/s11783-013-0548-6

Behar, A., 2010. The elasticity of substitution between skilled and unskilled labor in developing countries is about 2. International Monetary Fund. Selected works.

Belinskij, A., 2015. Water-energy-food nexus within the framework of international water law. *Water*, 7(10), pp.5396-5415. https://doi.org/10.3390/w7105396

Bell, A., Matthews, N. and Zhang, W., 2016. Opportunities for improved promotion of ecosystem services in agriculture under the Water-Energy-Food Nexus. *Journal of Environmental Studies and Sciences*, 6(1), pp.183-191. https://doi.org/10.1007/s13412-016-0420-7

Belmonte, B.A., Benjamin, M.F.D. and Tan, R.R., 2017. Biochar systems in the water-energy-food nexus: the emerging role of process systems engineering. *Current Opinion in Chemical Engineering*, 18, pp.32-37. https://doi.org/10.1016/j.coche.2017.08.005

Bennett B, Park L, Wilkinson R., 2010. Embedded energy in water studies: water agency and function component study and embedded energy - water load profiles. California Public Utilities Commission.

Benson, D., Gain, A.K. & Rouillard, J.J., 2015. Water governance in a comparative perspective: From IWRM to a “nexus” approach? *Water Alternatives*, 8(1), pp.756–773.

Bergendahl, J.A., Sarkis, J. and Timko, M.T., 2018. Transdisciplinarity and the food energy and water nexus: Ecological modernization and supply chain sustainability perspectives. *Resources, Conservation and Recycling*. https://doi.org/10.1016/j.resconrec.2018.01.001

Bhardwaj, 2016. ‘Food imports rise as Modi struggles to revive rural India’, Economic News *https://in.reuters.com/article/india-farming/food-imports-rise-as-modi-struggles-to-revive-rural-india-idINKCN0VA3NL*

Bhardwaj, R.M., 2005. Status of wastewater generation and treatment in India. Intersecretariat Working Group on Environment Statistics (IWG–Env) Joint Work Session on Water Statistics, Vienna, pp.20-22.

Bhattacharjya, S., Chaudhury, S. and Nanda, N., 2017. Import Dependence and Food and Nutrition Security Implications: The Case of Pulses in India. *Review of Market Integration*, 9(1-2), pp.83-110.

Bieber, N., Ker, J.H., Wang, X., Triantafyllidis, C., van Dam, K.H., Koppelaar, R.H. and Shah, N., 2018. Sustainable planning of the energy-water-food nexus using decision making tools. *Energy Policy*, 113, pp.584-607. https://doi.org/10.1016/j.enpol.2017.11.037

Biewald, A., Rolinski, S., Lotze-Campen, H., Schmitz, C. and Dietrich, J.P., 2014. Valuing the impact of trade on local blue water. *Ecological Economics*, 101, pp.43-53.

Biggs, E.M., Bruce, E., Boruff, B., Duncan, J.M., Horsley, J., Pauli, N., McNeill, K., Neef, A., Van Ogtrop, F., Curnow, J. and Haworth, B., 2015. Sustainable development and the water–energy–food nexus: A perspective on livelihoods. *Environmental Science & Policy*, 54, pp.389-397. https://doi.org/10.1016/j.envsci.2015.08.002

Bindra, S.P., Hamid, A., Salem, H., Hamuda, K. and Abulifa, S., 2014. Sustainable integrated water resources management for energy production and food security in Libya. *Procedia Technology*, 12, pp.747-752. https://doi.org/10.1016/j.protcy.2013.12.558

Bizikova, L., Roy, D. & Swanson, D., 2013. The Water-energy-food Security Nexus: Towards a Practical Planning and Decision-support Framework for Landscape Investment and Risk Management. , (February), p.28, viewed online 29 December 2017, http://www.iisd.org/sites/default/files/pdf/2013/wef_nexus_2013.pdf.

Black, J. N., 1971. Energy relations in crop production-a preliminary survey. *Annuals of applied biology*, 67(2), 272-278

Bogra, S., 2017. India's water metabolism analyses: Insights for sustainability assessments from macro-economic-ecological modelling. PhD thesis, TERI University.

Bonsch, M., Humpenöder, F., Popp, A., Bodirsky, B., Dietrich, J.P., Rolinski, S., Biewald, A., Lotze-Campen, H., Weindl, I., Gerten, D. and Stevanovic, M., 2016. Trade-offs between land and water requirements for large-scale bioenergy production. Gcb *Bioenergy*, 8(1), pp.11-24. https://doi.org/10.1111/gcbb.12226

Boyle, G., 2012. Endangered Waters: Impacts of coal-fired power plants on water supply. Greenpeace India Society.

Brauch, H. G., 2006. Security Threats, Challenges, Vulnerability and Risks, in: Oswald Spring, Ú. (Ed.): International Security, Peace, Development, and Environment (EOLSS Publishers).

Briggs, L. J, and Shantz, H. L., 1913. The water requirements of plants. I. Investigations in the Great Plains in 1910 and 1911. U. S. Dept. Agr. Bur. Plant Ind. Bull. 284, 49 pp.

Briggs, L. J., and Shantz, H. L., 1914. Relative water requirements of plants. *J. Agr. Res*. 3, pp.1-63

Briscoe, J. and Malik, R.P.S., 2006. India's water economy: Bracing for a turbulent future. New Delhi: Oxford University Press.

Bromwich, B., 2015. Nexus meets crisis: a review of conflict, natural resources and the humanitarian response in Darfur with reference to the water–energy–food nexus. *International journal of water resources development*, 31(3), pp.375-392. https://doi.org/10.1080/07900627.2015.1030495

Brouwer, F., Avgerinopoulos, G., Fazekas, D., Laspidou, C., Mercure, J.F., Pollitt, H., Ramos, E.P. and Howells, M., 2018. Energy modelling and the Nexus concept. *Energy Strategy Reviews*, 19, pp.1-6.

Brouwer, F. and Joshi, P.K. eds., 2016. International Trade and Food Security: The Future of Indian Agriculture. CABI.

Brunner, K.M., Mandl, S. and Thomson, H., 2018. Energy Poverty: Energy Equity in a World of High Demand and Low Supply. The Oxford Handbook of Energy and Society, p.297.

Budholai, B., 2009, Environment Protection Laws in the British Era, Hidayatullah National Law University, Raipur (C.G), viewed online 4 September 2018 http://www.legalserviceindia.com/articles/brenv.htm

Burfisher, M.E., 2011. Introduction to Computable General Equilibrium Models. Cambridge University Press, New York.

Burian, S.J. and Edwards, F.G., 2002. Historical perspectives of urban drainage. In Global Solutions for Urban Drainage (pp. 1-16).

Burke, P.J. and Csereklyei, Z., 2016. Understanding the energy-GDP elasticity: A sectoral approach. *Energy Economics*, 58, pp.199-210.

Cai, X., Wallington, K., Shafiee-Jood, M. and Marston, L., 2018. Understanding and managing the food-energy-water nexus–opportunities for water resources research. *Advances in Water Resources*, 111, pp.259-273. https://doi.org/10.1016/j.advwatres.2017.11.014

Cairney, P., 2015. Policymaking in the UK: What is Policy and How is it Made? In Cairney, P., 2015, Policy and Policymaking in the UK. Basingstoke: Palgrave, viewed online 23 August 2017 https://paulcairney.files.wordpress.com/2013/08/chapter-2-20-8-13-cairney-policy-policymaking-uk.pdf

Calzadilla, A., Zhu, T., Rehdanz, K., Tol, R. S., & Ringler, C., 2013. Economywide impacts of climate change on agriculture in Sub-Saharan Africa. *Ecological Economics*, 93, 150-165.

Canning, P., 2011. Energy use in the US food system. Diane Publishing.

Cao, S.,Xie, G., Zhen, L., 2010. Total embodied energy requirements and its decomposition in China's agricultural sector, 69(7), pages 1396-1404

Carrillo, A. M. R., & Frei, C., 2009. Water: A key resource in energy production. *Energy Policy*, 37(11), 4303-4312.

Carter, S. and Gulati, M., 2014. Climate Change, the Food Energy Water Nexus and Food Security in South Africa, Understanding the Food Energy Water Nexus. WWF-South Africa.

Cassman, K.G., & Liska, A. J., 2007. Food and fuel for all: realistic or foolish? *Biofuels, Bioproducts and Biorefining*, 1(1), 18-23.

CEA (Central Electricity Authority), 2012. Report on minimisation of water requirement in coal based thermal power stations, viewed online16 October 2016, http://www.cea.nic.in/reports/others/thermal/tetd/min_of%20water_coal_power.pdf

CEA (Central Electricity Authority), 2018. National Electricity Plan: Generation: Volume I. Ministry of Power, Government of India

Chadha, R., & Tandon, A., 2012. GTAP 8 Data Base Documentation - Chapter 7.G: India (Center for Global Trade Analysis). Purdue University, West Lafayette, IN: Global Trade Analysis Project (GTAP), viewed online 5 March 2017, https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=3986

Chakrabarty, S., 2018. By the Numbers: New Emissions Data Quantify India's Climate Challenge, World Resources Institute, viewed online 7 October 2018, https://www.wri.org/blog/2018/08/numbers-new-emissions-data-quantify-indias-climate-challenge

Chand, R., Raju, S.S. and Pandey, L.M., 2008. Progress and potential of horticulture in India. Indian Journal of Agriculture Economics, 63(3), pp.299-309.

Chandran, M.S, 2015. Glimpses into the Subaltern System of Natural Resource Management in Ancient India. Conference: Conference: UGC Sponsored National Seminar on Flora and Fauna in Ancient Indian Literature, At Dr A V Baliga College of Arts & Science, Kumta

Chartres, C., & Sood, A., 2013. The water for food paradox. Aquatic Procedia, 1, 3-19.

Chaudhary, V.P., Gangwar, B. and Pandey, D.K., 2006. Auditing of energy use and output of different cropping systems in India. Agricultural Engineering International: CIGR Journal.

Chauhan, N.S., Mohapatra, P.K. and Pandey, K.P., 2006. Improving energy productivity in paddy production through benchmarking—an application of data envelopment analysis. *Energy conversion and Management*, 47(9-10), pp.1063-1085.

Chel, A., & Kaushik, G., 2010. Renewable energy for sustainable agriculture. Agronomy for Sustainable Development. Page 111

Chen, H.G. and Zhang, Y.H.P., 2015. New biorefineries and sustainable agriculture: Increased food, biofuels, and ecosystem security. *Renewable and Sustainable Energy Reviews*, 47, pp.117-132.
https://doi.org/10.1016/j.rser.2015.02.048

Chikkatur, A. P., Sagar, A. D., & Sankar, T. L., 2009. Sustainable development of the Indian coal sector, *Energy*, 34(8), pp. 942-953

Christopher, F., 2008. Time to move to a second generation of biofuels. Washington D.C: Worldwatch Institute; 13 February 2008.

Clemmer, S., Rogers, J., Sattler, S., Macknick, J., & Mai, T., 2013. Modeling low-carbon US electricity futures to explore impacts on national and regional water use. *Environmental Research Letters*, 8(1), 015004.

Cleveland, C. J., 1995a. Resource degradation, technical change, and the productivity of energy use in US agriculture. *Ecological Economics*, 13(3), 185-201.

Cleveland, C. J., 1995b. The direct and indirect use of fossil fuels and electricity in USA agriculture, 1910–1990. *Agriculture, ecosystems & environment*, 55(2), 111-121.

CMWSSB (Chennai Metropolitan Water Supply and Sewerage Board), n.d. Project Description. viewed online 14 July 2018, http://environmentclearance.nic.in/writereaddata/FormB/TOR/Brief_Summary/24_May_2016_1624419333HRHT81UProjectDescription-400.pdf

Coles, A., and Wallace, T. (Eds.), 2005. Gender, Water and Development. Berg, Oxford

Conway, D., Van Garderen, E.A., Deryng, D., Dorling, S., Krueger, T., Landman, W., Lankford, B., Lebek, K., Osborn, T., Ringler, C. and Thurlow, J., 2015. Climate and southern Africa's water–energy–food nexus. *Nature Climate Change*, 5(9), p.837.
https://doi.org/10.1038/nclimate2735

Cozzens, S., Cortes, R., Soumonni, O. and Woodson, T., 2013. Nanotechnology and the millennium development goals: water, energy, and agri-food. *Journal of Nanoparticle Research*, 15(11), p.2001.
https://doi.org/10.1007/s11051-013-2001-y

CRISIL, 2016. Macro view on rural India. Viewed online 5 August 2017
https://www.spratings.com/documents/20184/0/Rural+India/b969b96a-8e89-44a9-9bab-579e5cf13e46

Crow, B. and Sultana, F., 2002. Gender, class, and access to water: Three cases in a poor and crowded delta. *Society &Natural Resources*, 15(8), pp.709-724.

CSO (Central Statistics Office), 2014. GDP at Factor Cost at 2004-05 Prices, Share to Total GDP and % Rate of Growth in GDP (31-10-2014). in Planning Commission Databook 2014, viewed online 18 June 2017, http://www.planningcommission.gov.in/data/datatable/data_2312/DatabookDec2014%202.pdf

CWC(Central Water Commission), 2017. Pricing of water in public system in India, Information System Organisation Water Planning & Projects Wing, viewed online 21 October 2017 http://cwc.gov.in/main/downloads/Pricing%20of%20Water%20in%20Public%20System%20in%20India%202017.pdf

Daher, B.T. and Mohtar, R.H., 2015. Water–energy–food (WEF) Nexus Tool 2.0: guiding integrative resource planning and decision-making. *Water International*, 40(5-6), pp.748-771. https://doi.org/10.1080/02508060.2015.1074148

Dalgaard, T., Halberg, N., & Porter, J. R., 2001. A model for fossil energy use in Danish agriculture used to compare organic and conventional farming. *Agriculture, Ecosystems & Environment*, 87(1), 51-65.

Dasgupta, S., Satija, S. and Gauba, P., 2017, June. The Pattern of Inter-fuel Substitution in Energy Intensive Manufacturing Industries in India During 2000-01 ∃ 2011-12. In Meeting the Energy Demands of Emerging Economies, 40th IAEE International Conference, June 18-21, 2017. International Association for Energy Economics.

Davidson, E.A., Galloway, J.N., Millar, N. and Leach, A.M., 2014. N-related greenhouse gases in North America: innovations for a sustainable future. *Current Opinion in Environmental Sustainability,* 9, pp.1-8.

Davis, M., 2001. Late Victorian holocausts: El Niño famines and the making of the third world, London: Verso.

