Development and Application of a Photovoltaic Financial Model

by

Brad Dietz

B.S. Finance
Oakland University, 2005

SUBMITTED TO THE MIT SLOAN SCHOOL OF MANAGEMENT IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN MANAGEMENT STUDIES

AT THE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JUNE 2010

Signature of Author: ______________________

Brad Dietz
MIT Sloan School of Management
May 7, 2010

Certified by: ______________________

Richard L. Schmalensee
Howard W. Johnson Professor of Economics and Management
Applied Economics Group
Thesis Supervisor

Certified by: ______________________

Joshua Linn
Assistant Professor
University of Illinois at Chicago
Thesis Reader

Accepted by: ______________________

Michael A. Cusumano
SMR Distinguished Professor of Management
Technological Innovation, Entrepreneurship, and Strategic Management Group
Faculty Director, M.S. in Management Studies Program (MSMS)

Development and Application of a Financial Photovoltaic Model

by

Brad Dietz

SUBMITTED TO THE MIT SLOAN SCHOOL OF MANAGEMENT ON May 7, 2010 IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN MANAGEMENT STUDIES

ABSTRACT

Due to the relative immaturity of the solar farm industry, there are very few comprehensive financial models in use. I address this by developing a photovoltaic NPV financial model and apply the model to various base cases and current and future economic situations in Southern California to determine the viability of solar farms as a renewable energy source. Furthermore, this study demonstrates the need for increased incentives and improved policy guidelines in order to encourage the investment in additional highly desirable renewable solar energy projects.

Thesis Supervisor: Richard L. Schmalensee
Title: Howard W. Johnson Professor of Economics and Management

Thesis Reader: Joshua Linn
Title: Assistant Professor, University of Illinois at Chicago

ACKNOWLEDGEMENTS

First and foremost I would like to thank Professor Joshua Linn. Without his guidance I would not have been able to produce a thesis that exceeds my expectations. Also, thanks to Professor Richard Schmalensee as he introduced me to Professor Linn and acted as my Sloan advisor.

I would further like to thank Chanh Q. Phan and Gabriela Viana who helped assist Prof. Cusumano in the creation of the Management Studies degree. Without the opportunity to study at MIT I would have missed out on meeting many amazing people and educational experiences. Furthermore, the MSMS degree gave me a chance to study at a world class business school and I will be forever grateful.

I would not be who I am without the continued love and support of my Family. Thank you for your assistance Mom and Dad! Love you always.

Finally let me thank all the friends who helped me through the tough times or assisted in the production of my thesis: Thank you Apurv, Victor and Derick.

Contents

1 Objectives

California is a leader in championing green energy by requiring that renewable energy generates 20% of all power by 2010 and 33% by 2020. [1] Many other states and countries are attempting to emulate successful programs in order to increase the amount of renewable green energy. The success of the California green energy programs has far reaching implications for the future of renewable energy in America.

This thesis has dual objectives: 1) to provide investment guidance to developers and investors in large-scale photovoltaic (PV) farms, and 2) to indicate the requirement for subsidy modifications to effectively encourage the development of the photovoltaic projects in southern California. Currently, PV systems subsidies are not an efficient means of generating green Watts per dollar, and the conclusions of this paper could easily support the cessation of PV subsidies due to their inadequacy. However, the author believes that a temporary increase in PV subsidies is essential for America to retain its status as one of the PV technical leaders. Since PV sites are nearly limitless, adequate subsidies can be expected to create a viable PV market. In the future, the adoption of a national renewable portfolio standard is anticipated, as are some form of carbon taxation and the creation of a "green" bank. [2]

The following Sections are summarized as follows: Section 2, Data, describes the insolation and pricing data the model uses. Section 3, Model Description, includes the model assumptions and calculations for solar insolations, net present values, and levelized cost of electricity. Section 4, Model Generation Test, compares the generation of the thesis model to the industry standard model known as PVWatts.

Section 5, Application of the Model, describes the application process and presents the outcome of 2010 investments, California Solar Initiative (CSI) subsidies, and feed-in tariff (FIT) subsidies. Section 6, Analysis, analyses the data from section 5. Section 7 is the conclusion. Section 8 is the works cited.

2 Model Description

2.1 Overview

The model values the net present value of debt and equity holders of photovoltaic farms in southern California in the service area of Southern California Edison. While the model may evaluate a multitude of system configurations, the subsidies and tax regime are setup for developers and investors of systems selling the electricity to a utility. The overall project value depends on a variety of technical, financial, and environmental variables along with governmental subsidies. One of the strengths of the model is its flexibility and the speed of comparison between different locations and systems.

The model is based in excel with a connection to a MYSQL database in SQL and VBA. The MYSQL database holds hourly location and pricing data. The excel model queries the MYSQL database and imports all relevant data. MS Excel automatically computes the generation weighted average price, yearly generation, and hourly/yearly cash flows. These inputs plug into the net present value (NPV) calculation that is the financial method used to measure economic value. The NPV calculation accounts for capital structure, macroeconomic factors, taxes, subsidies, operating and capital costs, and discounted cash flows.

2.2 Assumptions

2.2.1 Federal Loan Guarantees

The only federal or state loan incentives or policies available are two federal loan guarantee programs: the U.S. Department of Energy has the Federal Loan Program (FLP) [3] and the U.S. Department of Agriculture has the Rural Energy for America Program (REAP) [4]. Modeling the guarantees demands an extraordinary amount of time due to complexity and will not be a part of this thesis. For the basis of this thesis, assume that the project developers are credit worthy and able to take out loans for 80% of the project value without the use of the FLP or REAP guarantees.

2.2.2 Model Assumptions

- Market prices are unaffected by the project.
- The financial analysis ignores other solar projects.

2.2.3 Base Case Assumptions

- The objective is to maximize NPV.
- Riverside, California (Latitude 33.85/Longitude -117.35), where a 7.5 MW PV plant finished construction in late 2009[5], is the base case location. It is a location of high insolation. Southern California Edison is the electric utility.
- The 30% Federal subsidy used is the Investment Tax Credit (ITC). The Grant is not used because it is limited to projects "placed in service" or that start construction in 2009-2010.
- State depreciation is Modified Accelerated Cost Recovery System (MACRS) because the company will either be a LLC or S Corporation. C Corporation requires 12-year straight line state depreciation.

- The maximum Feed-In-Tariff is 25-years and will serve as the project term for the CSI, FIT and wholesale pricing cases.
- The Developer may choose between selling the energy using the CSI, FIT or wholesale pricing scheme. The choices are mutually exclusive and independent.
- This model does not provide any additional economies of scale between farms. A fixed array 100MW farm has essentially the same installed cost per watt as a fixed array 500kW farm. Additional economies of scale are not a part of this thesis.
- The optimal revenue collector tilt and azimuth angles are 18.72° and -10.42° (The collector azimuth angle is positive in the southeast direction and negative in the southwest).
- A fixed-axis system installed cost is \$3.50/W. \$3.50/W installed cost is an aggressive but realistic price compared to new systems by First Solar and Applied Materials. [6]
- In 2008, tracking systems have an average installed cost of \$4.00/W, or \$0.50/W higher than fixed-axis systems. [7] A 1-axis system has an installed cost of \$3.90/W. A 2-axis system has an installed cost of \$4.15/W.

The following tables indicate all of the model variables by category:

Project Time	
System Lifetime/Contract (yrs)	25
Base Date	1/1/2010

Construction

Installed Costs ($/W)	See Above
Construction Time (Mths)	12 [8]
Effective Const. Real Cost of Cap	7.3%
Escrow Construction Fund Interest Rate	3.0%
Salvage Value (%)	0%
Sales Value (%)	50%

Solar Array	
DC to AC Derating Factor	77% [9]
Inverter Lifetime (yrs)	10
Photovoltaic Degredation Rate	1% [10]

CA Solar Initiative	
Payment (EPBB or PBI)	PBI
Current Step	5
Current Price	0.22

Costs	
Land	250,000
Fixed O&M Cost ($/kWdc/Yr)	6.29 [11]
User Defined Fixed Cost ($/Wp/Yr)	0
Variable O&M Cost ($/K Wh/Yr)	0 [11]
User Defined Variable Cost ($/K Wh/Yr)	0
Insurance (%)	0.5% [11]
Property Taxes (%)	0 [11],[12]
Inverter Replacement Cost ($/Wp)	0.84 [13]

Financials	
Loan Debt Ratio	80.0% [14]
Equity Interest Rate	14.9% [15]
Debt Interest Rate	7.27% [8]
Interest Only Term (Yrs)	0 [15]
Amortization Term (Yrs)	12 [15]
Federal Depreciation Type	MACRS
State Depreciation Type	MACRS
30% Federal Subsidy	ITC
Electricity Growth Rate	5.617%
Inverter Price Decrease Rate (%)	2.6% [13]
Sales Tax	8.25% [16]

State Income Tax	8.84% [17]
Federal Income Tax	35.00% [18]
Effective Tax Rate	40.75%
Capital Gains Tax	15.00% [19]
Creditor Cost of Capital	3.25%
General Inflation Rate	2.80% [20]
Real Discount Rate	14.90% [15]
Nominal Discount Rate	18.12%

2.2.4 Wholesale Energy Price Growth

2.2.4.1 Validate ISO Wholesale Generation Weighted Average Price

The wholesale generation weighted-average price is based on Solar effective ISO pricing data meaning that the calculation uses only the ISO pricing data during sunlight hours specific to the particular location (base case). These are the effective wholesale energy prices available to a photovoltaic system at the location. Using the base case to determine a wholesale generation weighted average price gives rather interesting results for the previous two years of data. The ISO wholesale pricing data from 4/1/08 to 3/31/09 (old pricing data) and 4/1/09 to 2/28/10 (new pricing data) provide vastly different generation weighted average prices demonstrating a -45.33% change in price:

	Old	New
Average Wholesale Generation Weighted Average Price	$ 0.0653	$ 0.0357
% Change		-45.33%

The calculation of the old and new average generation weighted average price equals the base case's average of the 3 solar arrays (Fixed, 1-axis, and 2-axis) wholesale generation weighted average price.

