Solar Energy Guide

A tool for promoting self-generated energy within Costa Rican Industries

An Interactive Qualifying Project Submitted to the Faculty of WORCESTER POLYTECHNIC INSTITUTE in partial fulfillment of the requirements for the Degree of Bachelor of Science by:

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Abstract

The goal of this project was to work with la Cámara de Industria de Costa Rica (CICR) to address high industrial energy prices by promoting photovoltaic systems for self-generation. Through interviews with solar providers, electricity distributors, and companies who have photovoltaic systems, information was gathered on the installation process, system pricing, providers of technology, and success cases. This information was organized into a guide, tailored to Costa Rican industries, that brings the reader step-by-step through the necessary considerations for implementing a photovoltaic system.

Executive Summary

In the past two decades, the proportion of energy produced from renewable sources has increased following greater threats of climate change and diminishing fossil fuels (Fendt, 2015). Costa Rica has continuously been a leader in the clean energy movement over the past decade, making a commitment to using renewable energy and pursuing carbon neutrality. Hydroelectric, geothermal, wind, biomass, and solar energy currently account for about 98% of Costa Rica's electricity generation (McKenna, 2017). The country is reliant on large hydroelectric plants to supply a majority of their energy, which supply about 75% of the total electricity production (McKenna, 2017). Many of the major hydroelectric plants are maintained by the government owned Costa Rican Institute of Electricity (*Instituto Costarricense de Electricidad)*, or ICE. ICE accounts for 92% of the electricity that is distributed throughout the nation and influential in determining the renewable energy projects that the nation pursues (I.Salazar, personal communication, January 28, 2018).

Despite the success Costa Rica has had in creating a low carbon energy matrix, industrial energy prices have increased dramatically within the past decade as a result of the investment in these renewable energy projects (G. Brouton, personal communication, February 22, 2018). Industrial energy prices in Costa Rica are about 60% higher than those in Europe and more than double those of the United States, causing Costa Rican industries to lose global competitiveness (Montenegro, 2018). Since ICE is a government-owned company and has such dominance in electricity distribution, they have great, unopposed control over the nationwide industrial energy prices.

The Costa Rican Chamber of Industries (*La Cámara de Industrias)*, or CICR, represents the industrial sector of Costa Rica. The CICR's mission is to strengthen Costa Rica's industrial sector while promoting the use of sustainable practices with an emphasis on energy efficiency. Thus, the CICR identified high industrial energy prices as a pressing issue. The CICR has recognized on-site, solar energy systems for self-generation as an effective way for industries to meet their energy needs while reducing the amount of energy purchased from ICE and other electricity distributors. Given the available technology and irradiation levels in Costa Rica, there is a great potential for solar energy, however it only makes up 0.1% of the nation's energy production (McKenna, 2017). This is due to the market barriers resulting from ICE's dominance, as well as inaccurate price information and a lack of understanding about how to pursue solar energy. The goal of this project was to work with the CICR to address these problems by creating an online guide to educate Costa Rican companies on the benefits of solar energy, how to pursue it, and what providers offer systems in Costa Rica.

Methodology

The primary objectives for accomplishing this goal were to:

1. Obtain a better understanding of the production and distribution of energy within Costa Rica
2. Create a profile of solar panel providers within Costa Rica
3. Create case studies of companies that have already implemented solar energy
4. Organize all this information and present it in an online guide

To obtain a better understanding of the production and distribution of energy, we conducted interviews with members of ACESOLAR, ICE, and solar panel providers. ACESOLAR is a non-profit organization dedicated to advancing the usage of solar energy in Costa Rica.

Through meetings with the CICR and research of published information, we identified some of the most prominent solar panel providers in Costa Rica. Questions during our in-person interviews focused on: 1.) basic background about the company; 2.) the types of projects they have done in the past; 3.) what technologies they offer; 4.) general cost data for the different sized systems; 5.) obstacles the providers have faced in expanding their business; and 6.) any suggestions they had for our guide. During our interviews with solar panel providers, we also asked for any reports on past projects that they had constructed. We were then able to contact these case study companies with solar panel systems already installed.

Our methods for developing case studies of companies that already installed solar panel systems were in-depth interviews and site visits. Our questions addressed the financial statistics behind their systems, such as initial investment and return on investment, their reasoning behind choosing solar energy, and anything they would suggest to companies considering solar energy.

Through brainstorming sessions, whiteboard draw-ups, and discussions with our sponsor and advisors, we developed a communication strategy to present all of our information in an online guide geared towards the needs of companies that may consider self-generated solar energy.

Findings

Through evaluation of our interview data we were able to develop the following findings:

ICE's energy market dominance hinders growth of solar panel usage
ICE was a significant influence on the creation and implementation of roadblocks in the form of the tariffs and regulations that limit the widespread usage of solar panels (K.Tat, personal communication, January 29, 2018).

Several tariffs and regulations that must be considered when installing solar panels and connecting them to the grid
Misinterpretation of the rules listed below can result in companies associating solar panel systems as costs rather than investments, so it was essential that they were presented well in our guide. First, there is a 13% general importation sales tax that applies to everything sold in the country. Second, there is an additional 1.13% tax on all imports as of Law 6946. Lastly, there is a variable importation tax that varies based on the product. This is 36% for lithium-ion batteries. Solar panels and inverters are exempt from all importation taxes. All excess energy that is not consumed at the time of generation is injected into the grid if the facility does not have energy storage options. There are two regulations that apply to this excess energy:

1. Of all the energy that is put back into the grid, only 49% can be returned back to the company for consumption.
2. An access tariff is applied to any of the energy consumed within that 49%. This tariff is about 25% of the regular energy cost and varies depending on the electricity provider. Energy consumed from the grid beyond the 49% mark is priced regularly.

There is a mandated permitting process for installing solar panel systems
Three to four permitting steps must be followed for solar panels to be installed by businesses, taking anywhere from three to six months.

1. No more than 15% of the total energy demand in a circuit can come from self-generated sources and this percentage can be reduced for any reason by the electricity provider. The electricity provider must be paid $50 to $350 to check if the size of the proposed solar panel system will fit within the given percentage.
2. The solar panel provider must submit all designs and technical specifications of the equipment being used to the electricity provider for approval.
3. The company receiving the solar panels must then commission the installation.
4. Some electricity distributors add a fourth step of inspecting the system after completion.

Solar energy has specific financial benefits for Costa Rican industries
Solar energy can reduce energy costs by self-generating energy rather than purchasing it from the grid. There is potential for even more savings if a company can reduce their monthly energy consumption from the grid to below 3,000 kWh. If a company that consumes more than 3,000kWh per month they are charged for their instantaneous peak demand. Solar panels can reduce the monthly energy consumption from the grid to below 3,000kWh, so there are no additional charges for this peak consumption. Even if this under 3,000 kWh goal cannot be achieved, solar systems can still greatly reduce peak energy consumption from the grid, thus reducing additional peak energy demand charges.

Solar panel provider profiles
When talking to the four solar providers that we interviewed with, we found very similar pricing and return on investments for differently sized system. These values are displayed in the table below.

System size	Price per peak watt installed	Estimated ROI
< 10 kW	around $2.00	7 - 8 years
10 - 100 kW	$1.20 - $1.50	6 - 8 years
100 - 200 kW	$1.00 - $1.20	5 - 7 years
200 kW +	$1.00 or less	3 - 5 years

Table 1: General system cost information

CieloVivo, greenenergy©, HiPower, and Purasol all use Tier 1 solar panels, a Bloomberg classification of the highest quality solar panels on the market. Additionally, all four companies offer high quality inverters from companies like Fronius, SMA, SolarEdge, Sunshine, and Growatt along with micro inverters from ABB and enphase. Both warranty and maintenance plans are offered dependent on the customers' needs. Even though energy storage can be pricey, all four companies offer battery storage options.

greenenergy© Focuses mainly on commercial and industrial solar projects. Several large projects were recently completed, including a 2.5 megawatt system and a 1 megawatt system for several large companies within Costa Rica. greenenergy© does all of the engineering and design of their solar systems and has a joint venture with Grupo Clima who preforms the panel installations.

Purasol has completed close to 1000 solar projects. Purasol focuses mainly on commercial systems, but plans to expand to more industrial applications. As an EPC (engineering, procurement, and construction) company, the entire process from design to installation of the system is overseen by Purasol.

Cielo Vivo, an EPC company, has completed about 20 projects in the year and a half spent as a PV provider. Cielo Vivo focuses mainly on small commercial projects, generally between 250W and 300kW, although they do have a 1 MW project in the works.

HiPower, an EPC company, focuses on photovoltaic systems but also provides solutions for solar-thermal systems, a combination of PV and thermal, and energy storage. A majority of HiPower's projects are both residential and commercial, along with off-grid systems, sized below 500kW.

Case study companies

Establishment Labs is a, high-tech medical device and aesthetics company. A 220 kW solar array composed of 864 Candian Solar photovoltaic panels accounts for 60% of their energy demands. Two lithium-ion battery banks providing 1 MWh or storage and 500 kW peak stores any excess energy, avoiding the 49% rule and access tariff.

Antojitos, a restaurant in San Pedro, San Jose, improved efficiency to reduce energy usage and costs. A solar system, which successfully brought them below the 3,000 kWh mark, saved a large sum of money on energy expenses.

BAC (Banco America Central) Installed 160 photovoltaic solar panels on their roof in 2011. BAC was able to reduce the amount of energy purchased from the grid by about 40% using this system, which paid for itself in 2016. All BAC buildings are carbon neutral certified and 25 are ISO 14001 certified, a certification for excellent environmental management.

Purdy Motor is a Toyota dealership in the process of finishing a 995kW photovoltaic solar array mounted on their roof. This system of 3,154 panels will provide for 47% of their energy demand, returning the investment in five years. Another location in Ciudad Curridabat just finished installing a smaller 34.56kW system of 108 panels. This system supplies 45% of the building's energy needs and will also return the investment in five years.

Astek is a manufacturer of flavorings and natural and artificial colorings. A $70,000, 51.2kW system of 160 panels reduced the energy bought from the grid by 88% for an annual savings of $17,000. The ROI is five years.

Deliverable

All of this information was then categorized and organized into our online guide. A screenshot of the guide homepage showing the categories we grouped the information in is shown in Figure 1. This guide is on the CICR website, available to all Costa Rican businesses, at www.cicr.com.

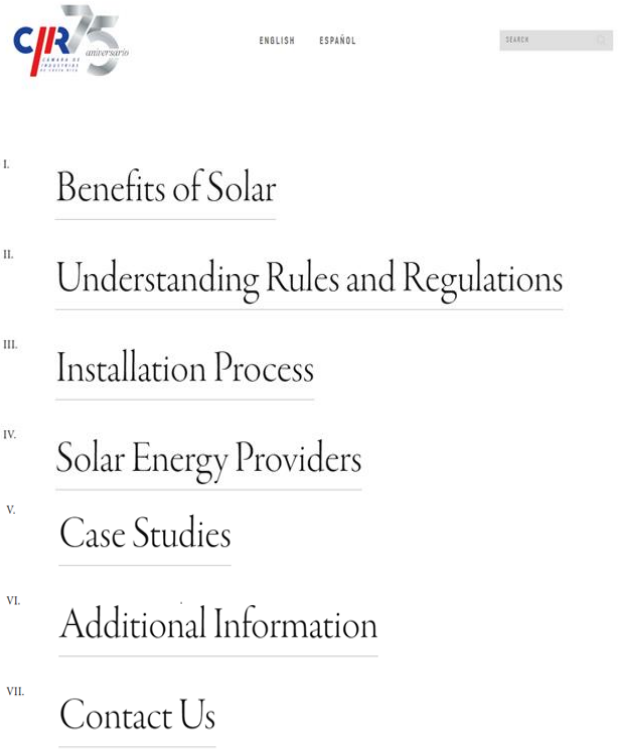

Figure 1: English version homepage screenshot

Recommendations

We were able to develop a set of recommendations to further enhance our guide and promote solar energy in Costa Rica.

We recommend that the CICR enhances our guide in the future:
Make an announcement to promote the guide and continue to expand the number of provider profiles and case studies.

We recommend that the CICR educates businesses on the benefits of making energy efficient investments.
Long term investments require careful budgeting and planning, which is not a practice that every business follows. We recommend that the CICR takes measures to educate businesses on the importance of making energy efficient investments.

We recommend that MINAE work to expand the 49% and 15% rules to a higher percentage and reduce or completely remove the access tariff.
With these tariffs and regulations as the main obstacles to increasing the usage of solar panels in industry, we suggest that the MINAE take legislative action. This would benefit individual businesses and Costa Rica's economy as a whole.

We recommend that ACESOLAR pushes for legislation to reduce the importation tax on lithium-ion batteries.
At their current state, with the 13% import tax, 1.13% tax, and additional 36% tax, lithium-ion batteries are extremely expensive in Costa Rica. It is in the best interest of Costa Rican industries that the 36% import tax on lithium-ion batteries is lowered or lifted so they are more accessible to businesses.

We recommend that ACESOLAR and MINAE push for mandatory standards for the installation of imported solar panels and inverters.
By setting standards for the quality of imported solar panels and inverters, customers can be more confident with their installations and unsafe, poor quality installations can be reduced.

Table of Authorship

Section	Written by	Edited by
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Costa Rican Industries and their Relationship with renewable energy	Spencer	Davianna and Chris
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Create a profile of solar panel providers in Costa Rica	Spencer and Chris	Davianna
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The Installation Process	Ethan	Chirs
Solar Panel Provider Profiles	Chris and Davianna	Ethan
Case Study Companies	Spencer and Xavier	Davianna
Additional Information	Xavier	Spencer
Conclusions and Recommendations		
Summary of Key Findings	Spencer, Chris, and Ethan	All
Recommendations	Spencer, Chris, and Ethan	All

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Chapter 1: Introduction

In the past two decades, the proportion of energy produced from renewable sources has increased following greater threats of climate change and diminishing fossil fuels (Fendt, 2015). Much of the world is taking steps to implement renewable energy, and many nations have already made large strides in creating effective renewable energy sources (EcoWatch, n.d.). The small Central American country of Costa Rica has continuously been a leader of the global clean energy movement, promoting and implementing a successful clean energy strategy before clean energy and climate change were large topics for debate. Hydroelectric plants, and other renewable sources such as solar, wind, and geothermal systems produce about 98% of Costa Rica's energy (McKenna, 2017).

Costa Rica's geographical location gives the country a significant advantage over other nations. It receives high amounts of rainfall and has an abundance of rivers and dams that can be used to produce large amounts of renewable energy. Therefore, the country relies heavily on hydroelectric energy while other renewable energy sources, such as solar, are under-utilized.

While Costa Rica boasts almost 100% renewable electricity generation, there are still problems to be addressed. The infrastructure needed to produce hydroelectric plants requires a large spatial area and is often located in remote sites. The cost to build these systems is very high, and many are built by the same electricity distributor that has a large control over energy distribution throughout the country. High initial investment, coupled with the need for electricity distributors to fund those investments, leaves industries to face high energy prices.

One potential solution is to use on-site, photovoltaic solar systems to help lower the amount of energy purchased from the grid and replace it with self-generated energy. Costa Rica has the available technology and environmental conditions for photovoltaic energy to be an

efficient means of generating energy. This could increase the industrial sector's competitiveness by lowering energy costs through self-generated energy, allowing businesses to spend this money elsewhere. However, there is a lack of knowledge concerning solar power within Costa Rica. Widespread inaccurate information on solar panel pricing, confusion about the solar panel installation procedures, several complicated tariffs and regulations, and lack of support from the government and electricity distributors contribute to the underutilization of solar technology.

The goal of this project was to work with the Costa Rican Chamber of Industry to create an online guide to educate Costa Rican companies on photovoltaic solar systems for self-generation and promote their usage. To accomplish this goal, we set out to understand the tariffs and regulations regarding solar panel usage, create profiles of different solar panel providers, compile case studies of companies that have implemented solar panels, and effectively portray this information in an online guide. These objectives will provide companies with a centralized source of information on the installation process, applicable tariffs, available technologies, and how these technologies have benefited other businesses. This successfully promotes solar panel usage and portrays it as an economical option for businesses.

Chapter 2: Background

Costa Rican Energy Production, Obstacles and Prices

Costa Rica has reached almost 100% electricity generation from renewable energy sources. This is thanks largely in part to the Costa Rican Institute of Electricity (*Instituto Costarricense de Electricidad)*, or ICE, and the large hydroelectric plants they have constructed. While electricity generated and distributed from renewable energy sources has increased greatly, so has energy prices faced by industries. Increased energy prices has led to increased spending on energy and loss of global competitiveness for Costa Rican industries. This section will closely examine production of electricity in Costa Rica, obstacles that have surfaced as a result of these means of production, and the relationship between energy production and electricity prices.

Energy Production

In 2010, Costa Rica's President Oscar Arias set a goal for the country to become carbon neutral by 2021 (Fendt, 2015). In March of 2015 on Earth Day, ICE announced that Costa Rica had been running on only renewable power sources for the entire year so far, which was 75 consecutive days at the time. Not only was this a record for Costa Rica, but a record for longest consecutive days powered by only renewable energy sources in any country (Fendt, 2015). Now looking back, Costa Rica has managed to improve on these accomplishments.

In 2016, Costa Rica ran entirely on renewable energy for 271 days (International Hydropower Association, 2017). This was the second year that it powered itself solely on renewable energy for more than two thirds of the year. For 2016, renewables supplied a staggering 98.1% of Costa Rica's electricity, following up on a consistent number of 98.8% of Costa Rica's electricity supplied by renewable power sources in 2015. The breakdown of the specific renewable energy types that made up this 98.1% is explained below.

Breaking down Costa Rica's 98.1% consumption of renewable energy, hydropower clearly leads the way, producing 74.35% of Costa Rica's electricity. In second place is geothermal energy production at 12.74% with wind power following at 10.3%. Biomass contributed only 0.72% of Costa Rica's electricity. Solar power came in last place at a surprisingly low value of producing only 0.01% of Costa Rica's electricity. Diesel-fueled thermal power plants filled in the gaps of low energy production from renewable power sources, producing 1.88% of Costa Rica's electricity (McKenna, 2017). This high level of renewable energy production, especially for hydropower, is due to the abundance of rainfall Costa Rica received in 2015 and 2016.

Although hydroelectric plants have performed well in the past, climate change will likely increase with global warming, causing an increase in unsteady rain patterns (Fendt, 2015). Costa Rica benefitted from an abundance of rainfall in 2015 and 2016, but in 2013 and 2014 the country faced a drought. With their dependence on hydropower, this can be a large risk towards Costa Rica's goal of 100% energy production from renewable sources.

At the conclusion of 2016, Costa Rica reached a total installed hydropower capacity of 2.12 Gigawatts, making it the top Central American country for installed hydropower capacity (International Hydropower Association, 2017). In 2016 alone, two new hydropower facilities in Costa Rica were completed. Another hydropower facility is under development as well, known as the El Diquís hydroelectric project. This ICE facility is sized at a staggering 631 Megawatts, having the potential to be the biggest hydropower facility in Central America. The project, however, is currently suffering significant delays under the domestic Supreme Court and UN legal framework due to potential ecological damage from heightened water levels and the relocation of native inhabitants (International Hydropower Association, 2017).

The first of the two new hydropower facilities built in Costa Rica in 2016 was the Bijagua facility in Upala, Alajuela province, sized at 17 Megawatts (Fendt, 2015). The second facility was the previously mentioned Reventazón Hydroelectric plant. This 305.5 Megawatt facility was a 1.4 billion USD project, making it the largest project in Central America second only to the Panama Canal (Fendt, 2015). The immense investment in the Reventazón Hydroelectric plant further proves how dedicated Costa Rica is to having 100% energy production from renewable power sources.

Energy Trends and Prices

Costa Rica's rapid population and gross domestic product growth led to a 130% increase in energy consumption from 1990 to 2010 (Staff, 2015). Since then, electricity prices have continued to rise. In March of 2015, prices rose 12.5% (CentralAmericaData, 2015) higher than what they were in 2014, and prices jumped again in April of 2017 when customers had to pay an additional 8% (Arias, 2017). While not mentioned in the world atlas due to its status as a developing nation, Costa Rica is considered to have among the highest industrial energy prices in the world (Lopez, 2016). As can be seen from Figure 2 below, increases in energy prices are reflected in the industrial sector rather than the residential sector, unlike the major European nations and the United States.

Figure 2: Industrial energy prices in CR, USA, and Europe (Montenergro, 2018)

Costa Rican electricity prices vary throughout the day between "peak", "valley", and "night" periods. These prices reflect the demand of energy at that time. This setup results in peak energy prices that are extremely high when compared to prices in Europe and the United States. Table 1 below is a breakdown of energy price fluctuations throughout the day of one of Costa Rica's prominent energy providers, National Power and Light Company (*Compañía Nacional de Fuerza y Luz),* or CNFL.

	Peak Period From 10:00 to 12:30 and from 5:30 to 8:00 p.m. Block of 0-300 per kWh	Valley Period From 6:01 to 10:00 and from 12:30 to 17:30 Block of 0-300 per kWh	Night period From 20:00 to 6:00 Block of 0-300 per kWh
Consumption from 0 to 300 kWh	$0.26	$0.11	$0.04
	Peak Period From 10:00 to 12:30 and from 5:30 to 8:00 p.m. Block of 301-500 per kWh	Valley Period From 6:01 to 10:00 and from 12:30 to 17:30 Block of 301-500 per kWh	Night period From 20:00 to 6:00 Block of 301-500 per kW
Consumption of 301 to 500 kWh	$0.30	$0.12	$0.05
	Peak Period From 10:00 to 12:30 and from 5:30 to 8:00 p.m. Block Greater than 500 per kWh	Valley Period From 6:01 to 10:00 and from 12:30 to 17:30 Block Greater than 500 per kWh	Night period From 20:00 to 6:00 Block Greater than 500 per kWh
Consumption greater than 501 kWh	$0.35	$0.14	$0.07

Table 1: CNFL price fluctuations (CNFL, 2017)

Costa Rica is currently dealing with increased electricity prices due to the upfront cost of making the switch to renewable energy (B. Johst, personal communication, January 31, 2018). The power alternatives Costa Rica is implementing, mostly through large hydroelectric plants, requires more infrastructure. This includes not only the installation of the systems, usually in remote hillsides, the coast, or in thermal areas, but also the transmission systems to transport that power to the urban areas where it is used (Staff, n.d.). As a result, energy prices are currently increasing with the addition of these projects. Even after this dramatic increase in energy prices, they will continue to rise in the upcoming year. In October 2017, ICE issued an increase of 18.82% of the general electricity tariff, which applies to a majority of Costa Rican companies (Montenegro, 2018).

Costa Rican Industries and Their Relationship with Renewable Energy

As discussed in the previous section, rising electricity prices are a big problem for Costa Rican industries. This section will give a brief overview on electricity regulation in Costa Rica and how it relates to the high energy prices.

Electricity Regulation

In Costa Rica, government-owned ICE holds dominance over almost all electricity distribution and generation. ICE is responsible for the major renewable energy plant projects in Costa Rica over the past ten years, including the controversial Reventazón hydroelectric project previously mentioned above. There are a few exceptions, such as the CNFL, a subsidiary of the ICE, or other public institutions and cooperatives that are authorized by law to generate and sell electricity (Monge, Volio, & Lopez, 2017). Since ICE holds this energy market dominance, all private generation that is not consumed must be sold to ICE for distribution to the public.

The main electrical regulatory authority is the Public Services Regulatory Authority (*Autoridad Reguladora de Servicios Públicos),* or ARESEP. ARESEP establishes all of the electricity tariffs from sale to final.

Two tariffs apply to Costa Rican industries' energy use: the general tariff and the medium voltage tariff. Small commercial and industrial businesses pay the general tariff (T-GE). In the T-GE, businesses face additional charges for maximum power demand if their monthly electricity consumption exceeds 3,000 kWh (Sperling, 94). The medium voltage tariff (T-MT) applies to businesses with a medium voltage grid connection and an annual consumption over 120,000 kWh (Sperling, 95). Three price levels are applied depending on the time of day, as previously depicted by Table 1.

Since prices are so high during the peak period, there has been a large push for self-generation as a means to economically power businesses during this time in order to offset the high prices of electricity. However, there are tariffs and regulations that apply to self-generation systems that are interconnected with the grid.

There is an access tariff which compensates for the cost of investment, operation, and maintenance of the distribution grid. The access tariff is paid by a business when they have a self-generation system and inject their excess energy into the grid because they cannot store it. Preliminary calculations from the Costa Rican Association for Solar Energy (ACESOLAR) estimate this tariff to be about $0.03/kWh for CNFL and $0.05/kWh for ICE (Sperling, 2015). The ICE tariff is more expensive due to maintenance of a larger distribution grid. To obtain a good understanding of how the access tariffs affect solar panel profitability, calculations from Sperling's (2015) thesis in Table 2 are used to show this relationship for residential, commercial, and industrial applications. Focusing on the ROI rows for ICE and CNFL, the estimated ROI without the access tariff is shown in parenthesis, and with the tariff is shown as normal text. "R" stands for the residential tariff, "C" for commercial applications in the T-GE tariff, and "I" for industrial applications in the T-MT tariff.

Distributor	Parameter	R	R	R	R	C	C	C	I	I
	PV power (kW)	1.6	2.4	4.0	8.0	8.0	32	48.4	80	160
	Avg. monthly consumption (kWh)	198	298	496	992	992	3,968	6,000	9,920	19,840
	Elec. Tariff	RE	RE	RE	RE	GE	GE	GE	MT	MT
ICE	ROI [years, months]	14,3 (11,3)	10,6 (6,4)	5,6 (3,4)	11,4 (3,4)	5,3 (3,8)	3,6 (2,9)	13,3 (8,5)	>25 (17,1)	>25 (16,2)
CNFL	ROI [years, months]	15,1 (14,1)	13,9 (12,7)	11,10 (9,6)	14,3 (6,8)	6,0 (4,8)	4,0 (3,4)	13,3 (11,2)	24,8 (18,2)	24,8 (18,1)

Table 2: Example calculations to show access tariff effect on ROI (Sperling, 2015)

Although these are crude calculations, the table provides adequately demonstrates the magnitude of the access tariff. In general, the access tariff greatly harms large industrial businesses with high energy consumption. Businesses with smaller energy consumption had lengthened returns on investment, however they were still relatively short. It is important to note that although self-generating systems such as solar arrays are privately owned and operated, they are connected to the distribution system unless batteries are used to store the energy. This connection is a public service, therefore tariffs on auto-production are set by the ARESEP.