De Fraiture, C., Giordano, M., & Liao, Y., 2008. Biofuels and implications for agricultural water use: blue impacts of green energy. *Water Policy*, 10, 67.

de Grenade, R., House-Peters, L., Scott, C.A., Thapa, B., Mills-Novoa, M., Gerlak, A. and Verbist, K., 2016. The nexus: reconsidering environmental security and adaptive capacity. Current *Opinion in Environmental Sustainability*, 21, pp.15-21. https://doi.org/10.1016/j.cosust.2016.10.009

De Laurentiis, V., Hunt, D.V. and Rogers, C.D., 2016. Overcoming food security challenges within an energy/water/food nexus (ewfn) approach. *Sustainability*, 8(1), p.95. https://doi.org/10.3390/su8010095

de Strasser, L., Lipponen, A., Howells, M., Stec, S. and Bréthaut, C., 2016. A methodology to assess the water energy food ecosystems nexus in transboundary river basins. *Water*, 8(2), p.59. https://doi.org/10.3390/w8020059

de Vito, R., Portoghese, I., Pagano, A., Fratino, U. and Vurro, M., 2017. An index-based approach for the sustainability assessment of irrigation practice based on the water-energy-food nexus framework. *Advances in Water Resources*, 110, pp.423-436. https://doi.org/10.1016/j.advwatres.2017.10.027

Delgado, A., 2012. Water footprint of Electricity Production, Masters Thesis, Massachusetts Institute of Technology, viewed on 20 June, 2016, http://sequestration.mit.edu/pdf/AnnaDelgado_Thesis_June2012.pdf

Dhavan, V., 2017. Water and Agriculture in India: Background paper for the South Asia expert panel during the Global Forum for Food and Agriculture (GFFA) 2017, OAV – German Asia-Pacific Business Association, viewed online15 October 2018, https://www.oav.de/fileadmin/user_upload/5_Publikationen/5_Studien/170118_Study_Water_Agriculture_India.pdf

Dias, A.C., Lemos, D., Gabarrell, X. and Arroja, L., 2014. Environmentally extended input–output analysis on a city scale–application to Aveiro (Portugal). *Journal of cleaner production*, 75, pp.118-129.

Doukkali, M.R. and Lejars, C., 2015. Energy cost of irrigation policy in Morocco: a social accounting matrix assessment. *International journal of water resources development*, 31(3), pp.422-435. https://doi.org/10.1080/07900627.2015.1036966

Dubash, N.K., 2007. The electricity-groundwater conundrum: Case for a political solution to a political problem. *Economic and Political Weekly*, pp.45-55.

Dubash, N.K., Khosla, R., Rao, N.D. and Bhardwaj, A., 2018. India's energy and emissions future: an interpretive analysis of model scenarios. *Environmental Research Letters*, 13(7).

Duchin, F. and Steenge, A.E., 2007. Mathematical models in input-output economics. Rensselaer Polytechnic Institute, Troy, NY.

Economic and Political Weekly (EPW), 2018. The Unemployment Paradox: Looking at growth without jobs, viewed online 1 November 2018 https://www.epw.in/engage/article/unemployment-jobs-growth-india

Edmonds, J., & Reilly, J., 1983. A long-term global energy-economic model of carbon dioxide release from fossil fuel use. *Energy Economics*, 5(2), 74-88.

EIA (Energy Information Administration), 2018. Frequently Asked Questions, What countries are the top producers and consumers of oil?. viewed online 27 September 2018, https://www.eia.gov/tools/faqs/faq.php?id=709&t=6

Elena, G., Esther, V., 2010. From water to energy: The virtual water content and water footprint of biofuel consumption in Spain. *Energy Policy*, 38(3), 1345-1352.

Endo, A., Burnett, K., et al., 2015b. Methods of the water-energy-food nexus. *Water (Switzerland),* 7, pp.5806–5830. https://doi.org/10.3390/w7105806

Endo, A., Tsurita, I., et al., 2015a. A review of the current state of research on the water, energy, and food nexus. *Journal of Hydrology: Regional Studies*. https://doi.org/10.1016/j.ejrh.2015.11.010

Escobar, J. C., Lora, E. S., Venturini, O. J., Yáñez, E. E., Castillo, E. F., & Almazan, O., 2009. Biofuels: environment, technology and food security. *Renewable and sustainable energy reviews*, 13(6), 1275-1287.

ET (Economic Times), 2013. 'India incurs Rs 2 trillion/year post harvest loss of fruits, veggies'. viewed online 29 June 2017, https://economictimes.indiatimes.com/news/economy/agriculture/india-incurs-rs-2-trillion/year-post-harvest-loss-of-fruits-veggies/articleshow/22204097.cms

Faber, A., Idenburg, A.M. and Wilting, H.C., 2007. Exploring techno-economic scenarios in an input-output model, *Future*, Vol. 39, pp.16-37.

Fabiola, R., Dalila 2016. How the Nexus of Water/Food/Energy can be Seen with the Perspective of People well-being and the Italian BES Framework. *Agriculture and agricultural science procedia*, 8, pp.732-740. https://doi.org/10.1016/j.aaspro.2016.02.057

Falkenmark M, Lundqvist J and Widstrand C., 1989. Macro-scale water scarcity requires micro-scale approaches. in *Natural Resources Forum*, 13(4), pp. 258–267

FAO (Food and Agriculture Organisation), 2011, FAOSTAT Online Database, viewed 10 September 2017, http://faostat. fao.org/.

FAO (Food and Agriculture Organisation), 2013, FAOSTAT Online Database, viewed 5 September 2017, http://faostat. fao.org/

FAO (Food and Agriculture Organisation), n. d. Food Balance Sheets, viewed online 12th May 2017, http://www.fao.org/economic/the-statistics-division-ess/publications-studies/publications/food-balance-sheets/en/

FAO (Food and Agriculture Organization of the United Nations), 2006. Rapid Growth of Selected Asian Economies: Lessons and Implications for Agriculture and Food Security: China and

India, Part II: Indian agriculture and scenario for 2020, Regional Office for Asia and the Pacific. Bangkok.

FAO (Food and Agriculture Organisation), 2018. Food Security Indicators. viewed online 22 September 2018, http://www.fao.org/economic/ess/ess-fs/ess-fadata/en/#.XGgzwFwzZPY

FAO (Food and Agriculture Organization), IFAD (International Fund for Agricultural Development) and WFP (World Food Program), 2015. The State of Food Insecurity in the World 2015. Meeting the 2015 international hunger targets: taking stock of uneven progress. Rome, FAO.

FAO (Food and Agriculture Organization) 2016. AQUASTAT Main Database, Food and Agriculture Organization of the United Nations (FAO). viewed online 23 June 2018, http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en

FAO (Food and Agriculture Organization), WFP (World Food Program) and IFAD (International Fund for Agricultural Development), 2012. The State of Food Insecurity in the World 2012:. Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition. Rome, FAO, viewed online 20 June 2018, http://www.fao.org/docrep/016/i3027e/i3027e03.pdf

Fargione, J., Hill, J., Tilman, D., Polasky, S., & Hawthorne, P., 2008. Land clearing and the biofuel carbon debt. Science, 319(5867), 1235-1238

Farley, K.A., Jobbágy, E.G. and Jackson, R.B., 2005. Effects of afforestation on water yield: a global synthesis with implications for policy. Global change biology, 11(10), pp.1565-1576.

Fasel, M., Brethaut, C., Rouholahnejad, E., Lacayo-Emery, M.A. and Lehmann, A., 2016. Blue water scarcity in the Black Sea catchment: Identifying key actors in the water-ecosystem-energy-food nexus. *Environmental Science & Policy*, 66, pp.140-150. https://doi.org/10.1016/j.envsci.2016.09.004

FICCI (Federation of Indian Chambers of Commerce & Industry), 2010. Bottlenecks in Indian Food Processing Industry: Survey 2010, viewed online 15 July 2017 http://ficci.in/SEDocument/20073/Food-Processing-Bottlenecks-study.pdf

Finley, J.W. and Seiber, J.N., 2014. The nexus of food, energy, and water. *Journal of agricultural and food chemistry*, 62(27), pp.6255-6262.

Flammini, A., Puri, M., Pluschke, L. and Dubois, O., 2014. Walking the nexus talk: assessing the water-energy-food nexus in the context of the sustainable energy for all initiative. FAO.

Foran, T., 2015. Node and regime: Interdisciplinary analysis of water-energy-food nexus in the Mekong region. *Water Alternatives*, 8(1).

Fragiadakis, K., Leonidas, P., Nikos, K., Pantelis, C., 2012. A Multi – Country Econometric Estimation of the Constant Elasticity of Substitution. Paper presented at the Final WIOD Conference: Causes and Consequences of Globalization, Groningen, The Netherlands, 24-26 April.

Friedrich, E., Pillay, S., & Buckley, C. A., 2007. The use of LCA in the water industry and the case for an environmental performance indicator. Water SA, 33(4).

Friedrich, T., & Kassam, A. H., 2009. Adoption of Conservation Agriculture technologies: constraints and opportunities. In Invited paper, 4th World Congress on Conservation Agriculture (pp. 4-7).

Friedrich, T., Kassam, A. H., & Shaxson, F., 2009. Conservation agriculture. Agriculture for Developing Countries. Science and Technology Options Assessment (STOA) Project. Karlsruhe, Germany: European Technology Assessment Group.

Fthenakis, V., Kim, H., 2010. Life-cycle uses of water in U.S. electricity generation, *Renewable and Sustainable Energy Reviews,* 14, 2039–2048

Gaard, G., 2001. Women, water, energy: An ecofeminist approach, Organization & Environment, 14(2), pg. 157-172

Gain, A.K., Giupponi, C. and Benson, D., 2015. The water–energy–food (WEF) security nexus: the policy perspective of Bangladesh. *Water International*, 40(5-6), pp.895-910. https://doi.org/10.1080/02508060.2015.1087616

Gallagher, L., Dalton, J., Bréthaut, C., Allan, T., Bellfield, H., Crilly, D., Cross, K., Gyawali, D., Klein, D., Laine, S. and LeFlaive, X., 2016. The critical role of risk in setting directions for water, food and energy policy and research. *Current opinion in environmental sustainability*, 23, pp.12-16. https://doi.org/10.1016/j.cosust.2016.10.002

Gandhi, V.P. and Zhou, Z., 2014. Food demand and the food security challenge with rapid economic growth in the emerging economies of India and China. *Food Research International*, 63, pp.108-124.

Gangopadhyay, S., Ramaswami, B. and Wadhwa, W., 2005. Reducing subsidies on household fuels in India: how will it affect the poor?. *Energy Policy*, 33(18), pp.2326-2336.

Garcia, D.J. and You, F., 2016. The water-energy-food nexus and process systems engineering: a new focus. *Computers & Chemical Engineering*, 91, pp.49-67. https://doi.org/10.1016/j.compchemeng.2016.03.003

Garg, n.d. Impact of Coal Mining on Climate Change & Different Forest Types in India, viewed online18 June 2018 http://www.terisas.ac.in/mct/pdf/new/environment/IGNFA.pdf

Gay, P.W. and Proops, J.L.R., 1993. Carbon-dioxide Production by the UK Economy: An input-output assessment. *Applied Energy*, 44(2), 113-130.

Gelman, A. and Hennig, C., 2017. Beyond subjective and objective in statistics. Journal of the Royal Statistical Society: Series A (Statistics in Society), 180(4), pp.967-1033.

Gephart, J.A., Troell, M., Henriksson, P.J., Beveridge, M.C., Verdegem, M., Metian, M., Mateos, L.D. and Deutsch, L., 2017. The seafood gap'in the food-water nexus literature—issues surrounding freshwater use in seafood production chains. *Advances in Water Resources*, 110, pp.505-514.

Gerbens-Leenes, W., Hoekstra, A. and van der Meer, T., 2008. The water footprint of energy consumption: an assessment of water requirements of primary energy carriers. ISESCO science and technology vision, 4(5), pp.38-42.

Gerbens-Leenes, P. W., Hoekstra, A. Y., & Van der Meer, T., 2009. The water footprint of energy from biomass: A quantitative assessment and consequences of an increasing share of bio-energy in energy supply. *Ecological economics*, 68(4), 1052-1060.

Gerbens-Leenes, P. W., Van Lienden, A. R., Hoekstra, A. Y., & Van der Meer, T. H., 2012. Biofuel scenarios in a water perspective: The global blue and green water footprint of road transport in 2030. *Global Environmental Change*, 22(3), 764-775.

Gheewala, S.H., Berndes, G. and Jewitt, G., 2011. The bioenergy and water nexus. *Biofuels, Bioproducts and Biorefining*, 5(4), pp.353-360.

Ghosh, 2017. Reinvigorating urban water planning using metabolism approach: Delhi as a case study, TERI University, 10, Institutional Area, Vasant Kunj New Delhi - 110070, India

Ghosh, R., Kansal, A. and Aghi, S., 2016. Implications of end-user behaviour in response to deficiencies in water supply for electricity consumption–A case study of Delhi. *Journal of Hydrology*, 536, pp.400-408.

Giampietro, M., Aspinall, R., Ramos-Martín, J. and Bukkens, S.G.F., 2013b. Resource accounting in sustainability assessments: establishing a nexus between land, water, food, energy and wealth using the MuSIASEM* approach.

Giampietro, M., Aspinall, R.J., Bukkens, S.G.F., Cadillo Benalcazar, J., Diaz-Maurin, F., Flammini, A., Gomiero, T., Kovacic, Z., Madrid, C., Ramos-Martín, J., Serrano-Tovar, T., 2013a. An Innovative Accounting Framework for the Food-Energy-Water Nexus - Application of the MuSIASEM approach to three case studies, Environment and Natural Resources, Working Paper No.56 – FAO, Rome.

Giampietro, M., Sorman, A. H., & Gamboa, G., 2010. Using the MuSIASEM approach to study metabolic patterns of modern societies. In Energy Options Impact on Regional Security (pp. 37-68). Springer Netherlands

Gilovich, T., Griffin, D. and Kahneman, D. eds., 2002. Heuristics and biases: The psychology of intuitive judgment. Cambridge university press, pp 8-9.

Gjorgiev, B. and Sansavini, G., 2018. Electrical power generation under policy constrained water-energy nexus. *Applied Energy*, 210, pp.568-579.

Gleeson, T., & Wada, Y., 2013. Assessing regional groundwater stress for nations using multiple data sources with the groundwater footprint, *Environmental Research Letters*, 8(4), p. 044010

Gleick, P. H., & Cooley, H. S., 2009. Energy implications of bottled water, *Environmental Research Letters*, 4(1), 014009.

Gleick, P.H., 1994. Water and energy. Annual Review of Energy and the Environment 19, 267–299

Goel, V. P., 2017. Technical and vocational education and training (tvet) system in India for sustainable development, viewed online 12 July 2018 http://adapt.it/adapt-indice-a-z/wp-content/uploads/2014/09/VT_Sustainable_Dev.pdf

GoI (Government of India), 2006. National Environment Policy, 2006. Ministry of Environment and Forests, viewed online 5 September 2017, http://envfor.nic.in/sites/default/files/introduction-nep2006e.pdf

GoI (Government of India), 2011. Mid-Term Appraisal Eleventh Five Year Plan 2007–2012. Planning Commission, Government of India, viewed online 15 August 2018, http://planningcommission.gov.in/plans/mta/11th_mta/chapterwise/chap21_water.pdf

GoI (Government of India), 2012. Export Of Agricultural Products. Ministry Of Commerce And Industry, Lok Sabha, Unstarred Question No 657, Answered On 13.08.2012

GoI (Government of India), 2013. Cost of Cultivation / Production & Related Data: 2013-14, Directorate of Economics and Statistics, Cooperation and Farmers Welfare, Department of Agriculture Ministry of Agriculture and Farmers Welfare, viewed online 15 March 2017 https://eands.dacnet.nic.in/Cost_of_Cultivation.htm

GoI (Government of India), 2014a. National Mission for Sustainable Agriculture (NMSA), Operational Guidelines. Department of Agriculture & Cooperation, Ministry of Agriculture, viewed online13 September 2018, http://agricoop.nic.in/sites/default/files/Final_guidelines_1.pdf

GoI (Government of India), 2014b. India Energy Security Scenarios (IESS) 2047, Sector Specific Insights, Research Division, Planning Commission.

