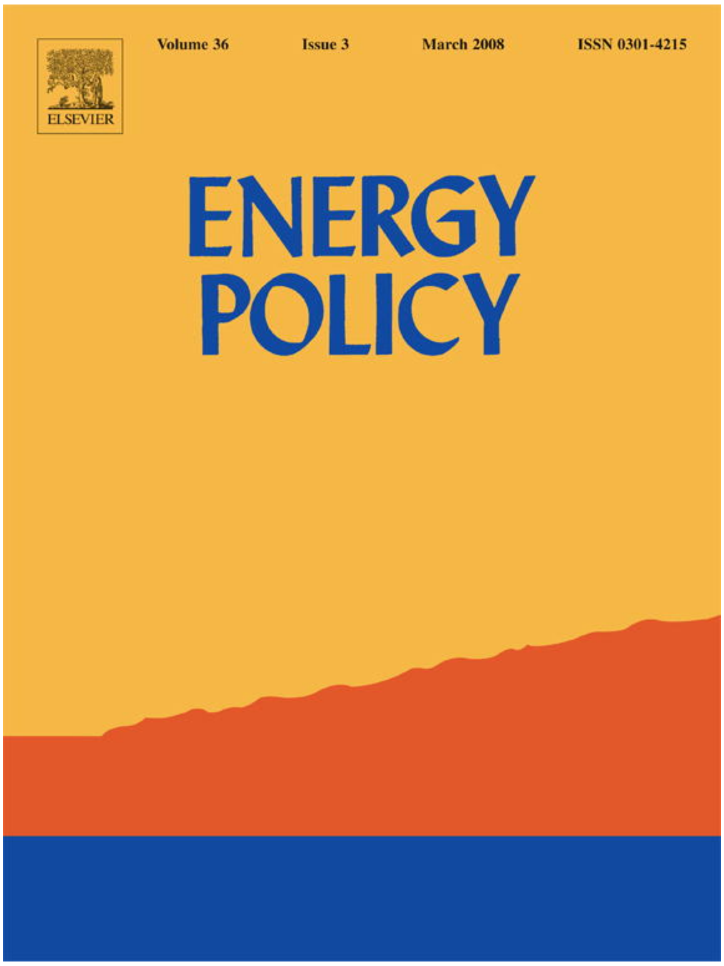
Volume 36
Issue 3
March 2008
ISSN 0301-4215
ELSEVIER
ENERGY
POLICY

Energy Policy 36 (2008) 981–990

ENERGY POLICY

www.elsevier.com/locate/enpol

# Design of an economically efficient feed-in tariff structure for renewable energy development

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Received 27 June 2007; accepted 9 November 2007
Available online 26 December 2007

**Abstract**

Evidence suggests, albeit tentatively, that feed-in tariffs (FITs) are more effective than alternative support schemes in promoting renewable energy technologies (RETs). FITs provide long-term financial stability for investors in RETs, which, at the prevailing market price of electricity, are not currently cost-efficient enough to compete with traditional fossil fuel technologies. On the other hand, if not properly designed, FITs can be economically inefficient, as is widely regarded to have been the case under the Public Utility Regulatory Policies Act of 1978 (PURPA). Under PURPA, too high a guaranteed price led to the creation of so-called ''PURPA machines''—poorly performing generating units that could survive financially only because of heavy subsidies that came at the expense of retail customers. Similarly, because of their adverse impacts on retail electricity rates, German FITs have been subject to increasing political pressure from utilities and customers. In this paper, we propose an innovative two-part FIT, consisting of both a capacity payment and a market-based energy payment, which can be used to meet the renewables policy goals of regulators. Our two-part tariff design draws on the strengths of traditional FITs, relies on market mechanisms, is easy to implement, and avoids the problems caused by distorting wholesale energy markets through above-market energy payments. The approach is modeled on forward capacity market designs that have been recently implemented by several regional transmission organizations in the USA to address needs for new generating capacity to ensure system reliability.


*Keywords:* Renewables; Feed-in tariffs; Auctions

## 1. Introduction

Regulatory policy approaches to promote renewable energy technologies (RETs) have taken on increasing importance in many countries. Although the relative weight given to underlying reasons for accelerating RET development may vary (e.g., reducing global climate change, a desire to reduce dependence on imported fossil fuels, increased portfolio diversity, local economic development, etc.), ultimately policy instruments used to promote renewables must necessarily balance several competing objectives, including

(1) Specific positive environmental impacts, such as reduced emissions of air pollutants and greenhouse gases, versus perceived negative impacts on bird populations and landscape esthetics (in the case of wind turbines, for example).
(2) Reduced dependence on fossil fuels, greater portfolio diversity, and lower exposure to fuel price volatility, versus adverse economic impacts of higher retail electric rates, including lessened economic competitiveness and lack of affordability.

Consideration of the trade-offs within each of these objectives is unavoidable, and there are a number of multi-objective methodologies that can be employed to this end which are both efficient and consistent (Madlener and Stagl 2005).[1] Regardless of how policymakers evaluate such trade-offs, however, the policies they implement to encourage accelerated RET development should be as

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[1]For a rigorous development of multi-attribute methods, see Keeney and Raiffa (1976).

