Energy Policy ∎ (∎∎∎∎) ∎∎∎–∎∎∎

Contents lists available at ScienceDirect

Energy Policy

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

Retail electricity tariff and mechanism design to incentivize distributed renewable generation

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HIGHLIGHTS

- Survey different incentive mechanisms used to spur renewable investment.
- Highlight the cost-recovery issue raised by distributed renewable energy.
- Propose real-time pricing and two-part tariffs with demand charges as two solutions to cost-recovery issue.

ARTICLE INFO

Article history:
Received 7 August 2015
Received in revised form
7 December 2015
Accepted 30 December 2015

Keywords:
Distributed generation
Retail electricity pricing
Incentive mechanisms

ABSTRACT

This paper examines the question of how to incentivize the adoption and use of renewable energy resources, with particular attention on distributed renewable energy (DRE). Prior experience suggests that price and quantity-based programs, such as feed-in tariffs, provide more efficient renewable adoption and use and lower program costs than programs that set quantity targets only. We also examine some cost-allocation issues raised by the use of DRE systems and fixed time-invariant retail pricing. This combination can result in customers with DRE systems paying a disproportionately small portion of system capacity costs. We suggest two retail-pricing schemes, real-time pricing and a two-part tariff with demand charges, to address these issues.

1. Introduction

Recent years have seen increasing installation and use of distributed renewable energy (DRE), especially photovoltaic (PV) solar, in many parts of the world. This has been spurred, in part, by subsidies for and favorable regulatory treatment of these technologies. According to Sawin et al. (2014), at least 144 countries had some type of renewable energy target or incentive program in place as of early 2014. The aim of these incentive mechanisms has been to reduce the privately incurred cost and risk of installing these technologies, spurring greater use in the short-run. In the long-run, the greater use of these technologies is intended to lead to cost reductions through economies of scale in manufacturing and installation and 'learning-by-doing' effects. This increases the competitiveness of these technologies compared to alternatives, decreasing the cost of financing and deploying DRE systems. If taken to fruition, these programs are meant to lead DRE technologies to a point of maturity that they can compete with alternatives without any incentive mechanisms.

Different jurisdictions have used various combinations of incentive mechanisms to spur DRE adoption. These mechanisms can be differentiated based on the extent to which they provide a direct financial subsidy for either DRE adoption or use as opposed to providing a guaranteed market for DRE energy. Experience to date shows that these mechanisms have different levels of success in encouraging DRE adoption. Moreover, there are very important and nuanced implementation details that can help or hinder the performance of incentive mechanisms. Some of these incentive mechanisms have also created unintended negative cost-allocation issues. These cost-allocation issues are mostly related to the fact that retail electricity pricing lumps the variable cost of energy generation with the fixed cost of investing in generation, transmission, and distribution capacity. These two types of costs are remunerated using a volumetric charge on energy consumption to retail customers. Some price-based incentive mechanisms for DRE result in capacity-related costs being increasingly borne by customers who do not have access to DRE, creating undesirable cross-subsidies. As such, some jurisdictions have, *ex post*, limited or rescinded incentive programs to mitigate these issues.

This paper studies these problems in incentive and retail tariff design to efficiently encourage DRE adoption and use. It also provides lessons learned from previous attempts and failures. It further makes some recommendations on how to mitigate the

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http://dx.doi.org/10.1016/j.enpol.2015.12.041
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unintended cost-allocation consequences of DRE-related incentive schemes through better tariff design. The remainder of this paper is organized as follows: Section 2 summarizes the types of incentive programs used to date. It provides a comparative assessment of how well different programs work in incentivizing DRE adoption and reducing financing risks and costs. This section also discusses some of the philosophical reasons that certain mechanisms are sometimes favored over others. Section 3 introduces the negative cost-allocation consequences of these programs. Section 4 discusses two proposals for retail tariff design—real-time pricing and two-part tariffs with demand charges—that can address some of the cost-allocation issues discussed in Section 3. It should be noted that the pricing schemes proposed are not novel. Sakhrani and Parsons (2010) discuss the historical use of demand charges and time-variant energy charges for small residential customers in some jurisdictions. Rather, our contribution in Section 4 is to model and study the benefits of using such pricing schemes for cost recovery in the context DRE. Section 5 concludes.

2. Distributed renewable generation incentive policies

This section provides an overview of the different types of incentive mechanisms commonly used in different jurisdictions to encourage the adoption and use of DRE.[1] DRE historically has two competitive disadvantages relative to alternatives. The first is that DRE can be seen as a risky investment compared to better understood conventional alternatives. *Ceteris paribus*, investors may prefer conventional alternatives to DRE, increasing DRE financing costs. Secondly, DRE technologies may have higher upfront costs due to their relative immaturity compared to conventional alternatives.

