Energy Policy 68 (2014) 70–79

Contents lists available at ScienceDirect

Energy Policy

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

The target decomposition model for renewable energy based on technological progress and environmental value ☆

Zhen Liu [a,b,*], Jenny Lieu [c], Xiliang Zhang [b]

[a] Business Administration College Chongqing University of Technology, Chongqing 400050, China
[b] Institute of Energy, Environment and Economy, Tsinghua University, Beijing 100084, China
[c] SPRU (Science and Technology Policy Research), Sussex Energy Group, University of Sussex, Brighton BN1 9RF, England

HIGHLIGHTS

- The target decomposition model for renewable energy are proposed based on technological progress and environmental value.
- Total target and sub-target (power, oil, gas, heating) of renewable energy were generated by model.
- The model projected that the economic capacity of renewable energy generation in Fujian province.
- The priority development regions and technologies can be developed by model.

ARTICLE INFO

Article history:
Received 15 October 2012
Received in revised form
15 December 2013
Accepted 21 December 2013
Available online 20 February 2014

Keywords:
Renewable energy
Technology progress
Environmental value
Target decomposition model

ABSTRACT

One of the key aspects of developing a regional renewable energy plan involves incorporating national renewable energy targets into provincial targets whilst including interim phase targets and technology targets. This paper proposes a renewable energy model based on national targets 'decomposed' into regional targets that incorporate technological processes and environmental conditions at the individual project level. At the project level, resource potential is allocated into individual projects based on the current technological level. The available resources and renewable energy generation of each project changes as the technology evolves and the environmental conditions change over time. The model can be adjusted according to actual needs of each region; thus policymakers can establish the respective targets for power, heating, oil and gas as well as renewable energy based on the regional context. Overall, the total national target can be decomposed into regional targets and technological targets. This paper proposes long-term regional development targets for renewable energy based on the total supply curve for renewable energy in different periods. Fujian province will be applied as an example to validate the target decomposition model of renewable energy targets of various regions and technologies in China. The model projected that the economic capacity of renewable energy generation in Fujian province for dam hydropower, offshore wind power, onshore wind power, photovoltaic power and waste incineration power is expected to reach 4748 MW, 4036 MW, 3581 MW, 2663 MW and 766 MW, respectively by 2025. The research result could have wider implications such as achieving GHG emissions reductions targets, addressing environmental concerns, providing high tech jobs within the region and contributing to energy security at the local and national level.

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1. Introduction

Developing renewable energy has been an essential component of China's energy development strategy in the past decade, and has played an important role in diversifying the energy mix and improving energy security, reducing greenhouse gas emissions, adjusting the energy structure, and improving the ecological environment. Renewable energy was first promoted at a national level in 2005, with the enactment of the "Renewable Energy Law" (REL). The REL served as a broad framework for developing renewable energy technologies and was a regulatory basis for formulating more detailed supplementary renewable energy policies. Several years later in 2007, renewable energy targets were implemented in China's "Long-term national development plan for renewable energy" (LNDP). One of the key challenges with implementing the "REL and the LNDP" has been to combine the

☆Research has been supported by the National Natural Science Foundation of China (71073095 and 71210107007), the National Basic Research Program of China (973 Program) (2012CB955802) and the Chinese Ministry of Education, Humanities and Social Science Foundation (10YJ630161).

* Corresponding author at: Business Administration College Chongqing University of Technology, Chongqing 400050, China. Tel.: +86 23 62563167.
E-mail address: zhenliu@tsinghua.edu.cn (Z. Liu).

0301-4215/$ - see front matter © 2014 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enpol.2013.12.043

national and the regional plans as well as to decompose or break down the national target into each province.

At present, there are various planning models for renewable energy. The mainstream planning models can be divided into three categories: the top-down planning model, the bottom-up planning model and the multi-agent based planning model.

The first category, the top-down planning model for renewable energy, is seen in models such as the Computable General Equilibrium (CGE) economy–energy–environment model. There are several examples of studies that have applied the CGE model. For instance, Levent and Mustafa (2011) developed a top-down TurGEM-D model based on the CGE model to study the impact of oil price fluctuations in the Turkish economy, which is heavily reliant on petroleum and natural gas imports. The TurGEM-D model is a dynamic and multi-industry general equilibrium model that analyzes the effect of the oil price fluctuation on macroeconomic variables such as: interest rate, GDP, consumption price index, tax revenue and carbon emissions. Other studies include Levent and Mustafa's application of the CGE model to analyze three oil price fluctuation scenarios: the stable oil price, the lower oil price fluctuation and the higher oil price fluctuation. He et al. (2010) also applied the top down model to examine the effect of adjusting the coal price in the electric power industry and the effect of adjusting the electricity price in the macro-economy based on the CGE model. Arbell's (2010) proposed a scenario simulation model that applies a static, multi-area and computable general equilibrium model. Abrell's research indicated that integrating the transportation system into the European Union (EU) carbon emissions transaction system is more effective in terms of social welfare maximization compared to constructing the transportation system as an independent carbon transaction system or implementing a carbon tax on the transportation system to reduce emissions. In another study, Guivarch et al. (2009) proposed an Imaclim-R model which is a global mix and computable general equilibrium model based on macro-economic data.

