THE FEASIBILITY OF A SOLAR FEED-IN TARIFF PROGRAM FOR THE STATE OF OREGON: A CASE STUDY OF EUGENE WATER & ELECTRIC BOARD

By

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Abstract

Background: The Solar Photovoltaic (PV) industry has been developing rapidly worldwide, generating clean energy and offsetting carbon emissions. In 2007, Eugene Water & Electric Board (EWEB) launched its current solar programs: direct generation and residential net-metering. Since then, the number of local solar installations has increased every year.

Aim: The aim of this study is to determine the levelized cost of electricity (LCOE) generation to residential solar electric systems owners between 2007 and 2011. This paper also investigates the appropriate level of FIT rates for a feed-in tariff (FIT) program based on the conditions of different years.

Method: A quantitative analysis of levelized cost for 121 residential net-metered programs and calculation of FIT rates for a FIT program has been employed. Interviews with professionals were used to supplement quantitative research.

Results: In general, levelized cost for solar electricity generation decreased significantly on a year-to-year basis. FIT rates for a FIT also showed similar decrease. In 2011, FIT rate for a 25-year FIT program with 5% return on investment (ROI) was 16 cents/kWh after taking into consideration federal and state tax credits. FIT rate is likely to reach retail rate grid parity with retail electricity price sometime between 2020 and 2027.

Conclusion: The findings support the notion that it is feasible to design a feed-in tariff program with periodic adjustment in FIT rate based on levelized cost in Eugene. Recommendations have been made to further promote distributed solar PV deployment.

Key words: Solar Photovoltaic, levelized cost, feed-in tariff, retail rate grid parity

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Chapter I: Introduction

"*Historia magistra vitae*." Cicero

Background and Literature Review

A quick review of human history and the development of its civilizations reveal that major changes in our society have been closely tied to changes in human energy use (Armaroli and Balzani 2011). Starting from the discovery and use of fire, domestication of animals, and advancement in agriculture, up through generation of electricity and invention of batteries, to the creation of today's complex energy storage and distribution systems, mankind has displayed a prodigious capacity for consuming energy. The history of human civilizations shows that progress in science and technology, art, architecture, and other arts occurs when there is enough energy, and declines when energy resources are in short supply (Odum 1971). Armaroli and Balzani (2011) warn us that "the lesson that too large resource absorption can lead to collapse of a society is clear from history and should be taken into serious consideration by society" (p. 26). Yet, the current global energy consumption rate in both developed and developing countries is very likely to put mankind's long term prosperity and well-being in jeopardy.

It is well known that fossil fuel will one day be depleted. According to research conducted by Shafiee and Topal (2011), global reserves of oil, gas, and coal will be exhausted in approximately 35, 37, and 107 years respectively. This means that coal might be the only remaining fossil fuel after 2050, though the time until fossil fuel depletion could vary with the overall economic growth rate and the pace of renewable energy deployment. The fact is that, even before the world faces fossil fuels depletion, the mounting price of oil, gas, and coal will render these types of fuels impractical as energy sources. The unpleasant fact is that today, fossil fuel still dominates the world's energy market, and is worth around 1.5 trillion dollars annually (Goldemberg 2006). In 2011, the United States consumed over a billion tons of coal, of which 92.6% was used to generate 42.5% of total U.S. electricity need (Energy Information Administration 2012).

The burning of fossil fuel to support our economy and maintain our current level of consumption contributed to the release of 30.2 billion metric tons of world energy-related carbon dioxide (CO2) emissions in 2008 (EIA 2011). Based on the current fossil fuel consumption rate, annual world energy-related CO2 emissions could increase to 35.2 billion metric tons (16.6% increase from year 2008) in 2020, and to 43.2 billion metric tons (43% increase from year 2008) in 2035 (EIA 2011). CO2 concentration in the atmosphere has constantly increased over the last century. The CO2 concentration level in 2005 (379 parts per million in volume, or ppmv) was about 35% higher than that in the 1850s (IEA 2011). The continuing accumulation of CO2 in the atmosphere could eventually lead to anthropogenic warming and a rise in the sea level that may become irreversible (IEA 2011). The negative effects of burning fossil fuels have been well documented and are alarming (Shea 2007; Kirkinen et al. 2008; MacCracken 2008; Patz et al. 2008; Muller et al. 2011). Most notable is a 2011 Berkeley Earth Surface Temperature study, which confirmed that global warming is scientifically observable (Muller et al. 2011). The study found convincing evidence that the average world land temperature has risen approximately 1 degree Celsius since the mid-1950s (Muller et al. 2011).

The control and use of fire differentiated human beings from their ancestors and symbolized the start of human civilization (Goudsblom 1992). However, despite the benefits humanity has reaped from the discovery of combustion, the excessive burning of fossil fuels that has been occurring since the Industrial Revolution has resulted in negative social, economic, and environmental consequences. Renewable energy, such as solar and wind, offers us desirable (if problematic) alternatives. Though renewable energy technologies face challenges related to energy storage, intermittency, and grid connection (Deutch 2011), they could alleviate pressing problems, such as energy shortages, unchecked global warming, and air and water deterioration. Fthenakis et al. (2009) conducted a feasibility study of solar energy for the U.S. and found that "it is clearly feasible to replace the present fossil fuel energy infrastructure in the U.S. with solar power and other renewables, and reduce CO2 emissions to a level commensurate with the most aggressive climate change goals". After comparing different energy systems, such as nuclear, fossil fuels, biofuels, wind, solar, and water, Jacobson (2009) concluded that, in the long term, renewable energy forms (wind, water, and solar) are much better options for fulfilling our societal energy needs in terms of energy sustainability and reduced environmental and health risks when compared to nuclear power, fossil fuels, and bio-fuels.

Though it is theoretically feasible to replace fossil fuel energy generation with renewable energy technologies (RETs, Fthenakis et al. 2009; Sovacool and Watts 2009), high cost and technical challenges related to energy storage, intermittency, and grid connection still remain the primary barriers to faster deployment of renewable energies. Though constrained by higher upfront installation costs, solar photovoltaic (PV) technology is the fastest growing renewable energy technology (RETs) in the world (Kirkegaard et al. 2010; IEA 2011). Solar

PV more effectively provides us with clean and sustainable energy with fewer negative environmental effects when compared to fossil fuel, biofuel, wind, and water (Sims et al. 2003).[1] From 2000 to 2010, world installation of solar PV increased 62-fold, from a mere 0.26 GW to 16.1 GW (Mints 2011); this is a 40% annual growth rate. However, solar capacity still only represents a tiny percentage of global electricity generation capacity. In recognition of the importance of preparing for a future powered by clean and renewable forms of energy, various European governments have developed incentives and renewable energy portfolio standards (RPS). One of these incentive programs is the solar feed-in tariff (FIT) program.

The feed-in tariff program, according to Cory et al. (2009), is an agreement requiring utilities to buy back electricity generated using customer-owned generators at a guaranteed rate and for a certain set period of time. The FIT program was first introduced with the "Stromeinspeisungsgesetz" (*StrEG*) in 1991, which played a major role in promoting renewable energy in Germany (Runci 2005). The *StrEG* required public utilities to purchase electricity generated from renewable resources and to cover investor's costs in generating electricity. In 2000, Germany introduced Erneuerbare Energien Gesetz (*EEG*), the Renewable Energy Sources Act (Gipe 2010). The *EEG* is different from *StrEG* in that it guarantees grid connection and has changed the FIT calculation to guaranteed rates that are separate from average electricity rate (Mabee et al. 2011). Germany's feed-in tariff programs, enabled by *EEG* and offering predictable and attractive rates, proved to be a huge success.

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[1] The production and disposal of solar panels could contribute to greenhouse gas emissions. Future increase in solar cells production efficiency and recycling of solar panels could potentially lower the environmental impacts brought by the usage of solar panels.

Though FIT programs have experienced significant growth and great success in Germany, solar PV deployment in the U.S. still faces tremendous political and economic barriers. Trial FIT programs have been started in several states, such as California, Florida, Oregon, Vermont, Washington, and Wisconsin (Couture and Cory 2009). As of 2009, Gainesville Regional Utilities (GRU) district was the only public utility district (PUD) in the United States that had a FIT program based on the cost of renewable energy (RE) generation (Couture and Cory 2009). There is no overarching federal policy that requires certain amounts of renewable energy deployment. Legislation that has aimed to pass permanent tax credit for renewable energy has failed in Congress, and renewal of federal investment tax credit and other incentives has faced significant opposition.

One of the major arguments against solar PV generation is that it is costly compared to existing grid electricity prices. [2] There is a growing body of research on the cost-effectiveness of solar PV that addresses this concern (Kannan et al. 2006; Jogleka and Graber-Lopez 2008; Song et al. 2008; Bhandari and Stadler 2009; Breyer et al. 2009; Denholm et al. 2009; Klein 2010; Yang 2010; Branker et al. 2011; James et al. 2011; Woodhouse et al. 2011). It is believed that for solar PV technology to be cost effective, the solar PV generated electricity price needs to reach parity with existing grid electricity price. According to Branker et al. (2011), grid parity[3] refers to the situation in which the average full-cycle solar PV electricity generation price is equivalent to the average grid electricity price (from conventional sources)

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[2] I have conducted interviews with utility commissioners, City of Eugene officials, law professors, and professionals. Almost all of them cited the high cost of solar PV as a major barrier to distributed rooftop generation.

[3] I will use the term retail rate parity to specify the parity between retail electricity rate and tariff for a feed-in-tariff program. Because grid parity could also describe a situation in which the whole sale electricity price is equivalent with tariff, in this project, I will use retail rate grid parity to refer to grid parity to avoid confusion.

in a certain region during a certain period of time. To better describe the feasibility of solar PV generation projects, the levelized cost of electricity (LCOE) generation is often employed by utilities and policy makers to evaluate grid parity (Bhandari and Stadler 209; International Energy Agency 2010; Branker et al. 2011; Deutch 2011). LCOE for solar PV generation captures the average full-cycle solar PV electricity generation price. It is defined as the total cost of solar PV generation over its lifetime against the total electricity generated during that lifetime (cents/kWh).

Research Questions

In this study, I will employ the LCOE methodology proposed by Branker et al. (2011) and Woodhouse et al. (2011) to assess current residential solar programs at Eugene Water & Electric Board (EWEB) in terms of their ability to achieve retail rate grid parity. I will do so by calculating the levelized cost of solar electricity generation for residential solar PV projects installed between 2007 and 2011. I will also calculate the appropriate level of FIT rate for a feed-in tariff (FIT) program based on the conditions of different years. Furthermore, I will calculate the years it may take for the FIT rate to reach retail rate grid parity with retail electricity price. Finally, I will make recommendations to promote solar energy deployment locally.

The study will be based on three primary research questions:

- What are the respective levelized costs of electricity generation for residential solar PV projects in Eugene in 2007, 2008, 2009, 2010, and 2011?

- What are the appropriate levels of FIT rates for a feed-in tariff program with a 5% return on investment over a 25-year contract period based on the conditions of different years?
- How many years does it take for FIT rate to reach retail rate grid parity with retail electricity price?

Overview of the Solar Program in Eugene, Oregon

In 1999, the State of Oregon passed net metering legislation that mandated that utilities allow distributed, customer-owned generation systems to connect to the grid (IERP Advisory Team 2011). From 2000 to 2005, EWEB had a small Solar Pilot Program in place for research and demonstration purposes. During those five years, a total capacity of 240 kW of new PV was installed in Eugene (IERP Advisory Team 2011). EWEB adopted a net metering policy that allowed customers to sell excess energy back to the EWEB grid. According to the EWEB's Integrated Electric Resource Plan (IERP) Advisory Team Background on EWEB Solar Programs, the net metered program continues to "credit customers at the highest price tier in EWEB's residential rates for generation consumed onsite" (IERP Advisory Team 2011).

The current solar programs offered by EWEB were launched in January of 2007, with a production incentive of 15 cents/kWh. The rate was calculated using a value-based approach that includes value of energy based on avoided costs, renewable energy certificate (REC), carbon, and BPA renewable rate credit (Erben 2011; IERP Advisory Team 2011; Couture and Cory 2009). However, the fixed rate was dropped to 12 cents/kWh in 2008, and to 11 cents/kWh in 2010 (Erben 2011). From 2007 to 2011, this pilot program resulted in annual installation of 450 kW (Erben 2011). The most current EWEB solar programs include net metering and direct generation (see Appendix B for more details). Direct generation is reserved for solar electric systems larger than 10 kW. The generated electricity is fed entirely to EWEB's grid and EWEB pays generators a set rate per kWh (see Table 1 for the direct generation prices in different years).

As mentioned before, EWEB also offers a net metering program. The net metering program allows a generator to feed excess power generated onsite back to the grid and receive a bill credit. EWEB offers upfront cash grants to generators for participating in the program. As of 2012, the EWEB cash grant is offered on a "first come first served basis". The incentive is worth $1.7/Watt AC up to $6,000.

Table 1.1 EWEB Solar Programs Installation and Price (2007 - 2011)

Program Year	Direct Generation(DG) kW Installed	Net Metered kW Installed	DG Price (value)
2007	1088	48	15 cents/kWh
2008	533	34	12 cents/kWh
2009	224	63	12 cents/kWh
2010	366	73	11 cents/kWh
2011 Projection	175	350	11 cents/kWh

Source: Erin Erben's presentation on solar discussion at EWEB

Methodology

Data

The data will be collected from the following sources:

- Solar projects data in Eugene from EWEB, Solarize Eugene, and The Resource Innovation Group
- Email exchange with EWEB, the City of Eugene, and Solarize Eugene
- City of Eugene solar survey report: Solar Technology Survey conducted for EWEB and the City of Eugene in 2011
- Interview with EWEB staff and commissioners, solar industry professionals, City of Eugene officials, University of Oregon professors, solar groups and organization representatives.

Measures

The independent variables[4] for this project are factors that contributed to the price of solar electricity generation projects in Eugene. They are:

- T : Life of the project (years)
- t : Year t
- CF : Capacity factor.
- E_t : Energy produced for t ($)
- $O\&M_t$: Maintenance and operating costs for t ($)
- r : Annual increase in utility prices over a 25-year period
- i : Annual loan interest for a 5-year home equity loan
- DR : Discount rate.
- d : Degradation rate (%)
- I_t : Initial cost of PV systems for t ($)

The dependent variables in this study will be the levelized cost of electricity generation from solar PV projects. The value of RECs has been factored into the power

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[4] I have referred to methodology used by Branker et al. (2011) and Woodhouse et al. (2011) in selecting variables. See Chapter II for a complete list of variables.

purchase rate for direct generation programs. For residential net metered projects, system owners keep the RECs. The definition and formula for LCOE is given by the following:

$$LCOE(\$/kWh)=\frac{TotalLifeCycleCost(\$)}{TotalLifetimeEnergyProduction(kWh)} \tag{1-1}$$

$$LCOE_t=\frac{InitialCost_t+CapitalCost+\left(\sum_{t=1}^{T}\frac{AnnualO\,\&\,MCosts}{(1+DiscountRate)^t}\right)-Incentives-ElectricityValue}{\sum_{t=1}^{T}(kW_p\times 8760\times CapacityFactor)\times(1-SystemDegradationRate)^{t-1}} \tag{1-2}$$

To calculate the generated solar electricity value by a solar PV system over T-year period:

$$ElectricityValue=\sum_{t=1}^{T}\frac{[A\times(1+r)^{t-1}\times kW_p\times 8760\times CF]}{(1+DiscountRate)^{t-1}} \tag{1-3}$$

Where A is electricity rate at year one ($t=1$), r is annual electricity rate increase, kW_p is the rated system output, CF is capacity factor.

Below is the formula to measure the appropriate FIT rate for a feed-in tariff program.[5]

$$Tariff=\frac{TI+CC}{(1+ROI)\times\sum_{t=1}^{T}(kW_p\times 8760\times CF)\times(1-d)^{t-1}} \tag{1-4}$$

Where TI is total investment, CC is cost of capital, ROI is return on investment, kW_p is the rated system output, CF is capacity factor, and d is solar PV system degradation rate. Total investment includes permitting cost, initial installation cost, operating and maintenance

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[5] Refer to Chapter II for detailed explanation of methodology.

cost, interconnection cost, etc., minus federal and state tax credits over the contract period of years T.

Analytic Approach

I will examine how each variable, such as life cycle, loan interest rate, degradation rate, and other variables contributed to the LCOE and FIT rate by conducting sensitivity analysis. The overall goal is to explore ways to lower the LCOE and FIT rate to reach retail rate grid parity with utility price sooner.

Later, a discussion will follow the sensitivity analysis to identify policy changes and recommendations to promote solar generation in Eugene.

Overall, this project aims to study the feasibility of current solar FIT available at EWEB and explore ways to promote distributed solar generation deployment.

Organization of Report

Chapter I introduces the background and the context for this study of solar programs in Eugene, Oregon and the research questions, methodology, and measurement displayed in the study; Chapter II details the methodology and data sources for this research; Chapter III presents the analytical results, synthesizes interview responses, and discusses the preliminary findings from both quantitative and qualitative sources. Chapter IV explores the implications of the results, draws conclusions regarding the feasibility of current solar programs operated by EWEB, and offers recommendations to move toward greater promotion and deployment of distributed rooftop generation in Eugene and Oregon.

Chapter II: Methodology and Data

In order to assess the cost-benefit effectiveness of EWEB's current solar programs, a levelized cost of electricity generation should be used to capture the average solar electricity generation cost to a solar PV owner or investor over the whole life-cycle of solar PV systems. In this paper, the levelized cost of electricity generation (LCOE) for commercial direct generation (FIT) solar systems, and residential net-metering solar PV systems between the years 2007 and 2011 is calculated through a case study of Eugene Water & Electric Board (EWEB)'s solar programs. Solar PV systems typically have high upfront purchase and installation costs. Over the lifetime of solar PV panels (25 years or above), the relative cost is lower, and the solar system's electricity output could still remain at 80% of its original output after 30 years.[6] Therefore, to compare the relative cost-effectiveness of solar electricity with retail electricity cost, it is justified to use the LCOE as a proxy for the cost of solar electricity.

The development of my solar electricity generation cost methodology has involved numerous meetings with professors, utility professionals, solar installers, and officials. Compared to conventional power plants, such as coal, natural gas, or nuclear plants, solar PV electricity generation has several unique characteristics[7]: 1. solar PV systems have a low operating and maintenance cost;[8] 2. solar energy reduces CO2 emissions and brings other

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[6] Interview with Dr. Frank Vignola, director of Solar Radiation Laboratory at the University of Oregon.

[7] See Zweibel, K. 2010. "Should solar photovoltaic be deployed sooner because of long operating life at low, predictable cost?" *Energy Policy.* 38 (11): 7519-7530.

[8] Email exchange with Joshua Skov, principal at Good Company; discussion with Justin Daily from Advanced Energy Systems.

environmental and health related benefits (avoiding external costs); 3. Solar PV has increased energy value due to daytime generation during peak time demand;[9] and 4. Most distributed generated electricity is used on site, avoiding expensive transmission cost. Because of these unique characteristics of solar PV electricity generation, it is fairer to compare the average cost of solar electricity over its lifespan with the average cost of electricity generation from coal plants, natural gas plants, and nuclear plants.

It is beyond the scope of this research project to dig into the average cost of electricity generation from coal, gas, nuclear, and oil. The pricing of external cost, including carbon price, health cost, and global climate change impact, is hard to quantify. As of 2010, 7% of EWEB's power is from coal, 3% is from natural gas, 4% is from nuclear, 7% from biomass, 5% from wind, and 74% from hydropower.[10] Since about 86% of EWEB's power is from clean energy that has low or little CO2 emissions, solar PV generated electricity will not significantly displace the use of fossil fuels or carbon. Therefore, in this study, I will analyze the average solar electricity cost and benefit to a solar PV system owner or investor. In addition, based on the cost-benefit analysis of solar electricity generation in Eugene, I will propose a well-designed feed-in tariff program for Eugene and the State of Oregon.

From another perspective, LCOE also represents the additional cost of solar electricity per kilowatt hour (kWh) to the solar system owner. Ideally, the additional cost of solar electricity per unit should be zero or negative. A negative number means that a solar PV

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[9] This is true for many regions of the U.S., such as California, Arizona, Hawaii, etc. However, in Eugene, the peak demand for power usually does not match the peak generation of solar PV.

[10] See EWEB 2011. *EWEB 2010 Sustainability Report*. http://www.eweb.org/public/documents/sustainability/sustainabilityReport2010.pdf (accessed May 3, 2012)

owner makes profits for each kWh of solar electricity that is generated over the life of the investment with good care of their systems. It also means that with all the federal and state tax credits, utility incentives and/or electricity sale value (11cents/kWh for direct generation, and 5.7 cents/kWh for net metering in 2011), a solar owner or investor should not pay extra money for every additional unit of solar electricity generation. If the additional cost per kWh generation is zero, a solar PV systems owner neither makes nor loses money. The return on investment (ROI) is zero.

Assumptions and Overview of Methodology

In this study, a few critical assumptions have been made to facilitate the calculation of the levelized cost of electricity generation and the FIT rate for a feed-in tariff program. The development of the solar PV industry experienced a lot of uncertainties and variations across regions, and among different types of contracts, technologies, sizes, and policies. Without these assumptions, it is impossible to conduct any meaningful study. I will list the assumptions here:

- No differentiation will be made between the types of solar modules installed in Eugene from 2007 to 2011. Currently, there are three major types of solar modules: mono-crystalline silicon modules (highest efficiency, more expensive), polycrystalline silicon modules (slightly lower efficiency, less expensive), and thin film (amorphous silicon, lower efficiency and cheaper, with loss of wattage per sq. ft. installed) modules.[11] The most commonly used modules are polycrystalline silicon. In this

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[11] See Atlantech Solar, "Types of Photovoltaic Solar Panels", http://www.atlantechsolar.com/types_photovoltaic_solar_panels.html (accessed April 26, 2012)

study, I will use the average installed solar PV capacity and cost data for the calculation.

- Assume that almost all the electricity generated by the residential PV systems has been used on-site. Therefore, the value of electricity generated on-site is the value of displaced retail electricity that would otherwise be supplied by EWEB at retail price. The average size of net-metered systems is 3.1 kW, generating about 3,258 kWh of electricity per year. A typical household consumes about 10,000 kWh of electricity in a year. The amount generated is far less than the amount needed by a household. Of course, there might be days when excess generation will be fed back to the grid. However, overall, most of the solar electricity will be used on site.
- There will be no taxation on the saved electricity bills due to the solar electricity generation on site. Solar electricity generation reduced the amount of electricity supplied by EWEB. It allowed households to avoid paying electricity bills.
- Assume home equity loan interest is 6.5% annually. As of 2012, the annual interest rate for a 5-year home equity loan ($5,000 - $100,000) at Umpqua Bank through Green Street Lending is 6.5%.[12] U.S. Bank also offers a minimum $15,000 home equity loan with an annual percent rate (APR) of 6.24%.[13]

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[12] Interview with Alison Major, Store Manager at Umpqua Bank. According to Umpqua Bank's Green Street Lending brochure, one will get better rates on financing for energy efficiency improvements or renewable energy systems; solar and wind energy projects are among qualified projects.

[13] Rates at Yahoo Finance. http://finance.yahoo.com/rates/result?t=h&u=HomeEquityRatesByMarket&s=7&e1=3&e2=5&e3=9&a=2&p=438&b=0&st=OR&m=588 (accessed May 20, 2012)

- Assume that a typical household needs a 5-year loan of $15,000 to finance a residential solar PV project on top of EWEB's cash grants.[14] Tax credits are not available until a homeowner files a tax return during the year following the installation, and Oregon BETC is distributed over four years. Thus, the upfront cost for a solar investor is typically more than $10,000 for an average residential PV system. The cost of capital for a $15,000 home equity loan is $2,609 after a 5-year payback period.[15] The average project cost of residential solar PV after an EWEB cash grant was $24,318 in 2007 and $17,146 in 2011. Assume that the remaining project cost could be covered by personal funds and other financing schemes, such as refinanced mortgage loans.

Scope of This Study

The scope of this study includes two parts: calculating the levelized cost of electricity generation and an appropriate level of FIT rate for a feed-in tariff with a 5% return on investment for residential net-metered solar PV projects in EWEB's service territory between 2007 and 2011. I exclude commercial direct generation and commercial net-metered solar projects for the following reasons:

1) There is a very limited number of commercial direct generation and net-metered projects put in service between 2007 and 2011. In the past 5 years, there have been 31

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[14] Alison Major informed me that she worked with the Solarize Eugene program to help homeowners finance residential PV projects. One home equity loan through Umpqua Bank's Green Street Lending was $9,100. Based on a conversation with Justin Wilbur of Advanced Energy Systems, the typical loan request for a residential PV project is about $10,000. With the decreasing cost of solar PV, requested loan amounts could be lower in 2012, thus reducing the cost of capital.

[15] In reality, the amount of loan that one can get from a bank and the cost of capital could differ a lot individually, depending on the credit score of the individual and the equity values of his or her home.

commercial direct generation projects and 21 commercial net-metered ones. The majority of direct generation projects were established in 2007 to take advantage of the high EWEB power purchase rate (15 cents/kWh) and the Business Energy Tax Credit (BETC). Only a couple of projects were put in service in 2010 and 2011 due to the increasing difficulty in applying for BETC and the decreasing EWEB purchase rate. The limited number of projects makes the levelized cost calculation statistically insignificant. Ideally, a sample size greater than 15 projects per year would make the LCOE trend statistically significant. On the other hand, there were 136 residential net-metered projects put in service during the same time, with at least 20 per year.

2) Little is known about the financing scheme of these projects and cost of capital. Most of these projects cost more than half a million dollars. It is not clear whether these projects could qualify for BETC and how much tax the business would pay. In addition, it is hard to determine what taxation bracket should apply to the solar electricity generation revenue. These uncertainties leave a lot of room for errors to happen, and may distort the real cost of solar electricity generation. Without further information regarding financing and taxation, it is counterproductive to include these projects.

3) There has been growing interest in and increasing deployment of residential net-metered solar PV projects in Eugene. With the expiration of BETC (50% of project cost) in 2011, commercial projects have become less economically viable. On the other hand, there is great potential to deploy more residential PV systems in Eugene. As of 2010, there were 33,271 owner-occupied housing units in Eugene, representing

50.1% of all housing units.[16] Assuming that only 20% of the owner-occupied housing units are suitable for rooftop solar PV, that translates into 6,654 housing units or potential PV projects. Between 2001 and 2011, there were a total of 152 residential PV projects completed on 0.46% of all owner-occupied housing units.

Definitions of Residential Solar PV Systems

A residential solar PV system has a size range of 1 kW to several kW, usually smaller than 10 kW. These systems are typically put on the rooftops of individual houses. The average size of a rooftop PV system is about 3 kW to 4 kW. In this study, I will exclude the 1 kW net-metered residential projects.[17] Those systems usually exhibit unusually high cost and may misrepresent the cost for a typical rooftop project.

Calculating FIT Rate for a Feed-in tariff Program

To design a feed-in tariff in Eugene and Oregon, with 5% of Return on Investment (ROI) over a 25-year power purchase contract, we can backtrack and calculate the appropriate level of FIT rate that needs to be set for direct generation solar PV systems.

$$ROI = \frac{ElectricityValue - (TotalInvestment + CapitalCost)}{TotalInvestment + CapitalCost} \tag{2-1}$$

$$ElectricityValue = ElectricityTariff \times TotalElectricityGenerated \tag{2-2}$$

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[16] U.S. Census 2010.

[17] For the last five years, there have been a total of 10 projects with a size of 1 kW, representing about 7% of total residential solar PV projects installed during that time.

$$TotalElectricityGenerated = \sum_{t=1}^{T} (kW_p \times 8760 \times CapacityFactor) \times (1 - SystemDegradationRate)^{t-1} \quad (2\text{-}3)$$

From (2-1), (2-2), and (2-3), we can derive the appropriate level of FIT rate with a 5% ROI and T-year contract feed-in tariff program.

$$ElectricityTariff = \frac{TotalInvestment + CapitalCost}{(1 + ROI) \times TotalElectricityGenerated} \quad (2\text{-}4)$$

$$Tariff = \frac{TI + CC}{(1 + ROI) \times \sum_{t=1}^{T} (kW_p \times 8760 \times CF) \times (1 - d)^{t-1}} \quad (2\text{-}5)$$

Where TI is total investment, CC is cost of capital, ROI is return on investment, kW_p is the rated system output, CF is capacity factor, and d is solar PV system degradation rate. Total investment includes permitting cost, initial installation cost, operating and maintenance cost, interconnection cost, etc., minus federal and state tax credits over the contract period of years T.

For investors who can take advantage of federal and state tax credit, the Total Investment is the amount that a solar PV system owner invested after deducting tax credits. For middle or low income households who are not able to take advantage of federal or state tax credits, the Total Investment stands for the solar PV system purchasing cost, installation cost, balance of system cost, permitting cost, interconnecting cost, operating and maintenance cost, etc.

Calculating Levelized Cost of Electricity Generation

The levelized cost of electricity generation is defined as the generation cost to solar PV system owners, not to utilities. The value of RECs has been factored into the power purchase rate for direct generation programs. For residential net metered projects, system owners keep the RECs. The definition and formula for LCOE is given by the following:

$$LCOE(\$/kWh) = \frac{TotalLifeCycleCost(\$)}{TotalLifetimeEnergyProduction(kWh)} \tag{2-6}$$

$$LCOE_t = \frac{InitialCost_t + CapitalCost + \left(\sum_{t=1}^{T} \frac{AnnualO\&MCosts}{(1+DiscountRate)^t}\right) - Incentives - ElectricityValue}{\sum_{t=1}^{T}(kW_p \times 8760 \times CapacityFactor) \times (1 - SystemDegradationRate)^{t-1}} \tag{2-7}$$

To calculate the generated solar electricity value by a solar PV system over T-year period:

$$ElectricityValue = \sum_{t=1}^{T} \frac{[A \times (1+r)^{t-1} \times kW_p \times 8760 \times CF]}{(1+DiscountRate)^{t-1}} \tag{2-8}$$

Where A is electricity rate at year one ($t = 1$), r is annual electricity rate increase, kW_p is the rated system output, CF is capacity factor.

Quantitative Solar Electricity Cost Variables and Data

- T: Life of the project (years)

This variable is used to describe the total terms of future cash inflows (electricity generation, tax incentives) and outflows (maintenance and operating, inverters, interest rate, etc.). Typically, the lifecycle of solar PV systems in Eugene is 30 years.[18] Due to aging, dust, and other natural forces, solar PV systems' generation output decreases on a yearly basis. However, it is very likely that with technological advances, lifetimes above 30 years are becoming more common. In 2009, BBC News reported that tests showed that over 90% of solar panels lasted 30 years, rather than the predicted 20 years lifespan.[19] Most solar panels have a 25-year warranty. In this study, I will use 25 years for the calculation of levelized cost and designing a feed-in tariff.

- t : Year t
- A : Electricity rate at year one for a 25-year contract period. For example, for a project put in service in 2011, the base electricity rate is the rate of that year, which was 8.846 cents/kWh.[20] In this study, I will use the retail residential rate (excluding monthly basic charge) to calculate the solar electricity revenue for a solar investor. In 2012, the rate is 8.1 cents/kWh (delivery cost + generation cost).[21]

- r : Annual increase in utility prices over a 25-year period. I will use an annual growth rate of 4%. According to Colleen Wedin and Sibyl Geiselman of EWEB, an annual

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[18] Interview with Frank Vignola, Director of Solar Radiation Monitoring Laboratory at the University of Oregon.

[19] Harrabin, Roger. Solar panel cost 'set to fall', BBC News, 30 November, 2009. http://news.bbc.co.uk/2/hi/8386460.stm (accessed April 17, 2012)

[20] The residential retail electricity rate includes basic charge ($9/month), delivery charge (2.887 cents/kWh, for first 800 kWh), and energy charge (4.834 cents/kWh, for first 800 kWh). It amounts to 8.846 cents/kWh in 2011 (for first 800 kWh). The rate increased to 9.35 cents/kWh in 2012. See Appendix D for more details.

[21] See Appendix C.

rate of 4% is still a conservative estimation for electricity rate increase for the next 10 to 20 years in Eugene.[22] In recent years, EWEB has constantly raised electricity rates to cover its own increasing expenses (mainly attributed to capital project improvement and decreasing revenue) and the higher cost of power from Bonneville Power Administration.[23] Earlier this year, EWEB raised its residential electricity rate by 5.5%, in addition to a 5% rate increase in November 2011.[24]

- *CF* : Capacity Factor. This concept is used to measure how much electricity a solar PV system could generate over a period of time, typically a year. CF is the percentage of time that a solar PV system needs to operate at its maximum rated capacity in a year to generate the number of kilowatt-hours that it generates under real situations in that year.[25] Currently, EWEB uses a capacity factor of 12% to 14% for the solar PV systems in Eugene.[26] In this study, I will use 12% as the capacity factor. Therefore, for a 5 kW solar PV system in Eugene, the annual electricity output (kWh) = 5kW*8760h*12% = 5,256 kWh. Here, 10 kW is the Rated Capacity, 12% is the capacity factor, and 8,760 hours is the number of total hours in a year.

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[22] Email exchange with Sibyl Geiselman, EWEB energy analyst.

[23] Wihtol, Christian, "EWEB to cut 50 jobs, overtime," *The Register Guard*, May 26, 2012, http://www.registerguard.com/web/newslocalnews/28125818-41/eweb-agency-gray-smith-costs.html.csp (accessed May 26, 2012)

[24] *Ibid.*

[25] See Zweibel, K. 2010. "Should solar photovoltaics be deployed sooner because of long operating life at low, predictable cost?" *Energy Policy.* 38 (11): 7519-7530.

[26] Interview with Frank Vignola, Director of Solar Radiation Monitoring Laboratory at the University of Oregon; email exchange with Colleen Wedin, Energy Management Specialist at EWEB.

- I_t: Initial cost of PV systems for t ($)

  This variable is used to capture the installation cost of modules and balance of the system, grid interconnection, and permitting and system design cost. The upfront cost is the major cost for a PV system, and the average price per watt installed has decreased significantly. Data from Solarize Eugene shows that "in 2011 Q4, the price drop was dramatic, dipping from Q3 average of $6600 [$6.6/watt] to Q4 average of $5800 per kWh [$5.8/watt]". [27] As of April 2012, the average cost per watt for 12 residential projects sponsored by the Solarize Eugene project is $4.79/watt.[28] That represents a 44.3% drop in the average installed price compared to that of 2009 for 23 residential projects ($8.6/watt).

- Cost of capital (CC) and interest rate (i). In this study, assume that a 5-year loan of $15,000 will finance most of the net-metered project. Annual interest rate is 6.5%. Total amount of interest paid is $2,609. If $i = 5.5\%$, CC = $2,191; if $i = 4.5\%$, then CC = $1,778. The lower the interest rate is, the lower the cost of capital.

- C_t: EWEB incentives, federal and State of Oregon tax incentives
    - EWEB incentives. Before 2012, the EWEB cash incentive for net-metered projects was $2/Watt AC up to $10,000. Effective from January 2012, the

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[27] Email exchange with Sarah Mazze, program manager of the Solarize Eugene Program, The Resources Innovation Group.

[28] *Ibid*.

incentive is $1.7/Watt AC output up to $6,000.[29] The limited amount of EWEB funding is offered on a "first come, first served" basis.[30]

- State of Oregon Residential Energy Tax Credit (RETC): for solar PV systems, $2.10 per watt DC at Standard Tested Capacity (STC) with a maximum limit of $6,000 ($1,500 per year over 4 years), or up to 50% of the net cost.[31] The net cost is calculated after taking any state incentives into account. As of January 1, 2011, residents who are leasing a solar system are also eligible for the tax credit. Start date: 1/1/2006, expiration date: 1/1/2018.
- Federal Residential Renewable Energy Tax Credit: 30% of the system cost. For solar electric PV systems established before January 1, 2009, there was a $2,000 maximum cap. For solar PV systems placed in service after January 1st, 2009, a taxpayer could claim a credit of 30% of solar systems expenditure as their tax credit for a residential system that is located inside the United States.[32] Start date: 1/1/2006, expiration date: 12/31/2016. For residential solar PV projects in Eugene, the EWEB incentives (upfront rebate) will be subtracted from the project cost to determine the federal tax credit basis. For

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[29] See EWEB. Net Metering Program. http://www.eweb.org/solar/netmetering

[30] See Appendix B for more details on EWEB incentives offered in 2012.

[31] See DSIRE Solar, Database of State Incentives for Renewables & Efficiency, Department of Energy. 2011. Oregon Incentives/Policies for Solar. http://www.dsireusa.org/solar/incentives/incentive.cfm?Incentive_Code=OR17F&re=1&ee=1 (accessed April 17, 2012)

[32] DSIRE Solar, Database of State Incentives for Renewables & Efficiency, Department of Energy. 2011. Federal Incentives/Policies for Renewables & Efficiency.http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=US37F&re=1&ee=1 (accessed April 17, 2012)

example, if a project costs $25,000, and the EWEB incentive is $6,000, then the federal tax credit amount = 30% * ($25,000 - $6,000) = $6,333.

- E_t: Energy produced for year t (kWh)

  This is the amount of electricity (kWh) produced in a given year over the lifecycle of solar systems. If E_1 is the output for year 1, then for year t, the output is:

  $E_t = E_1 \times (1-d)^{t-1}$ where d is the PV system degradation rate. Generally, one kilowatt (kW) installed panels will generate an average of 1,100 kilowatt hours (kWh) of electricity annually.[33] In this study, I will use a capacity factor of 12%, representing an equivalent electricity generated 1,051 kWh/kW/year.

- $O\&M_t$: Maintenance and operation costs for year t ($)

  The operating and maintenance cost mainly comes from the replacement of inverters roughly every 10 years, cleaning of panels, repair of electrical systems, and so forth.[34] Inverter reliability and cost is also improving rapidly,[35] meaning that inverters could last more than 10 years. Some are even designed to last 20 years, depending on the type of inverter. So far, there is no indisputable data on maintenance and operating cost. However, Zweibel (2010) considers $15/kW/year to be a fair estimate. In the United States, as of 2012, the price of an inverter is $ 0.771 per continuous watt.[36] In

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[33] EWEB. 2012. About Solar Energy. http://www.eweb.org/solar/about (accessed April 20, 2012)

[34] National Renewable Energy Laboratory (U.S.). 2006. *A review of PV inverter technology cost and performance projections final presentation report to [the] National Renewable Energy Laboratory*. Golden, CO: National Renewable Energy Laboratory. http://purl.access.gpo.gov/GPO/LPS89013.

[35] Heacox, E., 2010. Inverter Cost Analysis. *Solar Industry*. P. 28- 31, July.

[36] SolarBuzz. http://www.solarbuzz.com/facts-and-figures/retail-price-environment/inverter-prices

other words, for a 10 kW solar PV system, the inverter price is about $7,771. In this study, I will use $15/kW/year to calculate O&M cost.

- r : Discount rate for t (%)

  This variable is used to describe the different value placed on cash inflow and outflow in different time periods, locations, and circumstances.[37] It is known that the private sector prefers a higher short-term discount rate so as to reap the investment and benefits quickly, whereas governments determine social discount rate for public projects based on long-term social benefits.[38] Generally, a 20-year interest loan or a home equity loan rate is a good proxy for discount rate. The choice for a solar system owner is as follows: if she has extra cash, she can either use the cash to pay off a loan and reduce debt, or she can use the extra capital to invest in a solar PV system without reducing debt service. In this study, the discount rate is 5%.

- RC : Rated capacity for a solar PV system (kW DC)
- d : Degradation rate (%)

  The degradation rate for a PV system is about 0.5% in Eugene.[39] Generally, a degradation rate of 0.2% to 0.5% per year is considered a reasonable estimate based on technological advances. [40] In this study, the degradation rate is 0.5%.

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[37] See Branker et al. Bhandari R., and Stadler I. 2009. "Grid parity analysis of solar photovoltaic systems in Germany using experience curves". *Solar Energy*. 83 (9): 1634-1644.

[38] *Ibid.*

[39] Interview with Dr. Frank Vignola, Director of Solar Radiation Monitoring Lab at the University of Oregon.

[40] See Branker et al. Bhandari R., and Stadler I. 2009. "Grid parity analysis of solar photovoltaic systems in Germany using experience curves". *Solar Energy*. 83 (9): 1634-1644.

Data Source and Analysis Steps

The data for the above mentioned levelized cost of solar electricity generation have been gathered from EWEB, Oregon Department of Energy, Advanced Energy Systems, Solar Radiation Morning Lab, interviews, and other online sources. EWEB formally launched its current solar program (direct generation and net-metering) in 2007; therefore, the solar PV projects data ranges from 2007 to 2011. For each year from 2007 to 2011, I will perform levelized cost analysis for residential net-metering projects. I will use the average project cost, average PV system capacity, and average annual PV system output in each specific year to calculate the levelized cost in that year. Levelized cost will be calculated under four different situations: 1. Levelized cost without federal and state tax credits or EWEB incentives; 2. Levelized cost with only federal tax credit, without state tax credits; 3. Levelized cost with both federal and state tax credits; 4. Levelized cost with federal and state tax credits and EWEB incentives.

In addition, I will calculate the appropriate level of FIT rate paid to the system owner so that the owner could have a lifetime 5% return on investment. Similarly, FIT rates will be derived under three scenarios: 1. without tax credits; 2. with only federal tax credits; 3. with both federal and state tax credits.

A sensitivity analysis will follow the levelized cost study to determine how FIT rate in future will change with different input variables. These variables include interest rate, and annual utility price increase.

Chianese, D., Realini, A., Cereghetti, N., Rezzonico, S., Bura, E., Friesen, G.., 2003. Analysis of Weather c-Si PV Modules. LEEE-TISO, University of Appled Sciences of Southern Switzerland, Manno.

In addition to quantitative research, I also interviewed more than twenty utility professionals, professors, solar installers, and other stakeholders. Their opinions on reducing solar cost, overcoming political, economic, and social barriers, and promoting solar deployment have been synthesized to compliment the quantitative results. Overall, the qualitative and quantitative results will help us understand the true incremental cost of solar electricity to solar PV system owners. I hope that the results of this study can spur further discussion on the feasibility of deploying solar PV systems in Eugene in the short and long term. Hopefully, the research can shed light on appropriate solar program design and policy.

Chapter III: Data Analysis and Results

In this chapter, the levelized cost of solar electricity generation has been calculated for residential net-metering solar PV systems in the EWEB service territory. Altogether, 121 residential net-metered projects undertaken between 2007 and 2011 were selected in order to analyze the average solar electricity generation cost to solar PV investors and owners. In addition, a further analysis looks into the appropriate FIT rate design for a feed-in tariff program for EWEB customers based on the last five years' cost data.

The 121 residential net-metered projects have an average size of 3.1 kW and a $3.1/Watt net average capital cost (see Table 1 for more details). The net capital cost dropped from $4.9/Watt in 2007 to $1.55/Watt in 2011, representing a 68% decrease in price. Meanwhile, the capital cost fell from $8.86/Watt in 2007 to $6.06/Watt in 2011. The decrease is mainly due to the falling price of solar panels (see Figure 3.1).

Table 3.1: Residential Net Metered Projects (2007-2011)

YEAR	NO. OF PROJECTS	AVERAGE KW CAPACITY	INSTALLED CAPACITY	AVERAGE EWEB INCENTIVE AMOUNT	AVERAGE PROJECT COST	PROJECT COST AFTER EWEB INCENTIVES	FEDERAL TAX CREDITS (ITC)	RESIDENTIAL ENERGY TAX CREDITS (RETC)	NET PROJECT COST (AFTER INCENTIVES)	CAPITAL COST ($/Watt, W/O INCENTIVES)	NET CAPITAL COST ($/Watt)
2007	9	3.3	30	$ 5,206	$ 29,525	$ 24,318	$ 2,000	$ 6,000	$ 16,318	8.86	4.90
2008	12	2.7	32	$ 4,889	$ 24,623	$ 19,734	$ 2,000	$ 6,000	$ 11,734	9.23	4.40
2009	22	2.8	62	$ 4,889	$ 24,252	$ 19,363	$ 5,809	$ 5,918	$ 7,636	8.61	2.71
2010	26	2.7	70	$ 5,019	$ 20,563	$ 15,545	$ 4,663	$ 5,654	$ 5,227	7.64	1.94
2011	52	3.9	201	$ 6,291	$ 23,437	$ 17,146	$ 5,144	$ 6,000	$ 6,002	6.06	1.55
Average/ Sum	121	3.1	395	$ 5,259	$ 24,480	$ 19,221	$ 3,923	$ 5,914	$ 9,384	8.08	3.10

However, without taking into consideration federal, state, and EWEB incentives, average capital cost for the residential solar systems is much higher, standing at $8.08/Watt. From Figure 3.2, we can see that from 2007 to 2011, both the total number of residential net-metered solar PV projects and the total installed capacity experienced significant growth. The number of installed residential PV projects in 2011 was almost six times greater than that in 2007. With more residential systems installed each year, capital cost of PV systems (without incentives) and net capital cost (with tax credits and incentives) both witnessed continuous drops in price, reaching prices of $6.06/Watt and $1.55/Watt in 2011 respectively. This represented a 31.5% decrease for capital cost and a 68.2% decrease for the net capital cost between 2007 and 2011 for the residential projects in Eugene.

The sharp increase in the number of residential projects installed in Eugene is partially due to the continuous drop in solar PV panel prices (see Figure 3.1), [41] the lift of the federal tax credit cap of $2,000 for residential PV systems, and EWEB cash incentives.

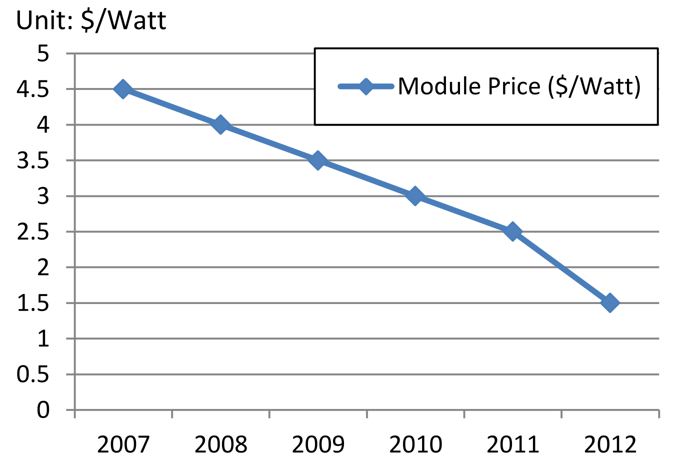

Figure 3.1: Retail Module Prices in Oregon

After 2008, with the drop of silicon prices, solar PV modules underwent a sharp price decrease. For example, average Chinese-made Crystalline silicon (c-Si) PV module prices dropped from around $2.2/Watt in 2009 to $0.9/Watt in 2011, representing a 59% decrease in

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[41] Email exchange with Justin Daily, Solar Designer and Consultant, Advanced Energy Systems. Figure 3.1 is based on the historical retail prices of solar panels in the Eugene area, I made Figure 3.1.

c-Si PV module prices over a three year period.[42] From January 1, 2009, residential PV projects were eligible to receive federal tax credits that amounted to 30% of the project cost. Through RETC, EWEB incentives, and federal tax credits, residential PV systems have become more economically viable to solar PV owners and investors.

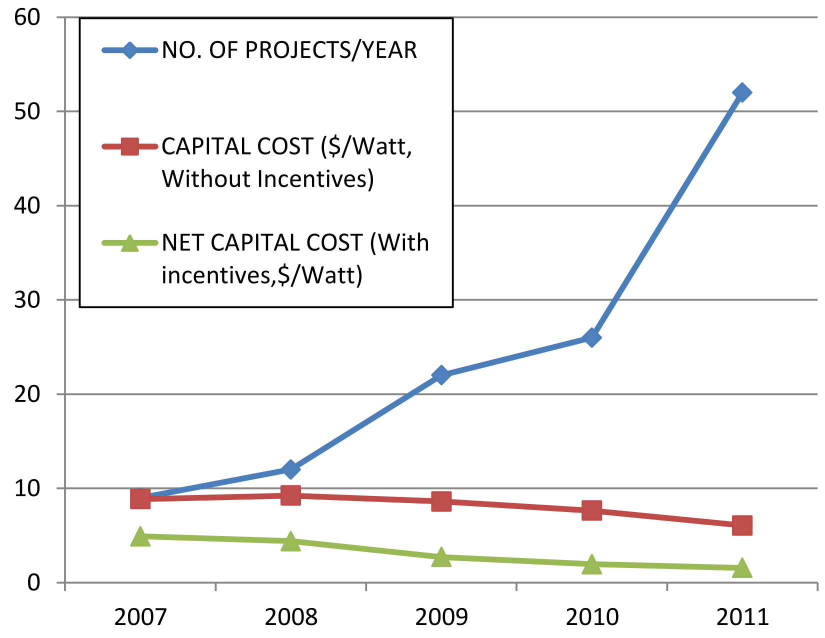

Figure 3.2: Capital Cost and Net Capital Cost for Residential Systems

Levelized Cost of Electricity for Residential Net Metered PV Projects

From 2007 to 2011, a total number of 136 residential net metered solar PV projects were installed in Eugene. A net-metered solar electricity program is one that allows a solar PV owner to sell surplus solar electricity to EWEB at an avoided generation cost of $0.0586/kWh. If the solar PV system generates less electricity than the household needs, EWEB will provide the remaining electricity. If the solar PV system generates more

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[42] See Bazilian, M et al. 2012. "*Re-considering the Economics of Photovoltaic Power*," Bloomberg New Energy Finance. www.bnef.com/WhitePapers/download/82 (accessed May 20, 2012)

electricity than is consumed, the surplus electricity will be fed back to the grid, and the meter will be reversed. If a situation arises in which the same household needs extra electricity provided by EWEB, the meter will move forward again. At the end of year, customers will either pay for net electricity consumed or receive credits for extra electricity generated.

In all, out of the 136 projects, 121 residential net-metered projects were selected for analysis. Fifteen projects were dropped due to either missing project cost data or small system size (1 kW system size). The average size for the residential net-metered PV systems is 3.1 kW. The 121 net-metered projects represent a total installed capacity of 395 kW.

Levelized cost analysis for residential solar PV projects is conducted under four different scenarios: 1. LCOE without federal tax credits (ITC), State of Oregon residential energy tax credit (RETC), or EWEB incentives; 2. LCOE with ITC; 3. LCOE with both ITC and RETC; 4. LCOE with ITC, RETC, and EWEB incentives.

The purpose of using different combinations of tax credits and EWEB incentives is to provide a clear picture of how much each additional kWh of electricity generation would cost a solar system owner under different policy designs. By looking at the levelized cost differences under different policy schemes, we can understand how much weight ITC, RETC, or EWEB incentives have in the cost reduction of solar power. Through applying the formulas presented in Chapter II on LCOE calculation under the four different scenarios, the range of LCOE values are determined, as presented in Figure 3.3 and Table 3.2.

