ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Evolving strategies for energy planning in India

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ABSTRACT

Energy planning process cultivates and examines possibilities available to different utilities for meeting the energy supply requirements. The options embrace demand-side and supply-side substitutes which are gauged on an equal basis. The energy plan develops plans which diagnose the contribution to be expected from new energy use managing platforms and reports the need for developing plans which are flexible to changing conditions and quantify the cost as it relates to different supply-side source decisions. Literature reveals that different models are being established and used worldwide. Energy planning methods can be categorized into three categories: 1) planning by models, 2) by analogy and 3) by inquiry. There are short-term and medium-term (up to 10 and 20 years), long-term (beyond 20 years) planning periods generally used. Computer-based modeling, Decentralized energy planning (DEP), General Algebraic Modeling System (GAMS), long-term dynamic linear programming, Linear Programming (LP) Mixed Integer Linear Programming (MILP) model are some of the models which can be used to assist in the choice of renewable energy technologies in order to evolve a model for promoting the use of renewable energy sources for energy planning in India.

KEY WORDS: Energy Planning, Renewable energy, Energy models.

1. INTRODUCTION

The energy consumption in India is the fourth biggest after China, USA and Russia. About 70% of India's electricity generation capacity is from fossil fuels, with coal accounting for 40% of India's total energy consumption followed by crude oil and natural gas at 28% and 6% respectively. India is largely dependent on fossil fuel imports to meet its energy demands by 2030, India's dependence on energy imports is expected to exceed 53% of the country's total energy consumption. Due to rapid economic expansion, India has one of the world's fastest growing energy markets and is expected to be the second-largest contributor to the increase in global energy demand by 2035, accounting for 18% of the rise in global energy consumption. Given India's growing energy demands and limited domestic fossil fuel reserves, the country has ambitious plans to expand its renewable and nuclear power industries. India has the world's fifth largest wind power market and plans to add about 20GW of solar power capacity by 2022. India also envisages to increase the contribution of nuclear power to overall electricity generation capacity from 4.2% to 9% within 25 years The country has five nuclear reactors under construction (third highest in the world) and plans to construct 18 additional nuclear reactors (second highest in the world) by 2025. Energy intensity, defined as the energy input associated with a unit of gross domestic product (GDP), is a measure of the energy efficiency of a nation’s economy. India’s energy intensity has been declining over the years and is expected to decline further. Falling energy intensity implies that the growth in energy used is less than the growth of GDP, which in turn implies that energy elasticity, that is, the ratio of the growth of energy to the growth of GDP is less than unity. In fact, this elasticity has been declining over the years.

Table.1.Energy Intensity for Total Primary Energy*

Period	Energy Intensity [Kgoe/US$]**
1981	1.09
1991	0.99
2001	0.85
2011	0.62

* Energy intensity indicated is energy required to produce a unit of GDP.
** Kgoe: Kilograms of oil equivalent. [Source: Planning Commission]

1.1. Renewable Energy Technologies: Renewable energy technologies are the invaluable energy resources for marketable energy by converting natural phenomena into useful forms of energy which uses the sun’s energy and its direct and indirect effects on the earth (solar radiation, wind, falling water and various plants, i.e. biomass), gravitational forces (tides), and the heat of the earth’s core (geothermal). These resources have massive energy potential, but they are generally diffused, not fully accessible, intermittent, and have distinct regional variability. Except bio-fuels and hydropower, most renewable energy sources are of a fluctuating nature and “use it or lose it” of character. Economic optimizations criteria include e.g. total energy systems costs, capacity costs and societal costs. From a techno-operational perspective, optimization criteria include fuel savings, CO_2 emissions, reserve/back-up capacity, required condensing mode power generation, minimization of import/export, and elimination of excess power generation. All of these criteria can be applied to assess how well the system integrates renewable energy. Renewable energy technologies are less competitive than traditional electric energy conversion systems, mainly because of their intermittency and the relatively high maintenance cost. They have several advantages, such as the reduction in dependence on fossil fuel resources and the reduction in carbon emissions to the atmosphere. Renewable energies are away from the safety problems derived from atomic power. The improvement of renewable energy technologies will assist sustainable development and provide a solution to several energy related environmental problems. In this sense, optimization algorithms constitute a suitable tool for solving complex problems in the field of renewable energy systems.