Costa Rican Industry

Industry in Costa Rica is largely influential, accounting for 21 percent of the nation's GDP and projected to grow about 2.4 percent annually (Central Intelligence Agency, n.d.). The major industries that make up this sector include: medical equipment, food processing, textiles and clothing, construction materials, fertilizer, and plastic products (Central Intelligence Agency, n.d.). These industries consume about a quarter of all electricity produced. Consequently, renewable energy generation and electricity prices have a great effect on the industrial sector's

business climate, productivity, and global competitiveness and therefore the economic state of Costa Rica.

Recently, companies involved in industry have expressed discontent over the increased electricity costs (Lara, 2017). Production is now more expensive and exports are less competitive against international markets where electricity is cheaper.

CICR President, Enrique Ergloff, reported that the current situation of high electricity prices is causing problems with foreign investment in industry and is leading to high unemployment (Lara, 2017).

Our sponsor, the Costa Rican Chamber of Industries (*La Camara de Industrias)*, or CICR, also voiced its concern about Costa Rican companies possibly leaving the country to become more competitive, which will negatively affect the Costa Rican economy. The industrial sector accounts for 75 percent of all Costa Rican exports, therefore Costa Rica cannot afford to lose industrial competitiveness. Egloff (2017) attributes these issues to ICE and CNFL's inefficiency in spending, claiming their renewable energy generation projects cost more than their initial predictions, thus driving the rates up. One example of this claim is the Reventazón hydroelectric project, which had a final cost of $1.5 billion, more than double the $697 million projected in 2007 (Arias, 2017).

Costa Rica is highly dependent on foreign investment. Compared to the rest of Central America and Mexico, Costa Rica has attracted the highest percentage of foreign direct investment in the manufacturing sector within the last decade (Paus & Gallagher, 2017). Foreign direct investment in Costa Rica climbed from $409 million in 2000 to $2.2 billion in 2012 as the Costa Rican government has focused on attracting high-tech manufacturing companies (U.S. Department of State, 2014). An example of this is the American invested Intel microprocessor

manufacturing facility in Costa Rica, which once accounted for an impressive 25 percent of the nation's exports and five percent of the nation's GDP. Unfortunately, Intel decided to relocate and move this facility to three other countries in 2015 in order to save money, greatly hurting the Costa Rican economy (Aguildera, n.d.). Foreign direct investments have proven to be advantageous through both competitive pressures and spillovers, or the transfer of technology and knowledge (Paus & Gallagher, 2017). Since foreign investments have such a positive impact on the Costa Rican economy, it is Costa Rica's best interest to maintain or increase foreign investment into industry. Since high electricity rates have caused trouble with foreign investment, such as the moving of the Intel facility, the need to find cheaper energy sources for businesses is a pressing issue.

CICR

The Chamber of Industry of Costa Rica (CICR) is an organization that represents the industrial sector of Costa Rica. The CICR's mission is to strengthen Costa Rica's industrial sector while promoting the use of sustainable practices with an emphasis on energy efficiency. Their efforts to decrease the cost of energy by providing support against electricity tariffs is one of the many ways they are responsible for providing assistance to their 830 member companies.

Promotion of these causes is supported directly by the CICR in the form of debates and conferences. Recent initiatives include a debate in 2017 regarding the use of natural gas and increased awareness to aid in the diversification of energy production in Costa Rica. Conferences hosted by the CICR gives experts and companies in the field of renewable energy the opportunity to convene and share their ideas. Recently, a conference held in San Jose gave photovoltaic experts the opportunity to discuss the functionality and benefits of photovoltaic energy with the hope of increasing their usage in Costa Rica. Methods such as these will continue to be implemented as

the CICR pursues alternative energy methods to be used by their associated companies. Companies benefit from information on the CICR website, which contains documents concerning energy studies, environmental studies, public energy conservation classes, and Lean Six Sigma forums for the public to use. The CICR is dedicated to continuing the green way of life in Costa Rica while improving the state of the industrial sector.

As described in the previous section, the CICR sees high industrial energy prices as a pressing issue and is actively looking for solutions to help industries. Solar energy is seen as a viable option for self-generation to help lower energy costs and is explored further in the rest of this paper.

ACESOLAR

The Costa Rican Solar Energy Association, or ACESOLAR, is a non-profit organization dedicated to the promotion of solar energy usage in Costa Rica. The CICR partners with ACESOLAR to promote industrial usage of solar panels and identified it as a valuable resource. Any company interested in solar energy can be associated with ACESOLAR. Their membership includes professionals in engineering, law, and media at the international and national level (ACESOLAR, 2018). Companies that are affiliated with ACESOLAR benefit from a platform of information exchange, networking, and participation in workshops and conferences.

A directory of associated companies and helpful information on distributed generation and electricity regulation in Costa Rica is easily accessible through the ACESOLAR website. ACESOLAR also hosts an annual fair for solar power, ExpoSolar, where companies can make presentations on different topics in solar power. At the 2017 ExpoSolar, these topics included electric vehicles, smart grids, and learning activities for children. ExpoSolar attracted close to

5000 people who heard over 10 companies present on their different technologies (ACESOLAR, 2018).

Solar Energy Sources

The following section takes an in depth look at photovoltaic solar energy options and a case study regarding their usage.

Photovoltaic Solar Energy

Photovoltaic, or PV, solar energy is one form of energy that comes from capturing the sun's powerful rays, and using them directly to make electricity. It is the most common form of solar found on top of many households and businesses, in small electronics such as calculators, watches, and phone chargers; and in the open fields of solar farms. While this technology has been used for some time, it has developed extensively in the past decade and is expected to continue to grow in the coming years. PV energy is expected to be one of the most globally popular, thus cheapest, forms of renewable energy generation within the next decade (Guney, 2016). This method is preferred over other renewable methods mainly because of its low cost, reliable long-term use, and minimal maintenance. PV energy has gained popularity over time and its use is extremely diverse, however this resource does not always fit specific needs or high energy demands in that it depends on the availability of sunlight to operate. Considering the advantages and disadvantages, PV solar is the main focus of this project but is one of many options for renewable energy available in Costa Rica.

System Dynamics of Solar Power

The solar photovoltaic cell is the principal component of the system when collecting energy from the sun. The cells capture light and use it to produce an electrical current. Solar cells

can vary in size, starting at 120mm by 125mm (4.72in by 4.72in) to 156mm by 156mm (6.14in by 6.14in) and sometimes larger in specific instances. A collection of cells is called a module, which is what usually sits on the rooftops of houses. Many modules in a single area whose purpose is to collect mass amounts of PV energy is called an array, which is what can often be seen in open fields and solar farms. Mechanisms, such as inverters and transformers, convert PV energy into usable electricity while minimizing loss when the electricity must travel over long distances. This system has been in use for over a decade and has grown more efficient over the years. Alterations such as changing the angle at which the module is placed so it can collect the maximum amount of sunlight or changing the thickness of the layers of silicon within the cell have considerably increased the efficiency of this technology (Guney, 2016).

Tier 1 Solar Panels

Bloomberg has a list of what they call "tier 1" solar panel manufacturers. This is an exclusive list of the top 2 percent of manufacturers of solar panels. It exists to provide consumers of solar panels with a list of the best and most reliable solar panel providers. Tier 1 solar panels have a reputation of performance and long life. There is no tier 2 list, nor any other list of second-best manufacturers (Ladd, 2017). The criteria to be a tier 1 solar manufacturer are as follows: "At least 6 different projects of 1.5 MW's or more in the past 2 years, financed by 6 different non-recourse banks, ownership of production facilities and brand name, and having not filed for bankruptcy, insolvency, or defaulted on bond payments" (Ladd, 2017).

Greenwood Street Landfill Solar Array, Worcester, Massachusetts - A Case Study

In Worcester, Massachusetts, United States, the largest solar array in New England opened in August of 2017. This array covers about 26 acres of a plateau area that was once a

landfill, making it particularly sensitive because of the environmental consequences that can arise if the land is mistreated, such as pollution and leaching. The Greenwood Street Landfill was a plot of about 52 acres in area and was capped after it reached maximum capacity. After it was treated and capped, the city of Worcester proposed that it be turned into a solar farm. After reviewing rules and regulations, submitting documents, permits, and contracts, the solar farm was approved by the Environmental Protection Agency and the Massachusetts Department of Environmental Protection. This solar farm is significantly beneficial because it not only generates renewable energy, but also uses this otherwise underutilized reclaimed land. This practice takes many ramifications into consideration to ensure that the cap was protected by using new technology, such as implementing non-penetrating concrete ballast blocks to hold the solar panels above the cap without breaching its surface. This specific application maximizes the use of space and recognizes environmental consciousness. It demonstrates the versatile placement of solar panels, which will be a valuable feature for this project pertaining to Costa Rica.

Chapter 3: Methodology

The goal of this project was to create a solar energy guide for the CICR with the purpose of educating Costa Rican companies on the necessary considerations for implementing solar energy. Four objectives guided our project:

Obtain an Understanding of the Production and Distribution of Energy within Costa Rica

Through our background research, we discovered that much of Costa Rica's energy production and generation is controlled by the government company ICE. Since they are so influential, most of the country is forced to pay their energy prices and abide by their rules and regulations. There are a number of tariffs and regulations, enacted by ICE, that apply to the installation of solar panels and their connection to the distribution grid. In order to provide accurate information on our tool, it is necessary that we established a good understanding of what regulations are in place and how they affect a company looking to implement solar panels. Initial information was gathered in the literature review found in Chapter 2. We then acquired more information through interviews and meetings with our sponsor, solar panel providers, and ACESOLAR regarding the following topics:

- Specific tariffs and laws for installation of panels and connection to the grid
- Obstacles for solar panel installers and users
- ICE's energy market dominance

Tariffs and regulations for installation of panels and connection to the grid

To better understand the obstacles of solar energy implementation, we researched the tariffs and laws associated with solar panel installation and connection to the grid. We gathered information on the process of getting a solar panel system approved by the electricity distributor,

costs associated with putting excess energy into the grid, and restrictions on excess production. We obtained this information through meetings with our sponsor, an interview with Karen Tat of ACESOLAR, and several additional interviews with solar panel providers. The specific questions we asked her can be found in Appendix A: Interview Questions.

Information gathered from these interviews gave us a clear understanding of the costs and rules associated with purchasing and installing solar panels, which is located in the Findings section. The information regarding this process will also be included in our guide to inform companies considering solar energy about what they can expect in the process. This is important so companies know what to expect when implementing a system.

Obstacles for solar panel providers and users

To help tailor the information that goes into our guide, it is necessary that we understand the barriers that solar panel providers face in expanding their market. By addressing this topic, we began to understand some of the root causes of why solar panels are under-utilized and provide information in favor of their usage. The best way to determine these barriers was by asking solar panel providers directly what they consider the greatest obstacle for their businesses. When we conducted interviews with solar panel providers, we asked them about what they think is limiting solar panel usage in the industrial sector and any changes they would like to see going forward. A full list of the interview questions can be found in Appendix A. This information was valuable for our guide because some companies had their own unique obstacles while other common obstacles between companies became evident.

ICE's dominant role in the energy market

Our inquiry about the costs related to solar panel implementation brought up the topic of ICE and the influence they had on the energy distribution in Costa Rica. Their dominance in the energy market restricts the use and advancement of solar panels in Costa Rica. To learn about ICE's effect on the solar energy industry, we used the same methods as the previous goal in interviewing our sponsor, Karen Tat of ACESOLAR, and representatives from solar panel providers on their opinion of ICE and asking them what they think will change in the future regarding electricity laws and tariffs. Additionally, we interviewed Gaston Broutin, an ICE engineer who is conducting research on photovoltaic and thermal solar panels at an ICE laboratory. It was very important to get his point of view, being an employee of ICE, on the current situation of solar panel usage and the future for the technology. Questions directed at Gaston addressed the ICE solar panel pilot project and future projects, how the integration of solar panels will affect businesses in Costa Rica, and any predicted changes in ICE's relationship with the solar panel industry in the future.

Create a profile of solar panel providers in Costa Rica

We aimed to identify providers of photovoltaic energy systems that currently exist in Costa Rica as a foundation for developing our guide. This helped us determine what successful what technologies currently exist for industrial self-generation system and who can provide that technology. Our data collection focused entirely on photovoltaic systems.

To accomplish this objective, we first conducted online research to find credible information on solar panel providers that already existed in Costa Rica. We worked with the CICR to locate resources for this information as well as conducting searches on our own. The

companies that we chose to pursue were identified with the aid of the CICR, the ACESOLAR website, and other online literature reviews.

With the help of the CICR, we reached out to the solar panel providers via email to request an in-person interview to collect data about their company. These interviews addressed questions on types of projects they have done, general installation costs for different system sizing, the area that they generally distribute to, and any obstacles they have had in expanding their market. A full list of questions can be seen in Appendix A.

Create case studies of companies that have successfully implemented solar energy

Once the available solar energy providers were established, we developed case studies of companies that have used these solar providers to implement self-generation systems for their businesses. The CICR provided us with companies that they have worked with in the past, and we also learned about case study companies from the solar panel providers. This greatly enhanced our renewable energy guide because it provided evidence that solar energy systems have financially benefited businesses. It also gave us an in-depth evaluation on the installation process with all of the necessary steps taken to put these systems in place. Insight into the ease of this installation process was also useful information to teach companies considering solar energy about the installation process.

To obtain this information, we interviewed companies who had installed solar systems and asked questions pertaining to their specific system. We used these opportunities to gather quantitative data that were used to persuade other businesses to use renewable energy, since specific statistics show that self-generation has the potential to save companies money. Quantitative information included: when the panels were installed, how long the installation

process took, costs of the installation and any maintenance, sizing of the system, and expectations for return on investment. We also asked for their opinion on the installer they used, pros and cons of their switch to solar energy, anything they wish they did differently, and advice for companies thinking about switching. This information helped us create recommendations and tailor the content in our guide. A list of all the questions we asked can be found in Appendix A.

All of this information was then described in our renewable energy tool. The purpose of this objective was so that companies can see real examples of how other businesses in the same economic climate, or in the same industry, have used solar energy to better their business. It aimed to present renewable energy for self-generation as a feasible way to combat the high electricity prices.

Organize all the information into a solar energy guide

After we collected the information from the previous objectives, it needed to be made easily accessible to the public. The goal of this guide was to educate and inform the readers of the costs, benefits and process of creating a photovoltaic energy system. After talking with our sponsors, we decided that making an online website would be the most efficient way to create an easily accessible guide.

In order to create an effective guide, we first needed to understand what information should to be included. We asked our sponsors and the solar panel distributors we interviewed what they thought was the most important information .Once we determined what information would be included in the renewable energy guide, we needed to determine how to convey the information in a manner that was easily understandable. Lastly, we compiled it into a website that was submitted to our sponsor as our final deliverable.

Chapter 4: Findings

Through interviews and research, we investigated the current tariffs and regulations that affect solar implementation, the current available technology, information on companies that provide this technology, and information about companies have already taken advantage of this technology. In this chapter, we discuss how the regulations in place affect the ability of a business to implement solar energy, what solar panel providers are available and the prices they offer, and how solar panels have affected businesses that have already implemented them. The data we collected adequately demonstrate the current status of solar panel usage in industry and why more businesses should use them.

Production and distribution of energy in Costa Rica

There are a number of factors to consider when discussing electricity distribution in relation to solar panels for auto consumption. This section addresses the tariffs and regulations, electricity providers, and subsequent obstacles that affect the industrial usage of solar panels.

Several tariffs and regulations must be considered when installing solar panels and connecting them with the grid

For a company to implement solar energy, there are several regulations that apply to the installation process. Once solar panels are installed, there is another set of tariffs that apply to the interconnection with the grid. These regulations and tariffs are outlined below:

General Tariffs

In Costa Rica, there are three general tariffs relating to imported goods that might affect the feasibility of a renewable energy project. First, there is a 13% general sales tax that applies to everything sold in the country. Second, there is a 1.13% tax described by Law 6946. Third, there

is tax that applies to imports and the amount can vary based on the product. Lithium-Ion batteries, for example, carry a hefty 36% import tax. Although solar panels and inverters are exempt from all taxes, other parts of renewable energy systems, such as batteries, wires, or installation material can sometimes carry high tariffs (I. Salazar, personal communication, January 30, 2018).

Regulations for the installation process

Three to four permitting steps must be followed for solar panels to be installed by businesses, which take anywhere from three to six months. This process begins after a system size is proposed by the solar panel provider.

1. Every company that consumes or generates electricity is part of a grid. Every grid is sized differently depending on the demand of the buildings it encompasses. The electricity provider (ICE, CNFL, etc.) controls the energy that goes into that grid. No more than 15% of the total energy demand in a circuit can come from self-generated sources and this percentage can be reduced for any reason by the electricity provider. The electricity provider must be paid to check if the size of the proposed solar panel system will fit within the given percentage. Costs for this inspection can range from $50 to about $350, depending on the electricity provider.
2. The solar panel provider must submit all technical specifications, such as the equipment being used, to the electricity provider for approval.
3. The company receiving the solar panels must then commission the installation.
4. Some electricity distributors add a fourth step of inspecting the system as it is being built.

Tariffs after installation

Once the solar panels are installed, they must be connected to the distribution network or grid, except for extreme cases in which the solar installation is allowed to operate as an "island." All of the energy that is not consumed at the time of generation is injected into the grid if it is not stored. There are a number of tariffs and regulations that apply to the relationship between self-generated energy and the grid.

1. Of all the energy that is put back into the grid, only 49% can be returned back for consumption.
2. An access tariff, as described in Chapter 2, is applied to any of the energy consumed within that 49%. This tariff is about 25% of the regular energy cost and varies depending on the electricity provider. Energy consumed from the grid after the 49% mark is reached is priced regularly.

Another regulation we discovered through our interview with Ignacio Salazar is that if a company consumes more than 3,000 kilowatt-hours of energy in a month, they are charged for whatever their peak demand was during that month. An example of this is shown in the breakdown of CNFL industrial prices below in Table 3.

Energy Usage	Price in colones
Monthly energy consumption below or equal to 3000 kWh (per kWh)	121.53
Over 3000 kWh per month: Block price for first 3000 kWh	219,480.00
Over 3000 kWh per month: Price per kWh above 3000 kWh	73.16
Over 3000 kWh per month:Block price, 0-8 kW peak demand	91,618.72
Over 3000 kWh per month: Price per kW over 8 kW peak demand	11,452.34

Table 3: CNFL industrial tariff price breakdown (Salazar, 2018)

In this breakdown for industrial tariffs, when the business consumes under 3000 kWh they are charged 121.53 colones ($0.21) per kWh as seen on line one. When the business consumes more than 3000 kWh per month they are charged 219,480 colones ($386.28) total for the first 3000 kWh, and then 73.16 colones ($0.13) per kWh above 3000 kWh as seen on lines two and three. If the company uses more than 3000 kWh they will be charged the additional cost of peak energy demand. This is 91,618 colones ($161.25) for less that 8kW of peak usage and an additional 11,452.34 colones ($20.16) per additional kW of peak usage, as seen in lines four and five. It is very uncommon that companies peak less than 8kW so that demand charge is very brutal for industrial companies (I.Salazar, personal communication, January 30, 2018). These figures will change based on the electricity provider and the industry.

How these tariffs and regulations affect solar panel usage in industry

The regulations for solar panel installation and the tariffs after installation would deter a company from incorporating solar panels. There are many complicated rules that must be applied, and for a company that is new to this process, it may be overwhelming. This is why it is necessary that this information be conveyed in a simple and organized manner in our guide. Due to the nature of energy pricing, as shown in Table 3, if solar panels could be used to reduce a company's energy consumption from the grid to below the 3000 kWh threshold, or reduce the magnitude of their peaks, then that company could benefit greatly from solar panels.

There are several obstacles that solar panel providers face in expanding their market

Solar panel providers have different opinions on the limiting factors to the growth of their market. All the findings listed in this section were taken directly from interviews with representatives of solar panel providers.

The first and most obvious of these obstacles are the tariffs and regulations presented in the first findings section. Not only do the tariffs and regulations decrease the achievable energy savings and ease of installation of solar panels, but customers looking to install solar panels often don't understand these tariffs and regulations. Customers often learn about rules, such as the access tariff, and associate solar panels as costs rather than investments for their businesses (P. Lambot, personal communication, February 1, 2018). This is why it is important to provide businesses with accurate, easy to read information on all the tariffs and regulations. Furthermore, the exemption of solar panels from import taxes, as described in the first findings section, can be a lengthy process. While the paperwork is being completed, the solar panels sit in a storage facility which is rented out by the solar panel provider who is purchasing them. Depending on how long it takes for the paperwork to be approved and the tax exemption to be applied, it can be less expensive to skip the exoneration process and pay the taxes rather than pay for the storage of the panels (A. Garivia, personal communication, February 1, 2018).

Another aspect of the import taxes that hurts the solar industry is the variable tax as previously described in the first findings section. This tax is 36% for lithium-ion batteries, which are the most efficient and compact batteries. With the inclusion of the 13% and 1.13%, solar panel providers must pay over 50% of the cost in taxed for these batteries. Consequently, the providers must charge customers a large sum of money if they want to install the batteries in their system. Most customers don't have the money for this investment, ruling out energy storage as an option for most businesses (I. Salazar, personal communication, January 30, 2018).

The next obstacle has to do with the current underdeveloped status of the solar panel market in Costa Rica. There are two main problems that arise from the nature of this market. The first is that, since the solar panel market is so small, whenever a provider is contacted to do

business they must accept this proposal regardless of location. This causes solar panel providers to travel all over the county to do installations, which is costly for their business (P. Lambot, personal communication, February 1, 2018). Solar panel providers in countries such as the United States typically don't travel more than two to three hours to do an installation. The second problem that arises from the underdevelopment of the solar panel market is that many solar panel providers purchase low quality panels. Some providers will purchase uninspected panels from other Central American countries that resell them from the manufacturer for a low price (I. Salazar, personal communication, January 30, 2018). These providers can then sell and install the panels at lower cost than those who use a trusted manufacturer of tier 1 panels, making uneducated customers more likely to buy them. The widespread usage of cheap panels that have poor performance gives solar panels a bad name and propagates the idea that all solar panels perform poorly.

ICE's energy market dominance hinders the growth of solar panel usage

Costa Rica has the technology and environmental conditions for solar panels to be widely used. ICE's dominance in energy production and distribution has inhibited those trying to install solar. ICE was a significant influence on the creation and implementation of roadblocks in the form of tariffs and regulations that limit the widespread usage of solar panels (K.Tat, personal communication, January 29, 2018). Since ICE controls a majority of electricity distribution, if more people relied on auto-consumption of energy rather than purchasing from the grid, it damages ICE's business. ICE is also concerned with the possibility that if solar energy is advanced in the country, then residences and businesses could completely disconnect from the grid. Additionally, if industries started implementing self-generation systems, ICE would then need to raise the rates on the companies that cannot self-generate in order to pay off the major

projects in which ICE had already invested (K.Tat, personal communication, January 29, 2018). ICE has historically used hydroelectric plants as their main source of energy and has yet to change since they're able to set prices with only one main energy source that they control (K.Tat, personal communication, January 29, 2018).

Since ICE is so influential, their projects and the information they release to the public is widely accepted, which can be dangerous, because sometimes this information can be swayed by ICE's ambitions to sustain their dominance.

Our interview with Gaston Broutin gave us further insight into the intricate relationship of ICE and solar panel systems for self-generation. Gaston, and many other members of ICE, recognize that solar energy has a promising future in Costa Rican industry, and its integration is inevitable even though ICE's history is in big hydropower, including their massive 305.5 MW Reventazón Hydroelectric Plant mentioned in the Background chapter. Years prior, when many of these hydro plants were in the works, Costa Rica knew its energy demands were going to increase. At the time, hydropower was the most viable option for ICE to fill these energy needs. This was not the cheapest option, but it was the most environmentally friendly option that was capable of fulfilling Costa Rica's growing energy demand. Now that Costa Rica's energy demand has leveled out, it is believed that big hydropower usage will be reduced in time with a transition towards wind and solar power (G.Broutin, personal communication, February 22, 2018). This can already be seen in the difficulty approving the 631 MW El Diquís hydroelectric project. Not only has this facility faced lash back from the public, environmentalist, and government for its approval, but within ICE only about half of the administration is in its support (G.Broutin, personal communication, February 22, 2018). Some ICE members believe that more

investment must be made into smart grids, updating grid infrastructure, and incorporating more grid monitoring systems, ultimately making the grid more reliable for their customers.

ICE is currently looking into its own projects to incorporate solar energy, given all their concerns about external companies providing this technology, as described earlier. There is, however, the need for significant research into the quality of imported products, financial feasibility, and how the systems behave over time before any major steps can be taken (G.Broutin, personal communication, February 22, 2018). ICE is also considering becoming a provider of solar technology, though they need to fully evaluate the financial aspect of this decision and train their employees in the correct way to install and monitor the systems. Another option for ICE is partnering with an existing solar provider like Greenenrgy. This would be easier for ICE because an existing solar provider already has the installation knowledge, infrastructure, and installers equipped to install solar systems, eliminating the cost of ICE doing their own training and purchasing of installation equipment. A future pilot project in conjunction with a solar provider is potentially in the works to see if this partnership is a worthwhile endeavor. This gives the notion that there is a big future for solar, since the most influential, government owned, electricity distributor is putting in the thought and research for its eventual implementation.

Our interview also gave us insight into the different ICE imposed tariffs and regulations for solar panel usage. The rules, such as the 49%, 15%, and access tariff are a result of proposed legislation from ICE that is then discussed between ICE, the *Ministero de Ambiente y Energía* (Ministry of Environment and Energy, or MINAE), and the Costa Rican government. They are a result of the expensive maintenance of such a large energy grid so that their customers are assured that they have a stable energy source (G.Broutin, personal communication, February 22,

2018). However, Gaston strongly believes that the 49% and 15% rules will be expanded to a higher percentage or entirely different rules soon due to the current and projected growth of solar, especially in industry, and high pressure from many external sources to change them. A good balance must be found because the grid must still be protected from high energy fluctuations and requires thorough maintenance. ICE's goal is to not be looked at as a barrier to solar energy. This gives companies even more reason to invest in solar, since it is very likely that the laws around their usage will change, for the benefit of industry, in the near future.