0301-4215/$ - see front matter 
doi:10.1016/j.enpol.2007.11.007

economically efficient as possible. In other words, while economic theory may not be able to fully answer whether government-mandated RET development or development of specific RETs are themselves *Pareto-superior* policies,[2] economic theory can help determine the most efficient, ''least-cost'' approaches to achieve the chosen policy goals.[3]

Increasingly, feed-in tariffs (FITs), rather than minimum percentage requirements for RETs used in the USA and Great Britain, have been argued to be a superior policy approach for promoting RETs (Rowlands, 2005, 2007; Sijm, 2002), especially in their ability to reduce financial risks for RET developers (Mitchell and Connor, 2004). Germany, for example, has been especially aggressive about FIT implementation. Germany's Renewable Energy Law (Erneuerbare Energien Gesetz, EEG) was implemented in 1991 and revised in 1998. By 2002, total generation by RETs in Germany had increased to over 20 terawatt-hours (TWh) per year (Mitchell et al., 2006). The payments schemes vary by technology, plant vintage, and location. For example, under the German system, payments for solar photovoltaic plants are over seven times greater than payments for geothermal plants.

Yet, FITs are not a panacea. In particular, one difficulty with the development of FITs compared with renewable portfolio standards (RPS) and ''renewables obligations'' (RO) is that they require policymakers to define administratively FIT attributes, specifically payments *amounts* for individual technologies (e.g., wind, solar, geothermal), payment *structures* (e.g., fixed or declining), and payment *duration*. All three attributes can require significant ''guesswork'' on the part of policymakers as to future market conditions and rates of technological improvements. Essentially, traditional FIT designs require government policymakers to substitute their judgment for that of markets in the selection of long-term, technological ''winners and losers.'' However, long-term forecasting is notoriously imprecise and inaccurate, given the multitude of uncertainties that affect the future. Moreover, once specific price paths (i.e., level, structure, and duration) are specified, changing those paths is both difficult and costly, as it creates excessive regulatory uncertainty that, in turn, increases investment costs.

FITs were first used in the guise of ''avoided cost'' payment schemes mandated as part of the US Public Utility Regulatory Policies Act of 1978 (PURPA). Under PURPA, US electric utilities were required to purchase all of the output from so-called ''qualifying facilities'' (QFs) at prices that reflected the utilities' long-term avoided costs. Since there were no direct market prices that could be used, such as futures markets, avoided costs were administratively established and approved by state energy regulators, who typically relied on various forecast models to estimate future fossil fuel prices and electric prices. For example, in the 1980s, it was not uncommon to see predictions that crude oil prices would reach more than $100 per barrel by the year 2000; the actual price turned out to be less than $30 per barrel. Moreover, during the entire decade of the 1990s, crude oil prices were less than $25 per barrel.[4]

QFs were either industrial plants using co-generation technologies or renewable resources, including hydroelectric facilities with less than 80 MW capacity, wind, biomass, and solar power. As a result of overestimated avoided costs, electric utilities and their retail ratepayers were saddled with sometimes copious amounts of high-priced generation, and this led to the derisive description of many co-generation facilities as ''PURPA machines'' (Barclay et al., 1989).[5] Moreover, several states, notably California, established a number of alternative ''Standard-Offer'' contracts for QFs, depending on the type and size of generator (Gipe, 2007). Some of these, especially the Standard Offer Four (SO 4) contract provided for even higher payments without regard for actual energy produced, and thus further distorted the electric markets.[6]

Like avoided cost rates set under PURPA, FITs whose prices are set too high or that last too long will needlessly subsidize RETs and create welfare losses for society. Not only do such subsidies distort electric markets and reward inefficient RET developers and operators; they negatively impact electricity consumers because they are a tax that increases as the overall share of RET increases. Even the highly successful German FIT—successful when measured in terms of renewable capacity developed—has been criticized for its adverse impact on electric rates,[7] and retail customers increasingly protest its implementation.

The challenge, therefore, is to develop a FIT mechanism that achieves the broader policy goals associated with accelerated renewables development at the least possible cost. Such an economically efficient FIT will provide incentives for owners of renewable generation to maximize their energy production, without distorting wholesale energy market prices. Finally, an efficient FIT mechanism should not work at cross purposes with other renewable energy policies, especially tradable green certificates (TGCs) and RPS.

The remainder of this paper is organized as follows: Section 2 compares FIT and other RET support schemes.

[2]A Pareto-superior policy is one that achieves greater benefit at the same cost, or equivalently, the same benefit at lower cost.

[3]We recognize that some may question whether the benefits of government intervention to promote RETs exceed the costs. Although we recognize this as an important policy question, in this paper our aims are more limited. Specifically, since such intervention already occurs, we focus on policy instruments that will achieve government goals at the lowest possible cost.

[4]US Energy Information Administration, Refiner acquisition cost of crude, available at: http://tonto.eia.doe.gov/dnav/pet/hist/r0000____3a.htm, accessed 28 May 2007.

[5]The Energy Policy Act of 2005 (EPAct 2005) made significant changes to PURPA, modifying co-generation rules to prevent ''PURPA machines'' and altering the requirements for electric utilities to purchase the output from QFs.

[6]See Morris (2000, pp. 8–10).

[7]See Butler and Neuhoff (2005, pp. 8–9) and Meyer (2003, pp. 5–6).

Section 3 provides a brief literature review on FIT design and experience in Europe, where FITs are most common, including a discussion of the differences between FITs and other common RET support schemes, including quotas and auctions. Section 4 discusses the key components of an economically efficient FIT. Section 5 describes the forward capacity market (FCM) auction approach that is the basis for our proposed two-part FIT design, which also incorporates incentive mechanisms to maximize RET energy generation. We focus on the auction-determined capacity payment, explaining the economic benefits of this approach compared with other FIT designs. Section 6 offers some policy guidelines and concluding thoughts.

