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How to enhance the future use of energy policy simulation models through ex post validation

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ABSTRACT

Although simulation and modeling in general and system dynamics models in particular has long served the energy policy domain, ex post validation of these energy policy models is rarely addressed. In fact, ex post validation is a valuable area of research because it offers modelers a chance to enhance the future use of their simulation models by validating them against the field data. This paper contributes by presenting (i) a system dynamics simulation model, which was developed and used to do a three dimensional, socio-economical and environmental long-term assessment of Pakistan's energy policy in 1999, (ii) a systematic analysis of the 15-years old predictive scenarios produced by a system dynamics simulation model through ex post validation. How did the model predictions compare with the actual data? We report that the ongoing crisis of the electricity sector of Pakistan is unfolding, as the model-based scenarios had projected.

1. Introduction

Pakistan, like most other countries of the world, embraced the liberalization and privatization of its energy sector in the 1990s. The crux of these enacted energy policies (e.g., 1994 Energy Policy [1], 1995 Energy Policy [2], and 1998 Energy Policy [3]) was to attract foreign investments through independent power producers (IPPs) to meet the growing electricity demand in Pakistan. The key policy incentives of these policies, hereinafter called the Energy Policy of Pakistan, included [4]:

- A Bulk Tariff of US cents 6.5/kWh (kilo-watt hour) charged to Water And Power Development Authority, a state entity, for the sale of electricity
- A guaranteed payment of a fixed “Capacity Price” regardless of generation of electricity
- Simplified procedures for IPPs
- Protection against specific force majeure risk
- Exemption from corporate income tax, customs duties, sales tax, and other surcharges on imported equipment by IPPs
- A power purchase agreement
- A fuel supply agreement
- Guaranteed foreign exchange conversion facility
- Protection against changes in certain taxes and duties

To perform a critical assessment and gain an understating of the dynamics of these energy sector developments, a system dynamics simulation model, MDESRAP (Modeling the Dynamics of Energy Supply, Resources, and Pollution), was developed in 1999. MDESRAP-based analysis, insights, and scenarios of Pakistan's Energy Policy were made public in 2001 [5]. MDESRAP, like any other simulation model, was subjected to a set of stringent validity tests [7–9] for the credibility of its predictions; the decision makers in the energy policy sector of Pakistan could use MDESRAP's warnings in terms of the escalating electricity demand and supply gap, electricity-related carbon dioxide (CO_2) emissions, and rising electricity prices for consumers in their policy decisions [5]. Now, in 2015–2016 when Pakistan's energy sector is going through severe crises, it is interesting and timely research to perform a posterior analysis and assessment after 15 years of MDESRAP's predictions. Therefore, the key objectives of this paper are: (i) to provide a structural overview of MDESRAP, and (ii) to assess the extent to which MDESRAP's scenarios are credible close to the reality that 15 years' actual data has created, i.e., an ex post validation.

In fact, system dynamics models have been widely used for energy policy design, analysis, and assessment studies. Some examples of successful use of system dynamics models in addressing

