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A BUSINESS MODEL FOR CROWDFUNDING SOLAR PV PROJECTS IN MONTERREY, MEXICO

FERNANDO FUENTES DE LA PARRA
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Reviewed and approved* by the following:

Jeffrey Brownson
Associate Professor of Energy & Mineral Engineering
Thesis Supervisor

Sarma Pisupati
Professor of Energy & Mineral Engineering
Program Chair of Energy Engineering
Honors Adviser

* Signatures are on file in the Schreyer Honors College.

ABSTRACT

The main objective of this study was to assess the possibility of a business model to crowdfund solar PV projects in Monterrey, Mexico. Factors (drivers and challenges) and actors affecting the likelihood of success of this business model were identified and analyzed. These were analyzed qualitatively and quantitatively. A literature review served as the foundations for the research. These secondary sources of data included scholarly articles and extensive reports by research and advisory firms & governmental agencies. Twenty different runs were performed using the System Advisor Model (SAM) by NREL as part of a robust solar techno-economic simulation. Sensitivity analysis of varying independent variables one at a time produced quantitative data that supported qualitative findings in the literature review. On the quantitative side, a hypothetical commercial system in Monterrey underperformed an identical one in CA primarily due to higher insurance payments (Δ= + 62%) and a less competitive cost of capital (Δ= + 52%). This lead to a higher LCOE ((Δ= + 27%) and a lower scaled-NPV (Δ= - 20%). Electricity rates were confirmed as main drivers of industry development: at an 8.5% escalation rate, the scaled-NPV of the system in Monterrey was almost 50% higher than that of the system in California. Incentives were confirmed as another main driver for growth, discerning between different combinations of investment tax credits, production tax credits, and direct cash incentives to find the optimal instruments. For example, a standalone PTC at 0% escalation rate and a standalone 30% non-taxable cash grant both outperform the 30% ITC, the current de facto incentive. This finding supports the work of renowned economists in the subject. A holistic assessment of the simulation led to the recommendation for project developers in Monterrey to place strategic focus on reducing system costs on a “dollars-per-Watt-installed” basis and on

lowering the overestimated risk perception of other actors. These actors include lending agencies, insurers, and customers. On the qualitative side, sociocultural factors present themselves as challenges to the business model proposed: the average Mexican does not actively invest, will rarely own a credit/debit card to engage in online transactions, is worried about cybersecurity, and underestimates the value of solar leases/PPAs in favor of direct ownership. All these are *secondary reasons* to why the business model presented is highly unlikely to be implemented at the time of this writing. The *main reason* is that the legal framework for equity crowdfunding is not in place. However, the quantitative study and other qualitative factors (like renewable energy education & environmental awareness in Monterrey) point at Monterrey as the ideal place to implement this business model once the equity crowdfunding industry has reached the right stage of development.

TABLE OF CONTENTS

LIST OF FIGURES v

LIST OF TABLES vi

ACKNOWLEDGEMENTS vii

INTRODUCTION 1

BACKGROUND 4

Why Monterrey? 4
What is Community Solar? 5
What is Crowdfunding? 7

RESULTS & DISCUSSION 12

Driver: Basic Solar Resource Assessment 12
Techno-Economic Analysis of Benchmark Runs #1 and #1A 13
Bottleneck: A Fundamental Access To Capital Problem 17
Challenge: Cost of Capital 21
Driver: Decreasing Solar Costs Across The Board 24
Challenge: High Risk Perception Leads to High Insurance Rates 27
Driver: Rising Grid Electricity Prices 29
Current Challenge, Future Driver: Policy, Legislation, & Incentives 33

CONCLUSION 41

Summary of Key Quantitative Findings 41
Strategic Focus: Recommendation to Key Industry Participants 44
A Business Model to Crowdfund Solar PV Projects in Monterrey, Mexico 45
Limitations & Suggested Future Work 46

EXPERIMENTAL METHODS 48

Literature Review 48
SAM Simulation 1: Basic Solar Resource Assessment 49
SAM Simulation 2: Robust Techno-Economic & Sensitivity Analysis 50
Sensitivty Analysis of Cost of Capital: Runs #1-5 50
Sensitivity Analysis of Insurance Rate & Risk Perception: Runs #1,6,7 51
Sensitivity Analysis of Electricity Price Escalation Rate: Runs #1,8 51
Sensitivity Analysis of Decreasing Solar Costs: Runs #1,1A,2A,9 52
Sensitivity Analysis of Having Different Policy Incentives: Runs #1, 11-18 52

Appendix A Table 8. Detailed listing of input parameters and their sources for techno-economic analysis using the *System Advisor Model* by NREL. 55