The goal of incentive mechanisms is to reduce the privately incurred cost and risk of adopting and using DRE technologies. The incentive mechanisms that have been historically used can be differentiated by how they achieve this cost and risk reduction. We now summarize the key features of four major incentive mechanisms seen in use: the (i) feed-in tariff (FiT), (ii) quota-obligation, (iii) tendering, and (iv) net-metering systems. We also discuss other financial subsidy systems that have been used and some other important technical considerations relating to integrating renewables and DRE into electric power systems.

2.1. Feed-in tariff

FiTs are currently the most widely used DRE-related incentive mechanism. While the designs vary between jurisdictions, Umamaheswaran and Seth (2015) define the fundamental features of an FiT as a guaranteed price for and guaranteed purchase of energy produced by a DRE system. That is to say an FiT program provides a guaranteed payment for each kWh of energy produced by a qualifying DRE installation. Most FiT programs also require the local utility or system operator to accept any DRE energy provided by the end customer, except when doing so is technically infeasible. These design features reduce the risk of investing in a DRE system by providing a guaranteed market for energy produced.

The primary advantage of an FiT program is that it effectively manages revenue risk for a DRE system by guaranteeing the quantity of energy sold and the price at which it is sold. According to Lipp (2007) these price and quantity guarantees are often provided for eight to 30 years. Fouquet and Johansson (2008) and Umamaheswaran and Seth (2015) note that this reduced risk allows DRE developers to more effectively leverage debt to bring down financing costs. Lipp (2007) also notes that an FiT program can be tailored to different DRE technologies. For instance, the guaranteed price for a kWh provided by a distributed solar plant can be set differently from that for a distributed wind plant. This allows the FiT program to accommodate the relative maturity of different technologies. van der Linden et al. (2005) and Lipp (2007) note that the price guarantees in an FiT program can also decline over time. This allows the program to adapt to changing technology maturity levels over time and can also provide strong incentives for technology cost reductions.

van der Linden et al. (2005) note that the main criticism of the FiT system is that its efficiency depends on the price guarantee being set correctly. If the price is too high the system could result in excessive windfall profits to generators at the expense of consumers or taxpayers. If it is set too low, the program may be ineffective in spurring any DRE development. The information needed to correctly set FiT price guarantees largely comes from DRE owners or developers, who may not have any incentive to reveal their true costs. Indeed, these agents may have strong incentives to overstate costs. FiT design is in fact even more complex than this information asymmetry suggests. The mix of generation technologies that is ultimately deployed depends on the relative price guarantees set for them. This becomes an even more formidable task for a regulator, as it must know the costs of technologies and what an 'optimal' technology mix is, taking into account relative technology maturity and performance. Another criticism of FiTs that Lipp (2007) mentions is that the guaranteed prices for different DRE technologies do not encourage competition between technologies. As such, the mix of DRE technologies deployed may not be least-cost.

FiTs have been implemented in a number of jurisdictions successfully, in the sense that they have spurred DRE adoption. Lipp (2007) provides a succinct history of FiT programs. One of the first examples was the Public Utility Regulatory Policy Act (PURPA) of 1978 in the United States. PURPA guaranteed payments for qualifying energy-producing facilities. The payments were based on assumed future fossil fuel costs, which were estimated at $100 per barrel of oil by 1998, and the estimated avoided cost of conventional generation. The high price guarantees of PURPA did not prevail, however, and the programs were ended as a result of falling fossil fuel prices and the introduction of restructured wholesale electricity markets in the late 1990s and early 2000s.

The second wave of FiTs were implemented in Germany and Denmark in the 1990s. These programs required utilities to purchase energy from qualifying renewable-energy installations at prices that were established by the government. The rationale behind these price premia was to compensate renewable-energy facilities for the unpriced environmental and other benefits of their generation. Denmark introduced its FiT program in 1993 with a fixed price paid to qualifying facilities. This was modified in 2001 to have a more market-based design. Under the new design, qualifying facilities are paid the price established by NordPool[2] plus an environmental premium. According to Mitchell et al. (2006) this does create some added price risk for a DRE deployment, because part of the guaranteed payment is tied to a volatile wholesale electricity market price. However, a portion of the price guarantee (*i.e.*, the environmental premium) is fixed through legislation.

Germany began DRE-related incentive programs in the 1970s. As with PURPA, these programs were spurred by high fossil fuel prices. The first German program had a similar design to PURPA,

[1] The incentive mechanisms discussed here have typically been applied to all sources of renewable energy, including DRE and utility-scale systems.

[2] NordPool is the wholesale electricity market operator in the Scandinavian countries.

Please cite this article as: Sioshansi, R., Retail electricity tariff and mechanism design to incentivize distributed renewable generation. Energy Policy (2016), http://dx.doi.org/10.1016/j.enpol.2015.12.041