Profiles of solar panel providers within Costa Rica

After conducting interviews, completing internet research, and meeting with our sponsor, we compiled a list of companies that make up a few of the main providers of solar technology in Costa Rica. From meetings with these companies, we learned about the types of technologies they provide, their distribution zones, the general sizes of the systems they provide, and their general cost per kWh that their systems provide. This section discusses these topics, as well as provides the list of providers of technology. We were not able to collect information on every solar panel provider, as it was not feasible in the time allotted for our project. However, we were able to identify the most influential solar panel providers through the aid of our sponsor to begin a basis for profiling every solar panel provider that can be expanded upon in the future. Tables 4 and 5 show the list of solar panel providers and case study companies that we collected information on.

Solar Providers	
Company Name	*Contact Name*
Greenenergy	Ignacio Salazar
Purasol	Pierre Lambot
CieloVivo	Arturo Gaviria
HiPower	Marco Varela

Table 4: Solar panel providers that we interviewed

Case Study Companies	
Company Name	*Contact Name*
Establishment Labs	Anthonie Latouche Soto
Purdy Motor Toyota	Jonathan Mata
Astek Costa Rica	Gladys Ponce
Antojitos San Pedro	Muni Figueres

Table 5: Case study companies we interviewed

In this section, we compiled the information gathered in the interviews to create a profile for each company. ACESOLAR constantly receives phone calls from companies inquiring about solar panels, but they don't know where to purchase them (K.Tat, personal communication, January 29, 2018). Therefore, there profiles are intended to be detailed, going beyond just cost information. Included in the profile is the company name and contact information, a brief background of the company, what the company have to offer, as well as any information that we have learned from them. These findings will ultimately help us create our final deliverable.

greenenergy©

greenenergy© is a solar provider that has been around in Costa Rica for 9 years. They focus mainly on commercial and industrial solar projects, but do residential solar projects as well. Thermal solar energy was their initial work, as with many solar providers in Costa Rica, but have now graduated to photovoltaic solar panels. Our interview was conducted with Ignacio Salazar who is an electro-mechanical engineer with an extensive background of working with renewable energy companies in the country.

As a company, greenenergy© prides itself on three categories: correct execution; identification with clients; and warranty. For proper execution, they follow the POASEN technical standard, which defines the Planning, Operation and Access to the National Electric System (AR-NT- POASEN) which was published on April 8, 2014. It ensures that the quality of the electric service throughout the country is maintained, establishes obligations to the electricity distribution companies, and deals with distributed generation of electricity (I. Salazar, personal communication, January 28, 2018). greenenergy© also aims to have a close relationship with their clients and to keep the client's best interests in mind. For warranty, greenenergy© offers a 5 year warranty on their inverters that can be expanded to 20 years and their solar panels come with a 10 year factory warranty and a 25 years of controlled generation performance.

Trina Solar, a Chinese based company, is the only manufacturer of solar panels from which greenenergy© purchases solar panels. Trina Solar is a Tier 1 solar panel manufacturer, which is the Bloomberg classification of the highest quality solar panels. For the past few years, Trina Solar has been battling back and forth in the top three spots of Tier 1 classification solar panels and is currently ranked first in this top quality classification. These panels have a controlled performance decay rate of 0.6–0.8% per year. greenenergy© uses inverters made by

Fronius, which is currently regarded as one of the top inverter companies in the market. Further information about greenenergy© can be found in Table 6 below.

Area of Distribution	Cost of Installation (without storage)		Typical ROI		Companies Who Have Been Customers
All of Costa Rica *outside GAM is more costly	0-100kW 100kW+	$1.20 - $1.50 per watt $1.10 - $1.25 per watt	w/ peak savings w/out peak savings	3-4 years (industrial) 4-6 years (residential) 7-8 years	Toyota Grupo Acón POPS Automercado De Monte

Table 6: Green energy pricing information

The largest project greenenergy© has completed is a 2.5 Megawatt solar installation for Grupo Acón in Limón, Costa Rica. This is the largest private industry solar energy project in Costa Rica so far (I.Salazar, personal communication, February 23, 2018). They have also completed an 860 kW solar installation for Toyota. Even though greenenergy© has been responsible for solar installations throughout Costa Rica, interacting with all the different energy distributors such as ICE, CNFL, etc., installation costs tend to be higher outside of the GAM (Greater Metropolitan Area of Costa Rica). This is due to additional meal and lodging costs for workers on projects outside the GAM. greenenergy© has a joint venture with Grupo Clima, a Costa Rican company with 45 years of experience, who does their panel installations. This is for financial reasons with the high cost of having employees in Costa Rica due to bosses having to pay high health insurance rates to their employees, but greenenergy© still does all of the engineering and design of their solar systems.

Even though energy storage is heavily limited by the 36% import tax on Lithium-Ion batteries, greenenergy© does offer energy storage options. For residential units, Blue Ion and LG batteries are used. For larger commercial and industrial applications, they offer battery storage

units from a company called NEC. Such an energy storage system can even monitor load profiles, training itself to know when to charge and discharge efficiently. Due to their high cost, however, the ROI of solar panel installations including these energy storage units is typically pushed back to 8 years and greenenergy© has only installed one of these systems due to this high initial investment for customers.

Purasol

Purasol is a solar energy provider that has been in business for 9 years and has completed close to 1000 solar projects. It focuses mainly on commercial systems, but also installs residential solar systems and plans to expand to more industrial applications. During ICE's solar pilot project, discussed in the second methodology objective, Purasol installed one-third of the solar installations that were part of this initiative. As a company, Purasol prides itself on providing turnkey systems to the customer, as they both provide and install their solar systems. Additionally, they provide both photovoltaic and thermal solar energy systems.

In the past they offered wind turbines, but found these did not make much sense in Costa Rica due to a lack of steady wind in residential areas. They completed a smaller-scale hydropower installation in the past as well, but found the permitting process to be very extensive and tedious. These systems are no longer installed because they damage the ecosystem at various levels, whereas solar energy systems do not damage the ecosystem through their installation.

For its installations, Purasol only offers high quality tier 1 solar panels manufactured by Canadian Solar. Enphase microinverters and single, centralized inverters by SolarEdge and Sunshine Inverters are offered as inverter options, but the enphase microinverters tend to be the most cost effective option. These inverters are also believed to be the best option because they are easily installed on the backside of the panels, are easy to replace, and have a good factory

warranty (25 years in the United States and 10 years in Costa Rica). In addition to inversion, these microinverters provide optimization, so if one solar panel in the array is damaged, the entire system does not stop producing energy. During installations, Purasol uses all emt piping instead of the less durable, cheaper pvc option that many other companies use. They also use all brass fittings even though they are up to 20 times more expensive than their pvc alternatives, once again because of their high level of durability. Table 7 below provides a cost breakdown for their grid-tie installations.

Project Size	**Cost per Watt Installed**	**Est. ROI**	**Permitting Costs**	**Financing**
< 3kW	$2.5 - $3.0	7 - 8 years	$1,200.00	10 years
3kW - 10kW	$2.0 - $2.5	7 - 8 years	$1,200.00	10 Years
20kW - 100kW	Single Phase $1.5 - $2.0 Three Phase $1.0 - $1.5	6 - 8 years	$2,000.00	10 Years
100kW - 200kW	$0.85 - $1.0	6 - 8 years	$2,000.00 + cost of meters	None

Table 7: Purasol pricing information

Purasol also offers off-grid solar installations. These systems typically cost $4.50-$5.00 per watt installed and have higher maintenance costs because the charge controllers for the batteries typically have a lifespan of three years, and the batteries themselves typically have a lifespan of about five years. This battery lifespan could be shortened if the batteries are not properly maintained, such as over discharging and recharging the batteries too quickly. There is no true return on investment for such systems because they serve customers who need them because they do not have access to the grid.

Quick start to finish time for their projects is another area of pride for Purasol. The time from which the customer hires Purasol for an installation to the end point where the solar system is completed is typically 2-3 months. The longest expected time is 6 months. This includes the permitting, design, and design approval steps as well. Location of installation plays an important role in this timeline because Purasol offers installation all throughout the country working with all of the various electricity distributors and does not charge more money for installations outside of the GAM. Most of their customers tend to be in the south of the country with about 10% of their customers located in the center of the country and roughly another 10% of their customers located elsewhere throughout the country. Purasol also has a company within Panama with 250 home solar systems installed and a 200 kW commercial solar system completed. In the future, Purasol aims to expand to Columbia as well.

Purasol works with Sunshine Costa Rica to provide financing solutions for people who cannot provide the upfront cost of solar panels. Sunshine offers a package called SunLease, which offers 10 years of financing for solar systems. The customer also does not have to provide any financial statements to use the financing.

CieloVivo

CieloVivo started as a roofing contractor and has been installing solar panels for a year and a half, completing about 20 projects in that time. CieloVivo focuses mainly on small commercial projects, generally between 250 and 300 kW, which are tailored to the business, although they do have a 1 MW project in the works. They offer only tier 1 solar panels however the company they use depends on the market and whichever is cheaper at that time. Additionally, they are an EPC (engineering, procurement, and construction) company, overseeing the entire process from design to installation of the system.

Their prices and ROI are typical of the other companies previously listed, anywhere from $1 - $2.50 per watt installed and an ROI between three to eight years depending on the size of the system: the larger the system, the less expensive it is per watt installed and the lower the ROI.

CieloVivo does projects everywhere in Costa Rica, although projects outside of the GAM are slightly more expensive. An important aspect for their projects is making sure the building on which panels are being installed has sturdy roofing. It is extremely difficult to maintain a roof that has panels on it, and the panels may have to be removed and reinstalled after roof maintenance.

HiPower

HiPower is a solar company that focuses on photovoltaic systems but also provides solutions for solar-thermal systems, a combination of PV and thermal, and energy storage. They are an EPC company that has been installing solar panels for 8 years and installs both residential and commercial projects, with a majority of their projects sized below 500 kW. They install on- and off-grid systems throughout the country, including islands off the coast. As with most solar panel providers, projects outside of the GAM are slightly more expensive. They use tier 1 Canadian Solar panels and a variety of high quality inverters including SMA, SolarEdge, Growatt, and Fronius, along with microinverters from ABB and Enphase. They also offer SolarEdge optimizers paired with a centralized SolarEdge inverters. Monitoring systems are installed in all of their projects so they can extract energy data to determine the success of their systems. Additionally, HiPower incorporates a maintenance plan into their installations where they conduct equipment check-ups twice a year.

HiPower offers energy storage systems that can be used in conjunction with or separate from a photovoltaic system. They use small, powerful Lithium-Ion batteries in their storage solutions, most often times LG battery banks with a 10 kWh energy storage capacity. These battery banks tend to be around $10,000. Off-grid applications require batteries for energy storage, but on-grid situations can use batteries as a backup energy source, or a way to shave peaks off of energy consumption for peak energy savings. Financing options are also available through Banco San José, Banco Nacional, Banco Popular, and other Costa Rican banks.

When asked for advice for companies interested installing solar power, they put an emphasis on knowing energy consumption, not just power. This is because specific energy usage is crucial information in order to properly design the solar system. The more detailed the energy consumption profile, the more optimized and properly sized the system can be to fit to the customer's specific needs. This information is easier to obtain through distributors for commercial needs, which is especially helpful when trying to reduce peak consumption throughout various points during the day. Specific residential load profiles are much harder to obtain, often requiring a monitoring device, which can be a waste of time and money for the installer if the customer does not follow through with the installation. For HiPower, the longest part of the installation process is the one month time frame for the distributor to conduct a study to determine if the grid can handle the added energy production under the 15% rule previously explained. The consultation and design of the system typically only take a week and the physical installation occurs within 3 months after the distributor's study is finished. Additional information on HiPower's solar photovoltaic grid-tied systems can be seen in Table 8 below.

Area of Distribution	Cost of Installation		Typical ROI	
All of Costa Rica	residential	$2.00 per watt	residential	6-8 years
*outside GAM is more costly	commercial	$1.00 - $1.50 per watt	commercial	3-4 years

Table 8: HiPower pricing information

Case study companies

In this section we have compiled profiles of companies that have already implemented solar panels and cost breakdowns for customers that are considering solar panel usage but haven't installed the system yet. This information will be included in our deliverables and will serve as examples of the benefits of solar panel implementation for businesses.

Establishment Labs

The facility we visited was only one year old, and was built with the renewable energy system in mind. The building's physical form and functionality fit the energy system very well as the result of careful planning. Establishment Labs has a 220kW solar array on the rooftop of their manufacturing facility courtesy of RioGrande Renewables and Demand Energy. This system is composed of 864 Canadian Solar photovoltaic solar panels and six Canadian Solar inverters. Unlike many solar systems within Costa Rica, Establishment Lab's system also has a Lithium-Ion battery bank. The two battery banks within their system combine to a total energy capacity of 1MWh and can provide a 500kW peak supply of electricity.

The entire solar system at Establishment Labs was designed to provide 60% of the facility's energy. This is because 60% of the facility's loads are critical loads, or equipment that has high priority of staying powered. The energy used during the day is directly consumed from the solar array and no energy is supplied back to the grid. The purpose of this is so Establishment

Labs does not lose 51% of the energy supplied back to the grid as they would due to the 49% consumption rule previously explained. The company also does not have to pay the access tariff for taking back any energy supplied to the grid since they do not supply their excess energy back to the grid. The battery banks are used to store this excess energy if it is not directly consumed throughout the facility. Electricity is still drawn from the grid at Establishment Labs, but it is only drawn during the night when energy is the least expensive. This energy is used to make ice, which is then stored in ice banks. These ice banks are used for air conditioning throughout the facility and can be seen in Figure 3 below. All of the energy consumption and energy production is monitored in real time throughout the facility and recorded using DEN.OS monitoring software.

Figure 3: Establishment Labs ice banks

In addition to proven performance benefits, from a financial standpoint the micro grid also delivers value beyond simple backup power. Because its normal operation generates

revenue and cost savings that help pay for itself, the system is not a stranded cost. Further, not only does it provide backup support during an outage, it also delivers essential load relief, lowers operational costs, and helps reduce greenhouse gas emissions (A.Latouche, personal communication, February 23, 2018).

Additional information obtained through interview was a problem with harmonic distortion during the installation process, but this was resolved. Advice for companies looking to install a solar system was to have detailed comprehension of their facility and energy usage. This will aid in understanding how to reduce peak consumption and which loads are critical loads that need to be covered to ensure optimization and power supply.

Purdy Motor Toyota

Purdy Motors, a Toyota dealership located near San José in Ciudad Toyota La Uruca, is currently in the process of finishing a 995kW photovoltaic solar array mounted on their roof. Purdy Motor started consulting with greenenergy© in December 2017, and the project is expected to be completed in March 2018. The details of the system can be seen in Figure 4 below.

Ciudad Toyota greenenergy

Parámetro	Descripción
Cantidad de Módulos FV	3 154
Cantidad Inversores	62
Potencia @STC (kWp)	995
Compensación de consumo promedio Anual (kWh)	1 444 034,80
Compensación de consumo energético promedio anual (%)	82%
Compensación del monto factura eléctrica anual (%)	47%
kWh/kWp estimado ($)	1.37
Retorno inversión años	5
Toneladas CO_2 evitadas por año	97
Equivalente número de hogares	529

Figure 4: Ciudad Toyota system information (Mata, 2018)

The system was strategically designed to produce 82% of their energy consumption because it is undesirable to supply excess energy back to the grid, due to both the 49% rule and the access tariff explained in the first Findings section. No battery storage was installed, so the goal of sizing the system in this way is that the facility will directly consume the energy produced by the solar panels and then only purchase energy from the grid to cover excess energy consumption. The return on investment of the system is expected to be five years as seen above, but this is regarded as a conservative estimate, given the estimated 47% annual energy savings.

During the installation, the main obstacle was the roof stability because it was not made to withstand people walking on it. Consequently, the roof was damaged in some areas, but greenenergy© is paying for the new roof because the installation process was the cause of the

damage. greenenergy© is also providing a 30 year warranty on the solar system, with the annual energy production expected to drop by only 5% at the end of the 30 year warranty.

A large motivator behind the installation of this system was a much smaller photovoltaic solar system installed by Sunshine at another Toyota dealership located in the city of Curridabat near San José. The details of this system can be seen Figure 5 below.

Curridabat	Sunshine
Parámetro	**Descripción**
Cantidad de Módulos FV	108
Cantidad Inversores	3
Potencia @STC (kWp)	34,56
Compensación de consumo promedio Anual (kWh)	49 380,00
Compensación de consumo energético promedio anual (%)	70%
Compensación del monto factura eléctrica anual (%)	45%
kWh/kWp estimado ($)	1.21
Retorno inversión años	5
Toneladas CO_2 evitadas por año	65
Equivalente número de hogares	16
m^2 techo	230

Figure 5: Purdy Motor Curridabat solar installation details

This 34.56kW system is much smaller than the 995kW system installed at the Purdy Motor in Ciudad Toyota, but still has brought great benefit to the Ciudad Curridabat dealership. The return on investment was estimated to be five years with this system as well, but the dealership has noticed a much quicker payback on the system. For the first year of installation shown in Figure 6 and Figure 7 below, the system installation was completed and turned on in

November. After the installation, there is a noticeable drop in both energy consumption from the grid, and therefore money spent on energy from the grid.

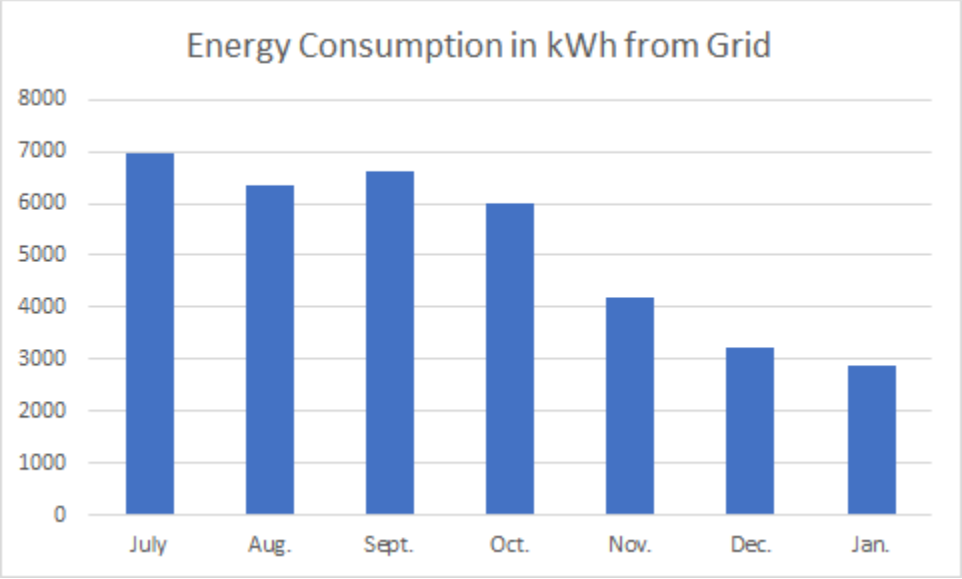


Figure 6: Purdy Motor Curridabat Energy Consumption

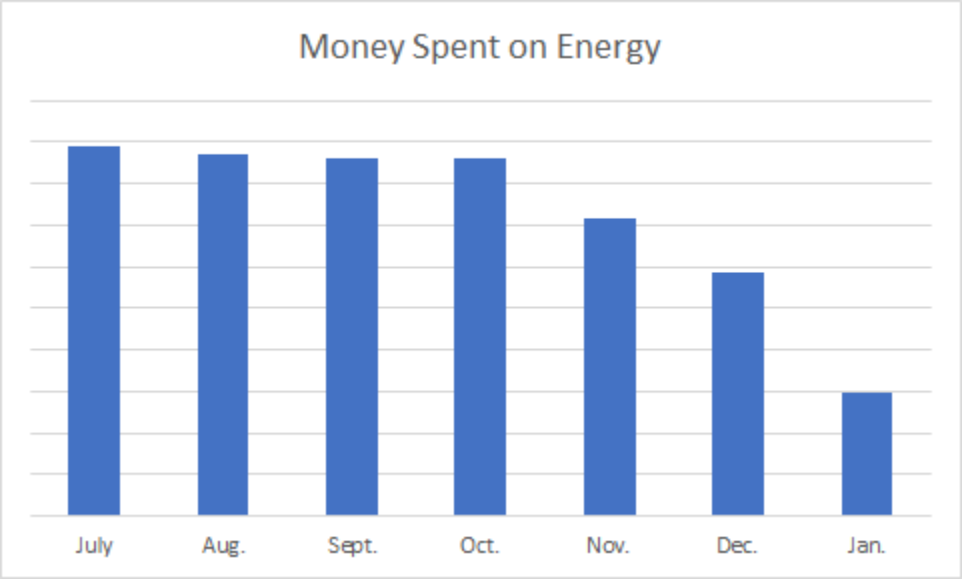


Figure 7: Purdy Motor Curridabat money spent on energy

During the installation process of this photovoltaic solar system, only two problems were encountered. In the beginning, a cheap inverter from China was tested after installation and blew up when turned on. They then switched to a higher end Fronius Inverter and have not faced a problem since. Besides this, a few cable issues occurred where green cables were used instead of

white, so they overheated, and other cables needed additional support so that they would not be in contact with the roof. For general advice, they highly recommended solar of any size, but noted that it is crucial to make the facility as efficient as possible first, know the updated energy consumption and load profiles for optimal system design, and pick a reputable company for a high quality installation as they had done.

Astek Costa Rica

Astek Costa Rica manufactures fragrances, food coloring, and various flavorings. They currently have a 51.2kW photovoltaic solar system constructed by Enertiva installed on their roof. After a $70,000 initial investment, the expected return on investment of the system was predicted to be 7 years, but with current implementation, the system is actually expected to have a return on investment of only 5 years. Further details of this system can be seen Figure 8 below.

Figure 8: Astek solar panel system details

The system installation was a 3 month process, with the physical installation of the panels, inverters, and other infrastructure only taking 3 weeks. The only obstacle faced during

the installation process was a 3 ½ week delay on the final inspection after the system installation was complete and before the system was turned on to start producing energy. A 15 year warranty was included with the system along with a maintenance plan where the panels are cleaned once every three months. There is also system inspection once a year.

After installation, the amount of electricity pulled from the grid was greatly reduced since it was consumed directly from the solar panels. Figures 9 and 10 below show the drop in energy consumed from the grid both numerically and visually.

Consumo real kw-h	generación solar kw-h	promd % gen solar	consumo de la red leído y facturado Kw-h
6081	0	0	6081
6860	0	0	6860
6170	0	0	6170
5454	7135	130,8	0
6728	5529	82,2	1199
7075	5639	79,7	1436
6322	5292	83,7	1030
6855	5977	87,2	878
6597	5732	86,9	865
6787	5476	80,7	1311
7450	5929	79.6	1521
5837	7083	121.3	0
Total 78216 Solar 59105	53792	92.46 %	Total 24424 Desde Ent Solar 5313

ASTEK
Creadores de aromas y sabores

Figure 9: Numerical breakdown of Astek energy consumption after solar installation

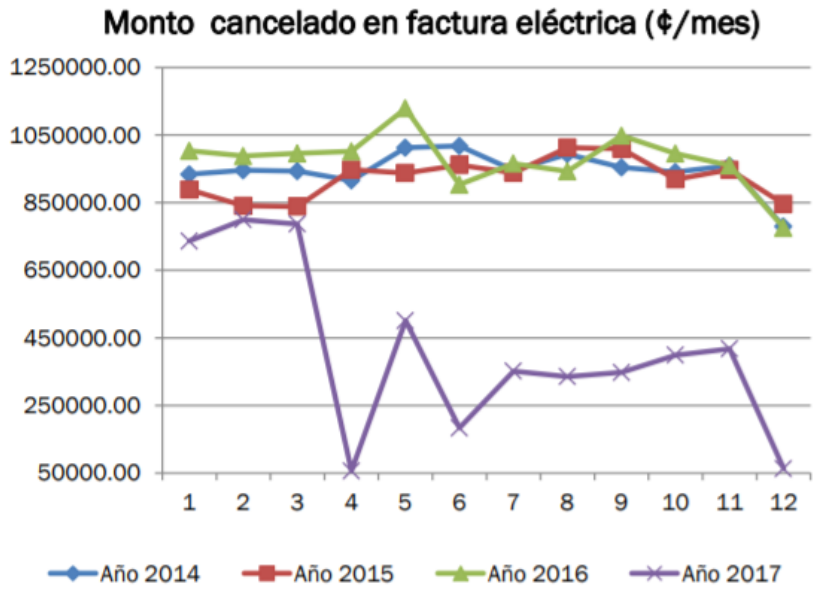


Figure 10: Visual breakdown of Astek energy consumption after solar installation

During the first month, the solar panel system alone provided all of the energy for the facility, with no energy taken from the grid. Since the system was first installed, Astek was also able to lower their load demand by 10%.

All of the system production is monitored, recorded, and accessible on multiple applications including smartphone devices. If something goes wrong within the system, an email notification is sent out to ensure the problem is dealt with as soon as possible. Astek's goal is to their panels and monitor their consumption to continue to lower their energy demand until no energy will be consumed from the grid during any month of the year.

Antojitos

Antojitos is a restaurant located in the San Pedro district of San José. In February of 2014, they had a set of photovoltaic solar panels installed on their roof. After a three-year period of satisfaction with this system, they installed more solar panels on their roof by the solar panel provider Sunshine, in May, 2017. They have a 10 year warranty on both the panels and inverters

along with an annual maintenance checkup. They wash the panels each month with water due to the ash in the air from nearby active volcanoes.

