

THE IMPACT OF THE FINANCIAL INCENTIVES ON RESIDENTIAL AND  
COMMERCIAL PHOTOVOLTAIC SYSTEMS IN ARIZONA

by

SIYUAN JIANG

(Under the Direction of Jeffrey D. Mullen)

ABSTRACT

Arizona has adopted financial incentives to encourage the adoption of solar energy technology. This study presents an economic analysis of state and federal financial incentives, including tax incentives on the Net Present Value (NPV) of residential and commercial photovoltaic systems, and evaluates the elasticities of NPV with respect to financial parameters. Measuring the effects of tax credit and exemption programs on NPV in Arizona, and the elasticities of NPV concerning financial incentives provides information on the efficacy of these programs. The analysis results of this thesis could contribute to the improvements in the U.S. solar policies. The results indicate that state income tax credit and property tax exemption impact more on solar energy technology. The analysis results of this thesis could contribute to the improvements in the U.S. solar policies.

INDEX WORDS: Tax Incentive, Financial Incentive, Solar energy policy, Log-log  
Regression, Net Present Value

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## DEDICATION

I would like to dedicate this thesis to my parents, my grandmother, my husband and my older sisters, for their love and support in allowing me to go so far.

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## CHAPTER 1

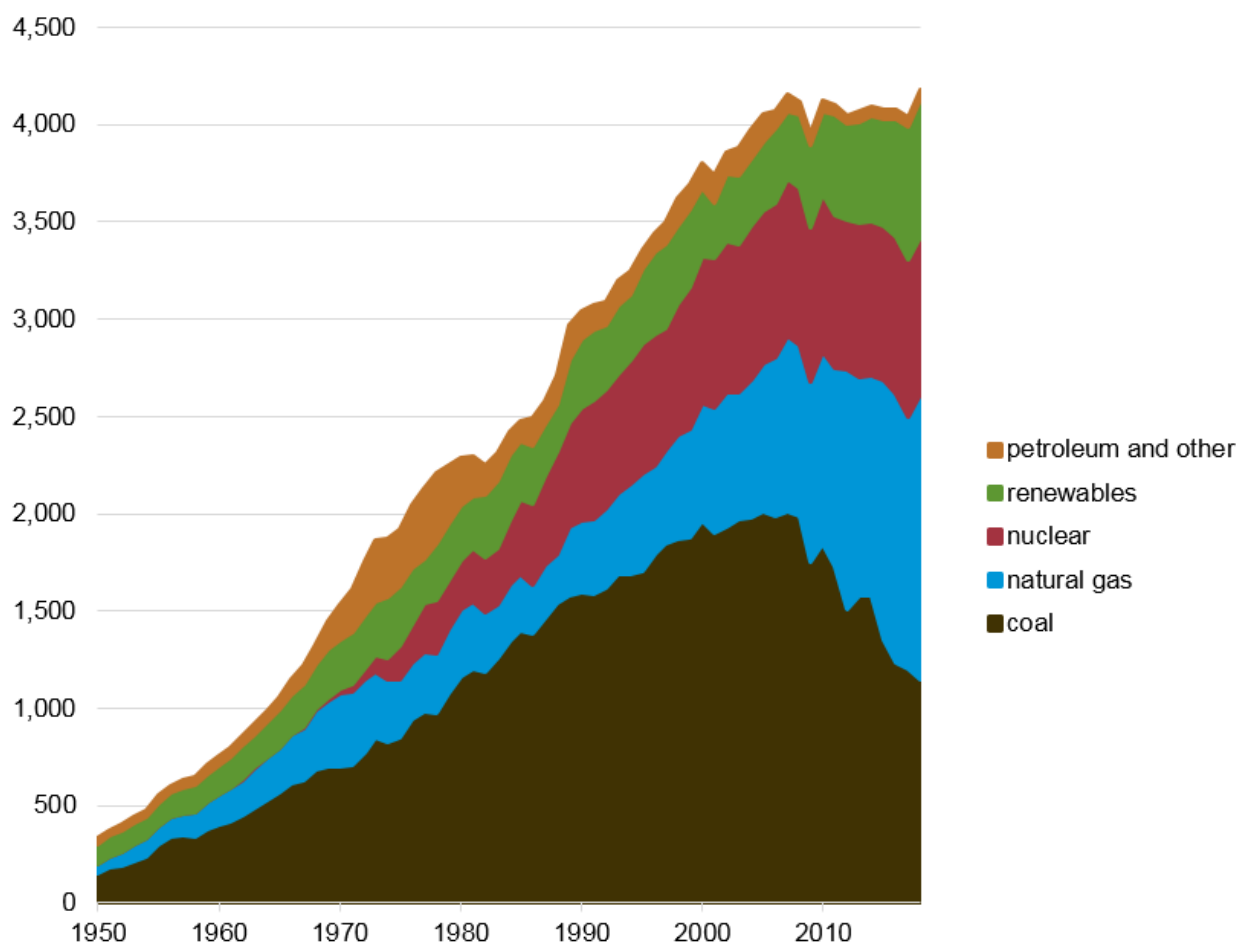
### INTRODUCTION

Electricity consumption is predicted to comprise an increasing share of the global demand for energy over the next two decades (Abolhosseini 2014). The growth rate of electricity consumption are also expected to exceed other sources of energy, including liquid fuels, natural gas, and coal (Hassett 1995).

Many different energy sources and technologies are used to generate electricity in the United States. The sources and technologies have changed over time with more general adoption of some specific sources and technologies in a particular period. Three major categories of energy to generate electricity are fossil fuels (including coal, natural gas, and petroleum), nuclear energy, and renewable energy sources. Fossil fuels are the largest source of energy for electricity generation. In 2018, 35% of U.S. electricity was generated by natural gas, 27% by coal, and nuclear energy provides another 19%, renewable energy sources provide nearly 20% of U.S. electricity, with solar energy accounting for about 2% (U.S EIA). Photovoltaic (PV) and solar-thermal power are the two main types of solar electricity generation technologies. PV conversion produces electricity directly from sunlight in a photovoltaic cell.

## U.S. electricity generation by major energy source, 1950–2018

billion kilowatthours



Note: Electricity generation from utility-scale facilities.

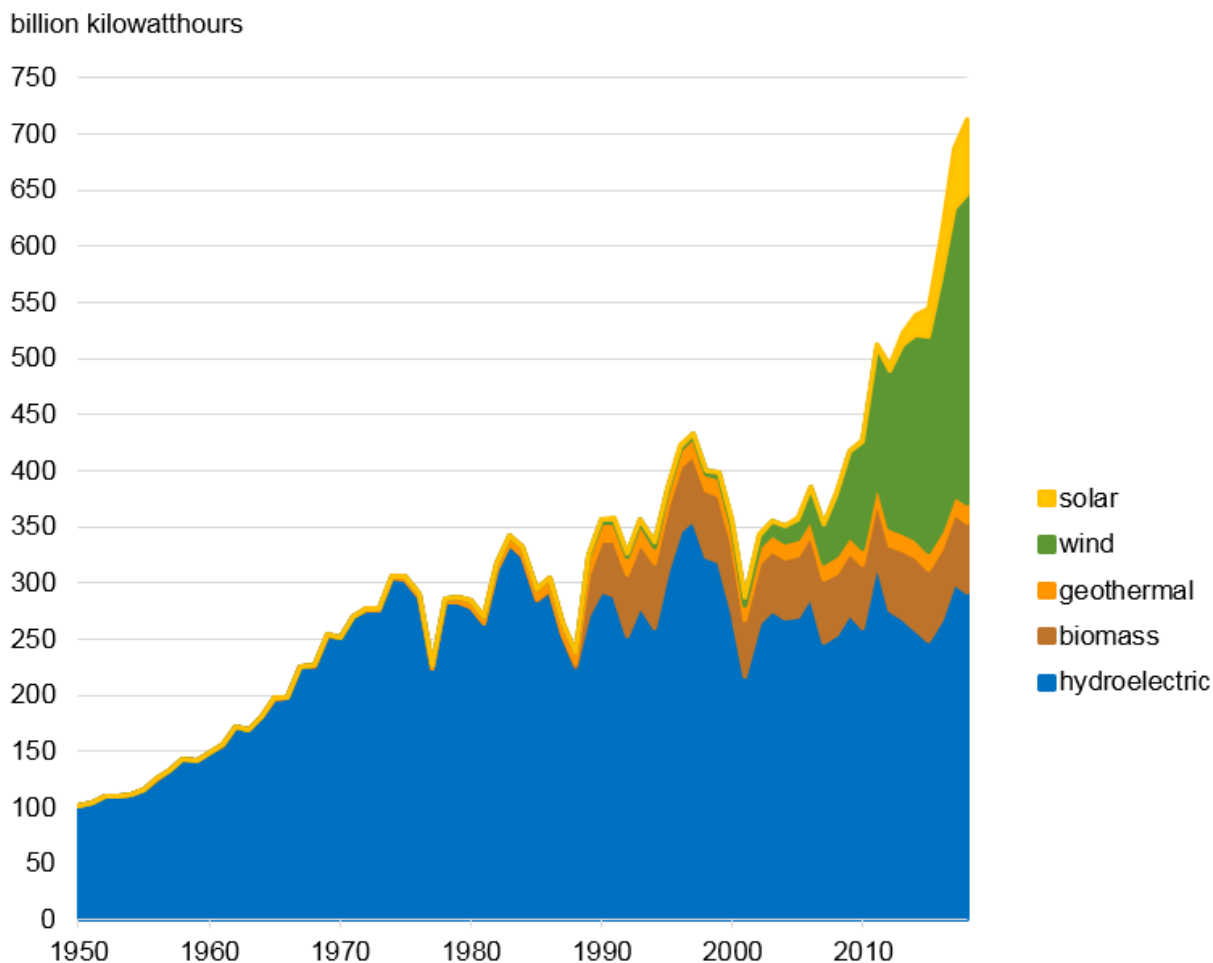
Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 7.2a, March 2019



Source: U.S. Energy Information Administration (EIA)

Figure 1 Source of U.S. electricity generation, 2018

## U.S. electricity generation from renewable energy sources, 1950–2018



Note: Electricity generation from utility-scale facilities. Hydroelectric is conventional hydropower.

Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 7.2a, March 2019



Source: U.S. Energy Information Administration (EIA)

Figure 2 Source of U.S. electricity generation from renewable energy, 2018

## 1.1 Greenhouse Gas (GHG) Emissions

Considering that the global climate change has become a severe issue, great efforts have been taken aimed at reducing GHG emissions world widely. Greenhouse gas (GHG) emissions associated with the widespread consumption of fossil fuels are having a profound effect on climate patterns in the U.S. and around the world. Many renewable energy resources, including solar, wind, and biofuels, are becoming leading technologies for a sustainable energy supply and are poised to play a significant role in shifting away from over-reliance on traditional hydrocarbon resources

In 2017, total gross U.S. greenhouse gas emissions were 6,456.7 MMT, or million metric tons, of carbon dioxide (CO<sub>2</sub>) Eq. Total U.S. emissions have increased by 1.3 percent from 1990 to 2017, and emissions decreased from 2016 to 2017 by 0.5 percent (35.5 MMT CO<sub>2</sub> Eq. (U.S. EPA 2017). As the largest source of U.S. greenhouse gas emissions, CO<sub>2</sub> from fossil fuel combustion has accounted for approximately 77% of GHG emissions since 1990. The reduction of carbon dioxide emissions from fossil fuel consumption can help to control the total greenhouse gas emissions.

Recently, with the declining costs of renewable energy sources, electricity generated from renewable resources in the U.S. increases and the shares of coal decreases. U.S. EIA 2019 Outlook 2019 predicted that the share of coal would drop to 17% of total electricity generated by 2050 from 28% in 2018, and the share of renewable energy would increase to 31% from 18% in 2018 (U.S. EIA Outlook 2019). Solar energy as an alternative source to produce electricity, could not only help to reduce GHG emissions and its negative impact on the environment, but also maintain the stability of fossil fuel prices. The declining costs and improving performance make solar energy increasingly competitive compared with other renewable resources. In

addition, new solar installations can be incentivized through federal and state tax credit programs. However, Solar Investment Tax Credits (ITC) will phase-down after 2024. But using solar energy to generate electricity are expected to continue due to the continuous declining of the costs for solar installation (U.S. EIA 2019).

Producing electricity from renewable energy sources rather than fossil fuels could not only significantly benefit public health, but improve environmental quality. The air and water pollution emitted by coal and natural gas plants are linked to breathing problems, neurological damage, heart attacks, and cancer (Machol, 2013). Replacing fossil fuels with alternative energy has been found to reduce mental illness and overall healthcare costs (Machol, 2013).

## 1.2 State and Federal Renewable Energy Policies

There are three main types of support mechanisms applied to expand the renewable energy market, including feed-in-tariffs, tax incentives (including subsidies and tax deductions), and tradable green certificates. Direct supports paid to producers or consumers have not been considered because renewable energy market creation has been the main target of state and federal government programs. Tax policies have been aimed at encouraging solar installations both to residential and commercial properties.

As both federal and state government tax credits, have been implemented, with some about to expire, it becomes meaningful to question how effective have these policies been, and what is the likely impact of their expiration?

The federal level subsidy, which is known as the Solar Investment Tax Credit (ITC), covers 30% of the investment in a PV installation from federal taxes, but only after deducting the value of state rebates. The ITC applies to both residential and commercial systems, and there is

no limit on its amount. However, this credit is scheduled to step down from 30% at the end of 2019, the tax credit for systems in service will drop to 26% in 2020, and decline further to 22% in 2021. In 2022, there is no federal credit for residential systems, and the credits will drop to 10% for commercial solar energy systems (SEIA ITC, 2018).

At the state government level, taking Arizona as an example, there are three types of subsidy for residential solar systems in Arizona: 1) Residential Solar Energy Systems Tax Credit, which includes the Arizona Income Tax Credit of 25% to a maximum of \$1,000; 2) Sales Tax Exemptions where Arizona provides a sales tax exemption for the retail sale of solar energy devices and the installation of solar energy devices by contractors; 3) Property Tax Exemptions, for property tax assessment purposes, the solar energy devices are considered to add no value to the property (NC Clean Energy- DSIRE).

Also, there are four types of subsidy for commercial solar systems: 1) Sales Tax Exemptions; 2) Property Tax Exemptions; 3) Production Tax Credit, which equals \$0.01 to \$0.04 (varies by year) per kilowatt-hour (kWh) for the first 200,000 megawatt-hours (MWh) of electricity produced in a calendar year for a period of ten years at a maximum of \$2 million per year (the tax credit for PV systems varies depending on the year of electricity production according to a schedule); 4) Non-residential Solar Tax Credit, the maximum credit per taxpayer is \$25,000 for any one building in the same year and \$50,000 in total credits in any year (NC Clean Energy- DSIRE).

### 1.3 Arizona Solar Energy Consumption

The utility-scale solar photovoltaic (PV) power plants in the United States operated at about 25% of their electricity generating capacity, based on an average of annual values from

2014 through 2017, and Southwestern states have better solar resources and higher solar PV capacity factors (U.S. EIA 2019). Arizona has abundant solar radiation, and its utility-scale solar PV plants performed better than those in any other state. It has achieved a 29.1% capacity factor from 2014 through 2017, and Arizona's installed utility-scale solar PV capacity was 1.7 gigawatts (GW) at the end of 2017, which is about 7% of the national total. Also, the electricity generation in Arizona from solar energy exceeded production from hydroelectric power, which makes the state ranked second in the nation in total solar generation in 2017 (U.S. EIA 2019). The large electric utilities in Arizona currently offer tax incentives for the installation of solar devices, including photovoltaic (PV) systems for both residential and commercial buildings.

#### 1.4 Objectives and Hypothesis

This paper assesses the economic impact of the anticipated ITC step-down and state level tax incentives on individual and commercial PV-solar installations at varying scales in Arizona, under various market conditions. In particular, the primary objective of this paper is to evaluate the main financial factors that can affect the costs and returns to solar power systems in Arizona, including sell rate, inflation rate, debt fraction, loan rate and loan term. Given that, this study will estimate the elasticities of Net Present Value with regard to these economic and physical parameters. The hypothesis in this paper is both residential and commercial solar electricity generation can provide positive financial returns on investment, with proper financial and physical parameters combined with the available tax credit. Also, this paper hypothesizes that the state and federal incentives are needed, and tax incentives play more important role on the solar installations for the residential property. The results from this study would be interpreted by

constructive economic figures and provide significant suggestions to the residential and commercial solar installation choices in Arizona.

### 1.5 Overview

The rest of the thesis is organized in the following order. In the next chapter is the literature review about U.S renewable energy policies, photovoltaic systems, federal solar energy subsidy, and the solar energy tax policy programs in Arizona. The third chapter provides an overview of the data and methodology for evaluating the economic effects on the individual and commercial photovoltaic energy systems. The fourth chapter presents the results of the economic feasibility study of photovoltaic installations and financial models for Arizona. And finally, conclusions have been presented.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Renewable energy policies

To increase the contribution of renewable energy to the total energy supply, local, state and federal governments need to develop policy initiatives to establish short and long-run objectives. In the United States, these initiatives have included financial incentives, technical assistance and regulatory policies. These approaches have evolved in response to technology advances and cost reductions, increasing the shares of renewable energy sources in total energy generation.

Financial incentives have been widely implemented by governments to encourage the market deployment of renewable energy technologies and practices. There are three common financial incentives have used to promote renewable energy technologies ranging from large-scale commercial renewable energy systems to small-scale residential solar installations: 1) tax measures, including tax deductions or credits, and tax exemptions; 2) rebates, grants, and performance-based incentives, which provides a direct cash incentive to support renewable energy and do not require repayment; 3) loan programs, guarantees, and credit enhancements, which provides lower interest loans and reduces loan risks for renewable energy technologies and projects (Cox, S. 2016).

