Energy Policy 56 (2013) 456–465

Contents lists available at SciVerse ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Optimization of India's power sector strategies using weight-restricted stochastic data envelopment analysis

Joy P. Vazhayil*, R. Balasubramanian

Centre for Energy Studies, Indian Institute of Technology, Delhi-110 016, India

HIGHLIGHTS

- ► Stochastic DEA model appropriate for efficiency optimization of power sector strategies.
- ► Optimal strategy portfolios of Indian power sector.
- ► Weight-restricted model for outputs with limited substitutability.
- ► Efficiency comparison of different DEA models.
- ► Design of attributes for economic growth, energy security, energy equity and climate sustainability.

ARTICLE INFO

Article history:
Received 29 January 2012
Accepted 3 January 2013
Available online 8 February 2013

Keywords:
Power sector optimization
Data envelopment analysis
Climate sustainability

ABSTRACT

India's power sector has a significant impact on the country's development and climate change mitigation efforts. Optimization of energy planning is therefore, key to achieving the overall planning goals. The hierarchical multi-objective policy optimization is a policy-centric multi-level bottom-up iterative approach, designed from a developing country perspective, utilizing the optimality principle of dynamic programming. It is applied to the Indian power sector by grouping the strategies into three portfolios, namely, power generation mix, demand side efficiency group and supply side efficiency group. Each portfolio is optimized taking into account the objectives of cost minimization and comprehensive risk and barrier reduction. The portfolios are further combined and optimized at a higher level with respect to higher level objectives, namely, economic growth, energy equity, energy security and climate sustainability. This paper focuses on the second level optimization utilizing data envelopment analysis (DEA). Both the deterministic and stochastic variations have been analysed and the results compared in respect of unrestricted as well as restricted weight models. The analysis shows that weight-restricted stochastic DEA model is most appropriate for efficiency optimization of power sector strategies. The methodology can be effectively used for energy planning in developing countries.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

The importance of electricity sector in India in the context of development and sustainability can hardly be overemphasised. During 1994 to 2007, electricity sector in India projected the highest compound annual growth rate of 5.6% among all other sectors (INCCA, Ministry of Environment and Forests, India, 2010). India has set an ambitious target of capacity addition of 100,000 MW for the 12th Five Year Plan (Planning Commission of India, 2011). Optimization of energy strategies to achieve the macro-economic objectives of planning becomes critical for a developing country like India. Large-scale conversion to clean, perpetual, and reliable energy at low cost together with increased energy efficiency are key strategies for solving the problems of climate change, pollution, and energy insecurity (Jacobson and Delucchi, 2011). Optimal generation planning including renewables in the portfolio as well as optimal supply side and demand side energy efficiency planning are, therefore, critical ingredients to be incorporated into an effective sustainable energy development paradigm.

The generation portfolio should incorporate renewables as a key strategy for energy security and emissions reduction. As increased scarcity of resources shifts (André and Smulders, 2004) technical change progressively towards energy-saving technological change at the cost of total factor productivity growth, energy efficiency sector has great potential in India. However, improvements in energy efficiency will require active market interventions to overcome barriers and to

* Corresponding author. Tel.: +91 471 2439442; fax: +91 471 2326990.
E-mail address: joy.vazhayilp@gmail.com (J.P. Vazhayil).

0301-4215/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enpol.2013.01.003

stimulate drivers (Reddy et al., 2009). Moreover, the actual impact of energy efficiency measures will depend on the price elasticity of demand.

We utilize the hierarchical multi-objective optimization framework (Vazhayil and Balasubramanian, 2012) for addressing the strategy planning issues in the Indian power sector. It essentially follows the dynamic programming approach where the complexity of the problem is tackled by a 'divide and conquer' approach. The optimization problem is divided into a number of sub-problems at hierarchical levels. For optimization at each level, objectives appropriate to that level are identified. As the policy strategies combine into portfolios and move up the optimization pyramid, the objectives of optimization get suitably modified in synchronism. The strategies get optimized at different hierarchical levels of objectives. After an entire cycle of optimization is completed, iterative improvement incorporates feedback arising on account of the chosen higher level objectives or corrections due to the assumption of the monotonicity of the objective function in dynamic programming. For the higher level optimization of the power sector, efficiency optimization using DEA (Zhou et al., 2008) is made use of. This paper focuses on the implementation of DEA and identifies appropriate model and presents the results of comparison with alternatives.