The first set of panels were financed for 6 years, but paid for themselves after only 3 years. The entire system combined is expected to have an 8 year return on investment. Before both of these solar panel installations, the monthly energy consumption was about 6800 kWh coming entirely from the grid. They reduced this monthly consumption by 2000 kWh per month from the total combined solar system. They also saved an additional 2000 kWh per month by making the restaurant more energy efficient. They did this by installing LED light bulbs throughout the entire restaurant, swapping out outdated wiring to new, more efficient wiring throughout the whole restaurant, changing the refrigerator condenser motor to a more efficient model, adding transparent roof tiles to increase natural lighting in the dining areas, purchasing a more energy efficient dishwasher, and installing a solar thermal hot water tank. At the time that all the lightbulbs were replaced with LEDs throughout the restaurant, this was a big investment for Antojitos because LEDs were around $15 per bulb. Now, LEDs can be purchased for as low as $3 a piece, making the potential even greater for facilities to become more energy efficient. After all of these improvements, they only consume 2700-2800 kWh of energy from the grid per month.

Taking their energy efficiency to the next level, Antojitos purchased an electric motorcycle for all of their food deliveries. The bike is charged during the day, so the solar panels directly provide the electricity for the motorcycle. Antojitos also produces practically no waste from their establishment. All of their organic food waste is taken to a facility that makes organic fertilizer, and all of their oil waste is taken to a facility that makes biodiesel. They purchase all their products from eco-friendly companies that are comprised of people who have faced

adversity in their lives. Antojitos was also the first restaurant in Costa Rica to ban straws in their restaurant and purchase fish from only sustainable seafood certified companies. Furthermore, Antojitos holds a dinner twice a year for 120 elderly people who do not have family members or have been abandoned by their family. They also hire 3 workers at a time working in conjunction with the nearby university helping to train mentally disabled individuals to perform a job.

The biggest obstacle they faced during the installation of their solar panels was waiting to be interconnected to the grid where they lost a couple months of energy production. Antojitos highly recommends solar to other companies, based not only on the financial savings, but the impact on the environment. They also suggest that caring for the environment is a mindset, and a solar energy system is only a small step towards an end goal of being efficient and taking care of the earth.

BAC San José

In 2011, BAC (Banco America Central) San José located in the San Pedro district of San José installed 160 photovoltaic solar panels on their roof, courtesy of Poderco Renewable Energy Systems. This system covers 95% of their roof that is suitable for solar panels, and typically produces 5520 kWh per month, which reduces their monthly energy demand purchased from the grid by 30-37%. The design of the building optimizes the use of natural light, so the main energy demand is not from artificial lights but computers, especially their supporting servers. The initial investment for the system was $180,000 and returned the investment after six years. Poderco Renewable Energy Systems also provided a 10 year warranty on this system.

All of BAC's branches are certified carbon neutral, and 25 branches are ISO 14001 certified, showing the company's commitment to Costa Rica's nationwide carbon neutrality goal. One branch located in the city of Curridabat in Costa Rica is currently trying to install a

photovoltaic solar system of their own, but are facing pushback from the CNFL, the energy distributor within that zone. The CNFL is not approving this project because it surpasses the 15% rule. When asked to give advice for other companies looking to install solar, solar energy was recommended if feasible. It is important to note, however, that there is more of a commitment than just installing the panels. Lowering energy consumption by making the facility as energy efficient as possible along with pushing towards carbon neutrality was highly stressed, as we have heard from our other case study companies.

The Renewable Energy Tool

After talking with our sponsor, conducting interviews with ACESOLAR and several solar panel providers, and evaluating the important information pertaining to our guide, we decided that the best way to portray the information we collected was through an easy-to-read, informative online webpage. An information-based guide filled with text and graphics is the easiest way to communicate the large amount of complicated information we have collected and was the most feasible within the span of our project. This webpage contains all of the information displayed in the previous findings section in a concise and easy-to-read manner.

The goal of the webpage was to provide a person with no prior knowledge of the solar panel industry in Costa Rica with a good understanding of all the tariffs and regulations, which companies offer solar panels, and how solar panels have already helped businesses economically and otherwise. We decided on using Squarespace, a website development application, to create our guide. Squarespace allowed our team to easily input all of our information and make it aesthetically appealing. It will also make it easy for out sponsor to update the website in the future.

Chapter 5: Deliverables

This is an outline of the information that appears on our webpage and how it is organized. Each topic (i.e. benefits of solar energy, understanding rules and regulations, etc.) has its own tab and within that tab, there is detailed information on the topic. Figure 11 below is a flow chart of the organization of the guide with the different sections and what the each section contains. Our webpage has an English and Spanish version, but for the purpose of this paper we will only show information from the English version. The guide can be viewed from the CICR website at: http://www.cicr.com.

Figure 11: Website flow and organization

A view of the homepage with the tab setup can be seen in Figure 12 below.

Figure 12: Screenshot of the website homepage

Benefits of Solar Energy

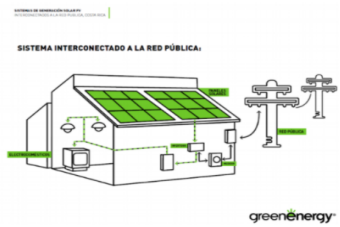
This first section gives a very brief overview of the benefits of using solar energy. This is meant to quickly inform the reader on why solar energy would be a good choice without overloading the reader with information and detracting from the rest of the guide. There is some broader information about solar panels that was necessary to add, but the information is meant to be tailored to Costa Rican businesses. This includes information regarding peak shavings and the 3000 kWh rule as previously described in the first Findings section. The main points are:

- Reduced energy costs from self-generating energy rather than always purchasing from the grid
- Peak shavings during instances of high demand
- Short return on investment due to high industrial energy prices in Costa Rica
- Easy maintenance
- Warranties on all equipment
- Short process from system design to final installation
- No harm to the environment

Below in Figure 13 is a screenshot of what this section looks like online.

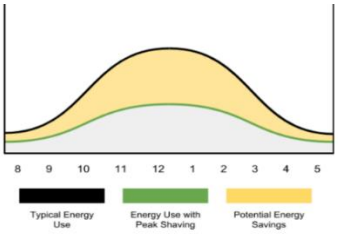
Benefits of Solar Energy

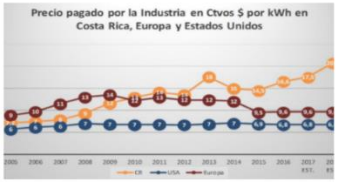
Solar energy harvesting is an advancing technology that have proven to be extremely beneficial to Costa Rican businesses. Once installed, they provide clean and free energy that result in long term savings while reducing a businesses' carbon footprint. They have a number of specific benefits, including:



Reduced energy costs from self-generating energy rather than always purchasing from the grid

Peak shavings during instances of high energy consumption to reduce peak demand charges





Short return on investment due to high industrial energy prices in Costa Rica

No harm to the environment

Easy maintenance and warranties on all equipment

Short process from system design to final installation

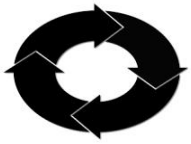


Figure 13: Benefits of solar energy section screenshot

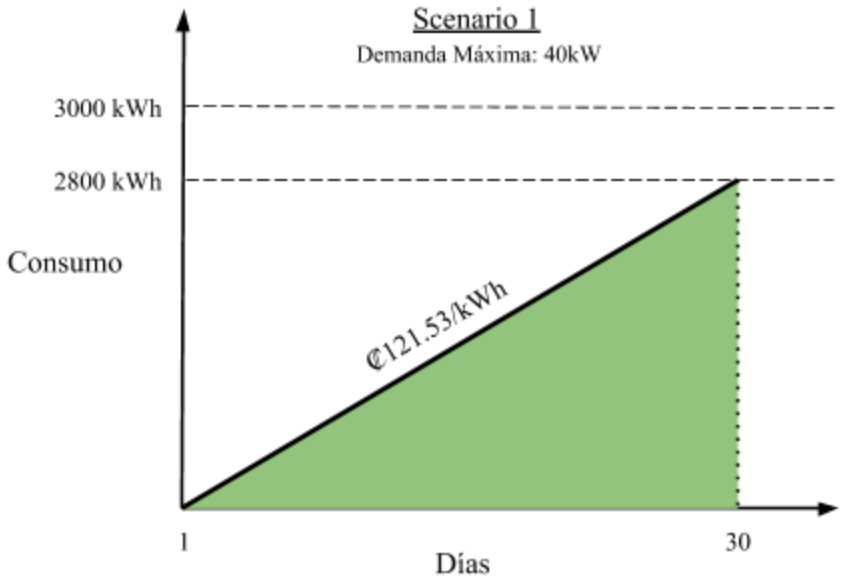
Understanding the Rules and Regulations

Before explaining the installation process, we explain all the important information regarding industrial energy usage and how it relates to a solar panel system with all the tariffs and regulations described in the first Findings section. It is important that the information is presented in this order because before a company can even start thinking about installing a system, they need to be educated on all the financial components that are involved. These components will be the biggest determinant as to whether a company considers installing a system.

Understand energy consumption information and load profile

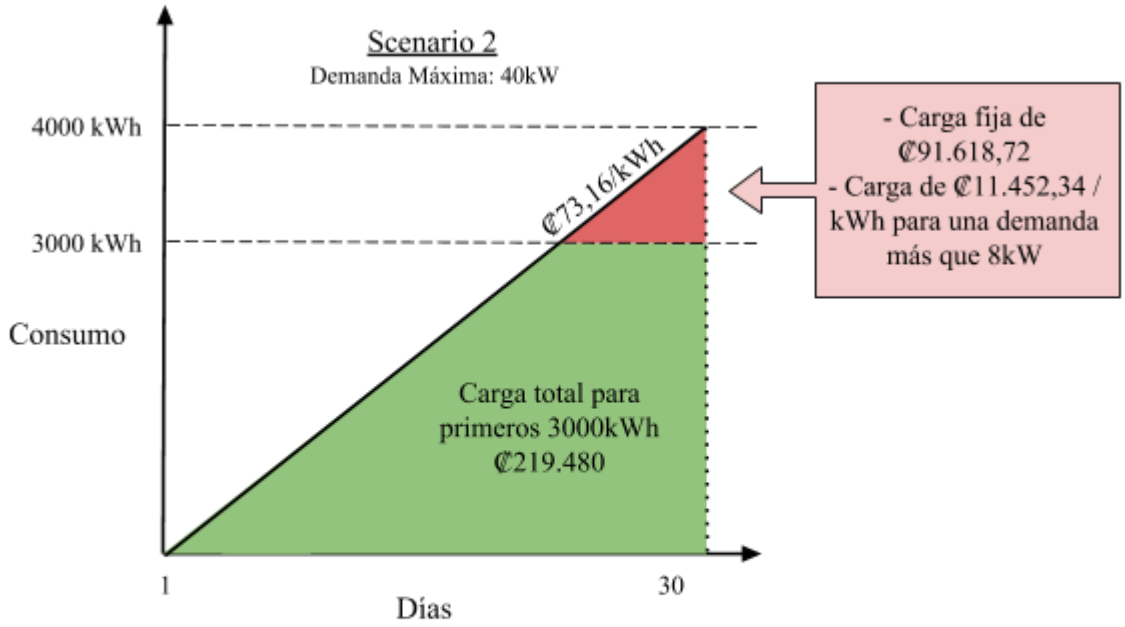
In order for an engineer to design the best solar system possible for your business, it is very important to obtain all the possible information about your energy consumption. Just providing your electricity bill for a few months is not enough, because it does not fully illustrate your energy needs. The best information to provide is the load profile and electricity bills for the past year. The load profile gives energy consumption information on an hourly basis. From this one can extract the time of day when they consume the most energy and when they experience peaks in demand. These are both essential for optimal system design.

The information regarding the 3,000 kWh rule is also presented in this section, after the discussion of the importance of knowing your energy consumption. To help in the explanation of this complicated rule, we added visuals to explain the scenario for the CNFL industrial tariff when a business consumes under or equal to 3,000 kWh, and when they consume over 3,000 kWh in a month. This can be seen in the Figures 14 and 15 below.



Costo:
₡121,53/kWh x # of kWh
₡121,53/kWh x 2800kWh = ₡340.284

Figure 14: Monthly Energy Consumption under 3000kWh



Costo:
₡219.480 (0kWh - 3000kWh) + ₡73,16/kWh x # kWh (>3000kWh) + ₡91.618,72 (0kW - 8kW) + ₡11.452,34/kW x # kW (>8kW)

₡219.480 + (₡73,16/kWh x 1000 kWh) + ₡91.618,72 + (₡11.452,34/kW x 32 kW) =₡750.722

Figure 15: Monthly Energy Consumption over 3000kWh

It is important to note that in both scenarios the peak demand of electricity is the same (40 kW), but the additional 1200kWh of energy consumption in the second figure results in an energy cost of more than double that in the first figure, due to the additional peak costs from monthly energy consumption exceeding the 3000kWh mark. This is why many companies aim to add enough solar panels to their facility to bring their monthly energy consumption from the grid below 3000kWh.

Your company and the grid

Every company that consumes or generates electricity is part of a grid. Every grid is sized differently depending on the demand of the buildings it encompasses. An example of buildings in a grid is shown below in Figure 16.

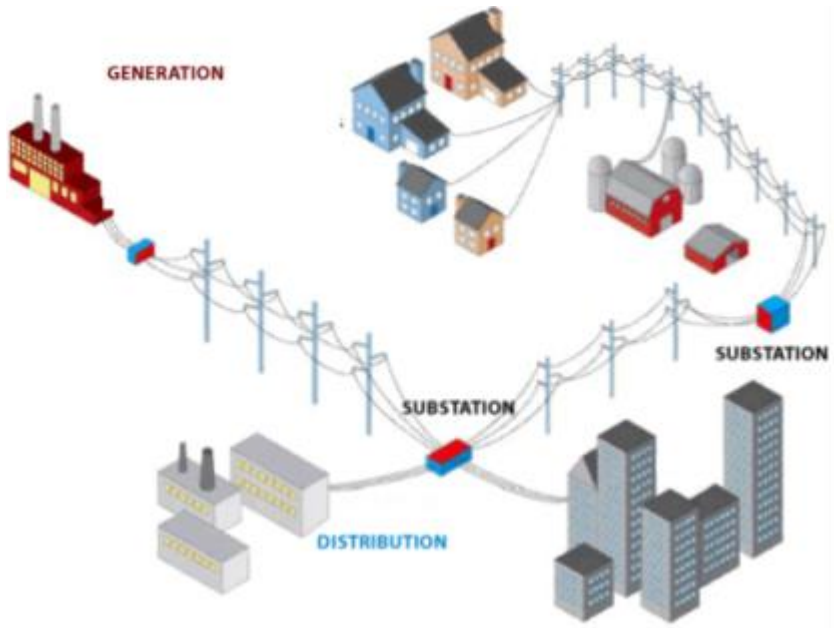


Figure 16: Representation of buildings in a grid (Guardian Stabiliser, 2017)

The electricity provider (ICE, CNFL, etc.) controls the electricity that goes into that grid. No more than 15% of the total energy demand from the consumers in a circuit can come from self-generated sources. This percentage can be reduced by the electricity provider if they need to

reserve capacity for future projects. The electricity provider must be paid to check if the size of the proposed solar panel system will fit within the given percentage. Costs for this inspection can range from $50 to about $350, depending on the electricity provider.

Import taxes for solar system equipment

There are import taxes on everything imported to Costa Rica. A general 13% import tax, a 1.13% tax as of Law 6946, and a variable tax depending on the product applies to all imports. The variable tax is 36% tax for Lithium-Ion batteries. Solar panels, inverters, and Lead-acid batteries are exempt from all taxes courtesy of Law 8829. Since solar panels and inverters are not manufactured in Costa Rica, they are imported and paperwork must be filed by the solar panel provider for the tax exemption. Shipping and processing of the paperwork is often the lengthiest part of the installation process.

Connection with the grid

This section of the guide contains the information presented in "tariffs after installation" in the first Findings section.

Once the solar panels are installed, they must be connected to the distribution network/grid, unless the business is running completely on self-generated energy. All the energy that is not consumed at the time of generation is injected into the grid, unless the facility has storage options. This relationship is represented by Figure 17 below.

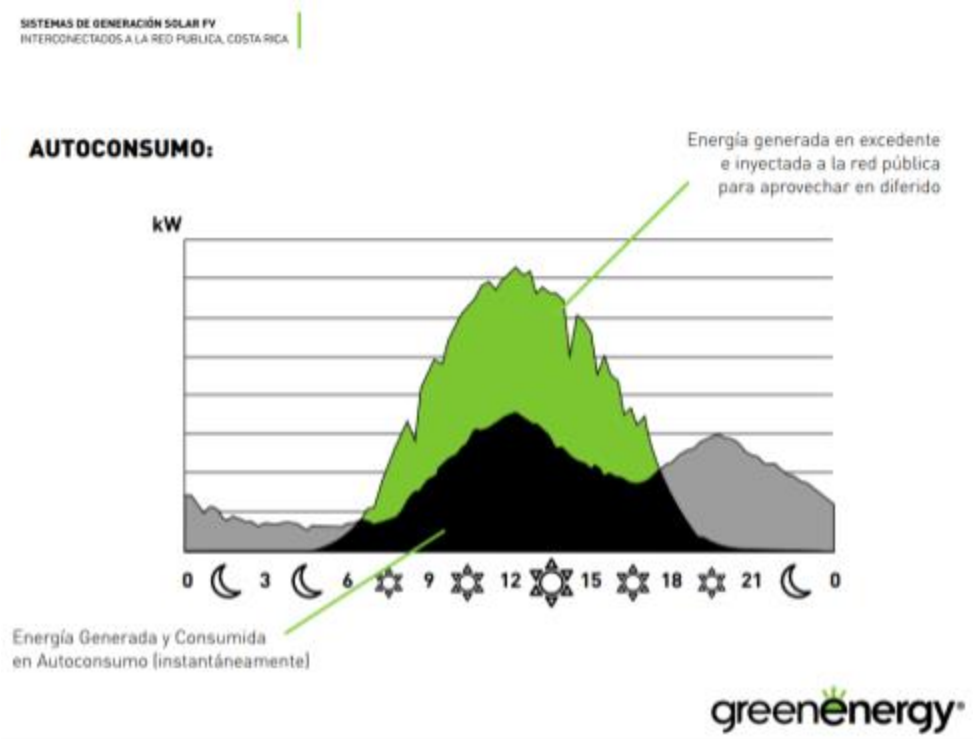


Figure 17: Representation of excess energy produced (Salazar, 2018)

There are a couple of tariffs and regulations that apply to the relationship between self-generated energy and the grid.

1. Of all the excess energy that is put back into the grid, only 49% can be returned back for consumption. Visually, this means you get back 49% of the green portion in Figure 17, the rest is used by the electricity provider. Therefore, the solar panel system should be sized so that the energy received back from the 49% can account for the energy consumed when the solar panels aren't producing anything at night or early in the morning.

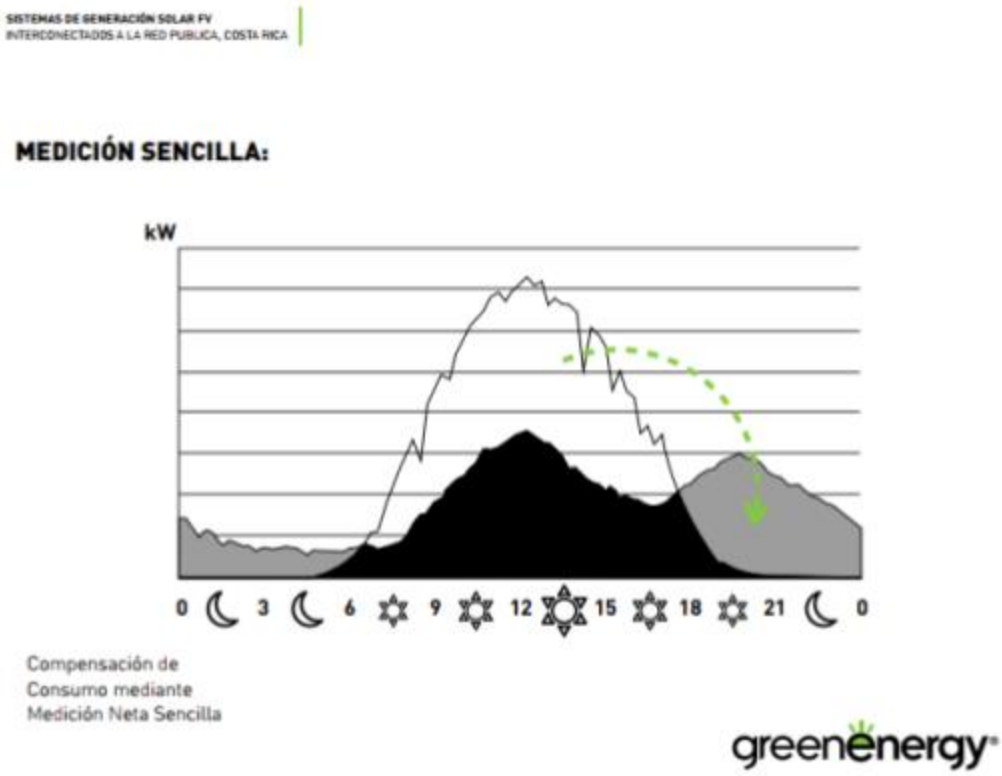


Figure 18: Representation of consuming excess energy that was injected into the grid (Salazar, 2018)

2. An access tariff is applied to all of the energy consumed within that 49%. The access tariff accounts for the maintenance and upkeep of the grid that you are using to store your excess energy to be consumed later. Energy taken back for consumption within the 49% is bought at a discounted price, about 20% of the regular energy cost. This percentage varies slightly between electricity distributors. In summary, 49% of the energy that is not consumed immediately can be bought back at about 20% of the normal cost. Energy consumed from the grid after the 49% mark is reached is priced regularly.

The Installation Process

This section of the guide serves as educational content to inform companies thinking about using solar panels on what to do before they contact a solar provider, and what to expect

during the installation process. The information provided in this section consists of suggestions collected from solar panel providers during our interviews. All of these steps are strongly advised to ensure proper system design and minimize future maintenance. Below in Figure 19 is a screenshot of what this section looks like in the guide.

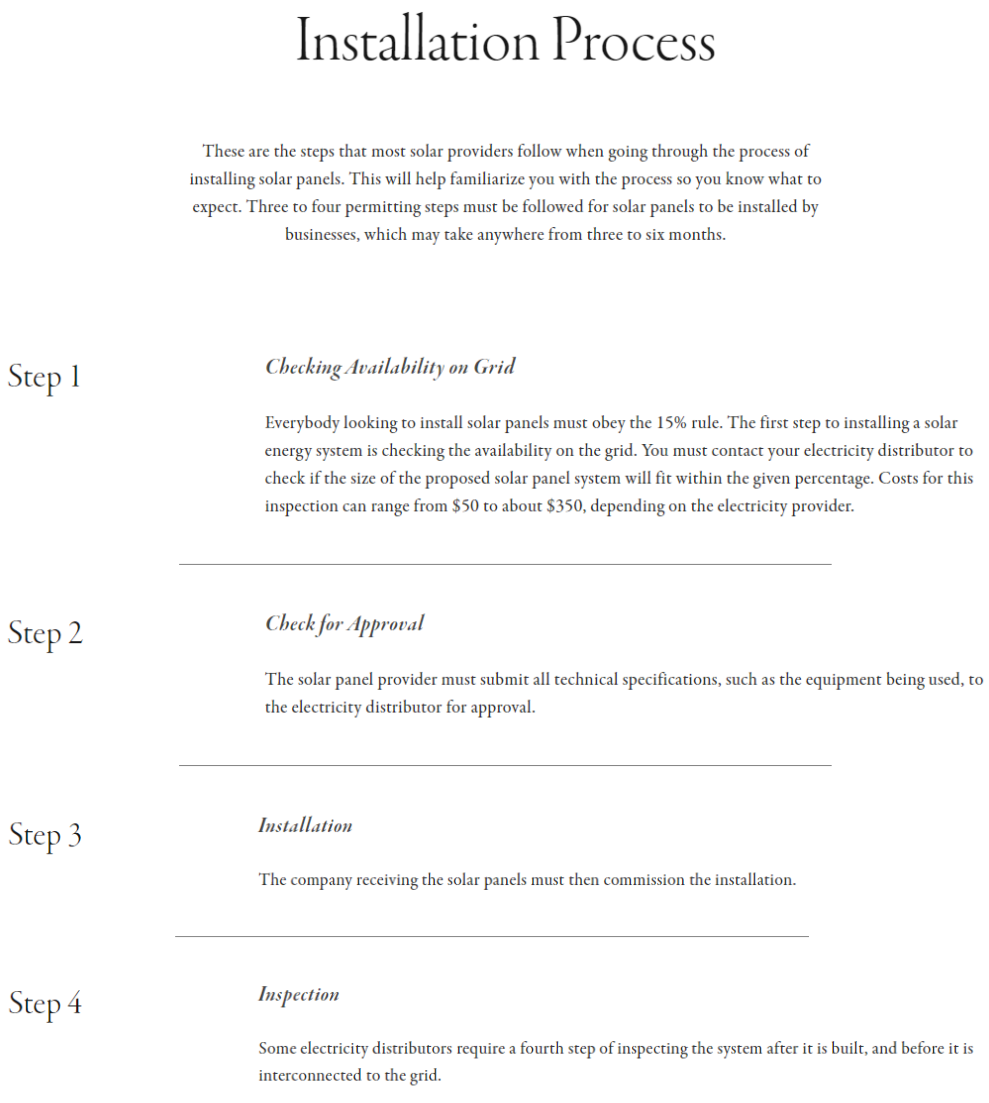


Figure 19: Installation Process screenshot

Before Installation

Step 1: Understand the rules and regulations

The first step is to understand all the information in the previous page. This well help in understanding how solar panel systems are designed and the associated costs.

Step 2: Become energy efficient

Take all possible measures to improve your energy efficiency. This includes using energy efficient appliances, LED light bulbs, ensuring all roofs, windows, and pipes are properly insulated; and employing good energy usage practices. These measures are not necessary but they will reduce energy consumption, leading to smaller system design and a smaller initial investment. If a company implements these measures their energy consumption will decrease, which will change their consumption data and load profile. Listed below are some of the measures a business can take to become more energy efficient. This information is from an article on business energy efficiency by Rinkesh Kukreja of the website Conserve-Energy-Future.