GoI (Government of India), 2015a. India Energy Security Scenarios (IESS) 2047-Version 2, New Delhi: NITI Aayog, viewed online 21 September 2016, http://indiaenergy. gov. in

GoI (Government of India), 2015b. Indian Fertilizer Scenario 2015. Department of Fertilizers, Ministry of Chemicals and Fertilizers

GoI (Government of India), 2016a. Agricultural Statistics at a glance, Ministry of Agriculture and Farmers Welfare, Department of Agriculture, Cooperation and Farmers welfare, Directorate of Economics and Statistics, viewed online 15 September 2017, http://www.indiaenvironmentportal.org.in/files/file/agricultural%20statistics%20at%20a%20glance-2016.pdf

GoI (Government of India), 2016b. Indian Labour Year Book 2013 And 2014, Labour Bureau, Ministry Of Labour And Employment.

GoI (Government of India), 2017a. Shortage of water. Press Information Bureau, Ministry of Water Resources, viewed online 24 January 2018, http://pib.nic.in/newsite/PrintRelease.aspx?relid=168727

GoI (Government of India), 2017b. Changing Structure of Rural Economy of India Implications for Employment and Growth. National Institution for Transforming India, NITI Aayog.

GoI (Government of India), 2018a. NOTIFICATION National Policy on Biofuels,MINISTRY OF PETROLEUM AND NATURAL GAS, viewed online 8 August 2017 http://petroleum.nic.in/sites/default/files/biofuelpolicy2018_1.pdf

GoI (Government of India), 2018b. Finance Minister Present Economic Survey 2017-18 In Parliament, https://timesofindia.indiatimes.com/realtime/Economic_Survey_2017_18.pdf

Goldar, B., Pradhan, B.K. and Sharma, A.K., 2014. Elasticity of substitution between capital and labour in major sectors of the Indian economy. Institute of Economic Growth Working Paper, (335).

Gondhalekar, D. and Ramsauer, T., 2017. Nexus City: Operationalizing the urban Water-Energy-Food Nexus for climate change adaptation in Munich, Germany. *Urban Climate*, 19, pp.28-40. https://doi.org/10.1016/j.uclim.2016.11.004

Gosain, A. K., Rao, S., & Basuray, D., 2006. Climate change impact assessment on hydrology of Indian river basins. *Current science*, 90(3), pp.346-353.

Gowdy, J. and Miller, J., 1968. An input-output approach to energy efficiency in the USA and Japan, *Energy,* 16, pp.897-902.

Grady, P. and Muller, R.A., 1986. On the use and misuse of input-output based impact analysis in evaluation. *The Canadian Journal of Program Evaluation*, 3(2), pp. 49-61.

Granit, J., Jägerskog, A., Lindström, A., Björklund, G., Bullock, A., Löfgren, R., de Gooijer, G. and Pettigrew, S., 2012. Regional options for addressing the water, energy and food nexus in Central Asia and the Aral Sea Basin. *International Journal of Water Resources* Development, 28(3), pp.419-432. https://doi.org/10.1080/07900627.2012.684307

Grebenstein, C.R. and Field, B.C., 1979. Substituting for water inputs in US manufacturing. *Water Resources Research*, 15(2), pp.228-232.

Green, R.F., Joy, E.J., Harris, F., Agrawal, S., Aleksandrowicz, L., Hillier, J., Macdiarmid, J.I., Milner, J., Vetter, S.H., Smith, P. and Haines, A., 2018. Greenhouse gas emissions and water footprints of typical dietary patterns in India. *Science of the Total Environment*, 643, pp.1411-1418.

Grubb, M., Butler, L. and Twomey, P., 2006. Diversity and security in UK electricity generation: The influence of low-carbon objectives. *Energy policy*, 34(18), pp.4050-4062.

Grubert, E. A., Beach, F. C., & Webber, M. E., 2012, Can switching fuels save water? A life cycle quantification of freshwater consumption for Texas coal-and natural gas-fired electricity. *Environmental research letters*, 7(4), 045801.

Guillaume, J.H., Kummu, M., Eisner, S. and Varis, O., 2015. Transferable principles for managing the nexus: Lessons from historical global water modelling of central Asia. *Water*, 7(8), pp.4200-4231. https://doi.org/10.3390/w7084200

Gulati, A. and Banerjee, P., 2015. Rationalising fertiliser subsidy in India: Key issues and policy options (No. 307). Indian Council for Research on International Economic Relations (ICRIER) Working paper.

Gulati, M., Jacobs, I., Jooste, A., Naidoo, D. and Fakir, S., 2013. The water–energy–food security nexus: Challenges and opportunities for food security in South Africa. *Aquatic Procedia*, 1, pp.150-164. https://doi.org/10.1016/j.aqpro.2013.07.013

Gupta, R.K., 2002. Water and energy linkages for groundwater exploitation: a case study of Gujarat State, India. *International Journal of Water Resources Development*, 18(1), pp.25-45.

Gurdak, J.J., Geyer, G.E., Nanus, L., Taniguchi, M. and Corona, C.R., 2017. Scale dependence of controls on groundwater vulnerability in the water–energy–food nexus, California Coastal Basin aquifer system. *Journal of Hydrology: Regional Studies*, 11, pp.126-138. https://doi.org/10.1016/j.ejrh.2016.01.002

Gurgel, A., Chen, Y., Paltsev, S., & Reilly, J., 2016. Linking Natural Resources to the CGE framework: the case of Land Use Changes in the EPPA Model (Presented at the 19th Annual Conference on Global Economic Analysis, Washington DC, USA). Purdue University, West Lafayette, IN: Global Trade Analysis Project (GTAP), viewed online 3 August 2017 https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=4934

Gurgel, A., Reilly, J.M., Paltsev, S., 2008. Potential land use implications of a global biofuels industry. *Journal of Agricultural and Food Industrial Organization*, 5(2). https://doi.org/10.2202/1542-0485.1202.

Hake, J.F., Schlör, H., Schürmann, K. and Venghaus, S., 2016. Ethics, sustainability and the water, energy, food nexus approach–a new integrated assessment of urban systems. *Energy Procedia*, 88, pp.236-242. https://doi.org/10.1016/j.egypro.2016.06.155

Halbe, J., Pahl-Wostl, C., A. Lange, M. and Velonis, C., 2015. Governance of transitions towards sustainable development–the water–energy–food nexus in Cyprus. *Water International*, 40(5-6), pp.877-894. https://doi.org/10.1080/02508060.2015.1070328

Halim, R.A. and Seck, M.D., 2011. The simulation-based multi-objective evolutionary optimization (SIMEON) framework. In Simulation Conference (WSC), Proceedings of the 2011 Winter (pp. 2834-2846). IEEE.

Hall, P., 2014. Water, energy and food security: Applying Wiener's theories to validate a macro-economic nexus model. In Norbert Wiener in the 21st Century (21CW), IEEE Conference from 24-26 June 2014 (pp. 1-8). IEEE. https://doi.org/10.1109/NORBERT.2014.6893939

Haltas, I., Suckling, J., Soutar, I., Druckman, A. and Varga, L., 2017. Anaerobic digestion: a prime solution for water, energy and food nexus challenges. *Energy Procedia*, 123, pp.22-29. https://doi.org/10.1016/j.egypro.2017.07.280

Hang, M.Y.L.P., Martinez-Hernandez, E., Leach, M. and Yang, A., 2016. Designing integrated local production systems: a study on the food-energy-water nexus. *Journal of Cleaner Production*, 135, pp.1065-1084. https://doi.org/10.1016/j.jclepro.2016.06.194

Hanjra, M. A., & Qureshi, M. E., 2010. Global water crisis and future food security in an era of climate change. *Food Policy*, 35(5), 365-377.

Harris, F., Green, R.F., Joy, E.J., Kayatz, B., Haines, A. and Dangour, A.D., 2017. The water use of Indian diets and socio-demographic factors related to dietary blue water footprint. *Science of the Total Environment*, 587, pp.128-136.

Hart, E.K. and Jacobson, M.Z., 2012. The carbon abatement potential of high penetration intermittent renewables. *Energy & Environmental Science*, 5(5), pp.6592-6601.

Hart, E.K., Stoutenburg, E.D. and Jacobson, M.Z., 2012. The potential of intermittent renewables to meet electric power demand: current methods and emerging analytical techniques. *Proceedings of the IEEE*, 100(2), pp.322-334.

Hazell P., 2003, Agricultural Research and Poverty Reduction: Some Issues and Evidence, eds Mathur S, Pachico D [Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia], pp 43–58

Headey, D. and Fan, S., 2008. Anatomy of a crisis: the causes and consequences of surging food prices. *Agricultural economics*, 39, pp.375-391.

Heard, B.R., Miller, S.A., Liang, S. and Xu, M., 2017. Emerging challenges and opportunities for the food–energy–water nexus in urban systems. *Current Opinion in Chemical Engineering*, 17, pp.48-53. https://doi.org/10.1016/j.coche.2017.06.006

Hellegers, P., Zilberman, D., Steduto, P., & McCornick, P., 2008. Interactions between water, energy, food and environment: evolving perspectives and policy issues. *Water Policy*, 10, 1.

Helmstedt, K.J., Stokes-Draut, J.R., Larsen, A.E. and Potts, M.D., 2018. Innovating at the food, water, and energy interface. *Journal of environmental management*, 209, pp.17-22. https://doi.org/10.1016/j.jenvman.2017.12.026

Henderson, J., Rodgers, C., Jones, R., Smith, J., Strzepek, K., & Martinich, J., 2013. Economic impacts of climate change on water resources in the coterminous United States. Mitigation and Adaptation Strategies for Global Change, 1-23.

Hermann, C.F., 1909. Defining National Security. American Defense Policy, p.19.

Hermann, S., Welsch, M., Segerstrom, R.E., Howells, M.I., Young, C., Alfstad, T., Rogner, H.H. and Steduto, P., 2012, November. Climate, land, energy and water (CLEW) interlinkages in Burkina Faso: An analysis of agricultural intensification and bioenergy production. In *Natural Resources Forum*, 36(4), pp. 245-262).

Hess, T., Andersson, U., Mena, C., & Williams, A., 2015. The impact of healthier dietary scenarios on the global blue water scarcity footprint of food consumption in the UK. *Food Policy*, 50, 1-10.

Hewage, L. G. 1982. 'Survival and Development— Toward a Buddhist Perspective.' Mahabodhi, April- June 1982, pp. 103-114.

Hira, G.S., 2009. Water management in northern states and the food security of India. *Journal of Crop Improvement,* 23(2), pp.136-157.

Hoddinott, J. and Yohannes, Y., 2002. Dietary diversity as a food security indicator. Food consumption and nutrition division discussion paper, 136(136), p.2002.

Hoddinott, J., 1999. Choosing outcome indicators of household food security. Washington, DC: International Food Policy Research Institute.

Hoekstra A.Y. (ed.), 2003. Virtual water trade: Proceedings of the International Expert Meeting on Virtual Water Trade, Value of Water Research Report Series No.12. UNESCO-IHE, Delft, Netherlands

Hoekstra A.Y., 2007. Human appropriation of natural capital: a comparison of ecological footprint and water footprint analysis. Value of Water Research Report Series No. 23, UNESCO-IHE Institute for Water Education, Delft, the Netherlands, viewed online 9 September 2017, https://waterfootprint.org/media/downloads/Report23-Hoekstra-2007.pdf

Hoekstra A.Y., Hung, P.Q., 2002. Virtual water trade: A quantification of virtual water flows between nations in relation to international crop trade, Value of Water Research Report Series No.11. UNESCO-IHE, Delft, Netherlands

Hoekstra, A. Y., & Chapagain, A. K., 2007. Water footprints of nations: water use by people as a function of their consumption pattern. Water resources management, 21(1), 35-48.

Hoff, H., 2011. Understanding the NEXUS, Background Paper for the Bonn 2011 Conference: The Water, Energy and Food Security Nexus. Stockholm: Stockholm Environment Institute, viewed online 5 May 2017, http://www.water-energy-food.org/en/whats_the_nexus/background.html.

Hogan, W. W., & Manne, A. S., 1977. Energy economy interactions: the Fable of the Elephant and the Rabbit? *Advances in the Economics of Energy and Resources*, 1, pp.7-26.

Hogwood, B. and Gunn, L., 1984. Policy Analysis for the Real World (Oxford: Oxford University Press)

Holt, N., Shukla, S., Hochmuth, G., Muñoz-Carpena, R. and Ozores-Hampton, M., 2017. Transforming the food-water-energy-land-economic nexus of plasticulture production through compact bed geometries. *Advances in Water Resources*, 110, pp.515-527. https://doi.org/10.1016/j.advwatres.2017.04.023

Hoolohan, C., Larkin, A., McLachlan, C., Falconer, R., Soutar, I., Suckling, J., Varga, L., Haltas, I., Druckman, A., Lumbroso, D. and Scott, M., 2018. Engaging stakeholders in research to address water–energy–food (WEF) nexus challenges. *Sustainability Science*, pp.1-12. https://doi.org/10.1007/s11625-018-0552-7

Hophmayer-Tokich, S., 2010. Wastewater Management Strategy: Centralized v. Decentralized technologies for small communities. In: Institute UoTatC (ed.), Leewarden, The Netherlands.

Houillon, G., & Jolliet, O., 2005. Life cycle assessment of processes for the treatment of wastewater urban sludge: energy and global warming analysis, *Journal of cleaner production*, 13(3), 287-299

Howarth, C. and Monasterolo, I., 2016. Understanding barriers to decision making in the UK energy-food-water nexus: The added value of interdisciplinary approaches. *Environmental*

Science & Policy, 61, pp.53-60. https://doi.org/10.1016/j.envsci.2016.03.014

Howarth, C. and Monasterolo, I., 2017. Opportunities for knowledge co-production across the energy-food-water nexus: Making interdisciplinary approaches work for better climate decision making. *Environmental Science & Policy*, 75, pp.103-110. https://doi.org/10.1016/j.envsci.2017.05.019

Howells, M., Hermann, S., Welsch, M., Bazilian, M., Segerström, R., Alfstad, T., Gielen, D., Rogner, H., Fischer, G., Van Velthuizen, H. and Wiberg, D., …Ramma, I.,2013. Integrated analysis of climate change, land-use, energy and water strategies. *Nature Climate Change*, 3(7), 621–626. https://doi.org/10.1038/nclimate1789

Hwang, A.S., 1996. Positivist and constructivist persuasions in instructional development. *Instructional Science*, 24(5), pp.343-356.

International Atomic Energy Agency (IAEA), International Energy Agency (IEA), 2001. Indicators for Sustainable Energy Development, report presented at the Ninth Session of the Commission on Sustainable Development, 16–27 April 2001, New York.

ICIMOD (International Centre for Integrated Mountain Development), 2012, Contribution of Himalayan ecosystems to water, energy, and food security in South Asia: A nexus approach. Kathmandu, Nepal: International Centre for Integrated Mountain Development.

ICSA (Institute of Chartered Secretaries and Administrators) International, n.d. Principles of Corporate Governance for Charities, p. 2.