The remainder of paper is organized as follows: Section 2 introduces the hierarchical multi-objective optimization model for the Indian power sector. Next section introduces the DEA for constant returns to scale (CRS) and variable returns to scale (VRS) and discusses the evaluation of the input and output parameters of the decision making unit (DMU). Section 4 introduces the stochastic model of the DEA. Section 5 looks at the impact of weight restrictions in DEA models. Results and conclusions are presented in Section 6 and Section 7.

2. Optimization of Indian power sector

We consider a bi-level optimization algorithm for India's power sector. The objectives of optimization are selected based on the approach to the 12th Five Year Plan as well as India's National Action Plan on Climate Change (PMCCC (Prime Minister's Council on Climate Change), India, 2009). The latter focuses on the use of new strategies and technologies in key sectors. The objectives of the first level optimization are project level parameters, namely, levelized cost and Comprehensive Risk-Barrier Index (CRBI). CRBI is a composite index (Vazhayil and Balasubramanian, 2012) capturing the joint influence of cost risks as well as implementation barriers in energy projects. This index has been designed in view of the fact that barriers exert a key influence on project implementation in developing countries. After grouping the power sector strategies into three portfolios, namely, generation mix, demand side efficiency group and supply side efficiency group, each portfolio is optimized using genetic algorithm, for cost minimization and CRBI reduction. These portfolios are further optimized at the second level using weight-restricted stochastic data envelopment analysis. Optimization at each level is sequential (Fig. 1), taking into account the optimality principle of dynamic programming.

For the optimization of the first level portfolios, portfolio optimization methods (Markowitz, 1952; Steuer et al., 2005) are utilized to get a number of near-optimal portfolios with minimum cost and CRBI. The power generation portfolio consists of various generation sources, namely, coal, natural gas, nuclear, hydro and renewable energy sources, the proportion of which constitutes the decision vector. Cost of conserved energy or of conserved fuel and CRBI can be employed as optimization parameters for energy efficiency strategies.

Analytic Hierarchy Process (Ramanathan, 2003), a widely used decision making technique with its applications increasing exponentially in recent times (Sipahi and Timor, 2010), can be used for the evaluation of the barriers. The cost risks are estimated from the standard deviations of the respective costs. In the Indian scenario, we consider the barriers relating to land availability, public policy, environmental clearance, infrastructure and resource availability as well as grid connection and markets.

Objectives of optimization at the second level are: (i) economic growth (ii) energy equity (iii) energy security and (iv) climate sustainability. Economic growth is a key productivity criterion for strategic policies. Energy equity is particularly relevant in the context of developing countries since affordable modern energy is key to improving living standards (Ekholm et al., 2010). Along with growth and equity, energy policies must particularly take into account energy security and climate sustainability. A methodology to identify and assess the impact of climate policies on energy security to guide policy making has been developed in

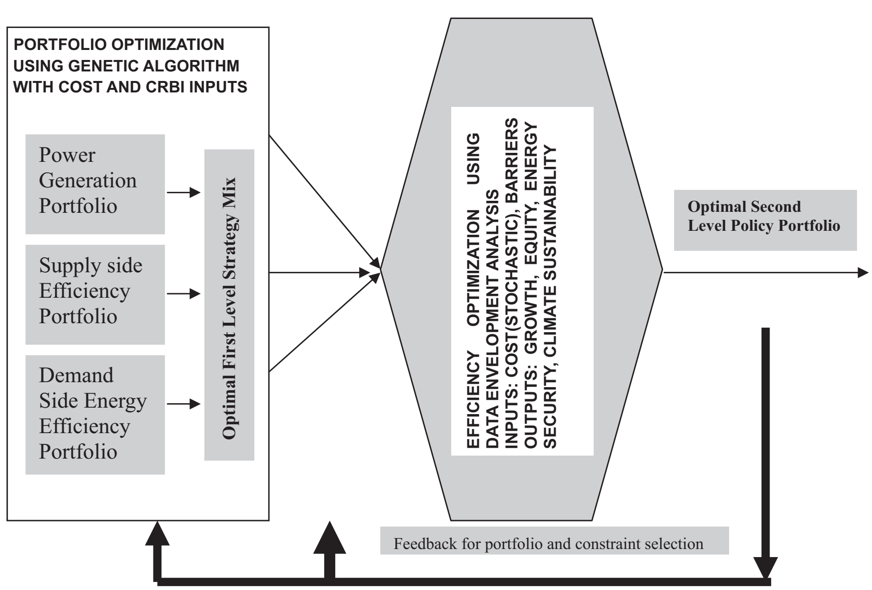

Fig. 1. Hierarchical multi-objective optimization of power sector.

متن کامل مقاله ← دریافت فوری

ISIArticles
مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات