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System dynamics methodology for the energy demand fulfillment in India: A preliminary study

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Abstract

Higher energy demand and shortage of energy has made energy modeling a very common researchable area in developing and developed countries. Proper and efficient execution of policy plays a vital role in the implementation and adoption of innovations, such as, the higher usage of solar generated energy over conventional electricity. This paper contributes to the existing literature by proposing a system dynamics based hypothetical framework that would have policy implication for the sustainable use of solar energy at the wide country level. The methodology explains the feedback loop through causal diagram. Additionally, it also explains the involvement of various stakeholders and the variables necessary for the acceptance of renewable energy in India.

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Keywords: system dynamics; energy demand; solar energy; forecasting; energy supply

1. Introduction

The high usage of fossil fuels has led to pollution and environmental damage. This has also shifted the research focus on solar energy as an alternative source of energy generation. The worldwide effectiveness of solar energy is not only addressed for its use at domestic and industrial level, but also indicated as a one of the potential investment for good financial returns by several scientists and academicians [13]. In India too, because of limited

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coal mining, and large dependency upon coal import from neighboring countries, renewable policies of India at central and state level have been now modified to attract solar consumers and investors [1]. To develop such policies various tools at different levels have been deployed. However, system dynamics tool because of its uniqueness to present data in visual form, has found great importance in conducting such kind of activities – more details are covered in literature review section. According to the System Dynamics Society [2], "System dynamics (SD) is a computer-aided approach to policy analysis and design. It applies to dynamic problems arising in complex social, managerial, economic, or ecological systems – literally any dynamic systems characterized by interdependence, mutual interaction, information feedback, and circular causality." For details on system dynamics please see Ahmadian [3].

Objective of this article is to explore solar energy as an alternative source of energy for the fulfillment of energy demand in India through a system dynamics approach. Details are covered under "system dynamic model" section of this article.

To our best understanding, system dynamics based methodology for the energy demand fulfillment, in Indian context, is not available in the energy literature. Therefore, this paper contributes to the existing literature by proposing the System dynamics based methodology that would have policy implication for the sustainable use of solar energy at the country level. The diagram explains the involvement of various stakeholders, and the dependency of factors necessary for acceptance. The first section of this paper deals with the literature review. The second introduces system dynamics diagram portraying causal effects, and explanation of variables used in the methodology. Finally, paper ends with limitations, suggestions, and the scope for further research.

2. Brief literature review

India is one of those countries that have high-energy demand after USA and China [1]. A question on effective production and efficient marketing of clean energy has been the topic of research for several agencies and Universities worldwide. This area is important for several reasons. Since the area we are trying to study is multidisciplinary in nature, literature is pulled under different themes. This section of an article is divided into three sections – energy demand, need for adoption of solar energy in India, and basic system dynamics approach.

2.1. Why system dynamics approach?

Due to high order of non-linearity, it is difficult to solve the models analytically [4]. Additionally, in simpler systems multiple feedback loops could introduce unexpected behaviours in a system [5]. For an instance, Ahmadian [3] states "in a system that contains non-linearity and multiple loops, the behavior of the system can become surprisingly insensitive to change in value of the majority of the system parameters. This means a major inputs of a system can be changed without substantially affecting an output behavior of a system. This is partly because of a dilution of a single parameter in a large numbers. This behavior is common in models of complex systems" [3]. Conversely, system dynamics can visually show the parameters in a system that can considerably affect the whole system – changing those parameters can alter the system behavior. Thus, system dynamics can be used to study different systems, such as, social systems and technical systems [5].

Moreover, system dynamics models can organize knowledge of a certain system in an efficient way. It can provide better understanding of an important system that has previously shown unclear or controversial behavior. Specifically, a system dynamics project can change the way people look and interpret a system [5].

Overall, system dynamics is a tool which can analyze various systems in qualitative and quantitative way. For an instance, system dynamics is popularly used to analysis and address the environmental and political systems.

2.2. System dynamics methodology to energy modelling

Important and related scholarly articles (years 2000 to 2013) on system dynamics modelling were reviewed. The policy formulation using this tool has been studied by several scientist [6, 7], whereas, energy studies is also one of an interested areas to a specific pool of scientists. Further, demand and energy resources represent