Energy Economics 34 (2012) 882–891

Contents lists available at SciVerse ScienceDirect

Energy Economics

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

Exploring renewable energy pricing with analytic network process — Comparing a developed and a developing economy

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ARTICLE INFO

Article history:
Received 22 June 2011
Received in revised form 5 April 2012
Accepted 9 April 2012
Available online 21 April 2012

JEL classifications:
O32
Q42
Q48
Q41
Q55
Q50

Keywords:
Analytic network process
Decision analysis
Renewable energy pricing
Pricing components

ABSTRACT

Increasing use of renewable sources has a vital importance in mitigating increasing energy demand and global warming. The limited reserves and negative environmental impacts associated with fossil fuel consumption make the renewable energy sources considerable alternatives in case environmental externalities are taken into consideration. Pricing models for renewable energy alternatives are commonly based on the same fundamentals as the fossil fuels, but this approach neglects some of the characteristics that are unique to renewable energy alternatives. In order to develop more accurate pricing models these unique variables which are mostly considered as market externalities need to be integrated in the current forms of pricing models. The originality of this work is its ability to combine social, technical, environmental and economic aspects using analytic network process in order to provide a more holistic point of view on factors impacting renewable energy pricing through a comparison of two case studies. United States (U.S.) and Turkey are the two cases analyzed in this paper. U.S. represents a developed economy whereas Turkey represents a developing economy. It is expected that the results of this work would be helpful for further research in understanding the dynamics behind pricing mechanism of the renewable sources in different environments. For instance, fundamental differences in relative importance of pricing factors between two case countries have been identified as different levels of enforcement through laws and regulations, impact of geographic characteristics on site selection and job opportunities created through new investments.

1. Introduction

As seen in recent publications (Noailly and Batrakova, 2010; Soderholm and Pettersson, 2011; Toke, 2011), there has been an increase in planning for renewable energy. There has been increased interest in trying to find out how to incentivize the adoption of different types of renewable energy (Bassi and Shilling, 2010; Luiten et al., 2006; Meyer and Winebrake, 2009; Tsoutsos and Stamboulis, 2005).

Renewable energy sources are considered as a part of total energy supply and there is a global movement towards increasing the renewable energy share (Glover and Enz, 1996). Although renewable energy alternatives have been recognized as an ineffective alternative for fossil fuels, however recent developments are able to change this point of view permanently. Increasing energy consumption, limited reserves as well as negative environmental impacts associated with fossil fuels have recently created significant concerns worldwide. This situation has definitely impacted the diffusion and technical development of renewable energy alternatives. With the help of financial support provided by governments renewable energy generation sites have been deployed all around the globe, however in order to sustain the growth levelized cost of energy production from renewable alternatives needs to be lowered significantly without tax credits provided. Recent policy studies aiming to incorporate some of the market externalities through emission taxing such as carbon dioxide have been focusing to address different characteristics of renewable and conventional energy alternatives. However in order to bring assessment of conventional and renewable energy alternatives to the same level some of the other externalities need to be considered as well. For instance, air pollution is also a direct result of the use of fossil fuels, resulting in smoke and degradation of human health and plant growth. There are also local ecologic problems where the fossil fuel is produced, ecosystems are heavily impacted by oil spills and coal mining. In comparison to conventional sources renewable energy alternatives are obviously less harmful than the fossil fuels, but some practices can cause minor environmental and social impacts.

Financially, renewable energy is a real challenge for investors. Fossil fuels have still significant cost advantages versus renewable sources and the presence of the huge sunk investment on fossil fuel energy production supply chain is another inhibiting factor. The future energy shortage and environmental impacts caused by use of fossil fuels make renewable energy a key element in the European energy scenarios in which clean and sustainable energy is planned to be

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doi:10.1016/j.eneco.2012.04.005

brought to public. As the highest decision maker organization in Europe, the European Union prepares and establishes a set of laws, legislations and promotions. On the public side the press runs the propaganda of renewable energy usage to get the idea into the public life. For a better explanation to the point of view of European Union towards renewable energy a wider perspective have to be considered. The so-called "20-20-20 community" has taken effect in December, 2008. According to the policy, a 20% reduction on greenhouse gas emissions will be achieved by 2020. Another goal that is aimed to be achieved by 2020 is 20% use of renewable energy use in total energy consumption.

