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# Levelized cost of electricity (LCOE) of renewable energies and required subsidies in China

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## HIGHLIGHTS

- Levelized cost of electricity (LCOE) of renewable energies is systemically studied.
- Renewable power generation costs are estimated based on data of 17 power plants.
- Required subsidies for renewable power generation are calculated.
- Electricity price reform is the long-term strategy for solving problem of high cost.

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## ABSTRACT

The development and utilization of renewable energy (RE), a strategic choice for energy structural adjustment, is an important measure of carbon emissions reduction in China. High cost is a main restriction element for large-scale development of RE, and accurate cost estimation of renewable power generation is urgently necessary. This is the first systemic study on the levelized cost of electricity (LCOE) of RE in China. Results indicate that feed-in-tariff (FIT) of RE should be improved and dynamically adjusted based on the LCOE to provide a better support of the development of RE. The current FIT in China can only cover the LCOE of wind (onshore) and solar photovoltaic energy (PV) at a discount rate of 5%. Subsidies to renewables-based electricity generation, except biomass energy, still need to be increased at higher discount rates. Main conclusions are drawn as follows: (1) Government policy should focus on solving the financing problem of RE projects because fixed capital investment exerts considerable influence over the LCOE; and (2) the problem of high cost could be solved by providing subsidies in the short term and more importantly, by reforming electricity price in the mid-and long-term to make the RE competitive.



## 1. Introduction

### 1.1. Research background

China is currently experiencing rapid development of urbanization, along with the requirement for adequate energy supply (Jiang and Lin, 2012). The Chinese government proposed that both energy intensity and carbon intensity would be reduced by 40–45% in 2020 compared to the level in 2005, implying that China's economic growth is constrained by carbon emissions reduction. Therefore, it is necessary for China to develop new technologies and new energies to meet the growing energy demand, and simultaneously, to optimize energy consumption structure. Renewable energy (RE) will play an increasingly important role in energy diversification and the development of low-carbon economy (IEA, 2011; Li and Lin, 2013).

Supportive government policies have underpinned the rapid development of RE industry in China (Qi et al., 2014). However, the problem of high-cost is a main restriction for the large-scale development of RE (Lin, 2012). On one hand, power generation costs of RE are higher than that of traditional energy resources; on the other, significant cost reductions cannot be achieved in the short term. Environmental value is highly related to per capita

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income (Flores and Carson, 1997). At present, the relatively low level of per capita income in China results in the relatively low evaluation and assessment of environmental quality by the general public, and the low willingness as well as low ability to pay for environment. Apparently, it is difficult for the Chinese government to encourage the public to support clean energy development and pay for the renewable energy cost. Therefore, support policies are essential for the deployment of RE in China.

Financial subsidy is an important method in dealing with the problem of high-cost of RE. The development of RE requires large-scale investment in research and development (R&D), which is characterized by high-risk, high-investment and uncertain-return, thus market competition alone cannot meet the substantial investment demand. The United States government provides continued financial support for R&D of RE (Congressional Budget Office, 2012). Presently, financial funds are sufficient for the Chinese government to support the development and utilization of RE, thereby to promote the development of RE industry (Lin, 2012). The direct financial transfer, including the feed-in-tariff (FIT) system, has been commonly used by governments in subsidizing RE (IEA, 2011). Subsidies to RE in China are mainly for power generation projects. An accurate estimation of renewable power generation cost is the basis of effective government subsidies, which determines the future development of RE in China.

### 1.2. The LCOE of renewables and the FIT system

The LCOE method, which estimates the cost of lifetime-generated energy, is used as a benchmarking tool to assess the cost-effectiveness of different energy generation technologies (OECD, NEA/IEA, 2010). The method of LCOE has been widely used for the estimation of power generation cost (Wiser et al., 2009; Singh and Singh, 2010; NREL, 2013). For example, IRENA (2012a, 2012b) estimated power generation costs of different technologies around the world in 2010. OECD, NEA/IEA (2010) did a comprehensive research based on data of 190 power plants located in 21 countries. Roth and Ambs (2004) accessed the LCOE of 14 electricity generation technologies. Results indicated that incorporating externalities into the full cost approach has an enormous impact on the LCOE and the relative attractiveness of electricity generation options. Darling et al. (2011) calculated the LCOE for photovoltaics based on input parameter distributions feeding a Monte Carlo simulation.

