San Diego County Single Family Residential Home Solar Model

A Project Report

Submitted to the Graduate Faculty of the

National University, School of Engineering and Computing

in partial fulfillment of the requirements for the degree of

Master of Science in Engineering Management

Prepared By:

Arjun Jaggi

Michael Osuna

Lawrence Palacio

Edward White

National University

April 2018

MASTERS THESIS APPROVAL FORM

We certify that we have read the project of Arjun Jaggi, Michael Osuna, Lawrence Palacio, and Edward White entitled – **San Diego County Single Family Residential Home Solar Model** and that, in our opinion; it is satisfactory in scope and quality as the project report for the degree of Master of Science in Engineering Management at National University.

Approved:

Prof. Ben Radhakrishnan
Instructor, Department of Applied Engineering
National University

6/20/18
Date

Dr. Timothy J. Pettit
Associate Professor, School of Business and Management
National University

6/20/2018
Date

Dr. Shekar Viswanathan, Ph.D., Advisor and Program Director
Professor, Department of Applied Engineering
National University

June 19/18
Date

DEDICATION

In full gratitude, we would like to thank all the National University faculty and support groups, such as the library staff, writing center, and math lab, that made this capstone a successful and enjoyable project. Special thanks to Dr. Shekar Viswanathan for his guidance, wisdom, and devoted dedication as the team's program chair and capstone advisor. The partnership of GRID Alternatives' San Diego office played an integral role in providing technical expertise and PV installation data for analysis, comparison, and validation of the developed model used as the basis of this capstone project. Finally, last but not least, thank you to the support and sacrifices of the team's family members. Without them, the end results would have never been achieved.

Arjun Jaggi, Michael Osuna, Lawrence Palacio, Edward White

ABSTRACT

San Diego County residents have been subjected to rate increases from the energy distributor SDG&E (San Diego Gas & Electric). In order to balance the financial situation, San Diegans are seeking alternative ways to reduce the cost of electricity bills. Solar photovoltaic systems (PV) are an effective solution with tremendous financial benefits. Although many have heard about solar power for several years, they know very little about technical and financial feasibility of the available systems, associated costs, and its life-cycle costs. In addition, the lack of information on available systems, their associated costs, and the complex assessment of various financial methods in acquiring a system reduces the customer confidence in selecting the right system. The objective of the hypothesis is analyzed through the research data provided by GRID Alternatives, a non-profit organization that has installed over 200 PV panel systems within San Diego County since 2016. The model developed based on EXCEL takes into account independent variables such as geographical location, insolation, roof size, panel and inverter efficiency, and average energy consumption. The model analyzes dependent variables such as specification requirements, panels needed per roof area and produces a purposeful configuration based on the data analyzed and presents a financial analysis model to conduct a cost benefit analysis. Based on model outputs, a comparative analysis can be made to determine whether single-family residential homeowners in San Diego County will financially benefit from the installation of a PV system. The applicability of the developed model using a CHI Square test was conducted by comparing five randomly selected GRID Alternatives project sites indicates that the model is valid with 90% accuracy.

List of Figures

List of Tables

CONTENTS

Chapter 1 Project Introduction

1.1 Introduction

The objective of this project is to develop an analytical model that will help median sized single-family residential homes in San Diego County to examine solar panel installation requirements and eliminate time consuming efforts of working with different vendors and contractors to collect and evaluate detailed estimates. According to the United States Census Bureau (2017), the median sized single-family home in San Diego County is 2,378 square feet. Existing web-based tools lack the requirements of gathering appropriate information for solar power system estimates and they do not provide a level of detail to make an informed investment decision. Generic calculators and tools for solar panel installations available over web are only good for negotiation purposes with vendors.

The proposed model will be advanced with more features using variables like geographical location, roof size, panel orientation, and average energy consumption. These independent variables will be used in design requirements of any single-family home in San Diego and the output will not only provide customized design requirements, but it will also analyze costs of various levels of panel technology.

In the past few years, residents of San Diego County have been subjected to rate increases from monopolistic energy distributors such as SDG&E (San Diego Gas & Electric). Increased cost of living and low purchasing power has already affected people of the region. In order to balance the financial situation of homeowners, San Diegans are seeking alternative ways to reduce the cost of electricity bills. Solar photovoltaic systems

(PV) are an effective solution with tremendous financial benefits. However, it takes time, effort, knowledge, and expertise to determine the best solar panel system selection and installation with the most efficient approach using financial methodologies.

This new analytical model will also incorporate independent financial variables such as lease option, loans, or cash purchase. The model will incorporate project management methodologies and will serve to measure, track and optimize energy conservations and cost-savings to benefit single family home owners.

1.2 Background of Study

Solar photovoltaic energy comprises about less than 1% of renewable electric energy in production in the U.S. (U.S Energy Information Admistration 2016). Despite this fact, it has grown at a rapid pace within the last decade and experts predict continued growth by over 15 % within the next 20 years. (U.S Energy Information Admistration 2016). To put it in perspective, Solar PV Energy has more than tripled since 2010 and in 2015 there were more than 900,000 U.S. homes using solar panels (Solar Energy Industries Association 2015). As more consumers seek Solar PV energy applications for the cost-saving benefits and eco-friendliness, very few models have been developed solely to benefit the average single-family residential home owner. Specifically, this includes customized design requirements and whether to buy or not buy decision making analytic options.

Many models have been proposed in relation to PV potentiality to include 3-Dimensional Web based analysis such as a Transient System Simulation Program (TRNSYS) that utilizes geographical information systems (GIS) and light detection and ranging (LiDAR). There are also many solar potential mapping sites online that are bombarded with many solar panel installation companies offering estimates and discounts to meet uptrend demand. In fact, the cost of solar residential installation has been steadily decreasing and is also offset by a 30% federal tax break. This is evident by technological advances and comparatively, a single panel cost $100 per watt in 1960 versus .57 cents in 2016 (Munsell, 2016).

As aforementioned, the objective of this study will include an output analytic model that any single-family residential home owner can use to incorporate variables such as specification requirements and a cost-benefit analysis. This will project current utility usage by kilowatt hours (kWh) baselined by conventional power provided by SDG&E and proposed Solar Panel (PV), to include average installation payback time. Power purchase agreements (PPA)/leases, financing options, and cash purchases will be factored in the analysis to help choose the most viable option. Previous studies have lacked in information using these variables as it has been noted predicting return on investment and expense of installation are barriers that have faced the solar industry in recent years. (Carl 2014)

1.3 Project Delimitations

This project will be limited to the County of San Diego in Southern California. San Diego County is the fifth largest county in terms of population in the United States and is currently ranked number two in California. San Diego County consists of at least 63 cities, towns, and unincorporated communities covering a span of 4, 206.63 square miles. Since there are large gaps of values for a single-family residential home ranging from approximately $391,000 to $19.9 million based on data from leading realtor website (Zillow, 2018), the target focus of this project will be set to the median square footage of single-family homes. The value of the home is a relevant variable to consider because it correlates to the total income per household and the financial affordability of having a solar photovoltaic system in operation, however, single-family home size in square footage is more relevant to translate electricity usage output per household. In areas where higher home values exist, solar installation on single-family units have become the norm and in areas with lower home values, solar installation on homes is more sporadic. According to the United States Census Bureau (2017), the median value of owner-occupied single-family unit in San Diego County is $454,600 with the median size of 2,378 square feet and median income per household is $79,300 (San Diego County, 2017). This data does not include new construction single-family homes as figures would be substantially higher, due to the large varying degrees of variables related to home values and geographical areas within San Diego County. The County of San Diego will be used as the baseline for the proposed analytical model. Based on the researched data, the project delimitations are as follows:

- Any home that is not a single-family home.
- Any structure that is not a single structure such as a townhome, condo, or apartment.
- Any commercial building.
- Any single-family home outside of San Diego County.
- Any single-family home with old style electrical system (knob and wire).
- Existing Single-family residential unit is in San Diego.
- Existing Single-family residential unit size is from 2,000 to 2,500 square feet.

These delimitations will allow the project to focus on developing analytical tools geared toward the average homeowner in San Diego with regards to a decision-making process on whether to invest or not invest in a solar power system.

1.4 Definitions

The following are some definitions of terms to provide clarity of their use and applicability to this project.

Analytical model. For this study, an Excel based model will determine a near optimal solar photovoltaic system design based on carefully selected independent input variables. Users will enter information into the Excel model specific to their home characteristics. In addition to receiving a detailed system configuration of panel sizes, types, and quantity as well as other required components, the user will also receive the current industry cost for that system. Furthermore, the system cost in conjunction with chosen financing is used to provide the user a cost-benefit analysis and buy back period assessment.

Single-family residential home. A stand-alone dwelling structure with the purpose of housing one family. A family in this sense generally consists on average of four members.

Solar photovoltaic system. A system designed to absorb solar energy in special photovoltaic panels and convert it into electricity for multiple uses. Solar photovoltaic systems also include inverters to convert the direct current (DC) voltage into useable alternating current (AC) voltage commonly used in residential and commercial buildings.

Lease option. Means for consumers to achieve the benefits of solar photovoltaic systems through a contractual agreement with a company that installs the system on the house, but still retains ownership. The homeowner pays the company for use of the system until it is removed from the structure.

Finance option. Means for consumers to borrow money to cover the cost and installation of the system with a schedule to payback the principle with interest over a period of time. Consumer owns the system after all payments are made.

Buy option. Means for consumers to purchase and install a solar system with cash up front while claiming ownership of the system right away.

Renewable energy. A term that includes sources such as solar, water, and wind that can be transferred into form of energy such as electricity and mechanical motion.

Geographical Information System. System designed to capture, store, analyzing, and present data relating to the Earth's surface in order to understand geographic patterns and relationships (Society, N. G., 2012).

Light Detection and Ranging (LiDAR). System designed to utilize laser transmission to analyze variances in depth of the Earth's surface by analyzing return laser signals.

Kilowatt hours (kWh). Common term for unit of measure of energy consumption. It is equivalent to 1,000 watts. A watt is the single unit of power equivalent to the flow of one ampere current flow with one volt of voltage.

Power Purchase Agreement (PPA). A simple contractual agreement between the purchaser of electricity and seller of electricity. In terms of solar photovoltaic systems in the county of San Diego, the homeowner is the producer of electricity and the buyer is San Diego Gas and Electric Company (SDG&E). The amount the seller receives is typically a fraction of the value of electricity supplied back onto SDG&E's power grid. To consider all pertinent variables, the following variables will be included on the analytical model.

Geographical location. An independent variable used in the model that represents a home's location on Earth by means of latitude and longitudinal coordinates.

Roof size. Size of single-residential home roof in square feet used as an independent variable in the proposed model.

Panel orientation. Includes two independent variables for degree of panel's angle on the roof relative to even ground and the cardinal direction of the roof. For example, 30-degree panel angle facing South West.

Panel type. For this study, panel type is considered to be either low, medium, or high quality in terms of power absorption and transfer based on current technology. This is an independent variable required to determine optimal solar system design.

Average energy consumption. An independent variable for this study considered to be the average daily Kilowatt per hour (kWh) used over a one-month period.

Solar Photovoltaic System Cost. Current cost of all materials and components required to build customized solar system based on input variables.

Cost-benefit analysis. Analysis of solar photovoltaic system costs and life cycle costs including maintenance and upkeep in comparison to current energy consumption needs and SDG&E rates.

Buy back period assessment. Decision making tool to determine the length of time to pay off a solar photovoltaic system based on its costs and energy savings.

1.5 Summary

Homeowners are facing the pressure of finding alternative ways to reduce the increasing economic costs of running their households. As technology improves, more and more electrically powered devices are being added to the home's infrastructure which in turn increases the average energy consumption over time. Although solar photovoltaic systems have diminished in costs over the recent years, they still require a sizeable investment to purchase, install, and maintain. Many homeowners are aware of the overall cost and environmental benefits of solar, but still find it challenging to assess the true cost benefits. This ultimately holds them back from making a definitive decision. The anticipated outcome of this study is to provide these homeowners the means of choosing the right solar system based on their individual needs, the cost of the system, and the benefits they will receive based on current technology and regulations. The overall objective is defined by the following hypotheses:

H_1: Median-sized single-family residential homeowners in San Diego County will financially benefit from the installation of a solar photovoltaic system.

H_0: Median-sized single-family residential homeowners in San Diego County will not financially benefit from the installation of a solar photovoltaic system.

The use of the proposed analytical model along with the analysis and synthesis of data will set out to either prove or disprove this claim. However, before going in depth on the particulars, it is important to review and understand previous studies similar to this proposal. This will prove beneficial in building the foundation and support of this study.

Chapter 2 Literature Review

2.1 Introduction

Previous studies have been conducted on PV installation systems based on roof potential and material efficiency alone. However, there is a limited number of useful models that integrate technical requirements with financial analysis to benefit the average single-family homeowner. Many easy to assess models have also been proposed using web-based analysis utilizing GIS and LiDAR (Chahal, 2016). A PROQUEST engine search was conducted using key words such as solar panel models in single family homes and solar system installation modeling with limited results for the stated project. Throughout this research and analysis, references to peer-evaluated journals and other works will be cited for the purpose of literature review and understanding similarities and differences in relation to the proposal.

2.2 Historical Overview

Historical legends and ancient civilizations have provided the modern world with technologies of how to harness the power of the sun. Dio Cassius, a 2nd Century Roman historian, claimed that solar energy had been deployed using special mirrors which ignited a flame and destroyed an invading Roman fleet in Greece, 212 B.C. (Cassius). This example illustrates the focus of historical interest regarding solar power and the know-how of converting solar energy into any purposeful use.