## 2. Comparison of FIT and other RET development approaches

Various RET support schemes share one feature: they create an "artificial" demand for RETs by providing incentives for investment in RET capacity, imposing constraints on energy suppliers, or by constraining final consumption. The basic premise of all renewable energy development policies is that they create demand that otherwise would not exist whatsoever or would not exist at desired levels under current market conditions. However, the various RET support schemes that have been developed differ in the channels through which additional incentives for RET operate. Better understanding the strengths and weaknesses associated with various RET support approaches provides valuable lessons for improving those mechanisms (Menanteau et al., 2003; Reiche and Bechberger, 2004; Sawin, 2004).

The most common component of FIT design is a guarantee of a long-term minimum price for generated electricity. (The same thing existed under the US PURPA of 1978.) The advantage of FITs is that they provide individual RET developers with a degree of financial stability, and thus a hedge against future energy market volatility. This encourages RET capacity installation. However, this advantage of FITs is also an Achilles' heel: a fixed, long-term price—or a price series with a built in technology adjustment factor—will almost certainly deviate from realized market prices by greater amounts over time, thus distorting wholesale and retail energy markets. If the resulting FIT rates are too high, electricity prices will increase, reducing economic well-being. If the resulting FIT rates are too low, RETs will not be developed at the rates desired by policymakers, and the associated policy goals of RET development will not be met.

Another common approach is the use of TGCs.[8] Once a quota of TGCs is specified by policymakers, market mechanisms and competition determine the certificate price (Hogendorn and Kleindorfer, 2008). A benefit of TGCs is that they foster competition—they favor lower cost renewables over higher cost ones, and more efficient producers over less efficient ones. However, there are two major problems with tradable certificates. First, uncertainty about the current and future price of TGCs can increase the financial risks faced by RET developers and reduces their incentives to invest in RETs. At the same time, potential sharp increases in the price of TCGs, at least in the short term (when installed renewable generating capacity is not adequate to meet government-set demand), also increase the risks faced by electric utilities and, eventually, consumers. Second, and more importantly, TGCs affect competition between different RETs at different stages of development. Since a uniform price is paid on a given unit of TGC regardless of the specific RET used for generation, more technologically mature and, hence, lower cost RETs, such as wind, would likely dominate the market. Less technologically mature, but potentially promising RETs, such as PV, may not receive a sufficient share of support to meet policymakers' development goals. The result can be greater inefficiency and higher costs in the long term.

A third approach, best characterized by Britain's non-fossil fuel obligation (NFFO), called for tenders on RETs energy suppliers to fulfill specific quotas for each RET in different time periods. For example, in 1993, the British government set a goal of 1500 MW of "declared net capacity" by the year 2000.[9] Developers competed to provide the contract amounts, and those offering capacity at the lowest price were awarded contracts. Similar to TGCs, the competition in the tender process was designed to distinguish more efficient RET producers from less efficient RET producers, and since a separate quota is specified for each RET, the NFFO bypassed the second problem faced by green certificates, namely, the fairness of competition among various RETs. But the NFFO had several problems of its own. First, less than one-third of the winning bids for wind power were realized, so the actual installed capacity fell far short of the prescribed quotas. Second, the lack of a set schedule for NFFO requirements, such as quotas for consecutive years, increased financial uncertainty and reduced the incentive to invest in RETs. Britain abandoned the NFFO and replaced it with a specific renewables obligation, which is similar to a TGC program. The government specifies the proportion of renewables to be supplied to retail electric customers by distribution utilities (which is a form of renewable portfolio standard). Those utilities can either own generating capacity or buy renewable generation credits. Suppliers can also exercise a "buy-out" option by paying a fixed penalty, which theoretically caps the price of credits.

[8] Tradable renewable certificates are commonly called "green tags." For an excellent discussion on the economics of green tags, see Hogendorn and Kleindorfer (2008).

[9] "Declared net capacity (DNC) is the equivalent capacity of baseload plant that would produce the same average annual energy output as the renewable energy plant. In Britain, wind power DNC was calculated as approximately 40 percent of its installed capacity. Thus, 1500 MW (DNC) of wind would require about 3750 MW of installed wind capacity.

## 3. Efficacy of existing FIT designs

Current FIT policies share several characteristics. First, they provide an above-market energy payment to generators. Thus, there is an incentive for generators to produce as much energy as possible. Second, they are time limited, recognizing that offering payments forever is inefficient. Third, FITs often include technology improvement factors designed to reduce payments over time. Similar to performance-based regulation schemes that use an "RPI-X" approach, FITs allow utilities to raise electric rates annually by no more than the rate of inflation, less a predetermined productivity (*X*) factor, which is set by the regulator.[10] Fourth, FITs are typically differentiated by technology: prices paid to wind power suppliers, for example, are not the same as those paid for solar power or biomass. Fifth, by setting tariff prices rather than tariff quantities, the overall impact of FITs on retail electric rates is subject to increased uncertainty. Too high an FIT will stimulate over-investment, causing too rapid development of above-market RETs and triggering adverse economic impacts owing to higher than expected electric rates, as well as customer backlash.

Other than as applied under the original "avoided cost" guidelines of PURPA, in the USA, FITs have not been used to spur RET development. Instead, US regulators have adopted RPS together with so-called tradable "green-tag" systems. Typically, an RPS establishes a gradually increasing annual minimum supply percentage of renewable generation for electric utilities, including traditional vertically integrated utilities, as well as distribution utilities that have standard offer service (SOS) obligations to serve a subset of retail (typically residential) customers. However, individual state RPS designs differ, often substantially. First, the types of generation that are deemed "renewable" can vary owing to political and economic considerations. In Vermont, for example, natural gas-fired distributed generation is considered renewable. In several other states, waste-to-energy plants (i.e., burning garbage) are considered renewable. In Pennsylvania, generators that burn waste coal are considered renewable—this leverages that state's coal deposits and mining industry. Individual state RPS designs also typically segregate renewables into several categories and require different minimum percentages of each type. However, the categories are not generally defined by individual resource but by specific "classes" of renewables. Connecticut, for example, has three separate renewables classes, each with its own set of target requirements.