Appendix B Table 9. The effect of different drivers on modeled project's LCOE & NPV relative to benchmark. 59

Appendix C..60

Case Study: *Mosaic* 60

Appendix D..63

Sociocultural Context..63

Appendix E 69

Energy Policy & the Crowdfunding Industry in Mexico 69

BIBLIOGRAPHY 73

LIST OF FIGURES

Figure 1. Business success is determined by many factors & actors, both internal and external to the business in question. These are the main factors & actors affecting the success of an online crowdfunding platform for solar PV projects. 3

Figure 2. Electricity Consumption per unit GDP: Mexican States' Energy Intensity Index. ...5

Figure 3. Financing new ventures with respect to stage of venture development (x-axis) and amount of capital needed (y-axis). The risk-return profile of the investor at each stage and the funding gap are two things to note and consider..8

Figure 4. Cost of Capital: Crowdfunding vs. Other Investment Vehicles. Data is unavailable for the (hypothetical) return of Mexican equity crowdfunding so this graph is based on American figures. At 9% expected return, "crowdfunded debt would be pricier than US utility-scale wind debt financing today" [2]. 17

Figure 5. Recent global growth of crowdfunding by region. 18

Figure 6. Recent global growth of crowdfunding by type. 19

Figure 7. Geographical location of Nuevo Leon in relation to other Mexican states and the U.S. Monterrey is its capital...20

Figure 8. Sensitivity analysis of the cost of capital. The effect of an increasing interest rate in 100% debt financing on project's LCOE...22

Figure 9. Optimizing project financing to maximize utility: the effect of decreasing the lender's interest rate on NPV as a percentage of total project costs. 23

Figure 10. Swanson's Law: the cost of the photovoltaic cells needed to generate solar power falls by 20% with each doubling of global manufacturing capacity......................................25

Figure 11. The effect of varying the annual insurance rate on project LCOE and NPV. 28

Figure 12. The effect of varying the annual insurance rate as a percentage of total system cost on payback period and the present value of cumulative insurance expenses. 29

Figure 13. Electricity prices in Mexico are expected to increase after fundamental changes to the structure of CFE product of the energy reform. This graph portrays the effect of a higher electricity price escalation rate on project utility, as measured by scaled-NPV & payback period. 31

Figure 14. The effect of combining different incentives (tax & cash, investment-based & production-based) on levelized cost of energy using a PTC at a 10.09% escalation rate as a reference point. 38

Figure 15. Annual federal tax savings for 3 modeled systems in Monterrey with different government incentives: no incentives, 30% ITC, and a $0.09/kWh PTC at a 10.09% escalation rate. 39

Figure 16. Overview of Types of Literature Reviewed. 48

Figure 17. Incentive Type Grid. X-axis is the basis upon which the incentive is calculated (initial investment or energy production) while y-axis represents the means through which the benefit is granted (as a tax credit or a direct cash benefit). 53

Figure 18. Mosaic's proposed business model as a solar project crowdfunding platform. 61

Figure 19. Business to Consumer E-Commerce Sales in Mexico & the U.S., 2010-2016. Prepared by author with data from Massolution[10]. 65

LIST OF TABLES

Table 1. Top Electricity Consumption by State in Mexico..4

Table 2. Ownership, Financing, and Purchasing Methods for Distributed PV Systems. 6

Table 3. Basic solar resource comparison between Oakland (CA), Monterrey (Mexico), and Freiburg (Germany). 13

Table 4. Summary of key findings: Comparison between the two benchmark runs in California & Monterrey, Mexico. 14

Table 5. Absolute & relative effect of halving total system cost on 3 economic metrics: real LCOE, NPV, and payback period...26

Table 6. Qualitative ranking of the effect of different combinations of incentives on project 3 fundamental project finance metrics. 35

Table 7. Key drivers for enhanced development of the solar industry in Monterrey. Note that electricity cost does not apply as an LCOE driver since the LCOE calculation doesn’t take into account electricity savings...44

Appendix A Table 8. Detailed listing of input parameters and their sources for techno-economic analysis using the *System Advisor Model* by NREL. 55

Appendix B Table 9. The effect of different drivers on modeled project's LCOE & NPV relative to benchmark. 59

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INTRODUCTION

The motivation for this research work arose in 2014, when an article in The Energy Collective was published about a renewable energy project attaining the world crowdfunding (**CF**) record. In September 2013, 1700 Dutch households raised EUR 1.3 million in thirteen hours by buying shares in a cooperative wind turbine. Dutch company WindCentrale sold shares for EUR 200 each, corresponding to approximately 500 kWh of electricity per year[1]. Follow-up readings pointed out the fact that crowdfunding has enormous potential to democratize the financing of renewable energy projects, unlock *$280 billions*[2] in private wealth, and accelerate the deployment of clean energy solutions and the transition to a more sustainable future.

