

UNIVERSITY OF TECHNOLOGY SYDNEY

Faculty of Engineering and Information Technology

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

By

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degree Doctor of Philosophy**

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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.

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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 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.

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List of Abbreviations

AAV	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.