Photovoltaics is defined as the direct conversion of light into electricity. In 1839, French scientist Alexandre-Edmond Becquerel discovered photovoltaics (PV) as he observed light converted into electricity by a solar cell that he had created. By the 1860s and 1870s another scientist, Augustin Mouchot (Mouchot, 1869), realized the depletion of coal was inevitable and published a book regarding practical industrial applications of solar power, to include production of steam.

In recent history, the focal point has been solar energy as the most renewable alternative to generate electricity than the one using traditional utilities. Research has led to discoveries of materials with the highest conversion efficiency. Beginning in 1883 with 1% efficiency, American Charles Fritts created the first solar power cell using selenium (a nonmetallic material that has semiconducting properties), (Begos, 2016). Some materials possess a property known as photoelectric effect whereby photons (particles of light) are absorbed and negative electrons are captured to produce electricity.

The greatest breakthrough came in the 1950s when Bell laboratories from New Jersey discovered that using silicon (an ingredient of sand) mixed with gallium (an ingredient used in thermometers) theoretically reached efficiency rates up to 25% (Begos, 2016). In 1958, the Soviet Union used a solar array to power radios on their Sputnik 3 satellite and other countries such as China and Germany began to see the potential use of solar energy as well (US Dept. of Energy, 2018). Today's residential solar panel efficiencies have tested up to 25% but cell efficiencies are always higher than module efficiencies. When looking at materials, the module efficiency must be considered to determine solar panel system installation. Crystalline silicon has been the most prevalent material used with 85% market share worldwide PV module production (US Dept. of Energy, 2018). This also has the highest module efficiency of 18 to 22% based on standard testing.

As module technology and manufacturing processes improve, the cost of solar panel systems have become more affordable for the single-family homeowner

(Munsell, 2016). However, the cost of installation based on current technology and regulations must be factored into the cost benefit analysis (CBA) in determining the most economically viable system available.

2.3 Solar Panel Systems, Components, and Functionality of Photovoltaic System

Components of photovoltaic systems vary depending on the site location, climate, needs and expectations. Also, operational and functional requirements determine which components will be included in photovoltaic system. PV systems include components including DC-AC power inverter, auxiliary energy resources, battery and system controller, battery bank and electric loads. Figure 1 illustrates a schematic diagram of how solar energy is converted into electricity through the use of photovoltaic cells, inverter (for energy inversion and conditioning), battery (to store electric current) and utility meter for energy distribution to appliances.

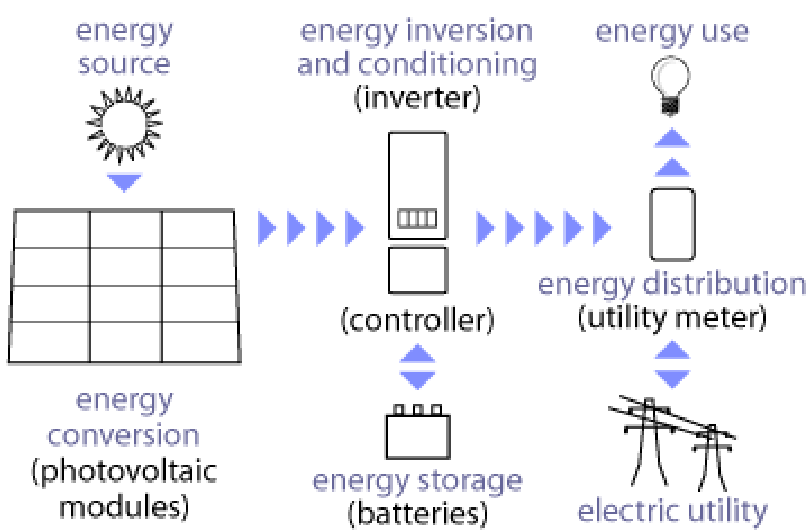

Figure 1 Solar photovoltaic components (Complete Photovoltaic Systems, n.d.)

2.3.a Inverter

The inverter converts DC (direct current) into AC (alternating current) which can be used for household electric components and it synchronizes with utility power whenever electricity is distributed by the electric grid. The inverter also ensures the frequency of AC cycles to be 60 cycles per second and appropriate for the application. Grid-connected inverters can be installed outdoors but most off-grid inverters are not designed for extreme weather conditions.

2.3.b Battery

The function of the battery is to store excess energy and provide a backup in case of emergency or when electricity is required. The energy storage comes at a cost as solar panels maintain battery charge by re-charging the same each day which reduces the efficiency and output of PV systems. There are two types of batteries which are commonly used in PV systems namely lead-acid batteries (flooded or sealed) and alkaline batteries (nickel-cadmium or nickel-iron).

Lead-acid batteries are commonly used in PV systems and sealed lead acid batteries are generally used in grid-connected systems. Sealed batteries don’t require maintenance as they are spill proof. Flooded lead-acid batteries are low maintenance, but they require distilled water once every month to replenish lost fluids during charging process. (WSU Energy Extension, 2017).

Sealed lead acid batteries are of two types: sealed absorbent glass mat (AGM) and gel cell. AGM batteries are industry standard because of low maintenance and compatibility with grid-tied systems. Gel-cell batteries are generally a poor choice as they are designed for freeze-resistance and overcharging can damage the battery.

Alkaline batteries are only recommended in areas with cold temperatures (-50 F degrees or less) or for certain commercial/industrial applications (WSU Energy Extension, 2017). These batteries have advantage over lead-acid batteries which include tolerance of freezing or high temperatures, low maintenance requirements and ability to be completely discharged without harm.

2.3.c Utility Meter

Utility power is an automatic power which is provided during the time at which the utilization exceeds solar electric power production. The utility meter allows for credit on excess electric bills against future utility bills as it actually spins backwards when solar power production exceeds the demand.

2.3.d Charge Controller

The charge controller helps in preventing overcharging of battery and increases the battery life of the PV system. Additionally, it consists of wiring, overcurrent and surge protection, disconnect devices, and other processing equipment.

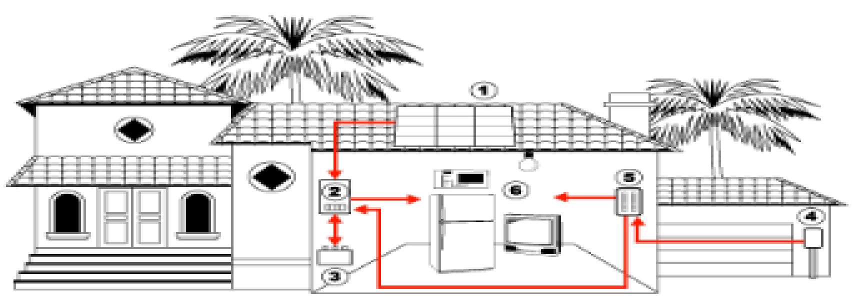

Figure 2 Solar photovoltaic home schematic (Solar PV Electric, n. d.)

The function of solar PV panel is to convert sunlight into DC power. The Photo Voltaic system also operates during a utility power outage. DC electricity is then supplied through the inverter which further transforms into utility-grade AC electricity to power the residential place. If more electricity is required than the capacity of solar panel system, then the excess requirement is fulfilled by the local provider/electric company. Most of the residential electric load is powered by the inverter connected to the household circuit breaker box. Figure 2 depicts an ideal situation of a residential home where a solar panel system is installed and how PV panels convert sunlight into DC power, which is further supplied to inverter to generate AC electric current which can be distributed to appliances.

2.4 Review of Relevant Theoretical Literature applicable to Independent Variables

Darbali et al. (2015) present a formula for determining a solar photovoltaic system's generation of power in kilowatt per hour.

$$E_{PV} = I_{solar} \times n_{PV} \times n_{eff} \times A_{PV}$$

E_{PV} represents the desired energy generation of the solar photovoltaic system in *kWh*. The total solar radiation for a specific geographic area, measured in kWhm^2 is represented by I_{solar}. The percent efficiency of the solar panels used in the system design is represented as n_{PV}, while the percent efficiency of the system's inverter and any other losses in the system is represented by n_{eff}. A_{PV} represents the panel area or roof orientation of the solar panels. Kilowatt output generated from solar radiation resources leads to the purposeful utilization of this formula as it encompasses independent variables such as geographical location (also known as solar radiation resources or area exposure to the sun), roof size, panel orientation, panel system and material efficiency, and panel type. By determining the appropriate solar panel configuration or E_{PV} based on the amount of solar radiation exposure, the number of panels required, and the overall solar system efficiency, this formula will help determine the appropriate solar photovoltaic system cost per residential single-family unit application and cost-benefit analysis of investing in such system by the homeowner. E_{PV} values can be used to estimate daily, monthly, and yearly kilowatt output generation in contrast to current kilowatt usage without an installed solar system to see the cost savings over a given period of time.

However, for the purpose of the model developed and used in this study, the equation is changed to isolate the dependent variable A_{PV} leaving the independent variables grouped together.

$$A_{PV} = \frac{E_{PV}}{I_{solar} \ x \ n_{PV} \ x \ n_{eff}}$$

Many additional factors such as multiple electric utility companies to compare, the types of meters used in grid-connected solar power systems varies, and differences in consistent weather conditions in certain geographical areas are included when dealing with a larger scope at a state-wide region when compared to a county sized area. For example, San Diego County has three variations of weather conditions that includes coastal, inland, and desert that are within +/- 10^{o} difference at any given moment (National Weather Service, n. d.). Statewide geographical areas will exhibit vast differences in weather conditions and differences in solar radiation resources than a local area. In addition, the aforementioned formula will address the relationship and integrate the decision-making process of each independent variable. For example, by having known values of $E_{PV},$ the total desired kilowatt generation, and $A_{PV},$ the number of solar panels per usable roof area, the homeowner can estimate the cost of the solar panel system and system configuration based on the homeowner's budget.

2.5 Review of Relevant Literature Related to Independent Variable and Outputs

The independent variables unique to a specific single-family residential home in San Diego can be used in the above equation to determine the number of panels needed to supply power to the house based on the needs of the family and system components. For example, desired energy output of the system can be determined by the homeowner's previous 12-month average of energy consumption as shown on the SDG&E bills. Published manufacturer specifications of the panels, inverters, and components chosen for a particular system are used to adjust requirements based on efficiency ratings. The final piece of the data required is the solar radiation at the home's geographical location in San Diego County. There are three typical measures of solar radiation: Direct Normal Irradiance (DNI), Diffuse Horizontal Irradiance (DHI), and Global Horizontal Irradiance (GHI). All three use the kWh/m_2 unit of measure. Figure 3 illustrates the difference between the path of solar radiation when measured.

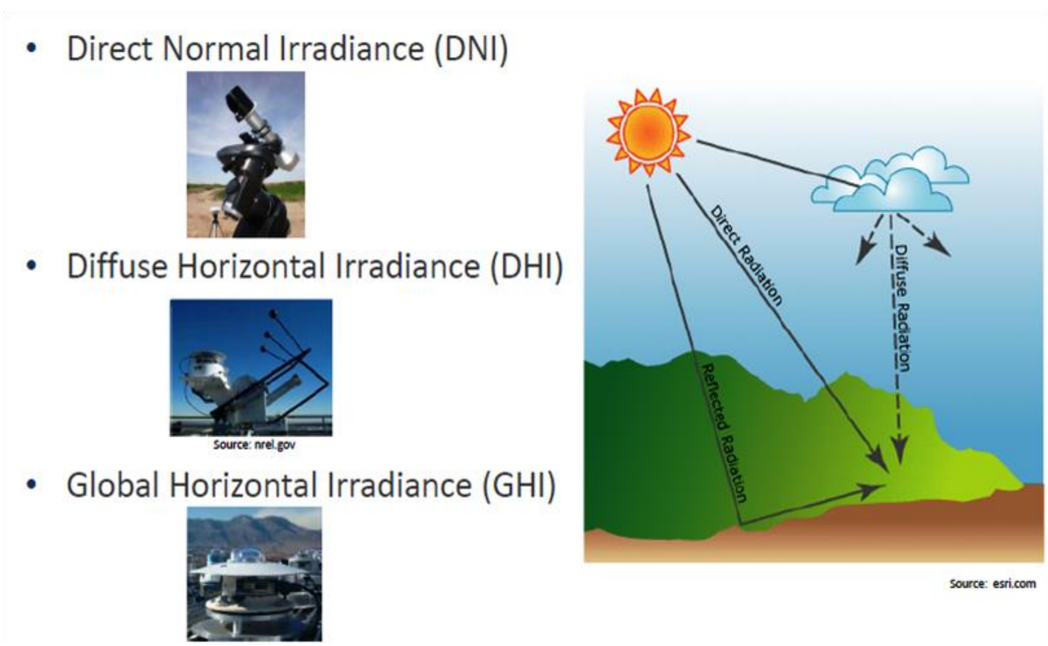

Figure 3 Measuring Solar Radiation (Differentiate between DNI, DHI & GHI, 2012)

Global Horizontal Irradiance (GHI) is generally the best method of measuring solar radiation for input in the determination of a solar photovoltaic system. This method measures radiation from both direct and horizontal irradiance.

Global Horizontal (GHI) = Direct Normal (DNI) X cos(θ) + Diffuse Horizontal (DHI) San Diego County's GHI is on average of 1919 kWh/m^2per year (Global Solar Atlas, n. d.). This is a constant in the use of the model's formula.

The dependent variable, in the objective function of the formula, is A_{PV}. By determining the panel area required, the home owner can make an informed decision of whether his or her southerly or westerly facing roof is large enough to accommodate such a system. This will be the first element in determining the system requirements and cost for a specific single-family residential home. The standard component cost of the system, such as inverter, charge controller, and battery, are summarized with the cost of the specified panel sizes to for a total system cost. The cost of the system along with installation, life time maintenance, and upkeep fees are then compared to the opportunity cost of remaining a SDG&E customer. This comparative analysis will provide a buy back period and break-even analysis. In return, it can be determined if installing a solar photovoltaic system is financially viable, thus answering the hypothesis in question.