A 45.33% change in price seems drastic but the difference accounts for the high prices in 2008 and drastic lows in 2009. An ISO data check is the change in energy production costs (in $/MWh) for utilities over the same time periods using production costs of a gas combined cycle generator as a proxy. These figures are provided in the U.S. Natural Gas Electric Power Price table below.

The heat rate for a gas combined cycle generator is 8.5 to 10.5 MBtu/MWh. [21] The calculations use an average of 9.5 MBtu/MWh. Current and historic gas prices are found at: http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm .

$/MWh using the first 11 months of the old dates:

Date	U.S. Natural Gas Electric Power Price (Dollars per Thousand Cubic Feet)	$/MWhr Old
Apr-08	10.19	94.25998
May-08	10.97	101.4752
Jun-08	12.41	114.7955
Jul-08	11.71	108.3204
Aug-08	8.97	82.97468
Sep-08	7.81	72.2444
Oct-08	6.74	62.34664
Nov-08	6.64	61.42162
Dec-08	6.9	63.82668
Jan-09	6.59	60.9591
Feb-09	5.65	52.26388

$/MWh using the most recent 10 months of the new dates:

Date	U.S. Natural Gas Electric Power Price (Dollars per Thousand Cubic Feet)	$/MWhr New
Mar-09	4.89	45.23369
Apr-09	4.63	42.82863
May-09	4.66	43.10613
Jun-09	4.58	42.36611
Jul-09	4.43	40.97858
Aug-09	4.25	39.31353
Sep-09	3.98	36.81597
Oct-09	5.01	46.34372
Nov-09	5	46.25122
Dec-09	6.23	57.62902

The newest data from the Energy Information Administration (EIA) website is missing two months of data compared to the ISO pricing data, therefore, the last month of data was removed from the "Old" pricing date to provide a more equitable balance between the two time frames. The change in energy production costs in $/MWh for utilities over the old and new time periods is 44.57%:

	Old	New
Average $/MWhr	79.53528	44.08666
% Change		44.57%

The percentage decrease in generation weighted average wholesale energy prices and average $/MWhr cost of utility production are quite similar. The slightly larger decrease in wholesale energy prices of 45.33% vs. the 44.57% decrease of the energy production costs may be explained not only by a decrease in gas prices but also lower consumer use of electricity due to the poor economy, however, the difference is not significant. This validates the drastic changes in old and new wholesale energy prices.

2.2.4.2 Nominal Energy Price Growth

Since US natural gas electric power prices are a good proxy for changes in wholesale energy prices (as determined by the last section Validate ISO Wholesale Generation Weighted Average Price), the forecast of the 25-year yearly average growth rate in electric power prices serves as the growth rate in project electricity prices starting from 2010 and ending 2034. The forecast of utility gas prices are found at:

http://www.eia.doe.gov/oiaf/forecasting.html

The results are a 25-year yearly nominal growth rate of 5.617% in electricity prices.

3 Data

3.1 Solar Insolation

Professor Richard Perez of the State University of New York (SUNY) created a model that estimates global and direct irradiance at hourly intervals for the years 1998 – 2005 on a 10-km by 10-km grid covering the continental U.S. The model was developed with high-resolution (10-km) solar maps using visible channel imagery from the geostationary weather satellite Meteosat yielding local irradiation data. The benefits of using the SUNY model include insolation data for anywhere in US where most of the other publically available models, (such as National Solar Radiation Data Base) are limited to specific meteorological data stations. However, the SUNY model is based on satellite data and is less accurate than ground based sources of insolation data.

- The model is publically available on the National Climatic Data Center (NCDC) website:
  - http://www.ncdc.noaa.gov/oa/reds/

The SUNY model data is processed by averaging eight years of hour-by-hour irradiance data providing a composite year for each 10-km grid of California.

3.2 Wholesale Pricing

This paper focuses on large scale PV installations that sell the energy to utilities on the wholesale market. Retail and commercial prices are available to individuals and companies that enter into a net-metering agreement with a utility company.

The California ISO (Independent System Operator) serves to operate the state's electricity grid and administer the wholesale electricity markets. As such, the

California ISO website has real-time hourly wholesale Location Marginal Pricing (LMP) Data using the OASIS system (part of the ISO website). In OASIS there are over 3,000 different California pricing nodes (locations). The 2 aggregate pricing nodes used in the analysis are TH_NP15_GEN-APND and TH_SP15_GEN-APND corresponding to Northern California and Southern California with Bakersfield as the dividing line. The data consists of hourly wholesale prices from 3/1/2009 to 2/1/2010 and provide a close approximation of 2010 wholesale prices.

- The public access California ISO website is:
    - http://www.caiso.com/

3.3 California Solar Initiative Pricing

In January 2006, the California Public Utility Commission (CPUC) initiated the California Solar Initiative (CSI), a $3.2 billion program to provide 3,000 MW of solar power by 2016. [22] For systems over the size of 50KW, the CSI is a performance-based incentive (PBI) that automatically decreases over the duration of the 10 step program. [23] The incentive reduction links to increases in the aggregate capacity of PV installations. The design of the gradually decreasing PBI payments mirrors CPUC forecasts of PV component prices. However, PV prices have fallen less than CPUC forecasts and as the CSI reduction steps increase the economic project feasibility greatly diminishes. Since the Expected performance-based buydown (EPBB) payments are for systems of 50KW or less, this model is based on CSI PBI payments. Note the CSI revenue is a State PBI and as such is taxable at the Federal and State level. In addition, the CSI incentive is only available for the systems first 5 years of operation. Under the CSI program, the system generates two streams of revenue:

The first is the monthly State PBI payments (for the first 60 months). The second is the monthly revenue from selling the energy at wholesale prices to the utility. Southern California Edison (SCE) is on step 5 for non-residential customers as of 3/27/2010 and will be the basis of our analysis as the other 2 utilities are on step 6 and as the newly constructed project modeled is in the SCE service area. [24]

The following table depicts as shaded the commercial PBI payment of $0.22 at step 5:

		EPBB Payments (per Watt) – Not Used			PBI Payments (per kWh)		
Step	Statewide MW in Step	Residential	Non-Residential: Commercial	Non-Residential: Government/ Non-Profit	Residential	Non-Residential: Commercial	Non-Residential: Government/ Non-Profit
1	50	n/a	n/a	n/a	n/a	n/a	n/a
2	70	$2.50	$2.50	$3.25	$0.39	$0.39	$0.50
3	100	$2.20	$2.20	$2.95	$0.34	$0.34	$0.46
4	130	$1.90	$1.90	$2.65	$0.26	$0.26	$0.37
5	160	$1.55	$1.55	$2.30	$0.22	$0.22	$0.32
6	190	$1.10	$1.10	$1.85	$0.15	$0.15	$0.26
7	215	$0.65	$0.65	$1.40	$0.09	$0.09	$0.19
8	250	$0.35	$0.35	$1.10	$0.05	$0.05	$0.15
9	285	$0.25	$0.25	$0.90	$0.03	$0.03	$0.12
10	350	$0.20	$0.20	$0.70	$0.03	$0.03	$0.10

The following table depicts the current step for each California Utility and a detailed description of how many MW remain. Step 5 for SCE is shaded:

Administrator	Customer Class	Current Step	Revised Total MW in Step	Issued Conditional Reservation Letters (MW)	MW Remaining	MW Under Review
PGE	Residential	6	29.04	19.96	9.08	3.66
	Non-Residential	6	80.43	35.49	44.94	17.82
SCE	Residential	4	21.05	14.34	6.71	2.15
	Non-Residential	5	83.99	50.52	33.47	13.3

	Residential	6	6.62	4.73	1.89	1.93
CCSE	Non-Residential	6	14.94	9.48	5.46	3.21

3.4 California Feed-in Tariff Pricing

The California Feed-in Tariff (FIT)[25] is a production contract between the utility company and the developer to supply energy at a specified price. Furthermore, the California FIT has a time of delivery (TOD) performance based incentive based on the utility's avoided costs. Energy production during utility peak hours requires a higher price reflecting the higher cost of generation during those hours. However, the energy production during off-peak hours is less valuable to the utility resulting in a lower price. The California Public Utilities Commission (CPUC) is responsible for regulating the privately owned utilities in the state of California. In January 2008, the CPUC enacted the Feed-in Tariff for California. The FIT will be available until the utilities invest in a statewide cumulative generation capacity of 750 MW. Each utility is responsible for a total generation capacity proportional to sales. [26]

To compute the revenue in $/kWh ($R_t$) for any given kWh produced and sold to the utility at time "t" would be calculated by the following formula [27]:

$$A_t * B * C_t = R_t$$

Where, A_t = kWh of energy distributed onto the utility grid at time "t",

B = MPR (Market Price Referents) fixed at time of actual commercial operation

C_t = TOD (Time of Delivery) adjustment factor for time "t"

This study uses the Southern California Edison FIT because it has the highest time of delivery adjustment factors and ease of comparability with the SCE CSI. The model uses the 25-Year Market Price Referents in the following table as that is the maximum time period for both the FIT and CSI subsidies. Also, the model assumes that all systems, in the thesis, are eligible for both the FIT and CSI subsidies. (although only one, either the FIT or the CSI, may be used in a development).