LED lights

LED lights use less energy and last longer than incandescent bulbs. They are one of the cheapest and easiest energy improvements, which is why many companies first turn to changing all of their light bulbs to LED light bulbs to make their facility more energy efficient.

Insulation

By using insulation on roofs, windows, and pipes, you can prevent warm or cold air from getting out or in. Insulation allows for the energy being used on heating or cooling to be more

efficiently used, allowing it to stay warm or cool for longer. Small drafts can result in a large loss on heating and cooling costs.

Shut off computers, turn of lights, and unplug appliances

A large portion of energy costs come from electronics that are not being used. Even if they are off or sleeping, many electronics still consume a fair amount of power. By using hibernation mode on computers or shutting them off at the end of the day, you can save on energy. Same goes for lights in rooms that are not being used or if no one is around. Unplugging appliances that are not in use can assure they are not using energy.

Purchase energy efficient equipment and appliances

Older appliances are not as efficient and use a lot of energy. By investing in newer more energy efficient appliances, you can save on the energy bill. Washers, dryers, refrigerator compressors, dishwashers, and ovens can often be upgraded accordingly.

Carefully schedule machine startups and ramp up motors at times of peak demand

In industry, starting a lot of large machines at once can result in large energy demand charges. If your business consumes over 3000 kWh of energy in a month, then you will be charged based on the peak demand, greatly increasing the energy bill. By carefully scheduling machine startups, you can avoid large peak demand. Additionally, ramping up motors instead of turning them on to max can help reduce the current draw.

Reduce paper waste

Reducing paper waste is not only a good energy practice, but it also saves energy on printing.

Buy a programmable thermostat

Having a programmable thermostat can allow you to adjust the temperatures when nobody is around.

Step 3: Ensure that the roofing can handle solar panels

Roofing is the base on which the solar panels are placed, so it is crucial that the roof of the facility is able to handle the weight of the system and for the length time that the solar panels will be there. Examining the roof before installation identifies how much space can be used for panels, which is important when calculating how much of the energy will come from the system. Also, checking the condition of the roof determines if maintenance is or will be necessary down the road. This is so that after the panels are installed, they do not have to be removed to perform roof maintenance.

Step 4: Contact solar provider

Reach out to a provider of technology to get a quote and possible system design. When getting a quote, it is important to understand that solar energy systems are an investment. There are upfront installation costs, however the system will return the investment and save money. A screenshot of this portion of the guide can be seen below in Figure 20.

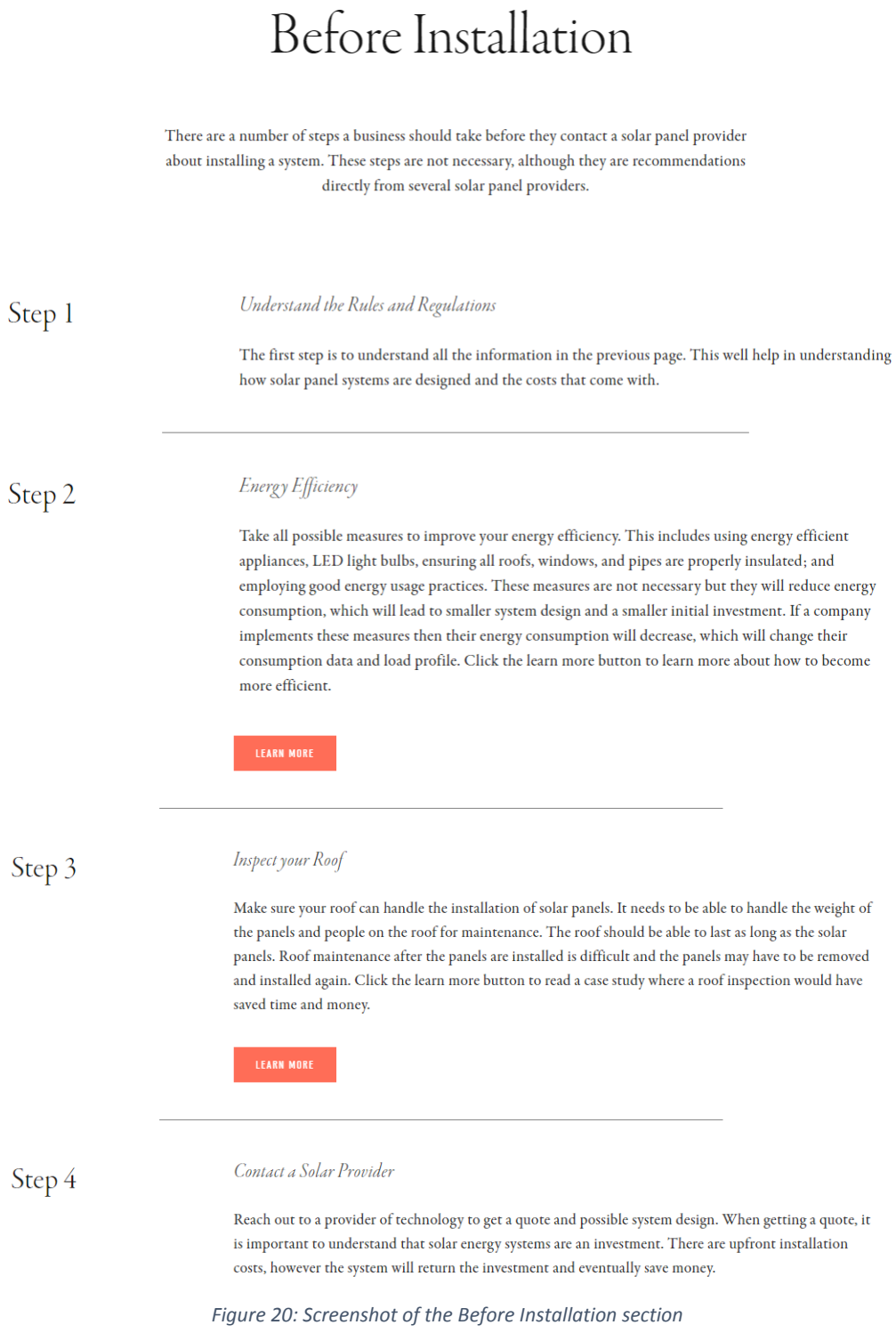


Figure 20: Screenshot of the Before Installation section

The Installation Process

This part of the guide contains all the information listed in our first finding under "regulations for the installation process". It is essential that companies understand the tariffs and

regulations and that the information is in one convenient place. We utilize as many graphics as possible to easily convey this information.

Three to four permitting steps must be followed for solar panels to be installed by businesses, which take anywhere from 3–6 months.

1. Everybody looking to install solar panels must obey the 15% rule as described in the previous section. The first step to installing a solar energy system is checking the availability on the grid. The electricity provider must be paid to check if the size of the proposed solar panel system will fit within the given percentage. Costs for this inspection can range from $50 to about $350, depending on the electricity provider.
2. The solar panel provider must submit all technical specifications, such as the design and equipment being used, to the electricity provider for approval.
3. The company receiving the solar panels must then commission the installation.
4. Some electricity distributors add a fourth step of inspecting the system once it is built and before connecting it to the grid.

A screen shot of this section is shown below in Figures 21 and 22.

Installation Process

These are the steps that most solar providers follow when going through the process of installing solar panels. This will help familiarize you with the process so you know what to expect. Three to four permitting steps must be followed for solar panels to be installed by businesses, which may take anywhere from three to six months.

Step 1

Checking Availability on Grid

Everybody looking to install solar panels must obey the 15% rule. The first step to installing a solar energy system is checking the availability on the grid. The electricity provider must be paid to check if the size of the proposed solar panel system will fit within the given percentage. Costs for this inspection can range from $50 to about $350, depending on the electricity provider.

Step 2

Check for Approval

The solar panel provider must submit all technical specifications, such as the equipment being used, to the electricity provider for approva

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Step 3

Installation

The company receiving the solar panels must then commission the installation.

Step 4

Inspection

Some electricity distributors add a fourth step of inspecting the system as its being built.

Figure 21: Installation process section screenshot 1

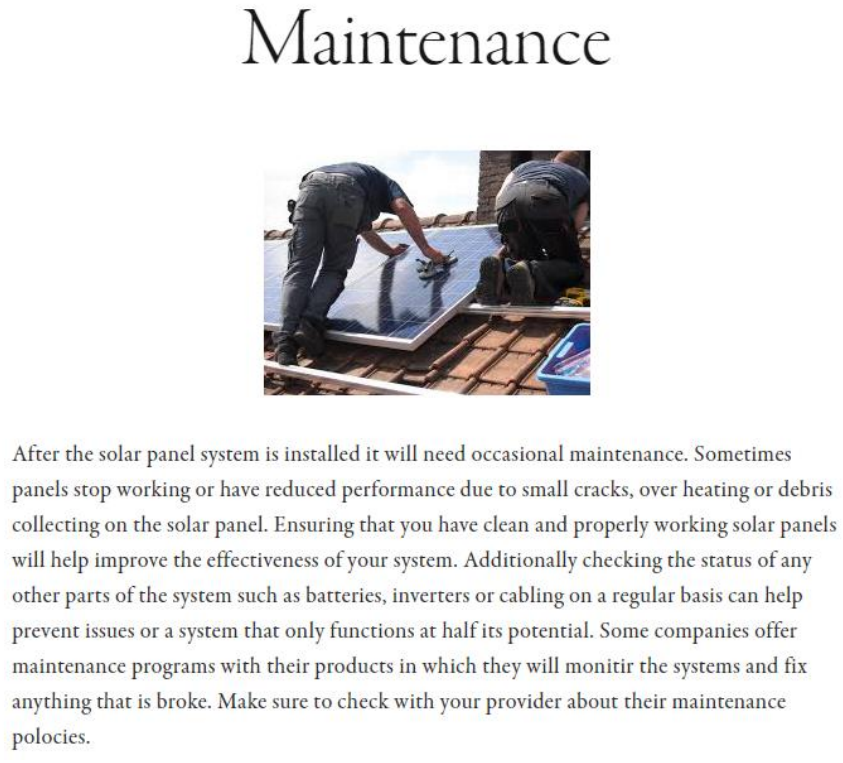

Figure 22: Installation process section screenshot 2

Solar Panel Provider Profiles

This section displays the information about the solar providers. It informs users about general costs, ROIs, areas of distribution, and contact information. Some of this information is displayed in tables and infographics, while other information is written in paragraph form.

As we conducted our interviews with the solar panel providers, we noticed that the information regarding system costs and ROI was very similar, with only some slight discrepancies. Therefore, rather than stating the prices for each solar panel provider we averaged them into one chart as seen below in Table 9.

System size	Price per peak watt installed	Estimated ROI
< 10 kW	around $2.00	7 - 8 years
10 - 100 kW	$1.20 - $1.50	6 - 8 years
100 - 200 kW	$1.00 - $1.20	5 - 7 years
200 kW +	$1.00 or less	3 - 5 years

Table 9: General system cost information

System design, and thus pricing, will be different for every company because every company has different needs, so it is important to note that these are just general price trends seen in Costa Rica. We decided this was better than listing the individual costs for each provider because it eliminates repetition and does not put a price tag on the providers. After general cost information is presented, our guide transitions to quick summaries of key information presented in the Findings section about each provider. The information listed below is exactly how it appears on the online guide, except that it is translated to Spanish in the guide. At the end of each summary we provide a link to the company website if the user wants to learn more about that specific provider.

greenenergy©

greenenergy© is a solar provider that has been around in Costa Rica for 9 years. They focus mainly on commercial and industrial solar projects, but they have also done a few residential solar projects as well. greenenergy© offers both thermal and photovoltaic systems and solutions. They strive to have a close connection with their clients and aim to keep their best interests in mind while ensuring that their work follows specific codes such as the POASEN technical standard. They have recently completed several large projects including a 2.5 megawatt system, the largest industrial solar panel installation in Costa Rica, and a 1 megawatt system for

several large companies within Costa Rica. greenenergy© does all of the engineering and design of their solar systems and has a joint venture with Grupo Clima, a Costa Rican company with 45 years of experience, who does their panel installations.

- Offers Trina Solar, solar panels, a Tier 1 solar panel manufacturer
- Uses inverters made by Fronius
- Offers a 5 year warranty on their inverters that can be expanded to 20 years and their solar panels come with a 10 year factory warranty, with 25 years of controlled generation performance.
- greenenergy© offers residential and industrial energy storage solutions.
- Offers their services to all of Costa Rica, cost are more expensive outside GAM

Purasol

Purasol is a solar energy provider that has been in business for 9 years and has completed close to 1000 solar projects. They focus mainly on commercial systems, but also install residential solar systems and plan to expand to more industrial applications. Purasol offers turnkey solutions for both thermal and photovoltaic systems. As an EPC (engineering, procurement, and construction) company, they oversee the entire process from design to installation of the system. Purasol focuses on the use of micro inverters for most of their solar installation. These micro inverters provide optimization, so if one solar panel in the array is damaged, the entire system does not stop producing energy.

- Offers high quality tier 1 solar panels manufactured by Canadian Solar
- Enphase microinverters and single, centralized inverters by SolarEdge and Sunshine Inverters are also offered as inverter options
- The inverters they normally use offer a 10 year factory warranty

- Offers battery storage solutions and off-grid solar installations mainly for small residential homes in areas not connected to the grid. Use mostly lead-acid batteries.
- Distributes to all of Costa Rica, prices are same inside and outside GAM
- Purasol works with Sunshine Costa Rica to provide financing solutions for people who cannot provide the upfront cost of solar panels. Sunshine offers a package called SunLease, which offers 10 years of financing for solar systems. The customer also does not have to provide any financial statements to use the financing.

CieloVivo

CieloVivo started as a roofing contractor and has been installing solar panels for a year and a half, completing about 20 projects in that time. CieloVivo focuses mainly on small commercial projects, generally between 250W and 300kW, which are tailored to the business, although they do have a 1 MW project in the works. Additionally, they are an EPC (engineering, procurement, and construction) company, overseeing the entire process from design to installation of the system. An important aspect for their projects is making sure the building on which panels are being installed has sturdy roofing. It is extremely difficult to maintain a roof that has panels on it and the panels may have to be removed and reinstalled after roof maintenance.

- Offer tier 1 panels, the brand of company depends on the market at the time
- Offers energy storage solutions
- Offers their services to all of Costa Rica, more expensive outside GAM

HiPower

HiPower is a solar company that has been installing systems for 8 years. They focus on photovoltaic systems but also provides solutions for solar-thermal systems, a combination of PV and thermal, and energy storage. They are an EPC company that installs both residential and commercial projects, with a majority of their projects sized below 500kW. On- and off-grid systems throughout the country are also offered, including islands off the coast.

- Use tier 1 Canadian Solar panels
- Offer a variety of high quality inverters including SMA, SolarEdge, Growatt, and Fronius, along with microinverters from ABB and Enphase. SolarEdge optimizers paired with a centralized SolarEdge inverters are also offered.
- HiPower incorporates a maintenance plan into their installations where they conduct equipment check-ups twice a year.
- HiPower offers energy storage systems that can be used in conjunction with or separate from a photovoltaic system. They use small, powerful Lithium-Ion batteries in their storage solutions, most often times LG battery banks with a 10kWh energy storage capacity.
- Offers their services to all of Costa Rica, more expensive outside GAM
- Financing options are also available through Banco San Jose, Banco Nacional, Banco Popular, and other Costa Rican banks.

Case Study Companies

Since the amount of information in the case study section is much denser than the solar panel provider section, we decided not to show it all at once. Instead, we provide a very brief summary about what we learned about the company followed by a "learn more" button which will take the reader to another page with more in depth information. The first page can be seen in Figures 23 and 24 below.

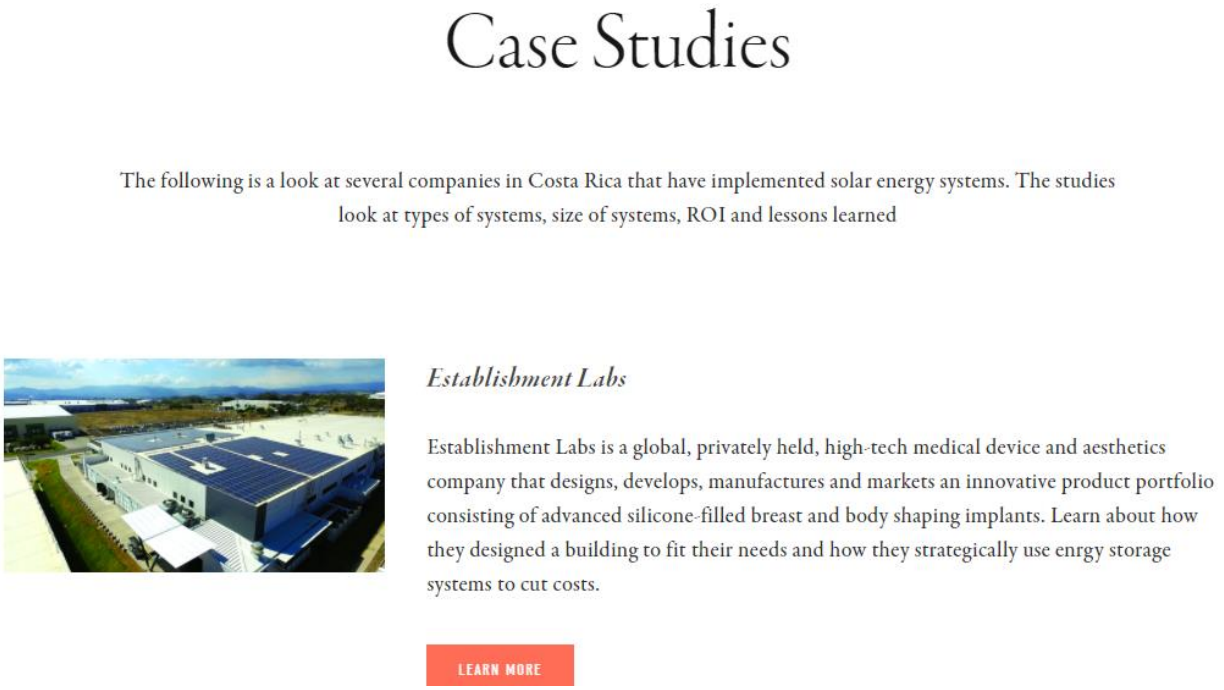

Figure 23: Case studies section screenshot 1

Antojitos

Antojitos is a restaurant located in the San Pedro district of San José. Its employees are dedicated to improving the business's impact on the community and the environment. They have persevered to create an extremely efficient and effective business model of helping out and conserving resources. Learn about more about of they improved efficiency in their restaurant to reduce energy usage and costs to better utilize their solar system.

LEARN MORE

BAC San José

BAC (Banco America Central) is located in the San Pedro district of San José. In 2011, BAC (Banco America Central) San José located in the San Pedro district of San José installed 160 photovoltaic solar panels on their roof, courtesy of Poderco Renewable Energy Systems. Learn more about their system, and how they use it to save money.

LEARN MORE

Purdy Motors Toyota

Purdy Motors is a Toyota dealership located near San Jose in Ciudad Toyota La Uruca. They are currently in the process of finishing a 995kW photovoltaic solar array mounted on their roof. They also have another location in Ciudad Curridabat that just finished installing a smaller 34.56kW. Learn more about these two cases studies and some of the problems they had to overcome regarding the installation process, roofs and cables.

LEARN MORE

Astek

Astek is a manufacturer of flavorings and natural and artificial colorings. They have a 51.2kW solar system which generates almost all of their electricity every day. Learn more about how they manage to generate all their electricity from solar.

LEARN MORE

Figure 24: Case studies section screenshot 2

We picked out the most important points from each interview on what made that specific business unique and portrayed that information in our deliverable. The exact information in the guide for each individual case study company can be seen in the sections below.

Establishment Labs

About Establishment Labs and their Solar System

Establishment Labs is a global, privately held, high-tech medical device and aesthetics company that designs, develops, manufactures and markets an innovative product portfolio consisting of advanced silicone-filled breast and body shaping implants. In 2016, they built a new building in Costa Rica with a renewable energy in mind. It was strategically placed in a tax free zone of Costa Rica meant specifically for industries in order to reduce some of the costs of installing a solar panel system. Establishment Labs has a 220kW solar array on the rooftop of their manufacturing facility courtesy of RioGrande Renewables and Demand Energy. This system is composed of 864 Canadian Solar photovoltaic solar panels and six Canadian Solar inverters. Unlike many solar systems within Costa Rica, Establishment Lab's system also has two Lithium-Ion battery bank. The two battery banks within their system combine to a total energy capacity of 1MWh and can provide a 500kW peak supply of electricity.

Ice Banks

Even though Establishment Labs has solar panels and batteries, they still use energy from the grid. During the night when energy is cheapest, Establishment Labs uses the energy to create ice in their ice banks. This is a way of storing the energy for later use. In their case, they use it for air conditioning throughout the facility. This allows them to save significantly on air

conditioning costs and direct the energy that would have otherwise been used to cool the air during the day to other parts of the facility. *We show Figure 3 here.*

Results

The energy used during the day is directly consumed from the solar array and no energy is supplied back to the grid. As a result, Establishment Labs keeps all of the energy they produce. They do not lose 51% of the energy supplied back to the grid as they would due to the 49% consumption rule previously explained and the company does not have to pay the access tariff for taking back any energy supplied to the grid since they do not supply their excess energy back to the grid. If any excess energy is created, the battery banks are used to store this excess energy. Additionally the battery banks are also tied into the grid, so that they can be charged by the grid if no energy is available to charge them.

In addition to proven performance benefits, from a financial standpoint the micro grid also delivers value beyond simple backup power. Because its normal operation generates revenue and cost savings that help pay for itself, the system is not a stranded cost. Further, not only does it provide backup support during an outage, it also delivers essential load relief, lowers operational costs, and helps reduce greenhouse gas emissions.

Antojitos

About Antojitos

Antojitos is a restaurant located in the San Pedro district of San José. Its employees are dedicated to improving the business's impact on the community and the environment. They have persevered to create an extremely efficient and effective business model of helping out and

conserving resources. The result of these efforts in efficiency, in addition to having lessened the restaurant's impact on the environment, have saved them money over the years of its operation.

Energy System and Impact

They had a set of photovoltaic solar panels installed on their roof in February of 2014. After three years, the solar panel provider Sunshine installed more solar panels on their roof by, in May, 2017. The first set of panels were financed for 6 years, but paid for themselves after only 3 years. The entire system combined is expected to have an 8 year return on investment. Before both of these solar panel installations, the monthly energy consumption was about 6800 kWh coming entirely from the grid. This monthly consumption was reduced by 2000 kWh per month from the total combined solar system.

Efficiency Efforts

Muni Figueres, the owner of Antojitos, understands the importance of efficiency. She has pushed efficiency measures on the restaurant that reduced their energy usage by an additional 2000 kWh per month. Muni was able to do this by doing the following: installing LED light bulbs throughout the entire restaurant; swapping out outdated wiring to new, more efficient wiring throughout the whole restaurant; changing the refrigerator condenser motor to a more efficient model; using transparent roof tiles to increase natural lighting in the dining areas; purchasing a more energy efficient dishwasher; and installing a solar thermal hot water tank. At the time of installation, LED light bulbs were about $15 per bulb, making that a substantial investment for the restaurant. Now, LEDs can be purchased for as low as $3 per bulb, making the potential even greater for facilities to become more energy efficient. After all of these improvements, Antojitos only consumes 2700-2800 kWh of energy from the grid per month.

Taking their energy efficiency to the next level, Antojitos purchased an electric motorcycle for all of their food deliveries. The bike charges during the day, so the solar panels directly provide the electricity for the motorcycle. Antojitos also produces practically no waste from their establishment. All of their organic food waste is taken to a facility that makes organic fertilizer, and all of their oil waste is taken to a facility that makes biodiesel. They purchase all their products from eco-friendly companies that are comprised of people who have faced adversity in their lives. Antojitos was also the first restaurant in Costa Rica to ban straws in their restaurant and purchase fish from only sustainable seafood certified companies.

The Result

Antojitos restaurant shows how far a business can go to improve their efficiency to maximize financial gain and environmental impact. This is the kind of dedication it takes to really make an impact on your business. When extreme efficiency measures are taken, like in the case of Antojitos, a business can maximize its potential savings while possibly utilizing a smaller solar system and having a smaller initial investment.

BAC San Jose

About BAC San José

The flagship branch of BAC (Banco America Central) is located in the San Pedro district of San José. It is one of the largest banks in Costa Rica, and has a positive image in the community for its efforts in carbon neutrality.

Solar System

In 2011, BAC San José installed 160 photovoltaic solar panels on their roof, courtesy of Poderco Renewable Energy Systems. This system covers 95% of their roof that is suitable for solar panels, and typically produces 5520 kWh per month, which reduces their monthly energy demand purchased from the grid from the CNFL by 30-37%. The design of the building optimizes the use of natural light, so the main energy demand is not from artificial lights but computers, especially their supporting servers. The system costed a total of $180,000 and started saving the bank money after its 6 year return on investment period. Poderco Renewable Energy Systems also provided a 10 year warranty on this system.

Carbon Neutrality and Further Efforts

All of BAC's branches are certified carbon neutral, and 25 branches are ISO 14001 certified, showing the company's commitment to Costa Rica's nationwide carbon neutrality goal. One branch located in the city of Curridabat in Costa Rica is currently trying to install a photovoltaic solar system of their own, but are facing pushback from the CNFL, the energy distributor within that zone. The CNFL is not approving this project because they do not want that facility to be bumped down to a cheaper tariff classification as a result of less energy being purchased from the grid.

The Result

BAC San José has a forward thinking attitude about sustainability. They are a company who designs its buildings with energy savings and generation in mind, and has big future plans to keep conserving energy. It is important to note that their commitment is more than just installing

solar panels. BAC San José highly stressed lowering energy consumption by making the facility as energy efficient as possible along with pushing carbon neutrality.

Purdy Motor Toyota

Purdy Motors is a Toyota dealership located near San Jose in Ciudad Toyota La Uruca. They are currently in the process of finishing a 995kW photovoltaic solar array mounted on their roof. Purdy Motor started consulting with greenenergy© in December 2017, and the project is expected to be completed in March 2018. The details of the system can be seen in the figure below. *We include Figure 4 here.*

The return on investment of the system is expected to be 5 years as seen above, but this is regarded as a conservative estimate with an estimated 47% annual energy savings. The system was strategically designed to produce 82% of their energy consumption so that they would not have to supply excess energy back to the grid, and as a result avoid the 49% rule and the access tariff. No battery storage was installed, so the goal of sizing the system in this way is that the facility will directly consume the energy produced by the solar panels and then only pull energy from the grid to cover excess energy consumption. greenenergy© is also providing a 30 year warranty on the solar system, with the annual energy production expected to drop by only a total of 5% by the end of the 30 year warranty.

Problems with the Roof

During the installation process at Purdy Motors, there were a few issues with their roof. The condition of the roof was overlooked and as a result, it was damaged in some areas because it was not made to withstand people walking on it. This resulted in a delay of the project and the need for a new roof. This case study shows that it is very important to check your roof before a

solar installation. It may not be in a good enough condition to handle the installation process or outlast the solar panels being installed on it. Handling any problems with your roof before installing solar panels will help save time and money down the road.

A Look at another Toyota Dealership

A large motivator behind the installation of the Purdy Motors system was a much smaller photovoltaic solar system installed by Sunshine at another Toyota dealership located in the city of Curridabat near San Jose. The details of this system can be seen in the figure below. *We include Figure 5 here*

This 34.56kW system is much smaller than the 995kW system installed at the Purdy Motor in Ciudad Toyota, but still has brought great benefit to the Ciudad Curridabat dealership. The return on investment was estimated to be 5 years with this system as well, but the dealership has noticed a faster payback on the system than expected. For the first year of installation, shown in the figures below, the system installation was completed and turned on in November where there is a noticeable drop in both energy consumption from the grid and price paid for energy from the grid. *We include Figures 6 and 7 here.*

Problems and Advice

During the installation process of the photovoltaic solar system at this Ciudad Curridabat dealership, only a couple problems were encountered. In the beginning, a cheap inverter from China was tested after installation and blew up when turned on. They then switched to the higher end Fronius Inverter and have not faced a problem since. Additionally there was a few issues with the cables that were used. Initially, they used green cables on the roof which ended up overheating in the sun, so they had to switch to white cables. Other cables that were being used

needed additional support so that they would not be in contact with the roof and would not overheat. For general advice, solar of any size was highly recommended, but it is crucial to make your facility as efficient as possible first, know your updated energy consumption and load profiles for optimal system design, and pick a reputable company for a high quality installation as they had done.

Astek

Astek Costa Rica manufactures fragrances, food coloring, and various flavorings. They currently have a 51.2kW photovoltaic solar system designed and installed by Enertiva on their roof. After a $70,000 initial investment, the expected return on investment of the system was predicted to be 7 years. With current implementation, however, the system is expected to be paid for in only 5 years.

The system installation was a 3 month process, with the physical installation of the panels, inverters, and other infrastructure only taking 3 weeks. The only obstacle faced during the installation process was a 3 ½ week delay on the final inspection after the system installation was complete and before the system was turned on to start producing energy. A 15 year warranty is included with the system along with a maintenance plan where the panels are cleaned once every three months. There is also a system inspection once a year.

After instillation, the amount of electricity pulled from the grid was greatly reduced since it was consumed directly from the solar panels. The figures below show the drop in energy consumed from the grid both numerically and visually. *We show Figures 9 and 10 here.*

During the first month, the solar panel system alone provided all of the energy for the facility, with no energy taken from the grid. When the system was first installed, Astek was also able to lower their load demand by 10% through improving efficiency.

All of the system production is monitored, recorded, and accessible on multiple applications including smartphone devices. If something goes wrong within the system, an email notification is sent out to ensure the problem is dealt with as soon as possible. Astek's goal is to use their panels and monitor their consumption to continue to lower their energy demand until no energy will be consumed from the grid during any month of the year.

Additional Information

The final section of the guide contains additional information that may be helpful to understand the technical aspects of solar technology, but not essential in the decision making process when considering solar energy for a business. The information in these sections are summarized from different websites and the links to those websites are provided at the bottom of each section. The different categories in the Additional Information section are: the difference between photovoltaic and solar thermal energy, ways for businesses to change their everyday practices to become more energy efficient, the most commonly used methods to store solar energy, factors that affect solar panel efficiency, and how ACESOLAR is a valuable resource if one wishes to learn more about solar energy. This is all information that is widely available on the internet, however we felt that it was beneficial to add at the end of our guide to act as a starting point for any further inquiries one may have into those topics.

Chapter 6: Conclusions and Recommendations

In this chapter we summarize our key findings and provide recommendations for further enhancing our guide and promoting solar energy based on these findings. Through our interviews, we gained a good understanding of the intricacies of the energy distribution in Costa Rica and all the associated tariffs and regulations. We also created profiles on some of the major solar panel providers within Costa Rica and case studies of companies that have benefitted from installing their own solar panel systems. While addressing these objectives, we also found it necessary to include information on the basic benefits of photovoltaic systems to better inform the reader. Finally, we organized all of this information in an easy to read website, providing a centralized source of all the important information regarding solar panel implementation for Costa Rican industries. After analyzing the information we collected and reflecting on some of the barriers to the widespread implementation of solar panels in industry, we make recommendations to the CICR and other stakeholders on how to better promote solar energy and what legislative actions will make solar energy more appealing. These recommendations are derived from our understanding of the current situation of solar energy usage in Costa Rica and suggestions from both the solar panel providers and case study companies we interviewed.

Summary of key findings

By interviewing solar panel providers, companies that already have solar panel systems, a member of ICE, and a member of ACESOLAR, we were able to gather information accounting for several sides of the stakeholders in the solar energy field. The result is a guide that can be used to fully understand the current situation of solar panel usage in Costa Rica while educating the reader on who can provide solar technology and how companies have improved their business climate with solar energy.

Several tariffs and regulations must be understood when considering solar energy

Interviews with solar panel providers and a member of ACESOLAR gave us great insight into the tariffs and regulations associated with solar panel usage by those directly affected by them. It is important for businesses considering solar energy to fully understand these rules and to know how solar energy can benefit them financially, preventing inconvenience or dissuasion by the steps and rules that must be followed when using solar.

First, it is essential that a business understands the charges for its electricity consumption. One important aspect of a business's consumption is the 3,000 kWh threshold. If a business exceeds 3,000 kWh of consumption in a month, it will most likely pay much more for electricity than it would if the consumption was under 3,000 kWh. This is due to the large charges for peak demand over the 3,000 kWh threshold. If a business can use solar panels to lower its consumption to under this 3,000 kWh mark, then solar panels will be an extremely beneficial investment.

In order for a business to install solar panels, it must follow a mandatory three to four step procedure. The company inquiring about the installation must pay the electricity distributor to perform a study to ensure that the size of the proposed system does not exceed 15% of the circuit's total demand. Once the electricity distributor verifies this, the solar system provider must submit all design plans and equipment specifications to the electricity distributor for approval. Once the electricity distributor fully understands the system design, the company receiving the panels must commission the installation. Some electricity distributors also require an inspection of the system after it is installed.

The tariffs and regulations once the system is interconnected with the grid are the most important rules for a company to understand. Fully understanding these rules can allow a

company to associate solar panel systems as an investment, whereas misinterpretation can result in companies associating solar energy with extra costs for their business. When sending excess energy back to the grid, only 49% of that energy is available for consumption in the future at a discounted rate. One can use the 49% of energy whenever one wants, but it has an access tariff applied to it, making it about 25% of the normal electricity price. The access tariff is not an additional cost to the normal price of energy, but rather a small payment to the electricity distributor for using their grid to temporarily store the energy that is generated but not immediately consumed.

The 49% rule, 15% rule, access tariff, and confusion on how exactly they are applied, are some of the biggest obstacles to expansion of the solar energy market in Costa Rica.

Solar panel providers in Costa Rica

The next piece of information that a company looking to implement solar energy would need is who can supply the technology. Therefore, it was necessary to provide a list of solar panel providers and a brief of summary of each provider as to what types of systems and technology they offer.

Through in person interviews, we were able to create profiles of four solar panel providers: greenenergy©, Purasol, Cielovivo, and HiPower. Several other providers were contacted via email, however they did not get back to use or we were unable to arrange an interview. After discussing this issue with our sponsor, we decided the best course of action was to send the solar panel providers who are CICR affiliated a questionnaire via email so that a profile can be developed for them as well. Upon evaluation of our methods, it was concluded that we would have benefited from trying to obtain other contacts for the companies that did not

respond to our emails, because it may have elicited a response and allowed us to create more solar panel provider profiles for our guide.

Case study companies

As a means to further articulate the benefits of solar energy systems in industry, we interviewed companies that have already implemented solar energy to see how it affected their business climate. These companies were identified through interviews with solar panel providers and discussions with our sponsor.

The most important information drawn from these companies, and perhaps one of the most persuasive arguments in favor of solar energy, was the financial information. This included initial investment, reduction in energy purchased from the grid, and return on investment.

Our group would have benefited from collecting an inventory of case study companies from more of a variety of sources. We asked ACESOLAR for any case studies they had, however, we never received this information. ACESOLAR would have been a good resource for this portion of our guide since all of their associated companies are interested in, or have a stake in solar energy. For this reason, it would have also been beneficial to send member companies on the ACESOLAR website a questionnaire, saving time from conducting in-person interviews.

The solar energy guide

After completing the previous objectives, we had to find the best way of presenting the abundance of information we gathered in a logical, easy-to-understand manner. When brainstorming the best way to do this, it was realized that our guide could be enhanced by adding a section on the benefits of solar energy. We had already answered the questions of how to implement solar energy, who provides the technology, and how it has benefited companies, but

the one question we had yet to answer after addressing our objectives was why should a company choose solar energy? Therefore, the first section of guide gives a brief overview of the benefits of solar energy. The highlights of the benefits include: energy savings over time, clean and free energy after installation, easy maintenance, and the potential to drop energy consumption below the 3,000 kWh and peak shavings.

The guide then transitions into understanding all of the tariffs and regulations discussed in the first objective. They are organized as understanding energy consumption in relation to the 3,000 kWh mark and peaks, regulations before installation (15% rule), and lastly tariffs and rules after installation (49% rule and access tariff). This presents all the information necessary to understanding the legislation for solar panels in a logical, sequential order.

The next section describes the steps involved in the installation process. This includes before during and after the installation process. The first part describes the steps that should be taken before installing solar panels such as understanding the rules and regulations, becoming more efficient, and inspecting your roof. The second section describes the actual installation process. This is the 15% check, submission of technical documents, commissioning of the installation, and inspection the system after installation depending on the electricity distributor. Finally, it concludes with a short section about maintenance and how to keep your system running as effective and efficient as possible after installation.

The guide then concludes with the solar system provider profiles and case study companies.

Recommendations

We were able to develop a set of recommendations to further enhance our guide and promote solar energy in Costa Rica.

Recommendations for the CICR to enhance our guide in the future:

Since the CICR will be responsible for maintaining our guide, all guide-related recommendations are directed towards the CICR.

Our first recommendation is to make some sort of announcement, whether it be through an email or a promotion on the CICR website, about our guide. This will increase the amount of people and companies that view the guide, aiding in the circulation of accurate information regarding solar energy around Costa Rican industries.

Continue to expand the number of profiles of solar panel providers and case study companies. Our team recognizes that we were only able to interview a limited amount of companies during our seven weeks and that there are many other solar panel providers and case study companies that would enhance our guide. Expansion can be done by sending out the list of questions we developed, or encouraging companies to send a profile of their own. The CICR has an abundance of resources and connections to make this recommendation feasible. A full list of the companies that we contacted but did not respond can be found in Appendix B.

We recommend that the CICR educates businesses on the benefits of making energy efficient investments.

When asking solar panel providers about the obstacles they face in expanding their business, a commonality in their answers was that many Costa Rican businesses do not stress long term thinking. They may choose not to make an energy efficient investment, such as solar panels, energy efficient appliances, or energy monitoring systems because of the magnitude of

the initial investment. Long term investments require careful budgeting and planning, which is not a practice that every business follows. Therefore, we recommend that the CICR takes measures to educate businesses on the importance of making energy efficient investments that will save them money over time. This can come in the form of seminars, workshops, or weekly courses. These measures would aid businesses in combating high electricity prices now and for years to come.

We recommend that MINAE work to expand the 49% and 15% rules to a higher percentage and reduce or completely remove the access tariff.

With these tariffs and regulations as the main obstacles to increasing the usage of solar panels in industry, we suggest that the MINAE take legislative action to expand these percentages and reduce, or remove, the access tariff. We recognize that these actions would hurt electricity distributors, such as ICE, by reducing the amount of electricity they sell from their grid. However, these measures would greatly enhance the potential for solar panels to save businesses money, allowing them to become more competitive in the global market. This is beneficial for both the individual businesses and Costa Rica's economy as a whole.

We recommend that ACESOLAR pushes for legislation to reduce the importation tax on lithium-ion batteries.

Lithium-ion batteries are the most efficient way to store solar energy (I. Salazar, personal communication, January 28, 2018). As seen in the Establishment Labs case study, lithium-ion batteries are extremely effective in saving a business money. This is because all or most of the energy that is generated can be saved for later consumption, without paying an access tariff, and stored energy can be used for peak shavings. At their current state, with the 13% import tax, 1.13% tax, and additional 36% tax, lithium-ion batteries are extremely expensive in Costa Rica

and are therefore scarcely used. It is in the best interest of Costa Rican industries that the 36% import tax on lithium-ion batteries is lowered or lifted so they are more accessible to businesses. In the past, ACESOLAR had success with fighting importation taxes for equipment used in solar systems. They were responsible for the passing of Law 8829, exonerating solar panels and inverters from all import taxes. Therefore, we recommend that they push for the lowering of the 36% import tax on lithium-ion batteries since they have helped pass similar legislation and are well equipped to do so for this case.

We recommend that ACESOLAR and MINAE push for mandatory standards for the installation of imported solar panels and inverters.

When talking to some of the solar providers that we interviewed, a common issue was that solar panel system had a bad reputation caused by low quality installations and cheap solar panels. Instances of some smaller, less-reputable companies using poor quality panels to save money are an issue occasionally faced within Costa Rica. Not only is this an issue for the customers who end up with solar installations that do not perform well or last, these less-reputable solar installers undercut the companies who take the time to do proper and safe installations with high quality equipment. By setting mandatory standards for installation of imported solar panels and inverters, customers can be more confident with their installations and unsafe, poor quality installations can be reduced.

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Appendix A: Interview Questions

Questions for Solar Providers

- The information collected is being used as research for the CICR to help promote the use of self-generated solar energy within the industries of Costa Rica. Ultimately we plan on using this data to create a guide or online tool that will help educate and promote the use of renewable energy. We are asking for your permission to use this information in our research. If there is any information you are unwilling to have public what is it so that we can make the information anonymous or omit it from any public publishings.
- What areas of the countries do you provide systems for?
- What electricity provider do your customers generally use?
- What types of solar systems do you install?
    - Thermal, photovoltaic, etc.
- Do you provide another form of renewable energy?
- What is your typical project size?
- How much do your systems cost?
    - Price ranges for corresponding size of system ranges
        - Cost for a system of 1-10kWh
        - Cost for a system of 10-50kWh
        - Cost for a system of 50-100kWh
        - Cost for a system of 100+kWh
    - Cost per kWh?
    - Installation cost?
    - Battery Cost?

- Do you offer financing?
- What is the average ROI of your systems?
    - Break-even point (ex. 7 years)
    - Any study cases
- On average how long does it take to set up a system (the whole process)?
    - Installation time
    - Permissions
    - Time to import panels
    - What are the limiting factors for time of installation?
        - Inverters, bi-directional meters, etc.
- Are your systems easily expandable?
    - Can you easily add additional solar panels onto a previously existing system?
- How much space do your systems need?
    - Square footage/watt related metric
    - Efficiency, surface area, components
- What brand of panels do you typically install and what tier company is this?
- Do you use power optimizers in your panel installations?
- Do your customers typically return extra energy to the grid or store it?
    - How is the energy stored? What are the energy storage solutions?
- What are some obstacles that you have faced in expanding your market?
- Have you heard of or used the BAC (bank solar calculator)? If so, what is your opinion on the bank solar calculator?

- If you could have an online tool or guide that would help promote the use and knowledge of solar energy, what do you think would be most useful to have in said tool or guide?

Questions for Case Study Companies:

- Who is your electricity distributor?
- Who installed your system?
    - Did the provider of technology install their system or did they sub-contact an installer?
- How big is the system, in both physical size and power generation?
- What percentage of your energy demands does the system generate?
    - If excess energy is produced, is it stored or fed back into the grid?
    - What storage method do you use, if any?
- Has the system been a worthwhile investment for your company (economically and any other factors)?
- Have you had to perform any maintenance on the system?
    - How much has this cost?
    - Frequency of maintenance?
- Do you have a warranty on your system?
    - If so, which components does it cover and for how long?
    - Have you ever had to use the warranty? If so, which components?
    - Have you ever had to replace anything that was not covered by your warranty? If so, which components?
- What obstacles have you faced (before, during, and after installation)?

    - Any permitting problems?
- Based on your experience, what would you advise other companies considering implementing solar to do?

Interview with Karen Tat of ACESOLAR

- Introduce ourselves and our project
- Can we record this interview solely for note taking purposes?
- What is ACESOLAR's main goal?
- What do you do within ACESOLAR?
- What is your opinion on the usage of solar panels in industry? Do you think they have a future and why?
- What do you think would be helpful in our guide?
- What information should we try to get from solar panel providers/what questions should we ask?
- Do you know any good case study companies that have already implemented solar panels that we could reach out to?
- In your opinion, what are some barriers that limit the potential of solar energy?

For our first interview we met with Karen Tat, an executive director for ACESOLAR. We asked her what her opinion was on the solar industry. Her response was that ICE does not want any solar projects which makes it difficult to promote solar energy. Costa Rica has the technology and conditions for solar panels to make a big impact but the only thing that is missing is government/ICE support. A reason for this lack of support is ICE's fear that people can become disconnected from the grid if solar panels are widely incorporated.

Conversely, if many people were to disconnect then all the money that is needed to pay off the hydroelectric plants would fall on the people who don't have the capital to make this investment. She believes there needs to be greater diversity in where the country generates its energy. There are members within ICE that believe this, however most are set in going with what has historically worked in hydroelectric plants and are reluctant to change since they're able to control prices with only one main energy source. Additionally, Karen told us that a lot of people call ACESOLAR inquiring about solar panels but don't know who to buy them from. She said that is very important that we include some sort of cost estimate in our tool. Solar panel providers will have case study information we can use and may be easier to collect data from them rather than asking the companies that have already installed them. She thinks it is very important that we understand all the tariffs and regulations for us to make an accurate tool.

Appendix B: Solar Contacts

Highlighted contacts never got back to us

Name	Company	Source of Contact Information
Paul Collar	**Owner**: Osa Power **Co-Owner**: RIver Run Hydro	Given at end of linked article
	Purasol Paneles Solares	ACESOLAR Company
	Costa Rica Solar Solutions	Google
	Nordteco	ACESOLAR Company
	Pura Vida Energy Systems	Google & ACESolar Company
Silvia Cháves	FLOREX	Akira
Yaudicia Vargas	FLOREX	Akira
Pierre Lambot	Purasol	Bernhardt
Carlos Meza	ACESOLAR	Bernhardt
Karen Tat	ACESOLAR	Bernhardt
Arturo Gaviria	Cielo Vivo	Bernhardt
Harold Steinvorth	Sunshine	Bernhardt
Alejandro Rojas	Solar Ing Costa Rica	Bernhardt
Luis Rojas	Matelpa	Bernhardt
Ignacio Salazar	Green Energy	Bernhardt
Marco Varela	Hipower	Bernhardt
Jan Borchgrevink	Refeel	Bernhardt
William Campos	Panasonic	Bernhardt

Jesus Castro	Soluciones Energéticas Renovables S.A (SOLER)	Akira
Mauricio Rojas	GBT	
Alejandro Brenes	Enertiva	Bernhardt
Hans Winiker	Enertiva	Bernhardt
Jorge Vargas	Bticino	Marbeth Delgadoo from Inteco
Gastón Broutin Sheik	ICE: Laboratorio de Eficiencia Energética	Marbeth Delgadoo from Inteco
Victor Valverde	ARESEP	Marbeth Delgadoo from Inteco
Carsoth Farrier Soto	ARESEP	Marbeth Delgadoo from Inteco
Aztek	Gladys Ponce	
Antojitos	Muni Figueres	
Establishment Labs	Mauricio Arce Prendas	
Banco San Jose		
La Liga Estadio		
Grupo Acon		
Toyota		
Purdy Motor	Jonathan Mata	

Table 10: List of solar panel providers and case study contacts

Appendix C: Costa Rica's Carbon Neutral Goal

At a glance, Costa Rica seems like a model for other countries to follow, but Costa Rica has the advantage of a smaller population and abundant natural resources. Even with their current success at attempting to become 100% carbon neutral, they still have several obstacles to overcome.

Costa Rica has a population of just under five million inhabitants and some prominent small industries, such as textile, clothing, medical equipment, and food processing (CIA, 2018). As a result, the energy usage of the country is much lower than other more developed countries. The reduced energy consumption coupled with rivers, coastlines, volcanoes, mountains and other natural resources makes Costa Rica suited to produce enough clean electricity to run the country.

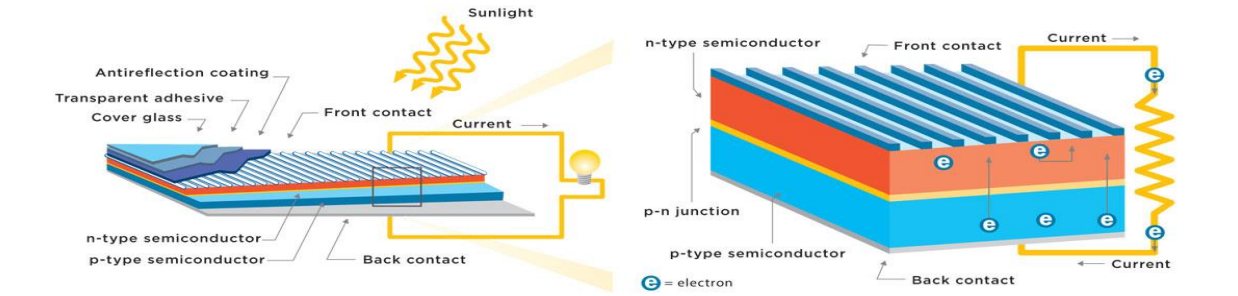
While Costa Rica still has many obstacles to overcome, they still serve as an example to other countries for making an effort at reducing carbon emissions and working towards 100% carbon neutrality. While the strategies and implementation of Costa Rica's carbon neutrality plan may not work for other countries, they will remain the center of the carbon neutrality topic for quite some time.

Even if Costa Rica was able to produce 100% of its energy in a clean and reliable manner, the transportation industry still relies on petroleum. It is estimated that 70% of Costa Rica's carbon emissions came from cars, busses and trains burning fuel (Fendt, 2015). Costa Rica has yet to make significant advances towards the use of hybrid cars, which would be able to utilize the clean energy from the grid.

Appendix D: Additional Information Included in the Guide

Solar Photovoltaic Systems

All of the information in the section was taken from an online article "How Solar Panels Work" (2015) from the Union of Concerned Scientists. Photovoltaic systems use the sun's energy to generate electricity. Solar panels are made out of two layers of semiconductor materials with opposite charges. When sunlight enters the cells it knocks electrons loose. Because the two layers are opposite charges the electrons want to flow from one layer to the other, but cannot because the semiconductor layers are separated. When the layers are connected together, for example with wires, the electrons are able to flow freely and this produces the electricity that is used by the consumer.



Solar cells are composed of two layers of semiconductor material with opposite charges. Sunlight hitting the surface of a cell knocks electrons loose, which then travel through a circuit from one layer to the other, providing a flow of electricity.

Figure 25: Technical information of photovoltaic panel layering

Benefits of PV systems

- PV panels provide free, clean energy
- Solar energy can be made almost anywhere there is sunlight
- Solar panel cost is currently going down as new technologies are coming out.
- Operation and maintenance costs of PV panels are extremely low and almost negligible compared to costs of other renewable energy systems

- Residential solar panels are easy to install on rooftops or on the ground without any interference to residential lifestyle.
- PV panels are totally silent, producing no noise at all; consequently, they are a perfect solution for urban areas and for residential applications

Potential Cons

- Energy storage is very expensive
- Limited to day time production
- Difficult to do any roof maintenance - roof needs to be properly designed before installation

The photovoltaic panel only generates electricity. There is a number of additional components that are required to properly transfer, control, convert and distribute the energy that is produced. Depending on the system, the required components may change but the major components of a photovoltaic system are the DC-AC power inverter, battery bank, battery controller, two way meter, installation equipment, wires, overcurrent, surge protection and disconnect devices. The figure below shows a basic diagram of a photovoltaic system and the relationship of individual components.

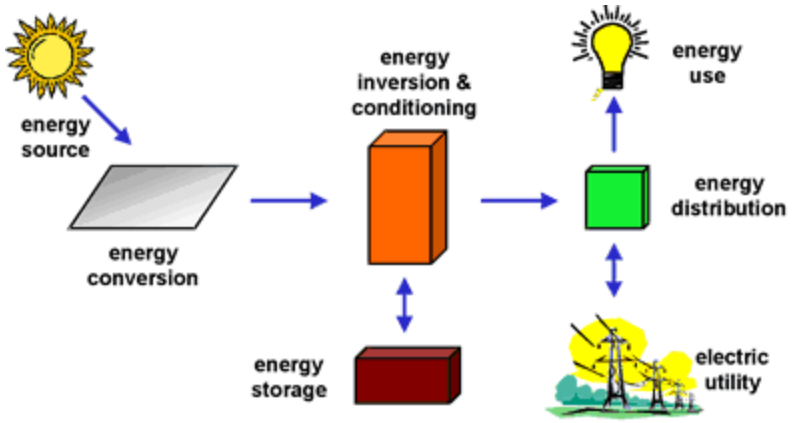


Figure 26: Diagram of a photovoltaic system (Florida Solar Energy Center, 2014)

A diagram of how the components of a PV system interact with each other.