Corporate and personal income tax incentives, property tax incentives, sales or value-added tax (VAT), and accelerated depreciation are the common tax measures have been applied to support renewable energy deployment. Corporate and personal income tax incentives are tax

credits or deductions, corporate investment tax credits are based on initial cost of renewable energy systems, while production tax credits depend on the actual energy production. Personal income tax incentives are based on investment or cost of a renewable energy technology or system. Property tax incentives reduce or eliminate taxes related to the property improvements, and sales or VAT tax incentives reduce or exempt sales or VAT taxes for renewable energy systems. The accelerated depreciation accelerates the fixed asset depreciation for renewable energy through reducing taxable income and deferring tax liability (Gouchoe, S. et al., 2002).

In addition to tax measures, rebates are applied to discrete purchases such as appliances, vehicle purchases, and on-site renewable energy systems, and they are provided after purchase or installation. Grants are usually provided before a technology is installed or after a system is under full operation through local governments, utilities or non-profits. Performance-based incentives support renewable energy systems based on performance (Cox, S. 2016).

With regard to loan incentive programs, subsidized traditional revolving loans provide a loan loss reserve fund to reduce loan interest rates. Mortgage loans provide funding for small-scale systems and green banks provide loans through public-private partnerships and innovative financing approaches.

Comparing to the former financial incentives, there are less studies in the technical assistance, the technical assistance for supporting renewable energy including direct advice on goals, tools and maps, and training. There are technical assistance centers could provide resources to assist with states and communities to reduce energy costs for low-income families. Also, the geothermal maps can identify renewable resources, possible locations for implementation and provide data related to renewable energy to assist with calculation and model construction (Kruckenberg, L. J. 2015).

There are two main types of regulatory policy widely applied to significantly contribute to the expansion of domestic renewable energy industrial activities in the U.S.: Feed-in tariff (FIT) and Renewable Portfolio Standard (RPS) (Sun, P. et al., 2015). A FIT is an energy supply policy used to accelerate investment in renewable energy technologies, and it offers a long-term purchase agreement for the sale of renewable energy electricity (Couture et al., 2010).

RPS is also in the form of renewable obligations and green certificates, was implemented in many jurisdictions, especially at the state level. It is a regulation that requires either producers or consumers to derive a certain percentage of their electricity from renewable energy sources.

## 2.2 Economic analysis of renewable energy policy performance

Tax credits as financial incentives, are offered for the installation cost of the solar photovoltaic systems, which includes federal and state level tax credits. The federal Investment Tax Credit for residential and commercial properties has helped the U.S. solar industry grow by more than 8,600% percent since it was implemented in 2006, with an average annual growth of 50% over the last decade alone (SEIA ITC). It is a solar incentive granted to all states in the U.S. and the taxpayer gets credit which accounts for 30% of the installation cost of PV systems. The state tax credit deducts 10-50% of the installation cost of the solar PV systems based on the solar policies in each state. Most states have 25% of the installation cost of solar PV system deductible. If there is state-level tax credit offered from the state government, both federal and state level tax credits can be granted to the taxpayer (Lee, M et al., 2018; Lee, M et al., 2016)

According to the Renewables Global Status Report (GSR 2019), there are 111 countries had FIT policies in place by the end of 2018. In 2018, Zambia entered its first FIT-based renewable energy support scheme that modeled on an existing program in Uganda. Japan has

postponed its deadline to September 2019 for the planned cut to FIT solar projects larger than 2 MW. Meanwhile, Serbia extended its existing FIT scheme for an additional year, which was set to expire at the end of 2018 (GSR 2019).

However, it has been argued that FIT does not have enough capability to create a liberalized and single electricity market, there is a trend to shift from a feed-in system to green certificates while experiencing both systems (Abolhosseini et al., 2014). Rickerson et al. (2007) analyzed regulatory renewable energy policies in Europe and evaluated the application to policies in the U.S. They found that the U.S. states could apply different approaches to implement policies since the states are not under federal pressure to comply with a harmonized energy policy.

In the United States, five states and the District of Columbia increased RPS levels in 2018, and the District of Columbia also established a new requirement for 100% renewable energy by 2032 (GSR 2019). Besides, California committed to 100% clean energy by 2045 as part of its RPS, both New Jersey set an RPS for 50% renewable electricity, and Connecticut passed a new mandate of 40% by 2030 (DSIRE 2018).

It is of significance to understand the costs and impacts of these policies for renewable energy. Some studies find the RPSs could increase electricity generation cost; others find that the reduced demand for nonrenewable energy sources could lower natural gas prices and electricity prices. There are two driving factors lead to the variation in the direction and magnitude of the effects: the elasticity of electricity supply from renewable energy relative to nonrenewable energy and the sufficient stringency of the target (Fischer, C. et al., 2010).

### 2.3 Solar photovoltaic systems

Solar electricity from photovoltaic power system has rapidly expanded in the twenty-first century in western countries such as the U.S., with continuous growth anticipated. The United States experienced the dramatic growth of installation of PV systems; there is a steady improvement from 13.3% in 2010 to 15.6% in 2015 for residential PV systems, and from 13.8% in 2010 to 16.7% in 2015 for commercial PV systems. The cost of PV system measured in \$/W has dropped at a rate between 15% and 17% per year from 2009 to 2015, the cost of solar installation varies across states and properties (Gillingham et al., 2016; Nemet et al., 2016). In the Gillingham et al. (2016) study, it has indicated that locations with higher installer concentrations would substantially reduce the costs. Also, the size of the installer and experience could contribute to the lower costs (Nemet et al., 2016).

A great deal of previous literature has been devoted to the assessment of solar PV systems from various aspects. There are two most significant outcomes of PV system installations: 1) system capacity, it specifies the rate of converting solar radiation energy into electricity under different work conditions; 2) electricity generation, which is the total amount of electricity that one system could generate in practice. Thus, the capacity and generation of a solar PV system are used in the performance assessment on PV power systems (Sueyoshi, T et al., 2017).

From prior studies ((Chang, 2009; Eke and Senturk, 2012; Huld et al., 2010; Kaldellis et al., 2014), there are endogenous and exogenous factors that could influence the performance of solar PV systems. The design and configuration of a PV system are endogenous factors which include module type, capacity, siting, inverter configuration, mounting rack type, and orientation. Exogenous is regarding the environment, which includes solar irradiance, ambient air temperature, wind speed, and dust.

## 2.4 Federal Investment Tax Credit

The Investment Tax Credit (ITC) is the only federal tax credit currently available to residential and commercial solar systems. Since the ITC was enacted in 2006, the U.S. solar industry has grown by more than 8600%, with a 54% average annual growth (SEIA ITC).

The ITC is originally established in the 1970s at a value of 10%, then the Energy Policy Act of 2005 (EPACT 05) temporarily increased the ITC value to 30% of installation costs that applied to projects placed in service between January 1, 2006, and December 31, 2007. In 2006, the Tax Relief and Health Care Act (H.R. 6111) extended these credits through 2009. After that, there is an eight-year extension of the residential and commercial ITC through the implementation of the Emergency Economic Stabilization Act; it eliminated the monetary limitation for residential solar installations. In 2015, the Omnibus Appropriations Act included a multi-year extension of the residential and commercial ITC, but the credit is scheduled to step down from 30% at the end of 2019, it will drop to 26% in 2020, and decline further to 22% in 2021. In 2022, there is no federal credit for residential systems, and the credits will drop to 10% for commercial solar energy systems (SEIA ITC; EIA 2016).

From the previous literature (Comello, S. et al., 2016; Comello, S et al., 2018), the anticipated ITC step-down in 2017 would increase the levelized cost of solar energy (LCOE) by a significant margin, but the decreasing ITC support would be sufficient to sustain the cost competitiveness for most of the systems. It also concluded that the LCOE of California solar systems was unaffected by the changes in the federal tax credit, but this conclusion is dependent on the presence of the 30% tax credit, if the ITC had been removed, the levelized cost would have risen by around half of the previous cost.

## 2.5 Arizona's solar energy tax policy programs

Many states have adopted state-level tax credits to encourage market deployment of solar energy technology. Arizona tax credit and incentive programs are generally divided into a tax credit and tax exemption. According to the Arizona Solar Center, the Renewable Energy tax credit was established by the Arizona legislature in 2009 to promote the renewable energy industry in the state.

There are three tax incentives with regard to the solar tax credit in Arizona (NC Clean Energy- DSIRE): 1) Residential Solar and Wind Energy Systems Tax Credit, the credit amount allowed 25% of the cost of the solar system deductible against the taxpayer's income tax, with a \$1000 maximum, the photovoltaics is included as one of the eligible technologies; 2) Arizona Renewable Energy Production Tax Credit, this incentive is a Corporate Tax Credit for electricity produced by certain eligible renewable systems annually over a ten-year period. For solar systems, the tax credit equals \$0.01 to \$0.04 (varies by year) per kilowatt-hour (kWh) for the first 200,000 megawatt-hours (MWh) of electricity annually over a ten-year period, the maximum credit for any system is \$2 million per year, the tax credit for PV systems varies depending on the year of electricity production according to the schedules, and the minimum system size requirement is 5 MW; 3) Non-residential Solar Tax Credit, it can be applied both to corporate and personal income taxes. There is a maximum credit of \$25,000 per taxpayer for any one building in the same year and an in total credit of \$50,000 per business in any year, and there is no restriction on the size of the system.