In states that have fully deregulated their local electric industry, in which local electric utilities are no longer responsible for securing generation supplies, RPS obligations fall onto retail providers.[11] Those providers must demonstrate that they have secured the mandated percentages of generation by different renewables or that they have purchased equivalent quantities of green tags. Typically, states impose a significant financial penalty, often 4 cents/kWh or higher, on firms that have not obtained sufficient renewable generation. Green tags thus encourage development of economically efficient, least-cost RETs. The largest flaw with a green-tag program, however, is that it discourages development of higher-cost, less mature technologies. Thus, if policymakers wish to provide differentiated incentives to those technologies, they must use other policy instruments. This is where FITs can provide a significant advantage. Owing to their prevalence in European Union, especially in Germany and Denmark, we next review the FIT programs in those two countries.

Germany's FIT was introduced in its Electricity Feed-in Law in 1991. Under this law, utilities are obligated to buy renewable energy at 90 percent of the retail rate of electricity. By creating the market for renewable energy and guaranteeing renewable energy producers a high price to cover their long-term costs for the life of the plant, the German Feed-in Law had a significant, positive impact on the development of renewable electricity generation in Germany. The installed wind capacity was over 6000 MW at the end of year 2000, up from less than 100 MW in 1990.[12]

However, the German Feed-in Law also created some problems. Electric utilities and their customers have opposed it because of the high costs they have had to bear to support the renewable energy producers.[13] In 2000, Germany passed the Renewable Energy Law (EEG), which set specific prices that independent renewable power producers could receive for each type of renewable energy source, but for a limited amount of time. For instance, in 2000, a new wind turbine project would be paid 0.178 DM/kWh (11 cents/kWh) for the first 5 years, and then the rate would begin to fall. The buyback tariff rate for PV systems was € 0.51/kWh and was set to decrease by 5 percent annually.[14] This law also better targets each RET by specifying different buyback rates for different RETs and taking their cost of generation into account.

[10]For a discussion of "RPI-X" regulation, see Lesser and Giacchino (2007, Chapter 4).

[11]Deregulation and "restructuring" are often used interchangeably in the US. However, they are not the same. Many states did not fully deregulate their electric industries, or imposed numerous requirements on local electric utilities, whose generating assets were either sold or spun off into unregulated affiliate companies. For example, in many cases, local electric utilities with only distribution assets also serve as "providers of last resort" or "default service" providers for customers who are either unable or unwilling to select a retail electric provider. In those instances, RPS requirements fall on the local distribution utility, which must purchase renewable energy or tradable certificates or, if allowed, build and operate its own renewable generation.

[12]Global wind energy market report, http://www.awea.org/pubs/documents/globalmarket2003.pdf, accessed 8 May 2007.

[13]See Meyer (2003, pp. 5–6); Support schemes for renewable energy in the Nordic countries, NEP, http://www.nordicenergyperspectives.org/Ten%20perspectives%20kap%209_11.pdf, accessed 29 May 2007, at 206.

[14]Energy Information Administration, Policies to promote non-hydro renewable energy in the United States and selected countries, http://www.eia.doe.gov/cneaf/solar.renewables/page/non_hydro/nonhydrorenewablespaper_final.pdf#page=1, accessed 8 May 2007.

Denmark's FIT began in 1992, when utilities became obligated to purchase renewable energy from private producers at a fixed price of between 70 and 85 percent of the retail price of electricity (a price higher than the price of privately generated fossil fuel-fired electricity). FIT, together with other market support programs, led to a sharp increase in the installed wind capacity in Denmark, from 343 MW in 1991 to 2300 MW by the end of the year 2000 (see footnote 14). In 2000, Denmark abandoned guaranteed pricing and introduced TGCs. The new goal is to create a market for green power via the TGCs. The change in policy seems to have led to a collapse of the Danish wind energy market. Since 2004, almost no new wind capacity has been installed, although there are several ongoing programs to replace older, smaller wind turbines with newer and larger ones.[15] Moreover, 200 MW of offshore turbines are expected to be on-line by 2009.

## 4. Components of an economically efficient FIT structure

It is not surprising that FIT policies, like most policies, have both benefits and costs. While it may be difficult to judge whether the policy goals justify the costs, once such policy goals are established, it is relatively straightforward to compare alternative policy proposals on their economic merits, i.e., to determine which approach will best meet the specified policy goals—economic and non-economic—at the lowest cost. In this section, we discuss the essential components in an economically efficiency FIT structure, regardless of its specific form.

First, since the policy goals of FITs are to encourage both new capacity installation of RETs and renewable electricity generation, an efficient FIT structure should directly target these objectives. More specifically, the FIT level should not be set so low that it provides inadequate incentives for producers to install new capacity and/or generate renewable energy. Nor should a FIT be set too high to "overcompensate" producers, since the "price tag" for FITs and, hence, supporting RETs is eventually borne by retail customers. Additionally, FIT policies should avoid distorting wholesale electric markets. Too high a price tag is not only economically wasteful, but can also raise political opposition to a well-intended policy. Therefore, striking an appropriate balance for RET development rates and costs is a challenging task faced by all policymakers.