1.2. Energy planning: Energy policy is very essential to energy systems of a country to the development of renewable or sustainable energy. Policymakers need to establish policies based on detailed assessment of competing technologies and huge amounts of scenario analyses. The power supply and distribution also need intellectual decision making. However, Policy making could be facilitated by superstructure based modeling and optimization. The recent advancements in modeling, optimization and simulation tools open new horizon for researchers to utilize and implement these techniques and tools to power supply networks. Modeling and optimization are proved as effective and useful tools for problem solving in power and supply sector and especially for policymakers to establish policies based on detailed assessment of competing technologies and huge amounts of scenario analyses. Energy planning is a dynamic process based on estimates and assumptions for future conditions. The energy planning process develops and analyzes options available to different utilities for meeting their energy supply obligations. These options include demand-side and supply-side alternatives which are evaluated on an equal basis. Cost-effective options are integrated into plans that achieve the corporate objective of providing reliable service at the lowest reasonable cost under a range of uncertain future conditions. The energy plan develops plans which recognize the contribution to be expected from new energy use management programs and addresses the need for developing exile plans which are adaptable to changing conditions and quantify the cost of this edibility as it relates to different supply-side resource decisions.

The energy plan integrates demand-side options (such as energy use management) and supply-side options (such as power purchases and generating plants) into plans which achieve the corporate objective of providing reliable service at the lowest cost over a range of future conditions. Changes in the national and local energy economy and business environment present significant uncertainty and challenge. In order to manage electively in this uncertain environment, utilities should place great emphasis on planning. One of the key planning tools used by utilities to help achieve their strategic goals is the energy plan. Resource plans recommended by the energy plan should be considered in conjunction with the overall capital and operating and maintenance expense requirements of the utilities to ensure the integrity of all utility operations. This information, along with engineering judgments, is used in reaching a decision as to which integrated resource plan should be pursued.

1.3. Centralized and Decentralized Energy Planning: The energy-planning involves finding a set of sources and conversion devices so as to meet the energy requirements/demands of all the tasks in an optimal manner. This could occur at centralized or decentralized level. The current pattern of commercial energy oriented development, particularly focused on fossil fuels and centralized electricity, has resulted in inequities, external debt and environmental degradation. The current status is largely a result of adoption of centralized energy planning (CEP), which ignores energy needs of rural areas and poor and has also led to environmental degradation due to fossil fuel consumption and forest degradation. Decentralized energy planning (DEP) is in the interest of efficient utilization of resources. The regional planning mechanism takes into account various available resources and demands in a region. This implies that the assessment of the demand supply and its intervention in the energy system, which may appear desirable due to such exercises, must be at a similar geographic scale. In this regard, the district is accepted as the appropriate planning level.

1.4. Energy optimization: A worldwide research and development using modeling, optimization and simulation tools in the field of renewable energy resources and systems is carried out during the last two decades. Over the second half of the 20th century, optimization found widespread applications in the study of physical and chemical systems, production planning and scheduling systems, location and transportation problems, resource allocation in financial systems, and engineering design. A large number of problems in production planning and scheduling, location, transportation, finance, and Engineering design require that decisions be made in the presence of uncertainty. In mathematics, optimization is the discipline concerned with finding inputs of a function that minimize or maximize its value, which may be subjected to constraints. The optimization under uncertainty includes the classical recourse-based stochastic programming, robust stochastic programming, probabilistic (chance-constraint) programming, fuzzy programming, and stochastic dynamic programming. Combinatorial optimization is a branch of optimization which is concerned with the optimization of functions with discrete variables. Computational optimization can be defined as the process of designing, Implementing and testing algorithms for solving a large variety of optimization problems. Computational optimization includes the disciplines of mathematics to formulate the model, operations research to model the system, computer science for algorithmic Design and analysis, and software engineering to implement the model.

1.5. Energy modeling: Energy models are like other models, simplified representations of real systems. Models are convenient tools in situations where performing tests or experiments in the real world are impractical, too expensive or out-rightly impossible. Optimization schemes in energy planning can be distinguished according to the models they adopt and techniques they employ in finding an optimal solution. In terms of models, schemes have adopted the time-stepped energy system optimization model (TESOM), market allocation model (MARKAL),energy flow optimization model (EFOM),or in exact community-scale energy model (ICS-EM); various linear programming methods such as interval linear programming (ILP), chance-constrained programming (CCP) and mixed integer linear programming (MILP) techniques have been employed to solve these models.