2.6 Disadvantages of Current Solar Photovoltaic System Estimators

Current solar photovoltaic system estimators, available online, include run off models taking various inputs such as average energy consumption, geographical location, and roof size similar to this study's proposed model. However, they lack the ability to provide the consumer with the ability to make a more informed decision. For example, the Affordable Solar Wholesale Distributor's model (Residential Solar Calculator, n. d.), provides an estimate solely based on average household energy consumption and available sun hours. It does not take into account the GHI of the geographical region. Additionally, current estimators fall short in providing educational information beneficial to selecting the various types of solar panels and inverters. These two components have the greatest effect on system efficiency and resulting overall panel area size. This is important for homeowners who require large amounts of energy generation but are limited to roof size. Therefore, less roof size may require a more efficient and higher cost system depending on the system output requirements. A lack of information of the available systems and their associated costs along with the complex assessment of various financial methods in acquiring a system reduce consumer confidence in the selection of the right system. No models currently researched provide such detailed information. Furthermore, none provide a financial analysis of whether a solar system will reduce the financial burden by looking beyond the saving of reduced electric company dependence. To achieve a true picture, estimators need to account for the costs of the system, installation, financing, and life time maintenance.

Chapter 3 Methodology

3.1 Introduction

The project's hypothesis states that, "Median sized single-family residential homeowners in San Diego County will financially benefit from the installation of a solar photovoltaic system". In order to analyze the stated hypothesis, a methodological approach is necessary, combined with a mixture of experimental analysis. From the most current research and theoretical analysis available seem to imply that installation of PV panel systems is both financially and technically viable (Thiangtam, 2016). Therefore, the proposed analytical model will include technical feasibility and financial feasibility that will be analyzed separately.

3.2 Technical Feasibility

Many modeling tools have been developed from the vendor-based perspective only to benefit company financial goals (Thiangtam, 2016). This project's model will differ from previous models as a bottom up approach creating a real time estimate for customer needs. As a result, the customers will get the data and knowledge needed to make a sound decision as to what solar system is needed for their homes. Technical feasibility will include design requirements such as geographical location, roof size, panel orientation, and average energy consumption. Geographical Information System (GIS) technology and data from several sources including the National Solar Radiation Database (NSRDB) will be used to determine solar radiation efficiency of the median sized single-family residential homeowner (MSRH). These independent variables will be entered into a model built using Microsoft Excel. Based on this analysis, the feasibility will be analyzed.

The formula used for Technical feasibility will be equated as follows:

$$E_{PV} = I_{solar} \times n_{PV} \times n_{eff} \times A_{PV}$$

Where: Epv = Energy produced by PV system in KWh

ISOL = Total solar radiation measured in KWh/m²

ηPV = Includes panel efficiency and additional system losses

N_{eff} = Includes the inverter efficiency and additional system losses

APV = Solar Panel area measured in m²

Table 1 shows how the data will be factored in the formula using the component efficiency averages. This data is then pivoted onto our user-friendly PV planner model (Figure 4), so that the end user will be able to make a GO or NO GO decision on what solar system configurations to choose.

System Formula Data					
Solar Radiation (I_{solar})					
GHI (kWh/m2 per month)	159.92				
Panels (n_{PV})					
Type	**Low**	**High**	**Average**		
Moncrystaline (300 w)	18%	22%	20%		
Polycrystaline (250 w)	12%	16%	14%		
Thin Film	7%	14%	11%		
Inverters (n_{eff})					
String	**Brand**	**Solis**	**SMA**	**Fronius**	**Average**
	Peak Eff	97.50%	97.50%	96.70%	97.23%
	Cost	$884.00	$1,375.00	$1,590.00	$1,283.00
DC-DC Optimizer	**Brand**	**Solar Edge P700**	**Solar Edge P400**	**Solar Edge P800**	**Average**
	Peak Eff	99.50%	99.50%	99.50%	99.50%
	Cost	$89.00	$77.00	$111.00	$92.33
Microinverter	**Brand**	**Emphas**	**Darfon**	**APSystems**	**Average**
	Peak Eff	96.50%	96.50%	95.50%	96.17%
	Cost	$163.00	$120.58	$195.48	$159.69

Table 1 Formula data inputs

Customer Input:

TECHNICAL FEASIBILITY

1. Annual energy usage (kWh): 5,224

2. Estimated square foot area of roof (ft^2): 570

FINANCIAL FEASIBILITY

3. Current loan Average Percentage Rate (APR): 2.90%

4. Length of loan in months: 240

Solar System Configurations:

Monocrystalline Panel with String Inverters

Panel Area	Roof Index	Fit Roof	No. Panels	Panel Costs	Number Inverters	Number Optimizer	Inverter Costs	Material Costs	Labor Costs	Permit Costs	System Cost
194.98	2.92	YES	12	$4,344.00	1		$1,283.00		$2,500.00	$300.00	$8,427.00

Monocrystalline Panel with DC-DC Optimizer

Panel Area	Roof Index	Fit Roof	No. Panels	Panel Costs	Number Inverters	Number Optimizer	Inverter Costs	Material Costs	Labor Costs	Permit Costs	System Cost
189.42	3.01	YES	11	$3,982.00	1	11	$2,298.67		$2,500.00	$300.00	$9,080.67

Monocrystalline Panel with Microinverters

Panel Area	Roof Index	Fit Roof	No. Panels	Panel Costs	Number Inverters	Number Optimizer	Inverter Costs	Material Costs	Labor Costs	Permit Costs	System Cost
197.71	2.88	YES	12	$4,344.00	12		$1,916.24		$2,500.00	$300.00	$9,060.24

Figure 4 PV Planning model

3.3 Financial Feasibility

Financial feasibility will include a detailed analysis of various financial options related to solar system namely to buy (outright purchase), finance, or utilize power purchase agreements (PPA). In doing so, questions such as “Can lease option, finance, or buy of a solar system provide the rate of return to justify the installation of solar PV system?”, and “What is the key independent variable that will determine both the cost and payback return?” will be answered. The analytic modeling tool will input the independent variables, and a comparison can be drawn to include a cost benefit analysis and a payback period assessment. A life cycle cost analysis (LCCA) will be included that accounts for maintenance and operation costs over this assessed payback period.

The output variables for financial model analysis will incorporate the following:

- Depreciation
- Interest (if leased or financed)
- Insurance rate

- Property tax rate (if purchased)
- Interest of average investment
- Maintenance costs
- Life span (7-year average payback)

Table 2 depicts annual rate averages and calculation methods used. The financial analysis will provide a comparison for financial options available to the homeowner. Several formulas will also be incorporated to reach total values which will be discussed in detail later.

Output Variables				
Output Name	**Var**	**Total**	**%**	**Calculation**
Depreciation	*a*	800.0		*a* = purchase price-salvage value ÷ years of payback
Interest Rate	*b*	800.00		*b* = purchase price + Salvage Value ÷ 2 * Interest Rate
Insurance Rate	*c*	$96		*c* = Purchase Price + Salvage Value ÷ 2 * Insurance Rate
Property Tax Rate	*d*	$165	1.2%	*d* = Average assessed value * Tax Rate
Interest of Average Investment	*e*	$800		*e* = 0.25*c* - ((2,000 × $10*y*) + ($100,000*a*) + ($125,000*b*)

Table 2 Financial variables

3.4 Methodology Summary

MSRH will be defined as owner-occupied single-family unit in San Diego County at $454,600 with the median size of 2,378 square feet (United States Census Bureau, 2017). Delimitations will be imposed as previously listed to focus on the decision-making process of GO or NO-GO criteria and based on technical and financial feasibility. The technical feasibility will be expressed by panel area (meter squared) divided by roof fit and represented by one. A variance of 20% will be allowed for roof size utilization and use capacity. The financial feasibility will be decided by home- owners debt to income ratio and monthly savings compared to traditional electricity expenses. This bicameral approach will reveal affirmation to our stated hypothesis or nullify and rephrase it as, “Median sized Single-family residential homeowners in San Diego County *will not* financially benefit from the installation of a solar photovoltaic system”.

The scope of the study will define financial benefits to include average payback of seven years and monthly savings. This will be compared to the ever-increasing monthly utility bill incurred from the SDG&E utility rates. The focus will be on the startup installation costs and the offset costs implementing low or no down payment programs available with government incentives.

3.5 Conclusion

In conclusion, theoretical and experimental analysis will help in proving the stated hypothesis by providing relevant customer-based research focused on PV installation requirements and financial viability. Deliverable application will be utilizing an Excel-based model with stated independent variables and dependent variables as shown in Figure 5. The data for independent variables will be provided by the end user and will calculate solar system configurations for optimum roof fit per panel size.

Chapter 4 Results and Discussion

4.1 Introduction

As previously stated, the lack of information on available systems, their associated costs, and the complex assessment of various financial methods in acquiring a system reduces the consumer confidence in selecting the right system. The objective of the hypothesis is analyzed through the research data provided by Grid Alternatives, a non-profit organization that has installed over 200 PV Panel systems within San Diego County since 2016 (Grid Alternatives, n.d.).

First, the data shown in Appendix A was analyzed, filtered, and modified according to the project scope of single family residential homes in San Diego County. Thin film technology proved to be unfeasible for single family home residential use as the industry standard dictated. Therefore, thin film was also delimited from the project's modelling tool as efficiency rates only yield about 10% and are more suitable for smaller mobile type units. The research identified that the most common types of panels used for solar installations were monocrystalline and polycrystalline panels based on variables such as roof size, expected annual output in kWh, and previous 12-month energy consumption. Five installation systems were randomly selected from this data and inputs were entered into this project's analytical modeling tool in order to analyze the results. As aforementioned, the modeling tool is based on the following formula:

$$A_{PV} = \frac{E_{PV}}{I_{solar}\ x\ n_{PV}\ x\ n_{eff}}$$

The model provided several PV system options based on input values such as panel area, system cost, and roof fit. These outputs were then used to compare the PV systems provided by Grid Alternative's currently installed solar system. The efficiency rate averages were factored into the formula that was used on configured Grid Alternatives' projects. Grid Alternatives uses Helioscope, a professional grade software program, paid by monthly subscription, to determine the specific appropriate PV panel systems to be installed. This project's analytical model differs from the for-profit solar industry as it gives the average home owner leverage with an estimated system configuration and solar power fundamental knowledge when approaching professional solar panel installers. The homeowner uses the model to raise awareness of viable options that are both technically sound and financially feasible.

While technical feasibility was analyzed on the five randomly selected installation systems, this project's analytical model provides other possible financial options such as outright purchase, financing, and lease or power purchase agreements (PPA). This additional element provides a distinctive feature that other modeling tools lack.

As stated, Grid Alternatives is the nation's largest non-profit solar installer that provides little to no cost PV installations to qualifying single family homes within San Diego County. Mainly, Power Purchase Agreements were used in financing PV installations as part of the program and thereby saving low income families thousands of dollars over the lifetime cycles. Based on the research, these savings were validated in accordance with this project's modeling tool as well as the technical feasibility. It is noted that after comparing data, the technicality of this project's model came within two to three panel variations in relational roof size to panel ratio.

4.2 Grid Alternatives Solar System Installations (2016 to Present)

Table 3 shows a comparison of five randomly selected PV installation systems representing coastal, inland, and desert weather variations to reflect solar radiation resources. However, the formula used a constant San Diego County's GHI average of 1919 kWh/m^2per year (Global Solar Atlas, n. d.) to test for efficiency and to analyze the results. Figure 8 shows that there is very little difference in climate variations between coastal and inland regions of San Diego County. Primarily, all the data fell within inland and coastal boundaries resulting in desert weather variation data to be excluded as a delimitation for a more precise analysis. A project address located in Jamul provided a PV system that included 20 Polycrystalline panels with an expected annual output of 6,887 kw per year or (6,887 divided by 12 months) = 574 KWh per month. This annual expected output was then entered in to the project's modeling tool in order to analyze the results. It was determined that 18 polycrystalline panels or 16 monocrystalline panels were provided as configuration options. The differences analyzed also accounted for system losses and degradation factors over the lifetime of the system. It also factored additional paneling for roof fit capacity. The remaining four solar system configurations were analyzed using the same approach with similar results and panel variations between two and four panels as shown in Table 3.

Project Address	Project City	Project Zip	Bed	Bath	Square Foot	Estimated Value	CEC-AC rating, kW	DC rating, kW STC	Expected Annual Output (kWh/yr)	Panel(s) Used
15955 Lyons Valley Road	Jamul	91935	3	3	1,608	$699,207	4.663	5.3	6887	20 SunEdison SE-F265KzD-3y
450 Las Flores Terrace	San Diego	92114	3	3	2,060	$549,900	4.662	5.3	7434	20 SunEdison SE-F265KzD-3y
943 Woodrow Avenue	San Diego	92114	3	2	1,410	$443,289	4.663	5.3	7348	20 SunEdison SE-F265KzD-3y
533 N Elm St	Escondido	92025	3	2	1,330	$377,022	1.632	1.855	2640	7 SunEdison SE-F265KzD-3y
484 Christina Ct.	Oceanside	92058	5	4	2,585	$650,144	1.166	1.325	2036	5 SunEdison SE-F265KzD-3y

Table 3 Five Grid Alternative PV Systems

For example, an Oceanside project located at 484 Christina Ct. was entered into the project's model as shown in Figure 5. The following results validated the independent variables and formula used to produce analytical model in regard to financial feasibility. A fixed monthly rate of $24.58 was given for an average 2036 kWh energy usage per year for financing option of a polycrystalline configuration. If any other month overproduces, the price is still set at $24.58 because the system was configured at four to five panels as listed on Grid Alternatives Data. Figure 6 provides a comparative analysis of solar system configuration and technical options produced by the model.

