Renewable and Sustainable Energy Reviews 38 (2014) 686–699

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Multi-faceted energy planning: A review

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ARTICLE INFO

Article history:
Received 4 September 2013
Received in revised form
9 May 2014
Accepted 6 July 2014
Available online 24 July 2014

Keywords:
Energy planning
Scenario
Model
Delphi method
Validation

ABSTRACT

Energy planning can be defined as a roadmap for meeting the energy needs of a nation and is accomplished by considering multiple factors such as technology, economy, environment, and the society that impact the national energy issues. Long-term energy planning is a strategic approach to study how structural changes of a nation would affect the energy demand and supply. This is done through scenario analysis which would also cater for uncertainty in planning. Good energy plan would ensure sustainable development which acts as a guiding factor for any energy scheme. In this paper, we present an overview of the different facets of energy planning based on a comprehensive literature review. It present the risks, uncertainties and errors involved in energy planning. The econometric, optimization and simulation models are reviewed and five appropriate computer models, that can be used for a small developing island nation's long-term energy planning using scenario analysis, are discussed. This paper also discusses the inquiry method and elaborates on why it can be used for energy planning in small developing island countries. Validation process of energy models is also presented and finally, recommendations are made for energy planners.

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http://dx.doi.org/10.1016/j.rser.2014.07.021
1364-0321/

1. Introduction

The development of a nation is highly dependent on its energy sector, as was demonstrated during the oil crisis in the 1970s. World-crisis.net [1] reports that the economy of oil importing countries can be adversely affected when there is a shortage in oil supply since it causes high price inflation. The energy sector of an economy interacts with demand, supply, technological progress, a technology's market potential, the environment and the society. Good energy planning takes into consideration of all these variables and parameters. Energy is utilized in all sectors of the economy, broadly taken as industrial, commercial, agricultural and residential. Hence, energy plays a role in production in the industrial sector as well as being a final product for consumption heating, transportation, cooking, etc. [2]. The amount of energy used for a unit of production (i.e. kilowatt hour (kWh) per tonne or kWh per dollar of output) or the amount of energy utilized per unit of service to satisfy household needs (e.g. kWh per lumens of light) depends upon the technology adopted by the end-user of energy [3].

Consumers will choose the type of technology used for harnessing energy by considering the technical and economic feasibility [4]. They are influenced by the policies in place (e.g. standards and labeling policy: energy star rating on electrical appliances has influenced customers to purchase energy-efficient appliances or carbon taxation policy that have influenced industrial consumers to emit less carbon) made on the basis of the energy planning research. An energy plan should always aim to support sustainable development. Neves and Leal [5] note three important sustainable development criteria: environmental, economic and social. Environmental criterion includes the reduction of the greenhouse gas (GHG) emissions, air pollution and depletion of natural resources which are caused by limited or inefficient supply chain and inefficient energy use. Economic criterion includes the reduction of fossil fuel dependence and increase in local investment in renewable energy (RE) and energy efficiency projects that generate business and wealth. Social criterion includes the improvement of human health, creation of jobs, greater comfort and the involvement of citizens in decision-making processes.

However, these are not the only criteria that guide energy planning; technical and geopolitical ones are also significant. The people responsible for making final policy decisions for a national energy system are governmental ministers and officials, but they must be guided, through energy planners, to make judicious decisions. Energy plan is one of the pillars for developing policies for sustainable development of a country. This paper reviews literature on the different aspects involved in energy planning focusing on risks, errors and uncertainty in energy planning, energy planning models, geographical level of energy planning and validation of planning methods. There are many existing reviews of energy planning literature mainly dealing with energy planning models (econometric, optimization and simulation). The present paper looks at the recent work published in these areas with some examples where such models are used. This review attempts to coherently bring together published literature on different aspects of energy planning. The authors believe this will be useful for energy planners in countries which are now developing their energy roadmaps as is the case in most of the Small Island Developing Countries (SIDS).

Most of the SIDS due to their relative geographical isolation, diverse topography, increasing population, and small resource base face unique challenges in their progress towards sustainable development. SIDS are heavily dependent on imported fossil fuels for most of their energy needs, due to limited technical and human resources for introduction of new energy harnessing technologies. Most SIDS have abundant renewable energy sources but financial constraints, restricted accessibility and availability of data and lack of qualified personnel lead to low penetration of renewable energy in electricity generation and transport.

Energy policies have been developed in some SIDS without any energy plan, roadmap or needs assessment. An energy plan (or roadmap) must be one of the pillars for a nation's sustainable development agenda. More often than not, energy related studies and policy development are conducted by energy consultants from developed countries or international organizations. It is imperative that the SIDS develop their own regional cadre of energy planners and specialists. The present review also focuses on inquiry method and computer assisted energy planning tools which would aid SIDS based researchers/energy planners.

The next section of this paper presents energy planning definitions and terms. Since there are risks, errors and uncertainty involved in energy planning, the third section of the paper focuses on these aspects. The forth section reviews literature on system analysis and decision making in energy planning as the results of the energy plan are used by governments for policy making process. The fifth section discusses energy planning models and presents five computer models that can be used for long-term national energy planning using scenario analysis. The inquiry method of energy planning is reviewed in Section 6 while Section 7 discusses the geographical level of energy planning. Section 8 presents validation of planning methods and finally some conclusions are drawn.

2. Definition of energy planning and planning terms

2.1. Energy planning definition

Different authors have defined energy planning in a variety of ways. A survey of some of them reveals a range of important emphases. According to Thery and Zarate [6] energy planning determines the optimum combination of energy sources to satisfy a given demand. This is done by taking into consideration the multi-criteria for decision making, which are, quantitative (economic and technical criterion) and qualitative (environmental impact and social criterion). Cormio et al. [7] suggest that the basis for energy planning is to satisfy the forecasted energy demand over a given time period by taking into account political, social and environmental considerations, as well as historical data collected for previous energy plans for the location under consideration. Hiremath et al. [8] more concisely state that energy planning involves finding a set of sources and conversion devices so as to meet the energy requirements/demand of all tasks in an optimal manner. Kleinpeter [9] identifies the main aim of energy planning as the guarantee of supply, which is achieved by sound management of the natural energy sources, diversification of energy supply sources to reduce energy imports, and rational use of energy.

In view of the above discussion, it is obvious that any energy planning needs to foster sustainable development. A good energy plan is based on sound research on the national energy consumption and energy supply, energy prices, demand and supply technologies, population growth, environment and social impacts, success of an energy harnessing technology and influence of political situation of