As was discovered with California's SO4 contracts, RET capacity will be of little value without corresponding electricity production. Thus, linking FIT payments to the amount of energy produced is appropriate and necessary. Although FITs linked to generation alone can provide financial support necessary to enhance RET development, the volatility of energy markets virtually assures that preset tariff structures will deviate by larger amounts from contemporaneous market prices as the tariff progresses over time.

Third, FITs encompass both short-term and long-term policy goals. In the short term, FITs are designed to encourage penetration of currently available RETs, even though they are not mature enough to be directly competitive against "traditional" generation technologies. Over the long term, FITs are designed to promote the technological advancement of RETs so that they can compete directly without the need for subsidies or prescribed quotas.

The difficulty confronting policymakers is that these short-term and long-term goals are unlikely to be perfectly aligned, since technological progress is endogenous. In other words, policies enacted today affect current and future R&D behavior, which in turn affects innovation rates and technological progress. Most importantly, these effects may be counterintuitive: increasing FIT rates may, in fact, *reduce* the rate of technological progress. Because the relative expected returns to RET investment favor technologies that are more promising in the long term rather than in the short term, too great a FIT may encourage more rapid growth of near-term RETs, thus diverting investment resources away from medium-term RETs. Too great a FIT may also encourage investment in RETs that are *too* speculative and far removed from practical application. If so, the probability of technological setbacks will increase, leading to increased perceived financial risk of investment in such technologies and reducing incentives for further investment. Thus, in setting traditional FIT values, policymakers must determine tariff levels that will maximize the rate of technological improvement for each technology covered.

In the face of uncertainty over market prices and technological progress, it is not clear how policymakers can meet these three objectives by using administratively determined FITs. Not only do policymakers need accurate information about current and near-future markets, they must also be able to accurately predict long-term market and technological trends. Thus, policymakers need accurate information about future market prices for electricity, as well as future capital and operating costs for both renewable and fossil generation resources. However, the prices and volatility of fossil fuel markets (which have proved difficult to forecast accurately over the long term) and the costs of new fossil generation will be driven by uncertainty over both future worldwide demand for electricity and future environmental regulations, such as carbon taxes and greenhouse gas emissions caps.

An efficient FIT will also attempt to minimize reliance on administrative information. Economic theory dictates, and policy experience has shown, that when asked directly, individuals may choose not to reveal their information truthfully.[16] All other things equal, RET developers will

[15] *Source*: World Wind Energy Association and Danish Wind Energy Association.

[16] One example is the US $SO_2$ market. The actual trading price of a ton of $SO_2$ emission permit was significantly lower than the estimated abatement cost reported by the industry, suggesting that the industry over-reported the abatement cost.

prefer higher administratively set FITs and lower technology advancement parameters, just as an electric utility operating under a performance-based regulation regime will want a higher inflation index and lower productivity factor. How to efficiently elicit truthful information from the industry without undue administrative burden is yet another important policy design challenge, because the right information set is fundamental to the effectiveness of a FIT structure.

## 5. Design of a two-part FIT

Rather than an administratively determined FIT price structure, we propose instead a two-part FIT that (1) uses proven market mechanisms to elicit truthful information, (2) ensures installation efficiency and generation efficiency both in the short term and in the long term, (3) guarantees timely achievement of policy goals, and (4) is easy to implement and monitor. The proposed two-part tariff consists of a capacity payment that is determined through an auction process, and an energy payment that is tied to the spot market price of electricity. Just as with other renewable generation policies, under our approach, policymakers must first specify the individual types and quantities of renewable generation they wish to encourage.[17] Clearly, such determinations should not to be taken lightly, as they require critical judgment regarding existing technology costs relative to wholesale market prices, environmental factors, and so forth. For example, providing subsidies to technologies that are already competitive or expected to be competitive within the next several years is inefficient. Nor is it efficient to subsidize technologies that will face significant environmental hurdles, regardless of prices offered to developers. At least, however, market mechanisms establish the prices to be paid, as opposed to policymakers having to further specify the actual price paths for individual technologies.

The design of our proposed two-part FIT is based on the design of FCM auction. As Crampton and Stoft (2006) discuss, the benefits of a FCM include coordination of new capacity entry, lower risk premiums, and stable prices. The approach consists of an annual capacity auction for the specific RETs for which policymakers wish to accelerate development. The auction is held several years in advance to allow winning bidders time to build their renewable capacity. The winning auction price is guaranteed for a predetermined number of years. The FCM also includes a ''pay-for-performance'' incentive. In the case of actual FCMs, this incentive is based on generators' availability when spot market energy prices are above a set amount (based on the estimated variable operating cost of a peaking generator).

### 5.1. Administrative inputs

The two-part FIT requires the following four administrative actions:

1. Identify the RETs that will be eligible to receive FIT subsidies.
2. Determine the desired capacity goals for each RET.
3. Determine the overall time horizon over which the FITs will be in place.
4. Set the payment period for the winning auction prices.

Clearly, these administrative actions have the potential to distort markets. To the extent policymakers determine that specific RETs require subsidies, these four inputs are critical. For example, if policymakers set unrealistic RET development goals, then costs are likely to increase rapidly.

Establishing which RETs will qualify for FIT subsidies will depend on policymakers' attitudes toward risk in pursuing technological progress. As a general guideline, it makes sense to focus on medium-term RETs. RETs that are currently market competitive clearly do not require any subsidies, but RETs whose costs are only slightly higher than market prices may derive additional benefits from a FIT. Moreover, ''near-market'' renewable technologies will require smaller subsidies, and thus cause less upward pressure on overall customer costs and electric rates. Technologies that are theoretically promising, but unlikely to be competitive for many years, may best be addressed under other policies, such as publicly funded/sponsored R&D, etc. Under our two-part tariff design, the prices paid to such technologies will be more likely to have adverse impacts on retail electric rates.