Customer Input:

TECHNICAL FEASIBILITY		FINANCIAL FEASIBILITY	
1. Annual energy usage (kWh):	2,036	3. Current loan Average Percentage Rate (APR):	2.99%
2. Estimated square foot area of roof (ft^2):	300	4. Length of loan in months:	240

Polycrystalline Panel with String Inverters								
Method	Total Base Cost	Taxes	Total Cost	Monthly Payment	Finance Cost	Lifetime Maint Cost	Tax Credit	Total Cost
Purchase	$5,463.00	$437.04	$5,900.04	NA	NA	$273.15	30%	$4,403.18
Finance	$5,463.00	$437.04	$5,900.04	$24.58	$1,946.03	$273.15	30%	$6,349.21
PPA	$5,463.00	$437.04	$5,900.04	$24.58	$1,946.03	$273.15		$8,119.22

Figure 5 Oceanside customer financial inputs

A separate analysis was conducted to include a comparison to average utility rates such as SDG&E TOU (time-of-use) electricity cost. This revealed a financially viable option for the Oceanside project homeowner, thus validating this project's objective. In order to understand the financial options available, it is necessary to list an overview of definitions and terms in the following section.

Solar System Configurations:

Monocrystalline Panel with String Inverters

Panel Area	Roof Index	Fit Roof	No. Panels	Panel Costs	Number Inverters	Number Optimizer	Inverter Costs	Material Costs	Labor Costs	Permit Costs	System Cost
75.99	3.95	YES	5	$1,810.00	1		$1,283.00		$2,500.00	$300.00	$5,893.00

Monocrystalline Panel with DC-DC Optimizer

Panel Area	Roof Index	Fit Roof	No. Panels	Panel Costs	Number Inverters	Number Optimizer	Inverter Costs	Material Costs	Labor Costs	Permit Costs	System Cost
73.83	4.06	YES	5	$1,810.00	1	5	$1,744.67		$2,500.00	$300.00	$6,354.67

Monocrystalline Panel with Microinverters

Panel Area	Roof Index	Fit Roof	No. Panels	Panel Costs	Number Inverters	Number Optimizer	Inverter Costs	Material Costs	Labor Costs	Permit Costs	System Cost
77.06	3.89	YES	5	$1,810.00	12		$1,916.24		$2,500.00	$300.00	$6,526.24

Polycrystalline Panel with String Inverters

Panel Area	Roof Index	Fit Roof	No. Panels	Panel Costs	Number Inverters	Number Optimizer	Inverter Costs	Material Costs	Labor Costs	Permit Costs	System Cost
96.12	3.12	YES	6	$1,380.00	1		$1,283.00		$2,500.00	$300.00	$5,463.00

Polycrystalline Panel with DC-DC Optimizer

Panel Area	Roof Index	Fit Roof	No. Panels	Panel Costs	Number Inverters	Number Optimizer	Inverter Costs	Material Costs	Labor Costs	Permit Costs	System Cost
93.68	3.20	YES	6	$1,380.00	1	6	$1,837.00		$2,500.00	$300.00	$6,017.00

Polycrystalline Panel with Microinverters

Panel Area	Roof Index	Fit Roof	No. Panels	Panel Costs	Number Inverters	Number Optimizer	Inverter Costs	Material Costs	Labor Costs	Permit Costs	System Cost
97.31	3.08	YES	6	$1,380.00	12		$1,916.24		$2,500.00	$300.00	$6,096.24

Figure 6 Oceanside customer technical options

4.3 Overview of Solar Lease and PPAs

The easiest way to reduce electricity bills is to opt for solar leases and PPAs (power purchase agreements). Installing a solar panel system on a single family residential home is considered a simple and low maintenance option. There are many solar lease and PPA options.

Most of the available options are zero dollar ($0) down payment agreements, but some of the options require initial investment upfront. By installing solar panels, one can expect 10-30% savings on the electricity bills depending on the usage (Solar Leases & PPAs, n.d.). However, with the lease option, the solar panel system doesn't belong to the owner of the home/property and then tax credits or financial benefits belong to the owner of the solar panel system. Solar leases and PPAs are similar to renting solar panel systems. The homeowner and the solar leasing company enter into an agreement that entitles the homeowner the benefits of the system (energy generation by solar panel system) for the contract term of around 20 years. Following the MOU (memorandum of understanding), the solar leasing company owns and maintains the solar panel system so it is entitled to the financial incentives, tax breaks and rebates while the homeowner can indirectly benefit from these saving through lower electric bills.

4.3.a Differences between Solar Leases and PPAs

The terms Solar Leases and PPAs are similar in practice, but there is a key difference between these two terms. Solar leases are fixed monthly rents or lease payment which is determined by the amount of electricity generated by the system. PPA is the agreement to purchase the power generated by the system at a set price of kWh, instead of paying rent for solar panel system. PPAs and lease agreements are generally provided with rate escalations compared to solar loan or cash purchase, but they provide the flexibility in the event of a change in circumstances. The list of common terms which are used in PPAs and solar leases are described below:

1. Term Length: The term lengths for residential solar leases are generally from 20-25 years. However, commercial leases can be customized and usually range from 7-20 years.
2. Performance and Maintenance: Leasing Company monitors system performance to ensure that it operates with maximum efficiency for the duration of lease. Also, they do the maintenance and repairs of the parts and components when required. However, solar panel systems generally require very little or low maintenance in their lifecycle.

3. Monitoring: Leasing companies provide free online, mobile application, and tablet programs to track the performance of solar panels.
4. Buying the System: The solar panel system can be purchased at any time during the lease period at the price defined in the contract or as per market standards.
5. Selling the Property: At the time of selling the property, homeowners can either transfer the remaining lease to the buyer or they can purchase the system and include in the overall price of the home.
6. End of Term: The solar system panels can be purchased at the end of term, or the homeowner can inform the leasing company to uninstall, or even renew the agreement.

4.3.b Types of Solar Lease & PPAs

A) Zero dollar down lease/PPA ($0)

With a $0 down solar lease, there are no upfront investment costs while signing the agreement. However, there will be flat monthly rental payment at a fixed per kilowatt per hour payable to the third-party owner for the duration of agreement. Monthly payments may increase at a rate of 1-3% every year which are also referred to "annual escalations" (Solar Leases & PPAs, n.d.). The financial benefits like federal-state tax credits and rebates belong to the third-party owner (TPO).

B) Custom down payment solar lease/PPA

With a custom down payment option, there is an upfront investment ranging from $1000-$3000 in exchange of monthly payments (in leases) or lower kilowatt per hour (in PPAs). Depending on the agreement and negotiations, many vendors waive annual rate escalations and fix costs of contract duration. However, the benefits of federal and state tax credits and rebates belong to the third-party owner.

C) Prepaid solar lease/PPA

Prepaid solar lease/PPA is similar to purchasing a solar panel system as 100% of investment is made upfront while signing the agreement and there are no further payments during the lifecycle. Third party owners generally make agreements in favor of homeowners since the whole cost is paid upfront. The benefits in this case belongs to the third-party owner which includes federal and state tax credits, rebates and solar renewable energy credits.

This last option makes up about 90% of the Grid Alternatives cases as government funding under the Single Family Affordable Solar Homes (SASH) Program pays to purchase the solar system outright on behalf of the home owner. The homeowner then pays a monthly rate to the third party for energy used in Kilowatts per hour (kWh), usually between .18 to .20 cents per kW.

4.4 Comparison of Pre-Model and Post Model PV Installation versus no Installation.

For the purpose of creating a baseline of a single family residential home without a solar panel system installation, a home in Eastern Escondido located within the San Diego County limits was selected for analysis. A two-year (2016-2018) energy usage and billing history was compiled from the SDG&E EVTOU2 -residential schedule. Figure 7 provides the details of electric service related to this home.

Electric Service

Rate: Time of Use - EVTOU2-Residential **Climate Zone:** Inland

Billing Period: 12/4/17 - 1/4/18 **Total Days:** 31

Meter Number: 05220790 *(Next scheduled read date Feb 5, 2018)* **Cycle:** 4

Meter Constant: 1.000

Circuit: 0788 **Block:** 115A

Total Usage: 757 (*Usage based on interval data*)

Figure 7 Escondido Home on SGD&E EVTOU2 Residential Schedule

A separate single family residential home located in Western Escondido was selected that had used a typical modeling tool found on many solar installation websites. This home was designed with a PV system and installed since 2016. A comparative analysis was made using this project's analytical modeling tool and the results were reviewed as depicted in Table 4.

Average Model Used vs. Project PV Model			
2690 Overlook Point Dr. West Escondido, Ca. 91902		Modelling Tool Outputs Comparative	Cost
Yearly Use (KWh)	5,985	Monocrystalline	
Roof square ft	322	with microinverters	$9,422.24
Monocrystalline		No.of Panels	13
Panels used	14		
System Installed	3.6 KW	Financial options	
		with 30% ITC	
		Outright Purchase	$7,594.33
		Finance 2.90%	
		20 Years	$10,841.00
		Monthly Pymt.	$42.40
		PPA (no 30% ITC)	$24,897.60

Table 4 West Escondido technical comparatives.

Based on the project's research, if the house selected in Eastern Escondido had used the project's modeling tool, a cost savings of over 30% on monthly electricity would have benefited the homeowner. It was also discovered that the house selected in West

Escondido installed a PV system that overproduced in kW output. A lifetime cost analysis over 20 years with a 3 percent annual increase of electricity costs was conducted for the East Escondido house to compare the difference between costs of having and not having a PV system as shown in Table 5. The 3 percent increase in the cost of electricity is a modest adjustment to the annual 6 percent increase seen over the period of 2000 to 2012 (San Diego's SUSTAINABLE FUTURE, 2013). These findings also served to validate the project's objective of PV system installation financial viability, the value of optimal PV installation, and technical feasibility.

No PV Installation (SDG&E vs. Going Solar)				
1305 Lemon Place, East Escondido SDG&E Bill 2018			Modelling Tool Outputs Best Configuration	
Month	KWh used	Cost		Cost
Jan-17	788	$216.69	Monocrystalline	
Feb-17	928	$284.23	with String Inv	$13,857.00
Mar-17	824	$247.63	No.of Panels	27
Apr-17	785	$208.82		
May-17	1,003	$322.02	Financial options	
Jun-17	936	$299.70	with 30% ITC	
Jul-17	1,294	$437.52	Outright Purchase	$11,168.74
Aug-17	1,687	$574.34		
Sep-17	1,464	$489.61	Finance 2.90%	
Oct-17	1,033	$303.39	20 Years	$15,943.53
Nov-17	918	$285.41	Monthly Pymt.	$62.36
Dec-17	851	$198.68		
Yr. Average:	1043	$322.34	PPA (no 30% ITC)	$52,045.77
Yr. Total:	12511	$3,868.04		
Life Cost (20 yrs)		$111,920.39	Life Cost Savings:	
			Outright Purchase	$100,751.65
			Finance	$95,976.86
			PPA	$59,874.62

Table 5 Lifecycle Cost Analysis for East Escondido Home.

4.5 The Applicability of the Developed Model using CHI Square Test

A comparative analysis of 213 selected GRID Alternatives project sites was conducted using a CHI Square test to show the probability and goodness of fit of the developed model. Table 6 shows all 213 selected PV systems installed within San Diego County that include expected annual production, panel type, and number of installed panels. The independent variables were entered into the developed model and the results were analyzed and compared to the actual PV systems installed by GRID Alternatives. A CHI Square test calculation indicates that the model is valid within 90% accuracy and that the developed model meets a 95% confidentiality. The null hypothesis which affirms the developed model's goodness of fit is not rejected.

Data	
Level of Significance	**0.05**
Number of Rows	213
Number of Columns	2
Degrees of Freedom	212

Results	
Critical Value	**246.967965**
Chi-Square Test Statistic	**27.8638796**
***p* -Value**	**1**
Do not reject the null hypothesis	

Table 6 Chi Square fit

4.6 Summary

The model developed here produces a purposeful configuration based on the data analyzed and presents a financial analysis model to conduct for a cost benefit analysis. Results of the Chi Square test of five randomly selected GRID Alternatives project sites indicate that the model is valid with 90% accuracy with goodness of fit. Recommendations will also be included to encourage additional research into PV system modeling and financial viability.

Chapter 5 Conclusions and Recommendations

5.1 Conclusions

The hypothesis analyzed by this research is whether median sized single-family residential homeowners in San Diego County will financially benefit from the installation of a solar photovoltaic system. Data was obtained from America's largest non-profit organization, Grid Alternatives, which has installed over 200 median sized single family residential PV systems within San Diego County. Research was conducted based on this data with delimitations of median value of owner-occupied single-family unit in San Diego County of $454,600, with the median size of 2,378 square feet.

The objective of this project was to develop an analytical model that will help single-family residential homeowners in San Diego County examine solar panel installation configurations and eliminate time consuming efforts of working with different solar power panel companies to collect and evaluate technical specifications. Existing web-based tools such as Helioscope used in the for-profit solar industry lack the requirements of gathering appropriate information for PV system options from the consumer homeowner perspective. It is important to note that the Helioscope software is a proprietary software program paid for on a monthly subscription basis by the solar panel installers. The fees for Helioscope usage by these companies are as high as $500 a month.