Adopted 2009 Market Price Referents[1] (Nominal - dollars/kWh)				
Contract Start Date	**10-Year**	**15-Year**	**20-Year**	**25-Year**
2010	0.08448	0.09066	0.09674	0.10020
2011	0.08843	0.09465	0.10098	0.10442
2012	0.09208	0.09852	0.10507	0.10852
2013	0.09543	0.10223	0.10898	0.11245
2014	0.09872	0.10593	0.11286	0.11636
2015	0.10168	0.10944	0.11647	0.12002
2016	0.10488	0.11313	0.12020	0.12378
2017	0.10834	0.11695	0.12404	0.12766
2018	0.11204	0.12090	0.12800	0.13165
2019	0.11598	0.12499	0.13209	0.13575
2020	0.12018	0.12922	0.13630	0.13994
2021	0.12465	0.13359	0.14064	0.14424

The following table provides the TOD (Time of Delivery) adjustment factor:

Southern California Edison Company			
Season	**Period**	**Definition**	**Factor**
Summer	On-Peak	WDxH[1], noon-6 pm	**3.13**
June 1 -	Mid-Peak	WDxH, 8-noon, 6-11 pm	**1.35**

September 30			
	Off-Peak	All other times	**0.75**
Winter October 1 - May 31	Mid-Peak	WDxH, 8 am-9 pm	**1**
	Off-Peak	WDxH, 6-8 am, 9 pm-midnight; WE/H[2] 6 am-midnight	**0.83**
	Super-Off-Peak	Midnight-6 am	**0.61**

4 Model Generation Test

The National Renewable Energy Laboratory created the industry standard photovoltaic generation and revenue calculator, PVWatts. PVWatts creates an hour-by-hour performance simulation much as in the thesis model and is an excellent test for AC generation. Both models are set to 2MW systems, tilts equal to latitude and azimuths equal to 180°.

Generation	KW/h/Yr		
	Fixed	1-Axis	2-Axis
PVWatts	2,916,710	3,840,389	4,039,269
Thesis	3,058,231	4,085,296	4,235,740
% Difference	4.85%	6.38%	4.86%

Only a few changes were made to the base case in order to test it against the PVWatts model. The % percent differences are well within acceptable parameters and explainable by different assumptions. PVWatts applies a power correction of -0.5% per degree Celsius for crystalline silicon PV modules. The thesis model is not setup to correct generation for module operating temperature. [22]

5 Application of the Model

5.1 2010 Investment Evaluation

These tables are the minimum installed costs where the equity partner's NPV=0, or any installed cost less than shown on the table provides the equity holder with a positive return. The debt holder will always have a positive return or else the money would never have been lent.

Developers may expect installed costs of $3.50/W for Fixed, $3.90/W for 1-axis and $4.15/W for 2-axis.

Minimum installed cost where Equity NPV=0		2-Axis								
		2MW			20MW			100MW		
		$/Wp	Real LCOE	Nom LCOE	$/Wp	Real LCOE	Nom LCOE	$/Wp	Real LCOE	Nom LCOE
Installed cost	Wholesale	0.8440	0.0788	0.0963	1.1252	0.0892	0.1089	1.1502	0.0901	0.1100
	CSI	4.0987	0.3147	0.3842	4.3799	0.3250	0.3968	4.4049	0.3259	0.3980
	FIT	2.6814	0.2120	0.2588	2.9626	0.2223	0.2714	2.9876	0.2232	0.2726

Minimum installed cost where Equity NPV=0		1-Axis								
		2MW			20MW			100MW		
		$/Wp	Real LCOE	Nom LCOE	$/Wp	Real LCOE	Nom LCOE	$/Wp	Real LCOE	Nom LCOE
Installed cost	Wholesale	0.7835	0.0773	0.0943	1.0627	0.0878	0.1073	1.0875	0.0888	0.1084
	CSI	3.9000	0.3117	0.3805	4.1792	0.3222	0.3934	4.2040	0.3232	0.3946
	FIT	2.5355	0.2090	0.2552	2.8146	0.2196	0.2681	2.8395	0.2205	0.2693

Minimum installed cost where Equity NPV=0		Fixed								
		2MW			20MW			100MW		
		$/Wp	Real LCOE	Nom LCOE	$/Wp	Real LCOE	Nom LCOE	$/Wp	Real LCOE	Nom LCOE
Installed cost	Wholesale	0.4130	0.0644	0.0787	0.6922	0.0782	0.0955	0.7170	0.0794	0.0970
	CSI	2.8030	0.2988	0.3649	3.0822	0.3126	0.3817	3.1070	0.3138	0.3832
	FIT	1.8598	0.2063	0.2519	2.1390	0.2201	0.2687	2.1638	0.2213	0.2702

The entries in blue are viable positive NPV options. The 2-Axis 20MW plant produces a NPV of $0.230/W to equity holders. The 2-Axis 100MW plant produces a

NPV of $0.255/W to equity holders. The 1-Axis 20MW plant produces a NPV of $0.279/W to equity holders. The 1-Axis 100MW plant produces a NPV of $0.304/W to equity holders.

5.2 California Solar Initiative Evaluation

The CSI subsidy automatically decreases over the duration of the 10-step program. The program is meant to end in 2015 with a step increasing each year from 5 in 2010 (for Southern California Edison). Since the base project length is 25 years it is necessary to use a natural gas price forecast to determine the 25 year electricity price growth rate. The Energy Information Administration (EIA) provides an electrical natural gas price from 2008 forecast until 2035. This forecast allows the evaluation of the 25-year CSI starting in 2011. In order to evaluate the progression of the CSI starting from 2011 to 2015 run a regression on the electric natural gas prices from 2009 to 2035 to forecast the prices from 2036 to 2039. Additionally, it is necessary to use the forecast to find the 2011 to 2015 growth in wholesale generation weighted average prices and nominal energy price growth. This data allows for the evaluation of the CSI in the most likely scenarios.

5.2.1 Electric Natural Gas Price Regression

The electric natural gas price regression from 2009 to 2035:

Regression Statistics	
Multiple R	0.9527504
R Square	0.9077334
Adjusted R Square	0.9040427
Standard Error	0.328781
Observations	27

ANOVA					
	Df	*SS*	*MS*	*F*	*Significance F*

Regression	1	26.587	26.5869	245.95	1.91024E-14
Residual	25	2.7024	0.1081		
Total	26	29.289			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-250.7159	16.426087	-15.263	3.5379E-14	-284.5460	-216.8856	-284.5460	-216.885
X Variable 1	0.1274021	0.0081236	15.6829	1.9102E-14	0.110671	0.144132	0.110671	0.144132

The regression produces the following forecast:

Year	Forecast
2036	8.67479
2037	8.802192
2038	8.929595
2039	9.056997

Section 5.3.4 uses the price forecasts.

5.2.2 25-Year Electricity Price Nominal Growth Rate

The nominal 25-year electricity growth rates (Using the regression forecast of gas prices) for the initial year are:

Year	Nominal Growth
2011	4.3501%
2012	4.0994%
2013	4.3185%
2014	4.4066%
2015	4.3422%

5.2.3 Installed Cost Forecast

Installed costs decline at an average of 3.6% per year.

The analysis uses the following installed costs:

	Installed Cost					
System	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
2-Axis	4.15	4.000600	3.856578	3.717742	3.583903	3.454882
1-Axis	3.9	3.759600	3.624254	3.493781	3.368005	3.246757
Fixed	3.5	3.374000	3.252536	3.135445	3.022569	2.913756

5.2.4 Wholesale Generation Weighted Average Price

The following wholesale generation weighted average prices are the result of inflating the 2010 price at the EIA forecast growth rate:

	Wholesale Generation Weighted Average Price					
System	2010	2011	2012	2013	2014	2015
2-Axis	0.03591	0.035674	0.036745	0.037259	0.037318	0.037600
1-Axis	0.03594	0.035697	0.036769	0.037283	0.037342	0.037624
Fixed	0.03500	0.034766	0.035811	0.036311	0.036368	0.036644

5.2.5 Base Case

The base case is the planned progression of the CSI subsidy or step 5 in 2010 to step 10 in 2015:

CSI Evaluation	Start Year	2010	Step	5					
	2-Axis			1-Axis			Fixed		
	2MW	20MW	100MW	2MW	20MW	100MW	2MW	20MW	100MW
Equity NPV	(24,748)	1,109,742	6,151,919	(4)	1,357,188	7,389,149	(384,617)	(2,488,942)	(11,841,498)
Real LCOE	0.3184	0.3083	0.3075	0.3117	0.3012	0.3003	0.3761	0.3622	0.3610
Nominal LCOE	0.3888	0.3765	0.3754	0.3805	0.3678	0.3667	0.4593	0.4423	0.4407

CSI Evaluation	Start Year	2011	Step	6					
	2-Axis			1-Axis			Fixed		
	2MW	20MW	100MW	2MW	20MW	100MW	2MW	20MW	100MW
Equity NPV	(396,593)	(2,608,763)	(12,440,630)	(359,890)	(2,241,731)	(10,605,472)	(644,930)	(5,092,137)	(24,857,501)
Real LCOE	0.3076	0.2976	0.2967	0.3011	0.2907	0.2898	0.3635	0.3496	0.3484
Nominal LCOE	0.3756	0.3633	0.3622	0.3677	0.3550	0.3538	0.4439	0.4269	0.4254

CSI Evaluation	Start Year	2012	Step	7					
	2-Axis			1-Axis			Fixed		
	2MW	20MW	100MW	2MW	20MW	100MW	2MW	20MW	100MW
Equity NPV	(724,937)	(5,892,321)	(28,858,472)	(677,801)	(5,420,958)	(26,501,658)	(873,664)	(7,379,593)	(36,294,829)

	2-Axis 2MW	2-Axis 20MW	2-Axis 100MW	1-Axis 2MW	1-Axis 20MW	1-Axis 100MW	Fixed 2MW	Fixed 20MW	Fixed 100MW
Real LCOE	0.2972	0.2872	0.2863	0.2910	0.2806	0.2796	0.3513	0.3374	0.3362
Nominal LCOE	0.3629	0.3506	0.3495	0.3553	0.3426	0.3414	0.4290	0.4120	0.4105

CSI Evaluation	Start Year	2013	Step	8					
	2-Axis			1-Axis			Fixed		
	2MW	20MW	100MW	2MW	20MW	100MW	2MW	20MW	100MW
Equity NPV	(959,275)	(8,235,434)	(40,573,917)	(905,032)	(7,693,000)	(37,861,750)	(1,034,065)	(8,983,334)	(44,313,418)
Real LCOE	0.2870	0.2770	0.2761	0.2811	0.2706	0.2697	0.3395	0.3255	0.3243
Nominal LCOE	0.3505	0.3382	0.3371	0.3432	0.3304	0.3293	0.4145	0.3975	0.3960

CSI Evaluation	Start Year	2014	Step	9					
	2-Axis			1-Axis			Fixed		
	2MW	20MW	100MW	2MW	20MW	100MW	2MW	20MW	100MW
Equity NPV	(1,036,823)	(9,011,002)	(44,451,801)	(980,978)	(8,452,554)	(41,659,558)	(1,081,818)	(9,460,957)	(46,701,574)
Real LCOE	0.2774	0.2673	0.2664	0.2716	0.2612	0.2603	0.3282	0.3142	0.3130
Nominal LCOE	0.3387	0.3264	0.3253	0.3317	0.3190	0.3178	0.4007	0.3837	0.3822

CSI Evaluation	Start Year	2015	Step	10					
	2-Axis			1-Axis			Fixed		
	2MW	20MW	100MW	2MW	20MW	100MW	2MW	20MW	100MW
Equity NPV	(954,579)	(8,188,625)	(40,339,942)	(902,751)	(7,670,344)	(37,748,538)	(1,014,869)	(8,791,522)	(43,354,425)
Real LCOE	0.2681	0.2580	0.2571	0.2626	0.2521	0.2512	0.3173	0.3034	0.3021
Nominal LCOE	0.3273	0.3150	0.3140	0.3206	0.3079	0.3067	0.3874	0.3704	0.3689

The only positive NPV equity holder investments are farms totaling 20MW and 100MW using the 2-axis and 1-axis systems in step 5 of 2010.