IEA (International Energy Agency), 2012. World Energy Outlook, Chapter 17 - Water for Energy, OECD Publishing, viewed online 25 November 2017, http://www.iea.org/publications/freepublications/publication/WEO2012_free.pdf

IEA (International Energy Agency), 2017. Electricity Access in Developing Asia. Energy Access Outlook, viewed online 1 August 2018, http://www.iea.org/energyaccess/database/

IIHS (India Institute for Human Settlements), 2014. Urban Water Supply & Sanitation in India: Sustaining Policy Momentum, IIHS RF Paper on Water Supply and Sanitation, viewed online 25 June 2018, http://iihs.co.in/knowledge-gateway/wp-content/uploads/2017/11/RF-WATSAN_reduced_sized.pdf

ILO (Indian Labour Organisation), 2013. Pocket Book of Labour Statistics, Labour Bureau, Ministry of Labour & Employment. Government of India, viewed online 17 June 2017, http://labourbureaunew.gov.in/UserContent/PBLS_2013.pdf

INDDEX (International Dietary Data Expansion) Project, 2018. Data4Diets: Building Blocks for Diet-related Food Security Analysis. Tufts University, Boston, MA, viewed online 6 August 2018 https://inddex.nutrition.tufts.edu/data4diets

Jadhav, S.V., Bringas, E., Yadav, G.D., Rathod, V.K., Ortiz, I. and Marathe, K.V., 2015. Arsenic and fluoride contaminated groundwaters: a review of current technologies for contaminants removal. *Journal of Environmental Management*, 162, pp.306-325.

Jain, A.,1985, The Impact of Development and Population Policies on Fertility in India. *Studies in Family Planning*, 16(4), 181-198. https://doi.org/10.2307/1967081

Jalilov, S.M., Amer, S.A. and Ward, F.A., 2018. Managing the water-energy-food nexus: Opportunities in Central Asia. *Journal of Hydrology*, 557, pp.407-425. https://doi.org/10.1016/j.jhydrol.2017.12.040

Jalilov, S.M., Keskinen, M., Varis, O., Amer, S. and Ward, F.A., 2016. Managing the water–energy–food nexus: Gains and losses from new water development in Amu Darya River Basin. *Journal of Hydrology*, 539, pp.648-661. https://doi.org/10.1016/j.jhydrol.2016.05.071

Jarvie, H.P., Sharpley, A.N., Flaten, D., Kleinman, P.J., Jenkins, A. and Simmons, T., 2015. The pivotal role of phosphorus in a resilient water–energy–food security nexus. *Journal of environmental quality*, 44(4), pp.1049-1062. https://doi.org/10.2134/jeq2015.01.0030.

Jeswani, H.K., Burkinshaw, R. and Azapagic, A., 2015. Environmental sustainability issues in the food–energy–water nexus: Breakfast cereals and snacks. *Sustainable Production and Consumption*, 2, pp.17-28. https://doi.org/10.1016/j.spc.2015.08.001

Jha, G.K., Pal, S. and Singh, A., 2012. Changing Energy-use Pattern and the Demand Projection for Indian Agriculture. *Agricultural Economics Research Review*, 25(1).

Jobbins, G., Kalpakian, J., Chriyaa, A., Legrouri, A. and El Mzouri, E.H., 2015. To what end? Drip irrigation and the water–energy–food nexus in Morocco. *International journal of water resources development,* 31(3), pp.393-406. https://doi.org/10.1080/07900627.2015.1020146

Johansson, R.C., Tsur, Y., Roe, T.L., Doukkali, R. and Dinar, A., 2002. Pricing irrigation water: a review of theory and practice. *Water policy*, 4(2), pp.173-199.

Jomini, P., Zhang, X.G. and Osborne, M., 2009. The Armington-Heckscher-Ohlin model-an intuitive exposition, viewed online 20th September 2017 http://gem.sciences-po.fr/content/publications/pdf/Jomini_AHOpaper05022009.pdf

Just, J., 1974. Impacts of New Energy Technology Using Generalized Input-Output Analysis, in Michael Macrakis (ed.), Energy: Demand Conservation and Institutional Problems. Cambridge, MA: MIT Press, 113–128.

Kahrl, F., & Roland-Holst, D., 2008. China's water-energy nexus. Water Policy,10, 51.

Kakinaka, M. and Miyamoto, H., 2012. Unemployment and labour force participation in Japan. *Applied Economics Letters*, 19(11), pp.1039-1043.

Kan, G., Zhang, M., Liang, K., Wang, H., Jiang, Y., Li, J., Ding, L., He, X., Hong, Y., Zuo, D. and Bao, Z., 2016. Improving water quantity simulation & forecasting to solve the energy-water-food nexus issue by using heterogeneous computing accelerated global optimization method. *Applied Energy*. https://doi.org/10.1016/j.apenergy.2016.08.017

Kankaria, A., Nongkynrih, B. and Gupta, S.K., 2014. Indoor air pollution in India: Implications on health and its control. *Indian journal of community medicine*: official publication of Indian Association of Preventive & Social Medicine, 39(4), p.203.

Kapoor, R., 2017. 'Food, energy, water security go together', BusinessLine, 14 March, viewed online 27 March 2017, https://www.thehindubusinessline.com/opinion/food-energy-water-security-go-together/article9583819.ece

Karabulut, A., Egoh, B.N., Lanzanova, D., Grizzetti, B., Bidoglio, G., Pagliero, L., Bouraoui, F., Aloe, A., Reynaud, A., Maes, J. and Vandecasteele, I., 2016. Mapping water provisioning services to support the ecosystem–water–food–energy nexus in the Danube river

basin. *Ecosystem Services*, 17, pp.278-292.
https://doi.org/10.1016/j.ecoser.2015.08.002

Karabulut, A.A., Crenna, E., Sala, S. and Udias, A., 2018. A proposal for integration of the ecosystem-water-food-land-energy (EWFLE) nexus concept into life cycle assessment: A synthesis matrix system for food security. *Journal of Cleaner Production*, 172, pp.3874-3889. https://doi.org/10.1016/j.jclepro.2017.05.092

Karan, E., Asadi, S., Mohtar, R. and Baawain, M., 2018. Towards the optimization of sustainable food-energy-water systems: A stochastic approach. *Journal of Cleaner Production*, 171, pp.662-674. https://doi.org/10.1016/j.jclepro.2017.10.051

Karatayev, M., Rivotti, P., Mourão, Z.S., Konadu, D.D., Shah, N. and Clarke, M., 2017. The water-energy-food nexus in Kazakhstan: challenges and opportunities. *Energy Procedia*, 125, pp.63-70. https://doi.org/10.1016/j.egypro.2017.08.064

Karlberg, L., Hoff, H., Amsalu, T., Andersson, K., Binnington, T., Flores-López, F., de Bruin, A., Gebrehiwot, S.G., Gedif, B., Johnson, O. and zur Heide, F., 2015. Tackling complexity: understanding the food-energy-environment nexus in Ethiopia's Lake tana sub-basin. *Water Alternatives*, 8(1).

Kattelus, M., Rahaman, M.M. and Varis, O., 2014, May. M yanmar under reform: Emerging pressures on water, energy and food security. In Natural Resources Forum (38(2), pp. 85-98). https://doi.org/10.1111/1477-8947.12032

Kaur, R., Sharma, M., 2012. Agricultural Subsidies in India Boon or Curse, IOSR Journal of Humanities and Social Science (JHSS), 2(4), 40-46

Keil, L., Folberth, C., Jedelhauser, M. and Binder, C.R., 2018. Time-Continuous Phosphorus Flows in the Indian Agri-Food Sector: Long-Term Drivers and Management Options. *Journal of Industrial Ecology*, 22(2), pp.406-421.

Keller, A.A., Tellinghuisen, S., Lee, C., Larson, D., Dennen, B. and Lee, J., 2010. Projection of california's future freshwater requirements for power generation. *Energy & environment*, 21(2), pp.1-20.

Kemmler, A. and Spreng, D., 2007. Energy indicators for tracking sustainability in developing countries. Energy policy, 35(4), pp.2466-2480.

Kenway, S. J., Priestley, A., Cook, S., Seo, S., Inman, M., Gregory, A., & Hall, M., 2008. Energy use in the provision and consumption of urban water in Australia and New Zealand. Water Services Association of Australia (WSAA): Sydney, Australia.

Keskinen, M. and Varis, O., 2016. Water-energy-food nexus in large Asian River basins. *Water* 2016, 8(10), p.446.
https://doi.org/10.3390/w8100446

Keskinen, M., Guillaume, J.H., Kattelus, M., Porkka, M., Räsänen, T.A. and Varis, O., 2016. The water-energy-food nexus and the transboundary context: insights from large Asian rivers. *Water*, 8(5), p.193.
https://doi.org/10. 3390/w8050193

Keskinen, M., Someth, P., Salmivaara, A. and Kummu, M., 2015. Water-energy-food nexus in a transboundary river basin: The case of Tonle Sap Lake, Mekong River Basin. *Water*, 7(10), pp.5416-5436.
https://doi.org/10.3390/w7105416

Keulertz, M. & Woertz, E., 2015. Financial challenges of the nexus: pathways for investment in water, energy and agriculture in the Arab world. *International Journal of Water Resources Development*, 31(January 2016), pp.312–325.

Keulertz, M. and Woertz, E., 2015. Financial challenges of the nexus: Pathways for investment in water, energy and agriculture in the Arab world. *International journal of water resources development*, 31(3), pp.312-325. https://doi.org/10.1080/07900627.2015.1019043

Khan, S. and Hanjra, M.A., 2009. Footprints of water and energy inputs in food production–Global perspectives. *Food Policy*, 34(2), pp.130-140. https://doi.org/10.1016/j.foodpol.2008.09.001.

Khan, S.A., Hussain, M.Z., Prasad, S. and Banerjee, U.C., 2009. Prospects of biodiesel production from microalgae in India. *Renewable and Sustainable Energy Reviews*, 13(9), pp.2361-2372.

Kibaroglu, A. and Gürsoy, S.I., 2015. Water–energy–food nexus in a transboundary context: the Euphrates–Tigris river basin as a case study. *Water International*, 40(5-6), pp.824-838. https://doi.org/10.1080/02508060.2015.1078577

Kibler, K.M., Reinhart, D., Hawkins, C., Motlagh, A.M. and Wright, J., 2018. Food waste and the food-energy-water nexus: A review of food waste management alternatives. *Waste Management*. https://doi.org/10.1016/j.wasman.2018.01.014

Kılkış, Ş. and Kılkış, B., 2017. Integrated circular economy and education model to address aspects of an energy-water-food nexus in a dairy facility and local contexts. *Journal of Cleaner Production*, 167, pp.1084-1098. https://doi.org/10.1016/j.jclepro.2017.03.178

Kinekar, B.K., 2011. Potassium fertilizer situation in India: Current use and perspectives. *Karnataka Journal of agricultural sciences*, 24(1).

Kitzes, J., 2013. An introduction to environmentally-extended input-output analysis. *Resources*, 2(4), pp.489-503.

Klein, S. J., & Rubin, E. S., 2013. Life cycle assessment of greenhouse gas emissions, water and land use for concentrated solar power plants with different energy backup systems. *Energy Policy*, 63, 935-950.

Klostermaier, K.K., 2007. Hinduism: A Beginner's Guide. Oneworld Publications.

Klostermaier, K.K., 2010. Ecology, Science, and Religion. In Seaweeds and their Role in Globally Changing Environments (pp. 401-421). Springer, Dordrecht, viewed online 11 July 2017, https://link.springer.com/content/pdf/10.1007%2F978-90-481-8569-6_23.pdf

Köhlin, G., Sills, E.O., Pattanayak, S.K. and Wilfong, C., 2011. Energy, gender and development: what are the linkages? Where is the Evidence?. The World Bank.

Konan, D.E. and Nasseri, I., 2012. Reducing Greenhouse Gas Emissions in Target Industries: A Computable General Equilibrium Model of Energy Conservation (No. 4577). EcoMod.

Koopman, J.F., Kuik, O., Tol, R.S. and Brouwer, R., 2017. The potential of water markets to allocate water between industry, agriculture, and public water utilities as an adaptation mechanism to climate change. Mitigation and adaptation strategies for global change, 22(2), pp.325-347.

Kopf, D., 2018. Stop obsessing about GDP growth—GDP per capita is far more important, Quartz, 22 February, viewed online 10 August 2018 https://qz.com/1194634/the-world-bank-wont-stop-reporting-gdp-instead-of-gdp-per-capita-and-it-is-driving-me-crazy/

Krishnan, S. and Hatekar, N., 2017. Rise of the new middle class in India and its changing structure. *Economic and Political Weekly*, 52(22), pp.40-48.

Kruyt, B., van Vuuren, D.P., de Vries, H.J. and Groenenberg, H., 2009. Indicators for energy security. *Energy policy*, 37(6), pp.2166-2181.

Kumar, A. and Kandpal, T.C., 2007. Renewable energy technologies for irrigation water pumping in India: A preliminary attempt towards potential estimation. *Energy*, 32(5), pp.861-870.

Kumar, M., & Basu, P., 2008. Perspectives of productivity growth in Indian food industry: a data envelopment analysis. *International Journal of Productivity and Performance Management*, 57(7), 503-522.

Kumar, M.D., 2003. Food security and sustainable agriculture in India: the water management challenge (Vol. 60). IWMI.

Kumar, M.D., 2005. Impact of electricity prices and volumetric water allocation on energy and groundwater demand management: analysis from Western India. *Energy policy*, 33(1), pp.39-51.

Kumar, M., Basu, P., 2008. Perspectives of productivity growth in Indian food industry: a data envelopment analysis. *International Journal of Productivity and Performance Management*, 57(7), pp.503-522. https://doi.org/10.1108/17410400810904001

Kumazawa, T., Hara, K., Endo, A. and Taniguchi, M., 2016. Supporting collaboration in interdisciplinary research of water–energy–food nexus by means of ontology engineering. *Journal of Hydrology: Regional Studies*. https://doi.org/10.1016/j.ejrh.2015.11.021

Kumazawa, T., Hara, K., Endo, A. and Taniguchi, M., 2017. Supporting collaboration in interdisciplinary research of water–energy–food nexus by means of ontology engineering. *Journal of Hydrology: Regional Studies*, 11, pp.31-43.

Kurian, M., 2017. The water-energy-food nexus: trade-offs, thresholds and transdisciplinary approaches to sustainable development. *Environmental Science & Policy*, 68, pp.97-106. https://doi.org/10.1016/j.envsci.2016.11.006

Ladanai, S. and Vinterbäck, J., 2009. Global potential of sustainable biomass for energy. Swedish University of Agricultural Sciences, Department of Energy and Technology, Report 013, ISSN 1654-9406, viewed online 20 July 2017 http://pub.epsilon.slu.se/4523/1/ladanai_et_al_100211.pdf

Landes, M.R., 2010. Growth and equity effects of agricultural marketing efficiency gains in India. DIANE Publishing.

Larcom, S. and van Gevelt, T., 2017. Regulating the water-energy-food nexus: Interdependencies, transaction costs and procedural justice. *Environmental Science & Policy*, 72, pp.55-64. https://doi.org/10.1016/j.envsci.2017.03.003

Lawford, R., Bogardi, J., Marx, S., Jain, S., Wostl, C.P., Knüppe, K., Ringler, C., Lansigan, F. and Meza, F., 2013. Basin perspectives on the water–energy–food security nexus. Current *Opinion in Environmental Sustainability*, 5(6), pp.607-616. https://doi.org/10.1016/j.cosust.2013.11.005

Le Coq, C. and Paltseva, E., 2009. Measuring the security of external energy supply in the European Union. Energy policy, 37(11), pp.4474-4481.

Lee, C. C., 2005. Energy consumption and GDP in developing countries: a cointegrated panel analysis. *Energy Economics*, 27(3), 415-427.

Lee, C. and Schluter, G., 1999. Effect of trade on the demand for skilled and unskilled workers. *Economic Systems Research*, 11(1), pp.49-66.