Table 3.2: LCOE for Residential Net Metered Solar PV Projects

	LCOE w/o ITC & RETC	LCOE with ITC	LCOE with ITC & RETC	LCOE with ITC & RETC & EWEB
2007	0.29	0.27	0.21	0.15
2008	0.31	0.28	0.20	0.06
2009	0.28	0.20	0.12	0.06
2010	0.24	0.17	0.10	0.02
2011	0.16	0.10	0.05	-0.02

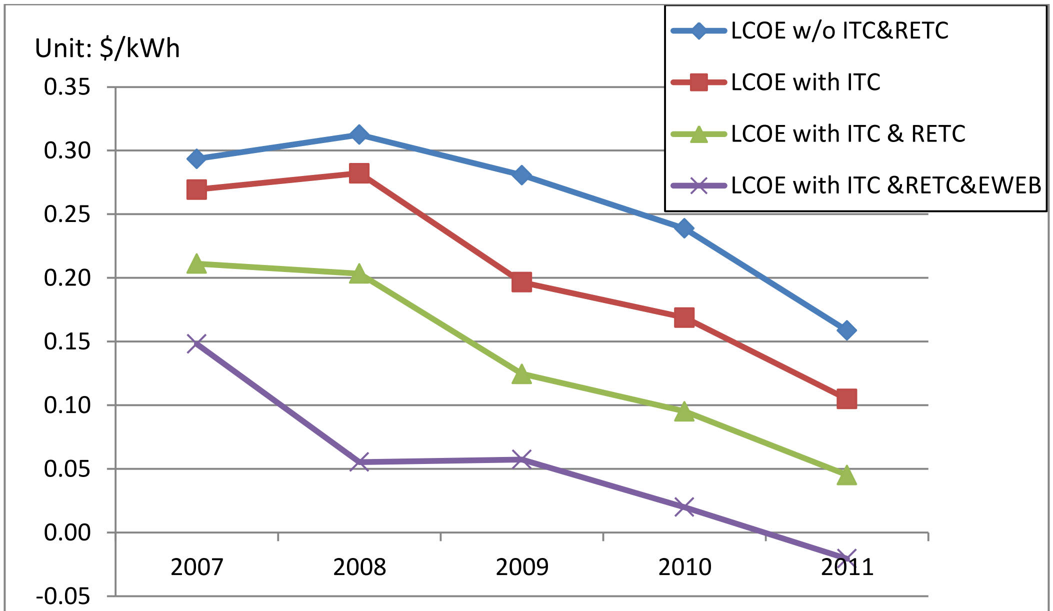

Figure 3.3: Levelized Cost of Electricity Generation for Residential Systems

From Figure 3.3 and Table 3.2, we can see that levelized cost under different scenarios generally experienced a continuous drop between 2007 and 2011. LCOE without any incentives or tax credits decreased by 46% during that period of time, whereas LCOE with ITC decreased by 61%, LCOE with ITC & RETC decreased by 78.6%, and LCOE with ITC & RETC & EWEB decreased by 113% (from 15 cents/kWh to -2 cents/kWh). On average, federal tax credits contributed to a 6 cents/kWh drop in LCOE, while RETC was responsible for a 6 cents/kWh drop in levelized cost, and the EWEB incentives contributed to a 9 cents/kWh decrease in levelized cost. In 2007 and 2008, ITC contributed to 2 cents/kWh and 3 cents/kWh decrease in LCOE respectively, while it helped lower LCOE by 8 cents/kWh, 7 cents/kWh, and 6 cents/kWh in 2009, 2010, and 2011. The monetary cap of $2,000 for federal residential energy tax credit in 2007 and 2008 may have limited the effect of federal tax credits in bringing down the levelized cost.

The different decrease rates of LCOE are due to a few factors: 1. Change of ITC from $2,000 in 2007 and 2008 to 30% of project cost; 2. Different amounts of EWEB cash grants available in different years; 3. Different total project cost break down during each year. From Figure 3.4, we can see that the proportion of net capital cost, ITC, RETC, and EWEB grant varied in different years.

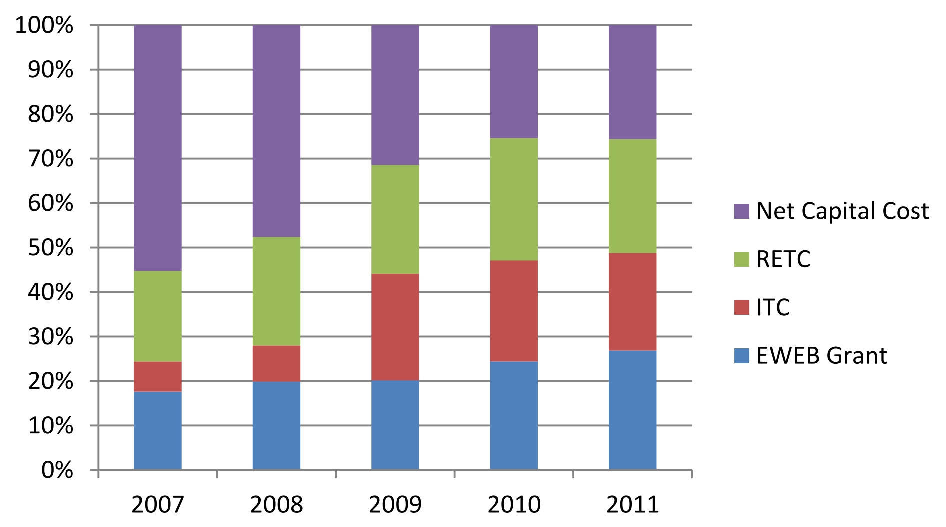

Figure 3.4: Residential PV Systems Cost Breakdown by Year

The LCOE results show that the economic viability of residential solar PV systems still relies heavily on federal and state tax credits and EWEB incentives to bring down the levelized cost. Without any tax credits or EWEB incentives, the high marginal cost for each additional kWh of electricity generation to solar PV system owners is a major barrier to promoting residential PV projects.

Overall, residential systems (with ITC, RETC, and EWEB incentives) put in service in 2007, 2008, 2009, and 2010 are costing solar PV owners 15 cents, 6 cents, 6 cents, and 2 cents for each kWh of electricity generated respectively. For a residential solar PV project with average cost and size put in service in 2011, that project owner is making a profit of 2 cents/kWh. If the retail electricity rate increases faster than the 4% used in this study, solar PV system owners could make even higher return on their investments for the years 2010 and 2011. It is safe to assume that all the electricity generated from the residential PV systems is consumed by the households. Therefore, the value of electricity generated on-site is the value of displaced retail electricity that would otherwise be supplied by EWEB at retail price. If the future retail electricity price is higher, the LCOE will be lower, making solar power more cost-effective compared to conventional electricity. Of course, further reduction in module prices, balance of system cost, installation cost and operating and maintenance cost will also drive down the LCOE and make solar electricity more cost-effective.

Design of a Feed-in tariff Program for Residential PV Projects

Based on the available historical project cost data, solar PV system data, and a set Return on Investment of 5%, I have calculated the appropriate level of FIT rate for residential solar PV projects in Eugene. Because of the complexity in qualifying for various levels of tax credits, I have analyzed the FIT rate for each year based on three different scenarios: 1. FIT rate without ITC & RETC/BETC; 2. FIT rate with ITC; 3. FIT rate with both ITC & RETC.

FIT Rate for Residential Solar PV Projects

Table 3.3: FIT Rate for Residential PV Systems

	FIT Rate w/o ITC & RETC	FIT Rate with ITC	FIT Rate with ITC & RETC
2007	0.38	0.36	0.30
2008	0.40	0.37	0.30
2009	0.38	0.31	0.23
2010	0.34	0.27	0.20
2011	0.27	0.22	0.16

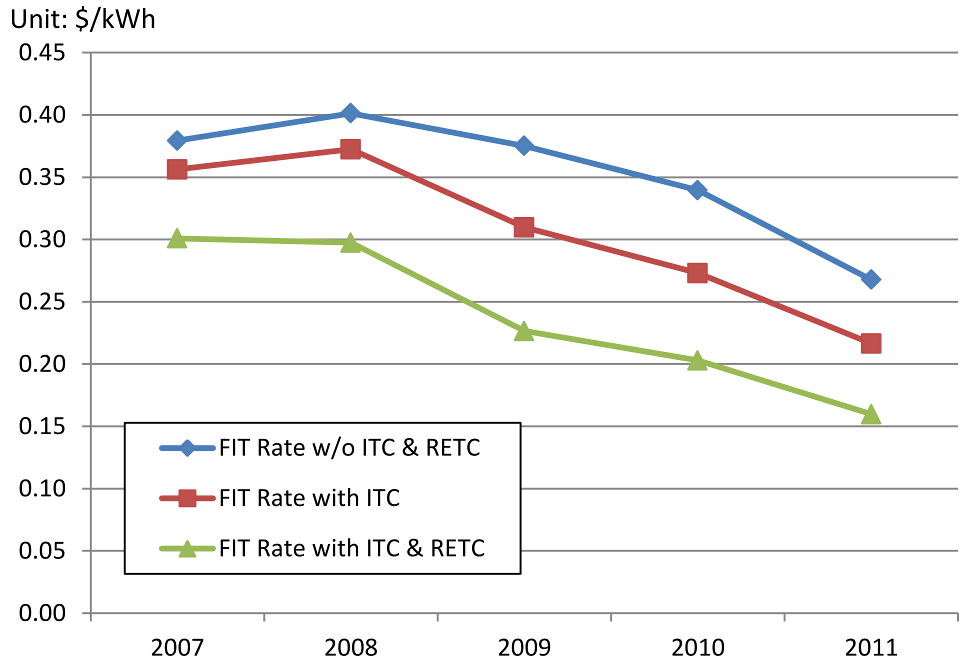

Figure 3.5: FIT Rate for Residential Feed-in-tariff Programs

From Table 3.3 and Figure 3.5, we can see that the level of FIT rate needed to ensure a 5% return on investment over a 25-year contract period experiences a steady drop (27 cents/kWh of FIT rate without any incentives, and 16 cents/kWh of FIT rate with tax credits and EWEB incentives in 2011). As time goes on, it takes lower levels of FIT rate to get a lifetime ROI of 5%. From 2009 to 2011, the aggregated annual decrease rate (AADR) for FIT rate without any incentives is 9.1%. The FIT rate decreased by 6% from 2008 to 2009, 9.5% from 2009 to 2010, and 21.1% from 2010 to 2011. If we assume that future FIT rate would continue to decrease by 6% on an annual basis, we can calculate the level of FIT rate for 2012, 2013, and so forth. I chose the smallest FIT rate decrease rate as a conservative future FIT rate projection. Of course, if I choose to use the AADR rate, the pace of future FIT rate drop will be even faster.

Assuming that the FIT rate decrease is 6.5%, the projected FIT rate in year Y is given by the following formula.

$$FITRate_Y = {FITRate_{2011}} \Big/ {(1+6.5\%)^{(Y-2011)}} \tag{3-1}$$

With the expiration of ITC and RETC in 2016 and 2018 respectively, it is imperative for us to calculate the appropriate level of FIT rate without any tax credits or utility cash grants. A well-designed feed-in tariff should be sufficient in covering all the costs of a solar PV project over a 25-year contract period of time. Eugene's 2011 level of FIT rate without any tax credits for a residential solar PV system is 27 cents/kWh. This is still much higher than the current residential retail electricity price (9.35 cents/kWh).[43] However, with the FIT rate continuing to decrease annually, while the retail electricity rate increases year by year, it is reasonable to believe that solar electricity in Eugene will reach retail rate grid parity somewhere between 2020 and 2024 (see Figure 3.6).

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[43] See Appendix C for more information regarding residential retail prices.

Sensitivity Analysis on Utility Price Increase

Although we know that, in general, the future utility rate will increase due to increases in BPA wholesale power price, capital improvement projects at EWEB, and increasing energy costs, it is less clear exactly how much the electricity prices will increase. As is mentioned in Chapter II, the 4% annual utility rate increase is a conservative figure. In order to reflect the uncertain nature of the utility rate increase, I will conduct a sensitivity analysis. Assuming that the FIT rate without incentives has an annual decrease rate of 6.5%, Figure 3.6 shows the time it takes to reach retail rate grid parity if utility prices increase by 4%, 6%, or 8% annually.

