Applied Energy 164 (2016) 237–244

Contents lists available at ScienceDirect

Applied Energy

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

Multicriteria-based decision aiding technique for assessing energy policy elements-demonstration to a case in Bangladesh

Md. Mizanur Rahman [a,b,*], Jukka V. Paatero [b], Risto Lahdelma [b], Mazlan A. Wahid [a]

[a] Department of Thermo-Fluids, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Malaysia
[b] Department of Energy Technology, Aalto University School of Engineering, POB: 14100, FI-00076 Aalto, Finland

HIGHLIGHTS

- A multicriteria technique for assessing energy policy elements has been proposed.
- Energy policy elements have been examined based on assigned criteria.
- This assessment gives results which are representative of all stakeholders.
- Policy elements which are chosen by this method promote sustainability.

ARTICLE INFO

Article history:
Received 16 September 2015
Received in revised form 29 November 2015
Accepted 30 November 2015

Keywords:
Multicriteria
Long-range
Sustainability
Policy element
Energy policy

ABSTRACT

The adverse environmental consequences and diminishing trend of fossil fuel reserves indicate a serious need for vibrant and judicious energy policy. Energy policy involves a number of stakeholders, and needs to incorporate the interests and requirements of all the key stakeholder groups. This paper presents a methodological technique to assist with formulating, evaluating, and promoting the energy policy of a country in a transparent and representative way with clear scientific justifications and balanced assessments. The multicriteria decision analysis approach has been a widely used technique for evaluating different alternatives based on the interests of a multitude of stakeholders, and goals. This paper utilizes the SMAA (Stochastic Multicriteria Acceptability Analysis) tool, which can evaluate different alternatives by incorporating multiple criteria, in order to examine the preferences of different policy elements. We further extend this technique by incorporating the LEAP model (Long-range Energy Alternatives Planning system) to assess the emission impacts of different policy elements. We demonstrate the application of this evaluation technique by an analysis of four hypothetical policy elements namely Business-as usual (BAU), Renewables (REN), Renewable-biomass only (REN-b), and Energy conservation and efficient technologies (ECET). These are applied to the case of sharing fuel sources for power generation for the Bangladesh power sector. We found that the REN-b and REN policy elements were the best and second best alternatives with 41% and 32% acceptability respectively. This technique gives transparent information for choosing appropriate policy elements that aimed at sustainable energy.

1. Introduction

Due to the trend of diminishing fossil fuel reserves, the environmental consequences of fossil fuel combustion, and rapid economic growth, there is a serious need for a vibrant and judicious energy policy for long-term sustainability in the energy sector [1–3]. Setting policies that address increasing environmental concern and reduce dependency on fossil fuel sources are a continuous challenges for many countries [4–6]. The challenges arise mainly because energy policy involves a number of stakeholders and needs to incorporate the interests and requirements of all the major stakeholders to make energy policy viable [7]. The stakeholders' interests and requirements are diverse and cannot be represented by a single criterion. Therefore, when aiming at sustainable and low-emission energy, strategic decision making arises from the multi-dimensionality of stakeholders interests, socioeconomic dynamics, sustainability goals, and the biophysical systems and long-range nature of the problems [8].

If energy policy is developed on the basis of political motives rather than careful scientific evaluation of multiple criteria, it eventually fails in terms of sustainability and acceptability.

* Corresponding author at: Department of Thermo-Fluids, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Malaysia. Tel.: +60 (0) 176480491; fax: +60 7 5566159.
E-mail address: mizanur@fkm.utm.my (Md.M. Rahman).

http://dx.doi.org/10.1016/j.apenergy.2015.11.091
0306-2619/

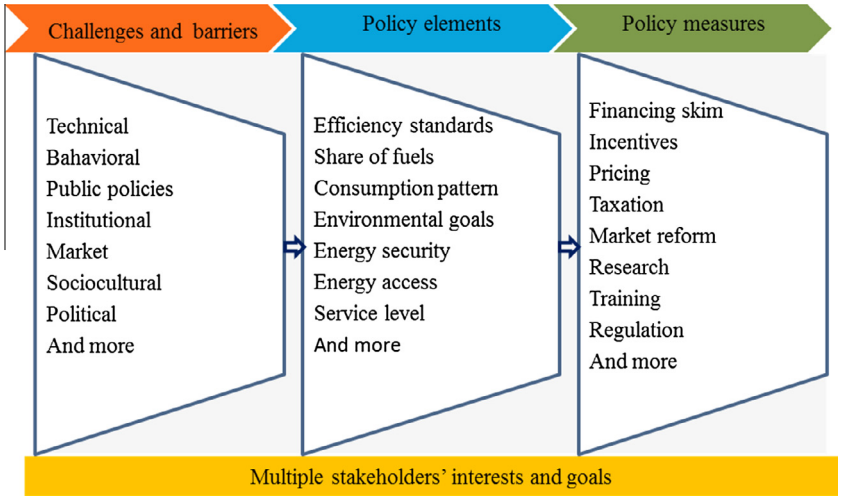

Fig. 1. Conceptual pathways for energy policy evolution.