Lee-post, A, 2004, Linear programming: Advantages and Disadvantages Of Using Optimization Models; page B6, viewed online 15 May 2017 http://www.uky.edu/~dsianita/300/online/LP.pdf

Leese, M. and Meisch, S., 2015. Securitising sustainability? Questioning the 'water, energy and food-security nexus'. *Water Alternatives*, 8(1).

Lele, U., Klousia-Marquis, M. and Goswami, S., 2013. Good governance for food, water and energy security. *Aquatic procedia*, 1, pp.44-63. https://doi.org/10.1016/j.aqpro.2013.07.005

Lenzen, M., 2000. Errors in conventional and Input-Output—based Life—Cycle inventories. *Journal of Industrial Ecology*, 4(4), pp.127-148.

Lenzen, M., 2011. Aggregation versus disaggregation in input-output analysis of the environment. *Economic Systems Research*, 23(1), pp.73-89.

Leontief, W., 1953. Studies in the structure of the American economy (Oxford University Press, New York).

Leontief, W., 1970. Environmental repercussions and the economic system, *Review of Economics and Statistics*, 52, 262-272.

Leontief, W., 1986. Technological change, prices, wages, and rates of return on capital in the U.S. economy,in: Input-output economics, 2nd edn. (Oxford University Press, New York).

Leontief, W.W., 1936. Quantitative input and output relations in the economic systems of the United States. *The review of economic statistics*, pp.105-125.

Levien, M., 2012. The land question: special economic zones and the political economy of dispossession in India. *The Journal of Peasant Studies,* 39(3-4), pp.933-969.

Li, G., Huang, D. and Li, Y., 2016. China's input-output efficiency of water-energy-food nexus based on the Data Envelopment Analysis (DEA) model. *Sustainability*, 8(9), p.927. https://doi.org/10.3390/su8090927

Liang, S., Zhang, T., 2011. Interactions of energy technology development and new energy exploitation with water technology development in China, *Energy*, 36:6960-6966. https://doi.org/10.1016/j.energy.2011.09.013

Liu, J., and Savenije, H. H. G., 2008. Food consumption patterns and their effect on water requirement in China, *Hydrol. Earth Syst. Sci*., 12, 887–898. https://doi.org/10.5194/hess-12-887-2008

Liu, Y., Wang, S. and Chen, B., 2017. Regional water–energy–food nexus in China based on multiregional input–output analysis. *Energy Procedia*, 142, pp.3108-3114. https://doi.org/10.1016/j.enpol.2017.11.037

Lodge, M., & Wegrich, K., 2012. Managing regulation: regulatory analysis, politics and policy. Palgrave Macmillan.

Lundy, J. and Bowdish, L., 2014. The Energy–Water–Food Nexus: Insights for the Business Community. US Chamber of Commerce Foundation, Washington, DC.

Luo, T., Krishnan, D., Sen, S., 2018. Parched Power: Water Demands, Risks, And Opportunities for India's Power Sector, Working Paper, World Resources Institute, viewed online 5 October

2018,
http://www.wri.org/sites/default/files/parched-power-india.pdf

Macknick, J, Newmark, R, Heath G, Hallett, K.C., 2012. Operational water consumption and withdrawal factors for electricity generating technologies: a review of existing literature, *Environ. Res. Lett.* 7, 045802 (10pp)

Macknick, J., Newmark, R., Heath, G., & Hallett, K. C., 2011. A review of operational water consumption and withdrawal factors for electricity generating technologies. National Renewable Energy Laboratory, Technical Report, NREL/TP-6A20-50900.

Maddison, A., 1971. The Economic and Social Impact of Colonial Rule in India. Angus Maddison, Class Structure and Economic Growth: India & Pakistan since the Moghuls, viewed online 17 June 2017,
http://www. ggdc. net/maddison/articles/moghul_3. pdf.

Markaki, M., Belegri-Roboli, A., Michaelides, P., Mirasgedis, S., & Lalas, D. P., 2013. The impact of clean energy investments on the Greek economy: An input–output analysis (2010–2020). *Energy Policy*, 57, 263-275.

Marlow, H.J., Harwatt, H., Soret, S. and Sabaté, J., 2015. Comparing the water, energy, pesticide and fertilizer usage for the production of foods consumed by different dietary types in California. *Public health nutrition*, 18(13), pp.2425-2432.

Martchamadol, J. and Kumar, S., 2012. Thailand's energy security indicators. Renewable and *Sustainable Energy Reviews*, 16(8), pp.6103-6122.

Martinez-Hernandez, E. and Samsatli, S., 2017. Biorefineries and the food, energy, water nexus—towards a whole systems approach to design and planning. *Current Opinion in Chemical Engineering,* 18, pp.16-22.
https://doi.org/10.1016/j.coche.2017.08.003

Martinez-Moyano, I.J., 2012. Documentation for model transparency. System Dynamics Review, 28(2), pp.199-208.
https://doi.org/10.1002/sdr.1471

Maslow, A. H., 1943, A Theory of Human Motivation. Psychological Review. 50(4), 370-96.

Maslow, A. H., 1954, Motivation and personality. New York: Harper and Row.

Mathpal, Y. D., 1985. Prehistoric Rock Paintings of Bhimbetka, Central India (New Delhi: Abhinav)

Mathur, O.P. and Thakur, S. 2006. Urban Water Pricing: Urban Water Pricing: Setting the Stage for Reforms. National Institute of Public Finance and Policy, viewed online 25 August 2017,
http://iipa.org.in/common/pdf/PAPER%203_Urban%20Water%20Pricing.pdf

Mathur, R., 2014. India's Energy Security: Challenges and Opportunities. Alternative Fuels, Yojana, viewed online 15 June 2018,
http://iasscore.in/pdf/yojna/2.%20Indian%20Energy%20Security.pdf

Matthews, A., O'Toole, R. and Jensen, J., 2003. The IMAGE Model: Decision Making Tool for the Food Industry. Department of Economics Trinity College, Dublin

Matthews, N. & Motta, S., 2015. Chinese state-owned enterprise investment in mekong hydropower: Political and economic drivers and their implications across the water, energy, food nexus. *Water* (Switzerland), 7, pp.6269–6284.

Matthews, N. and Motta, S., 2015. Chinese state-owned enterprise investment in Mekong hydropower: Political and economic drivers and their implications across the water, energy,

food nexus. *Water*, 7(11), pp.6269-6284.
https://doi.org/10.3390/w7116269

Mayanja, R.., 2010. Maintaining international peace and security: the importance of Security Council Resolution 1325(2000), Culture of Peace Distinguished Speaker Series, viewed online 14 February 2016
http://www.un.org/womenwatch/osagi/pdf/Soka-Gokka-Intl-09Nov2010.pdf

Mayor, B., López-Gunn, E., Villarroya, F.I. and Montero, E., 2015. Application of a water–energy–food nexus framework for the Duero river basin in Spain. *Water International*, 40(5-6), pp.791-808.
https://doi.org/10.1080/02508060.2015.1071512

McGinnis, R. L., & Elimelech, M., 2008. Global challenges in energy and water supply: the promise of engineered osmosis. *Environmental science & technology*, 42(23), 8625-8629.

McLeod, J., 2015. The history of India. Second Edition, ABC-CLIO, LLC, Santa Barbara, California.

McLeod, S., 2007. Maslow's hierarchy of needs. Simply Psychology, 1, viewed online 25 June 2018 http://highgatecounselling.org.uk/members/certificate/CT2%20Paper%201.pdf

Mehrotra, S., Parida, J. 2018. Unemployment in India: Real problems of country's job market are being ignored, Financial Express, viewed online October 29 2018.
https://www.financialexpress.com/opinion/unemployment-in-india-real-problems-of-countrys-job-market-are-being-ignored/1356434

Mekonnen, M. M., & Hoekstra, A. Y., 2014. Water footprint benchmarks for crop production: A first global assessment. *Ecological indicators*, 46, 214-223.

Meldrum, J., Nettles-Anderson, S., Heath, G., & Macknick, J., 2013. Life cycle water use for electricity generation: a review and harmonization of literature estimates. *Environmental Research Letters*, 8(1), 015031.

Merrey, D. J., 1997. Expanding the frontiers of irrigation management research. International Water Management Institute, Colombo, Sri Lanka.

Merschmann, P. R. D. C., Vasquez, E., Szklo, A. S., & Schaeffer, R., 2013, Modeling water use demands for thermoelectric power plants with CCS in selected Brazilian water basins. *International Journal of Greenhouse Gas Control*, 13, 87-101.

Middleton, C., Allouche, J., Gyawali, D. and Allen, S., 2015. The rise and implications of the water-energy-food nexus in Southeast Asia through an environmental justice lens. *Water Alternatives*, 8(1).

Mielke, E., Anadon, L.D., Narayanamurti, V., 2010. Water Consumption of Energy Resource Extraction, Processing and Conversion, Energy Technology

Milana, C., 2001. The input–output structural decomposition analysis of 'flexible' production systems. Input-Output Analysis: Frontiers and Extensions, New York, Palgrave, pp.349-80.

Miller, L.A., Ramaswami, A. and Ranjan, R., 2012. Contribution of water and wastewater infrastructures to urban energy metabolism and greenhouse gas emissions in cities in India. *Journal of Environmental Engineering*, 139(5), pp.738-745.

Miller, R.E. and Blair, P.D., 2009. Input-output analysis: foundations and extensions. Cambridge university press.

Mirzabaev, A., Guta, D., Goedecke, J., Gaur, V., Börner, J., Virchow, D., Denich, M. and von Braun, J., 2015. Bioenergy, food security and poverty reduction: trade-offs and synergies along the water–energy–food security nexus. *Water International*, 40(5-6), pp.772-790. https://doi.org/10.1080/02508060.2015.1048924

Misra, A. K., 2014. Climate change and challenges of water and food security. *International Journal of Sustainable Built Environment*, 3(1), 153-165.

Misturelli, F. and Heffernan, C., 2003. Poverty and participation: an analysis of bias in participatory methods. Livestock Development Group, University of Reading, UK.

Mittal, M.L., Sharma, C. and Singh, R., 2012. August. Estimates of emissions from coal fired thermal power plants in India. In 2012 International emission inventory conference (pp. 13-16).

MoDWS(Ministry of Drinking Water & Sanitation), 2013. National Rural Drinking Water Programme, Movement towards ensuring people's Drinking Water Security in Rural India, Government of India

MoEF (Ministry of Environment and Forests), 2010. India: Green House Gas Emissions 2007. Indian Network for Climate Change Assessment (INCCA), Government of India, New Delhi, viewed 13 September 2017, http://www.moef.nic.in/downloads/public-information/Report_INCCA.pdf

MoEF (Ministry of Environment and Forests), 2015. Notification, New Delhi, Tuesday, December 8, 2015/Agrahayana 17, 1937, REGD. NO. D. L.-33004/99, viewed online 20 August 2017, http://www.indiaenvironmentportal.org.in/files/file/Moef%20notification%20-%20gazette.pdf

Molle, F. et al., 2008. Irrigation versus hydropower: Sectoral conflicts in southern Sri Lanka. *Water Policy*, 10, pp.37–50.

Molle, F., Jayakody, P., Ariyaratne, R. and Somatilake, H.S., 2008. Irrigation versus hydropower: sectoral conflicts in southern Sri Lanka. *Water Policy*, 10(S1), pp.37-50. https://doi.org/10.2166/wp.2008.05

Monaghan, J. M., Daccache, A., Vickers, L. H., Hess, T. M., Weatherhead, E. K., Grove, I. G., & Knox, J. W., 2013. More 'crop per drop': constraints and opportunities for precision irrigation in European agriculture. *Journal of the Science of Food and Agriculture*, 93(5), 977-980

MoPNG (Ministry of Petroleum and Natural Gas), 2015. Indian Petroleum & Natural Gas Statistics 2015-16. Economics and Statistics Division, Government of India.

MoSPI (Ministry Of Statistics And Programme Implementation), 2011. Selected Socio-Economic Statistics India, Central Statistics Office, Government of India, New Delhi, viewed online 20 July 2018 http://mospi.nic.in/sites/default/files/publication_reports/sel_socio_eco_stats_ind_2001_28oct11.pdf

MoSPI (Ministry Of Statistics And Programme Implementation), 2013. Key Indicators of Household Consumer Expenditure in India. NSSO 68th Round (2011-12), Government of India.

MoSPI (Ministry Of Statistics And Programme Implementation), 2014. Infrastructure Statistics - 2014, Third issue, VOL. I, Central Statistics Office, Government of India http://www.indiaenvironmentportal.org.in/files/file/infrastructure%20statistics%20vol.1.pdf

MoSPI (Ministry Of Statistics And Programme Implementation), 2016. Horticulture Statistical Year Book India 2016, Government of India, viewed online 20 September, 2017 http://www.mospi.gov.in/statistical-year-book-india/2016/178

MoSPI (Ministry Of Statistics And Programme Implementation), 2017a. National Accounts Statistics 2017, Government of India, viewed online 21 January 2018 http://www.mospi.gov.in/publication/national-accounts-statistics-2017-1

MoSPI (Ministry Of Statistics And Programme Implementation), 2017b. Energy Statistics. Central Statistics Office, Government of India, viewed online 26 November 2018 http://www.mospi.nic.in/sites/default/files/publication_reports/Energy_Statistics_2017r.pdf.pdf

MoSPI (Ministry Of Statistics And Programme Implementation), 2018. Energy Statistics. Central Statistics Office, Government of India, viewed online 20 August 2018, http://mospi.nic.in/sites/default/files/publication_reports/Energy_Statistics_2018.pdf

MoUD (Ministry of Urban Development), 2012. Recent Trends In Technologies In Sewerage System. Government of India, viewed online 12 July 2018, https://sswm.info/sites/default/files/reference_attachments/MoUD%202012%20Recent%20Trends%20in%20Technologiespdf.pdf

MoWR (Ministry of Water Resources), 2014. Guidelines for Improving Water Use Efficiency in Irrigation, Domestic & Industrial Sectors. Central Water Commission http://mowr.gov.in/sites/default/files/Guidelines_for_improving_water_use_efficiency_1.pdf

MoWR (Ministry of Water Resources), 2014. Guidelines for improving water use efficiency in irrigation, domestic & industrial sectors. Performance overview and management organisation, Central Water Commission, Government of India.

Mueller, S.A., Anderson, J.E. and Wallington, T.J., 2011. Impact of biofuel production and other supply and demand factors on food price increases in 2008. *Biomass and Bioenergy*, 35(5), pp.1623-1632.

Mukherji, A., 2007. The energy-irrigation nexus and its impact on groundwater markets in eastern Indo-Gangetic basin: Evidence from West Bengal, India. *Energy Policy*, 35(12), pp.6413-6430.

Mukuve, F.M. and Fenner, R.A., 2015. The influence of water, land, energy and soil-nutrient resource interactions on the food system in Uganda. *Food Policy*, 51, pp.24-37. https://doi.org/10.1016/j.foodpol.2014.12.001.

Mulalic, I., Oslen, T., 2004 Sustainable Development Indicators: Based on National Accounts, Paper prepared for the 23:e Nordiska Statistikermötet, Technical University of Denmark, · Statistics Denmark.