In recent years, the scientific community has taken specific interest in community solar. Tying an innovative form of financing such as crowdfunding to community solar development is the topic of this research study. In the U.S., community solar has been studied since 2009. On crowdfunding, Moritz and Block offer a literature review of 127 scholarly articles. Around the same time community solar was first observed under the scientific lens, “the funding of companies over the crowd [was] discussed intensively […] and explored in practice and theory”[3]. However, “studies focusing on the role of crowdfunding platforms and their optimal business models remain scarce”, affirm Moritz & Block[3].

Business success is determined by many factors and actors. An online crowdfunding platform to finance solar PV projects implies the convergence of two rapidly evolving, complex industries: the community solar industry and the online microfinance industry. Figure 1 presents the main stakeholders and market factors that will affect the success of a business with the following characteristics: an online crowdfunding platform serving as a 3rd party capital aggregator to finance solar PV projects managed by solar developers in Monterrey*. Notice in Figure 1 that some factors pertain to the crowdfunding industry while others pertain to the solar industry. More importantly, distinguish the factors that within the scope of this research can be quantitatively analyzed using the System Advisor Model (**SAM**) and those that can only be qualitatively analyzed. The latter are either qualitative in nature or too expensive and/or time consuming to quantitatively measure.

This research study is two-pronged: on one hand, it is a sensitivity analysis of those factors that can be simulated in SAM (color-coded purple in Figure 1), with the objective to categorize the importance of these factors in relation to one another. Categorization will be based on the impact to SAMs outputs when varying each individual factor. On the other hand, the quantitative portion is complemented by qualitative analysis of secondary data on factors relevant to the crowdfunding industry and the solar industry in Mexico. Both portions will be presented in parallel, with the overarching goal of providing guidance to industry participants (particularly solar developers) as to where to focus most of their energy when working towards industry development or working on individual business strategy. Additionally, the conclusion will include a holistic assessment of the possibility to implement this business model today in Monterrey. SAM was developed as a tool for the solar industry**;** therefore, most of the factors quantitatively analyzed pertain to the solar and not the crowdfunding industry.

* From here on a.k.a. **MTY** for short.