The project's model was developed with the consumer in mind in order to address assumptions of technical feasibility that installer modelling provides. Grid Alternatives' data was focused as one of its kind as the market share they service is one that has been historically underserved due to low income qualifications under the federally funded

SASH program. As stated earlier, the method employed for the project was theoretically based on assumptions that all analytical models provided by installers were used to financially benefit single-family residential homeowners in order to agree and install PV systems. Experimental methodology was also employed by analyzing five PV system installations (Table 3) and adjusting the project's model to incorporate all technical feasibility and providing financial options. Thus, the objective was two-fold.

The technical aspects incorporated were further assessed to determine variances and how much it affected system configurations. Such aspects included geographical location, roof size, panel orientation, average energy consumption, and solar insolation. Figure 8 shows solar insolation per zip codes of over 150 PV installations conducted by Grid Alternatives. This data was analyzed and gathered to incorporate climate zones within San Diego County and it was noted that the average of these findings resulted in narrow variances. A discovery was also made that most systems developed use energy consumption averages which are incorporated into most solar industry modelling tools. Installers often focus on the low energy production months in the yearly production cycles to build PV systems that overproduce. This defeats the purpose of moving away from monopolistic energy distributors such as SDG&E (San Diego Gas & Electric) who benefit from such overproduction as they buy energy from home owners at nearly two cents a kilowatt. San Diegans need alternative ways to reduce the cost of electricity bills. Solar photovoltaic systems (PV) are an effective solution with tremendous financial benefits.

It takes time, effort, knowledge, and expertise to determine the best solar panel system selection and installation with the most efficient approach using financial methodologies. The project's model provides this as a catalyst to single-family residential homeowners and serves as an informative feature into the solar industry that other models lack. This new analytical model also incorporates independent financial variables such as lease option, loans, or cash purchase that are very important before deciding to invest or not to invest in a solar panel system.

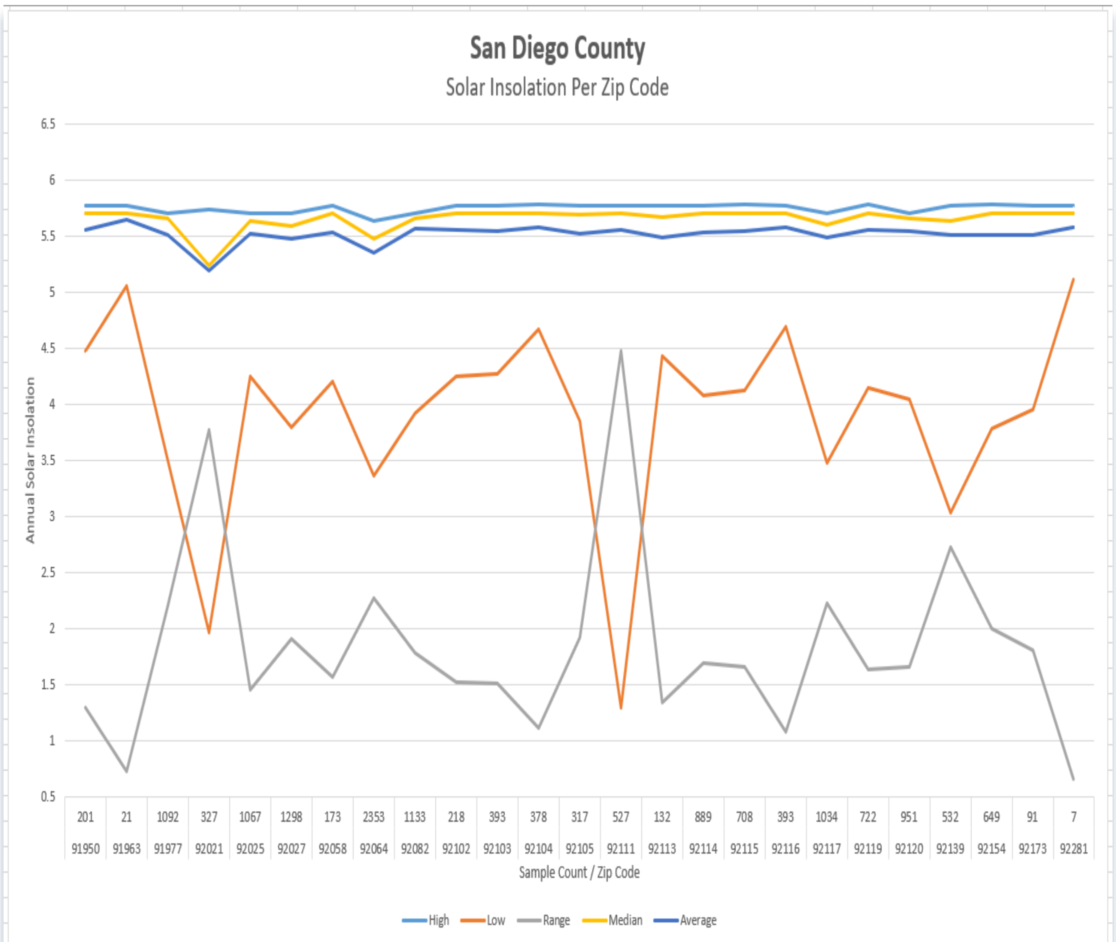

Figure 8 Solar Insolation Per Zip Code

Based on the project's conclusions, the industry currently has taken advantage of the government incentives which include investment tax credits for single-family residential homeowners. This became evident throughout the research into the cost benefit analysis and LCCA of PV system installations which includes the 30% tax credit. An analysis of Grid Alternatives' PV installation data reveals up to 90% monthly energy cost savings for the market sector served. The majority of the for-profit market, single-family residential homeowners do benefit financially as revealed in monthly energy cost savings compared to no PV system installations.

5.2 Recommendations

Based on the project's research that went into developing the analytical model, a modified database was developed using Grid Alternatives' 200 PV plus panel installations within San Diego County. As shown in Table 7, there seems to be a correlation between the square footage and market value of each installation system developed in comparison to expected annual output per year. The larger the square footage of the single family residential home, the more energy production is expected annually and coincidentally directly proportional to the estimated value of the home.

The developed model is based on technical and financial feasibility from the average residential homeowner. The model can be further developed to include square footage of the home with validated correlation research as to the expected annual output. This can serve for the purpose of providing consumer value as home market values often incorporate while emphasizing the possibility of increased home values with PV installations. Such models with these features are limited but assumptions are prevalent when deciding PV panel installations involving GO or NO-GO criteria.

Grid Alternatives
Solar System Installation Data

	Climate Zone	Bed	Bath	Square Foot	Estimated Value	CEC-AC rating, kW	DC rating, kW STC	Expected Annual Output (kWh/yr)
HIGH	14	5	5	3,200	1,012,303	5	6	8,144
LOW	7	1	1	480	90,089	1	1	2,015
MEDIAN	7	3	2	1,347	457,667	3	4	4,985
AVERAGE	7	3	2	1,424	476,713	3	3	4,939
No 7	133							
No 10	12							
No 14	2							

Project: Project Name	Project Address	Project City	Project Zip	Climate Zone	Bed	Bath	Square Foot	Estimated Value	CEC-AC rating, kW	DC rating, kW STC	Expected Annual Output (kWh/yr)
Marc Matanza Project-4713 Butternut Hollow Lane, Bonita, CA, 91902	4713 Butternut Hollow Lane	Bonita	91902	7	3	2.5	2,317	$708,764	4.962	5.6	6,438
Michael Kortz Project - 1691 Shasta Trail, Boulevard, CA 91905	1691 Shasta Trail	Boulevard	91905	14	3.0	2.0	2,353	$173,999	3.73	4.24	6,849
Michael Harvey-46 Sandalwood Dr,Chula Vista,CA,91910	46 Sandalwood Dr	Chula Vista	91910	7	3.0	3.0	2,391	$611,109	4.019	4.56	6,469
Amparo Morales-540 E Street,Chula Vista,CA,91910	540 E Street	Chula Vista	91910	7	4.0	3.0	1,381	$537,674	2.308	2.565	3,433
Christian Valdez-66 El Capitan Dr,Chula Vista,CA,91911	66 El Capitan Dr	Chula Vista	91911	7	3.0	2.0	1,322	$502,980	3.265	3.705	5,224
Shahab Pajoohesh-1555 Malta Ave,Chula Vista,CA,91911	1555 Malta Ave	Chula Vista	91911	7	5.0	2.0	1,611	$500,693	4.019	4.56	6,669
Thomas Urbanski-1136 Hemlock Ave,Imperial Beach,CA,91932	1136 Hemlock Ave	Imperial Beach	91932	7	4.0	2.0	1,407	$565,467	3.848	4.4	6,629
Les Shipley Project - 15955 Lyons Valley Road, Jamul, CA 91935	15955 Lyons Valley Road	Jamul	91935	10	3.0	3.0	1,608	$699,207	4.663	5.3	6,887

Table 7 Modified PV System Installations

A key variable that went into factoring the cost benefit analysis and LCCA was determined to be the 30% investment government tax credit. There has been much debate as to whether such tax credits will continue to benefit the solar industry and whether going off-grid all together will financially benefit the single-family residential homeowner in the near future. Traditional utility companies such as SDG&E are vouching for continued dependency on the grid and emphasize catastrophic societal effects by a mass exodus of going off grid (Begos, 2016, p. 387). The solar industry is much guided by current domestic and foreign policy from solar panel manufacturers to government subsidy and funding. This has been the case for many years with the objective of producing a reliable source of renewable clean energy and reduce dependency on fossil fuels.

As the solar industry continues to grow in San Diego County it will be tailored by the California Solar Initiative (CSI) policies and incentives as the ones previously mentioned. Continued research will be needed to determine the financial impact once the government investment tax credit is stopped or becomes gridlocked. An analysis can be evaluated from past years when no tax credits were given in comparison to current status quo and future impacts without such government incentives.

References

Begos 2016 CQ Researcher; in dept report on today's issues. *Solar Energy Controversies* 385-408 Sage publications www.cqresearcher.com

Complete Photovoltaic System (n.d.). Retrieved February 16, 2018, from http://www.solardirect.com/pv/systems/systems.htm

Darbali-Zamora, R., Gómez-Méndez, C. J., & Díaz-Castillo, A. J. (2015). Comparison of Residential Wind and Solar Energy Generation in the Island of Puerto Rico. *Renewable Energy and Power Quality Journal*, 500-505. doi:10.24084/repqj13.373

Differentiate between the DNI, DHI and GHI? (2012, May 03). Retrieved February 10, 2018, from https://firstgreenconsulting.wordpress.com/2012/04/26/differentiate-between-the-dni-dhi-and-ghi/

Global Solar Atlas. (n.d.). Retrieved February 10, 2018, from http://globalsolaratlas.info/?c=32.848996%2C-116.7569%2C9&s=32.834551%2C-117.184845

GRID Alternatives. (n.d.). Retrieved April 11, 2018, from https://gridalternatives.org/

Mouchot, A. (1869). (La) Chaleur solaire et ses applications industrielles. Gauthier-Villars.

Residential Solar Calculator. (n.d.). Retrieved February 15, 2018, from http://www.affordable-solar.com/solar-tools/residential-solar-calculator/

San Diego County. (2017). *San Diego county area median income (AMI) and income limits*. Retrieved from https://www.sandiegocounty.gov/content/sdc/sdhcd/rental-assistance/income-limits-ami.html

San Diego's SUSTAINABLE FUTURE. (2013, June 24). Retrieved April 11, 2018, from http://sdsustainablefuture.blogspot.com/2013/06/sdg-energy-rates-up-12-in-2013.html

Society, N. G. (2012, October 09). *GIS (geographic information system).* Retrieved January 22, 2018, from https://www.nationalgeographic.org/encyclopedia/geographic-information-system-gis/

Solar Leases & PPAs. (n.d.). Retrieved April 11, 2018, from https://www.energysage.com/solar/financing/solar-leases-and-solar-ppas/

Solar PV Electric. (n.d.). Retrieved February 10, 2018, from http://www.solardirect.com/pv/systems/solar-freedom.htm

Types of Solar Leases and PPAs. (n.d.). Retrieved April 11, 2018, from https://www.energysage.com/solar/financing/types-of-solar-leases-and-ppas/

United States Census. (2017). *Quickfacts San Diego County, California*. Retrieved from https://www.census.gov/quickfacts/fact/table/sandiegocountycalifornia,CA/PST045216

Zillow. (2018). *San Diego County CA single family homes.* Zillow. Retrieved from https://www.zillow.com/homes/for_sale/San-Diego-County-CA/house_type/2841_rid/3-_beds/2-_baths/priced_sort/33.839623,-115.521241,32.190722,-118.171692_rect/8_zm/