Muller, M., 2015. The "nexus" as a step back towards a more coherent water resource management paradigm. *Water Alternatives*, 8(1), pp.675–694

Mushtaq, S., Maraseni, T.N., Maroulis, J. and Hafeez, M., 2009. Energy and water tradeoffs in enhancing food security: A selective international assessment. *Energy Policy*, 37(9), pp.3635-3644.
https://doi.org/10.1016/j.enpol.2009.04.030

Nanduri, V., & Saavedra-Antolínez, I., 2013. A competitive Markov decision process model for the energy–water–climate change nexus. *Applied Energy* 111, 186-198.

Narayanan, S., 2014. The National Food Security Act vis-à-vis the WTO agreement on agriculture. *Economic & Political Weekly*, 49(5), p.41.

Narayanan, S., 2015. Food security in India: the imperative and its challenges. *Asia & the Pacific Policy Studies*, 2(1), pp.197-209.

Nawani, N.P., 1994. Indian experience on household food and nutrition security. In Regional Expert Consultation of the Asia-Pacific Network for Food and Nutrition on Household Food Security with Respect to Desirable Dietary Pattern, Bangkok (Thailand), 8-11 Aug 1994.

NCIWRD (National Commission on Integrated Water Resources Development), 1999. Integrated water resource development: a plan for action. Report of the National Commission for Integrated Water Resource Development (NCIWRD), Vol. I. Ministry of Water Resources, Government of India

Ndikumana, L. and Verick, S., 2007. The linkages between FDI and domestic investment: Unravelling the developmental impact of foreign investment (No. 2007-13). Working Paper, University of Massachusetts, Department of Economics.

NDTV, 2016. 'PM Narendra Modi's New Slogan To Farmers: Per Drop More Drop', All India, Indo-Asian News Service, viewed online 20 July 2018, https://www.ndtv.com/india-news/pm-narendra-modis-new-slogan-to-farmers-per-drop-more-crop-1395608

North, D. C., 1990. Institutions, Institutional Change, and Economic Performance. Cambridge: Cambridge University Press.

North, D. C., 1991. Institutions. *Journal of Economic Perspectives*, 5 (1) , pp. 97–112.

North, D. C., 1994. Economic Performance through Time. *American Economic Review*, 84(3), pp. 359–67

NSSO (National Sample Survey Office), 2014a. Household Consumption of Various Goods and Services in India 20ll-12, National Statistical Organisation 68th Round, JULY 2011 - JUNE 2012, Ministry of Statistics and Programme Implementation, Government of India

NSSO (National Sample Survey Office), 2014b. Nutritional Intake in India, 2011-12, National Statistical Organisation 68th Round, JULY 2011 - JUNE 2012, Ministry of Statistics and Programme Implementation, Government of India

O'Reilly, K., 2006. "Traditional" women,"modern" water: Linking gender and commodification in Rajasthan, India. *Geoforum*, 37(6), pp.958-972.

Odegard, I. Y. R., & van der Voet, E., 2014. The future of food—Scenarios and the effect on natural resource use in agriculture in 2050. *Ecological Economics*, 97, 51-59.

OECD (Organisation for Economic Co-operation and Development), 2010. 'Trade balance as a percentage of GDP', in Measuring Globalisation: OECD Economic Globalisation Indicators 2010. OECD Publishing, Paris. https://doi.org/10.1787/9789264084360-22-en

OECD (Organisation for Economic Cooperation and Development), 2013. Water Security for Better Lives. OECD Studies on Water, OECD Publishing. https://doi.org/10.1787/9789264202405-en

Okadera, T., Geng, Y., Fujita, T., Dong, H., Liu, Z., Yoshida, N., & Kanazawa, T., 2015. Evaluating the water footprint of the energy supply of Liaoning Province, China: A regional input–output analysis approach. *Energy Policy*, 78, 148-157.

Okagawa, A. and Ban, K., 2008. Estimation of substitution elasticities for CGE models. Discussion Papers in Economics and Business, 16.

Owen, A., Scott, K. and Barrett, J., 2018. Identifying critical supply chains and final products: an input-output approach to exploring the energy-water-food nexus. *Applied Energy*, 210, pp.632-642. https://doi.org/10.1016/j.apenergy.2017.09.069

Owen, W. F., 1982. Energy in wastewater treatment. Prentice-Hall, Inc., Englewood Cliffs, NJ

Ozturk, I., 2015. Sustainability in the food-energy-water nexus: Evidence from BRICS (Brazil, the Russian Federation, India, China, and South Africa) countries. *Energy*, 93, pp.999-1010. https://doi.org/10.1016/j.energy.2015.09.104

Pacey, A. and Cullis, A., 1986. Rainwater harvesting: the collection of rainfall and runoff in rural areas. Intermediate technology publications.

Pachauri, S. and Jiang, L., 2008. The household energy transition in India and China. *Energy policy*. 36(11), pp.4022-4035.

Pahl-Wostl, C., 2017. Governance of the water-energy-food security nexus: A multi-level coordination challenge. *Environmental Science & Policy*. https://doi.org/10.1016/j.envsci.2017.07.017

Pan, L., Liu, P., Ma, L., & Li, Z., 2012. A supply chain based assessment of water issues in the coal industry in China. *Energy Policy*, 48, 93-102.

Pandve, H.T., 2009. India's national action plan on climate change. *Indian journal of occupational and environmental medicine*, 13(1), p.17.

Papageorgiou, C., Saam, M. and Schulte, P., 2013. Elasticity of substitution between clean and dirty energy inputs-a macroeconomic perspective. *Review of Economics and Statistics*, 99(2), pp.281-290.

Parikh, J.K. and Ramanathan, R., 1999. Linkages among energy, agriculture and environment in rural India. *Energy economics*, 21(6), pp.561-585.

Parker, P., Letcher, R., Jakeman, A., Beck, M.B., Harris, G., Argent, R.M., Hare, M., Pahl-Wostl, C., Voinov, A., Janssen, M. and Sullivan, P., 2002. Progress in integrated assessment and modelling1. *Environmental modelling & software*, 17(3), pp.209-217.

Patton, C., Sawicki, D. and Clark, J., 2015. Basic Methods of Policy Analysis and Planning--Pearson eText. Routledge.

Patton, C.V. and Sawicki, D.S., 1993. Basic methods of policy analysis and planning. Englewood Cliffs: Prentice-Hall.

Perez-Arriaga, I.J. and Batlle, C., 2012. Impacts of intermittent renewables on electricity generation system operation. *Economics of Energy & Environmental Policy*, 1(2), pp.3-18.

Perrone, D. and Hornberger, G., 2016. Frontiers of the food–energy–water trilemma: Sri Lanka as a microcosm of tradeoffs. *Environmental Research Letters*, 11(1), p.014005.

Peters, J.C., 2016a. The GTAP-power data base: Disaggregating the electricity sector in the GTAP data base. *Journal of Global Economic Analysis*, 1(1), pp.209-250.

Peters, J.C., 2016b. GTAP-E-Power: An Electricity-detailed Extension of the GTAP-E model. In 2016 GTAP Conference Paper. GTAP Resource (Vol. 4891), viewed online 20 January 2017, https://www.gtap.agecon.purdue.edu/resources/download/8346.pdf

PIB (Press Information Bureau), 2012. Per Capita Water Availability. Press Information Bureau, Ministry of Water Resources, Government of India, viewed online 24 January 2015 http://pib.nic.in/newsite/erelease.aspx?relid=82676

PIB (Press Information Bureau), 2013a. National Food Security Act enacted to provide subsidized foodgrains to about 82 crore people , Press Information Bureau, Ministry of Consumer Affairs, Food & Public Distribution, Government of India, viewed online 4 October 2018 http://pib.nic.in/newsite/PrintRelease.aspx?relid=102057

PIB (Press Information Bureau), 2013b. NMSA for Promoting Sustainable Agricultural Growth in the Context of Climate Change, Ministry of Agriculture & Farmers Welfare, Government of

India, viewed online 24 January 2018, http://pib.nic.in/newsite/PrintRelease.aspx?relid=93761

PIB (Press Information Bureau), 2015. India to reduce the Emissions Intensity of its GDP by 33 to 35 Per Cent by 2030 from 2005 Level. Ministry of Environment, Forest and Climate Change, Government of India, viewed online 23 March 2017, http://pib.nic.in/newsite/PrintRelease.aspx?relid=128403

Pingali, P.L., 2012. Green revolution: impacts, limits, and the path ahead. *Proceedings of the National Academy of Sciences*, 109(31), pp.12302-12308.

Pittock, J., Orr, S., Stevens, L., Aheeyar, M. and Smith, M., 2015. Tackling trade-offs in the nexus of water, energy and food. *Aquatic Procedia*, 5, pp.58-68. https://doi.org/10.1016/j.aqpro.2015.10.008

Population Foundation of India (PFI), 2007. The Future Population of India: A Long-range Demographic View. Population Foundation of India, New Delhi and Population Reference Bureau, Washington.

Portney, K.E., Hannibal, B., Goldsmith, C., McGee, P., Liu, X. and Vedlitz, A., 2017a. Awareness of the food–energy–water nexus and public policy support in the United States: public attitudes among the American people. *Environment and Behavior*, p.0013916517706531. https://doi.org/10.1177/0013916517706531

Portney, K.E., Vedlitz, A., Sansom, G., Berke, P. and Daher, B.T., 2017b. Governance of the Water-Energy-Food Nexus: the Conceptual and Methodological Foundations for the San Antonio Region Case Study. Current Sustainable/Renewable Energy Reports, 4(3), pp.160-167. https://doi.org /10.1007/s40518-017-0077-1

Proops, J., Faber, M. and Wagenhals, G., 1993. Reducing CO2 Emissions: A Comparative Input-Output Study for Germany and the UK. Springer-Verlag, Berlin, Heidelberg.

Purohit, P. and Kandpal, T.C., 2005. Renewable energy technologies for irrigation water pumping in India: projected levels of dissemination, energy delivery and investment requirements using available diffusion models. *Renewable and Sustainable Energy Reviews*, 9(6), pp.592-607.

Quesnay, F., 1758. Tableau économique. Facsimile: http://www. taieb. net/auteurs/Quesnay/t1758m. html Text: http://www. taieb. net/auteurs/Quesnay/t1758. html, 15.

Racoviceanu, A. I., Karney, B. W., Kennedy, C. A., & Colombo, A. F., 2007. Life-cycle energy use and greenhouse gas emissions inventory for water treatment systems. *Journal of Infrastructure Systems*, 13(4), 261-270.

Radhakrishna, R., Subbarao, K., Indrakant, S. and Ravi, C., 1997. India's public distribution system: a national and international perspective, World Bank Discussion paper No.380, The World Bank.

Rahman, A.Z., 2004. Correlations between green revolution and population growth: revisited in the context of Bangladesh and India. *Asian Aff*, 26(2), pp.41-60.

Rajagopal, D., 2008. Implications of India's biofuel policies for food, water and the poor. *Water Policy*, 10(S1), pp.95-106.

Raju, S.S., Suresh, A., Chand, R. and Chauhan, S., 2015. Pattern and trend in labour use in Indian agriculture: An analysis across major crops and states. *Economic Affairs*, 60(1), p.99.

Ramakrishna, K., 1984. The emergence of environmental law in the developing countries: A case study of India. *Ecology LQ*, 12, p.907.

Ramaswami, A., Boyer, D., Nagpure, A.S., Fang, A., Bogra, S., Bakshi, B., Cohen, E. and Rao-Ghorpade, A., 2017. An urban systems framework to assess the trans-boundary food-energy-water nexus: implementation in Delhi, India. *Environmental Research Letters*, 12(2), p.025008. https://doi.org/10.1088/1748-9326/aa5556

Ramirez, C.A., Bakshi, B., Gibon, T. and Hertwich, E., 2013. Assessment of low carbon energy technologies: fossil fuels and CCS. *Energy Procedia*, 37, pp.2637-2644.

Räsänen, T.A., Joffre, O.M., Someth, P., Thanh, C.T., Keskinen, M. and Kummu, M., 2014. Model-based assessment of water, food, and energy trade-offs in a cascade of multipurpose reservoirs: Case study of the Sesan Tributary of the Mekong River. *Journal of Water Resources Planning and Management*, 141(1), p.05014007. https://doi.org/10.1061/(ASCE)WR.1943-5452 .0000459

Rasul, G. and Sharma, B., 2016. The nexus approach to water–energy–food security: an option for adaptation to climate change. *Climate Policy*, 16(6), pp.682-702. https://doi.org/10.1080/14693062.2015.1029865

Rasul, G., 2014. Food, water, and energy security in South Asia: a nexus perspective from the Hindu Kush Himalayan region☆. *Environmental Science & Policy*, 39, pp.35-48. https://doi.org/10.1016/j.envsci.2014.01.010

Rasul, G., 2016. Managing the food, water, and energy nexus for achieving the Sustainable Development Goals in South Asia. *Environmental Development*, 18, pp.14-25. https://doi.org/10.1016/j.envdev.2015.12.001

Ravindranath, N.H., Sita Lakshmi, C., Manuvie, R., Balachandra, P., 2011. Biofuel production and implications for land use, food production and environment in India. *Energy Policy*, 39, 5737-5745

Ren, D., Yang, Y., Yang, Y., Richards, K. and Zhou, X., 2018. Land-Water-Food Nexus and indications of crop adjustment for water shortage solution. *Science of The Total Environment*, 626, pp.11-21.

Reserve Bank of India (RBI), 2017. Table 2: Macro-Economic Aggregates (At Constant Prices), viewed online 30 October 2017, https://rbi.org.in/Scripts/PublicationsView.aspx?id=17777

Ringler, C., Bhaduri, A. and Lawford, R., 2013. The nexus across water, energy, land and food (WELF): potential for improved resource use efficiency?. *Current Opinion in Environmental Sustainability*, 5(6), pp.617-624. https://doi.org/10.1016/j.cosust.2013.11.002

Ringler, C., Willenbockel, D., Perez, N., Rosegrant, M., Zhu, T. and Matthews, N., 2016. Global linkages among energy, food and water: an economic assessment. Journal of *Environmental Studies and Sciences*, 6(1), pp.161-171. https://doi.org/10.1007/s13412-016-0386-5

Rohde, M.M., 2018. Securing Food, Energy, and Water in India. In Food, Energy and Water Sustainability, 21(37), pp. 21-37, Routledge in association with GSE Research.

Roland-Holst, D. and Heft-Neal, S., 2012, February. Food-water-energy nexus: GMS challenges of growth for 2020 and beyond. In Conference Proceedings at the International Conference on GMS (Vol. 2020, pp. 484-500).

Romero-Lankao, P., McPhearson, T. and Davidson, D.J., 2017. The food-energy-water nexus and urban complexity. *Nature Climate Change*, 7(4), p.233. https://doi.org/10.1038/nclimate3260

Rose, A. and C.Y. Chen, 1991. Sources of change in energy use in the U.S. Economy, 1972-1982, *Resources and Energy* 13, 1-21.

Rose, A., 1984. Technological Change and Input-Output Analysis: An Appraisal, *Socio-Economic Planning Sciences*, 18(5), pp.305-318

Rose, A., 1995. Input-output economics and computable general equilibrium models. *Structural change and economic dynamics*, 6(3), pp.295-304.

Rosegrant, M. W., & Ringler, C., 1999. Impact on food security and rural development of reallocating water from agriculture (No. 47). International Food Policy Research Institute (IFPRI).

Rosen, C. ed., 2000. World Resources 2000-2001: People and ecosystems: The fraying web of life. World Resources Institute, Elsevier Science. p.188

Rosenzweig, C., & Parry, M. L., 1994. Potential impact of climate change on world food supply. *Nature*, 367(6459), 133-138.