Therefore, energy policy modeling needs to explicitly consider multiple objectives that can suitably meet the stakeholders' interests and sustainability criteria. For that reason, policy-makers require detailed information and insights into multiple objectives to endorse appropriate policy measures [9]. Moreover, in addition to giving information on multiple objectives, the multicriteria method provides decision-makers with an opportunity to explore different energy options by trade-off their importance [10]. Complex interactions among multiple objectives (goals) require multicriteria technique to be integrated in the framing of appropriate policy directions [11–14].

Economic and environmental modeling techniques have been widely used by researchers to support developing energy and climate policies [15]. Policy frameworks for determining the optimal energy technology were also found in the existing literature [16,17]. Several studies examine the effects of different policy packages aimed at energy security, affordability, flexibility, extending services, and mitigating environmental pollution [18–23]. Studies also investigate the implications, social costs, benefits and climate-interactions for various policy supports and mechanisms [24–28]. Although significant efforts have been made in the development of energy and emission assessment methods, there are very few methods that include the multi-dimensionality of stakeholders' interests and sustainability criteria through use of Multicriteria Decision Analysis (MCDA) technique. This paper presents a multicriteria-based decision aiding technique for evaluating and choosing energy policy elements in a representative way. Because this method incorporates the stakeholders' interests and opinions through criteria values and weights, it eventually provides results which are relatively transparent and representative. This paper shows the relationship between energy-sector challenges, policy elements, and measures (regulatory, legislative or legal) in way to evolving of energy policy. Bangladesh, a developing country, is facing huge challenges in adopting renewable energy sources in its power generation mix, despite endowed with an abundant amount of evenly distributed renewable resources (e.g. average daily solar irradiation of 4.5 kW h/m^2 and annual recoverable bio-wastes generation of 0.54 tonne/capita). The reserve of indigenous energy resources in Bangladesh is very limited (i.e. recoverable natural gas reserve 580 billion cubic meter, oil 0.84 million tonne, and coal 1.75 billion tonne) [29]. The objectives of this work are to present a multicriteria based decision aiding technique and to demonstrate the application of this technique to a case. This paper demonstrates the application of this technique through an analysis of four assumed policy elements (i.e. four alternatives) against a particular aspect (i.e. share of fuel sources for power generation) of Bangladesh's power sector as a case.

The remainder of this paper is organized as follows: Section 2 describes the methodological framework for integrating multiple criteria and sustainability goal, and assessing the long-term emission impacts of policy elements. Section 3 presents datasets of four policy settings (elements), which will be applied to demonstrate the proposed technique. Section 4 presents the main results of this analysis according to the proposed technique and applied datasets. Finally Section 5 highlights the main conclusions obtained from this work.

2. Methodology

2.1. Conceptual pathways for evolution of energy policy

Energy sector faces various challenges and barriers, which range from technical and behavioral to sociocultural and political challenges. Energy *policy elements*[1] are the main ingredients of energy policy to deal with the energy-sector challenges and barriers through the undertaking of various *policy measures* or *instruments*[2] (Fig. 1). The development of energy policy, in many cases, occurs as a 'black box' process rather than with clear reasoning and understanding by the stakeholders (e.g. decision-makers) [1]. Essentially, energy policy can be evolved by linking *policy elements* with different quantifiable parameters in a transparent and representative way [30]. This work presented the technique to choose appropriate policy elements through multicriteria and long-term emission assessments. The chosen policy elements should be implemented by enacting appropriate policy measures (e.g. incentive provisions, tax exemptions, legislations, treaties, etc.).

2.2. Multicriteria technique for analyzing policy elements

Energy policy assessment models are usually developed in two ways–process analysis, and econometrics [31]. But the conflicts in sustainability are shared with broader environmental, socioeco-

[1] Policy elements are the basic ingredients of energy policy, each element consists of a combination of purposes, objectives, ambitions, commitments, etc. on energy related issues.

[2] Policy measures or instruments are the set of actions that lead to implementation of the tasks required by the chosen policy elements.