Appendix A: Grid Alternatives Data

DC rating, kW STC	Expected Annual Output (kWh/yr)	Panel Model	Total Panels	Panel Type	Panel Watts	Panel Efficiency	Inverter Type	Inverter Watts	Inverter Efficiency
5.6	6,438	REC Solar REC280TP BLK	20	Polycrystalline	280	16.80%	Grid-Tied String Inverter	5000	97.00%
4.24	6,849	SunEdison SE-F265KzD-3y	16	Monocrystalline	265	16.14%	Microinverter	250	96.50%
4.56	6,469	REC Solar REC285TP2	16	Polycrystalline	285	17.10%	Grid-Tied String Inverter	3800	97.90%
2.565	3,433	REC Solar REC285TP2	9	Polycrystalline	285	17.10%	Grid-Tied String Inverter	4050	97.70%
3.705	5,224	REC Solar REC285TP2	13	Polycrystalline	285	17.10%	Grid-Tied String Inverter	3800	97.90%
4.56	6,669	REC Solar REC285TP2	16	Polycrystalline	285	17.10%	Grid-Tied String Inverter	3800	97.90%
4.4	6,629	Canadian Solar CS6K-275M	16	Monocrystalline	275	16.80%	Microinverter	250	96.50%
5.3	6,887	SunEdison SE-F265KzD-3y	20	Monocrystalline	265	16.14%	Microinverter	250	96.50%
3.71	5,467	SunEdison SE-F265KzD-3y	14	Monocrystalline	265	16.14%	Microinverter	250	96.50%
2.12	3,045	Hanwha Q CELLS Q.PRO-G4 265	8	Polycrystalline	265	15.90%	Microinverter	195-330	97.00%
4	5,963	Renesola America JC250M-24/Bxh	16	Polycrystalline	250	15.40%	Microinverter	210-350	96.50%
3.36	5,025	REC Solar REC280TP BLK	12	Polycrystalline	280	16.80%	Grid-Tied String Inverter	3000	97.10%
4.2	5,890	REC Solar REC280TP	15	Polycrystalline	280	16.80%	Grid-Tied String Inverter	3800	97.90%
3.42	5,119	REC Solar REC285TP2	12	Polycrystalline	285	17.10%	Grid-Tied String Inverter	3800	97.90%
2.28	3,438	REC Solar REC285TP2	8	Polycrystalline	285	17.10%	Grid-Tied String Inverter	4050	97.70%
4.56	6,745	REC Solar REC285TP2 REC Solar REC285TP2	16	Polycrystalline	285	17.10%	Grid-Tied String Inverter	4050	97.70%
3.445	4,984	Hanwha Q CELLS Q.PRO-G4 265	13	Polycrystalline	265	15.90%	Microinverter	195-330	97.00%
4.16	5,831	SolarWorld SW 260 Mono	16	Monocrystalline	260	15.51%	Microinverter	210-350	96.50%
2.25	3,400	Renesola America JC250M-24/Bxh	9	Polycrystalline	250	15.40%	Microinverter	250	96.50%
3.64	5,503	Hyundai Heavy Industries HiS-S280RG Hyundai Heavy Industries HiS-S280RG	13	Monocrystalline	280	17.10%	Microinverter	195-330	97.00%
4.08	5,909	Renesola America JC255M-24/Bx	16	Polycrystalline	255	15.70%	Microinverter	210-350	96.50%

DC rating, kW STC	Expected Annual Output (kWh/yr)	Panel Model	Total Panels	Panel Type	Panel Watts	Panel Efficiency	Inverter Type	Inverter Watts	Inverter Efficiency
3.92	5,234	REC Solar REC280TP	14	Polycrystalline	280	16.80%	Grid-Tied String Inverter	3800	97.90%
2.8	4,355	Hyundai Heavy Industries HiS-S280RG	10	Monocrystalline	280	17.10%	Microinverter	195-330	97.00%
1.855	2,640	SunEdison SE-F265KzD-3y	7	Monocrystalline	265	16.14%	Microinverter	250	96.50%
3.08	4,661	Hyundai Heavy Industries HiS-S280RG	11	Monocrystalline	280	17.10%	Microinverter	195-330	97.00%
1.325	2,036	SunEdison SE-F265KzD-3y	5	Monocrystalline	265	16.14%	Microinverter	250	96.50%
2.9	4,230	REC Solar REC290TP2	10	Polycrystalline	290	17.40%	Grid-Tied String Inverter	2500	95.00%
3.92	6,168	REC Solar REC280TP	14	Polycrystalline	280	16.80%	Grid-Tied String Inverter	4200	97.60%
4.24	6,370	SunEdison SE-F265KzD-3y	16	Monocrystalline	265	16.14%	Microinverter	250	96.50%
4.24	6,914	SunEdison SE-F265KzD-3y	16	Monocrystalline	265	16.14%	Microinverter	210-350	96.50%
4.5	6,575	Renesola America JC250M-24/Bxh	18	Polycrystalline	250	15.40%	Microinverter	235-400	97.00%
4.4	6,215	Canadian Solar CS6K-275M	16	Monocrystalline	275	16.80%	Microinverter	250	96.50%
3.64	5,316	Canadian Solar CS6P-260P	14	Polycrystalline	260	16.16%	Microinverter	250	96.50%
3.5	4,718	Renesola America JC250M-24/Bxh	14	Polycrystalline	250	15.40%	Microinverter	250	96.50%
4.24	6,152	SunEdison SE-F265KzD-3y	16	Monocrystalline	265	16.14%	Microinverter	250	96.50%
4.24	5,477	SunEdison SE-F265KzD-3y	16	Monocrystalline	265	16.14%	Microinverter	250	96.50%
2.205	3,732	SunPower SPR-E20-245	9	Monocrystalline	245	20.00%	Microinverter	210-350	96.50%
2.45	3,261	SunPower SPR-E20-245	10	Monocrystalline	245	20.00%	Microinverter	210-350	96.50%
3.43	4,798	Trina Solar TSM-245PA05.08 Trina Solar TSM-245PA05.08	14	Polycrystalline	245	14.40%	Microinverter	210-350	96.50%
4.5	6,077	Trina Solar TSM-250PA05	18	Polycrystalline	250	15.30%	Microinverter	210-350	96.50%
3.85	5,548	changzhou Trina Solar Energy co. TSM-275PD05.08	14	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%
3.025	4,151	changzhou Trina Solar Energy co. TSM-275PD05.08	11	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%
2.25	3,036	Trina Solar TSM-250PA05 Trina Solar TSM-250PA05	9	Polycrystalline	250	15.30%	Microinverter	235-400	97.00%
3.025	4,038	Trina Solar TSM-275DD05A.05(II) Trina Solar TSM-275DD05A.05(II)	11	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%

DC rating, kW STC	Expected Annual Output (kWh/yr)	Panel Model	Total Panels	Panel Type	Panel Watts	Panel Efficiency	Inverter Type	Inverter Watts	Inverter Efficiency
2.28	3,528	Trina Solar TSM-285DD05A.08(II)	8	Monocrystalline	285	17.40%	Microinverter	235-400	97.00%
2.55	3,723	Trina Solar TSM-255PD05.05	10	Polycrystalline	255	15.60%	Microinverter	210-350	96.50%
2.915	4,374	SunEdison SE-F265KzD-3y	11	Monocrystalline	265	16.14%	Microinverter	250	96.50%
2.2	3,126	Canadian Solar CS6K-275M	8	Monocrystalline	275	16.80%	Microinverter	210-350	96.50%
3.06	4,191	Renesola America JC255M-24/Bx	12	Polycrystalline	255	15.70%	Microinverter	210-350	96.50%
4.4	6,127	Canadian Solar CS6K-275M	16	Monocrystalline	275	16.80%	Microinverter	250	96.50%
3	4,450	Renesola America JC250M-24/Bxh	12	Polycrystalline	250	15.40%	Microinverter	250	96.50%
2	3,092	Renesola America JC250M-24/Bxh	8	Polycrystalline	250	15.40%	Microinverter	250	96.50%
1.75	2,506	Renesola America JC250M-24/Bxh	7	Polycrystalline	250	15.40%	Microinverter	250	96.50%
3.18	4,519	SunEdison SE-F265KzD-3y	12	Monocrystalline	265	16.14%	Microinverter	250	96.50%
5.1	7,242	Renesola America JC255M-24/Bx	20	Polycrystalline	255	15.70%	Microinverter	210-350	96.50%
2.16	2,015	SolarWorld SW240 mono	9	Monocrystalline	240	14.31%	Microinverter	210-350	96.50%
3.975	5,447	SunEdison SE-F265KzD-3y	15	Monocrystalline	265	16.14%	Microinverter	210-350	96.50%
2.45	3,656	SunPower SPR-E20-245	10	Monocrystalline	245	20.00%	Microinverter	210-350	96.50%
2.45	3,499	SunPower SPR-E20-245 SunPower SPR-E20-245	10	Monocrystalline	245	20.00%	Microinverter	210-350	96.50%
2.64	4,024	Trina Solar TSM-240PA05.05	11	Polycrystalline	240	14.70%	Microinverter	210-350	96.50%
2.75	3,563	changzhou Trina Solar Energy co. TSM-275PD05.08	10	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%
1.65	2,506	changzhou Trina Solar Energy co. TSM-275PD05.08	6	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%
2.2	3,234	changzhou Trina Solar Energy co. TSM-275PD05.08 changzhou Trina Solar Energy co. TSM-275PD05.08	10	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%
2	2,641	Trina Solar TSM-250PA05	8	Polycrystalline	250	15.30%	Microinverter	235-400	97.00%
3.85	5,482	Trina Solar TSM-275DD05A.05(II) Trina Solar TSM-275DD05A.05(II)	14	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%

4.275	5,507	Trina Solar TSM-285DD05A.08(II) Trina Solar TSM-285DD05A.08(II)	15	Monocrystalline	285	17.40%	Microinverter	235-400	97.00%
2.2	3,244	Canadian Solar CS6K-275M	8	Monocrystalline	275	16.80%	Microinverter	250	96.50%
4	5,480	Trina Solar TSM-250PA05	16	Polycrystalline	250	15.30%	Microinverter	210-350	96.50%
5	6,556	Trina Solar TSM-250PA05 Trina Solar TSM-250PA05	20	Polycrystalline	250	15.30%	Microinverter	210-350	96.50%
4.24	6,263	SunEdison SE-F265KzD-3y	16	Monocrystalline	265	16.14%	Microinverter	250	96.50%
3.42	5,036	REC Solar REC285TP2	12	Polycrystalline	285	17.10%	Grid-Tied String Inverter	3800	97.90%
4.08	5,809	Renesola America JC255M-24/Bx	16	Polycrystalline	255	15.70%	Microinverter	210-350	96.50%
4.25	5,756	Trina Solar TSM-250PA05	17	Polycrystalline	250	15.30%	Microinverter	235-400	97.00%
3.5	5,313	Trina Solar TSM-250PA05 Trina Solar TSM-250PA05	14	Polycrystalline	250	15.30%	Microinverter	235-400	97.00%
4.845	6,486	Trina Solar TSM-285DD05A.08(II) Trina Solar TSM-285DD05A.08(II)	17	Monocrystalline	285	17.40%	Microinverter	235-400	97.00%
3.57	4,789	Trina Solar TSM-255PD05.05	14	Polycrystalline	255	15.60%	Microinverter	240	96.50%
4.4	6,349	Canadian Solar CS6K-275M	16	Monocrystalline	275	16.80%	Microinverter	250	96.50%
4	5,742	JC250M-24/Bxh	16	Polycrystalline	250	15.40%	Microinverter	250	96.50%
4	5,895	Renesola America JC250M-24/Bxh	16	Polycrystalline	250	15.40%	Microinverter	250	96.50%
2.75	3,673	Renesola America JC250M-24/Bxh	11	Polycrystalline	250	15.40%	Microinverter	250	96.50%
3.75	5,293	Renesola America JC250M-24/Bxh	15	Polycrystalline	250	15.40%	Microinverter	250	96.50%
3.64	4,985	Renesola America JC260M-24/Bxh	14	Polycrystalline	260	16.00%	Microinverter	250	96.50%
2.6	3,722	Renesola America JC260M-24/Bxh	10	Polycrystalline	260	16.00%	Microinverter	250	96.50%
2.6	3,204	Renesola America JC260M-24/Bxh	10	Polycrystalline	260	16.00%	Microinverter	250	96.50%
4.16	6,172	Renesola America JC260M-24/Bxh	16	Polycrystalline	260	16.00%	Microinverter	250	96.50%
3.71	4,691	SunEdison SE-F265KzD-3y	14	Monocrystalline	265	16.14%	Microinverter	250	96.50%
2.915	3,955	SunEdison SE-F265KzD-3y	11	Monocrystalline	265	16.14%	Microinverter	250	96.50%
3.18	4,525	SunEdison SE-F265KzD-3y	12	Monocrystalline	265	16.14%	Microinverter	250	96.50%
3.71	5,523	SunEdison SE-F265KzD-3y	14	Monocrystalline	265	16.14%	Microinverter	250	96.50%
5.3	7,434	SunEdison SE-F265KzD-3y	20	Monocrystalline	265	16.14%	Microinverter	250	96.50%

5.3	7,348	SunEdison SE-F265KzD-3y	20	Monocrystalline	265	16.14%	Microinverter	250	96.50%
1.855	2,319	SunEdison SE-F265KzD-3y	7	Monocrystalline	265	16.14%	Microinverter	250	96.50%
3.18	4,549	SunEdison SE-F265KzD-3y	12	Monocrystalline	265	16.14%	Microinverter	250	96.50%
2.915	4,335	SunEdison SE-F265KzD-3y	11	Monocrystalline	265	16.14%	Microinverter	250	96.50%
3.27	5,026	SunPower SPR-E20-327	10	Monocrystalline	327	20.40%	Grid-Tied String Inverter	3000	97.10%
3.27	4,869	SPR-E20-327	10	Monocrystalline	327	20.40%	Grid-Tied String Inverter	3100	97.60%
2.24	3,287	REC Solar REC280TP	8	Polycrystalline	280	16.80%	Grid-Tied String Inverter	3800	97.90%
2.8	3,836	REC Solar REC280TP	10	Polycrystalline	280	16.80%	Grid-Tied String Inverter	4200	97.60%
4.905	6,442	SunPower SPR-327NE-WHT-D	15	Monocrystalline	327	20.10%	Grid-Tied String Inverter	4200	97.20%
4.905	7,059	SunPower SPR-327NE-WHT-D	15	Monocrystalline	327	20.10%	Grid-Tied String Inverter	5150	97.50%
4.335	6,145	Renesola America JC255M-24/Bx	17	Polycrystalline	255	15.70%	Microinverter	210-350	96.50%
3.43	3,310	SunPower SPR-E20-245	14	Monocrystalline	245	20.00%	Microinverter	210-350	96.50%
2.205	3,682	SunPower SPR-E20-245	9	Monocrystalline	245	20.00%	Microinverter	210-350	96.50%
3.92	3,771	SunPower SPR-E20-245	16	Monocrystalline	245	20.00%	Microinverter	210-350	96.50%
3.6	4,623	Trina Solar TSM-240PA05	15	Polycrystalline	240	14.70%	Microinverter	210-350	96.50%
4.56	6,602	Trina Solar TSM-240PA05	19	Polycrystalline	240	14.70%	Microinverter	210-350	96.50%
4.08	5,982	Trina Solar TSM-255PD05.05 Trina Solar TSM-255PD05.05	16	Polycrystalline	255	15.60%	Microinverter	210-350	96.50%
3.85	5,605	changzhou Trina Solar Energy co. TSM-275PD05.08 changzhou Trina Solar Energy co. TSM-275PD05.08	14	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%
4.95	6,745	changzhou Trina Solar Energy co. TSM-275PD05.08 changzhou Trina Solar Energy co. TSM-275PD05.08	18	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%
3.25	4,467	Trina Solar TSM-250PA05	13	Polycrystalline	250	15.30%	Microinverter	235-400	97.00%
2.25	3,294	Trina Solar TSM-250PA05 Trina Solar TSM-250PA05	9	Polycrystalline	250	15.30%	Microinverter	235-400	97.00%