The second input, the time horizon of FIT, can either be a calendar date or depend on some ''trigger condition'' such as RETs providing a threshold percentage of total power generation. The third input, the duration of the auction payments for each RET vintage, balances the trade-off between providing necessary financial stability to encourage RET investment and not oversubsidizing RETs, especially when they become technologically obsolete and economically inefficient. Finally, the fourth input gives policymakers both control and flexibility in achieving the overall policy goals: they can adjust the annual *incremental* RET capacity according to market conditions, expected and unexpected technology breakthroughs, political developments, and so forth. Table 1 provides an example of possible criteria.

The data from Table 1 show that policymakers wish to develop 200 MW of geothermal capacity (''Geothermal 1'') in the first year of the program, between 2011 and 2015, and is assumed to begin in 2011. The annual geothermal capacity auction is held 3 years in advance. Thus, the

[17]Again, in this paper, we do not address whether policies to promote renewables are themselves efficient, since so many governments have already implemented such policies. Although policymakers would benefit from comprehensive cost–benefit analyses to help determine specific renewable energy goals, we are not aware of any such studies that have been performed by state energy regulators in the US. Such studies would be useful for broader questions, such as evaluating alternative energy portfolios in a mean-variance framework. See Awerbuch et al. (2007).

Table 1
Example fit parameters

| Technology | Auction year | First-year capacity goal (MW) | Payment duration (years) | FIT payment start year | FIT payment end year |
|---|---|---|---|---|---|
| *Geoth. FIT* | | | | | |
| Geothermal 1 | 2008 | 200 | 8 | 2011 | 2018 |
| Geothermal 2 | 2009 | 250 | 8 | 2012 | 2019 |
| Geothermal 3 | 2010 | 300 | 8 | 2013 | 2020 |
| Geothermal 4 | 2011 | 350 | 8 | 2014 | 2021 |
| Geothermal 5 | 2012 | 400 | 8 | 2015 | 2022 |
| *Solar FIT* | | | | | |
| Solar PV 1 | 2008 | 50 | 15 | 2010 | 2024 |
| Solar PV 2 | 2009 | 60 | 15 | 2011 | 2025 |
| Solar PV 3 | 2010 | 75 | 15 | 2012 | 2026 |
| – | – | – | 15 | – | – |
| Solar PV 10 | 2017 | 150 | 15 | 2019 | 2033 |

auction held in the year 2008 will secure geothermal capacity to be on-line in the year 2011, and so forth. Moreover, as Table 1 shows, the amount of geothermal capacity subject to bid is expected to increase by 50 MW each year, up to 400 MW in the fifth and final year of the auction. The winning bidders in each auction are assumed to receive capacity payments for an 8-year period.

For solar PV, the example assumes that policymakers have set a first year auction goal of 50 MW (“Solar PV 1”). However, the first year for payments will begin in 2010, on the assumption that developing new solar capacity requires less lead time than developing geothermal resources. Winning bidders in the solar PV auction will receive payments for 15 years and there will be 10 such auctions, with the final auction taking place in the year 2020.

One of the benefits of this approach is that the parameters can be adjusted over time, depending on market conditions. For example, if the first year's geothermal auction results in clearing prices that are higher than expected, policymakers could reduce subsequent auction capacities, extend the payment duration, and so forth, depending on market conditions. Or, if capacity prices are lower than expected, policymakers could reduce the number of auctions held.

To put the FIT into context, in California, the RPS establishes general guidelines for administrative inputs (specifically, the desirable level of alternative RETs and the time horizon for achieving policy goals), and the FIT is one of several policy instruments, such as the market price reference (MPR) and supplemental energy payments (SEP), that can be used to achieve policy goals. The advantage of the proposed two-part FIT over MPR/SEP is that it takes much of the “guesswork” out of the policy design and, by using markets, achieves greater economic efficiency in both capacity installation and energy generation of RETs.

### 5.2. Capacity payment

Once the specific inputs from policymakers are in place, i.e., the types and quantities of renewable generation desired, the rest of the two-part FIT is operated by market mechanisms. Starting with the annual target of incremental capacity for a qualified RET, the capacity payment for this vintage is determined through an auction process.[18] The auction for RET capacity is similar to the FCM approach, which has been recently introduced by several transmission system operators in the United States to ensure adequate supplies of electric-generating capacity to meet reliability standards.[19] The FCM establishes annual auctions for capacity through descending clock auctions, and the amount of capacity procured is the amount required to maintain the installed capacity requirement. Capacity payments also depend on a generator's availability during designated periods where generating reserves are lowest. Moreover, FCM auctions are designed to curb incentives to manipulate the market and distort capacity prices.

For example, the regional transmission organization known as PJM, which serves the US Middle Atlantic States, uses a FCM auction, which it refers to as the “Reliability Pricing Model” (RPM).[20] To determine the quantity of capacity to be auctioned off, PJM forecasts future peak electric demand and available generating capacity (based on known generation additions and retirements). This value forms the base called the “Forward Pool Requirement.”

A descending clock auction is used to obtain the required amount of new capacity.[21] The duration of the fixed auction price for new generating capacity is 4 years. For a FIT auction, of course, the auction price would likely be guaranteed for a longer period of time, although there is no uniquely “right” duration.

