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Towards building a multi perspective policy development framework for transition into renewable energy

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ABSTRACT

The objective of this research is to evaluate the effectiveness of energy policy instruments on increasing the adoption of renewable energy by developing a comprehensive evaluation model. Criteria used in this assessment depend on five perspectives that are perceived by decision makers as important for adoption process. The decision model linked the perspectives to policy targets and various energy policy instruments. These perspectives are: economic, social, political, environmental and technical. The research implemented the hierarchical decision model (HDM) to construct a generalized policy assessment framework. Results of this research identified economic feasibility improvement of renewable energy projects as the most influential perspective and that renewable portfolio standards and tax credits are the two most effective criteria to accomplish that.

Introduction

The demand for alternative energy resources has increased in the last two decades as a response to major concerns of projected scarcity in fossil fuel supply as well as climate change issues. After the oil crisis of the 1970's, renewable energy (RE) resources emerged as sustainable, clean, and abundant alternatives to fossil fuels [1–6]. As the fossil fuel system is deteriorating, however, with price increase and supply scarcity, the transition to a new era of renewable energy is inevitable [7]. Policy can play an important role in promoting the penetration of renewable energies into the power generations marketplace/portfolio [8]. Over the past decade, federal and state governments have adopted policies and initiated programs to accelerate the development and adoption of renewable energy technologies as energy sources. Nationwide, 30 states have mandatory plans to integrate renewable technologies in their energy mix by the year 2025 [9]. Federal and state governments are working to prepare and employ policies that can meet current energy demand from renewable sources, and in doing so, make a step toward a sustainable future. The emphasis is now on developing programs that foster research, encourage government-industry partnership, and promote tax credits and other incentives which can increase the rate of adoption of renewable energy technologies and expedite replacing traditional fuels [10]. With different energy policies implemented and still debated, literature emphasized on the need to evaluate these policy instrument to verify their ability of achieving their targets [11–13]. Adopting relatively new renewable energy sources is a multidimensional decision process that involves a number of different variables and several perspectives: economic, technical, social, political and environmental [14,15]. Multi criteria analysis can provide a technical-scientific decision-making support tool that is able to justify preferred options clearly and consistently in the renewable energy sector [16]. This study develops a research framework that can assist decision makers in the energy sector to develop a comprehensive energy policy while taking into consideration different perspectives that involve various goals in order to find the optimum policy pathways.

Literature review

Fossil fuels still account for over 80 per cent of the total primary energy supply worldwide. The diffusion of renewable energy technologies is beginning to take place and a new energy era has begun. This diffusion has so far been driven by environmental and socio-economic factors and political regimes [17]. However, we are still at a very early stage of the diffusion of these technologies.

Renewable energy adoption

There are different diffusion theories that could be used for understanding the adoption of new technologies, but the bulk of

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literature is based on the diffusion of innovation theory. Diffusion of innovation theory is a key methodology for this research. Rogers [18] defines diffusion as, "*the process by which an innovation is communicated through channels over time among members of a social system. It is a special type of communication, in that the messages are concerned with new ideas.*" Jacobson and Johnson emphasized the need to use an innovation system perspective when analyzing the processes of innovation and diffusion [19]. The Bass Model provides a good framework for analysis of energy technologies and description of interventions that may interact with the diffusion. Energy installed capacity can be used to obtain the diffusion parameters for the model which can reflect the rate of adoption of that certain technology [20,21]. Sales growth models have been proposed to measure the effectiveness or success of a new idea among end users [22,23] and the Bass Model is one of the most applied models in this area [21,24]. Cantono and Silverberg developed a network model of new technology diffusion to analyze the relationship among the diffusion of a new technology, learning economies and financial support, and to further investigate the path of diffusion of a new energy technology when some consumers are willing to pay more for goods that are perceived as "green" [25]. Kobos et al. argued that without institutional support, emerging energy technologies are limited from adoption and reaching consumer markets by their costs [26]. Their analysis explored the relationship among research and development (R&D) investments, energy cost reduction, and market penetration.