5.3 Feed-In Tariff Evaluation

5.3.1 2010 Prices

These are the 2010 FIT generation weighted average prices:

2010	2-Axis	1-Axis	Fixed

FIT GWAP	0.12400693	0.123761581	0.125971155

The installed costs are \$3.50/W for Fixed, \$3.90/W for 1-axis and \$4.15/W for 2-axis and used in this analysis.

This table shows the 2010 minimum FIT generation weighted average prices necessary for the equity partner's NPV=0. Any FIT higher than shown on the table provides the equity holder with a positive return.

2010 Minimum FIT where Equity NPV=0	IC = 4.15 2-Axis	IC = 3.9 1-Axis	IC = 3.5 Fixed
2MW	0.1774459	0.1756169	0.2142896
20MW	0.1672131	0.1650072	0.2001169
100MW	0.1663035	0.1640642	0.1988571

In 2010 no investment using a FIT contract produces positive equity holder value.

5.3.2 Electric Natural Gas Price Regression

Using the regression in section 5.2.1 provides the electric natural gas prices:

Year	Forecast
2036	8.67479
2037	8.802192
2038	8.929595
2039	9.056997
2040	9.184399
2041	9.311801
2042	9.439203
2043	9.566605

5.3.3 25-Year Electricity Price Nominal Growth Rate

The nominal 25-year electricity growth rates (Using the regression forecast of gas prices) for the initial year are:

Year	Nominal Growth
2010	5.6172%
2014	4.4066%
2015	4.3422%
2016	4.3426%
2017	4.3935%
2018	4.4187%
2019	4.4307%
2020	4.3976%

5.3.4 Installed Cost Forecast

Installed costs decline at an average of 3.6% per year.

The analysis uses the following installed costs:

	Installed cost							
System	2010	2014	2015	2016	2017	2018	2019	2020
2-Axis	4.15	3.583903	3.454882	3.330507	3.210608	3.095026	2.983606	2.876196
1-Axis	3.9	3.368005	3.246757	3.129874	3.017198	2.908579	2.803870	2.702931
Fixed	3.5	3.022569	2.913756	2.808861	2.707742	2.610263	2.516294	2.425707

5.3.5 Base Case

The next series of tables are the equity partners FIT net present value evaluations on a yearly basis. As time passes solar systems cost less and the FIT increases making investment more attractive:

FIT Evaluation	Start Year	2010							
	2-Axis			1-Axis			Fixed		
	FIT GWAP =	0.124006928		FIT GWAP =	0.123761581		FIT GWAP =	0.12597115	
	2MW	20MW	100MW	2MW	20MW	100MW	2MW	20MW	100MW
Equity NPV	(708,787)	(5,730,645)	(28,050,014)	(663,353)	(5,276,309)	(25,778,334)	(845,766)	(7,100,432)	(34,898,948)
Real LCOE	0.3184	0.3083	0.3075	0.3117	0.3012	0.3003	0.3761	0.3622	0.3610
Nominal LCOE	0.3888	0.3765	0.3754	0.3805	0.3678	0.3667	0.4593	0.4423	0.4407

FIT Evaluation	Start Year	2014							
	2-Axis			1-Axis			Fixed		
	FIT GWAP =	0.144006448		FIT GWAP =	0.143721533		FIT GWAP =	0.14628746	
	2MW	20MW	100MW	2MW	20MW	100MW	2MW	20MW	100MW
Equity NPV	(170,306)	(345,840)	(1,125,991)	(149,395)	(136,726)	(80,422)	(419,113)	(2,833,905)	(13,566,315)
Real LCOE	0.2774	0.2673	0.2664	0.2716	0.2612	0.2603	0.3282	0.3142	0.3130
Nominal LCOE	0.3387	0.3264	0.3253	0.3317	0.3190	0.3178	0.4007	0.3837	0.3822

FIT Evaluation	Start Year	2015							
	2-Axis			1-Axis			Fixed		
	FIT GWAP =	0.148536043		FIT GWAP =	0.148242166		FIT GWAP =	0.1508888	
	2MW	20MW	100MW	2MW	20MW	100MW	2MW	20MW	100MW

Equity NPV	(48,251)	874,660	4,976,486	(32,897)	1,028,200	5,744,185	(322,366)	(1,866,493)	(8,729,280)
Real LCOE	0.2681	0.2580	0.2571	0.2626	0.2521	0.2512	0.3173	0.3034	0.3021
Nominal LCOE	0.3273	0.3150	0.3140	0.3206	0.3079	0.3067	0.3874	0.3704	0.3689

FIT Evaluation	Start Year	2016							
	2-Axis			1-Axis			Fixed		
	FIT GWAP =	0.153189397		FIT GWAP =	0.152886313		FIT GWAP =	0.15561586	
	2MW	20MW	100MW	2MW	20MW	100MW	2MW	20MW	100MW
Equity NPV	73,512	2,092,170	11,063,982	83,346	2,190,514	11,555,703	(226,071)	(903,655)	(3,915,140)
Real LCOE	0.2591	0.2490	0.2481	0.2538	0.2434	0.2424	0.3068	0.2928	0.2916
Nominal LCOE	0.3163	0.3041	0.3030	0.3099	0.2972	0.2960	0.3746	0.3576	0.3561

FIT Evaluation	Start Year	2017							
	2-Axis			1-Axis			Fixed		
	FIT GWAP =	0.157991262		FIT GWAP =	0.157678677		FIT GWAP =	0.16049379	
	2MW	20MW	100MW	2MW	20MW	100MW	2MW	20MW	100MW
Equity NPV	195,521	3,312,521	17,165,856	199,857	3,355,881	17,382,654	(129,905)	58,269	894,598
Real LCOE	0.2503	0.2402	0.2394	0.2452	0.2348	0.2339	0.2965	0.2826	0.2813
Nominal LCOE	0.3056	0.2933	0.2922	0.2994	0.2867	0.2856	0.3620	0.3450	0.3435

FIT Evaluation	Start Year	2018							
	2-Axis			1-Axis			Fixed		
	FIT GWAP =	0.162929262		FIT GWAP =	0.162606908		FIT GWAP =	0.16551000	
	2MW	20MW	100MW	2MW	20MW	100MW	2MW	20MW	100MW
Equity NPV	316,624	4,523,463	23,220,524	315,538	4,512,607	23,166,248	(34,595)	1,011,278	5,659,601
Real LCOE	0.2420	0.2319	0.2310	0.2371	0.2267	0.2257	0.2867	0.2728	0.2716
Nominal LCOE	0.2954	0.2832	0.2821	0.2895	0.2768	0.2756	0.3501	0.3331	0.3316

FIT Evaluation	Start Year	2019							
	2-Axis			1-Axis			Fixed		
	FIT GWAP =	0.168003398		FIT GWAP =	0.167671005		FIT GWAP =	0.17066451	

	2MW	20MW	100MW	2MW	20MW	100MW	2MW	20MW	100MW
Equity NPV	437,387	5,731,039	29,258,378	430,928	5,666,443	28,935,401	60,219	1,959,358	10,399,975
Real LCOE	0.2339	0.2239	0.2230	0.2292	0.2188	0.2179	0.2773	0.2634	0.2622
Nominal LCOE	0.2856	0.2733	0.2723	0.2799	0.2672	0.2661	0.3386	0.3216	0.3201

FIT Evaluation	Start Year	2020							
	2-Axis			1-Axis			Fixed		
	FIT GWAP =	0.173188917		FIT GWAP =	0.172846264		FIT GWAP =	0.17593217	
	2MW	20MW	100MW	2MW	20MW	100MW	2MW	20MW	100MW
Equity NPV	557,979	6,936,840	35,287,332	546,175	6,818,801	34,697,139	154,703	2,904,084	15,123,554
Real LCOE	0.2262	0.2161	0.2152	0.2217	0.2113	0.2103	0.2683	0.2543	0.2531
Nominal LCOE	0.2761	0.2639	0.2628	0.2707	0.2579	0.2568	0.3276	0.3106	0.3090

The figures highlighted represent -the first years that the equity partner will begin to show a positive net present value with each subsequent year providing more profit:

	2-Axis			1-Axis			Fixed		
	2MW	20MW	100MW	2MW	20MW	100MW	2MW	20MW	100MW
+ Equity NPV	2016	2015	2015	2016	2015	2015	2019	2017	2017

6 Analysis

6.1 2010 Investment Evaluation

Based on the positive equity holder value and farm size factors we see that the 2010 investment landscape favors the largest investors. Not many small- to medium-size developers have the financial resources necessary to implement 20MW to 100MW farms costing from $78 to $415 million.