Ruel, M.T., 2003. Operationalizing dietary diversity: a review of measurement issues and research priorities. *J Nutr.*;133 (11 Suppl 2):3911S–3926S.

Rutovitz, J. and Harris, S.M., 2012. Calculating global energy sector jobs: 2012 methodology. For Greenpeace International, Institute for Sustainable Futures, University of Technology Sydney.

Sachs, L., Silk, D., 1990. Food and Energy: Strategies for Sustainable Development. United Nations University Press, Tokyo, Japan, pp. 90, viewed online 14 July 2017, http://archive.unu.edu/unupress/unupbooks/80757e/80757E00.htm

Sahin, V. and Hall, M.J., 1996. The effects of afforestation and deforestation on water yields. *Journal of hydrology*, 178(1-4), pp.293-309.

Salmoral, G. and Yan, X., 2018. Food-energy-water nexus: A life cycle analysis on virtual water and embodied energy in food consumption in the Tamar catchment, UK. *Resources, Conservation and Recycling*, 133, pp.320-330. https://doi.org/10.1016/j.resconrec.2018.01.018

Sampath, R.K., 1992. Issues in irrigation pricing in developing countries. *World Development*, 20(7), pp.967-977.

Sattler, S., Macknick, J., Yates, D., Flores-Lopez, F., Lopez, A., & Rogers, J., 2012. Linking electricity and water models to assess electricity choices at water-relevant scales. *Environmental Research Letters*, 7(4), 045804.

Sauer, A., Klop, P., Agrawal, S., 2010. Over Heating: Financial Risks from Water Constraints on Power Generation in Asia, World Resources Institute, viewed online 7 November 2014, http://www.wri.org/sites/default/files/pdf/over_heating_asia.pdf

Schaldach, R., Priess, J.A. and Alcamo, J., 2011. Simulating the impact of biofuel development on country-wide land-use change in India. *Biomass and bioenergy*, 35(6), pp.2401-2410.

Schlör, H., Venghaus, S. and Hake, J.F., 2018b. The FEW-Nexus city index–measuring urban resilience. *Applied Energy*, 210, pp.382-392. https://doi.org/10.1016/j.apenergy.2017.02.026

Schlör, H., Venghaus, S., Fischer, W., Märker, C. and Hake, J.F., 2018a. Deliberations about a perfect storm–The meaning of justice for food energy water-nexus (FEW-Nexus). *Journal* *of environmental management*, 220, pp.16-29. https://doi.org/10.1016/j.jenvman.2018.04.097

Schmidt, J.J. and Matthews, N., 2018. From state to system: Financialization and the water-energy-food-climate nexus. *Geoforum*, 91, pp.151-159. https://doi.org/10.1016/j.geoforum.2018.03.001

Scott, C. A., Pierce, S. A., Pasqualetti, M. J., Jones, A. L., Montz, B. E., & Hoover, J. H., 2011. Policy and institutional dimensions of the water–energy nexus. *Energy Policy*, 39(10), 6622-6630.

Scott, C.A. and Shah, T., 2004. Groundwater overdraft reduction through agricultural energy policy: insights from India and Mexico. *International Journal of Water Resources Development*, 20(2), pp.149-164.

Seagraves, J. A., & Easter, K. W., 1983. Pricing irrigation water in developing countries. *Water Resources Bulletin*, 4, 663–671

Semiat, R., 2008. Energy issues in desalination processes. *Environmental science & technology*, 42(22), 8193-8201.

Shah, T. and Verma, S., 2008. Co-management of electricity and groundwater: an assessment of Gujarat's Jyotirgram scheme. *Economic and Political Weekly*, pp.59-66.

Shah, T., 2006. Groundwater and human development: challenges and opportunities in livelihoods and environment. Groundwater research and management: Integrating science into management decisions.

Shah, T., 2007. Crop per drop of diesel? Energy squeeze on India's smallholder irrigation. *Economic and Political Weekly*, 4002-4009.

Shah, T., Bhatt, S., Shah, R. K., & Talati, J., 2008. Groundwater governance through electricity supply management: Assessing an innovative intervention in Gujarat, western India. *Agricultural Water Management*, 95(11), 1233-1242.

Shah, T., Giordano, M. and Mukherji, A., 2012. Political economy of the energy-groundwater nexus in India: exploring issues and assessing policy options. *Hydrogeology Journal*, 20(5), pp.995-1006.

Shah, T., Giordano, M., & Wang, J., 2004. Irrigation institutions in a dynamic economy: What is China doing differently from India?, *Economic and Political Weekly*, 3452-3461.

Shah, T., Van Koppen, B., de Lange, D. M. M., & Samad, M., 2002. Institutional alternatives in African smallholder irrigation: Lessons from international experience with irrigation management transfer (Vol. 60). IWMI.

Sharma, A.K. and Prakash, B., 2011. Causes and consequences of supply-demand gap for labour in sugarcane in India. *Agricultural Economics Research Review*, 24(347-2016-16996), p.401.

Sharma, A., Sutradhar, M., Monlai, S., and Kumari, N., 2018. Present and Past Status of Indian Agriculture. *Agriculture Research & Technology*: Open Access J., 17(5). https://doi.org/10.19080/ARTOAJ.2018.17.556040

Sharmina, M., Hoolohan, C., Bows-Larkin, A., Burgess, P.J., Colwill, J., Gilbert, P., Howard, D., Knox, J. and Anderson, K., 2016. A nexus perspective on competing land demands: Wider lessons from a UK policy case study. *Environmental Science & Policy*, 59, pp.74-84. https://doi.org/10.1016/j.envsci.2016.02.008

Shomali, M., 2008. Aspects of Environmental Ethics: An Islamic Perspective. Thinking Faith, *The Online Journal of The British Jesuits*, viewed online 23 August 2018 https://www.al-islam.org/articles/aspects-environmental-ethics-islamic-perspective-mohammad-ali-shomali

Siciliano, G., Rulli, M.C. and D'odorico, P., 2017. European large-scale farmland investments and the land-water-energy-food nexus. *Advances in Water Resources*, 110, pp.579-590. https://doi.org/10.1016/j.advwatres.2017.08.012

Sidamor, Z., Lemtaouch, L. and Bensouici, H., 2016. The Economic Consequences of the Political Instability in Arab Region. *Procedia-Social and Behavioral Sciences*, 219, pp.694-699.

Siegfried, T., Sobolowski, S., Raj, P., Fishman, R., Vasquez, V., Narula, K., Lall, U. and Modi, V., 2010. Modeling irrigated area to increase water, energy, and food security in semiarid India. Weather, *Climate, and Society*, 2(4), pp.255-270. https://doi.org/10.1175/2010WCAS1048.1

Singh, A., Singh, A., Mitra, S. 2015. Role of Horticulture in Agriculture Development and Food Security in India, National Seminar on "Sustainable Agriculture and Food Security", At MSSoA, CUTM, Paralakhemundi, Odisha

Singh, H., Mishra, D. and Nahar, N.M., 2002. Energy use pattern in production agriculture of a typical village in arid zone, India—part I. *Energy Conversion and Management*, 43(16), pp.2275-2286.

Singh, H., Singh, A.K., Kushwaha, H.L. and Singh, A., 2007. Energy consumption pattern of wheat production in India. *Energy*, 32(10), pp.1848-1854.

Singh, K., 2009. Act to save groundwater in Punjab: Its impact on water table, electricity subsidy and environment. *Agricultural Economics Research Review*, 22(2009), pp.365-386.

Singh, P., Carliell-Marquet, C. and Kansal, A., 2012. Energy pattern analysis of a wastewater treatment plant. *Applied Water Science*, 2(3), pp.221-226.

Singh, P., Kansal, A. and Carliell-Marquet, C., 2016. Energy and carbon footprints of sewage treatment methods. *Journal of environmental management*, 165, pp.22-30.

Singh, P. and Kansal, A., 2018. Energy and GHG accounting for wastewater infrastructure. Resources, Conservation and Recycling, 128, pp.499-507.

Singh, S.K., Chaudhary, K., Jain, H. and Chellani, N., 2017. Review on Sewerage Systems, Conditions & Awareness Measures. *World Wide Journal of Multidisciplinary Research and Development*, 3(11): 319-322

Skandhan, K.P., Amith, S., Karunatilake, L.P.A., Avni, K.P.S. and Singh, K., 2011. Water purification prescribed in Ayurveda. *Ayu,* 32(4), p.448.

Skolka, J., 1989. Input-output structural decomposition analysis for Austria, *Journal of Policy Modeling*, 11, pp. 45-66.

Smajgl, A., Ward, J. & Pluschke, L., 2016. The water-food-energy Nexus - Realising a new paradigm. *Journal of Hydrology*, 533, pp.533–540. https://doi.org/10.1016/j.jhydrol.2015.12.033

Smidt, S.J., Haacker, E.M., Kendall, A.D., Deines, J.M., Pei, L., Cotterman, K.A., Li, H., Liu, X., Basso, B. and Hyndman, D.W., 2016. Complex water management in modern agriculture: Trends in the water-energy-food nexus over the High Plains Aquifer. *Science of the Total Environment,* 566, pp.988-1001. https://doi.org/10.1016/j.scitotenv.2016.05.127

Smith, L.C. ed., 2003. The importance of women's status for child nutrition in developing countries (Vol. 131). Intl Food Policy Res Inst.

Snieska, V. and Simkunaite, I., 2009. Socio-economic impact of infrastructure investments. Engineering Economics, 63(4), *Sustainable Energy Reviews*, 16, 4818-4848

Sovacool, B.K., 2012. The political economy of energy poverty: A review of key challenges. *Energy for Sustainable Development*, 16(3), pp.272-282.

Sovacool, B.K. and Mukherjee, I., 2011. Conceptualizing and measuring energy security: A synthesized approach. *Energy*, 36(8), pp.5343-5355.

Spang, E.S., Moomaw, W.R., Gallagher, K.S., Kirshen, P.H. and Marks, D.H., 2014. The water consumption of energy production: an international comparison. *Environmental Research Letters*, 9(10), p.105002.

Spiegelberg, M., Baltazar, D.E., Sarigumba, M.P.E., Orencio, P.M., Hoshino, S., Hashimoto, S., Taniguchi, M. and Endo, A., 2017. Unfolding livelihood aspects of the Water–Energy–Food Nexus in the Dampalit Watershed, Philippines. *Journal of Hydrology*: *Regional Studies*, 11, pp.53-68.
https://doi.org/10.1016/j.ejrh.2015.10.009

Sreenivas, A. and Iyer, R.K., 2014. A comprehensive, multi-dimensional energy index for India. Pune: Prayas Energy Group.

Srinivasan, S., Kholod, N., Chaturvedi, V., Ghosh, P.P., Mathur, R., Clarke, L., Evans, M., Hejazi, M., Kanudia, A., Koti, P.N. and Liu, B., 2018. Water for electricity in India: A multi-model study of future challenges and linkages to climate change mitigation. *Applied Energy*, 210, pp.673-684.

Srivastava, L., 2017. 'India needs a strong narrative to push its SDGs in areas of climate change and energy'. Business Today, 30 December 2017, viewed online 10 January 2018, https://www.businesstoday.in/opinion/columns/india-needs-a-strong-narrative-to-push-its-sdgs-in-areas-of-climate-change-and-energy/story/267051.html

Srivastava, S. and Mehta, L., 2014. Not another Nexus? Critical Thinking on the New Security Convergence in Energy, Food, Climate and Water, STEPS Working Paper 75, Brighton: STEPS Centre

Stein, C., Pahl-Wostl, C. and Barron, J., 2018. Towards a relational understanding of the water-energy-food nexus: an analysis of embeddedness and governance in the Upper Blue Nile region of Ethiopia. *Environmental Science & Policy*, 90, pp. 173-182
https://doi.org/10.1016/j.envsci.2018.01.018

Stokes, J., & Horvath, A., 2006. Life cycle energy assessment of alternative water supply systems (9 pp). *The international journal of life cycle assessment*, 11(5), 335-343.

Sukhdev, P., Stone, S. and Nuttall, N., 2010. Green economy developing countries success stories. St-Martin-Bellevue: United Nation Environment Programme (UNEP).

Taniguchi, M., Masuhara, N. and Burnett, K., 2015. Water, energy, and food security in the Asia Pacific region. *Journal of Hydrology: Regional Studies*, 11, pp.9-19.
https://doi.org/10.1016/j.ejrh.2015.11.005

Thiede, S., Kurle, D. and Herrmann, C., 2017. The water–energy nexus in manufacturing systems: Framework and systematic improvement approach. *CIRP Annals*, 66(1), pp.49-52.

Tillman, A. M., Svingby, M., & Lundström, H., 1998. Life cycle assessment of municipal waste water systems. *The international journal of life cycle assessment*, 3(3), 145-157.

Timilsina, G. and Shrestha, R., 2006. General equilibrium effects of a supply side GHG mitigation option under the Clean Development Mechanism, *Journal of Environmental Management* 80, pp.327-341.

Tricker, R. I., 1998. Pocket Director: Essentials of Corporate Governance from A-Z (Economist Books) Essentials of Corporate Governance from A-Z (Economist Books) , p. 8.

Truelove, Y., 2011. (Re-) Conceptualizing water inequality in Delhi, India through a feminist political ecology framework. *Geoforum*, 42(2), pp.143-152.

Umesha, C., Sridhara, C.J., Kumarnaik, A.H., 2017. Recent forms of fertilizers and their use to improve nutrient use efficiency and to minimize environmental impacts. *Int. J. Pure App. Biosci*. 5(2): 858-863. https://doi.org/10.18782/2320-7051.2739

UN (United Nations), 2016. Human Development Report 2016, Human Development for Everyone, viewed online 30 September 2017, http://hdr.undp.org/sites/default/files/2016_human_development_report.pdf

UN (United Nations), 2017. World Population Prospects: The 2017 Revision, Key Findings and Advance Tables, Department of Economic and Social Affairs, Population Division, Working Paper No. ESA/P/WP/248.

UNCCD (United Nations Convention to Combat Desertification), 2013. A Stronger UNCCD for a Land-Degradation Neutral World, Issue Brief, Bonn, Germany

UNDESA (United Nations Department of Economic and Social Affairs), 2001, Indicators of sustainable development: guidelines and methodologies. Second edition, New York, USA: United Nations Department of Economic and Social Affairs.

UNDP (United Nations Development Programme), 1994. Human Development Report. New Dimensions of Human Security (New York, UNDP, 1994), viewed online 13 July 2017 http://hdr.undp.org/en/reports/global/hdr1994/

UNESCAP (United Nations Economic and Social Commission for Asia and the Pacific), n.d. What is Good Governance?,viewed online 28 August 2018 https://www.unescap.org/sites/default/files/good-governance.pdf

UNICEF (United Nations International Children's Emergency Fund) and WHO (World Health Organisation), 2015. Progress on sanitation and drinking water – 2015 update and MDG assessment, WHO Press, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland, viewed online 21 October 2017, http://files.unicef.org/publications/files/Progress_on_Sanitation_and_Drinking_Water_2015_Update_.pdf

UNSDSN (United Nations Sustainable Development Solutions Network), 2015, Indicators and a monitoring framework for the Sustainable Development Goals, A report to the Secretary-General of the United Nations by the leadership council of the Sustainable Development Solutions Network, viewed online 23 June 2018, https://sustainabledevelopment.un.org/content/documents/2013150612-FINAL-SDSN-Indicator-Report1.pdf

USDA (United States Department of Agriculture), 2014. India's Agricultural Exports Climb to Record High, International Agricultural Trade Report, viewed online 25 July 2018, https://www.fas.usda.gov/sites/default/files/2015-02/india_iatr_august_2014.pdf

Van der Meer, P. and Wielers, R., 2001. The increased labour market participation of Dutch students. Work, *Employment and Society*, 15(1), pp.055-071.

van Vuuren, D.P. and Smeets, E.M., 2000. Ecological footprints of benin, bhutan, costa rica and the netherlands. *Ecological Economics*, 34(1), pp.115-130.