5	7,415	Trina Solar TSM-250PA05 Trina Solar TSM-250PA05 Trina Solar TSM-250PA05	20	Polycrystalline	250	15.30%	Microinverter	235-400	97.00%
2.75	4,083	Trina Solar TSM-275DD05A.05(II)	10	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%
5.3	7,614	SunEdison SE-F265KzD-3y	20	Monocrystalline	265	16.14%			
5.3	8,144	SunEdison SE-F265KzD-3y	20	Monocrystalline	265	16.14%			
4.4	5,888	Trina Solar TSM-275DD05A.05(II)	16	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%
4.675	5,850	Trina Solar TSM-275DD05A.05(II) Trina Solar TSM-275DD05A.05(II)	17	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%
2.475	3,555	Trina Solar TSM-275DD05A.08(II)	9	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%
3.135	4,375	Trina Solar TSM-285DD05A.08(II)	11	Monocrystalline	285	17.40%	Microinverter	235-400	97.00%
3.135	4,826	Trina Solar TSM-285DD05A.08(II)	11	Monocrystalline	285	17.40%	Microinverter	235-400	97.00%
4.845	7,056	Trina Solar TSM-285DD05A.08(II) Trina Solar TSM-285DD05A.08(II)	17	Monocrystalline	285	17.40%	Microinverter	235-400	97.00%
3.85	4,955	Canadian Solar CS6K-275M	14	Monocrystalline	275	16.80%	Microinverter	250	96.50%
4.4	6,118	Canadian Solar CS6K-275M	16	Monocrystalline	275	16.80%	Microinverter	250	96.50%
2.65	3,914	SunEdison SE-F265KzD-3y	10	Monocrystalline	265	16.14%	Microinverter	250	96.50%
2.915	3,937	SunEdison SE-F265KzD-3y	11	Monocrystalline	265	16.14%	Microinverter	250	96.50%
3.71	5,568	SunEdison SE-F265KzD-3y	14	Monocrystalline	265	16.14%	Microinverter	250	96.50%
2.12	2,913	SunEdison SE-F265KzD-3y	8	Monocrystalline	265	16.14%	Microinverter	250	96.50%
2.385	3,506	SunEdison SE-F265KzD-3y	9	Monocrystalline	265	16.14%	Microinverter	250	96.50%
2.55	3,808	Trina Solar TSM-255PD05.05 Trina Solar TSM-255PD05.05	10	Polycrystalline	255	15.60%	Microinverter	235-400	97.00%
2.915	4,148	SunEdison SE-F265KzD-3y	11	Monocrystalline	265	16.14%	Microinverter	250	96.50%
3.315	4,692	Renesola America JC255M-24/Bx	13	Polycrystalline	255	15.70%	Microinverter	210-350	96.50%
2.2	3,134	changzhou Trina Solar Energy co. TSM-275PD05.08	8	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%
3.575	4,838	changzhou Trina Solar Energy co. TSM-275PD05.08	13	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%

3.575	5,278	changzhou Trina Solar Energy co. TSM-275PD05.08	13	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%
4.95	6,475	Trina Solar TSM-275DD05A.05(II)	18	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%
4	5,691	Renesola America JC250M-24/Bxh	16	Polycrystalline	250	15.40%	Microinverter	250	96.50%
3	4,418	Renesola America JC250M-24/Bxh	12	Polycrystalline	250	15.40%	Microinverter	250	96.50%
4.24	4,815	SunEdison SE-F265KzD-3y	16	Monocrystalline	265	16.14%	Microinverter	250	96.50%
4.48	6,274	REC Solar REC280TP	16	Polycrystalline	280	16.80%	Grid-Tied String Inverter	4200	97.20%
3.75	5,721	Renesola America JC250M-24/Bxh	15	Polycrystalline	250	15.40%	Microinverter	210-350	96.50%
3.675	5,156	SunPower SPR-E20-245	15	Monocrystalline	245	20.00%	Microinverter	210-350	96.50%
4.24	6,233	SunEdison SE-F265KzD-3y	16	Monocrystalline	265	16.14%	Microinverter	250	96.50%
2.385	3,269	SunEdison SE-F265KzD-3y	9	Monocrystalline	265	16.14%	Microinverter	250	96.50%
2.616	3,590	SunPower SPR-E20-327	8	Monocrystalline	327	20.40%	Grid-Tied String Inverter	3000	97.10%
3.92	5,651	SunPower SPR-E20-245	16	Monocrystalline	245	20.00%	Microinverter	210-350	96.50%
2.5	3,716	Renesola America JC250M-24/Bxh	10	Polycrystalline	250	15.40%	Microinverter	250	96.50%
3.575	5,074	Trina Solar TSM-275DD05A.05(II)	13	Monocrystalline	275	16.80%	Microinverter	235-400	97.00%

Appendix B: PV Planning Model

Single Family Residential Solar Photovoltaic System Planner

User Instructions:

1. Determine annual energy usage by adding the montly energy usage list on the last 12 monthly SDG&E bills. Enter total in Line 1 of Customer Input section.
2. Determine square foot of South West to South East facing roof where solar panels will be installed using PVWatts website. Convert from square meters to square feet using conversion caluculater and enter into Line 2 of the Customer Input section.
3. Enter the current annual percentage rate (APR) for financing a purchased system in Line 3 of the Customer Input section.
4. Enter the length of the loan, in months, in Line 4 of the Customer Input section.
5. The Solar System Configuration section will show system configurations based on either monocrystaline or polycrystalline panels and either a string inverters, DC-DC optimizers with a string inverter, or microinverters on each panel. If the roof index is 1.0 or greater, there is enough area to install a solar system configuration based on the annual energy production needed. The number of panels, thier costs, the number of inverters, material costs, labor costs, and permit costs are all factored in the final system cost.
6. The Financial Anaylsis section provides the financial stats for each system listed in the Solar System Configurations section. Information for purchasing, leasing, and prepaid purchase agreements allow users to determine which method of acquisition if best for them.

Websites:

SDG&E Residential Login Portal

PVWatts Roof Size Estimator

m2 to ft2 converter

Customer Input:

TECHNICAL FEASIBILITY

1. Annual energy usage (kWh): 5,224

2. Estimated square foot area of roof (ft^2): 570

FINANCIAL FEASIBILITY

3. Current loan Average Percentage Rate (APR): 2.90%

4. Length of loan in months: 240

Solar System Configurations:

Monocrystalline Panel with String Inverters

Panel Area	Roof Index	Fit Roof	No. Panels	Panel Costs	Number Inverters	Number Optimizer	Inverter Costs	Material Costs	Labor Costs	Permit Costs	System Cost
194.98	2.92	YES	12	$4,344.00	1		$1,283.00		$2,500.00	$300.00	$8,427.00

Monocrystalline Panel with DC-DC Optimizer

Panel Area	Roof Index	Fit Roof	No. Panels	Panel Costs	Number Inverters	Number Optimizer	Inverter Costs	Material Costs	Labor Costs	Permit Costs	System Cost
189.42	3.01	YES	11	$3,982.00	1	11	$2,298.67		$2,500.00	$300.00	$9,080.67

Monocrystalline Panel with Microinverters

Panel Area	Roof Index	Fit Roof	No. Panels	Panel Costs	Number Inverters	Number Optimizer	Inverter Costs	Material Costs	Labor Costs	Permit Costs	System Cost
197.71	2.88	YES	12	$4,344.00	12		$1,916.24		$2,500.00	$300.00	$9,060.24

Polycrystalline Panel with String Inverters

Panel Area	Roof Index	Fit Roof	No. Panels	Panel Costs	Number Inverters	Number Optimizer	Inverter Costs	Material Costs	Labor Costs	Permit Costs	System Cost
246.61	2.31	YES	15	$3,450.00	1		$1,283.00		$2,500.00	$300.00	$7,533.00

Polycrystalline Panel with DC-DC Optimizer

Panel Area	Roof Index	Fit Roof	No. Panels	Panel Costs	Number Inverters	Number Optimizer	Inverter Costs	Material Costs	Labor Costs	Permit Costs	System Cost
240.37	2.37	YES	14	$3,220.00	1	14	$2,575.67		$2,500.00	$300.00	$8,595.67

Polycrystalline Panel with Microinverters

Panel Area	Roof Index	Fit Roof	No. Panels	Panel Costs	Number Inverters	Number Optimizer	Inverter Costs	Material Costs	Labor Costs	Permit Costs	System Cost
249.67	2.28	YES	15	$3,450.00	12		$1,916.24		$2,500.00	$300.00	$8,166.24

Financial Analysis:

Monocrystalline Panel with String Inverters								
Method	Total Base Cost	Taxes	Total Cost	Monthly Payment	Finance Cost	Lifetime Maint Cost	Tax Credit	Total Cost
Purchase	$8,427.00	$674.16	$9,101.16	NA	NA	$421.35	30%	$6,792.16
Finance	$8,427.00	$674.16	$9,101.16	$37.92	$2,903.74	$421.35	30%	$9,695.91
PPA	$8,427.00	$674.16	$9,101.16	$37.92	$2,903.74	$421.35		$12,426.25

Monocrystalline Panel with DC-DC Optimizer								
Method	Total Base Cost	Taxes	Total Cost	Monthly Payment	Finance Cost	Lifetime Maint Cost	Tax Credit	Total Cost
Purchase	$9,080.67	$726.45	$9,807.12	NA	NA	$454.03	30%	$7,319.02
Finance	$9,080.67	$726.45	$9,807.12	$40.86	$3,128.98	$454.03	30%	$10,448.00
PPA	$9,080.67	$726.45	$9,807.12	$40.86	$3,128.98	$454.03		$13,390.13

Monocrystalline Panel with Microinverters								
Method	Total Base Cost	Taxes	Total Cost	Monthly Payment	Finance Cost	Lifetime Maint Cost	Tax Credit	Total Cost
Purchase	$9,060.24	$724.82	$9,785.06	NA	NA	$453.01	30%	$7,302.55
Finance	$9,060.24	$724.82	$9,785.06	$40.77	$3,121.94	$453.01	30%	$10,424.50
PPA	$9,060.24	$724.82	$9,785.06	$40.77	$3,121.94	$453.01		$13,360.01

Polycrystalline Panel with String Inverters								
Method	Total Base Cost	Taxes	Total Cost	Monthly Payment	Finance Cost	Lifetime Maint Cost	Tax Credit	Total Cost
Purchase	$7,533.00	$602.64	$8,135.64	NA	NA	$376.65	30%	$6,071.60
Finance	$7,533.00	$602.64	$8,135.64	$33.90	$2,595.69	$376.65	30%	$8,667.29
PPA	$7,533.00	$602.64	$8,135.64	$33.90	$2,595.69	$376.65		$11,107.98

Polycrystalline Panel with DC-DC Optimizer								
Method	Total Base Cost	Taxes	Total Cost	Monthly Payment	Finance Cost	Lifetime Maint Cost	Tax Credit	Total Cost
Purchase	$8,595.67	$687.65	$9,283.32	NA	NA	$429.78	30%	$6,928.11
Finance	$8,595.67	$687.65	$9,283.32	$38.68	$2,961.86	$429.78	30%	$9,889.97
PPA	$8,595.67	$687.65	$9,283.32	$38.68	$2,961.86	$429.78		$12,674.97

Polycrystalline Panel with Microinverters								
Method	Total Base Cost	Taxes	Total Cost	Monthly Payment	Finance Cost	Lifetime Maint Cost	Tax Credit	Total Cost
Purchase	$8,166.24	$653.30	$8,819.54	NA	NA	$408.31	30%	$6,581.99
Finance	$8,166.24	$653.30	$8,819.54	$36.75	$2,813.89	$408.31	30%	$9,395.88
PPA	$8,166.24	$653.30	$8,819.54	$36.75	$2,813.89	$408.31		$12,041.74