The only projects providing positive equity holder value are 2-axis and 1-axis systems that are 20MW or 100MW in size with the CSI subsidy. It is interesting to note that the smaller the project the less viable the project. Unfortunately, the CSI subsidy is the only positive investment. The FIT subsidy does not achieve a positive investment. As very few large scale projects are being financed it is challenging to determine effective projects characteristics. [2] Once the CSI enters stage 6, this thesis forecasts a precipitous drop in investment unless changes are made.

For 2010, a FIT necessary to stimulate photovoltaic investment in large farms should be much higher. A paper recently published by Matulka and DeShazo reaches much the same conclusion: The FIT is based on the value of the electricity, not on the cost of generation, and, thus, are not high enough to be effective. Solar developers have not used the FIT as a result. [28]

Wholesale market prices are far too low to encourage any investment.

6.2 California Solar Initiative Evaluation

The CSI subsidy decreases much too quickly as only 20MW and 100MW farms using 2-axis and 1-axis systems in 2010 with step 5 are positive equity holder net present value investments. In all subsequent years, every configuration provides no incentive to invest in a photovoltaic system unless drastic decreases in installed costs materialize or developers are able to realize significant economies of scale or cost synergies from the farm size. In order to transform the CSI subsidy into an effective means of encouraging investment past 2010 either: 1) increase the subsidy for each step, or 2) decrease the number of steps in the program at an increased the subsidy level. The challenge lies in the fact that the CSI PBI subsidy levels are attempting to incentivizing 650MW of PV investment. The state of California will need to pay for any changes to the subsidy levels or decrease the amount the program is set to incentivize to an amount far below 650MW to promote investment past step 5. Given that the state of California is nearing bankruptcy, the second option should provide a more palatable means of making the CSI subsidy a positive way to promote investment past step 5. However if no change to CSI subsidy levels or timing is possible, investors and developers should ensure that investment occurs immediately in step 5 and only step 5. CSI investments should be expected to be front loaded, steps 1 – 5, and trailing off in the latter half of the steps, steps 6 - 10.

6.3 Feed-In Tariff Evaluation

As time passes, the FIT generation weighted average price increases and installed cost decreases making investment an option as it is not in 2010. Each 2-axis and 1-axis system is worthwhile investments by a 2016 start date and fixed by 2019. The FIT market price referent should increase. As for the next 5 years, the incentive is far too low. The market price referent (MPR) should account for PV installed cost forecasts allowing for an incentive leveling effect transferring some of the incentives from later years to nearer years. Any changing of the MPR, by the state of California, will ultimately be passed onto the taxpayers in higher electricity costs as the MPR is the predicted annual average cost of production for a combined-cycle natural gas fired baseload proxy plant. Much to the ire of taxpayers, the state of California will need to subsidize the additional higher price utilities will pay. If no MPR change occurs, investors and developers should conduct their planning to provide for start dates not earlier than 2015 to invest in PV and enter into FIT contracts. However, the longer the wait, the higher the net present value to equity holders meaning a 2021 contract will be the most valuable of all contract years. Investors should not use FIT contracts during the first half of availability forcing a back loading of contracts.

7 Conclusion

This paper contributes to the debate about providing optimal incentives by using a detailed financial model. The model is based on actual incentive and policy parameters and demonstrates the need to increase the incentives and modify the policies to encourage near-term development. The CPUC forecast is overly optimistic and projects an excessive amount of innovation from PV manufacturers. As such, installed costs are expected to be too high to make profits in the near future. Although, the hope is for subsidies to drive innovation, the subsidies decrease much too quickly for that. As the efficiency and implementation cost of renewable energy technology improves, the U.S. Government, and specifically the state of California, must institute additional subsidies and incentives for renewable energy projects in order to spur all types and segments of renewable energy investment. If they do, large scale solar farms should be economically viable sources of energy for commercial development.

However, as this paper demonstrates, unless changes are made to the Californian incentive level and structure many opportunities to increase the amount of PV green energy will be lost. The current investment landscape suits only the largest developers with positive equity holder value in 1-axis and 2-axis farms with sizes of

20MW and 100MW using the CSI subsidy. Currently, investments using the feed-in tariff or wholesale prices lose money. The CSI subsidy payout decreases much too quickly after step 5 and subsequent investment is not recommended. A possible solution lies in changing the CSI by decreasing the amount of MW subsidized and concentrating the subsidy over fewer steps and a shorter time frame.

FIT investments encourage back loading of contracts as positive equity holder value begins in 2015. A suggested change to the FIT structure is to modify the MRP forecasts for PV installed costs in a manner that shifts the subsides forward to create positive NPV investments in the near term rather than in the distant future. Taking such actions will change Californian polices to spur innovation and allow America to stay at the forefront of renewable technology.

8 Works Cited

[1]. **The Climate Group.** States and Regions: Renewable Energy. *The Climate Group Website,* [Online] 2009. [Cited: April 15, 2010]. http://www.theclimategroup.org/programmes/states-and-regions/renewable-energy/

[2]. **Global Market Research.** Solar Photovoltaic Industry: 2010 Global Outlook. *Deutsche Bank,* 8 February, 2010. Obtained at: http://65.181.148.190/renewableenergyinfo/includes/resource-files/solar%20pv%20outlook%20fitt_8%20feb%2010_pdf.pdf

[3]. **U.S. Department of Energy.** Loan Guarantee Program: Loan Guarantee Solicitation Announcement. *U.S. Department of Energy Website,* [Online] October 7, 2009. [Cited: April 23, 2010]. http://www.lgprogram.energy.gov/Solicitationfinal.pdf

[4]. **U.S. Department of Agriculture.** Business and Cooperative Programs: Rural Energy for America Program Guarantee Loan Program (REAP Loan). *U.S. Department of Agriculture Website,* [Online] 2010. [Cited: April 23, 2010]. http://www.rurdev.usda.gov/rbs/busp/9006loan.htm

[5]. **Cleantech Group.** News: First Solar, SCE Sign PPA for 550 MW Solar Projects. *Cleantech Group Website,* [Online] August 18, 2009. [Cited: April 24]. http://www.cleantech.com/news/4854/first-solar-sce-sign-ppa-550-mw-sol

[6]. **Bourzac, Katherine.** Scaling Up Solar Power. April 2010, *Technology Review*, Vol. 113, Number 2, pp. 84-86.

[7] **Wiser, Ryan, et al.** Tracking the Sun II: The Installed Cost of Photovoltaics in the U.S. from 1998-2008. *Lawrence Berkley National Laboratory,* October, 2009.

[8]. **Federal Reserve Statistical Release.** H.15 Selected Interest Rates. *The Federal Reserve Board Website,* [Online] June 2009. http://www.federalreserve.gov/releases/h15/

[9]. **National Renewable Energy Laboratory.** PVWatts: DC-to-AC Derate Factor. *NREL Renewable Resource Data Center Website,* [Online] February 9, 2010. [Cited: April 13, 2010]. http://www.nrel.gov/rredc/pvwatts/changing_parameters.html#dc2ac

[10]. **Osterwald, C.R., et al.** Degradation Analysis of Weathered Crystalline-Silicon PV Modules. Goldon, CO : *National Reneable Energy Laboratory*, February, 2002.

[11]. **National Renewable Energy Laboratory.** Solar Advisor Model - Version 2.5 [Software Package]. Golden, CO : *U.S. Department of Energy (DOE),* 2009.

[12]. **North Carolina Solar Center.** Database of State Incentives for Renewables & Efficiency (DSIRE). *North Carolina State University Website,* [Online] 2010. [Cited: April 15, 2010]. http://dsireusa.org/

[13]. **Navigant Consulting Inc.** A Review of PV Inverter Technology Cost and Performance Projections. Burlington, MA : *Subcontract Report NREL/SR-620-38771*, 2006.

[14]. **Kistner, Rainer and Price, Henry W.** Financing Solar Thermal Power Plants. Maui, HI: *National Renewable Energy Laboratory*, 1999.

[15]. **Wiser, Ryan H. and Pickle, Steven J.** Financing Investments in Renewable Energy: The Impacts of Policy Design. April 1998, *Renewable and Sustainable Energy Review*, Vol. 2, pp. 361-386.

[16]. **California Board of Equalization.** California City & County & Sales & Use Tax Rates. *State of California Website,* [Online]2010. [Cited: April 14, 2010]. http://www.boe.ca.gov/sutax/pam71.htm

[17]. **The Tax Foundation.** The Tax Foundation. *State Individual Income Tax Rates, 2000-2009,* [Online] July 1, 2009. http://www.taxfoundation.org/taxdata/show/228.html

[18]. **US Internal Revenue Code.** 26 USC §11. 2009.

[19]. **IRS.** Topic 409 – Capital Gains and Losses. *U.S. Treasury Website,* [Online] March 4, 2010. [Cited: April 15, 2010]. http://www.irs.gov/taxtopics/tc409.html

[20]. **U.S. Bureau of Labor Statistics Division of Consumer Prices and Price Indexes.** Consumer Price Index (CPI). *Bureau of Labor Statistics Website,* [Online], 2009. [Cited: April 22, 2010]. http://www.bls.gov/cpi/

[21]. **Headquarters Department of the Army, USA.** Technical Manual TM 5-811-6: Electric Power Plant Design. *US Army Corps of Engineers Website*, 20 January 1984, pp. 8-1. Obtained at: http://140.194.76.129/publications/armytm/tm5-811-6/c-8.pdf

[22]. **California Public Utilities Commission.** California Solar Initiative: About the California Solar Initiative. *State of California Website,* [Online] June 23, 2009. [Cited: April 15, 2010]. http://www.cpuc.ca.gov/PUC/energy/Solar/aboutsolar.htm

[23]. **North Carolina Solar Center.** Database of State Incentives for Renewables & Efficiency (DSIRE): California Solar Initiative. *North Carolina State University Website,* [Online] January 4, 2010. [Cited: April 17, 2010]. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA134F&re=1&ee=0

[24]. **California Energy Commission.** California Solar Initiative: Statewide Trigger Point Tracker. *State of California Website,* [Online] April 23, 2010. [Cited: April 23, 2010]. http://www.csi-trigger.com/

[25]. **California Public Utilities Commission.** Energy Division Resolution E-4298. *State of California Website,* [Online] December 17, 2009. [Cited: April 15, 2010]. http://docs.cpuc.ca.gov/PUBLISHED/FINAL_RESOLUTION/111386.htm

[26]. **North Carolina Solar Center.** Database of State Incentives for Renewables & Efficiency (DSIRE): California Feed-In Tariff. *North Carolina State University Website,* [Online] October 12, 2009. [Cited: April 17, 2010]. http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA167F&re=1&ee=0

[27]. **California Public Utilities Commission.** Renewables: Feed-In Tariff Price. *State of California Website,* [Online] January 4, 2010. [Cited: April 15, 2010]. http://www.cpuc.ca.gov/PUC/energy/Renewables/Feed-in+Tariff+Price.htm

[28]. **DeShazo, J.R. and Matulka, Ryan.** Designing an Effective Feed-in Tariff for Greater Los Angeles. *Los Angeles Business Council Study in Partnership with the UCLA Luskin Center for Innovation in Public Affairs*, 2010. Obtained at: http://labusinesscouncil.org/online_documents/2010/Designing-an-Effective-Feed-in-Tariff-for-Greater-Los-Angeles-040110.pdf

[29]. **Masters, Gilbert M.** *Renewable and Efficient Electric Power Systems.* John Wiley & Sons, Inc., 2004.