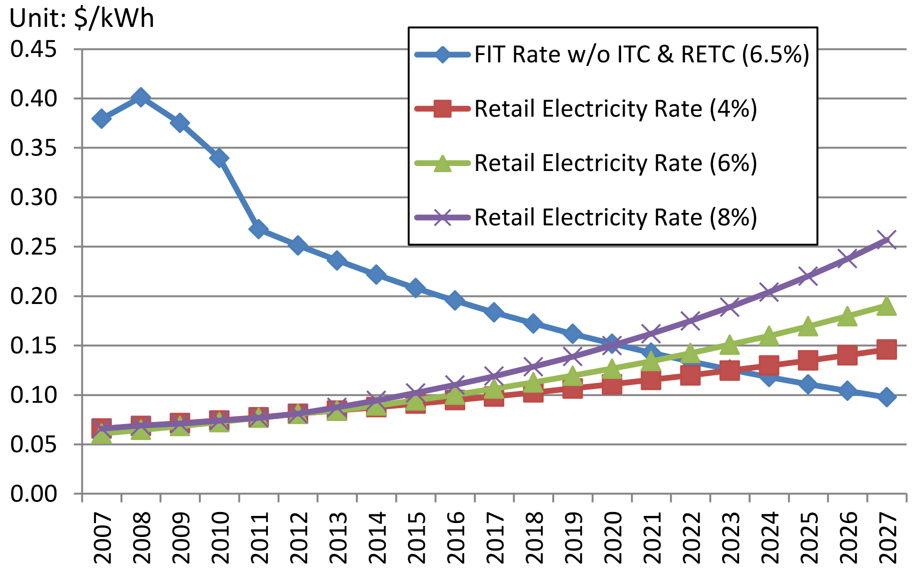

Figure 3.6: Projection of FIT Rate and Retail Rate Scenario 1

From Figure 3.6, we can see that if utility price increases at a faster pace, it takes less time for FIT rate to reach retail rate grid parity, when the FIT rate (without any incentives) is the same or less than the retail electricity price. Given that FIT rate decreases by 6.5% annually, if the utility price increases by 8% annually, retail rate grid parity will be reached around 2020; if the utility price grows by 4%, then retail rate grid parity will occur around 2024. It is not unlikely that utility prices will increase by more than 8% per year in the future, assuming that the economy picks up and large data centers or businesses move to Eugene. Regional drought, loss of water resources, and global warming are other possible factors that could contribute to rising utility prices. Of course, large scale solar PV deployment and high penetration of solar electricity in the grid (more than 10% to 20%) could lead to high retail utility price.

Sensitivity Analysis on FIT Rate Decrease

The future FIT rate decrease is projected based on the calculated FIT rate from the past five years (2007-2011) and has many inherent uncertainties related to the overall solar market and government policies. In order to address the uncertainties in the decrease rate, I employed a sensitivity analysis to illustrate how different FIT rate decrease could affect the time required for FIT rate to reach grid parity. In this case, I selected FIT rate decrease (without any incentives) at 3.9%, 6.5%, and 9.1% (see Figure 3.7).

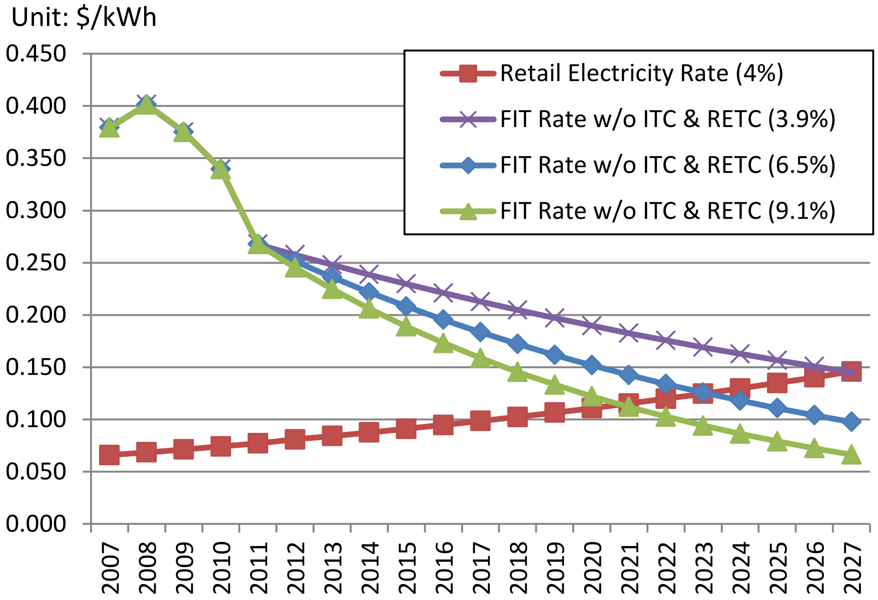

Figure 3.7: Projection of FIT Rate and Retail Rate Scenario 2

From Figure 3.7, we can see that the faster the FIT rate decreases, the sooner the FIT rate reaches grid parity. Given that utility price increases by 4% per year, if the FIT rate decreases by 3.9% annually, retail rate grid parity will occur around 2027; if the FIT rate decreases by 9.1%, retail rate grid parity will occur around 2020. The results are straightforward. Without any tax credits or utility cash grants, the decrease in FIT rate mainly comes from the drop in module price, balance of system, permitting and grid interconnection, system design, installation, and financing cost. Further drop in module price is still possible through improvement of supply chains and innovative production processes.[44]

Other factors, such as economy of scale, bulk purchase, community solar projects (e.g. Solarize Eugene), permitting, installation, and interconnection standardization could all contribute to further reduction of PV systems cost. There are also other ways to reduce the financing cost for solar systems, such as mortgage refinancing, loan guarantee programs,

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[44] Conversation with Ocean Yuan, president of GrapeSolar.

zero-interest loans offered by EWEB and the Energy Trust of Oregon, and Umpqua Bank's Green Street Lending Program.

Sensitivity Analysis on Tax Credits

It is also interesting to explore when retail rate grid parity will occur with consideration of ITC, and/or RETC. Although ITC and RETC will expire in 2016 and 2018, it is very likely either one or both of them will be renewed. With the help of ITC, retail rate grid parity will occur around 2020; with both ITC and RETC, parity will occur around 2018 (see Figure 3.8).

It is not surprising that federal and state tax credits help lower the FIT rate needed to ensure a 5% return on investment for solar investors over a 25-year period. The tax credits cover part of the project cost that would otherwise need to be shouldered by a higher level of FIT rate.

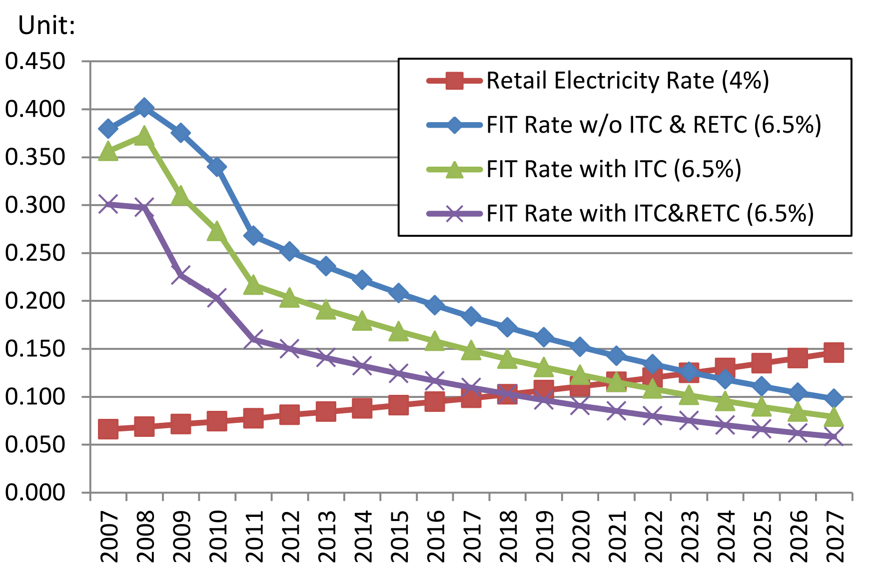

Figure 3.8: Projection of FIT Rate and Retail Rate Scenario 3

Sensitivity Analysis on Interest Rate

As mentioned in Chapter II, a typical residential solar investor needs a 5-year home equity loan of $15,000 to cover the upfront cost of a PV system. The interest rate that I used in this study is 6.5%. In order to determine the impact of different interest rates on the FIT rate, I selected interest rates of 0%, 3%, and 6.5% to calculate the FIT rate. From Figure 3.9, we can see that the higher the interest is, the higher the FIT rate needs to be to allow for a 5% ROI over a 25-year contract. Generally, the FIT rate with a zero-interest loan is 3.6 cents/kWh less than that with a 6.5% interest rate. Therefore, homeowners need to secure lower interest rate loans, such as those offered by the Energy Trust of Oregon, to bring down the FIT rate for a feed-in tariff program.

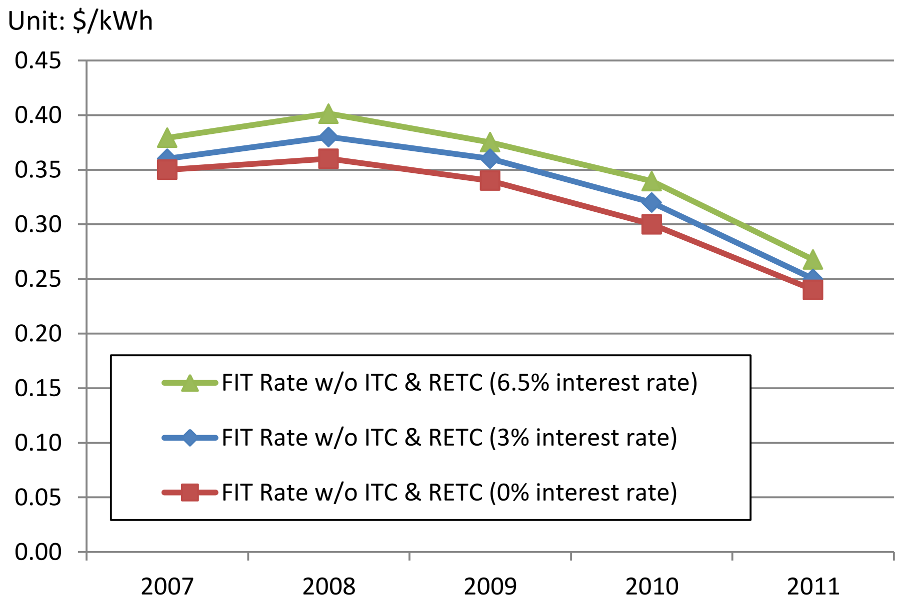

Figure 3.9: FIT Rate (without Incentives) and Interest Rate

Conclusion

Overall, between 2007 and 2011, there was a gradual shift from commercial direct generation to residential net metered solar PV programs in Eugene. Over the past five years, the average capital cost of residential PV systems, the average net capital cost, and the levelized cost of electricity generation have all witnessed continuous decreases. Clearly, the federal and State of Oregon tax credits (ITC, RETC) and EWEB incentives have played an important role in bringing down the cost of solar power. However, with the expiration of ITC and RETC in 2016 and 2018 respectively, the future of solar power application faces a lot of uncertainties.

By bypassing problems related to the uncertainty and the discontinuation of tax credits, a true feed-in tariff program offers utility companies and citizens a practical tool for promoting solar power. The FIT rate for residential PV systems has continued to decrease over the past four years. Still, the FIT rate for residential systems without any tax credits (27 cents/kWh) in Eugene in 2011 is still much higher than the current retail electricity price. However, based on the existing trend of FIT rate decrease rate and the current utility price increase rate, retail rate grid parity is likely to occur between 2020 and 2024 for residential solar PV systems. The particular amount of time needed to reach retail rate grid parity depends on many variables, such as utility price increase rate, FIT rate decrease, interest rate, continual cost reduction in modules and efficiency in production and supply chains. Higher utility price, lower PV systems cost, and lower financing cost will all help make solar electricity generation more viable and allow retail rate grid parity to occur earlier. A well-designed feed-in tariff program will drive down solar electricity cost and avoid the boom-bust cycles created by the uncertainties of federal and state tax credits. It is indeed feasible to employ a feed-in tariff program in Eugene and Oregon to promote the deployment of distributed solar PV generation.

Chapter IV: Conclusion and Discussion

With the constant drop in solar module prices since 2008 and the continuation of generous EWEB grants and federal and state tax credits, the number of residential-size solar PV projects has increased on a year-to-year basis between 2007 and 2011. Altogether, there were 136 residential net-metered solar PV projects put in service during that period of time, of which 121 were selected for this study. Using the average cost data from these projects, I have calculated levelized cost of electricity generation and FIT rate level for a feed-in tariff program with a 5% ROI over a 25-year contract. In addition, I conducted a sensitivity analysis to determine how interest rate, utility price increase, and projected FIT rate decrease will impact the time it takes for FIT rate to reach grid parity.

The data analysis results show that average capital cost and net capital cost in terms of dollars per watt experienced significant decreases over the last five years. In 2011, the average capital cost and net capital cost were \$6.06/Watt and \$1.55/Watt respectively, representing a 32% drop and 68% drop in prices compared to those in 2007. Due to the continuous decrease in PV systems cost, lucrative tax credits, and EWEB grants, more and more residents in Eugene have participated in the net-metered solar program offered by EWEB. In 2011 alone, there were 52 residential net-metered projects, double the number of projects established in 2010.