Also, there are two types of tax incentives related to state solar tax exemption in Arizona: 1) Solar and Wind Equipment Sales Tax Exemptions, Arizona provides a sales tax exemption for 100% of sales tax on eligible equipment, the PV system is included as one of the eligible

technologies, and there is no maximum amount; 2) Energy Equipment Property Tax Exemptions, the exemption is 100% of the increased value of the property from installing eligible energy systems (NC Clean Energy- DSIRE).

## 2.6 Contributions to the literature

From prior studies, we can conclude that the market share of solar energy has changed considerably, and the federal and state-level policies have increased. Few scholars that have examined the effects of federal or state-level tax incentives on whether it has increased the likelihood of installing solar systems or not. This study contributes to a comprehensive economic evaluation of the effectiveness of different types of solar tax incentives.

This thesis seeks to add to the existing literature on solar tax incentive policy by focusing specifically on solar photovoltaic systems in Arizona, and on federal and state-level financial incentives, which has not yet to be subject to extensive study in recent years. Also, the fiscal challenges most states faced today makes the tax incentive evaluation all of the more significance.

## CHAPTER 3

### METHODOLOGY

In this chapter, we will do the economic analysis with regard to both residential and commercial solar photovoltaic installations in Arizona. The analysis would evaluate the elasticities of NPV with respect to the financial parameters, and present the calculation of the net present value for solar installations under different scenarios through applying federal and state level tax credits and other financial factors, and provide potential suggestions to the current solar generation and market.

#### 3.1 Inputs and Outputs

In this study, we use the System Advisor Model (SAM) to simulate different scenarios for solar installation, each simulation involves assigning more than one value to one or more input variables to explore the dependence of a result on the inputs. SAM is a techno-economic model designed to facilitate decision making for people involved in the renewable energy industry, and the photovoltaic systems are included in the system.

This thesis aims at estimating the costs and financial benefits through the NPV of the residential and commercial solar energy market in Arizona, and evaluating the elasticities of NPV with regard to the financial parameters. The financial and technical data of 42 modules are based on two types of solar system properties, three electricity sell rates (\$/kWh), three debt fraction choices (%), three different loan terms (years), two selections of loan rate (%), five stages of the step-down federal tax incentive, and seven different state level solar tax incentives

corresponding to different solar system properties in Arizona. These collection of modules yields total of 15120 different system samples that would provide insight into Arizona's solar market. With the estimations of potential energy generating and market cost, this study can provide financial incentive evaluations concerning the market potential of solar electricity generation to the government, solar industries and individuals.

In this model, we use the net present value (NPV) of future residential and commercial solar systems as the output, which is calculated to evaluate the potential solar electricity generation. The inputs in the model are financial parameters for solar systems including debt fraction, loan rate, and loan term, system size, electricity sell rate, and federal and state level solar tax credit programs. The following paragraphs explain all inputs that are used in the model to estimate the NPV of a solar system installation.

System Size (kW), which is also named nameplate capacity, is the nominal generating output in an array of solar modules.

Electricity Sell Rate (\$/kWh), is the price of electricity generated by solar system sold to the grid, the electricity sell rate in Arizona is 0.129\$/ kWh, in this study, we select 0.1\$/ kWh, 0.129\$/ kWh, and 0.2\$/ kWh for analysis.

Debt Fraction (%), is defined as the ratio of total debt to total assets, which can be interpreted as the proportion of an individual or company's assets that are financed by debt. In this study, we select 100%, 80%, and 50% for analysis.

Loan Term (years), can be defined as the period between when a loan is received and when the loan is fully paid, the loan term in the study is selected as 15, 25, and 30 years.

Loan Rate (%), is the interest rate applied to a loan, the loan rate in the analysis is selected as 5% and 10%.

Analysis Period (years), in this study, is the period for the economic analysis is to be made, which is 25 years.

System Degradation Rate (%), is the annual multiplier (1%) used to account for lost generating efficiencies.

Inflation Rate (%), is the percentage at which a currency is devalued during a period, the inflation rate in Arizona is 2.04%.

Nominal Discount Rate (%), is the rate (3%) used to account for the time value of money used in time value of money and the uncertainties of future cash flows.

Federal Investment Tax Credit, is the federal tax credit currently available to residential and commercial solar systems in Arizona, the credit is scheduled to step down from 30% to 10% in 2012. In this study, we select 30%, 26%, 22%, 10%, and 0%, to estimate the effects of the decreasing tax credit on the Net Present Value of solar systems.

State Sales Tax Credit, which provides a sales tax exemption for 100% of sales tax on the photovoltaic solar systems in Arizona. In this study, we select 5% and 0% to indicate the difference between with and without the tax exemption in the analysis.

State Property Tax Credit, it provides 100% exemption of the increased value of the property from installing photovoltaic systems, in this analysis, we select 2% and 0% to estimate the difference between with and without the tax exemption in the analysis.

State Production Tax Credit, which equals \$0.01 to \$0.04 (varies by year) per kilowatt-hour (kWh) for the first 200,000 megawatt-hours (MWh) of electricity annually over ten years, the maximum credit for any system is \$2 million per year. The following Table 3.1 and Table 3.2 shows the process of calculating the PTC for commercial solar systems in 10 years.

State Residential Tax Credit, the credit allowed 25% of the cost of the solar system deductible against the taxpayer's income tax, with a \$1000 maximum.

State Non-residential Tax Credit, is a maximum credit of \$25,000 per taxpayer for any one building in the same year and an in total credit of \$50,000 per business in any year.

Net Present Value (\$), is a time series of the summed present value of future cash flows (costs and benefits).

### 3.2 Net Present Value

To access the output of photovoltaic systems in the model, a classic net present value approach is applied in the SAM simulations, all the formulas come from the SAM system, the discounted returns on the investment are weighed against the initial installation, operation and maintenance costs.

$$NPV = \sum_{t=0}^T \frac{B_t}{(1+r)^t} - \sum_{t=0}^T \frac{C_t}{(1+r)^t} \quad (1)$$

Where NPV is interpreted as net present value,  $B_t$  is the benefit in year t,  $C_t$  is the cost in year t, r stands for the discount rate, and T stands for the analysis period, which is 25 in this study.

The following is the benefit of a residential solar system  $i$  at time  $t \in \{1, \dots, T\}$ :

$$B_{it} = EG_{it} \times E_i + I_i + TIC_i \times (1 + S_i) \times F_{it} \quad (t = 1) \quad (2)$$

$$B_{it} = EG_{it} \times E_i \quad (1 < t \leq 25) \quad (3)$$

$B_t$  is interpreted as the benefit in year t,  $EG_t$  is the electricity generation in year t,  $E_i$  is the electricity sell rate.  $I_i$  is the state investment tax credit for residential solar systems (tax credit is different depends on the property), which will be deducted in year 1.  $TIC_i$  is the total installed

cost of the photovoltaic system.  $S_i$  stands for the sales tax rate. and  $F_{it}$  is the federal investment tax credit rate in year  $t$ .

In the same way, the following is the benefit of a commercial solar system  $j$  at time  $t$

$\in \{1, \dots, T\}$ :

$$B_{jt} = EG_{jt} \times E_j + I_j + T_j + TIC_j \times (1 + S_j) \times F_{jt} \quad (t = 1) \quad (4)$$

$$B_{jt} = EG_{jt} \times E_j + T_j \quad (1 < t \leq 25) \quad (5)$$

$T_j$  is the state commercial production tax credit for a commercial solar system  $j$ , which is a ten-year program.

$$C_t = TIC_{PV} \times (1 + S_t) \times (1 - D_t) \quad (t = 1) \quad (6)$$

$$C_t = \text{Debt Interest Payment in year } t + \text{Debt Repayment in year } t + \text{Operation Costs} \quad (1 < t \leq 25) \quad (7)$$

*Debt Balance in Year One = Total Installed Costs  $\times$  (1+Sales Tax Rate)  $\times$  Debt Fraction*

*Debt Balance in Year  $t > 1$  = Debt Balance in Year  $t-1$  + Debt Repayment in Year  $t-1$*

*Debt Interest Payment in Year  $t$  = Debt Balance in Year  $t$   $\times$  Loan Rate*

*Debt Repayment in Year  $t$  = PPMT (Loan Rate, $t$ ,Loan Term,Principal Amount,0,0)*

*The total operating costs include operation and maintenance (O&M) costs, and insurance and property tax payments:*

*Operating Costs = Fixed O&M Annual + Fixed O&M + Variable O&M + Fuel + Insurance + Property Taxes - Salvage Value*

$C_t$  is interpreted as the cost in year  $t$ ,  $D_t$  is the debt fraction in year  $t$ . Principle Amount is the debt balance in year one. The debt repayment amount is the annual payment on principal amount assuming constant payments over the loan term. SAM calculates the amount using the levelized mortgage payment methodology equivalent to Excel's PPMT function. Operation Costs

is not the main variable we will consider in this study, but this cost will be simulated by the SAM automatically based on the inputs.