[30]. **US Internal Revenue Code.** 26 USC §168. 2009.

[31]. **California Franchise Tax Board.** Analysis of Amended Bill. *State of California Website,* [Online] April 3, 2008. [Cited: April 15, 2010]. http://www.ftb.ca.gov/law/legis/07_08bills/ab2491_040308.pdf

[32]. **US Internal Revenue Code.** 26 USC §48. 2009.

[33]. **Office of the Fiscal Assistant Secretary.** Payments for Specified Energy Property in Lieu of Tax Credits under the AMERICAN RECOVERY AND REINVESTMENT ACT OF 2009. *U.S. Treasury Department,* 2009. Obtained at: http://www.treas.gov/recovery/docs/guidance.pdf

[34]. **Sunpower Corporation.** The Drivers of the Levelized Cost of Electricity for Utility-Scale Photovoltaics. *Sunpower Corporation,* 14 August, 2008. Obtained at: http://us.sunpowercorp.com/downloads/SunPower_levelized_cost_of_electricity.pdf

9 Appendix

9.1 Solar Calculation

The following calculations are made on an hour by hour basis for each hour of sunlight at the current location queried by the database. [29]

9.1.1 Location Solar Calculations

Table 9.1.1: Location Solar Variables
δ = Solar Declination
n = Current Day Number
H = Hour Angle
Φ_S = Solar Azimuth Angle
β = Solar Altitude Angle
L = Latitude

$$\delta = 23.45 \sin\left[\frac{360}{365}(n-81)\right]$$

$$H^* = \left(\frac{15^\circ}{hour}\right) * (HoursBeforeSolarNoon)$$

*If $\cos H \geq \frac{\tan\delta}{\tan L}$, then $|\phi_S| \leq 90^\circ$; otherwise $|\phi_S| > 90^\circ$

$$Sin\beta = \cos L * \cos\delta * \cos H + \sin L * \sin\delta$$

$$Sin\phi_S = \frac{Cos\delta * \sin H}{Cos\beta}$$

9.1.2 Fixed Solar Array

Solver, the Microsoft Excel Add-On, optimizes the collector tilt angle calculation by maximizing the Wholesale revenue calculation by pressing the tilt angle button. The collector azimuth angle is positive in the southeast direction and negative in the southwest.

9.1.2.1 Direct-Beam and Diffuse Radiation

Table 9.1.2.1: Fixed Direct-Beam and Diffuse Radiation Solar Array Variables
I_{BDH} = Direct-Beam and Diffuse Insolation on a Horizontal Surface
I_{BD} = Direct-Beam and Diffuse Radiation (Normal to the Rays)
I_{BDC} = Direct-Beam and Diffuse Insolation Striking the Collector

θ = Incidence Angle Between a Normal to the Collector Face and Incoming Solar Beam Radiation
Φ_S = Solar Azimuth Angle
β = Solar Altitude Angle
Φ_C = Collector Azimuth Angle
Σ = Collector Tilt Angle

$$I_{BDH} = I_{BD} * \sin\beta$$

$$\cos\theta = \cos\beta * \cos(\phi_S - \phi_C) * \sin\Sigma + \sin\beta * \cos\Sigma$$

$$I_{BDC} = I_{BD} * \cos\theta$$

9.1.2.2 Reflected Radiation

Table 9.1.2.2: Fixed Reflected Radiation Solar Array Variables
I_{RC} = Reflected Radiation Striking the Collector
I_{BH} = Direct-Beam and Diffuse Insolation on a Horizontal Surface
ρ = Ground Reflectance (Default Value 0.2)
Σ = Collector Tilt Angle

$$I_{RC} = \rho * I_{BH} * \left(\frac{1-\cos\Sigma}{2}\right)$$

9.1.3 1-Axis Solar Array

9.1.3.1 Direct-Beam Radiation

Table 9.1.3.1: 1-Axis Direct-Beam Radiation Solar Array Variables
I_B = Direct-Beam (Normal to the Rays)
I_{BC} = Direct-Beam Insolation Striking the Collector
δ = Solar Declination

$$I_{BC} = I_B * \cos\delta$$

9.1.3.2 Diffuse Radiation

Table 9.1.3.2: 1-Axis Diffuse Radiation Solar Array Variables
I_{DH} = Diffuse Insolation on a Horizontal Surface
I_{DC} = Diffuse Insolation Striking the Collector
δ = Solar Declination
β = Solar Altitude Angle

$$I_{DC} = I_{DH} * \left[\frac{1+\cos(90^\circ - \beta + \delta)}{2}\right]$$

9.1.3.3 Reflected Radiation

Table 9.1.3.3: 1-Axis Reflected Radiation Solar Array Variables
I_{BDH} = Direct-Beam and Diffuse Insolation on a Horizontal Surface
I_{RC} = Reflected Insolation Striking the Collector
ρ = Ground Reflectance (Default Value 0.2)
δ = Solar Declination

β = Solar Altitude Angle

$$I_{RC} = \rho * I_{BDH} * \left[\frac{1 - \cos(90^\circ - \beta + \delta)}{2} \right]$$

9.1.4 2-Axis Solar Array

9.1.4.1 Direct-Beam Radiation

Table 9.1.4.1: 2-Axis Direct-Beam Radiation Solar Array Variables
I_B = Direct-Beam (Normal to the Rays)
I_{BC} = Direct-Beam Insolation Striking the Collector
δ = Solar Declination

$$I_{BC} = I_B$$

9.1.4.2 Diffuse Radiation

Table 9.1.4.2: 2-Axis Diffuse Radiation Solar Array Variables
I_{DH} = Diffuse Insolation on a Horizontal Surface
I_{DC} = Diffuse Insolation Striking the Collector
δ = Solar Declination
β = Solar Altitude Angle

$$I_{DC} = I_{DH} * \left[\frac{1 + \cos(90^\circ - \beta + \delta)}{2} \right]$$

9.1.4.3 Reflected Radiation

Table 9.1.4.3: 2-Axis Reflected Radiation Solar Array Variables
I_{BDH} = Direct-Beam and Diffuse Insolation on a Horizontal Surface
I_{RC} = Reflected Insolation Striking the Collector
ρ = Ground Reflectance (Default Value 0.2)
δ = Solar Declination
β = Solar Altitude Angle

$$I_{RC} = \rho * I_{BDH} * \left[\frac{1 - \cos(90^\circ - \beta + \delta)}{2} \right]$$

9.1.5 Yearly and Hourly Insolations

Table 9.1.5: Yearly Insolation Variables
Ψ_Y = Yearly Global Insolation Striking the Collector (Wh/m^2)
K_H = Hourly Insolation Striking the Collector (Wh/m^2)
I_{BC} = Hourly Direct-Beam Insolation Striking the Collector (Wh/m^2)
I_{DC} = Hourly Diffuse Insolation Striking the Collector (Wh/m^2)
I_{RC} = Hourly Reflected Insolation Striking the Collector (Wh/m^2)

$$\Psi_y = \sum_{h=1}^{8760} [I_{BC} + I_{DC} + I_{RC}]$$

The yearly insolation of the system is equal to the hourly sum of the location specific direct-beam, diffuse and reflected insolations striking the collector.

$$K_H = I_{BC} + I_{BC} + I_{DC}$$

The hourly insolation of the system at any given hour is equal to the sum of the location specific direct-beam, diffuse and reflected insolations striking the collector.

9.2 NPV Calculations

9.2.1 Solar Revenue

9.2.1.1 DC Generation

Table 9.2.1.1: DC Generation Variables
GDC_Y = Yearly DC Generation (KWh) Ψ_Y = Yearly Global Insolation Striking the Collector (Wh/m^2) W_P = Peak Watt Rating of the PV System (W) AM1.5G = Global Air Mass Constant = 1000 W/m^2

$$GDC_y = \frac{\Psi_Y * W_P}{AM1.5G}$$

9.2.1.2 AC Generation

Table 9.2.1.2: AC Generation Variables
GAC_Y = Yearly AC Generation (KWh) GDC_Y = Yearly DC Generation (KWh) ε = DC-to-AC Derating Factor (%)

$$GAC_y = GDC_y * \varepsilon$$

Direct Current generation converts into Alternating Current at the derating factor (ε) accounting for module mismatch and dust factor, array temperature factor, wiring efficiency factor and inverter efficiency factor. The DC-to-AC derating factor is the industry standard 77%.

9.2.1.3 Current AC Generation

Table 9.2.1.3: AC Generation Variables
GAC_Y = Yearly AC Generation (KWh) $CGAC_Y$ = Current Yearly AC Generation (KWh) D_F = Degradation Factor (%) CY = Current Year

$CGAC_Y = GAC_Y * (1 - D_F)^{CY}$

Many factors such as packing material degradation, adhesional degradation, interconnect degradation, moisture intrusion and semiconductor device degradation leads to module degradation. The hardware degradation of Photovoltaic systems ranges from 0.3% to 1% with an average of 0.71% per year leading to a loss of generation ability.