Solar panels generate energy that is inverted from DC to AC power. This energy can then travel two places. If the building is consuming energy, then the energy generated from the solar panels is used to power the building. Any excess energy that is generated travels to the grid and is registered by the building's meter. If energy is being consumed and the solar panels aren't generating anything, energy is taken from the grid and registered by the building's meter. A schematic of this relationship is shown in Figure 27 below.

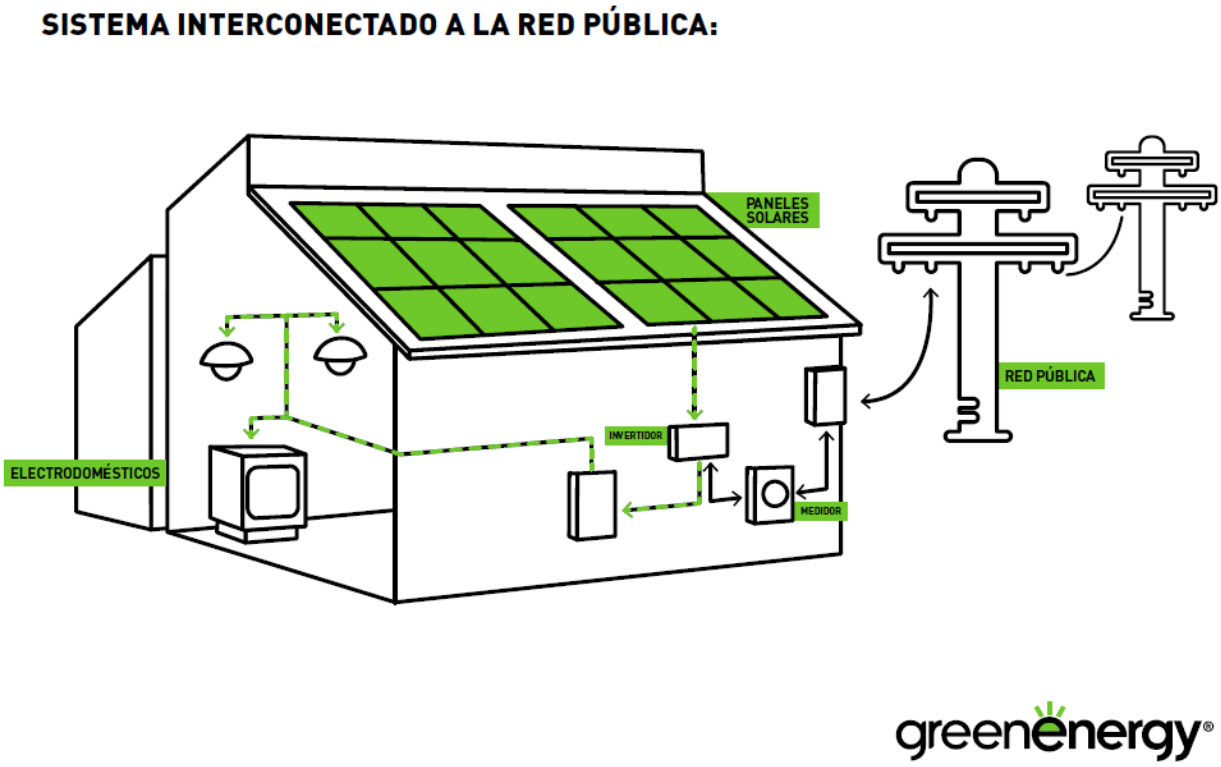


Figure 27: Grid-tied photovolatic system (Salazar, 2018)

Solar Thermal system

Solar thermal systems uses solar radiation as heat energy, in order to heat up a fluid. This is different than solar photovoltaics, which use sunlight to produce electricity.

How solar heating works

Solar thermal works in principle like a dark garden hose lying in the sun. The surface of the hose absorbs the sunlight and in particular the heat radiation so that the water therein is heated. The solar collector absorbs the sunlight via the absorber where a special fluid designed specifically for absorbing heat is used. A pump transfers this fluid to the heat exchanger of the solar storage where the thermal energy is then transferred to the storage tank. If the solar radiation is not enough to meet all of the hot water demands or heat up the water a conventional

heating system can used in conjunction to heat up the tank to a desired temperature

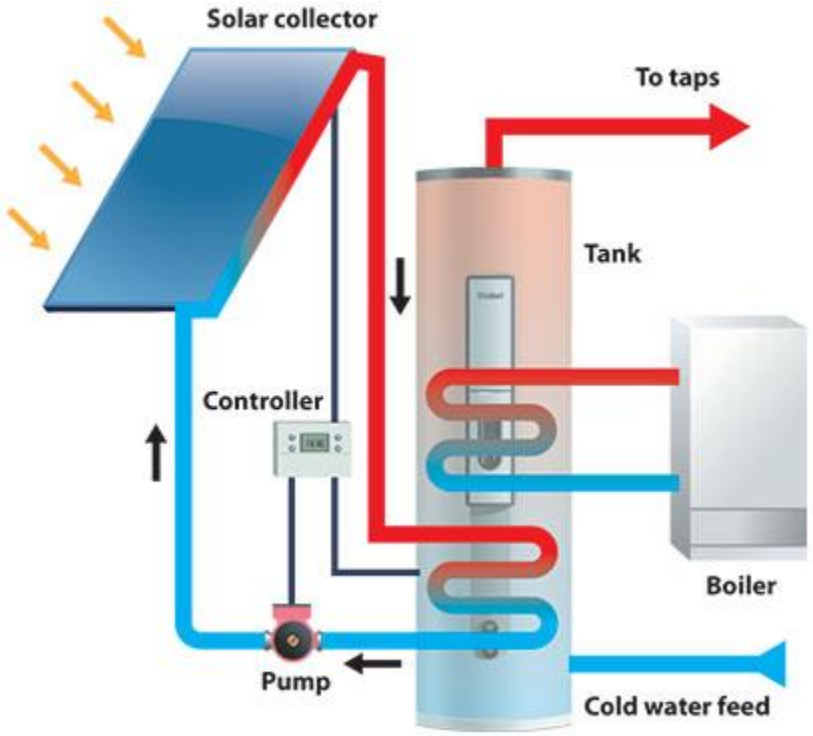


Figure 28: Solar thermal system depiction (Greenfields Heat & Power)

The benefits of solar heating:

- Endless amounts of energy, free of charge
- No CO2 emissions during operation
- Cost savings: up to 60% less energy to heat water, up to 35% less energy for space heating
- Reduced consumption of fossil fuels
- Solar thermal systems can be integrated into existing systems
- Modern systems work efficiently even in winter

Factors that affect solar panel efficiency and performance

All of the information provided in this section is taken from an online article "Solar Panel Efficiency" from PurSolar.

Solar Panel Pitch and Orientation

The pitch and orientation of your solar panels can affect their performance. Solar panels should be placed facing the sun at an angle that will allow them to catch the most amount of sunlight. Sometimes depending on where you live, it is recommended that the panels be adjusted throughout the year to account for the change in the sun's movement. Some larger commercial systems have solar tracking systems that automatically follow the sun's tilt through the day. Due to their high costs, they are not typically used for residential solar installations.

Temperature

High temperatures can severely reduce the output performance of a solar panel. The high temperatures affect the components within the solar panel and cause a reduction in the voltage across the cells. Depending on the location, excess heat can reduce the output by 10-25%. There are few ways to combat over heating the solar panels. First is installing the panels a few inches off of the roof to allow for air circulation. You can also use panels that are designed to be more efficient in hot environments. Ensure that panels are constructed with light-colored materials, to reduce heat absorption. Inverters and combiners can be moved into the shaded area behind the array.

Shade

Shade can drastically affect the efficiency of solar panels. Most solar arrays are connected in series, meaning that they operate at the current level of the weakest cell. If one cell experiences shade, then it may adversely influence the output of the others. Make sure that the

solar panels will receive as little shade as possible throughout the day. Some shade like cloud coverage is not avoidable. However, just because there are clouds does not mean the solar panels are not producing energy, they are just producing less energy.

Surface soiling

Solar panels are not the most effective if there is something covering them. This could be dirt, bird droppings, leaves, or something else. Making frequent physical inspections and spraying water on your modules can help reduce this problem.

Electrical Efficiencies

There are several other factors that affect the efficiency of solar panels with regards to the electrical systems used with panels. These include the efficiency of the wires to transport the energy and the inverters that are converting the energy from DC-AC. These calculations are taken into consideration with the design of the electrical systems.

Appendix E: Website Maintenance Guide

Accounts and Passwords

Google Account: wpicicr@gmail.com

Google Password: CICRsolarguide

https://www.squarespace.com/

Account name: wpicicr@gmail.com

Password: CICRsolarguide

Maintenance Guide

First in order to make any edits to the squarespace website first log into squarespace.com and sign in using the information above. This will bring you to a page that will allow you to select the renewable energy guide or change account settings.

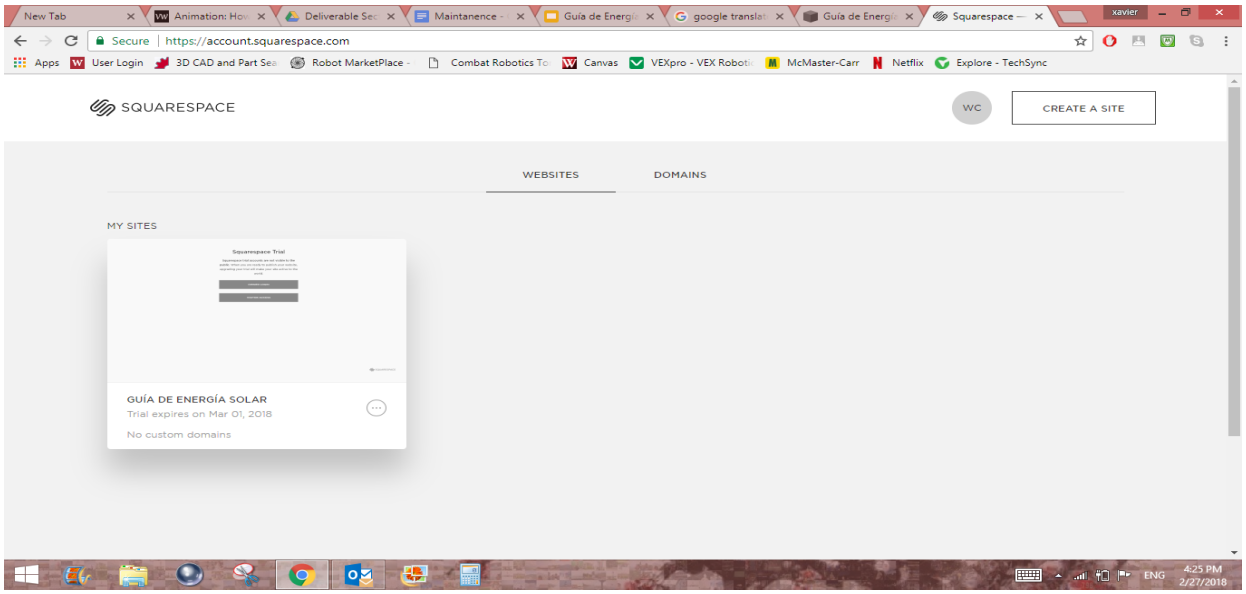


Figure 29: Squarespace opening page

For example you can change the email linked with squarespace if you so choose. This can be done in the account settings under change email. The password can be done the same way.

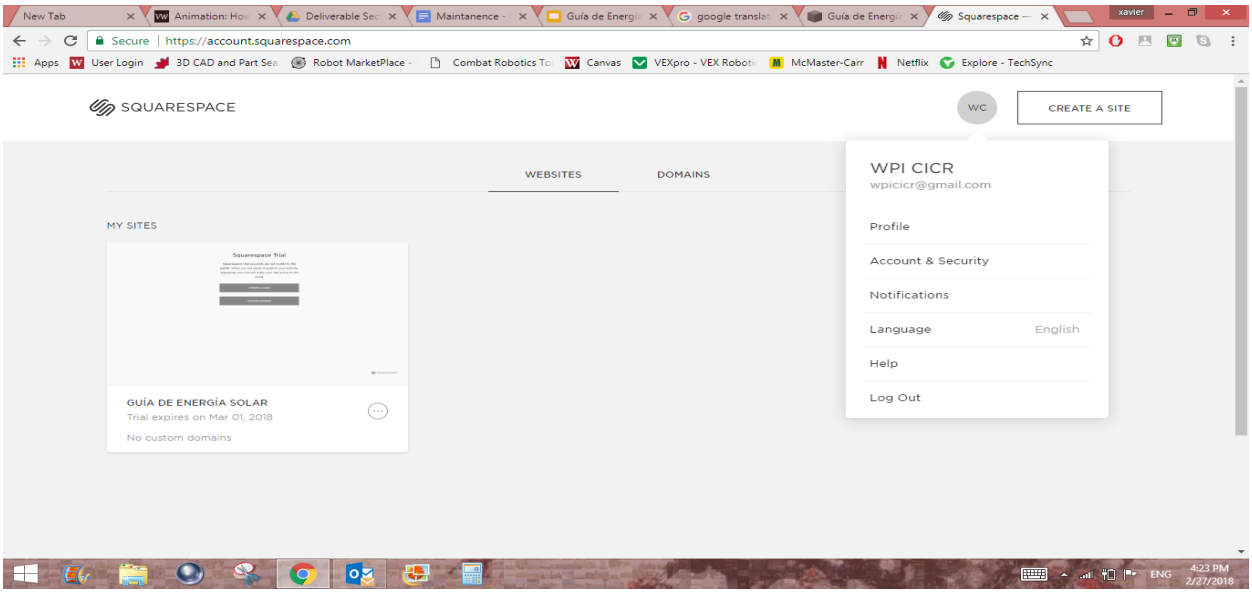


Figure 30: Squarespace account settings

There are a few things that need to be done in order to get the website up and running. They are listed here and then below is a walk through on how to do them and how to edit the website.

Pay for the website

Change Domain

Change email in contact form

Change URL slugs

Add Solar providers to contacts list

Update Information as it changes

Proof read information

Additionally, this is a pretty intuitive platform to use however it can be a little tricky in some spots. I will attempt to walk you through how to use everything in this document but these links will be able to provide a much clearer visual and explanation on some things. Any other problems can be found out with a simple google search of the problem or by contacting the squarspace award winning 24/7 Customer Service.

https://support.squarespace.com/hc/en-us/articles/205809798-Video-Series-Getting-Started-with-Squarespace

https://support.squarespace.com/hc/en-us/articles/206756327-Getting-started

Pay for website

First thing is first, the website is currently on a free trial. You will need to upgrade the website in order to activate all the features and allow it to go live. To do this click on the button below the website that says upgrade now or if you are in the account page with the websites, you can click the circle with the three dots on the website icon and then upgrade from there. The costs is $12 a month. However if you use the coupon code PHILLYD or GIMME10 you can get 10% off. How to upgrade the website can also be found in the links above.

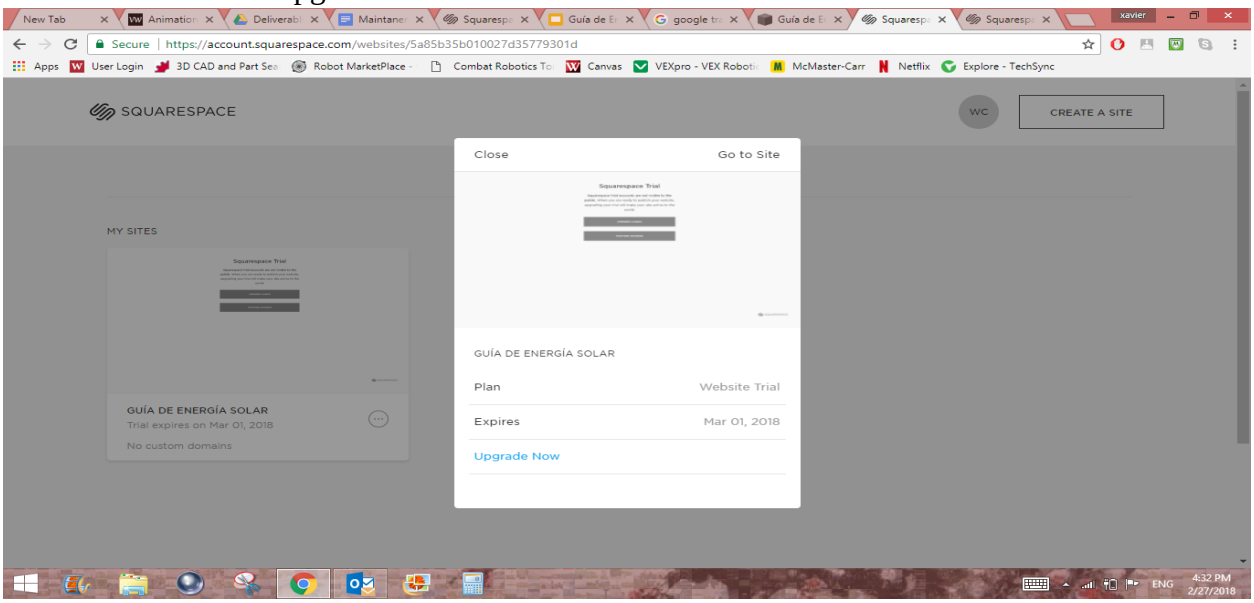


Figure 31: How to upgrade the website

Change Domain

The domain is essentially the url that visitors use to access the website. The current domain of the website is wpi-cicr.squarespace.com. Typing this into a browser will bring up the website. However this doesn't explain the website well and is not very good. After paying for an annual subscription of the website you can create a brand new domain name of your choosing. This can be done from the website editing section. First click on the renewable energy guide from the account page. This will bring you to a page that looks like this.

Figure 32: Opening page

Next click on the settings tab in the section to the left and then the link that says domains. Bringing you to a page that looks like this.

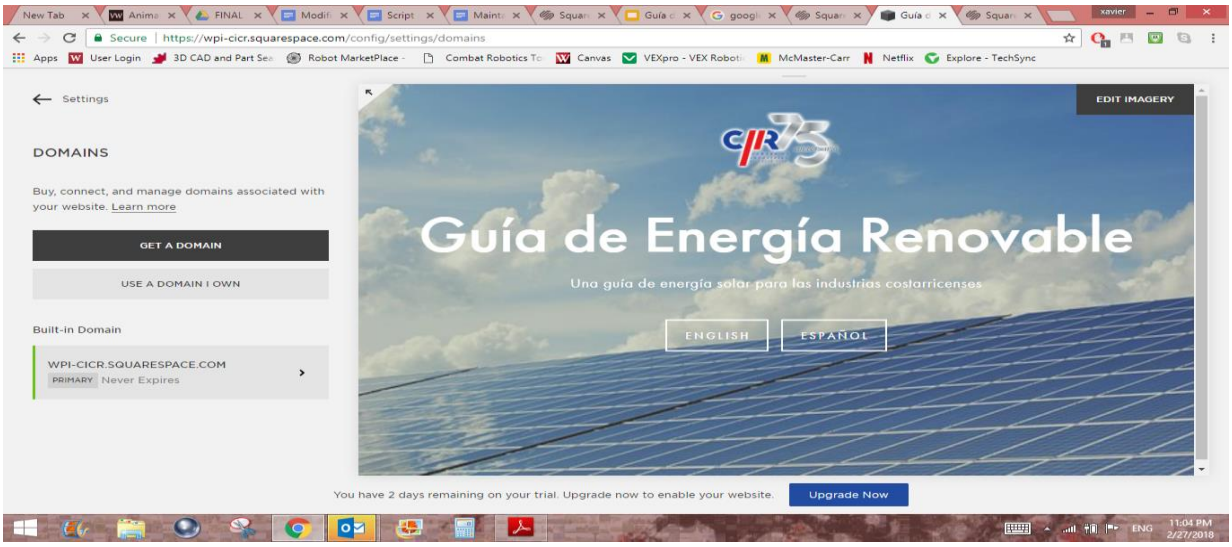


Figure 33: Website domains

Clicking on the get a domain will prompt you to enter in a new domain. This can be anything you want however several recommendations are GuíasolarCICR or GuíasolarCosta Rica. When you enter what you want and if you have already paid for the annual subscription it should give you several available domain names and they should be free. Clicking on the one you want and following the next steps should result in a brand new domain for the website that is easy to type

in and informative.

Familiarizing yourself with the website

When you click on the renewable energy guide from the account page it will bring you to a separate page that will allow you to edit the webpage. There are several sections of this. First on the left is a gray box with some navigation tools. The key elements to this will be the pages page and the design page.

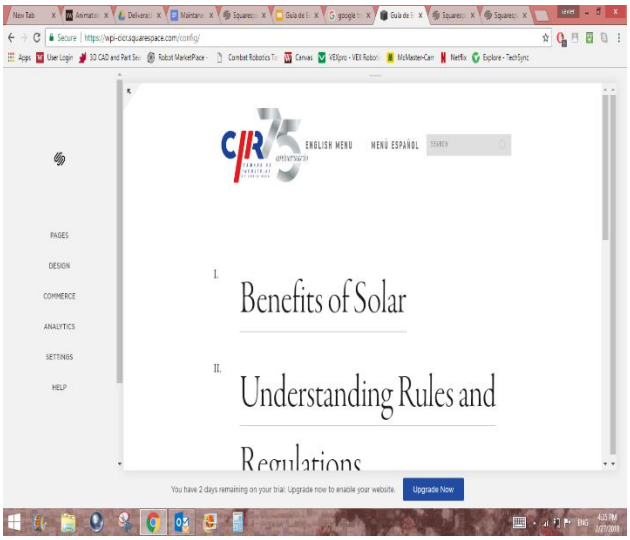


Figure 34: Navigation tools

The pages page will allow you to navigate through the website or change the order in which pages are listed or if they appear in the navigation bars at the top. If a page is listed in the main navigation folder it will appear in the top navigation. If it is unlinked it is still public and accessible however it will not display in any of the navigations.

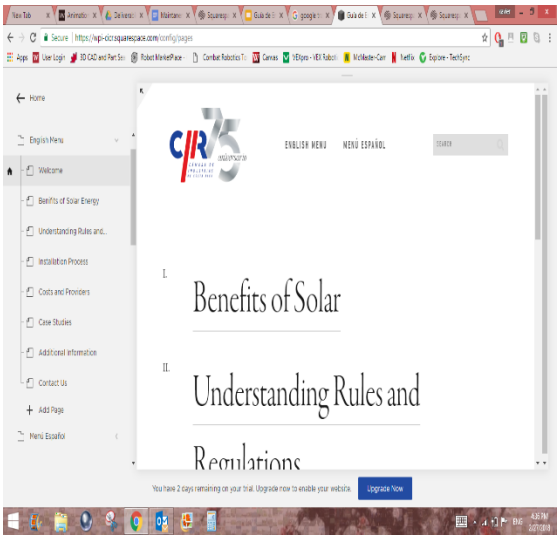


Figure 35: Navigation tool folder drop-down

This navigation will also allow you to access the cover page which is the first page people will see.

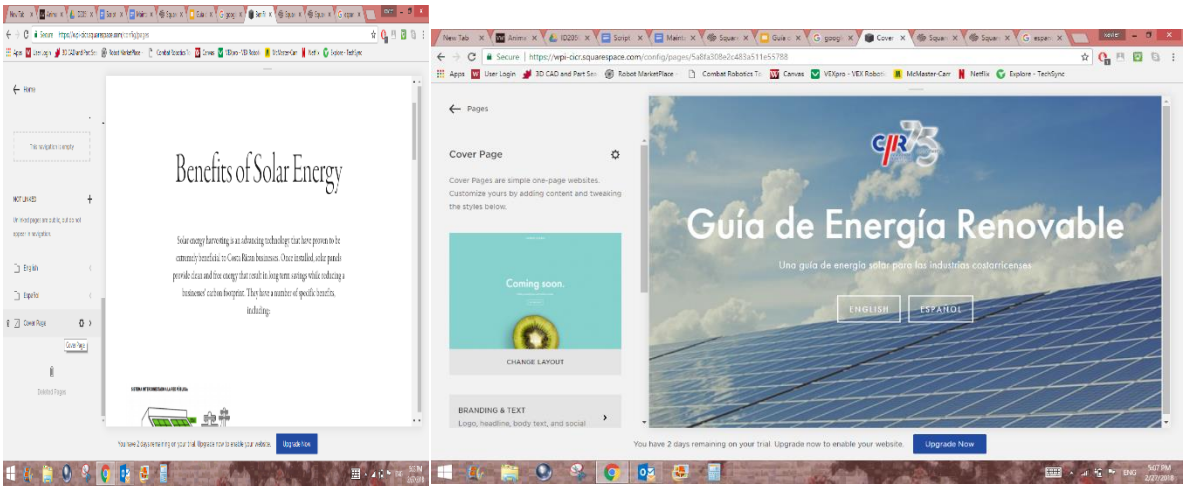


Figure 36: Accessing the cover page through the navigation tool

Under the designs page is a link that says style editor. This will allow you to change things such as fonts, color, sizes and spaces of anything on the website. If you want to change the color of the website in the future this is where you would do it.

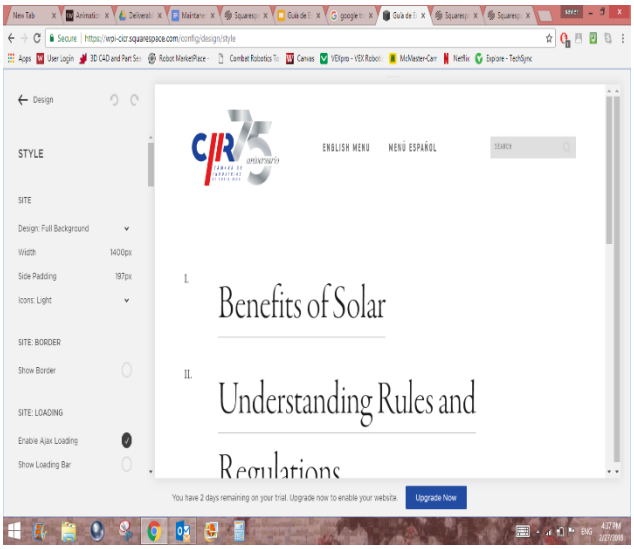


Figure 37: Style editor screenshot

Editing Information

All the information in squarespace is organized in blocks of different types. This includes text, photos, spacers, lines, etc…To add or remove information first go to the page you want to edit by navigating to it through the site or by using the navigation panel in the pages section of the screen. Then you hover over the section you want to edit and click edit.