### 3.3 The regression model

This paper calculates the elasticities of NPV with respect to financial parameters from log-log regression models for residential and commercial photovoltaic systems.

The NPV of a residential solar system  $i$  at time  $t \in \{1, \dots, T\}$  can be thought of as a function of the effects of the electricity sell rate  $E_i$ , debt fraction  $D_i$ , loan term  $L_i$ , loan rate  $R_i$ , sales tax credit  $S_i$ , property tax credit  $P_i$ , federal investment tax credit  $F_{it}$  state investment tax  $I_i$ :

$$\text{NPV}_{it} = f(E_i, D_i, L_i, R_i, S_i, P_i, F_{it}, I_i) \quad (8)$$

Using a dummy variable for each exogenous change is a common technique for estimating the exogenous changes occur in functional relationships. For a residential system, we select three variables as dummy variables in this study,  $D_S$  is the dummy when applying the sales tax exemption  $S_j$ ,  $D_P$  as when there is property tax exemption  $P_j$  in the model, and  $D_I$  is the dummy when applying the state investment tax credit  $I_j$ . Suppose that this relationship takes the following form at each time period  $t$ :

$$\text{NPV}_{it} = E_i^{\beta_E} D_i^{\beta_D} L_i^{\beta_L} R_i^{\beta_R} F_{it}^{\beta_F} (\exp(\beta_S D_S + \beta_P D_P + \beta_I D_I)) \exp(\varepsilon_i) \quad (9)$$

where  $\varepsilon_i$  is a mean-zero stochastic error term. This would then imply the following log-log specification:

$$\ln(\text{NPV}_{it}) = \beta_0 + \beta_E \ln(E_i) + \beta_D \ln(D_i) + \beta_L \ln(L_i) + \beta_R \ln(R_i) + \beta_F \ln(F_{it}) + \beta_S D_S + \beta_P D_P + \beta_I D_I + \varepsilon_i \quad (10)$$

Where  $\beta_E$  can be interpreted as the elasticity of a NPV of a residential solar system with respect to the electricity sell rate,  $\beta_D$  is the elasticity of NPV with respect to debt fraction,

$\beta_L$  is the elasticity with respect to loan term,  $\beta_R$  is the elasticity of NPV with respect to loan rate, and  $\beta_F$  is the elasticity of NPV with respect to the federal investment tax credit.

In the same way, the NPV of a commercial solar system  $j$  at time  $t \in \{1, \dots, T\}$  can be thought of as a function of the effects of the electricity sell rate  $E_j$ , system capacity  $C_j$ , debt interest  $D_j$ , loan term  $L_j$ , loan rate  $R_j$ , sales tax credit  $S_j$ , property tax credit  $P_j$ , federal investment tax credit  $F_{jt}$ , state investment tax  $I_j$ , state production tax  $T_{jt}$ .

$$\text{NPV}_{jt} = f(E_j, C_j, D_j, L_j, R_j, S_j, P_j, F_{jt}, I_j, T_{jt}) \quad (11)$$

In this study,  $D_S$  is the dummy when applying the sales tax exemption  $S_j$ ,  $D_P$  as when there is property tax exemption  $P_j$  in the model,  $D_I$  is the dummy when applying the state investment tax credit  $I_j$ , and  $D_T$  means the dummy variable when using state production tax  $T_{jt}$  in the model. Suppose that this relationship takes the following form at each time period  $t$ :

$$\text{NPV}_{jt} = E_j^{\gamma_E} C_j^{\gamma_C} D_j^{\gamma_D} L_j^{\gamma_L} R_j^{\gamma_R} F_{jt}^{\gamma_F} (\exp(\gamma_S D_S + \gamma_P D_P + \gamma_I D_I + \gamma_T D_T)) \exp(\mu_j) \quad (12)$$

where  $\mu_j$  is a mean-zero stochastic error term. This would then imply the following log–log specification:

$$\begin{aligned} \text{Ln}(\text{NPV}_{jt}) = & \gamma_0 + \gamma_E \text{Ln}(E_j) + \gamma_C \text{Ln}(C_j) + \gamma_D \text{Ln}(D_j) + \gamma_L \text{Ln}(L_j) + \gamma_R \text{Ln}(R_j) + \\ & \gamma_F \text{Ln}(F_{jt}) + \gamma_S D_S + \gamma_P D_P + \gamma_I D_I + \gamma_T D_T + \mu_j \end{aligned} \quad (13)$$

Where  $\gamma_E$  can be interpreted as the elasticity of a NPV of a commercial solar system with respect to the electricity sell rate,  $\gamma_C$  is the elasticity of NPV with respect to system capacity,  $\gamma_D$  is the elasticity of NPV with respect to debt interest,  $\gamma_L$  is the elasticity with respect to loan term,  $\gamma_R$  is the elasticity of NPV with respect to loan rate, and  $\gamma_F$  is the elasticity of NPV with respect to the federal investment tax credit.

### 3.4 Data Description

The data and information are collected from different sources and incorporated in the analysis of the residential and commercial solar systems, to analyze the potential solar generation and corresponding financial benefits. The sizes of the commercial system spanning from 20kW (kilowatts) to 2000 kW, and three sizes were chosen (20 kW, 200 kW, and 2000 kW) as a representation of the commercial solar market. The nameplate size of the residential system is 4 kW, which is based on the source from the System Advisor Model (SAM), a techno-economic model designed to do better decision making for people involved in the renewable energy industry.

In order to ensure the accuracy of the specific solar systems consider in the study, the market data and solar system physical data was compiled from official government websites and solar industry magazine sources, including solar system degradation rate, debt fraction, loan term, loan rate, inflation rate, nominal discount rate, and federal and state tax incentives. This study focuses on the analysis of the cost and benefits under different policies designed to promote solar installations for residential and commercial properties.

In the previous chapter, there has been literature that investigates the solar market across the world and the effectiveness of some federal and state level renewable energy policies in the U.S. However, there has yet to be a study that focuses on Arizona's solar market, which is one of the most promising states with regard to the electricity generation in the U.S. In 2017, the solar energy starts to exceed production from hydroelectric power, and makes Arizona ranked second in the nation in total solar generation (U.S. EIA 2019). This study serves to add to the existing literature on federal and state level solar tax incentives.

In this study, module specification data were collected to simulate datasets for residential and a commercial photovoltaic generating systems, in order to analyze the market for solar electricity generation in Arizona. Considering all essential financial and physical factors, there are 2160 system samples (from 22 modules) are used to estimate the potential solar electricity generation for the residential solar systems; and there are 12960 system samples (from 27 modules) for the commercial systems in Arizona. These system samples applied the various parameters needed to be considered for solar systems in this study.

## CHAPTER 4

### RESULTS

From the data and log-log models outlined in the previous chapter, this chapter presents the evaluation of the economic feasibility of solar PV systems. Results of the log-log models for residential and commercial photovoltaic systems are presented in Table 4.1 and Table 4.2. These models include dummy variables for solar systems in order to apply specific state tax policies. A dummy variable indicates whether or not the observation applied the corresponding policy for solar installation.

Since the coefficient in the log-log model represents the elasticity of the NPV with respect to the financial variables, which is the estimated percent change in NPV for a percent change in the corresponding financial variable. From the Table 4.1, the result from the residential log-log model indicates the elasticities of NPV with respect to debt fraction, loan term, loan rate, and federal tax credit are statistically significant. For example, the elasticity with respect to loan rate is -0.7919, it means a 1% increase in the loan rate would result in an around 0.79% percent decrease in the NPV of a residential solar system, on average.

For the tax incentives, the elasticity of NPV with respect to all state tax credit and exemption programs shows statistical significance. Besides, from the Table 4.1 results, it is not hard to say that the magnitude of the coefficient for federal ITC policy is smaller with regard to the residential solar installations, since the elasticity of the NPV with respect to federal ITC is 0.141, which means a 1% increase in the federal ITC would result in a 0.14% increase in the NPV.

From the results of the commercial log-log model in Table 4.2, it is clear that the debt fraction, loan rate and loan term are negatively correlated with the NPV, and the elasticity of NPV with respect to loan rate is -0.1953, it means a 1% increase in the loan rate is associated with an around 0.20% percent decrease in the NPV of a commercial solar system. Besides, the electricity sell rate and system capacity are positively correlated with the NPV, the elasticity of NPV with respect to the sell rate is 0.4211, it means a 1% increase in the sell rate would cause a 0.42% increase in the NPV of commercial solar installation.

For the evaluation of tax policies, the magnitude effects from the property tax policy is bigger than from the sales tax policy on the NPV. From the Table 4.2 results, it is clear that commercial solar installation decisions are just slightly affected by federal ITC policy, as the elasticity of the NPV with respect to federal ITC is 0.0305, which means a 1% increase in the federal ITC would result in a 0.03% increase in the NPV.