9.2.1.4 Wholesale Market Revenue

Table 9.2.1.4: Wholesale Market Revenue Variables
$GWAPI_W$ = Initial Wholesale Generation Weighted Average Price ($)
K_H = Hourly Insolation Striking the Collector (Wh/m^2)
P_{HW} = Hourly Wholesale Price ($/KWh)
RI_{YW} = Initial Yearly Revenue Using Wholesale Market Prices ($)
W_P = Peak Watt Rating of the PV System (W)
AM1.5G = Global Air Mass Constant = 1000 W/m^2
ε = DC-to-AC Derating Factor (%)
$GWAPC_W$ = Current Wholesale Generation Weighted Average Price ($)
EI = Electricity Inflation Rate (%)
CY = Current Year
RC_{YW} = Current Yearly Revenue Using Wholesale Market Prices ($)
$CGAC_Y$ = Current Yearly AC Generation (KWh)

California ISO provides the hourly wholesale market prices and an explanation for the prices are given in section 2.2 (Wholesale Pricing Data).

$$GWAPI_W = \frac{\sum_{h=1}^{8760}[K_H * P_{HW}]}{\sum_{h=1}^{8760}[K_H]}$$

$$RI_{YW} = \sum_{h=1}^{8760}[K_H * P_{HW}] * \frac{W_P}{AM1.5G} * \varepsilon$$

The wholesale market is the only pricing scheme where the price grows at the electricity inflation rate because the CSI and FIT are constant contract prices set at the onset of operation.

$$GWAPC_W = GWAPI_W * (1 + EI)^{CY}$$

$RC_{YW} = CGAC_Y * GWAPC_W$

9.2.1.5 California Feed-In Tariff Revenue

Table 9.2.1.5: California Feed-In Tariff Revenue Variables
$GWAP_{FIT}$ = Feed-In Tariff Generation Weighted Average Price ($)
K_H = Hourly Insolation Striking the Collector (Wh/m^2)
TOD_H = Time Of Delivery Factor at time H
MRP = Market Price Referent ($/KWh)
RI_{YFIT} = Initial Yearly Revenue Using California Feed-In Tariff Prices ($)
W_P = Peak Watt Rating of the PV System (W)
AM1.5G = Global Air Mass Constant = 1000 W/m^2
ε = DC-to-AC Derating Factor (%)
RC_{YFIT} = Current Yearly Revenue Using California Feed-In Tariff Prices ($)
$CGAC_Y$ = Current Yearly AC Generation (KWh)

Section 2.3 (California Feed-In Tariff Pricing Data) explains the TOD and MRP variables.

$$GWAP_{FIT} = \frac{\sum_{h=1}^{8760}[K_H * TOD_H * MRP]}{\sum_{h=1}^{8760}[K_H]}$$

$$RI_{YFIT} = \sum_{h=1}^{8760}[(K_H * TOD_H * MRP)] * \frac{W_P}{AM1.5G} * \varepsilon$$

$$RC_{YFIT} = CGAC_Y * GWAP_{FIT}$$

9.2.2 Capital Investment

Table 9.2.2: Capital Investment Variables
TCC = Total Installed Cost After Accounting for Interest Earned & Paid ($)
CC = Monthly Cost ($)
CC_I = Installed Cost ($)
M = Months of Construction
M_C = Current Month of Construction
I_E = Monthly Interest Earned on Escrow Funds ($)
I_P = Monthly Interest Paid on Spent Escrow Funds ($)
ECF_I = Escrow Construction Fund Interest Rate (%)
CCC_I = Effective Construction Real Cost of Capital (%)
D/E_R = Debt to Equity Ratio (%)
D_I = Debt Interest Rate
E_I = Equity Interest Rate

$$CCC_I = D/E_R * D_I + (1 - D/E_R) * E_I$$

$$I_E = \left(CC_I - \sum_{M=1}^{M_C} CC\right) * \frac{ECF_I}{12}$$

$$I_P = \sum_{M=1}^{M_C} CC * \frac{CCC_I}{12}$$

$$TCC = \sum_{M=1}^{M} \left[\frac{CC - I_E + I_P}{\left(1 + \frac{CCC_I}{12}\right)^{M_C}} \right]$$

9.2.3 Costs and Expenditures

Table 9.2.3: Costs and Expenditures Variables
$OMCE_Y$ = Yearly Operation and Maintenance Costs & Capital Expenditures ($)
W_P = Peak Watt Rating of the PV System (W)
$CGAC_Y$ = Current Yearly AC Generation (KWh)
CF_Y = Yearly Fixed Cost ($/$KW_{DC}$ h)
CV_Y = Yearly Variable Cost ($/$KW_{AC}$ h)
CI = Inverter Cost ($)
P_I = Price of Inverter ($)
I_I = Inverter Deflation Rate (%)
IL = Inverter Lifetime (Years) = 10 years
GI_I = General Inflation Rate (%)
IC_Y = Yearly Insurance Cost
IR = Insurance Rate (% of CC_I)
CC_I = Installed Cost ($)
CY = Current Year

In California, solar system property Taxes are 0% for systems installed between January, 1999 and December 2016.

$$CI = P_I * W_P * (1 - I_I)^{CY}$$

Assume inverter lifetime is equal to the 10 year standard warranty.

$$IC_Y = IR * CC_I * (1 + GI_I)^{CY}$$

$$OMCE_Y = \begin{cases} If\ CY\ Modulo\ IL = 0, Then: CI + CF_Y * W_P * (1 + GI_I)^{CY} + CV_Y * CGAC_Y * (1 + GI_I)^{CY} + IC_Y \\ Else: CF_Y * W_P * (1 + GI_I)^{CY} + CV_Y * CGAC_Y * (1 + GI_I)^{CY} + IC_Y \end{cases}$$

9.2.4 Financing

Table 9.2.4: Financing Variables
D_M = Monthly Total Payment on Loan ($)
P_M = Monthly Principal Payment on Loan ($)
I_M = Monthly Interest Payment on Loan ($)
L = Loan Term in Years

PR = Remaining Principal Balance on Loan ($)
N_M = Number of Paid Monthly Loan Payments
IP = Initial Principal Balance on Loan ($)
TCC = Total Installed Cost After Accounting for Interest Earned & Paid ($)
LD = Cost of Land ($)
D/E_R = Debt-to-Equity Ratio (%)
D_I = Debt Interest Rate (%)

$$IP = (TCC + LD) * D/E_R$$

$$D_M = IP * \frac{\frac{D_I}{12}}{1 - \left(1 + \frac{D_I}{12}\right)^{-L*12}}$$

$$I_M = PR * \frac{D_I}{12}$$

$$P_M = D_M - I_M$$

The Remaining principal balance left on the loan at any given month:

$$PR = IP * \left(1 - \frac{\left(1 + \frac{D_I}{12}\right)^{N_M} - 1}{\left(1 + \frac{D_I}{12}\right)^{L*12} - 1}\right)$$

All calculations are done on a monthly basis and the summation is equal to the yearly totals. The Excel functions CUMIPMT and CUMPRINC easily calculate the sum of the monthly total giving the yearly interest and principle paid.

9.2.5 Depreciation

9.2.5.1 Federal Depreciation

The most beneficial federal depreciation applicable to photovoltaic projects is the Modified Accelerated Cost Recovery System (MACRS) allowable for all persons. [30] It is based on the double declining balance and allows for greater depreciation during the beginning of the life of the capital asset which advantageously mirrors the initial capital investments. The following schedule is the MACRS depreciation schedule that applies to the depreciable basis:

Operating Year	1	2	3	4	5	6
Depreciation Percentage	20.00%	32.00%	19.20%	11.52%	11.52%	5.76%

Table 9.2.5.1: Federal Depreciation Variables
FDE_Y = Yearly Federal Depreciation Expense ($)
D_{CY} = Depreciation Percentage for the Current Year (%) MACRS Depreciation Schedule
DBF = Federal Depreciable Basis ($)
TCC = Total Installed Cost After Accounting for Interest Earned & Paid ($)
G = Total of Federal Grant Subsidy ($)
ITC = Total of Federal Investment Tax Credit Subsidy ($)

$$DBF = \begin{cases} If\ Federal\ Subsidy = Grant, then: DBF = TCC - G * 0.5 \\ Elseif\ Federal\ Subsidy = ITC, then: DBF = TCC * 0.85 \end{cases}$$

$$FDE_Y = D_{CY} * DBF$$

Interestingly, the depreciable basis is the same regardless of the federal subsidy.

9.2.5.2 State Depreciation

The California state depreciation depends on the taxable entity. Personal income tax filers and S-Corporations may use MACRS depreciation. However, C-Corporations cannot use MACRS and must use straight-line (SL) depreciation. [31] The most advantageous depreciation for C-Corporations is 12 year SL because the depreciation is the shortest allowable term.

The following schedule is the SL depreciation schedule that applies to the depreciable basis:

Operating Year	1	2	3	4	5	6
Depreciation Percentage	8.33%	8.33%	8.33%	8.33%	8.33%	8.33%

Operating Year	7	8	9	10	11	12
Depreciation Percentage	8.33%	8.33%	8.33%	8.33%	8.33%	8.33%

The following schedule is the MACRS depreciation schedule that applies to the depreciable basis and the base case:

Operating Year	1	2	3	4	5	6
Depreciation Percentage	20.00%	32.00%	19.20%	11.52%	11.52%	5.76%

Table 9.2.5.2: State Depreciation Variables
SDE_Y = Yearly State Depreciation Expense ($)
D_{CY} = Depreciation Percentage for the Current Year (%) Either SL or MACRS Depreciation Schedule
DBS = State Depreciable Basis ($)
TCC = Total Installed Cost After Accounting for Interest Earned & Paid ($)

$$DBS = TCC$$

$$SDE_Y = D_{CY} * DBS$$

It is worth noting that rebates and state tax credits reduce the state depreciable basis. However, these reductions are primarily for private individuals filing personal taxes not S-Corporations, C-Corporations or LLC's.