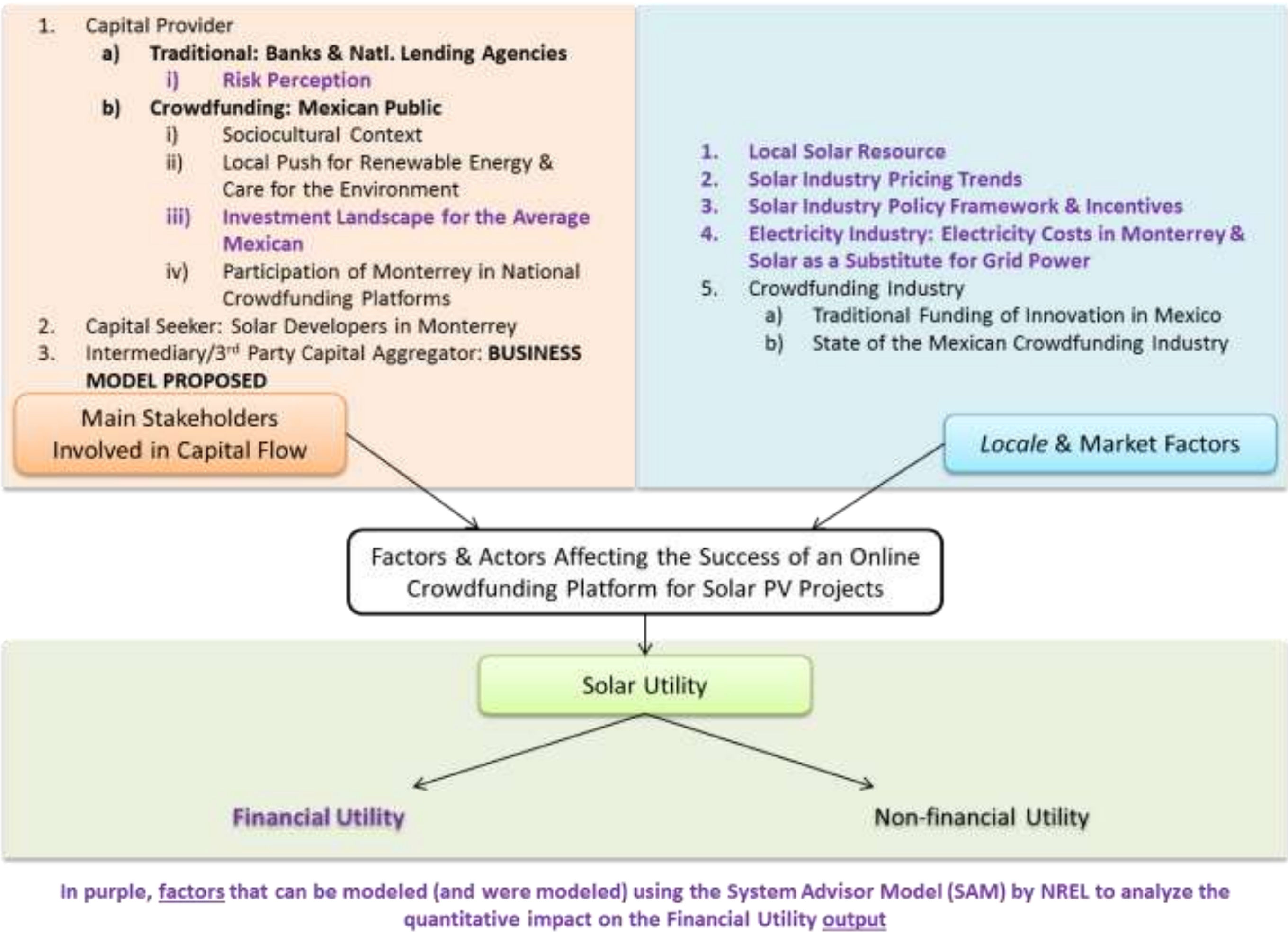

Figure 1. Business success is determined by many factors & actors, both internal and external to the business in question. These are the main factors & actors affecting the success of an online crowdfunding platform for solar PV projects.

BACKGROUND

Why Monterrey?

In Mexico, more than 2 million people lack electric service[4]. Contrastingly, Monterrey remains the nation's top electricity consumer with 16,020 GWh and 8.6% of total consumption in 2011 (see Table 1. Being the industrial capital of the nation, Figure 2 shows that Nuevo Leon's energy intensity (consumption per unit GDP) is the highest in the nation. These two pieces of data point towards the fact that attempting to accelerate solar adoption in Nuevo Leon would provide the biggest absolute benefit for the nation. The solution for 2 million Mexicans in energy poverty is rural electrification, a separate research topic in its own right. The solution to making Monterrey's electricity more sustainable includes accelerating solar penetration. This paper will explore one possibility to accelerate solar deployment in Monterrey.

Table 1. Top Electricity Consumption by State in Mexico.

Year	Estado de Mexico	Nuevo Leon	Mexico City	Jalisco
2005	15 441 616,00	13 703 088,00	13 366 503,00	10 049 967,00
2006	15 448 731,00	14 536 307,00	13 376 328,00	10 460 974,00
2007	15 648 714,00	14 719 314,00	13 550 605,00	10 751 228,00
2008	15 556 858,00	15 084 121,00	13 944 579,00	10 954 175,00
2009	15 233 258,39	14 857 775,54	14 036 849,49	11 082 661,30
2010	16 089 553,79	15 512 881,87	13 287 271,68	11 323 237,08
2011	15 489 921,11	16 019 655,49	12 569 091,19	10 992 378,69