In addition, the results in Table 7 and 8 show, for the commercial and residential solar system simulations, the net present values of 90% simulations in commercial system and 85% simulations in residential system are positive even if the federal Investment Tax Credit is not applied, when all state level tax incentives are considered except the state Investment Tax Credit. The results in Table 8 show more than two thirds of the NPVs are positive when there are no federal and state level tax policies applied in the simulations for commercial solar system; while half of the NPVs are negative when there are no federal and state level tax incentives applied in the simulations for residential solar system.

## CHAPTER 5

### CONCLUSION

This study conducted an economic analysis of federal and state solar incentives in U.S. based on financial incentives and tax incentives. In the aspect of solar incentive strategy for NPV improvement, it is recommended to offer high state income tax credit and at least the property tax exemption, in order to guarantee the economic feasibility of the residential and commercial solar photovoltaic systems. Also, a lower loan rate and higher electricity sell rate is recommended for the NPV improvement.

From the results, we can conclude that the tax incentives would cause more effect on residential solar systems than commercial solar systems, which means the implementation of tax credits would contribute more to the deployment of individual solar market. The commercial solar systems are affected by the system capacity, and becomes a significant factor when considering the NPV of solar installation.

The expiration of federal Investment Tax Credit would slightly affect the NPV both for residential and commercial solar systems. Based on these simulation estimates, this paper suggests the photovoltaic installations to be an economically viable option for residential and commercial properties, despite the step-down of the ITC from 30 percent to 10 percent for commercial solar systems and step-down to 0 percent for residential properties.

However, due to the time limitation, this study analyzed the elasticities of NPV on financial and tax incentive parameters based on the representative values of solar incentives (i.e. maximum value, minimum value and most likely value), and all the data we used in the model

are simulated from the SAM. Still, the models in this study could make the decision maker involved in solar installation to find out the optimal solar photovoltaic incentive scenario and incentive rates, which could meet their objectives and preferences.

With the current tax credit and exemption programs in place, the results of this thesis indicate the financial feasibility of photovoltaic generation in Arizona. Through the analysis, this study could provide a proper solar incentive strategy to Arizona solar industries and the government. The analysis results of this thesis could contribute to the improvements in the U.S. solar policies.

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Table 1 Log-log regression results for residential solar system

<b>Variables</b>	<b>Residential Solar System</b>
<i>Dependent variable: NPV</i>	
(Intercept)	12.1489***
sell_rate	0.0002
debt_fraction	-0.4136***
loan_rate	-0.7919***
loan_term	-0.172***
federal_itc	0.141***
state_itc_dummy	0.1365***
property_tax_dummy	0.4239***
sales_tax_dummy	0.0713***
R-square	0.5775
F-statistic	367.5***

\*Significance at the 0.1 level in all tables.  
 \*\*Significance at the 0.05 level in all tables.  
 \*\*\*Significance at the 0.01 level in all tables.

Table 2 Log-log regression results for commercial solar system

<b>Variables</b>	<b>Commercial Solar System</b>
<i>Dependent variable: NPV</i>	
(Intercept)	13.3494***
sell_rate	0.4211***
system_capacity	0.1663***
debt_fraction	-0.0841***
loan_rate	-0.1953***
loan_term	-0.0261**
federal_itc	0.0305***
state_itc_dummy	0.0188***
state_ptc_dummy	0.0894***
property_tax_dummy	0.1048***
sales_tax_dummy	0.0156**
R-square	0.5708
F-statistic	1722***

\*Significance at the 0.1 level in all tables.

\*\*Significance at the 0.05 level in all tables.

\*\*\*Significance at the 0.01 level in all tables.

Table 3 The electricity generation under three commercial system sizes

<b>Electricity Generated (kWh)</b>			
<i>under three commercial system sizes(kW)</i>			
<b>Year</b>	<b>20kW</b>	<b>200kW</b>	<b>2000kW</b>
Year1	34,094	340,940	3,409,400
Year2	33,753	337,531	3,375,310
Year3	33,416	334,156	3,341,560
Year4	33,081	330,814	3,308,140
Year5	32,751	327,506	3,275,060
Year6	32,423	324,231	3,242,310
Year7	32,099	320,989	3,209,890
Year8	31,778	317,779	3,177,790
Year9	31,460	314,601	3,146,010
Year10	31,146	311,455	3,114,550

Table 4 The State Production Function Credit under three commercial system sizes

<b>Production Tax Credit (PTC)</b>				
<i>under three commercial system sizes(kW)</i>				
<b>Year</b>	<b>\$/kWh</b>	<b>Credit (20kW)</b>	<b>Credit (200kW)</b>	<b>Credit (2000kW)</b>
Year1	0.04	\$1,324	\$13,240	\$132,403
Year2	0.04	\$1,272	\$12,726	\$127,262
Year3	0.035	\$1,070	\$10,703	\$107,030
Year4	0.035	\$1,028	\$10,287	\$102,873
Year5	0.03	\$847	\$8,475	\$84,752
Year6	0.03	\$814	\$8,146	\$81,461
Year7	0.02	\$521	\$5,219	\$52,198
Year8	0.02	\$501	\$5,017	\$50,171
Year9	0.015	\$361	\$3,616	\$36,167
Year10	0.01	\$231	\$2,317	\$23,175
		\$7,743	\$77,432	\$774,321
			max\$/year	\$200,000
			Discount rate	0.03

Table 5 The variables in residential solar systems

<b>Variable Name</b>	<b>Units</b>	<b>Description</b>	<b>Range</b>	<b>Mean</b>
System Size	kW	Also called nameplate capacity, is the nominal generating output in an array of solar modules	4	4
Electricity Sell Rate	\$/kWh	The price of electricity generated by solar system sold to the grid	0.1; 0.129; 0.2	0.143
Electricity Generation	kWh	The amount of electric energy produced by solar systems	6060	6,060
Installation Cost	\$	The costs of installing a solar system	10783	10,783
Debt Fraction	%	The proportion of an individual or company's assets that are financed by debt	100; 80; 50	76.67
Loan Term	years	The period between when a loan is received and when the loan is fully paid	15; 25;30	23

Loan Rate	%	The interest rate applied to a loan	5; 10	7.5
Loan Amount	\$	The amount that a borrower is authorized to borrow	10,783; 8,286; 5,391	8,153
Analysis Period	years	The period for the economic analysis is to be made	25	25
System Degradation Rate	%	The annual multiplier used to account for lost generating efficiencies.	1	1
Inflation Rate	%	The percentage at which a currency is devalued during a period	2.04	2.04
Nominal Discount Rate	%	The rate used to account for the time value of money used in time value of money and the uncertainties of future cash flows	3	3
Federal Investment Tax Credit	%	The allowed percentage of the cost can be deducted for solar installation	30; 26; 22; 10; 0	17.6

State Sales Tax Credit	%	Tax exemption of sales tax on solar systems	5; 0	2.5
State Property Tax Credit	%	Tax exemption on the increased value of the property from installing eligible energy systems	2; 0	1
State Residential Tax Credit	\$	The allowed annual amount of the cost can be deducted for solar installation	1,000	1,000

Table 6 The variables in commercial solar systems

<b>Variable Name</b>	<b>Units</b>	<b>Description</b>	<b>Range</b>	<b>Mean</b>
System Size	kW	Also called nameplate capacity, is the nominal generating output in an array of solar modules	20; 200; 2000	740
Electricity Sell Rate	\$/kWh	The price of electricity generated by solar system sold to the grid	0.1; 0.129; 0.2	0
Electricity Generation	kWh	the amount of electric energy produced by solar systems	See Graph 3.1	
Installation Cost	\$	The costs of installing a solar system	36,379; 363,799; 3,637,990	1,346,056
Debt Fraction	%	The proportion of an individual or company's assets that are financed by debt	100; 80; 50	77
Loan Term	years	The period between when a loan is received and when the loan is fully paid	15; 25;30	23
Loan Rate	%	The interest rate applied to a loan	5; 10	8

			For 20kW size: 36,380; 29,103; 18,190	
Loan Amount	\$	The amount that a borrower is authorized to borrow	For 200kW size: 36,3800; 29,1030; 18,1900	928,770
			For 2000kW size: 36,38000; 29,10300; 18,19000	
Analysis Period	years	The period for the economic analysis is to be made	25	25
System Degradation Rate	%	The annual multiplier used to account for lost generating efficiencies.	1	1
Inflation Rate	%	The percentage at which a currency is devalued during a period	2	2
Nominal Discount Rate	%	The rate used to account for the time value of money used in time value of money and the uncertainties of future cash flows	3	3
Federal Investment Tax Credit	%	The allowed percentage of the cost can be deducted for solar installation	30; 26; 22; 10; 0	18
State Sales Tax Credit	%	Tax exemption of sales tax on solar systems	5; 0	3

State Property Tax Credit	%	Tax exemption on the increased value of the property from installing eligible energy systems	2; 0	1
State Production Tax Credit	\$	The allowed annual deductible amount based on the electricity produced for solar systems	See Graph 3.2	
State Non-residential Tax Credit	\$	The allowed annual amount of the cost can be deducted for solar installation	50,000	50,000

Table 7 The proportion of solar systems' simulations that applied all state tax incentives except state Investment Tax Credit