Feed-in-tariff (FIT), a policy mechanism for subsidizing RE, is more effective than alternative supportive schemes in promoting renewable energy technologies, as it provides long-term financial stability for investors (Lesser and Su, 2008). Recent experience from countries around the world suggested that FIT was the most effective policy that promoted the rapid and sustained deployment of RE (European Commission, 2008; Couture and Gagnon, 2010; Thiam, 2011). Degression of tariff rates could deliver renewable generation capacity at lower cost (Mabee et al., 2012). Unit subsidy cost of renewables is expected to fall gradually over time thanks to ongoing R&D and learning-by-doing, coupled with rising fuel and wholesale electricity prices and higher $CO_2$ prices (IEA, 2011). Klein et al. (2008) analyzed different FIT designs that were applied in the Member States of the European Union, and proposed that national FIT design should take local conditions such as renewable electricity potentials, the cost of electricity grid as well as social aspects into account. If not properly designed, FIT could be economically inefficient. Lesser and Su (2008) put forward an innovative two-part FIT, consisting of both a capacity payment and a market-based energy payment. Moore et al. (2013) indicated that FIT needed to meet industrial payback and industrial targets. Jenner et al. (2013) assessed the strength and effectiveness of renewable FIT in Europe, and showed that the interaction of policy design, electricity price and electricity production cost was a more important determinant of renewable electricity development than policy enactment alone.

Studies showed that the RE policy in China still needed to be improved. Wu and Xu (2013) reviewed the FIT policy as well as subsidy policy of RE in China, and showed that the effects of policy implementation were unsatisfactory. Zhang et al. (2009) analyzed opportunities and challenges for RE policy in China, and pointed out that government support was the key power for RE development. Schuman and Lin (2012) indicated that China's Renewable Energy Law, which regulated the FIT system and funding mechanisms, had led to rapid growth of RE in China. However, there are still numerous problems for China's supportive policies for RE development. Huo and Zhang (2012) pointed out that there was no predetermined degression of the capital subsidy to push cost reduction; moreover, insufficient R&D in China had impeded the future development of RE.

To the best of our knowledge, there has been no study that systematically estimates the LCOE of RE as well as the required subsidies under the current FIT system in China. This paper fills a much needed research gap. Undoubtedly, the problem of high-cost is imperative for the development of RE. In this study, we concentrate on evaluating the LCOE of renewables and required subsidies under the existing FIT mechanism in China. Based on our findings, we propose policy recommendations for decision makers on shaping the short-term tactics and the long-term strategy for RE development.

The remainder of this paper is organized as follows. Section 2 describes methodology. Section 3 presents results. Section 4 discusses required subsidies for renewable power generation. Section 5 summarizes our findings and draws policy implications.

## 2. Methodology

Levelized cost of electricity (LCOE) is a convenient tool for comparing the unit costs of different technologies over their economic life (OECD, NEA/IEA, 2010). The LCOE methodology is an abstraction from reality and is used as a benchmarking or ranking tool to assess the cost-effectiveness of different energy generation technologies (Branker et al., 2011). Estimation of the LCOE of renewables is the basis of the appropriate FIT.

There are two models for calculating the LCOE: (1) the EGC Spreadsheet model and (2) the System Advisor Model (SAM). The former has been widely used in research reports by the OECD and IEA/NEA in the cost estimation of power generation, while the later is developed by National Renewable Energy Laboratory (NREL). The advantage of the EGC Spreadsheet model is that it can estimate the LCOE of different generation technologies under the constraint of limited data. Therefore, we use this method to predict the LCOE of renewables in China.

As shown in Fig. 1, there are four major components determining the LCOE of renewable power generation technologies – resource quality, equipment cost and performance, the balance of project cost and the capital cost. All of them can vary significantly between individual projects and countries (IRENA, 2012a, 2012b). Khatib (2010) reviewed “Projected costs of generating electricity—2010 Edition” by OECD, NEA/IEA (2010), and emphasized the key conclusion of the study “the LCOE is determined by country-specific circumstances”. Therefore, in order to obtain more accurate results, the LCOE of RE should be studied based on specific countries. Following the above principle, this paper attempts to estimate the LCOE of renewable energies based on the data of 17 power plants in China.