The levelized cost has been employed in this study to capture the marginal cost per kWh of solar electricity generation to solar PV investors and owners. It is defined as the net present value of the total cost divided by the total amount of electricity generated over the lifespan of a solar PV system. In this study, I calculated the net present value of electricity revenue, net present cost of operation and maintenance expenses, the present value of accumulated cost of capital, etc. The LCOE results show that between 2007 and 2010, an average solar PV system investor needed to pay an additional 2 cents to 15 cents per kWh generated. In 2011, for the first time, a solar investor was making a profit of about 2 cents per kWh generated. It is important to keep mind that the calculation of levelized cost employed data from a project with an average project cost, average incentives, and average size in each different year. The levelized results do not necessarily mean that all the generators in that year, on average, are making 2 cents/kWh profit. Overall, the LCOE without any incentive, LCOE with ITC, LCOE with ITC&RETC, and LCOE with ITC&RETC&EWEB grant all witnessed decreases over the last five years. This trend is important because it shows us that LCOE will eventually become even lower and make residential solar PV projects more economically viable.

It is important to be aware of the assumptions used in this study for the levelized cost calculation. As stated in Chapter III, I used an annual utility price increase of 4%, which is a very conservative estimate. The actual utility rate increase could be much higher, depending on the overall demand for power, energy cost, pricing of carbon, loss of regional hydro-power, and global warming. If a higher utility increase is used, then the solar electricity will be worth more, and the levelized cost could be lower.

In addition, the levelized cost results are conservative numbers because I assumed solar owners financed the upfront cost mainly through home equity loans, specifically 5-year

$15,000 loans with an APR of 6.5%. According to EWEB employees and solar installers, most of the solar electric systems were installed on owner-occupied housing units. Some solar owners used their savings and discretionary income to finance the upfront cost of their solar electric systems, which was generally less than $10,000 in 2012.[45] In such cases, the actual cost of financing could be much lower, thus making the levelized cost lower than the numbers I have provided. Without the cost of financing, the levelized cost is generally 3 to 4 cents lower than it would be otherwise. Even with conservative LCOE numbers, the results show that LCOE is decreasing rapidly each year.

In order to address the problems associated with tax credits as a way to finance residential PV projects, I have designed a 25-year feed-in tariff program with a 5% ROI over that time span. I have calculated the appropriate FIT rate needed to achieve that goal under three different policy schemes: FIT rate without tax credits, FIT rate with ITC only, and FIT rate with both ITC and RETC. I have included FIT rate calculations with ITC and RETC in case ITC and/or RETC get renewed in 2016 and 2018.

Generally, the calculation shows that FIT rate decreases in all three situations. Based on the calculated FIT rates from the last five years, I have projected the future FIT rate decrease under different scenarios. The sensitivity analysis shows that with utility prices increasing by 4% annually and FIT rate decreasing by 6.5% per year, retail rate grid parity is likely to occur around 2024. If utility prices increase faster, FIT rate decreases more, and interest rates remain lower, then grid parity will come at an earlier time, most likely around 2020. However, if FIT rate decreases slower at 3.9% and utility price increases by 4%, grid

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[45] One residential net-metered project proposal prepared by the Advanced Energy System shows that in March of 2012, initial cost to system owner was $9,961 for a 2.82 kW solar electric system.

parity might not occur until around 2027. Therefore, the results show that a well-designed feed-in tariff program with annual FIT rate adjustments based on the actual cost of solar electric systems will eventually make solar electricity reach grid parity with conventional electricity. Within another 8 to 15 years, FIT rate will drop to a level below retail utility electricity price. At that time, solar electricity generation would no longer need FIT rate or subsidies. Even though solar electricity generation cost would no longer fall after this point, consumers would continue to enjoy access to clean and cheap solar energy. The effect of tax credits in driving down the levelized cost is less clear. It is interesting to compare the role of tax credits, cash grants, and a feed-in tariff program in making solar energy cost effective.

I have proposed a feed-in tariff program to gradually replace the existing net-metering program based on the following rationale: 1. Overall, a feed-in tariff is a more efficient scheme to drive down solar cost, spur more innovation, and deploy more solar in scale than the cash grants and tax credits employed by the current net-metering program.[46] 2. Generators participate in a feed-in tariff for the right reasons rather than just to take advantage of tax credits and EWEB's upfront cash grants.[47] 3. A feed-in tariff program allows generators to receive annual FIT rate payment rather than a one-time large cash handout ($6000-$10,000 per net-metered project), and therefore, lowers the financial burden and risk to EWEB. There is no guarantee that a net-metered generator will keep their PV system in good condition so that it will continue generating electricity. On the other hand, a feed-in tariff participant will have incentives to take good care of their systems and keep feeding electricity back to the grid

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[46] Commission of the European Communities. 2008. "The support of electricity from renewable energy sources," http://ec.europa.eu/energy/climate_actions/doc/2008_res_working_document_en.pdf (accessed May 10, 2012)

[47] This point is based on conversation with Colleen Wedin, Energy Management Specialist at EWEB, who oversaw EWEB's residential and commercial net-metered programs.

to receive the FIT rate. There are also other justifications for implementing a feed-in tariff program. Please see the following section for more details.

Tax Credits and Grants versus a Feed-in tariff

Tax credits are given out to applicants with federal and/or state tax liability regardless of the average project cost and project competitiveness. ITC covers 30% of the total project cost and RETC awards $2.1/Watt DC with a cap of $6,000. The more a project costs, the more federal tax credits an investor will get. Similarly, RETC indiscriminately awards tax credits to solar PV investors who have State of Oregon tax liability. In this way, more tax credits may have been unintentionally awarded to less cost-effective and less economically viable projects. This may have contributed to a waste of tax revenue and a slower pace in driving down solar project cost. Ideally, more tax credits should be directed to cost-competitive projects, and average cost ($/Watt) should be one of the approval criteria. [48]

In addition, tax credits are structured in such a way that they favor people with federal and state tax liability, who are more likely to be wealthier. Individuals without tax liability or with little tax liability cannot take advantage of tax credits. Such a policy is neither fair nor efficient in allocating funds to ordinary households that need assistance in acquiring solar electric systems.

On the other hand, a feed-in tariff in lieu of federal and state tax credits is a preferred method that truly selects and promotes cost-effective solar projects. It is also a much more equal and accessible way of financing solar projects. The FIT rate established in a FIT acts

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[48] Based on conversation with Joshua Skov, principal of Good Company, I would like to thank him for this bright observation and suggestion.

like a filter that discourages solar projects with high levelized cost while offering incentives to projects with lower levelized cost. The FIT is also much more equitable in the sense that one does not need to have tax liability to participate in this program. Renters and homeowners without suitable rooftops could possibly participate in a community solar program or other solar cooperative programs.

Furthermore, a feed-in tariff establishes a long term contract with solar PV investors, and thus offers a guaranteed return on investment and lowers the risk, whereas tax credit renewal is subject to the vagaries of political atmosphere and change of administration. Unfortunately, political changes create a lot of uncertainty for investors who wish to make long term plans and investments. Policy uncertainties increase investment risks and discourage investment in solar projects. On-and-off tax credit policy could also create boom and bust cycles in which investors rush to apply for tax credits before expiration and halt investment after tax credits expire.

Upfront incentives or cash grants may not be as effective as a feed-in tariff program to drive down technological cost, encourage innovation, or spur broader market adoption of solar energy.[49] Currently, the EWEB incentives program offers a maximum $6,000 cash grant or $10,000 (before 2012) to citizens who undertake residential net-metered solar PV projects. Only a limited number of project participants can receive these grants. Colleen Wedin, an energy management specialist at EWEB who oversees EWEB's cash grants program for residential and commercial solar programs, commented that some homeowners participated in

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[49] Lantz, Eric, and Elizabeth Doris. 2009. *State clean energy practices renewable energy rebates*. Golden, CO: National Renewable Energy Laboratory. http://purl.access.gpo.gov/GPO/LPS123866.

EWEB’s net-metering programs just to take advantage of the cash grants and tax credits. Projects undertaken for such a reason might not be cost effective and might not be well maintained so as to ensure optimal output. A feed-in tariff program only pays a solar PV owner when electricity has been produced, and it offers incentives for a PV owner to maintain the system and ensure optimal electricity output. In short, cash grants might not be well utilized to produce electricity because there is no follow up after cash grants have been given out to make sure that the system continues working for 10 to 20 years. A feed-in tariff program offers generators incentives to maximize their output and lower their cost. Other research also supports the notion that a feed-in tariff program works better to drive down cost and spur innovation and encourage deployment. A report completed by the Commission of the European Communities shows that “well-adopted feed-in tariff regimes are generally the most efficient and effective support schemes for promoting renewable electricity.”[50] Another report from Deutsche Bank shows that “appropriately-designed and budgeted feed-in tariffs have demonstrated their ability to deliver renewable energy at scale.”[51]

A feed-in tariff program based on the changing levelized cost and a 5% ROI will help drive down the FIT rate over time. Hypothetically, if an investor participated in a FIT in 2011, then his or her project would have been locked in the FIT rate of that year for 25 years. Similarly, if one participates in the FIT in 2013, then his or her project will be locked in the FIT rate offered in that year. FIT rate will be adjusted periodically to reflect the cost of solar

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[50] Commission of the European Communities. 2008. “The support of electricity from renewable energy sources,” http://ec.europa.eu/energy/climate_actions/doc/2008_res_working_document_en.pdf (accessed May 10, 2012)

[51] Deutsche Bank. 2009. “Global climate policy tracker: an investor’s assessment,” http://www.dbcca.com/dbcca/EN/_media/Global_Climate_Change_Policy_Tracker_Exec_Summary.pdf (accessed May 12, 2012)

PV systems. Overall, the FIT is much more transparent, predictable, and efficient compared to tax credit options. Therefore, a feed-in tariff program is much more suitable and effective in promoting the deployment of residential solar PV projects.

Nonetheless, feed-in tariff does have its own limitations that need further investigation. A FIT program does not address the problem of financing the high upfront project cost. It offers a flow of guaranteed income over a long period of time. It is generally assumed that the long term contract and stable cash inflow will help secure long-term debt financing.[52] Future research should look into this possibility and other mechanisms to address the high upfront cost issue.

In addition, solar deployment experience from Spain and other jurisdictions shows that fixing the FIT rate or announcing decrease in FIT rate in advance could lead to overheating in project subscriptions. If FIT rate goes down significantly, the number of participating programs may decrease rapidly. To prevent potential boom-bust cycles associated with a feed-in tariff program, FIT rate should be designed in a way that reflects changing system costs in a predictable way: by announcing a schedule for regular FIT rate review and by linking FIT rate changes with the deployment volume.[53] Policy makers can also set a cap on the volume of solar deployment at a certain range of FIT rates or refer to the German "breathing cap" mechanism.[54] In Germany, the FIT rate degression is linked to the

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[52] Couture, Toby, and Karlynn S. Cory. 2009. *State Clean Energy Policies Analysis (SCEPA) project an analysis of renewable energy feed-in tariffs in the United States*. Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy09osti/45551.pdf.

[53] International Energy Agency, and Organisation for Economic Co-operation and Development. 2011. *Deploying renewables 2011: best and future policy practice*. Paris: OECD/IEA.

[54] *Ibid*.

deployment volume. If deployment exceeds a certain volume, then FIT rate will be cut; if deployment does not meet planned volume, then FIT rate will increase accordingly. Overall, there are many different policy schemes that could be used in combination to avoid the boom-bust cycles associated with a feed-in tariff program.

Besides, large scale solar deployment may lead to rate increase, as rate payers need to pay more for solar electricity before further reduction in system cost makes solar electricity competitive with conventional electricity. I would recommend that EWEB gradually transform its current cash grants program to a feed-in tariff program paid by EWEB's Green Power funds. In this way, there will be no rate impact on average rate payers. If after another five to ten years solar PV system costs decrease significantly, or if the community as a whole agrees to pays more for solar electricity, the feed-in tariff program can be deployed on a larger scale.

Challenges and Limitations

Although solar PV technology was first explored many decades ago, the solar PV industry is still in its nascent stage. Many of the interviewees for this study identified the high upfront cost of solar PV systems as the main barrier to residential solar project deployment. It is beyond the scope of this study to delve into the complexity and messiness of different financial tools and schemes to finance solar projects.