Vanham, D., 2016. Does the water footprint concept provide relevant information to address the water–food–energy–ecosystem nexus?. *Ecosystem services*, 17, pp.298-307. https://doi.org/10.1016/j.ecoser.2015.08.003

Vanitha, S.M., S.N.S. Chaurasia, P.M. Singh and Prakash S. Naik. 2013. Vegetable Statistics. Technical Bulletin No. 51, IIVR, Varanasi, pp. 250, viewed online13 August 2017 https://www.iivr.org.in/sites/default/files/Technical%20Bulletins/7.%20Vegetable%20Statistics.pdf

Venghaus, S. and Hake, J.F., 2018. Nexus thinking in current EU policies–The interdependencies among food, energy and water resources. *Environmental Science & Policy*, 90, pp.183-192 https://doi.org/10.1016/j.envsci.2017.12.014

Vera, I. and Langlois, L., 2007. Energy indicators for sustainable development. *Energy*, 32(6), pp.875-882.

Verburg, P.H., Eickhout, B. and van Meijl, H., 2008. A multi-scale, multi-model approach for analyzing the future dynamics of European land use. *The annals of regional science*, 42(1), pp.57-77.

Verhoeven, H., 2015. The nexus as a political commodity: agricultural development, water policy and elite rivalry in Egypt. *International journal of water resources development*, 31(3), pp.360-374.
https://doi.org/10.1080/07900627.2015.1030725

Verma, N., 2018. Exclusive: As oil forecasts call for $100, India considers cutting back crude imports, Reuters, September 23, viewed online 18 October 2018, https://www.reuters.com/article/us-india-oil-exclusive/exclusive-indian-refiners-may-reduce-oil-imports-as-crude-prices-soar-rupee-struggles-idUSKCN1M408G

Vetter, S.H., Sapkota, T.B., Hillier, J., Stirling, C.M., Macdiarmid, J.I., Aleksandrowicz, L., Green, R., Joy, E.J., Dangour, A.D. and Smith, P., 2017. Greenhouse gas emissions from agricultural food production to supply Indian diets: implications for climate change mitigation. *Agriculture, ecosystems & environment*, 237, pp.234-241.

Villamayor-Tomas, S., Grundmann, P., Epstein, G., Evans, T. and Kimmich, C., 2015. The water-energy-food security nexus through the lenses of the value chain and the Institutional Analysis and Development frameworks. *Water Alternatives*, 8(1), pp.735-755.

Villarroel Walker R., Beck, M.B., Hall, J.W., Dawson, R.J. and Heidrich, O., 2014. The energy-water-food nexus: Strategic analysis of technologies for transforming the urban metabolism. *Journal of environmental management*, 141, pp.104-115. https://doi.org/10.1016/j.jenvman.2014.01.054.

Vlotman, W.F. and Ballard, C., 2014. Water, food and energy supply chains for a green economy. *Irrigation and drainage*, 63(2), pp.232-240.
https://doi.org/10.1002/ird.1835

Von Braun, J. and Pachauri, R.K., 2006. The Promises and Challenges of Biofuels for the poor in Developing countries, IFPRI, Washington DC

von Grebmer, K., Saltzman, A., Birol, E., Wiesman, D., Prasai, N., Yin, S., Yohannes, Y., Menon, P., Thompson, J. and Sonntag, A., 2014. Global Hunger Index: The challenge of hidden hunger. IFPRI books.

Wa'el A, H., Memon, F.A. and Savic, D.A., 2017. An integrated model to evaluate water-energy-food nexus at a household scale. *Environmental Modelling & Software*, 93, pp.366-380. https://doi.org/10.1016/j.envsoft.2017.03.034

Wa'el A, H., Memon, F.A. and Savic, D.A., 2018. A risk-based assessment of the household water-energy-food nexus under the impact of seasonal variability. *Journal of Cleaner Production*, 171, pp.1275-1289. https://doi.org/10.1016/j.jclepro.2017.10.094

Walmsley, T.L., Aguiar, A.H., Narayanan, B., 2012. Introduction to the Global Trade Analysis Project and the GTAP Data Base, GTAP Working Paper No. 67, viewed online 6 August 2016 https://www.gtap.agecon.purdue.edu/resources/download/6122.pdf

Wang, M.C., Naidoo, N., Ferzacca, S., Reddy, G. and Van Dam, R.M., 2014. The role of women in food provision and food choice decision-making in Singapore: a case study. *Ecology of food and nutrition,* 53(6), pp.658-677.

Wang, Y., 2009. Integrated Policy and Planning for Water and Energy, *Journal of Contemporary Water Research & Education*, Issue 142, Pages 46-51

Wani, S.P., Garg, K.K. and Chander, G., 2016. Water needs and productivity of Jatropha curcas in India: myths and facts. Biofuels, *Bioproducts and Biorefining*, 10(3), pp.240-254.

Wintgens, T., Nattorp, A., Elango, L. and Asolekar, S.R. eds., 2016. Natural Water Treatment Systems for Safe and Sustainable Water Supply in the Indian Context: Saph Pani. IWA Publishing.

WB (World Bank), 2016. World Development Indicators 2016. Washington, DC: World Bank. https://doi.org/10.1596/978–1-4648–0683–4. License: Creative Commons Attribution CC BY 3.0 IGO

WB (World Bank), 2017. Data: GNI per capita, Atlas method (current US$), viewed online 20 September 2017, https://data.worldbank.org/indicator/NY.GNP.PCAP.CD

WB (World Bank), 2018a. Energy use (kg of oil equivalent per capita), World Development Indicators. viewed online 23 September 2018, https://data.worldbank.org/indicator/EG.USE.PCAP.KG.OE

WB (World Bank), 2018b. Energy imports, net (% of energy use). World Development Indicators, viewed online 24 September 2018, https://data.worldbank.org/indicator/EG.IMP.CONS.ZS

WEC (World Energy Council), 2013. World energy scenarios: Composing energy futures to 2050. Project Partner Paul Scherrer Institute (PSI), Switzerland, World Energy Council, London, London, viewed online 15 October 2016, www.worldenergy.org/publications/2013/world-energy-scenarios-composing-energy-futures-to-2050

WEF (World Economic Forum), 2011a. Water security: the water-food-energy-climate nexus, Washington: Island Press

WEF (World Economic Forum), 2011b. Global Risks 2011 Sixth Edition World Economic Forum in collaboration with: Marsh & McLennan Companies Swiss Reinsurance Company Wharton Center for Risk Management, University of Pennsylvania Zurich Financial Services World Economic Forum January 2011 ISBN: 92-95044-47-9978-92-95044-47-0

Weinberger, K. and Lumpkin, T.A., 2007. Diversification into horticulture and poverty reduction: a research agenda. *World Development*, 35(8), pp.1464-1480.

Weitz, N., Strambo, C., Kemp-Benedict, E. and Nilsson, M., 2017. Closing the governance gaps in the water-energy-food nexus: Insights from integrative governance. *Global Environmental Change*, 45, pp.165-173. https://doi.org/10.1016/j.gloenvcha.2017.06.006

Wellman, J. and A. Hunt., 2016, Methods for the assessment of systemic change, Deliverable 3.3. EC DG Research ECONADAPT Project. Grant Agreement no 603906

White, D.J., Hubacek, K., Feng, K., Sun, L. and Meng, B., 2018. The Water-Energy-Food Nexus in East Asia: A tele-connected value chain analysis using inter-regional input-output analysis. *Applied Energy*, 210, pp.550-567. https://doi.org/10.1016/j.apenergy.2017.05.159

Wichelns, D., 2017. The water-energy-food nexus: is the increasing attention warranted, from either a research or policy perspective?. *Environmental Science & Policy*, 69, pp.113-123. https://doi.org/10.1016/j.envsci.2016.12.018

Wiedmann, T., 2009. A review of recent multi-region input–output models used for consumption-based emission and resource accounting. *Ecological Economics*, 69(2), pp.211-222.

Wing, I.S., 2004. Computable general equilibrium models and their use in economy-wide policy analysis. Technical Note, Joint Program on the Science and Policy of Global Change, MIT.

Wolfe, M.L., Ting, K.C., Scott, N., Sharpley, A., Jones, J.W. and Verma, L., 2016. Engineering solutions for food-energy-water systems: it is more than engineering. *Journal of Environmental Studies and Sciences*, 6(1), pp.172-182. https://doi.org/10.1007/s13412-016-0363-z

Wong, K.V. and Pecora, C., 2015. Recommendations for Energy–Water–Food Nexus Problems. *Journal of Energy Resources Technology*, 137(3), p.032002.

Wong, K.V., 2015. Energy–Water–Food Nexus and Recommendations for Security. *Journal of Energy Resources Technology*, 137, p.034701. http://energyresources.asmedigitalcollection.asme.org/article.aspx?doi=10.1115/1.4028773.

Wood, A. and Ridao-Cano, C., 1999. Skill, trade, and international inequality. Oxford economic papers, 51(1), pp.89-119.

WRI (World Resources Institute), 2014. Climate Analysis Indicators Tool: WRI's Climate Data Explorer (Washington, DC: World Resources Institute)

WSP (Water and Sanitation Program), 2011. Cost Recovery in Urban Water Services: Select Experiences in Indian Cities, Technical Paper, viewed online 23 December 2017, https://openknowledge.worldbank.org/bitstream/handle/10986/17308/642940WP0Cost00r0Box03615350PUBLIC0.pdf?sequence=1&isAllowed=y

WSP (Water and Sanitation Program), 2014. 'Running Water in India's Cities: A Review of Five Recent Public-Private Partnership Initiatives', World Bank, viewed online 10 May 2018, https://www.wsp.org/sites/ wsp.org/files/publications/Running-Water-in-IndiaPublic-Private-Partnership-Initiatives.pdf.

Wu, W. and Ma, B., 2015. Integrated nutrient management (INM) for sustaining crop productivity and reducing environmental impact: A review. *Science of the Total Environment*, 512, pp.415-427.

WWDR (World Water Development Report), 2015. The United Nations World Water Development Report 2015: Water for a Sustainable World—Executive Summary, Paris: UNESCO, viewed online 2 June 2017, http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/images/WWDR2015ExecutiveSummary_ENG_web.pdf

WWF (World Wildlife Fund) and TERI (The Energy and Resources Institute), 2013. The Energy Report– India 100% Renewable Energy By 2050. Viewed online 20 July 2017, http://awsassets.wwfindia.org/downloads/the_energy_report_india.pdf

Yang, H., Zhang, X., & Zehnder, A. J., 2003. Water scarcity, pricing mechanism and institutional reform in northern China irrigated agriculture. *Agricultural Water Management*, 61(2), 143-161.

Yang, Y.E. and Wi, S., 2018. Informing regional water-energy-food nexus with system analysis and interactive visualization–A case study in the Great Ruaha River of Tanzania. *Agricultural Water Management*, 196, pp.75-86. https://doi.org/10.1016/j.agwat.2017.10.022

Yang, Y.E., Wi, S., Ray, P.A., Brown, C.M. and Khalil, A.F., 2016. The future nexus of the Brahmaputra River Basin: climate, water, energy and food trajectories. *Global Environmental Change*, 37, pp.16-30. https://doi.org/10.1016/j.gloenvcha.2016.01.002

Yao, Q., Joshi, P., Chang, C.F., McDonalds, C., Tran, J., Wheeler, W. and Hou, S., 2018. Advocating a New Approach to Governing Water, Energy, and Food Security: Testing the Effects of Message Inoculation and Conclusion Explicitness in the Case of the WEF Nexus. *Journal of International Crisis and Risk Communication Research*, 1(1), p.6. https://doi.org/10.30658/jicrcr.1.1.6

Yu, P.S., Yang, T.C. and Wu, C.K., 2002. Impact of climate change on water resources in southern Taiwan. *Journal of Hydrology*, 260(1-4), pp.161-175.

Zhai, H., Rubin, E. S., & Versteeg, P. L., 2011. Water use at pulverized coal power plants with postcombustion carbon capture and storage. *Environmental science & technology*, 45(6), 2479-2485.

Zhang, J., Campana, P.E., Yao, T., Zhang, Y., Lundblad, A., Melton, F. and Yan, J., 2017. The water-food-energy nexus optimization approach to combat agricultural drought: a case study in the United States. *Applied Energy*, *227*, pp.449-464. https://doi.org/10.1016/j.apenergy.2017.07.036

Zhang, X. and Vesselinov, V.V., 2017. Integrated modeling approach for optimal management of water, energy and food security nexus. *Advances in Water Resources*, 101, pp.1-10. https://doi.org/10.1016/j.advwatres.2016.12.017

Zhao, R., Liu, Y., Tian, M., Ding, M., Cao, L., Zhang, Z., Chuai, X., Xiao, L. and Yao, L., 2018b. Impacts of water and land resources exploitation on agricultural carbon emissions: The water-land-energy-carbon nexus. *Land Use Policy*, 72, pp.480-492. https://doi.org/10.1016/j.landusepol.2017.12.029

Zhao, X., Harbor, J., Engel, B., Theller, L., Yu, F., Cao, G., Cui, Y., Tang, W. and Zhang, M., 2018a. Analysis of food-energy-water nexus based on competitive uses of stream flows of BeiChuan River in eastern QingHai-Tibet Plateau, China. *Environmental Progress & Sustainable Energy*, 37(1), pp.62-72. https://doi-org.ezproxy.lib.uts.edu.au/10.1002/ep.12764

Zhou, P., Jin, R.Y. and Fan, L.W., 2016. Reliability and economic evaluation of power system with renewables: A review. *Renewable and Sustainable Energy Reviews*, 58, pp.537-547.

Zhu, T., Ringler, C. and Cai, X., 2007. January. Energy price and groundwater extraction for agriculture: Exploring the energy-water-food nexus at the global and basin levels. In International Conference of Linkages between Energy and Water Management for Agriculture in Developing Countries, Hyderabad, India.

Zilberman, D. et al., 2008. Rising energy prices and the economics of water in agriculture. *Water Policy*, 10, pp.11–21.

Zilberman, D., Sproul, T., Rajagopal, D., Sexton, S. and Hellegers, P., 2008. Rising energy prices and the economics of water in agriculture. *Water Policy*, 10(S1), pp.11-21. https://doi.org/10.2166/wp.2008.049

Zimmerman, R., Zhu, Q. and Dimitri, C., 2018. A network framework for dynamic models of urban food, energy and water systems (FEWS). *Environmental Progress & Sustainable Energy*, 37(1), pp.122-131. https://doi.org/10.1002/ep.12699

Ziv, G., Watson, E., Young, D., Howard, D.C., Larcom, S.T. and Tanentzap, A.J., 2018. The potential impact of Brexit on the energy, water and food nexus in the UK: A fuzzy cognitive mapping approach. *Applied Energy*, 210, pp.487-498. https://doi.org/10.1016/j.apenergy.2017.08.033

Zuberi, F., 2017. Green Urbanism in Medieval India, Agra Fort: A Sustainable Eco-City. *Procedia Environmental Sciences*, 37, pp.12-21.