Developing and Validating Mathematical Model for Electricity System Transition Planning

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Abstract

The transition from marginal to dominant renewable energy systems in electricity generation globally has posed new challenges in terms of intermittency, variability, uncertainty and low-reliability. This situation has led to a significant supply-demand gap in terms of temporal mismatch (times of supply and demand) and quantity mismatch (high supply with low demand, and vice versa). These mismatches lead to several issues, including surplus or insufficient electricity generation, erratic grid operation, etc. Hence, the electricity planners have to match "dynamic supply with dynamic demand.". In managing such a transitioning electricity system, the planning from the electricity supply side requires efficient management of existing electric power systems, on rationalizing generation portfolios. Therefore, to address these decisions, we have developed a generic linear programming-based optimisation model that dynamically balances supply and demand at least cost. In addition to achieving this objective of dynamic supply-demand balance, the model is designed to evaluate all the supply-side options and arrive at a least-cost generation portfolio. This would enable an RE dominated electricity taking in to account the inherent challenges associated with renewable energy integration. The model is validated using data from the electricity system of Karnataka, India where actual data was compared to modelled outputs for the calendar year 2019. Precision metrics, which measures standard error, were used to assess the model's accuracy. The results indicated that the standard error ranged from ±10%, which is within acceptable limits. This model can be effectively used for electricity transition planning and can provide critical inputs to policy makers.

Keywords
Electricity System Planning, Electricity System Transition, least cost optimisation model, model validation.

Biographies
Varun Jyothiprakash is a senior research scholar in the Department of Management Studies at the Indian Institute of Science (IISc). He has been working in the field of developmental strategies, energy system modelling, renewable energy studies and sustainability studies for the past 10 years. He has acquired substantial research experience from Indian Institute of Science, Indian Institute of Technology – Jodhpur, and Centre for Study of Science, Technology and Policy (CSTEP). In his PhD work, he looked into strategies for achieving India's 100% renewable energy (RE) growth by 2040. His thesis topic is "Optimal Integration of Supply-side and Demand-side interventions for managing Transitioning Electricity Systems". In this work, he has developed a novel linear optimisation model, which tracks the implications of different levels of dynamic integration of renewable energy sources over a period of time on the economic, technological, and environmental aspects of electricity systems for achieving 100% RE growth. Varun has published his work in various scientific journals and presented his research at national and international conferences. Various awards and fellowships have acknowledged his research work, including the Ministry of Human Resource Development (MHRD) and Toyohashi University of Technology, Toyohashi, Japan. His core competency is in

exploring the inter-linkages between energy technologies, low carbon growth, energy modelling and climate mitigation policies, and he has a commendable skillset in CPLEX GAMS Programming, R Programming and Python.

Dr. Balachandra Patil is a PhD from Indian Institute of Science, is an energy, environment, and sustainability expert, and ranked among top 10 management researchers in India (First in Strategic Management area). He is also ranked among top 2% of the Energy Scientists in the world. He has 35 years of experience as a faculty at the Indian Institute of Science, and as a visiting expert at Harvard University-USA, UNDP-Bangkok, AIT-Bangkok. and IGIDR-Mumbai. His research expertise includes energy & environmental economics and policy, sustainability transition, sustainable energy access, and energy system planning and modelling. He has investigated about 48 research & consultancy assignments for UNDP, European Commission, World Bank, SIDA, SANEI, RCUK, AIT, TERI, IGIDR, DST, and various ministries of government of India and private sector organisations. Has co-authored six books and published about 150 papers in International and National journals, conferences, and edited books with an H-Index of 29. He has supervised/mentored 38 PhD scholars (23 awarded and 15 ongoing). Has been conferred with the distinguished alumni award of Manipal University in 2011.

Samridh Sharma is a Senior Research Scholar in the Interdisciplinary Centre of Energy Research at the Indian Institute of Science (IISc). He has worked in renewable energy technologies, energy transition, energy system modelling and sustainability studies for the past five years. His thesis is on Temporal Complementarity and geographical endowment of Solar and Wind Energy Resources for low carbon transition of the Indian electricity system. The thesis tracks the method to achieve a 100 per cent renewable energy system by planning optimal energy mix and capacity expansion for future years. He developed and designed a mathematical model to simulate the scenarios for achieving green goals. His research experience is extensive and diverse in the design of fire safety devices, passive cooling systems for nuclear reactors, defence equipment and energy system modelling. He has a professional experience of 3.5 years as a Junior Manager in Eicher Engines. His key role area involved failure analysis, data analytics and product quality improvement. As an intern, the next 1.5 years involved research and designing small equipment components for Defence Research and Development Organization (DRDO). Samridh has published in scientific journals, co-authored in international conferences and received scholarships from the Ministry of Human Resource Development (MHRD). His core competency is designing and developing models for low carbon transition, and he has a keen interest in developing skillsets for model-based engineering systems. He also carries novice skills in machine learning, AI and data science. He is well versed in Python, R, GAMS, MATLAB and C++ programming.

Abhishek Das : Abhishek Das is a senior research scholar in the Department of Management Studies, Indian Institute of Science (IISc). His is pursuing his doctoral research on social and economic impacts of social and economic impact of decarbonisation of Indian electricity system on coal power value-chain wherein he is using a mathematical model-based approach to track the decarbonisation impacts. He is also a part of a collaborative project which has developed a novel reference energy system model to track and optimise renewable energy transition efforts in the Indian electricity system. Prior to joining the PhD program, he has been worked in coal mining and electricity sector for over 10 years. He has been a maintenance engineer with Coal India Limited. He has also been a consultant with PricewaterhouseCoopers Private Limited where he was responsible for advising clients (both Government and private) on regulatory and financial matters pertaining to the Indian electricity sector. At both the organisations, he has received letter of appreciations for his outstanding contributions. He holds an MBA degree with specialization in Power Management from National Power Training Institute, Faridabad, India which the apex training institute of the Ministry of Power, Government of India and a B.Tech in Mechanical Engineering from National Institute of Technology Karnataka, Surathkal, India. In his short research career, he has co-authored 2 peer-reviewed journal papers, 1 book chapter and 1 monograph.