Economic variables

Renewable energy sources are like any other new technologies where economic factors heavily influence the rate and extent of diffusion. Consumers are willing to adopt renewable energy and other alternatives if they are financially competitive to current sources. Diaz-Rainey & Tzavara linked the willingness to pay (WTP) literature with the current innovation literature by developing a diffusion model of an induced environmental customer market [27]. The cost of developing new technologies is one of the main concerns for both the supplier and consumer. Diffusion and adoption of renewable energy technologies depends on development of more mature technologies and cost cutting strategies which can be achieved through innovation and experience. Kapur et al. developed a two dimensional technology innovation model which combines the adoption time of technological diffusion and price of technology. The analysis confirmed that studying the key elements that influence the adoption of a technology is crucial to assess the competitiveness of new technologies [22]. Neij used experience curves to analyze the prospects for diffusion and adoption of renewable energy technologies [28]. There are different policies and legislative actions that help to set up the targets and directions to transfer the energy system to renewable energy utilization, but meeting the desired targets depends on the advancements of technologies and the change of consumption preference from customers. Feed-in-tariff, for example, is a price for electricity that is paid by national authorities for individuals or businesses when they produce and sell energy generated by RE sources, and it's usually higher than regular prices. This mechanism has been introduced in many European countries and in the United States (US) and is proven to be effective in stimulating the adoption of RE sources [29]. Several articles discussed renewable energy adoption in the US and European Union (EU) from the public policy and government legislation point of view. The European commission has established a project for the assessment of external energy cost (ExternE Project). This project produces a series of reports describing analysis of nuclear, fossil, and renewable fuel cycles for assessment of the externalities associated with electricity generation [30]. The methodology used in this project is called Impact-Pathway-Approach. Impact pathway assessment is a bottom-up-approach, meaning that by following the pathway from source emissions, physical impacts, environmental benefits and costs can be estimated for the energy and hence expressed in monetary benefits and costs [30].

Social acceptance

For many new technologies, customer interaction and satisfaction can enhance the image of the product and increase the acceptance of it, but the main motivation for acceptance remains the competitive price [22]. The option of purchasing electricity from renewable sources is increasingly available to customers across the United States but appropriate electricity pricing affects the use and choice of energy sources [31]. When energy prices are high, it's likely associated with drop of demand for that certain energy [27]. Kotchen and Moore analyzed household decisions about participating in green-electricity programs and investigated the factors that influence this participation [32]. Increasing awareness of the environmental consequences from conventional fuel usage and shifting values into using more environmentally friendly technologies can change individual and organizational attitudes toward the adoption of new technologies, such as the purchase of electricity from providers that generate it using renewable sources. Public satisfaction and market behavior can have a major influence on the rate of diffusion of any innovation. A marketing strategy focuses on select market niches and being able to integrate the innovation aspect into a policy toward marketing alternative renewable technologies [33,34]. A study by Harmon and Cowan examined the market for renewable (green) energy using the TOP framework (technical, organizational, personal) and discussed the market adoption barriers for green energy [35]. In addition to marketing strategies, the adoption of new products depends on its perceived value by the individual purchaser as well as other potential adopters in the same social network. Beck et al. studied the effect of customer networks and word of mouth on diffusion of new technology based on the similarities of previous ones. They developed a formal adoption and diffusion model to consider the roles of direct and indirect network effect to analyze investors' and consumers' adoption dynamics [36].

Institutional and government support

One of the driving forces to achieve technology diffusion is the channel of diffusion, which is the driving force between both the diffusing party and the recipient. Institutional support and research and development (R&D) investments are important factors that can push diffusion of emerging energy technologies [26]. Previous studies have shown that government support and energy strategies have a great impact on the diffusion of energy technologies [26,37]. Shi Yan et al. analysis of technology diffusion channels in China demonstrated that in addition to diffusion driving forces, diffusion channels are equally important to consider [38]. Patents are a direct channel for technology diffusion; a higher frequency of patent citation reveals a faster diffusion and greater adoption of the technology [38]. Patents are used to analyze technology trends, including growth and diffusion, as well as competitive parameters between emerging technologies [39,40]. Previous studies have found that the quantity of patents and amount of knowledge spillover are highly correlated with R&D expenditures [41–44]. On the other hand, bibliometrics can also be used to understand patterns of technology development and adoption and potentially forecast the future [45–47]. Norton defined bibliometrics as the measurement of text and information. Researchers have used bibliometric analysis to track academic journal citation and identify the competitive position of a technology and its level of maturity [48,49]. Both bibliometric and patent analysis can be used as a measures of technology maturity and hence adoption rate. These studies emphasized different policies