In short, pricing is a significant variable in success of renewable energy promotion. Thus, it is important to gain insight to renewable energy pricing by considering unique characteristics associated with renewable energy alternatives.

2. Methodology

This paper is unique in integrating the following ideas with the energy pricing topic:

Technology adoption — Prior research (Cowan et al., 2010; Daim and Iskin, 2010; Daim et al., 2011; Iskin et al., 2013) explored the adoption of renewable energy. This paper builds upon this prior work by integrating multiple research streams.

Hierarchical decision models — Researchers (Amer and Daim, 2011; Daim and Intarode, 2009; Daim et al., 2009; Wang et al., 2010) provided hierarchical models for evaluating renewable energy. This paper integrates these ideas in a much more comprehensive approach.

Technology assessment — Models for technology evaluation have recently been adopted at a higher rate than ever for renewable energy (Amer and Daim, 2010; Amer et al., 2011; Cinar et al., 2010; Cowan and Daim, 2009; Daim and Cowan, 2010; Daim et al., 2010, 2012a, 2012b; Harell and Daim, 2009). This paper therefore builds upon this stream of research and presents a comprehensive model for renewable energy pricing.

3. Brief overview on energy pricing

Energy pricing and forecasting is a common subject which contains a notable amount of articles and research papers. Reviewed articles are summarized in Table 1.

The price criteria are collected in five different clusters with respect to their properties and areas. These clusters are economic factors, technical factors, social factors, political factors and obstacles. These clusters were adopted from the work of Kocaoglu et al. (2011). Each cluster has its own criteria to compare. Criteria and their explanations are listed below:

4. Pricing factors

Factors proposed to impact renewable energy investment decisions are grouped under five different clusters with respect to their properties and areas they are associated with. These clusters are economic, technical, social, political factors and obstacles. Research framework and definition of each criterion can be seen below.

4.1. Economic factors

Economic factors are highly significant influencers on energy prices, market clearing prices are based on them.

Table 1
Analysis of energy pricing literature.

Researchers	Method	Data Years	Goal	Results
Glover and Enz (1996)	Statistical model	1990–1993	Pricing the variance of wind energy	The value of the energy produced is much more accurate for low and average demand days. For high demand days, however, this additional term does not improve the model significantly.
Aki et al. (2000)	Linear programming		Energy pricing and determination of its reduction effect on environmental impact	The results show that electricity pricing is less significant on electricity demand than the cooling and heating pricing. They also show that heating is the complementary goods for electricity and its price increases as the electricity prices increases.
Kian and Keyhani (2001)	Stochastic model	May 29–31, 2000	Price modeling	The predicted day-ahead prices match the real day-ahead prices closely. The estimated values of the lost load (VOLL) could help the power marketers to design optimal load leveling contracts and price tariffs for their customers.
Anders and Rodriguez (2005)	Neural networks and fuzzy logic	June 2002	Energy price forecasting	Taking a forecasted price as a basis for a bidding strategy may result in the participant gaining lower profits than otherwise possible.
Malliaris and Malliaris (2005)	Neural network, multiple regression models	1997–2002	Energy price forecasting	The computations show that there are sufficient data for an effective price prediction. It also shows that common statistical methods are far from presenting a successful forecast in this case.
Contreras and Santos (2006)	ARIMA, dynamic regression, transfer function methodology	1–24–168 hourly time series	Short term demand and price forecasting	Firstly it is proposed that the forecast models based on time series are most successful among the others. Secondly the forecast models have to work in a significance level less than 5%.
Teoh and Sheblé (2006)	Spot rate forecast technique, Market expectations theory	2001–2006	Estimating energy price uncertainties	Firstly single reactor is more beneficial than multiple reactors because of the higher probability of failure events. Secondly the benefits of reactors increase with years because aging failure probability also increases with years.
Haghi and Tafreshi (2007)	Non-stationary Markov models versus stationary hybrid models	January 1–7 , 2005	Modeling and forecasting energy prices	The research concludes that in short terms where the market actors do not change their behaviors wavelet transform models are very accurate. In long terms it is suitable to use hidden Markov models with its advanced mathematical background.
Filho et al. (2009)	Decision tree approach	2006–07	Pricing analysis	The suggested approach allows the classification and prediction of the short-term electricity price with high correct rate.