Under the proposed two-part FIT capacity payment auction, potential RET developers would submit their bids for capacity payments that would be sufficient to induce them to participate in the administratively established capacity investment. The design and format of the capacity auction could be based on a number of design formats. For example, the FCM developed by Independent System Operator-New England (ISO-NE, 2006) uses a descending clock auction structure. The auction begins with ISO-NE announcing a set price. Suppliers then announce the quantity of capacity they are willing to offer at that price. If there is more supply than is needed, ISO-NE decreases

[18] Auctions have been widely used in the public domain, including electromagnetic spectrum (bandwidth and frequency), mining, and logging rights on publicly owned lands, highway construction contracts, US Treasury bill issuances, and so forth.

[19] See, *Devon Power LLC*, Order Accepting Proposed Settlement Agreement, 115 FERC 61,340 (2008), par. 15ff. In PJM, the FCM is called the “Reliability Pricing Model.”

[20] A comprehensive set of documents describing the design and mechanics of the RPM can be found at the PJM website: http://www.pjm.com/markets/rpm/rpm.html.

[21] A discussion of the salient features of auction design, along with potential pitfalls, is beyond the scope of this paper. See, e.g., Salant (2000) and Hobbs et al. (2000). Crampton and Stoft (2006) discuss the specific design of the FCM auction. Revelation Auction in the Context of Energy Markets with Nonconcave Benefits, vol. 18, no. 1, July 2000, pp. 5–32.

the announced price. As it does, some suppliers will choose not to offer some of their capacity. This price-lowering process continues until the remaining capacity offered exactly equals the quantity of capacity requested. The resulting price is then the clearing price, which all selected suppliers are paid.

Once the market price has been established through the desired auction mechanism, the price is guaranteed for a pre-specified number of years. As with the FCM, winning RET bidders are then given several years to construct the generating capacity they have agreed to supply. Developers who fail to bring their capacity on-line as promised are required to pay a pre-established penalty.[22] Like the incentives embedded in the FCM design to reward capacity owners for availability during hours when market prices are highest, our proposed two-part FIT also includes a market incentive for RET developers. Specifically, the RET developer receives a performance-based capacity payment given by the following formula:

$$P_{V,N,T} = P_V \times \frac{CF_{V,N,T}}{CF_{V,T}},$$

where $P_V$ is the uniform cutoff level established through the auction process for the current RET vintage $V$; $CF_{V,N,T}$ is the capacity factor[23] for a specific firm $N$ of vintage $V$ in year $T$; and $CF_{V,T}$ is the average capacity factor for all the firms of vintage $V$ in year $T$.

Thus, the better the performance an individual developer has compared with its peers for the same type and vintage RET, the higher the capacity payment it will receive.

There are several economic advantages of an auction-determined capacity payment. First and foremost, a market-based auction is an effective way to elicit truthful information from potential RETs developers. Active bidders compete with each other to "win" the FIT, and in certain forms of auction such as the second-price sealed bid auction, it has been shown that the dominant strategy for each bidder is to bid truthfully, namely, bidders have no incentive to either underbid or overbid based on their own best estimates of current and future market conditions. Truthful bidding allows the policymakers to (1) distinguish more efficient versions from less efficient versions of the given RET, (2) distinguish more efficient RET developers from less efficient RET developers, and (3) ensure that FIT subsidizes RET producers at both the technology frontier and the operation frontier.

Second, since the overall capacity payment is linked to how an individual generating facility's capacity factor compares to the average capacity factor for other facilities of equivalent technology and vintage, it ensures efficient siting, which we refer to as *installation efficiency* (e.g., windy locales for wind turbines and sunny ones for solar PV). It also encourages winning bidders to maximize their actual energy production, which we call *operating efficiency*. This approach avoids the "PURPA machine" issue.

Third, for a given vintage of RET, the capacity payment is fixed for a sufficient period to provide financial stability for developers and reduce financial risk. Like traditional FIT energy payment approaches, this can reduce financing costs. However, unlike traditional FIT energy payment approaches, capacity payments for each new vintage will automatically adjust to the technological progress rate, because bidders in the auction take the current technological status into account and compete with one another to win the FIT subsidy. This avoids the difficult problem of policymakers having to determine administratively a fixed technological progress rate and an associated declining payment structure.

Finally, even though different RET developers are likely to have different actual costs, they will all receive the same capacity payments on average. As a result, the more cost-efficient developers will enjoy greater profits, and this provides the economic incentive for RET developers to invest in R&D. In the long run, developers with the greatest technological advantage and lowest installation costs will benefit, expand their market share, and gradually weed out less cost-efficient RET developers. In this way, the capacity payment aligns short-term and long-term policy goals: RET developers optimally decide how much to invest in which RETs, and this solves the endogeneity problem associated with rates of technological progress present in administratively determined FIT payment streams.

In California, to fulfill the RPS requirement, some investor-owned utilities have adopted a competitive solicitation practice to solicit renewable energy from potential suppliers. This practice enables utilities to distinguish more efficient from less efficient RET developers, and, in providing this advantage, it is very similar in nature to the proposed auction-based capacity payment. The major differences between competitive solicitation and the auction-based capacity payment are that competitive solicitation operates at the individual utility level without a uniform public policy guideline and that it is not as transparent or easily comparable across different utilities. If a uniformly designed auction procedure is used to determine the capacity payment for RETs, potential RET developers are not restricted by utility-by-utility solicitation procedures, and they can respond more efficiently across different utilities.

[22]Because contract failure (i.e., the inability of winning bidders to bring proposed capacity on-line on time) is a major factor under the UK's RO scheme, a more stringent compliance mechanism is needed to guarantee the success of the two-part FIT. Heavy penalties can deter potential contract failure, but more importantly, streamlining the siting/permiting process and putting strict deadlines on bureaucratic procedures can speed up the capacity installation process.