**For commercial solar system**

sell_rate(\$/kwh)	no_fedITC		fedITC_10%		fedITC_22%		fedITC_26%	fedITC_30%	total_sum
	NPV<0	NPV>0	NPV<0	NPV>0	NPV<0	NPV>0	NPV>0		
0.1	4	50	2	52	1	53	54	54	270
0.129	1	53	1	53	0	54	54	54	270
0.2	1	53	1	53	0	54	54	54	270
sum	6	156	4	158	1	161	162	162	810

**For residential solar system**

sell_rate(\$/kwh)	no_fedITC		fedITC_10%		fedITC_22%	fedITC_26%	fedITC_30%	total_sum
	NPV<0	NPV>0	NPV<0	NPV>0	NPV>0	NPV>0	NPV>0	
0.1	3	15	1	17	18	18	18	90
0.129	3	15	1	17	18	18	18	90
0.2	3	15	1	17	18	18	18	90
sum	9	45	3	51	54	54	54	270

Table 8 The proportion of solar systems' simulations that applied no state tax incentives

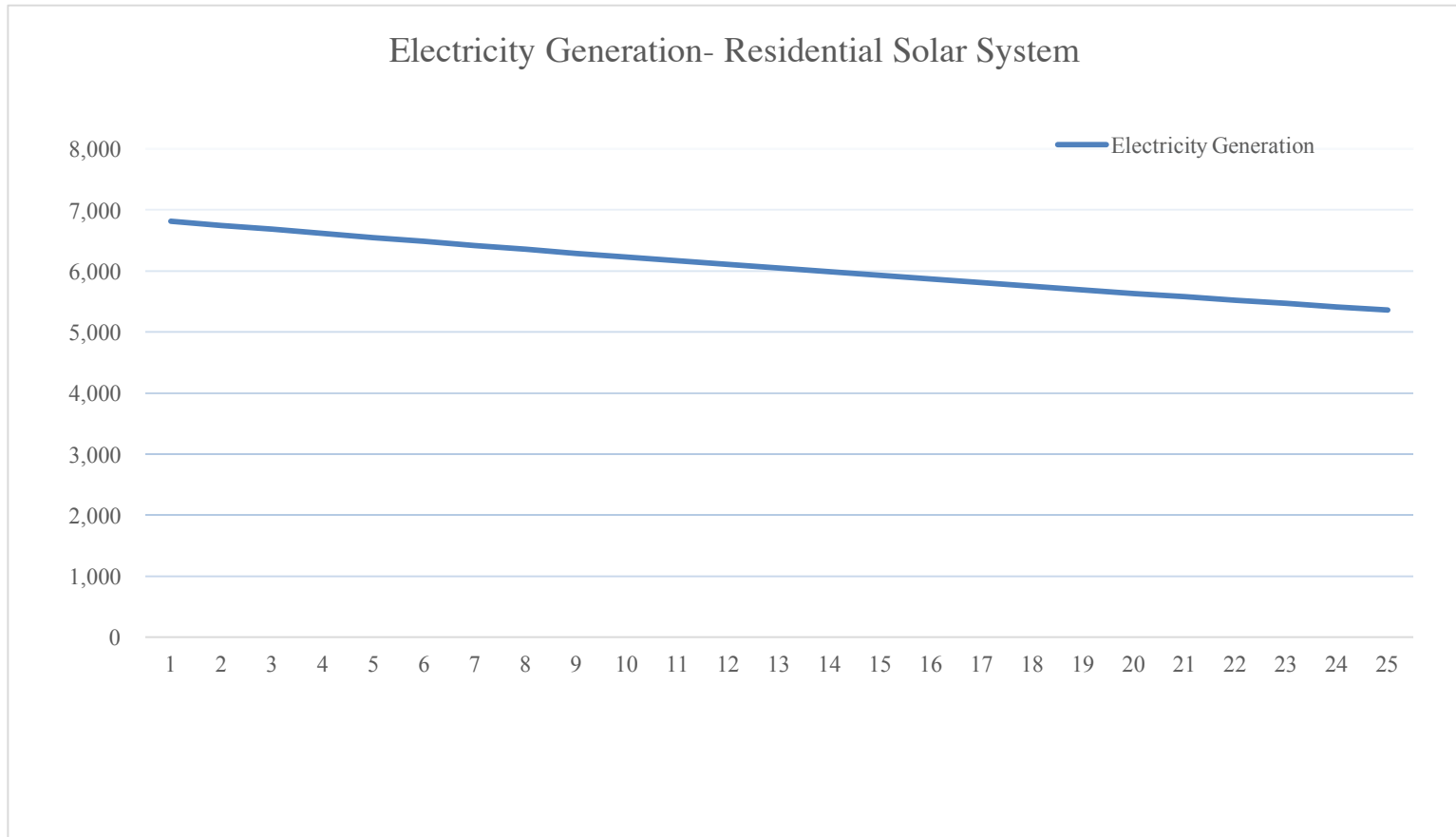
**For commercial solar system**

sell_rate(\$/kwh)	no_fedITC		fedITC_10%		fedITC_22%		fedITC_26%		fedITC_30%		total_sum
	NPV<0	NPV>0	NPV<0	NPV>0	NPV<0	NPV>0	NPV<0	NPV>0	NPV<0	NPV>0	
0.1	24	30	19	35	14	40	12	42	10	44	270
0.129	18	36	13	41	8	46	7	47	5	49	270
0.2	14	40	10	44	7	47	7	47	5	49	270
sum	56	106	42	120	29	133	26	136	20	142	810

**For residential solar system**

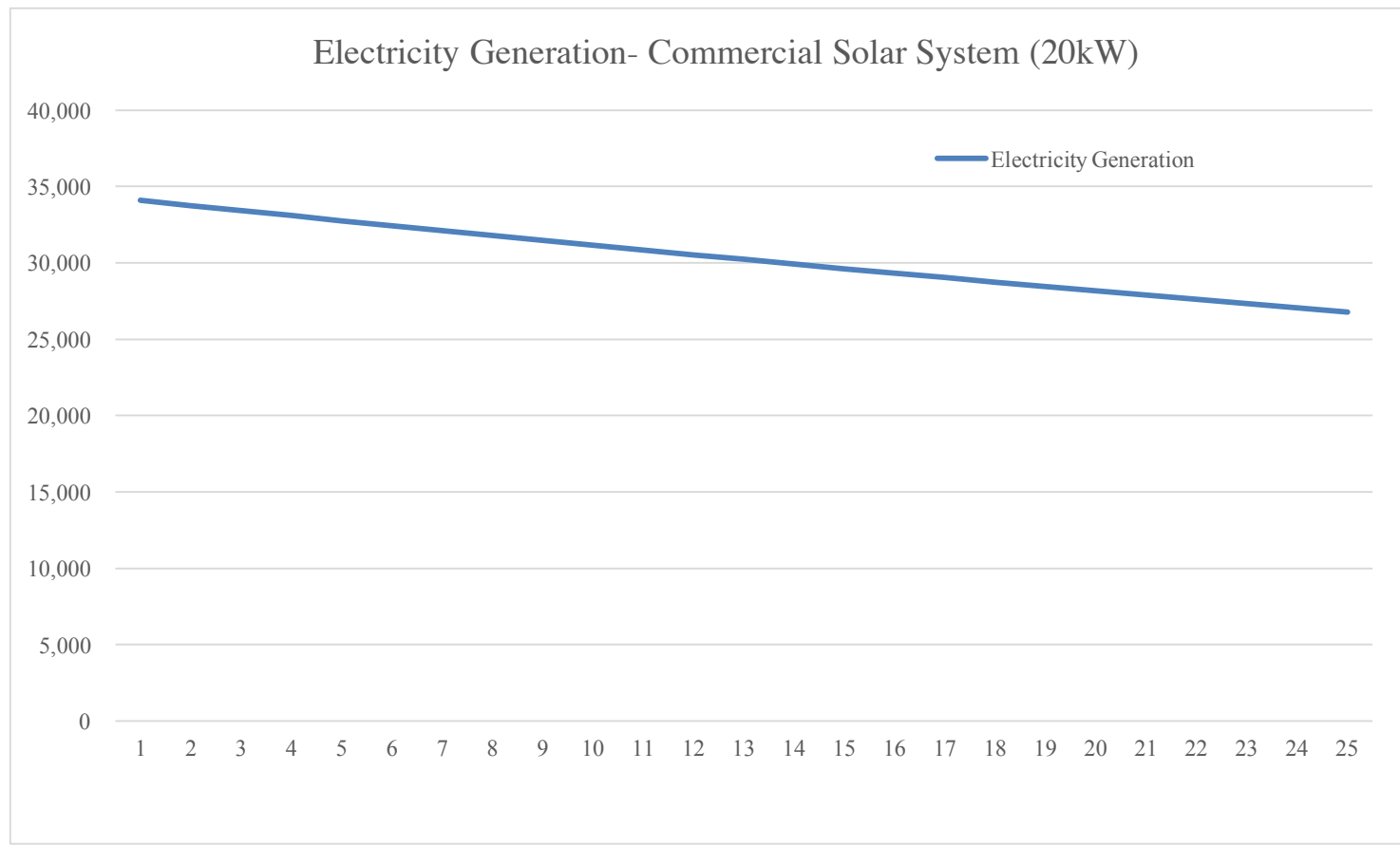
sell_rate(\$/kwh)	no_fedITC		fedITC_10%		fedITC_22%		fedITC_26%		fedITC_30%		total_sum
	NPV<0	NPV>0	NPV<0	NPV>0	NPV<0	NPV>0	NPV<0	NPV>0	NPV<0	NPV>0	
0.1	9	9	8	10	5	13	5	13	3	15	90
0.129	9	9	8	10	5	13	5	13	3	15	90
0.2	9	9	8	10	5	13	5	13	3	15	90
sum	27	27	24	30	15	39	15	39	9	45	270