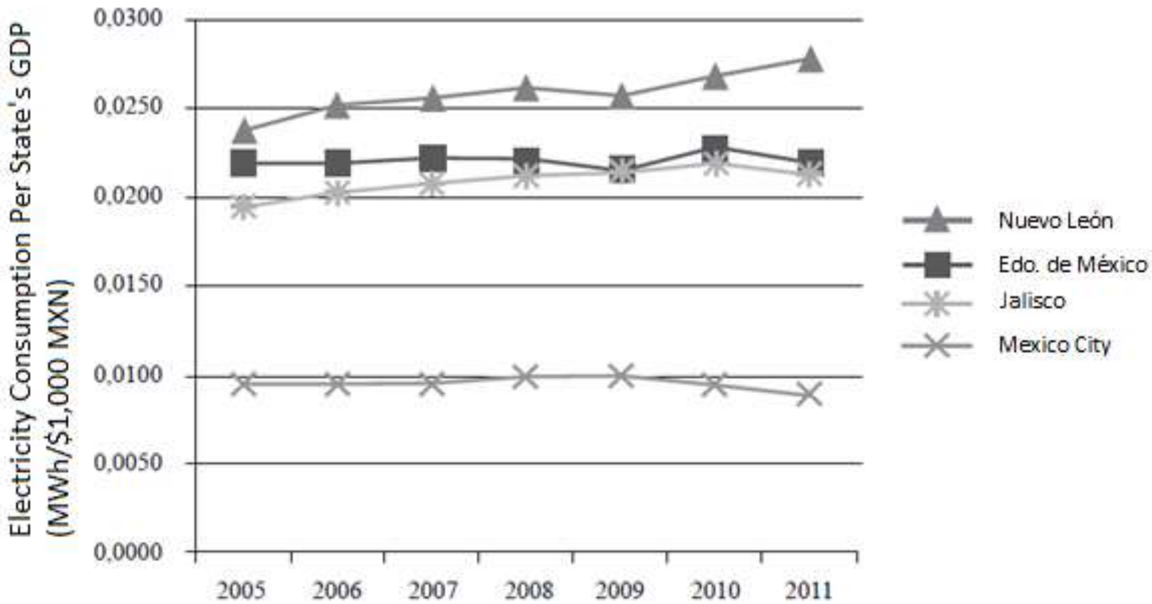

Figure 2. Electricity Consumption per unit GDP: Mexican States' Energy Intensity Index.

What is Community Solar?

Community solar models fall under the umbrella of distributed PV system models. In Table 2, onsite shared solar, offsite shared solar, and community driven financial models are all categorized as community solar. In short, community solar provides the possibility to go solar to individuals and businesses that previously could not. Highly obtrusive shading, limited roof space, lack of decision making power regarding the roof space, low credit scores leading to expensive financing, and the temporary nature of the residence are the typical obstacles prohibiting many individuals and businesses to go solar. For example, if an individual lives in a rented apartment, two main obstacles arise: she does not own the property and has no decision making power over what can be installed on the rooftop; and she will be moving out in 4 years so it doesn't make sense to install a system with a lifespan of 30 years or more. Community solar models connect community stakeholders and provide a solution for all of the aforementioned problems by allowing remote installation of the system with respect to its multiple owners. It allows for the transfer of benefits from the remote location to the community solar participant. Benefits include any or all of the following: electricity produced, revenue from electricity sold, renewable energy credits, etc. Certain states in the U.S. incentivize the development of community solar models through a variety of regulatory and policy instruments. The most important of these is *virtual net metering* (VNM). Through virtual net metering, the monthly electricity output of a community solar system is virtually apportioned between the community stakeholders in the form of an energy (kWh) credit to their utility bills. Utility companies allowing community solar customer relocation within the same territory or the transfer of ownership of community solar stakes are examples of other policies that foster the development of this business model. Community solar is a young and innovative industry experiencing rapid growth. It is under the scrutinizing eye of regulators as they (and all stakeholders involved) try to

Table 2. Ownership, Financing, and Purchasing Methods for Distributed PV Systems.

Arrangement	Location	Ownership	Number of Consumers per System	Group Purchasing
Onsite individual net metering	Onsite	Solely owned; TPO	Single	Not necessarily (community group purchasing, e.g., "solarize")
Offsite virtual net metering (VNM)	Offsite	Solely owned; TPO	Single	Not necessarily
Onsite shared solar (multi-unit buildings)	**Onsite**	**Jointly owned; TPO**	**Multiple**	**Yes**
Offsite shared solar (solar gardens)	**Offsite**	**Jointly owned; TPO**	**Multiple**	**Yes**
Community driven financial models (crowd-funding)	Offsite	Jointly owned; TPO	Energy not consumed by crowd-funding participants	Yes
"Green power" purchasing plans	Offsite	Utility; TPO	Consumption from no distinct system	Yes

understand industry dynamics and determine best practices.

What is Crowdfunding?

"Crowdfunding is part of the global democratization of personal finance spreading to the private capital markets."

– *Crowdfunding in Mexico*, Multilateral Investment Fund and Massolution, 2014

The following background on crowdfunding (CF) is mostly based on *Does Equity Crowdfunding Have Potential in the U.S.?*, a thesis in Finance by James Brandolini of the Pennsylvania State University[5] and *Collective Action and the Financing of Innovation: Evidence from Crowdfunding*, a dissertation by Dr. Sean D. Carr of the University of Virginia[6].