Appendix C: CHI Square Test

Expected Frequencies					
	Column variable				
Row variable	Installed Observed	Model Expected	Total	(fo-fe)^2/fe	
R1	5.131627735	4.868372265	10	0.003376	0.003559
R2	7.184278828	6.815721172	14	0.458897	0.483712
R3	6.157953281	5.842046719	12	0.004052	0.004271
R4	6.671116055	6.328883945	13	0.016214	0.017091
R5	6.671116055	6.328883945	13	0.016214	0.017091
R6	6.671116055	6.328883945	13	0.016214	0.017091
R7	6.671116055	6.328883945	13	0.016214	0.017091
R8	7.184278828	6.815721172	14	0.004727	0.004982
R9	7.184278828	6.815721172	14	0.004727	0.004982
R10	7.184278828	6.815721172	14	0.004727	0.004982
R11	7.184278828	6.815721172	14	0.004727	0.004982
R12	7.184278828	6.815721172	14	0.004727	0.004982
R13	7.184278828	6.815721172	14	0.004727	0.004982
R14	7.184278828	6.815721172	14	0.004727	0.004982
R15	7.184278828	6.815721172	14	0.004727	0.004982
R16	7.697441602	7.302558398	15	0.011892	0.012536
R17	7.697441602	7.302558398	15	0.011892	0.012536
R18	7.697441602	7.302558398	15	0.011892	0.012536
R19	7.697441602	7.302558398	15	0.011892	0.012536
R20	8.723767149	8.276232851	17	0.186705	0.196801
R21	8.210604375	7.789395625	16	0.005402	0.005694
R22	8.210604375	7.789395625	16	0.005402	0.005694
R23	8.210604375	7.789395625	16	0.005402	0.005694

R24	8.210604375	7.789395625	16	0.005402	0.005694
R25	8.210604375	7.789395625	16	0.005402	0.005694
R26	8.210604375	7.789395625	16	0.005402	0.005694
R27	8.210604375	7.789395625	16	0.005402	0.005694
R28	8.210604375	7.789395625	16	0.005402	0.005694
R29	8.210604375	7.789395625	16	0.005402	0.005694
R30	8.210604375	7.789395625	16	0.005402	0.005694
R31	8.723767149	8.276232851	17	0.008747	0.00922
R32	8.723767149	8.276232851	17	0.008747	0.00922
R33	8.723767149	8.276232851	17	0.008747	0.00922
R34	8.723767149	8.276232851	17	0.008747	0.00922
R35	9.236929922	8.763070078	18	0.063038	0.066447
R36	9.236929922	8.763070078	18	0.063038	0.066447
R37	9.236929922	8.763070078	18	0.063038	0.066447
R38	9.236929922	8.763070078	18	0.063038	0.066447
R39	11.28958102	10.71041898	22	0.650721	0.685909
R40	8.723767149	8.276232851	17	0.060047	0.063294
R41	8.723767149	8.276232851	17	0.060047	0.063294
R42	8.723767149	8.276232851	17	0.060047	0.063294
R43	8.723767149	8.276232851	17	0.060047	0.063294
R44	9.236929922	8.763070078	18	0.006077	0.006406
R45	9.236929922	8.763070078	18	0.006077	0.006406
R46	9.236929922	8.763070078	18	0.006077	0.006406
R47	9.236929922	8.763070078	18	0.006077	0.006406
R48	9.236929922	8.763070078	18	0.006077	0.006406
R49	9.750092696	9.249907304	19	0.006405	0.006752
R50	9.750092696	9.249907304	19	0.006405	0.006752
R51	9.750092696	9.249907304	19	0.006405	0.006752

R52	9.750092696	9.249907304	19	0.006405	0.006752
R53	10.26325547	9.736744531	20	0.052887	0.055747
R54	10.26325547	9.736744531	20	0.052887	0.055747
R55	10.26325547	9.736744531	20	0.052887	0.055747
R56	10.26325547	9.736744531	20	0.052887	0.055747
R57	10.26325547	9.736744531	20	0.052887	0.055747
R58	10.26325547	9.736744531	20	0.052887	0.055747
R59	10.26325547	9.736744531	20	0.052887	0.055747
R60	12.82906934	12.17093066	25	0.783751	0.826132
R61	9.236929922	8.763070078	18	0.165639	0.174596
R62	9.750092696	9.249907304	19	0.057706	0.060826
R63	9.750092696	9.249907304	19	0.057706	0.060826
R64	10.26325547	9.736744531	20	0.006753	0.007118
R65	10.77641824	10.22358176	21	0.004639	0.00489
R66	10.77641824	10.22358176	21	0.004639	0.00489
R67	10.77641824	10.22358176	21	0.004639	0.00489
R68	11.28958102	10.71041898	22	0.044705	0.047122
R69	11.28958102	10.71041898	22	0.044705	0.047122
R70	11.28958102	10.71041898	22	0.044705	0.047122
R71	10.26325547	9.736744531	20	0.155488	0.163896
R72	10.77641824	10.22358176	21	0.055939	0.058964
R73	10.77641824	10.22358176	21	0.055939	0.058964
R74	10.77641824	10.22358176	21	0.055939	0.058964
R75	10.77641824	10.22358176	21	0.055939	0.058964
R76	10.77641824	10.22358176	21	0.055939	0.058964
R77	10.77641824	10.22358176	21	0.055939	0.058964
R78	10.77641824	10.22358176	21	0.055939	0.058964
R79	11.28958102	10.71041898	22	0.007428	0.007829

R80	11.28958102	10.71041898	22	0.007428	0.007829
R81	11.28958102	10.71041898	22	0.007428	0.007829
R82	11.28958102	10.71041898	22	0.007428	0.007829
R83	11.28958102	10.71041898	22	0.007428	0.007829
R84	11.28958102	10.71041898	22	0.007428	0.007829
R85	11.80274379	11.19725621	23	0.003297	0.003475
R86	11.80274379	11.19725621	23	0.003297	0.003475
R87	12.31590656	11.68409344	24	0.037998	0.040053
R88	12.31590656	11.68409344	24	0.037998	0.040053
R89	12.31590656	11.68409344	24	0.037998	0.040053
R90	12.82906934	12.17093066	25	0.106873	0.112652
R91	12.82906934	12.17093066	25	0.106873	0.112652
R92	13.85539488	13.14460512	27	0.331952	0.349903
R93	11.28958102	10.71041898	22	0.147306	0.155271
R94	11.28958102	10.71041898	22	0.147306	0.155271
R95	11.28958102	10.71041898	22	0.147306	0.155271
R96	12.31590656	11.68409344	24	0.008103	0.008541
R97	12.31590656	11.68409344	24	0.008103	0.008541
R98	12.82906934	12.17093066	25	0.002277	0.002401
R99	12.82906934	12.17093066	25	0.002277	0.002401
R100	12.82906934	12.17093066	25	0.002277	0.002401
R101	12.82906934	12.17093066	25	0.002277	0.002401
R102	13.34223211	12.65776789	26	0.032428	0.034181
R103	13.34223211	12.65776789	26	0.032428	0.034181
R104	13.34223211	12.65776789	26	0.032428	0.034181
R105	13.34223211	12.65776789	26	0.032428	0.034181
R106	13.34223211	12.65776789	26	0.032428	0.034181
R107	13.85539488	13.14460512	27	0.094557	0.09967

R108	13.85539488	13.14460512	27	0.094557	0.09967
R109	13.85539488	13.14460512	27	0.094557	0.09967
R110	14.36855766	13.63144234	28	0.185238	0.195255
R111	16.42120875	15.57879125	32	0.779952	0.822127
R112	12.82906934	12.17093066	25	0.053578	0.056475
R113	12.82906934	12.17093066	25	0.053578	0.056475
R114	13.34223211	12.65776789	26	0.008778	0.009253
R115	13.34223211	12.65776789	26	0.008778	0.009253
R116	13.85539488	13.14460512	27	0.001509	0.001591
R117	13.85539488	13.14460512	27	0.001509	0.001591
R118	13.85539488	13.14460512	27	0.001509	0.001591
R119	13.85539488	13.14460512	27	0.001509	0.001591
R120	14.36855766	13.63144234	28	0.027749	0.02925
R121	14.88172043	14.11827957	29	0.084033	0.088577
R122	14.88172043	14.11827957	29	0.084033	0.088577
R123	14.88172043	14.11827957	29	0.084033	0.088577
R124	14.88172043	14.11827957	29	0.084033	0.088577
R125	15.3948832	14.6051168	30	0.167354	0.176404
R126	12.82906934	12.17093066	25	0.260775	0.274876
R127	13.34223211	12.65776789	26	0.135029	0.142331
R128	13.34223211	12.65776789	26	0.135029	0.142331
R129	13.34223211	12.65776789	26	0.135029	0.142331
R130	13.85539488	13.14460512	27	0.05281	0.055665
R131	14.36855766	13.63144234	28	0.009454	0.009965
R132	14.36855766	13.63144234	28	0.009454	0.009965
R133	14.36855766	13.63144234	28	0.009454	0.009965
R134	14.88172043	14.11827957	29	0.00094	0.000991
R135	14.88172043	14.11827957	29	0.00094	0.000991

R136	15.3948832	14.6051168	30	0.023785	0.025071
R137	15.3948832	14.6051168	30	0.023785	0.025071
R138	15.3948832	14.6051168	30	0.023785	0.025071
R139	15.3948832	14.6051168	30	0.023785	0.025071
R140	15.3948832	14.6051168	30	0.023785	0.025071
R141	15.3948832	14.6051168	30	0.023785	0.025071
R142	15.3948832	14.6051168	30	0.023785	0.025071
R143	15.3948832	14.6051168	30	0.023785	0.025071
R144	15.3948832	14.6051168	30	0.023785	0.025071
R145	15.3948832	14.6051168	30	0.023785	0.025071
R146	15.3948832	14.6051168	30	0.023785	0.025071
R147	15.3948832	14.6051168	30	0.023785	0.025071
R148	16.42120875	15.57879125	32	0.15179	0.159998
R149	16.93437152	16.06562848	33	0.251962	0.265587
R150	13.85539488	13.14460512	27	0.248458	0.261894
R151	13.85539488	13.14460512	27	0.248458	0.261894
R152	13.85539488	13.14460512	27	0.248458	0.261894
R153	14.36855766	13.63144234	28	0.130351	0.137399
R154	14.36855766	13.63144234	28	0.130351	0.137399
R155	14.88172043	14.11827957	29	0.052241	0.055066
R156	14.88172043	14.11827957	29	0.052241	0.055066
R157	14.88172043	14.11827957	29	0.052241	0.055066
R158	15.3948832	14.6051168	30	0.010129	0.010677
R159	15.90804598	15.09195402	31	0.000532	0.00056
R160	15.90804598	15.09195402	31	0.000532	0.00056
R161	15.90804598	15.09195402	31	0.000532	0.00056
R162	15.90804598	15.09195402	31	0.000532	0.00056
R163	15.90804598	15.09195402	31	0.000532	0.00056

R164	15.90804598	15.09195402	31	0.000532	0.00056
R165	16.42120875	15.57879125	32	0.0204	0.021504
R166	16.93437152	16.06562848	33	0.067057	0.070683
R167	17.96069707	17.03930293	35	0.231548	0.244068
R168	17.96069707	17.03930293	35	0.231548	0.244068
R169	18.47385984	17.52614016	36	0.345428	0.364107
R170	15.90804598	15.09195402	31	0.051832	0.054635
R171	15.90804598	15.09195402	31	0.051832	0.054635
R172	15.90804598	15.09195402	31	0.051832	0.054635
R173	15.90804598	15.09195402	31	0.051832	0.054635
R174	15.90804598	15.09195402	31	0.051832	0.054635
R175	16.42120875	15.57879125	32	0.010804	0.011388
R176	16.42120875	15.57879125	32	0.010804	0.011388
R177	16.42120875	15.57879125	32	0.010804	0.011388
R178	16.42120875	15.57879125	32	0.010804	0.011388
R179	16.42120875	15.57879125	32	0.010804	0.011388
R180	16.42120875	15.57879125	32	0.010804	0.011388
R181	16.42120875	15.57879125	32	0.010804	0.011388
R182	16.93437152	16.06562848	33	0.000254	0.000268
R183	16.93437152	16.06562848	33	0.000254	0.000268
R184	18.47385984	17.52614016	36	0.126076	0.132893
R185	15.90804598	15.09195402	31	0.228855	0.24123
R186	16.93437152	16.06562848	33	0.051555	0.054343
R187	16.93437152	16.06562848	33	0.051555	0.054343
R188	16.93437152	16.06562848	33	0.051555	0.054343
R189	16.93437152	16.06562848	33	0.051555	0.054343
R190	16.93437152	16.06562848	33	0.051555	0.054343
R191	16.93437152	16.06562848	33	0.051555	0.054343

R192	16.93437152	16.06562848	33	0.051555	0.054343
R193	16.93437152	16.06562848	33	0.051555	0.054343
R194	17.4475343	16.5524657	34	0.011479	0.0121
R195	17.96069707	17.03930293	35	8.6E-05	9.07E-05
R196	18.47385984	17.52614016	36	0.014985	0.015795
R197	18.98702262	18.01297738	37	0.054043	0.056966
R198	18.98702262	18.01297738	37	0.054043	0.056966
R199	17.4475343	16.5524657	34	0.120095	0.126589
R200	17.4475343	16.5524657	34	0.120095	0.126589
R201	18.47385984	17.52614016	36	0.012155	0.012812
R202	19.50018539	18.49981461	38	0.012811	0.013504
R203	19.50018539	18.49981461	38	0.012811	0.013504
R204	19.50018539	18.49981461	38	0.012811	0.013504
R205	17.96069707	17.03930293	35	0.214041	0.225616
R206	17.96069707	17.03930293	35	0.214041	0.225616
R207	18.98702262	18.01297738	37	0.051309	0.054084
R208	19.50018539	18.49981461	38	0.01283	0.013524
R209	20.01334816	18.98665184	39	8.9E-06	9.38E-06
R210	20.52651094	19.47348906	40	0.013505	0.014235
R211	21.03967371	19.96032629	41	0.051375	0.054153
R212	21.03967371	19.96032629	41	0.051375	0.054153
R213	21.03967371	19.96032629	41	0.439152	0.462899
Total	**2768**	**2626**	**5394**		