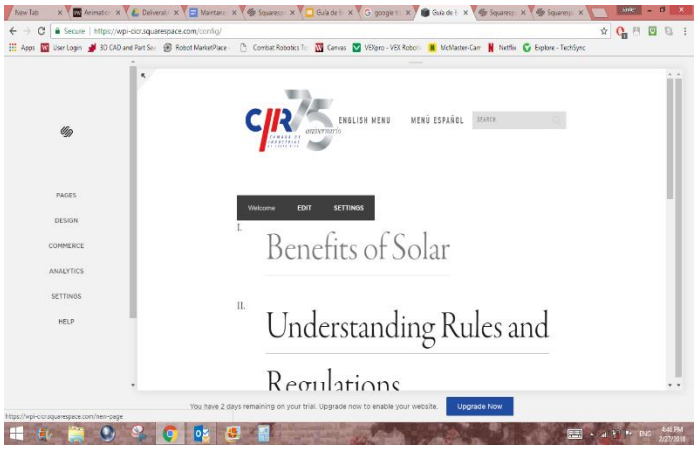


Figure 38: Editing information screenshot

If you are in the style editor or have the website in full screen mode from the little arrow in the corner you will not be able to edit the page

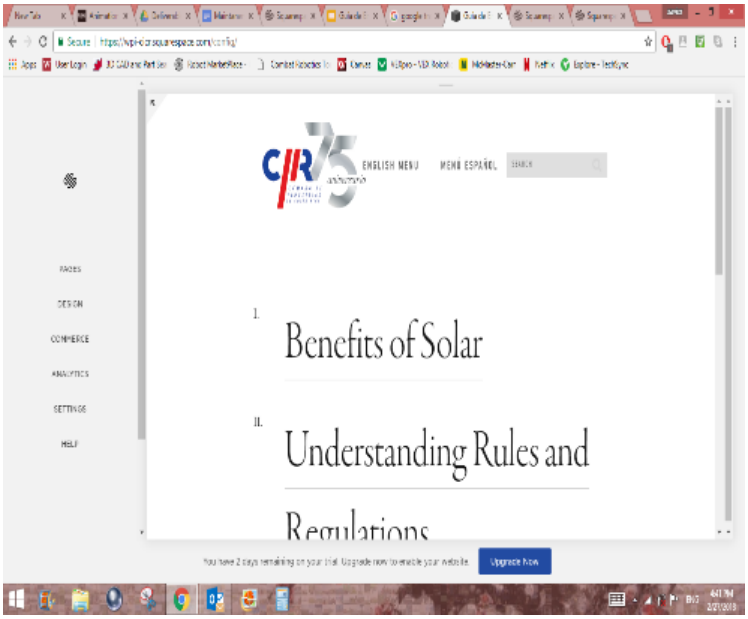


Figure 39: Closing out of edit mode

Clicking the edit button on a section will open just that section. If you hover under each block of information a little bubble arrow and a line will appear clicking on those bubbles will allow you to add a new block of information.

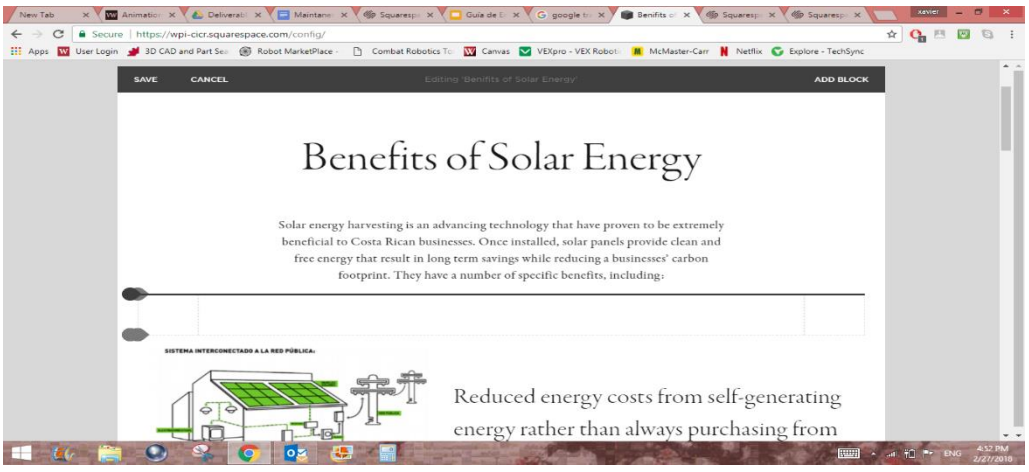


Figure 40: Adding a new block of information

After which you can drag that block to a new location and format it how you want. The format of each page is already set up so you just need to copy the previous format. The links above describe this in a video that is easy to follow.

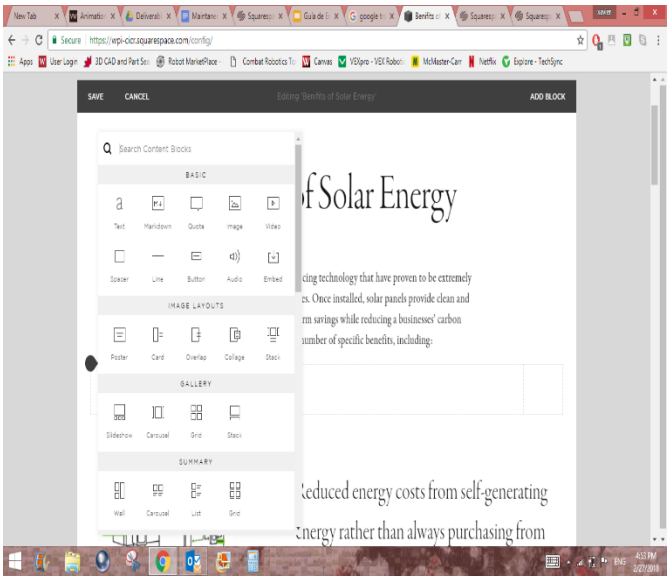


Figure 41: Page formatting screenshot

In order to allow the website to be in both Spanish and English we had to create two different collections of pages. These are the folders in the navigation page labeled English and Español. Any changes made in one site should be made in to other to keep the two consistent. Now that you know how to edit information there are a few key things that need to be done.

Proof read information

There is a lot of information in the website. We have red through the info several times and fact checked the information however there is a small chance that we missed something. Because this is going public it would be a good idea to double check everything.

Edit Contact Form

The contact us form is currently set up to send any responses to the wpicicr gmail. If you want to change this simply go to the form hover over it and click edit. Under the storage tab at the top you would then change the email to whatever you want. Again remember to change this in both the English and Spanish version.

Change URL slugs

The url slug is the additional bit of information at the end of a url link that is specific to each page. https://wpi-cicr.squarespace.com/new-page the bolded part is the URL slug. Right now all the url slugs in the website are random or say something along the lines of new-page3 or something. It is not necessary to change but if so desired they can be modified to the page title by clicking on the page settings (the gear looking button, or right clicking the page link) from the navigation on the left and editing the field labeled URL slug.

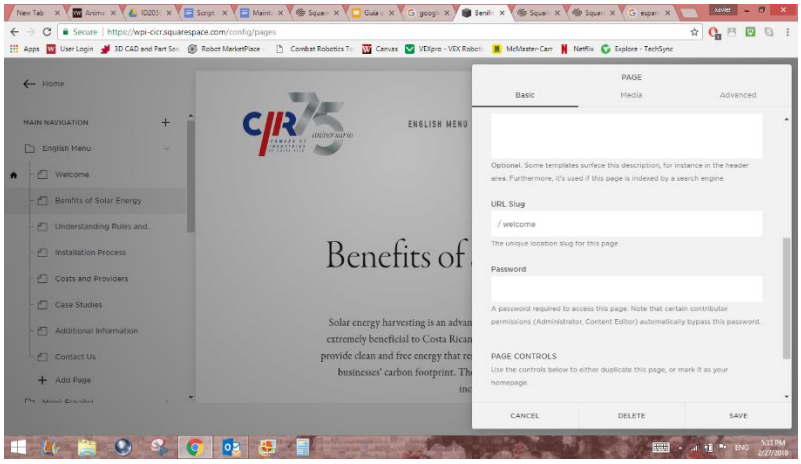


Figure 42: Changing the URL slugs

Add solar providers to contacts list

The current list of solar providers is incomplete. This will need to be added to following the same format as it is currently. Just copy the format. The information in the companies profile can be obtained by asking these questions. The questions are also organized to show what is in the paragraph of each profile and what is in the bulleted list.

Paragraph

What is the name of your company and how long have you been a solar provider in Costa Rica?

How many projects have you done?

What kinds of projects do you typically do? Residential, commercial industrial?

What is the typical size project you do?

Do you offer just Photovoltaic systems or Thermal as well?

Are you an ECP company or do you outsource part of the solar installation process?

Any other Information you want to share?

Bulleted List

Do you offer Energy Storage Solutions? If so what kind?

What brand of solar panels do you offer?

What kind of inverters do you typically use?

What area do you distribute to?

Do you offer maintenance, warranty or financing? If so what kind?

Update Information as it changes

Information will likely change so it will be key to make sure that everything is constantly up to date so that visitors can get the most up to date information when they read the website.

Appendix F: Deliverable Pages

I. Benefits of Solar

II. Understanding Rules and Regulations

III. Installation Process

IV. Solar Energy Providers

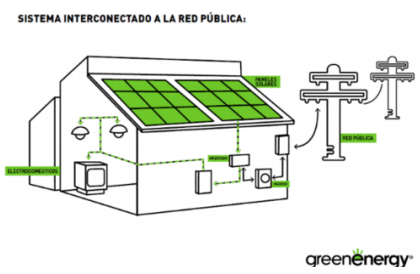
V. Case Studies

VI. Additional Information

VII. Contact Us

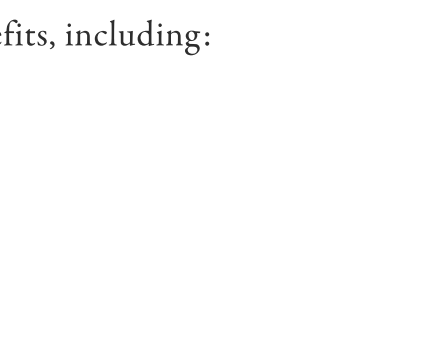
Benefits of Solar Energy

Solar energy harvesting is an advancing technology that have proven to be extremely beneficial to Costa Rican businesses. Once installed, solar panels provide clean and free energy that result in long term savings while reducing a businesses' carbon footprint. They have a number of specific benefits, including:



Reduced energy costs from self-generating energy rather than always purchasing from the grid

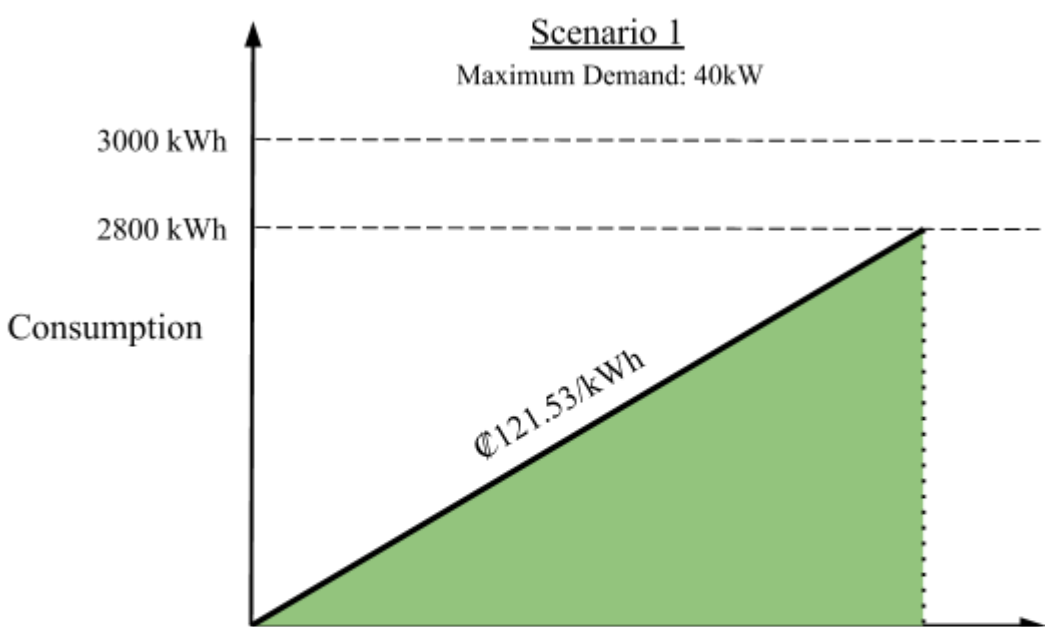
Peak shavings during instances of high energy consumption to reduce peak demand charges



Understanding Energy Usage

The first thing you need to know is your energy usage and how that will effect the design of a solar panel system. Obtain all the information you can about your energy usage, including load profile, peak demands, and critical loads. Company energy usage and load profile can be obtained from the electricity distributor if it is not already documented. This is a crucial step to get the most efficient system possible since the system design is tailored around this information. Additionaly knowing where you use the most energy and how the energy is used can help you cut energy usage in certain areas.

If a business consumes over 3000 kWh per month understanding energy usage is especially important. Below 3,000 kWh, a business is charged a set amount per kWh used. If the business exceeds 3,000 kWh, they are charged a block amount for the first 3,000 kWh, and an additional amount per kWh over 3000. Additionally, the business is charged per kW, for their peak demand when they exceed 3,000 kWh. This is were most of the energy costs for large industrial companies come from. Using solar panels to reduce the energy usage below 3000kW not only saves on energy cost per kWh but also eliminates the additional peak demand charge from the bill. The figures below illustrate this peak demand charge.



Before Installation

There are a number of steps a business should take before contacting a solar panel provider about installing a system. These steps are not necessary, although they are recommendations directly from several solar panel providers.

Step 1

Understand the Rules and Regulations

The first step is to understand all the information in the previous page. This well help with understanding how solar panel systems are designed and the costs that come with them.

Step 2

Energy Efficiency

Take all possible measures to improve energy efficiency. This includes using energy efficient appliances, LED light bulbs, ensuring all roofs, windows, and pipes are properly insulated; and employing good energy usage practices. These measures are not necessary but they will reduce energy consumption, which will lead to smaller system design and a smaller initial investment. If a company implements these measures then their energy consumption will decrease, which will change their consumption data and load profile. Click the learn more button to learn more about how to become more efficient.

LEARN MORE

Step 3

Inspect your Roof

Make sure your roof can handle the installation of solar panels. It needs to be able to handle the weight of the

Solar Panel Costs

Generally, prices for different sized systems are very similar between the different providers. Below is a very general summary of the pricing of different sized systems. System design and pricing will be different for every company because every company has different needs, so note that this are general price trends seen in Costa Rica.

If a business is able to use solar panels for peak shavings, then the return on investment period may be even shorter. Another important note is that the return periods given by solar panel providers are often very conservative and companies will experience shorter return periods than initially predicted. Also, prices outside of the GAM may be slightly more expensive due to travel time for installations.

System size	Price per peak watt installed	Estimated ROI
< 10 kW	around $2.00	7 - 8 years
10 - 100 kW	$1.20 - $1.50	6 - 8 years
100 - 200 kW	$1.00 - $1.20	5 - 7 years
200 kW +	$1.00 or less	3 - 5 years

Solar Panel Providers

Listed below are profiles of several solar panel providers in Costa Rica.

Cielo Vivo

Case Studies

The following is a look at several companies in Costa Rica that have implemented solar energy systems. The studies look at types of systems, size of systems, ROI and lessons learned.

Establishment Labs, Alajuela

Establishment Labs is a global, privately held, high-tech medical device and aesthetics company that designs, develops, manufactures and markets an innovative product portfolio consisting of advanced silicone-filled breast and body shaping implants. Learn about how they designed a building to fit their needs and how they strategically use energy storage systems to cut costs.

LEARN MORE

Antojitos, San Pedro

Antojitos is a restaurant located in the San Pedro district of San José. Its employees are dedicated to improving the business's impact on the community and the environment. They have persevered to create an extremely efficient and effective business model of helping out and conserving resources. Learn about more about of they improved efficiency in their restaurant to reduce energy usage and costs to better utilize their solar system.

LEARN MORE

BAC San José, San Pedro

BAC (Banco America Central) is located in the San Pedro district of San José. In 2011, BAC (Banco

Establishment Labs

About Establishment Labs and their Solar System

Establishment Labs is a global, privately held, high-tech medical device and aesthetics company that designs, develops, manufactures and markets an innovative product portfolio consisting of advanced silicone-filled breast and body shaping implants. In 2016 they built a new building in Costa Rica with a renewable energy in mind. It was strategically placed in a tax free zone of Costa Rica meant specifically for industries in order to reduce some of the costs of installing a solar panel system. Establishment Labs has a 220kW solar array on the rooftop of their manufacturing facility courtesy of RioGrande Renewables and . This system is composed of 864 Canadian Solar photo-voltaic solar panels and six Canadian Solar inverters. Unlike many solar systems within Costa Rica, Establishment Lab's system also has two Lithium-Ion battery bank. The two battery banks within their system combine to a total energy capacity of 1MWh and can provide a 500kW peak supply of electricity.

Antojitos

About Antojitos

Antojitos is a restaurant located in the San Pedro district of San José. Its employees are dedicated to improving the business's impact on the community and the environment. They have persevered to create an extremely efficient and effective business model of helping out and conserving resources. The result of these efforts in efficiency, in addition to having lessened the restaurant's impact on the environment, have saved them money over the years of its operation.

Energy System and Impact

They had a set of photovoltaic solar panels installed on their roof in February of 2014. After three years, the solar panel provider Sunshine installed more solar panels on their roof by, in May, 2017. The first set of panels were financed for 6 years, but paid for themselves after only 3 years. The entire system combined is expected to have an 8 year return on investment. Before both of these solar panel installations, the monthly energy consumption was about 6800 kWh coming entirely from the grid. This monthly consumption was reduced by 2000 kWh per month from the total combined solar system.

Efficiency Efforts

Muni Figueres, the owner of Antojitos, understands the importance of efficiency. She has pushed efficiency measures on the restaurant that reduced

Astek

Astek

Astek Costa Rica manufactures fragrances, food coloring, and various flavorings. They currently have a 51.2kW photovoltaic solar system designed and installed by Enertiva on their roof. After a $70,000 initial investment, the expected return on investment of the system was predicted to be 7 years. With current implementation, however, the system is expected to be paid for in only 5 years.

The system installation was a 3 month process, with the physical installation of the panels, inverters, and other infrastructure only taking 3 weeks. The only obstacle faced during the installation process was a 3 ½ week delay on the final inspection after the system installation was complete and before the system was turned on to start producing energy. A 15 year warranty is included with the system along with a maintenance plan where the panels are cleaned once every three months. There is also a system inspection once a year.

After instillation, the amount of electricity pulled from the grid was greatly reduced since it was consumed directly from the solar panels. The figures below show the drop in energy consumed from the grid both numerically and visually.

Purdy Motor

Purdy Motor in Ciudad Toyota

Purdy Motor is a Toyota dealership located near San Jose in Ciudad Toyota La Uruca. They are currently in the process of finishing a 995kW photovoltaic solar array mounted on their roof. Purdy Motor started consulting with Greenenergy in December 2017, and the project is expected to be completed in March 2018. The details of the system can be seen in the figure below.

Ciudad Toyota greenenergy

Parámetro	Descripción
Cantidad de Módulos FV	3 154
Cantidad Inversores	62
Potencia @STC (kWp)	995
Compensación de consumo promedio Anual (kWh)	1 444 034,80
Compensación de consumo energético promedio anual (%)	82%
Compensación del monto factura eléctrica anual (%)	47%
kWh/kWp estimado ($)	1.37
Retorno inversión años	5
Toneladas CO_2 evitadas por año	97
Equivalente número de hogares	529

Purdy Motor Ciudad Toyota solar installation details

The return on investment of the system is expected to be 5 years as seen above, but this is regarded as a conservative estimate with an estimated 47% annual energy savings. The system was strategically designed to produce 82% of their energy consumption so that they would not have to supply excess energy back to the grid, and as a result avoid the 49% rule and the access tariff. No battery storage was installed, so the goal of sizing the system in this way is that the facility will directly

BAC San José

About BAC San José

The flagship branch of BAC (Banco America Central) is located in the San Pedro district of San José. It is one of the largest banks in Costa Rica, and has a positive image in the community for its efforts in carbon neutrality.

Solar System

In 2011, BAC San José installed 160 photovoltaic solar panels on their roof, courtesy of Poderco Renewable Energy Systems. This system covers 95% of their roof that is suitable for solar panels, and typically produces 5520 kWh per month, which reduces their monthly energy demand purchased from the grid from the CNFL by 30-37%. The design of the building optimizes the use of natural light, so the main energy demand is not from artificial lights but computers, especially their supporting servers. The system costed a total of $180,000 and started saving the bank money after its 6 year return on investment period. Poderco Renewable Energy Systems also provided a 10 year warranty on this system.

Carbon Neutrality and Further Efforts

Additional Information

The following is a compilation of information regarding solar energy and solar energy systems. External links and information are neither maintained or the responsibilty of the CICR.

About Solar Energy

Learn about the different types of solar energy and how they work

LEARN MORE

Becoming More Efficient

Learn how to cut your energy usage and become greener

LEARN MORE

Energy Storage

Learn about energy storage options and how they effect your solar energy system

LEARN MORE

Factors that Effect Solar Panel Efficiency

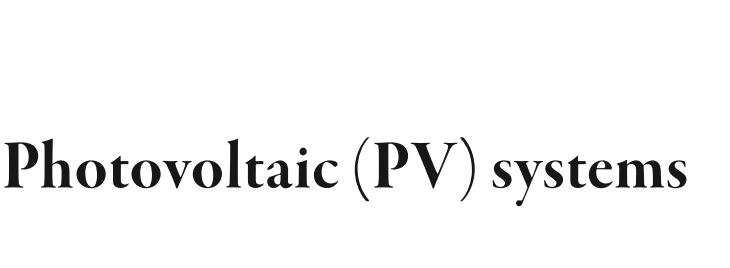
Learn how to get the most out of your solar panel

What is Solar Energy?

Solar renewable energy is energy that is harnessed from the sun and used in several different ways. Solar energy is split up into two categories. Photovoltaic systems and solar thermal systems.

Photovoltaic (PV) systems

Photovoltaic systems use the sun's energy to generate electricity. Solar panels are made out of two layers of semiconductor materials with opposite charges. When sunlight enters the cells it knocks electrons loose. Because the two layers are opposite charges the electrons want to flow from one layer to the other, but can't because the semiconductor layers are separated. When the layers are connected together, for example with wires, the electrons are able to flow freely and this produces the electricity that is used by the consumer.



Source

Benefits of PV systems

- PV panels provide free, clean energy
- Solar energy can be made almost anywhere there is sunlight
- Solar panel cost is currently going down as new technologies are coming out.
- Operation and maintenance costs of PV panels are extremely low and almost negligible compared to costs of other

Becoming More Efficient

Before installing solar energy it is recommend that your first reduce your electricity bill as much as possible and become more energy efficient. By reducing the amount of energy you consume, you can purchase a smaller system solar system and save even more money. There are a few ways to do this.

LED lights

LED lights use less energy and last longer than incandescent bulbs. They are one of the cheapest and easiest energy improvements.

Insulation

By using insulation on roofs, windows, and pipes, you can prevent warm or cold air from getting out or in. Insulation allows for a the energy being used on heating or cooling to be more efficiently used allowing it to stay warm or cool for longer. Small drafts can result in a large loss on heating and cooling costs.

Batteries

Batteries are often associated with solar panel systems. The PV panels usually produce more energy than is needed at the time, so it makes sense to store that energy somewhere for future use. Stored energy can be used to cut peak energy spikes, or as back up energy in case of power outages. Designing and implementing a completely off grid system is doable, but difficult and rare. This is typically seen only in small residential homes where there is no available connection to the grid. Batteries have many different uses when used in conjunction with a solar system. They can be used to create an off grid system, store energy for night time use, or as a back up source of energy. and cut peak energy usage and spikes.

Types of Batteries

There are two main kinds of batteries used in PV systems. Lithium-Ion and Lead Acid. The section below outlines the difference between the two.

Lead Acid

- 3x the weight of Lithium-Ion
- Loss of around 15 amps while charging and rapidly discharging drops voltage quickly and reduces the batteries' capacity.
- Less than 80% can be discharged and most manufacturers do not recommend more than 50%
- Can recharge 400-500 times

Lithium-Ion

- ⅓ weight of Lead Acid
- Nearly 100% efficient in both charge and discharge
- Can discharge up to 100% although realistically around 80 - 90%
- Can recharge about 5000 times
- Maintain voltage through discharge cycle
- High although requires less maintenance and lasts longer

Solar Panel Efficiency and Performance

Solar Panel Pitch and Orientation

The pitch and orientation of your solar panels can affect their performance. Solar panels should be placed facing the sun at an angle that will allow them to catch the most amount of sunlight. Sometimes depending on where you live it is recommended that the panels be adjusted throughout the year to account for the change in the sun's movement. Some larger commercial systems have solar tracking systems that automatically follow the sun's tilt through the day. Due to their high costs, they are not typically used for residential solar installations.

Temperature

High temperatures can severely reduce the output performance of a solar panel. The high temperatures affect the components within the solar panel and cause a reduction in the voltage across the cells. Depending on the location, excess heat can reduce the output by 10-25%. There are few ways to combat over heating the solar panels. First is installing the panels a few inches off of the roof to allow for air circulation. You can also use panels that are designed to be more efficient in hot environments. Ensure that panels are constructed with light-colored materials, to reduce heat absorption. Inverters and combiners can be moved into the shaded area behind the array.

Our Office

We are located 300 meters south of the Fuente de la Hispanidad, San José, San Pedro .

Contact Us

Your opinion interests us. If you have questions, suggestions, or comments complete the adjcacent form.
Or if you prefer to call (+506) 2202-5600.

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