Crowdfunding in the simplest terms means aggregating relatively small capital contributions from thousands of individuals in the general public to meet the funding requirements of their entrepreneur of choice. Dr. Carr from the University of Virginia correctly points out that crowdfunding couldn't have taken place without the antecedent of two phenomena: *crowdsourcing* and *microfinance*. "Crowdsourcing is the "outsourcing" of tasks to the general public over the internet" says Carr[6]. An individual submits an open call to perform a task, which can be editing code, solving a specific problem, providing feedback, etc. On-boarders can do it both for compensation or voluntarily. Voluntary contributions are motivated by social and professional reasons beyond the scope of this paper. The development of the open-source software (OSS) industry, for example, enables thousands of anonymous programmers to improve lines of code for software in the public domain. Perhaps the best example of crowdsourcing is Wikipedia, an online encyclopedia created and continuously updated by thousands of individual contributors. *Microfinance* (a.k.a. micro-lending) refers to small loans made to borrowers that typically have no credit history. 2006 Nobel Peace Prize winner Muhammad Yunus and the Grameen Bank in Bangladesh transformed microfinance from a lab experiment to a global phenomenon and multibillion-dollar industry[6]. Crowdsourced microfinance would not be possible without the ubiquitous power of the internet. The internet allows anyone with connectivity, anywhere in the world to attend a virtual gathering where financial transactions and capital flow happens. Crowdfunding wouldn't be possible without a digital platform that connects capital seekers to providers. These virtual platforms rely heavily on social network platforms like Facebook, LinkedIn, and Twitter and integrate these social media hubs through application program interfaces (APIs).

The birth of crowdfunding is a natural response to market failure in the form of an access-to-capital problem. One can categorize capital based on three characteristics: 1) amount of money typically provided, 2) risk the investor is willing to undertake, and 3) return the investor expects. As seen in Figure 3, this access-to-capital problem is a funding gap in the Startup/Early Growth stage of business development. The gap exists because the amount of capital required, investment information provided, and expected return for the risk-taking investor are not in sync. A list of traditional sources of capital in increasing order of amount of money typically provided and decreasing order of risk the investor is willing to undertake shows the importance of syncing of capital requirements with the capital source:

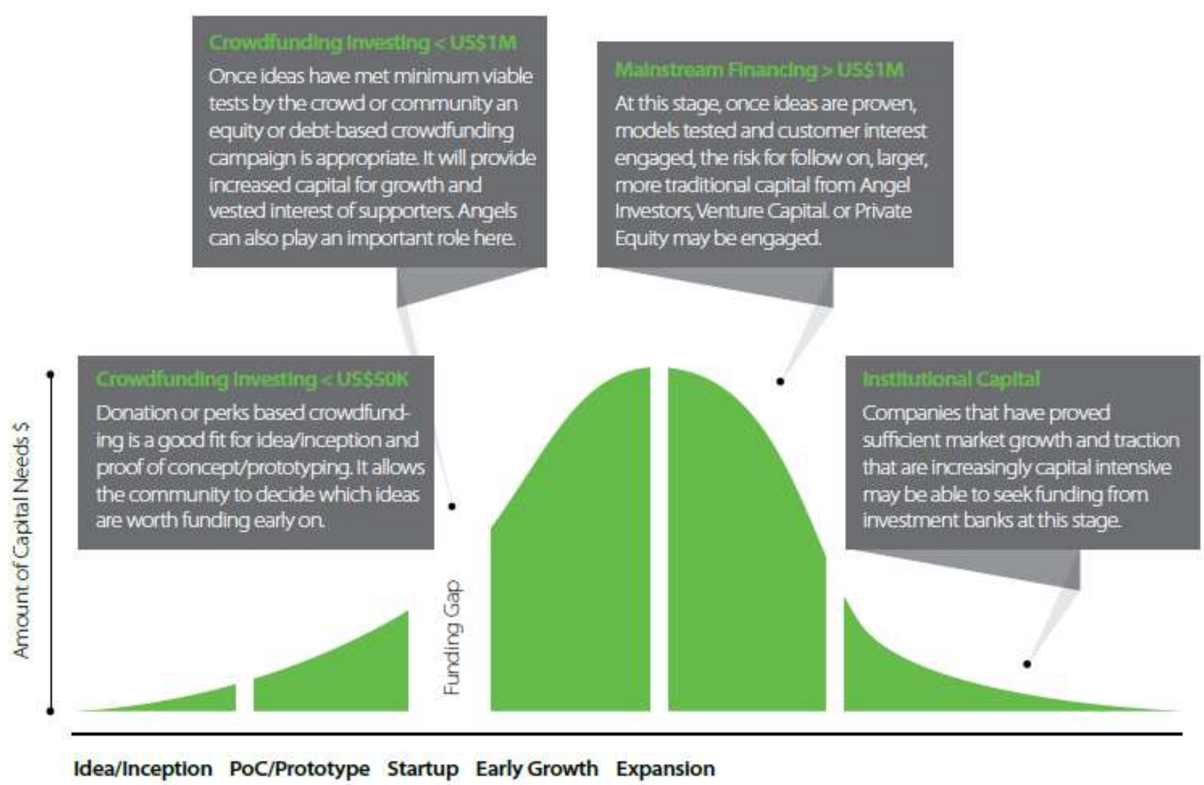

Figure 3. Financing new ventures with respect to stage of venture development (x-axis) and amount of capital needed (y-axis). The risk-return profile of the investor at each stage and the funding gap are two things to note and consider.