Figure 3 Range of Electricity Generation- Residential Solar System



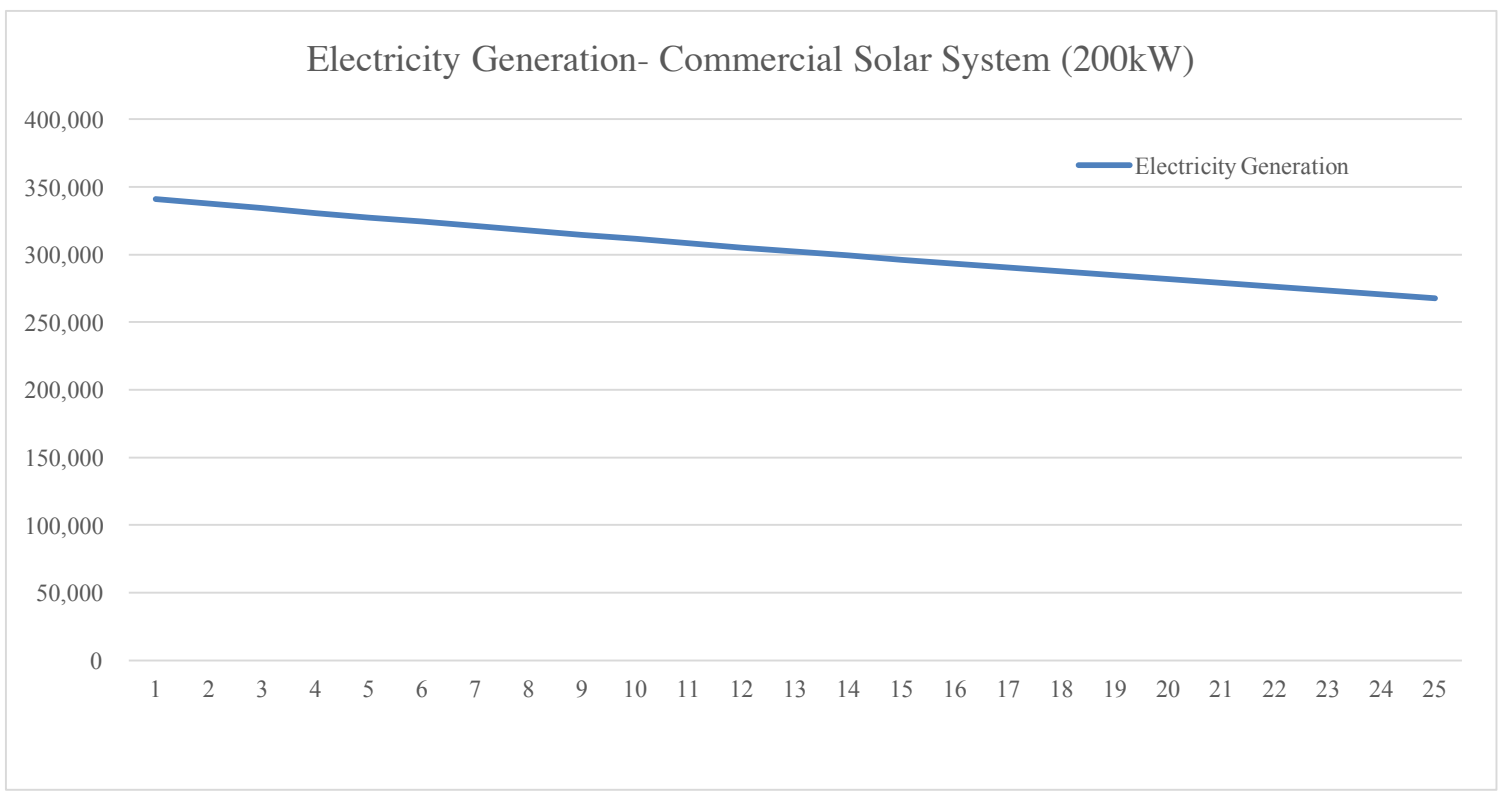
X: Electricity Generation (kWh); Y: Year

Figure 4 Range of Electricity Generation- Commercial Solar System (20kW)



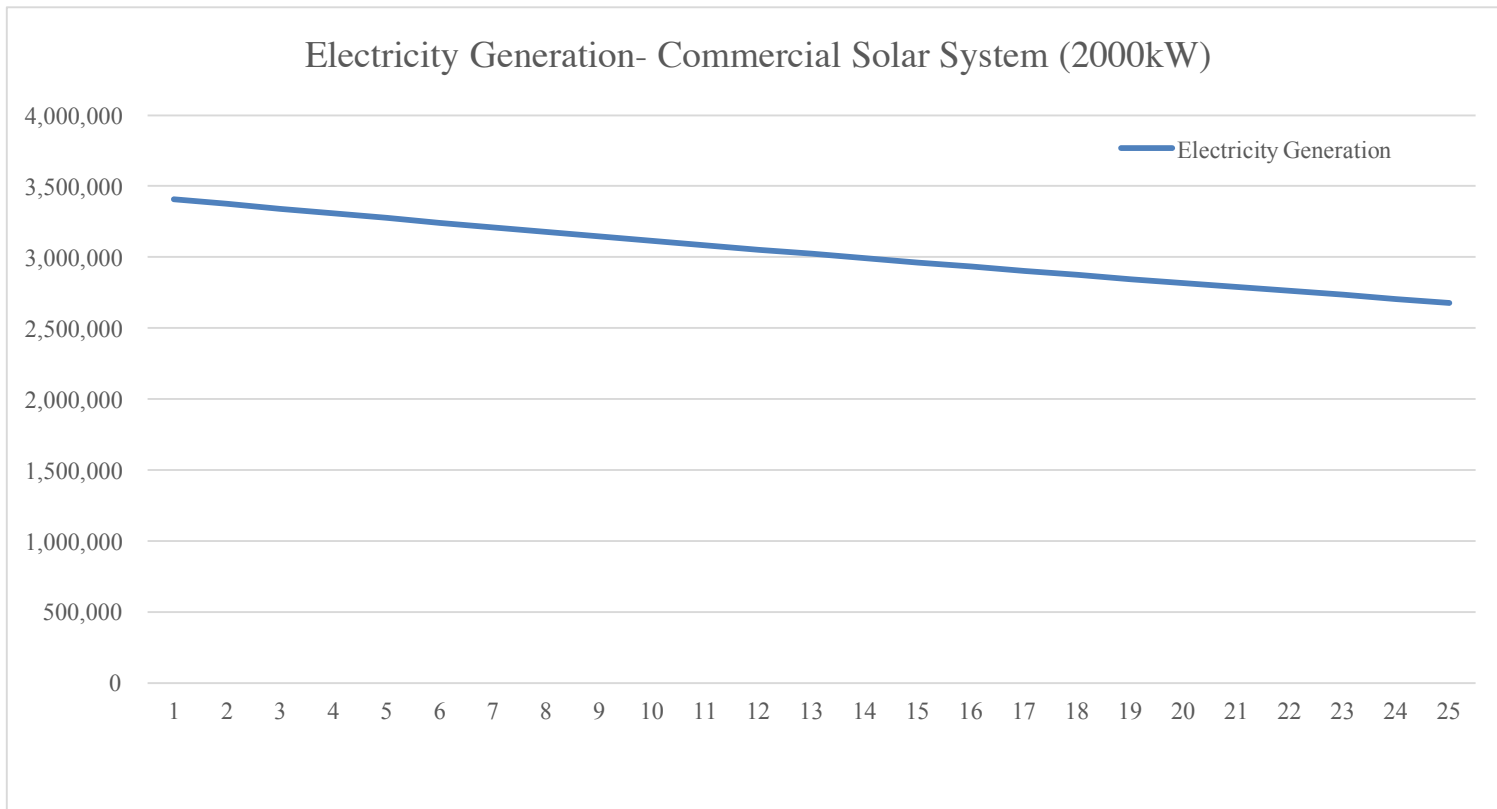
X: Electricity Generation (kWh); Y: Year

Figure 5 Range of Electricity Generation- Commercial Solar System (200kW)



X: Electricity Generation (kWh); Y: Year

Figure 6 Range of Electricity Generation- Commercial Solar System (2000kW)



X: Electricity Generation (kWh); Y: Year