Interested readers could refer to Couglin and Cory's (2009) report "Solar Photovoltaic Financing: Residential Sector Deployment"[55] and Coughlin and Kandt's (2011) report "Solar schools assessment and implementation project: financing options for solar installations on K-12 schools" for more details.[56] Couglin and Cory (2009) identify three new financial models: 1. Third-party ownership models; 2. Property Assessed Clean Energy (PACE) assessments; and 3. Renewable Energy Certificates (RECs) values. In third-party ownership models, a solar company, such as Solar City, leases a homeowner's rooftop and pays the owner a certain amount of benefit per month or year. This scheme is mainly used to take advantage of tax credits that otherwise cannot be used by residents. Property Assessed Clean Energy (PACE) assessments allow solar investors to pay solar electric system costs through property tax payments. Finally, solar electric system owners can sell Renewable Energy Certificates (RECs) to offset system costs. RECs "are a documented record of the generation of environmentally responsible, sustainable electricity".[57] Future studies should look into these new types of financing schemes to assess their effectiveness in promoting solar projects deployment.

This study did not address the technological, logistical, and energy storage issues related to solar energy. As pointed out in Chapter I, solar PV technology has its own limitations that may constrain the fast deployment of solar even if the financing problem is resolved. We know that solar energy is intermittent, and the storage of electricity by battery is

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[55] Coughlin, Jason, and Karlynn S. Cory. 2009. *Solar photovoltaic financing residential sector deployment*. Golden, CO: National Renewable Energy Laboratory. http://purl.access.gpo.gov/GPO/LPS112153.

[56] Coughlin, Jason, and Alicen Kandt. 2011. *Solar schools assessment and implementation project financing options for solar installations on K-12 schools*. Golden, CO: National Renewable Energy Laboratory. http://purl.fdlp.gov/GPO/gpo15618.

[57] EWEB. "Renewable Energy Credits (RECs)". http://www.eweb.org/greenpower/recs (accessed April 28, 2012)

still expensive. Moreover, this study does not address broad issues such as a potential global shortage of silicon in the face of large-scale global solar application. The impact of higher penetration of solar projects on the grid, the environment, and global supply chains should not be overlooked and needs further study. This study also does not address potential issues related to a feed-in tariff program such as rate impact, upfront cost financing, and energy conservation. Future study should investigate these issues and make policy recommendations to address them.

Future Study

Future study should look into the issues raised above, such as new and creative ways to finance solar projects and other public finance options, the impact of solar electricity on the grid, energy storage and demand management, rate impact, energy conservation, and the impact of panel manufacturing on the environment and global resources supply.

In addition, future research should also explore community solar projects that enable renters and homeowners without appropriate rooftops to participate in solar energy projects. Examples of community solar projects include community solar programs at the City of Ashland in Oregon and City of Ellesburg in Washington, solar cooperatives, and "virtual net-metering".[58] Again, interested readers can refer to presentations on these topics posted on the Oregon Future Energy Conference website (http://www.futureenergyconference.com). This conference covered topics on energy efficiency and storage, smart grids, feed-in tariff

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[58] Refer to "Aggregation and Community Ownership Models for Solar", Future Energy Conference, Portland, Oregon, April 25-28, 2012.

programs, renewable energy finance, etcetera. I believe that this is a good resource for interested readers to learn about these emerging fields.

Recommendations

Based on the statistical analysis and interview results, I have made the following recommendations to further promote solar development in Eugene and Oregon.

1. EWEB shall consider abandoning its current cash grant program and establishing a 25-year feed-in tariff program for residential solar projects with a 5% ROI. The FIT rate will be adjusted to reflect the actual system cost. For 2012, the FIT rate could be set at 15 cents/kWh with the availability of ITC and RETC. FIT rate needs periodic review to reflect the changing cost. EWEB could use the funds from the Green Power program to pay solar PV owners annual FIT rate over a 25-year period rather than one time upfront cash handout.
2. Encourage more customers to sign up for EWEB's Green Power program. Customers only need to pay a couple of cents more for each kWh of electricity they use per month. The Green Power fund is used by EWEB to finance solar programs.
3. Educate city officials, city building inspectors, and citizens on the basics of solar electric systems' costs and benefits, and how solar PV works.
4. Initiate dialogue with homeowners, renters, and other stakeholders to build consensus on how much solar power they want and how much they are willing to pay.
5. Reduce the solar programs transaction cost by streamlining the approval process, encouraging group purchasing, solar cooperatives, and other community based solar programs.

6. The City of Eugene shall consider establishing an information and service center to facilitate participation in solar programs. The Center shall serve as an information hub where interested residents, solar installers, and financial institutions could exchange supply and demand information.

The Debate on Our Energy Future

We are anticipating and hoping to enter a new industrial revolution age powered by innovations in renewable and clean energy. The decisions that we are making today on what kind of energy resources to replace fossil fuels will have long lasting impacts on our economy, society well-being, and whole human civilization. This generation faces its own unique opportunities and challenges in moving solar energy deployment forward. On one hand, the general public's awareness and support for a clean energy future is growing, new EPA regulations made building new coal plants much more difficult. On the other hand, we are facing unprecedented natural gas prices. As of March of 2012, the commercial natural gas price was only $8.46 per thousand cubic feet.[59] The sudden increase in shale gas extracted through the hydraulic fracturing process has changed the U.S. energy market in profound ways.[60] The availability of large deposits of cheap natural gas has posed challenges to renewable energy deployment.

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[59] Energy Information Administration (EIA), "Natural Gas Prices", http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm (accessed May 20, 2012)

[60] Gold, Russell, "The Siren Song of Natural Gas," *Wall Street Journal*, March 26, 2012, http://online.wsj.com/article/SB10001424052702304636404577301111353242458.html (accessed April 27, 2012)

There has been a growing debate on whether we should build more gas power plants or invest in renewable energy sources to replace traditional fossil fuels. One idea is that we could use natural gas plants as a bridge energy source before relying on large scale solar PV deployment (Podesta and Wirth 2009, Moniz 2010, Ragheb 2012). Though this suggestion seems to have some merit, it poses the risk of postponing real and much-needed energy restructuring indefinitely. Gold (2012) poses the important questions, "is gas still a bridge or a detour? Will it keep renewables from reaching viability that much longer?" One thing is certain: even shale gas will eventually be depleted, and will be depleted much faster if more gas plants are built. Additional gas plants will certainly drive up natural gas demand and price.[61] In addition, shale gas is not carbon free; according to Howarth et al. (2011), "3.6% to 7.9% of methane from shale-gas production escapes to the atmosphere in venting and leaks over the lifetime of a well". The global warming effect of methane is about 105 times greater than that of CO2 (Shindell et al. 2009). When gas becomes expensive after we have already invested huge amounts of capital in the natural gas infrastructure, we will be held hostage by the locked capital. Thus, gas would eventually cause the same problems we are facing with coal today.

Therefore, it is essential that we push the envelope and rethink energy issues in a holistic way, and from a long term perspective. In addition, we need to treat energy conservation as part of the overall energy portfolio. We should engage with diverse constituents to participate in a sincere dialogue about our energy future.

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[61] Based on conversation with Robert F. Young, assistant professor at the University of Oregon.

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Appendices:

Appendix A: Interview Questions

1. Do you think that a carbon tax will significantly help deploy solar PV in Eugene in the next 20 years? What other policies need to be changed or made to help deploy solar PV?

2. What creative funding strategies do you think that EWEB or any other institutions need to adopt to facilitate solar PV in Eugene and Oregon?

3. What do you think of the prospect of a community solar program in Eugene in terms of energy accessibility, equity, and cost?

4. Do you see solar PV as feasible in terms of long-term (2030) cost-benefit analysis in the City and the State of Oregon? When do you think that solar electricity will reach grid parity in terms of levelized cost of solar technologies?

5. What are the barriers to promoting solar PV in the City and the State of Oregon in terms of financial cost, political will, and community acceptance? What are the key market and policy-based drivers for residential rooftop PV markets in the greater Eugene area?

6. Do you think that levelized cost of electricity generation is an appropriate indicator to assess the cost-effectiveness of solar PV? Why?

7. Overall, what needs to happen to successfully promote Solar PV in the City and the State of Oregon? Please share any thoughts you have on this issue.

8. Is there anything that I have not asked you, that I should?

Appendix B: Current EWEB Net Metering and FIT Programs[62]

Direct Generation

For systems ranging from 10 kilowatts (kW) to 1,000 kW, you have the option to connect your system directly to the EWEB grid and sell all of the electricity generated to EWEB.

We will install a dedicated meter and contract with you to purchase all of the electricity generated. If you have electric usage at your site, all of it will be supplied by EWEB through your existing meter.

Direct generation incentive*

Summer (April through September billing cycles)
First 45,000 kWh per month..........................$0.11 per kilowatt hour (kWh)
Over 45,000 kWh per month........................$0.071 per kWh

Winter (October through March billing cycles)
First 30,000 kWh per month..........................$0.11 per kWh
Over 30,000 kWh per month........................$0.071 per kWh

* These rates have been extended through March 31, 2012. New rate information will be available soon. All terms subject to annual review.

Program requirements

The most important requirement is to contact EWEB early in the process before starting construction of your system. Additional steps before installation include:

- Obtain a building permit for the system, which must be installed within EWEB's service territory.
- Submit the appropriate program application and receive approval.
- Complete an EWEB Interconnection Agreement and Program Agreement.

Upon completion of the project, all systems must be inspected first by City or County building officials and then by EWEB.

Net Metering

If the photovoltaic system is installed on your side of EWEB's electric meter, the electricity will be used in your home or business first.

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[62] See EWEB website. http://www.eweb.org/solar/directgeneration (accessed April 4, 2012).

If your electric usage is greater than the PV system can produce, the rest is supplied by EWEB.

When your usage is less than your PV system generates, the excess electricity flows through your electric meter into the EWEB electrical grid. EWEB will credit your account for any generation in excess of what you use. You retain the renewable energy credits.

Incentives

Effective January 2012, the incentive rates for the PV net metered program are:

- Residential systems: $1.70 per AC output watt up to $6,000
- Commercial systems: $1.00 per AC output watt up to $20,000

All terms are subject to annual review. Incentives are based on the electrical output of the system after equipment and site losses are calculated. Incentive payments for net-metered systems will be made after the system has received final approval from EWEB.

Program requirements

The most important requirement is to contact EWEB early in the process before starting construction of your system. Additional steps before installation include:

- Review the new application process instructions below.
- Obtain a building permit for the system, which must be installed within EWEB's service territory.
- Submit the appropriate program application and receive approval.
- Complete an EWEB Interconnection Agreement and Program Agreement.

Upon completion of the project, all systems must be inspected first by City or County building officials and then by EWEB.

NEW application process

A new application process was introduced in 2012 that includes a reservation system for net metered incentives. The table below provides a summary of the reservation periods. Please carefully read the bulleted notes about the process to help facilitate a successful application:

UPDATE (Feb. 6): The first reservation period for EWEB's net metered program is now fully subscribed. We will accept applications for the next reservation period beginning April 16, 2012. Please do not apply early, as EWEB cannot hold applications. Read more about the new reservation process, which started in 2012. Any changes to the process will be posted on this page.

Reservation period	Project completion deadline	Funding limit for incentives
1: Jan. 9 - April 15	May 15	$65,000 (Fully subscribed as of Feb. 6, 2012 - Not accepting applications until Period 2)
2: April 16 - Aug. 15	Sept. 15	$120,000
3: Aug. 16 - Dec. 1	Dec. 15	$70,000

- Applications will only be accepted through an official mail delivery system such as the U.S. Postal Service, Fed Ex, UPS or similar service (hand delivery or email will not be accepted).
- Mail applications and supplemental information to:
  EWEB Energy Management Services
  ATTN: Solar Electric Program
  PO Box 10148
  Eugene, OR 97440-2148
- Reservations are made in the order that applications are postmarked. Priority will not be given to any customer or contractor.
- Applications must be postmarked on or after the first day of each reservation period.
- Incomplete applications will be returned to the customer unprocessed.
- Monies not allocated within a funding period will carry over to the next period.
- Applications will not be processed if we have reached the funding limit for that reservation period. If this occurs, the applications will be returned to the applicant for future submission.
- Customers that do not meet the 85% total solar resource fraction are still eligible for net metering and interconnection, but are not be eligible for the incentive funds. These customers may apply at any time, and are not subject to the reservation process.

Appendix C: Current EWEB Residential Electric Rate (April, 2012)[63]

Electric rates - Residential service

Basic charge	$9.00 per month
Delivery charge	2.887 cents per kWh

Energy charge, Winter (November through April billing cycles)

First 800 kWh	4.834 cents per kWh
Next 2,200 kWh	6.507 cents per kWh
Over 3,000 kWh	7.747 cents per kWh

Energy charge, Summer (May through October billing cycles)

First 800 kWh	4.834 cents per kWh
Next 900 kWh	6.507 cents per kWh
Over 1,700 kWh	7.747 cents per kWh

Residential service example
assumes energy consumption of 1,050 kWh:

Basic charge	$9.00
Delivery charge	
1,050 kWh x 2.887 cents	$30.31
Energy charge	
First 800 kWh x 4.834 cents	$38.67
Next 250 kWh x. 6.507 cents	$16.27
Total electric bill	**$94.25**

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[63] See EWEB website. http://www.eweb.org/electricrates/residentialservice (accessed April 5, 2012)