1. Family & friends (smallest amount and highest risk)
2. Angel investors
3. Venture capital firms
4. Commercial or retail banks
5. Institutional bank (largest amount and lowest risk)

Entrepreneurs that cannot meet the funding requirements and return expectations of these traditional sources of capital fall in the financing gap.

Before discussing the four different types of crowdfunding, some operative definitions must be presented:

1. Capital seeker: idea-rich, capital-poor entrepreneurs looking for capital to finance their ventures. In the context of this study, capital seekers are solar project developers.
2. Capital provider: according to the traditional definition, capital providers are idea-poor, capital-rich investors. In the crowdfunding definition, they typically are not capital-rich, but rather leverage the collective power of the crowd. In the traditional sense, capital providers are a small group of high net-worth individuals. In the crowdfunding sense, capital providers are a large group of individuals with varying degrees of funding capabilities.
3. Aggregator: a 3rd party that brings capital seekers and capital providers together and serves as the bridge for capital flow. Equivalent to the role of brokers in traditional capital markets.

A short description of each type of crowdfunding along with examples of online platforms operating under each of these business models follows. The naming convention is derived from the kind of incentive offered to the capital provider in each case.

Donations-based crowdfunding

No popular CF platform today is a donations-based business model. As the name implies, donations-based crowdfunding offers nothing in return other than personal satisfaction, and it differs from 0% interest lending-based CF in that in donations-based CF not even the principal amount is recovered. Capital providers participate in donations-based CF incentivized by pure philanthropy and other social motives. “Sites that do offer donations-based services tend to focus on charities and non-profit institutions.”[5]

Rewards-based or product pre-purchase crowdfunding

To incentivize investment in this kind of crowdfunding, capital seekers offer rewards in return. When these rewards take the form of the product the company is trying to commercialize the model can be called product pre-purchase CF. What other perks can entrepreneurs offer other than a product under development? A mention on the company's website, dinner with the founders, manufacturing facilities' tour, etc. Rewards-based crowdfunding surpasses any other type of CF activity in the United States. The most popular platform is Kickstarter, launched in April 2009. In March 2014, it had surpassed the $1 billion mark in amount pledged to projects through its platform. Another rewards-based platform is Indiegogo, originally launched to help independent (“Indie”) filmmakers and theater producers. It is similar in concept to Kickstarter but like any other, has its specific set of rules and regulations.

Lending-based crowdfunding

Lending-based CF is peer-to-peer (P2P) online lending. Uncollateralized loans are issued and the borrower is responsible for principal and interest repayment in a fixed amount of time. Lending Club and Prosper.com are two exemplary platforms. Interest rate determination depends on the platform. For example, Prosper.com sets a minimum rate and then allows potential lenders to bid a minimum margin they will accept. The final rate is the addition of Prosper.com's base and the lender's minimum margin. A main difference from other types of CF is that in lending-based CF, borrowers are not necessarily starting new projects or ventures. “According to a 2011 report by the U.S. General Accountability Office, 25% of borrowers on Prosper.com and 57% on Lending Club, were using P2P lending to consolidate debt or pay off credit cards.”[5] Kiva.org is a non-profit lending-based CF platform and arguably the most popular CF platform in the world. Kiva.org doesn't collect fees or interest on the loans it facilitates. Lenders to Kiva.org agree to donate any accumulated interest to fund other Kiva projects and only recover their principal, resulting in 0% interest loans and revolving funds on Kiva’s side of the equation.

Equity crowdfunding

Equity CF offers capital providers equity ownership and rights to future cash flows in return. It is the startup company equivalent of buying stock of publicly-traded, established corporations. This type of crowdfunding is the least developed but also one promising enormous growth in the medium to long term future. Equity CF presents many risks and challenges. For this reason, it is currently outside of the legal framework in most countries around the world, including the United States. However, equity crowdfunding business models have been operating in certain European countries for about 10 years.