9.2.6 Federal Subsidies

9.2.6.1 Federal Investment Tax Credit Subsidy

Table 9.2.6.1: Federal Investment Tax Credit Subsidy Variables
$FITCS_Y$ = Yearly Federal Investment Tax Credit Subsidy ($)
CC_I = Installed Cost ($)

The Federal Investment Tax Credit (ITC) is equal to 30% of the installed cost and vests 20% per year for the first 5 years of operation. [32] Either the Federal ITC or Grant may be taken, however, in the base case the ITC is used.

$$FITCS_Y = CC_I * 0.30 * 0.20$$

9.2.6.2 Federal Grant Subsidy

Table 9.2.6.2: Federal Grant Subsidy Variables
FGS = Federal Grant Subsidy ($)
CC_I = Installed Cost ($)

The Federal Grant is equal to 30% of the installed cost and awarded after six months of operation in one lump sum. Also, the Federal Grant is only available to projects "placed in service" or that start construction in 2009-2010. [33]

$FGS = CC_I * 0.30$

9.2.7 State Subsidy

9.2.7.1 California Solar Initiative Revenue

Table 9.2.7.1: California Solar Initiative Revenue Variables
RI_{YCSI} = Initial Yearly Revenue Using California Solar Initiative Prices ($)
K_H = Hourly Insolation Striking the Collector (Wh/m^2)
CSIP = CSI Price ($/KWh)
W_P = Peak Watt Rating of the PV System (W)
AM1.5G = Global Air Mass Constant = 1000 W/m^2
ε = DC-to-AC Derating Factor (%)
RC_{YCSI} = Current Yearly Revenue Using California Solar Initiative Prices ($)
$CGAC_Y$ = Current Yearly AC Generation (KWh)

$$RI_{YCSI} = \sum_{h=1}^{8760} [(K_H * CSIP)] * \frac{W_P}{AM1.5G} * \varepsilon$$

Section 2.4 (California Solar Initiative Pricing Data) explains the CSIP variable. The CSI subsidy is available for only the first five years of operation.

$RC_{YCSI} = CGAC_Y * CSIP$

9.2.8 Taxes

9.2.8.1 Sales Tax

Table 9.2.8.1: Sales Tax Variables
STXD = Sales Tax Due($)
CSTX = California Sales Tax (%)
CC_I = Installed Cost ($)

$STXD = CSTX * CC_I$

9.2.8.2 Property Tax

California property tax is 0% until 12/31/2016 and is not a part of the model.

9.2.8.3 State Tax

Table 9.2.8.3: State Tax Variables
ST_{CY} = Current Year State Taxes ($)
STR = State Tax Rate (%)
$OMCE_Y$ = Yearly Operation and Maintenance Costs & Capital Expenditures ($)
SDE_Y = Yearly State Depreciation Expense ($)
I_Y = Yearly Interest Expense on Loan ($)
STXD = Sales Tax ($)
RC_{YCSI} = Current Yearly Revenue Using California Solar Initiative Prices ($)

$ST_{CY} = STR * (OMCE_Y + SDE_Y + I_Y + STXD - RC_{YCSI})$

RC_{YCSI} is the State PBI and is taxable at both the State and Federal Level.

9.2.8.4 Federal Tax

Table 9.2.8.4: Federal Tax Variables
FT_{CY} = Current Yearly Federal Taxes ($)
FTR = Federal Tax Rate (%)
$OMCE_Y$ = Yearly Operation and Maintenance Costs & Capital Expenditures ($)
SDE_Y = Yearly State Depreciation Expense ($)
I_Y = Yearly Interest Expense on Loan ($)
STXD = Sales Tax ($)
RC_{YCSI} = Current Yearly Revenue Using California Solar Initiative Prices ($)
ST_{CY} = Current Year State Taxes ($)
$FITCS_Y$ = Federal Investment Tax Credit Subsidy ($)
FGS = Federal Grant Subsidy ($)

$$FT_{CY} = FTR * (OMCE_Y + SDE_Y + I_Y + STXD - RC_{YCSI} - ST_{CY}) + FITCS_Y + FGS$$

The current yearly Federal tax calculations include income taxes.

9.2.9 Equity Net Present Value

Table 9.2.9: Equity NPV Variables
EQF = Equity Financing ($)
TCC = Total Installed Cost After Accounting for Interest Earned & Paid ($)
LD = Cost of Land ($)
D/E_R = Debt to Equity Ratio (%)
ECF_{CY} = Current Yearly Equity Cash Flow ($)
RC_{YW} = Current Yearly Revenue Using Wholesale Market Prices ($)
RC_{YCSI} = Current Yearly Revenue Using California Solar Initiative Prices ($)
RC_{YFIT} = Current Yearly Revenue Using California Feed-In Tariff Prices ($)
ETR = Effective Tax Rate (%)
FT_{CY} = Current Yearly Federal Taxes ($)
ST_{CY} = Current Yearly State Taxes ($)
$OMCE_Y$ = Yearly Operation and Maintenance Costs & Capital Expenditures ($)
D_Y = Yearly Total Payment on Loan ($)
CY = Current Year
ITR = Income Tax Rate (%)
SVV = Salvage Value (%)
SLV = Sales Value (%)
CC_I = Installed Cost ($)
LD = Cost of Land ($)
GI_I = General Inflation Rate (%)
CGT = Capital Gain Tax Rate (%)
PT = Project Term in Years
E_I = Equity Interest Rate (%)
SRV = System Residual Value ($)
NPV_E = NPV of After Tax Net Equity Cash Flow ($)

$$EFQ = (TCC + LD) * (1 - \frac{D}{E_R})$$

$$ECF_{CY} = \begin{cases} If\ Pricing\ is\ Wholesale: RC_{YW} * (1 - ETR) + FT_{CY} + ST_{CY} - OMCE_Y - D_Y \\ If\ Pricing\ is\ CSI: RC_{YW} * (1 - ETR) + FT_{CY} + ST_{CY} + RC_{YCSI} - OMCE_Y - D_Y \\ If\ Pricing\ is\ FIT: RC_{FIT} * (1 - ETR) + FT_{CY} + ST_{CY} - OMCE_Y - D_Y \end{cases}$$

$$SRV = \begin{cases} If\ SLV > SVV:\ SVV * CC_I + (SLV - SVV) * CC_I * (1 - ITR) + (LD * (1 + GI_I)^{CY} - LD) * (1 - CGT) + LD \\ Else: SLV * CC_I + (LD * (1 + GI_I)^{CY} - LD) * (1 - CGT) + LD \end{cases}$$

$$NPV_E = \begin{cases} \sum_{PT=1}^{PT-1} \left[\frac{ECF_{CY}}{(1 + E_I)^{PT}}\right] - EFQ \\ \sum_{PT-1}^{PT} \left[\frac{ECF_{CY}}{(1 + E_I)^{PT}}\right] - EFQ + SRV \end{cases}$$

9.2.10 Creditor Net Present Value

Table 9.2.10: Creditor NPV Variables
TL = Total Loan Amount ($)
TCC = Total Installed Cost After Accounting for Interest Earned & Paid ($)
LD = Cost of Land ($)
D/E_R = Debt to Equity Ratio (%)
ETR = Effective Tax Rate (%)
FTR = Federal Tax Rate (%)
STR = State Tax Rate (%)
L = Loan Term in Years
PR_Y = Yearly Principal Payment Received ($)
IR_Y = Yearly Interest Payment Received ($)
DR_Y = Yearly Payment Received (%)
CIR = Creditor Cost of Capital (%)
NPV_C = NPV of After Tax Net Creditor Cash Flow ($)

$$TL = (TCC + LD) * D/E_R$$

$$ETR = FTR + (1 - FTR) * STR$$

$$DR_Y = PR_Y + IR_Y * (1 - ET)$$

$$NPV_C = \sum_{L=1}^{L} \left[\frac{DR_Y}{(1 + CIR)^L}\right] - TL$$

9.2.11 Project Net Present Value

Table 9.2.11: Project NPV Variables
NPV_P = NPV of the Project ($)
NPV_C = NPV of After Tax Net Creditor Cash Flow ($)
NPV_E = NPV of After Tax Net Equity Cash Flow ($)

The Project NPV is equal to the sum of the equity holders NPV and debt holders NPV.

$NPV_P = NPV_C + NPV_E$

9.3 Levelized Cost of Electricity

Table 9.3: Levelized Cost of Electricity Variables
TCC = Total Installed Cost After Accounting for Interest Earned & Paid ($)
DE_Y = Yearly Depreciation Expense ($)
$OMCE_Y$ = Yearly Operation and Maintenance Costs & Capital Expenditures ($)
SRV = System Residual Value ($)
$CGAC_Y$ = Current Yearly AC Generation (KWh)
ETR = Effective Tax Rate (%)
DR = Discount Rate
PT = Project Term in Years
GI_I = General Inflation Rate (%)
RD = Real Discount Rate (%)
ND = Nominal Discount Rate (%)

LCOE is a tool to compare energy systems with different scales of operations, investments or operating time periods.

The calculation is the net present value of total project life cycle costs divided by the amount of energy produced over the project life:

$$LCOE = \frac{Total\ Life\ Cycle\ Cost}{Total\ Lifetime\ Energy\ Production}$$

The full LCOE calculation [34] is:

$$LCOE = \frac{TCC - \sum_{PT=1}^{PT} \frac{{DE_Y}^{PT}}{(1+DR)^{PT}} * ETR + \sum_{PT=1}^{PT} \frac{{OMCE_Y}^{PT}}{(1+DR)^{PT}} * (1 - ETR) - \frac{SRV}{(1+DR)^{PT}}}{\sum_{PT=1}^{PT} \frac{CGAC_Y}{(1+DR)^{PT}}}$$

The two types of LCOE are real and nominal values. Compute the real value by using the nominal rate as the discount rate in the total life cycle cost (numerator) and the real rate as the discount rate in the total lifetime energy production (denominator). Calculate the nominal value by using the nominal rate as the discount rate.

In order to calculate the nominal rate, use the following equation:

$$ND = (1 + GI_I) * (1 + RD) - 1$$