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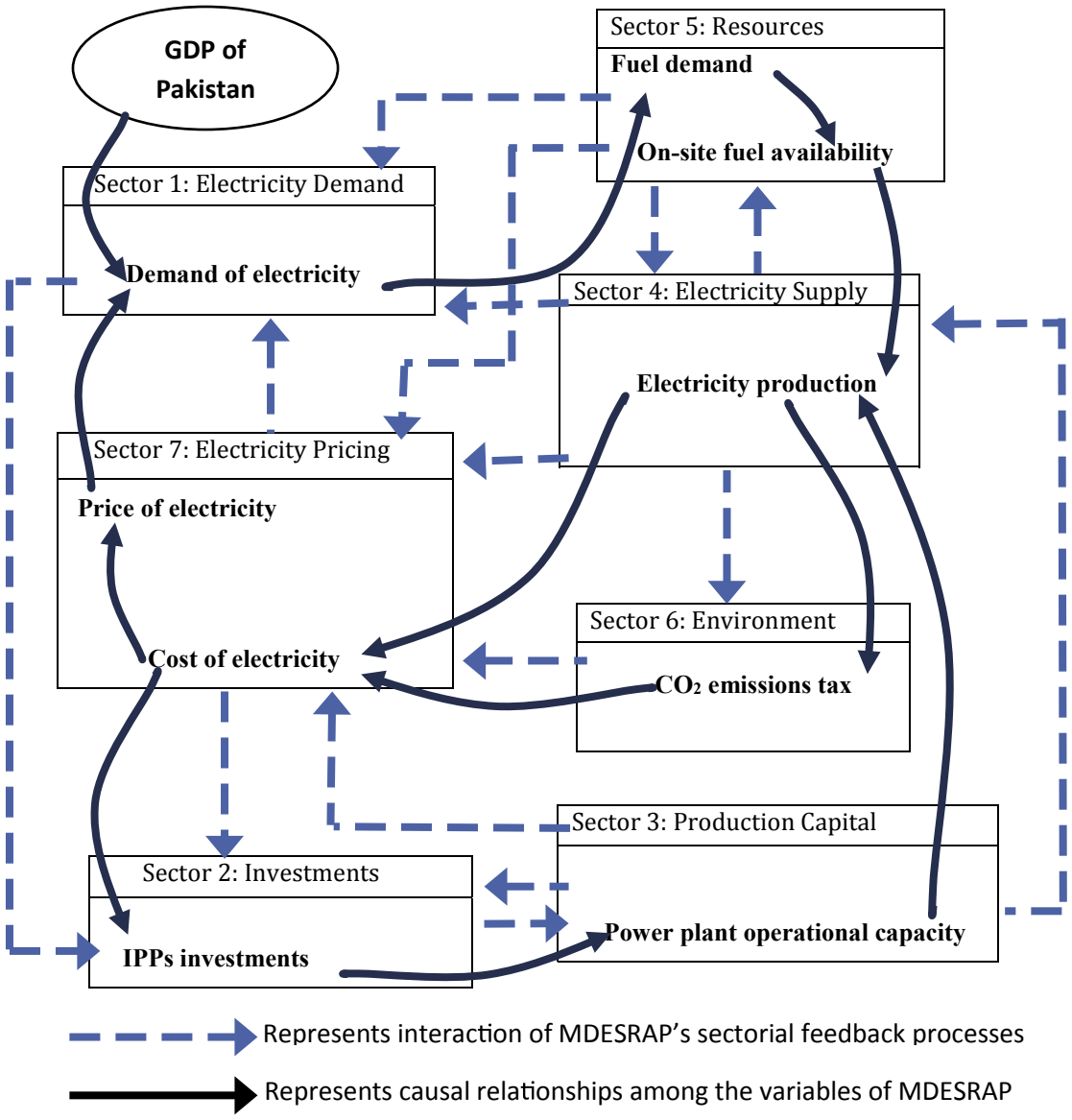

Fig. 1. Sectorial overview of MDESRAP.

various energy policy related issues include[1]:

(i) national energy policy design and assessment [4,10,14–18],
(ii) performance assessment of electricity utility industry [19,20,26],
(iii) effects of liberalization and privatization of the electricity industry [4,18,22,22],
(iv) energy conservation policy analysis [20,27],
(v) electricity related environmental emission policy analysis [6,23],
(vi) modeling of inter-fuel substitution [24,25],
(vii) energy efficiency analysis [27],
(viii) energy consumption analysis [28,29],
(ix) national gas policy [30], and
(x) renewable energy policies [21,31–35,39–42].

Although all of these models, including MDESRAP, have been subjected to some degree of structural and behavioral validation procedures, ex post validations of these models have rarely been published. Performing a critical assessment of the predictions of a simulation model, when they have unfolded in the face of reality, adds to the credibility of its results and leads to increased confidence in its future use. We, therefore, present an ex post validation and assessment of MDESRAP, 15 years after publication of its predictions. The key implication is that if this ex post validation of a model (e.g., MDESRAP) shows unacceptable deviations (i.e., predictions are substantially different from what the actual data has revealed) then the resurrection of that model should be questioned.

The next section of this paper provides a sectorial overview of MDESRAP. In Section 3, we present ex post validation, a comparative analysis of MDESRAP's scenarios and the current state of electricity-related CO_2 emissions, electricity prices, and electricity demand-supply gap in the electricity sector of Pakistan.

[1] These cited studies are not meant to be an exhaustive list of system dynamics models that have been used in energy policy domain but is representative. The interested reader can see a comprehensive account of system dynamics modeling work in the energy domain at: http://www.iip.kit.edu/downloads/1_Teufel_Review_of_Electricity_Models_with_System_Dynamics.pdf.