[23]"Capacity factor" measures the percentage of time a generating resource is on-line and generating electricity. For example, nuclear power plants typically run all the time, shutting down only to refuel. As such, those plants have capacity factors near 100 percent. Solar PV, on the other hand, operates only during daylight hours. Thus, its capacity factor is much lower.

### 5.3. Energy payment

The second part of the proposed two-part FIT is an energy payment tied directly to the market price for electricity. Energy payments are the most critical component of the FIT design. As renewable technologies mature, the proportion of revenue earned through sales into wholesale energy markets should increase, and the proportion of revenues earned through supplemental capacity payments should decrease, with an overall goal of fully competitive renewable technologies.

Rather than an administratively determined FIT energy price, under our approach renewables developers themselves decide how they prefer to sell the renewable electricity their facilities generate. Thus, renewable developers should be free to sell their output directly in wholesale spot markets, under bilateral contracts to wholesale and retail suppliers, such as those offering "green power," and so forth. Moreover, our approach can be used in conjunction with mandated RPS designs or green-tag systems. The concept is straightforward: more renewable generation means higher energy payments, which translate into higher capacity factors and ensure generation efficiency. However, because the energy sold by RET developers is priced at the market, it does not distort the overall wholesale energy market. Instead, it contributes to the competitiveness of wholesale energy markets by adding new supplies and new suppliers. And, just as with the FCM design, RET developers can receive higher energy payments if they generate proportionately more energy when market prices are high.

The energy payment also has a positive impact on generation efficiency, even for renewable energy that is not dispatchable, such as wind. Of course, non-dispatchability per se implies that wind developers cannot choose to produce more wind power when the spot market price is high, i.e., during the peak periods, but it does allow wind producers to increase the overall capacity factor through better management and maintenance. Because all wind producers deal with the same non-dispatchable resources, the capacity factor in either the energy payment or the capacity payment does not distort the relative efficiency among the same cohort of RET developers; it only acts as extra incentive for them to compete with each other, because the technological constraint is a given.

## 6. Summary and conclusions

Under our proposed two-part FIT, since RET developers receive market-based energy payments, the capacity payments function as the subsidy for RETs. Given that energy prices will vary over time, it is the sum of the capacity and energy payments that investors will focus upon when determining the expected rate of return on their investment. Thus, the proposed two-part FIT is not risk free; there will be market risk when spot market price fluctuates. However, unlike existing FITs with administratively determined energy payments, the two-part FIT allows developers themselves to allocate their necessary risk premium through the capacity market auction. The more concerned an individual RET developer is about market-price volatility, the higher the capacity market price he will bid for a given quantity of capacity. Since RET developers presumably are more knowledgeable about their proposed developments than policymakers, this market-based risk allocation mechanism will be more efficient than an administrative mechanism.

Of course, none of the existing FIT designs provide a guarantee of complete revenue certainty, nor should they. A guarantee of total revenue certainty eliminates the incentive to improve efficiency, which was one of the reasons that many PURPA-based generating resources were inefficient and costly. Moreover, even if a FIT is a fixed dollar number, there is still unavoidable market risk, such as inflation and interest rate risk. The proposed two-part FIT does not expose RET developers to market risk that is any greater than other (existing) FITs. However, it achieves greater economic efficiency through its unique approach of using the market to determine required subsidies and its allocation of that market risk based on developers' own requirements and risk attitudes.

Given the technological progress in RETs and the increasingly stringent market conditions for traditional FFTs (such as increasing and volatile fuel costs, stricter emissions requirements, and so forth), RET developers will bid more aggressively in the auction process for the capacity payment on their proposed RET capacity. This will tend to reduce capacity payments for subsequent RET vintages. Thus, even if policymakers start out with "wrong" expectations of how RET markets will evolve over time, the annual auction process automatically accounts for new market information and guarantees that annual RET targets are met at the lowest possible cost. When RETs can directly compete against traditional FFTs, the auction process ensures that the capacity payment will be driven down to zero, and policymakers need not worry about overcompensating RETs for too long. In summary, the proposed two-part FIT uses all available information, leads to economically efficient outcomes, is easy to implement, and imposes far less an administrative burden.

Many policymakers believe that government support schemes are needed to encourage the penetration of RETs. The question we have sought to answer is: given a set of administratively determined renewable capacity targets, what is an economically efficient policy design to meet those targets? Our proposed two-part FIT design avoids the need to develop long-term forecasts of market prices, thus eliminating the "avoided cost" errors that plagued PURPA. Moreover, it relies on proven auction market mechanisms to establish fixed capacity prices and encourage actual energy generation, without distorting wholesale energy market prices.

The two-part FIT introduces competition into the innate subsidy nature of a FIT. Thus, it provides the right level of long-term financial stability without overcompensating or undercompensating developers. Although many European countries have been successful using FITs to develop renewable generation, we believe those designs are inefficient, in that they needlessly pay too much for renewables, raise overall electric costs, and reduce economic competitiveness. The danger is that, if FITs are set too high, there is likely to be a political backlash that could abruptly halt the entire FIT approach. The proposed two-part FIT offers a solution to observed FIT problems, while avoiding the need for policymakers to set prices administratively and technology parameters that are likely to diverge substantially from the most well-intentioned estimates.

## Acknowledgments

We gratefully acknowledge the helpful comments of an anonymous referee. Research support for this work was provided by the California Energy Commission. However, none of the views expressed in this paper necessarily reflect those of the California Energy Commission, its employees, or the State of California.

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