The second category is a bottom-up planning model for renewable energy, which includes MARKAL, MESSAGE, and LEAP. A number of studies have explored these bottom-up planning approaches. Gül et al. (2009) applied the global multi-area MARKAL model, a bottom-up global energy system that establishes a global target for climate policy[1] by evaluating the key aspect and the main bottlenecks affecting the development of biomass and hydrogen. Their model considered different technology substitutions in the fuel chain to evaluate the effect of the greenhouse gas emissions on climate change. Chen et al. (2007) applied three common MARKAL models (MARKAL, MARKAL-AD and the MARKAL-MACRO model) to study the effect of the carbon reduction system and the related policies in the Chinese energy system on the macro-economy. The MARKAL-MACRO and MARKAL-ED models were used to carry out the simple description on the model structure and the economical feedback. The internal demand in the two models stressed that the constraining conditions (including technical, economic and renewable energy resource constraints) of carbon emission should be meet through reducing energy demand. Thirty energy intensive industries were selected to lower energy demand and the results of the two models were described, compared and analyzed. The effect of carbon mitigation on the social welfare was described by MARKAL and MARKAL-ED models while the effect of carbon mitigation on GDP, as well as the investment and expense were evaluated by the MARKAL-MACRO model. When a carbon emission constraint was given, changes in the quantity of energy consumption and primary energy, technology progress rate, and the variation for marginal cost of carbon mitigation in the three models could be analyzed. Hainoun et al. (2010) used the MESSAGE model based on the minimum cost of energy system, to optimize a long-term energy supply strategy from 2003 to 2030. In the model, the national energy supply chain covered all energy departments and energy transformation technologies. Other authors, Messner and Schrattenholzer(2000) claimed that MESSAGE-MARCRO could be used to link micro–macro models and energy supply models. The key objective of merging the micro–marco model was to evaluate the energy supply cost in the entire energy system. The energy supply cost could be determined by the energy supply model, which considered the most optimally allocated proportions of various energies sources in the macroeconomic model. Shabbira and Ahmad (2010) proposed a public transportation model developed by the LEAP system, which forecasted the total energy demand and emissions from vehicles over the timeframe of 2000–2030. Park et al. (2010) evaluated the carbon mitigation potential of the petroleum industry in South Korea by applying the mix SD-LEAP model. The model incorporated five new energy conservation technologies and several carbon mitigation technologies in the petroleum smelting industry, namely: crude distillation installment, vacuum distillation installment, light gas oil hydrodesulfurization installment and vacuum residuum hydrodesulfurization.

The third category is a renewable energy planning simulation model based on multi-agents, such as the Agent-Based Modeling (ABM) energy system simulation model. Ma and Nakamori (2009) claimed that the modeling and simulation based on multi-agents is becoming increasingly popular in energy systems research despite the fact that the process optimization[2] model has been the mainstream model for current energy systems. Ma and Nakamori compared the technical details of the modeling approach for different energy systems and maintained that each model had strengths and weaknesses due to the differing philosophical foundations (such as individual or enterprise behavior). They noted that when choosing to apply the optimization model or the model based on multi-agents in an energy decision system, the decision should be based on the context and background. Cong and Wei (2010) claimed that the multi-agent-based model was more appealing compared to other conventional models and established an electric power market model based on the multi-agent CET model. Beck et al. (2008) constructed an energy network planning by merging the global optimization model and the multi-agent-based modeling tool. Mauricio et al. (2010) used the multi-agent-based model to study the Brazil's carbon reduction emission potential in energy consumption under different low-carbon emissions scenario from 2005 to 2030.

The core concept of these models examines how to minimize investment costs and meet future energy demand by the various technologies and technical optimization while considering the constraints of resources, as well as economic, environmental and social conditions. For example, the MESSAGE model searches for the optimal technology decisions in each period. Different energy sources correspond to different technologies and each energy source can be developed by a certain energy extraction technology. The ABM model examines other aspects including the investment and construction of energy project in different periods based on different resource potential and technical, economic, environmental and social conditions. The investment for each project varies and the investment and construction times for projects are critical factors for the energy market.

Separate strategies should also be considered for different renewable energy development stages when studying correlation

[1] Various climate policies are considered including the Kyoto Protocol or post-Kyoto policies as well as three key.Climate stabilization scenarios: 650 ppmv CO_2 concentration in the atmosphere; 550 ppmv CO_2 concentration in the atmosphere; and450 ppmv CO_2 concentration in the atmosphere.

[2] Optimization includes all aspects of the production process while considering Technology, funding, personnel, and so on.

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