1.6. Mixed-Integer Linear Programming: A mixed-integer optimization model is a single mathematical model to represent all possible energy system alternatives within the superstructure, along with appropriate solution algorithms (MILP, MINLP, etc.). Mixed Integer Linear Programming (MILP) model that was developed for the optimal planning of electricity generation schemes for a nation to meet a specified CO_2 emission target. Ren and Gao (2010) developed a mixed-integer linear programming (MILP) model and Hatami (2009) used mathematical method based on mixed-integer stochastic programming. Rong and Lahdelma (2005) developed a linear programming (LP) model. Mariano (2008), developed nonlinear programming (NLP). Iyer and Grossmann (1997), used mixed-integer linear programming (MILP) to plan and schedule offshore oil facilities. Hashim (2010), developed a MINLP single-period optimization model to satisfy the electricity demand and CO_2 emission constraint at the least cost. The dynamic linear programming model, MESSAGE III, for the analysis of long-term energy strategies to mitigate climate change. MESSAGE III is a techno economic optimization model. Other well-known models in this class are, MARKAL, which was developed by the International Energy Agency (IEA) and is mostly used for national energy studies and EFOM, the model used by the European Union. MESSAGE III analyses future energy strategies in terms of available technologies, resources, energy service demands, and pollutant emissions. It is dynamic over time by integrating optimization for the whole time horizon into one objective function and linking different time steps (periods) in the model by various types of constraints.

1.7. Swarm Particle Models: Liang (2010), used a fuzzy optimization approach, Bhatt (2010), A GA/particle swarm intelligence based optimization model, Amjadi (2010), Particle Swarm Optimization (PSO), Algorithm based on Gross Domestic Product (GDP), Yucekaya (2009), A study presenting two particle swarm optimization (PSO) algorithms.

1.8. Mathematical Optimization Models: A mathematical modeling framework for carbon-constrained energy planning has been developed based on the extensions of previously developed pinch analysis approaches. Two specific contemporary applications are explored in detail with modified formulations on specific case studies, i.e. optimal production of biofuels for transportation under multiple (carbon and land) footprint constraints with a recourse to import; and optimal deployment of carbon dioxide capture and storage (CCS) retrofit in power generation with cost and carbon footprint considerations. Porkar (2010), mathematical optimization model by a new software package interfacing two powerful softwares (MATLAB and GAMS), Yusta (2010), A mathematical optimization model.

1.9. Stochastic Optimizing Models: Stochastic modeling of financial electricity contracts.S.-J. Deng and W. Jiang (2005) A class of stochastic mean-reverting models. Yang (2009), employs battery banks for calculating the system optimum configurations, A review on modeling of biomass gasification in bubbling and circulating fluidized bed (FB) gasifies focusing on Mixing and reactions, Stochastic DP that allows users to identify relations between time, investment decisions, construction periods and uncertainty.

1.10. Genetic Algorithm Technique: GA is a search technique used in computing to find exact or approximate solutions to optimization and search problems. First pioneered by John Holland in the 1960s, GA has been widely applied in bioinformatics, phylogenetics, computational science, engineering, economics, chemistry, manufacturing, mathematics, physics and other fields. GAs are a particular class of evolutionary algorithms (also known as evolutionary computation) that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover.

2. CONCLUSION

Energy planning models have already been reviewed earlier by Jebaraj and Iniyanfocusing on macro or national level models. Another review article on computer-aided modeling and planning has been presented by Sagie. A review of more than 90 published papers by Pohekar and Ramachandran focused on neural networks and analyzed the applicability of various methods and models. Energy system models are thus useful, as they depict immensely complicated systems that are beyond the ability of the human brain to comprehend and understand. The demand for energy is growing due to industrial development and population growth since the middle of the last century. New and renewable sources of energy gains priority in many countries all over the world. The need for proper planning in energy resources arises for sustainable development of human beings livable future keeping the balance with nature. Our century faces significant energy challenges and at the same time the energy systems required to meet the goal of conformance with the environmental, economic, and social goals of sustainable development. At present world's energy requirements are mostly fulfilled by fossil fuels (60% of world's electricity fuel source), which causes climatic change, with potential catastrophic effect with the insecurities abundantCO2 in large, particular greenhouse gas affecting energy transportation infrastructure. At this back drop arises the need for evolving strategies in energy planning to minimize risks through the deployment of smaller-scale, modular generation and transmission systems. The Twelfth Plan continues to focus on enhancing household access to cleaner forms of energy with an aim to promote sustainable development. The advancement of renewable energy technologies has made energy planning a more complex task. Energy scheduling drives the global energy system into a viable path.

3. ACKNOWLEDGEMENTS

The corresponding author firstly thanks the Almighty. He next thanks his parents who help him greatly in his research work. He also thanks the Department of Mechanical Engineering, Anna University, Chennai and Department of Physics, Anna University, Trichy for extending their expertise and facilities provided respectively.

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