RESULTS & DISCUSSION

Driver: Basic Solar Resource Assessment

It is possible that a specific location is not adequate for solar power production. Extreme examples serve well to prove a point: beyond the Arctic Circle, a solar system does not satisfy the needs of most stakeholders. Its non-dispatchable nature is exacerbated: exactly at the poles, the Sun is completely below the horizon for approximately 179 days every year. Devising a business model for solar project development requires a basic solar resource assessment. The solar resource of Monterrey was compared to that of two places relevant to this study. One location is Oakland, CA, city where Mosaic, an online platform aiming to crowdfund solar PV project, is headquartered and operating since 2011 (refer to Appendix C). The second location is Freiburg, Germany, coined the 'solar capital' of the world. Freiburg is home to the Fraunhofer Institute for Solar Energy Systems ISE, the largest solar applied research campus in the world. The Fraunhofer Institute covers an area of 27,000 m^2 and "conducts research on the technology needed to supply energy efficiently and on an environmentally sound basis in industrialized, threshold, and developing countries."[7] Germany is the world's solar powerhouse: in 2012, it ranked the top solar country in terms of solar power capacity (MW) per capita in the entire world. It also ranked second that year for new installed capacity per capita, just behind Bulgaria[8]. Comparing the solar resource in Monterrey against the best shall prove to be illustrating. Table 3presents the results of the simulation.

As seen in Table 3, Monterrey is a prime location for solar: the dummy system in Monterrey produced 92% of the energy of the system in California. In comparison, the system in the solar capital of the world (Freiburg) produced 62% of the energy relative to the system in California. Unquestionably, solar resource is not a prohibiting factor for successful solar development in Monterrey, Mexico.

Table 3. Basic solar resource comparison between Oakland (CA), Monterrey (Mexico), and Freiburg (Germany).

	Oakland (Benchmark)	Monterrey	Freiburg	Monterrey rel. to benchmark	Freiburg rel. to benchmark
Annual energy [kWh]	7041	6507	4350	92%	62%
Capacity factor (%)	17.00%	15.70%	10.50%	92%	62%
First year kWhAC/kWDC	1487	1374	919	92%	62%
Performance ratio	0.83	0.79	0.81	95%	98%

However, note that the performance ratio of Freiburg is higher than that in Monterrey. As defined in SAMs documentation, the performance ratio (**PR**) is a measure of a system's annual output compared to its nameplate capacity, *taking into account the solar resource at the system's location* [9]. By taking into account Germany's poorer solar resource, its PR turns out higher than that of Monterrey.

$$PR = \frac{Annual\,Energy\,(kWh)}{Input\,Radiation\,(kWh) * Module\,Efficiency\,(\%)} \qquad \textbf{Equation 1}$$

Where Input Radiation is the product of the total radiation incident on the array (after accounting for shading and soiling) and the total area of modules.

Techno-Economic Analysis of Benchmark Runs #1 and #1A

Table **4** summarizes the comparison between both benchmark runs, using the outputs for Monterrey as the basis of comparison:

Table 4. Summary of key findings: Comparison between the two benchmark runs in California & Monterrey, Mexico.

COLOR KEY: MTY performs worse than CA			
COLOR KEY: MTY performs better than CA	BENCHMARK		
SUMMARY	**CA**	**MTY**	**CA/MTY (%)**
Annual energy (kWh)	393,451	359,255	110%
Capacity factor (%)	18.00%	16.50%	109%
Performance ratio	0.87	0.83	105%
Levelized cost (real) (¢/kWh)	8.98	12.35	73%
Δ MTY rel. to CA = %MTY - %CA	N/A	N/A	+27%
Net savings / electricity cost without system (%)	20%	19%	105%
Net savings / annual energy ($/kWh)	$ 0.2953	$ 0.2110	N/A
Net present value (NPV) ($)	$664,317	$377,295	N/A
Initial cost ($)	$677,558	$460,477	147%
NPV as % of Total Installed Cost (%)	98%	82%	120%
Δ MTY rel. to CA = %MTY - %CA	N/A	N/A	-20%
Simple Payback Period (yrs)	5.9	6.4	92%
Annual POA total radiation (nominal) (kWh)	3.01E+06	2.88E+06	105%
global horizontal irradiance (kWh/m^2)	1.69E+06	1.73E+06	98%
PV of insurance and property tax ($)	$ 78,995.80	$ 210,033.00	38%
Δ MTY rel. to CA = %MTY - %CA	N/A	N/A	+62%

A *techno*-economic analysis compares both systems on a *technical* basis, an *economic* basis, and an *integrative* basis. In

Table **4** the five solely *technical* outputs are annual energy output, capacity factor, performance ratio, annual POA radiation (E_t), and global horizontal irradiance (GHI). In 4 out of the 5 outputs, CA outperforms MTY by 5%-10%. In the 5th output, annual GHI, Monterrey receives 2% more energy every year. Typically, a higher GHI results in a correspondingly higher POA radiation (E_t). That is not the case here. This depends on several factors like the site's latitude, the array orientation, irradiance components (direct and diffuse), ground surface reflectivity, and shading. Since reflectivity and shading are controlled in this experiment, the lower than expected E_t for MTY should be explained by the other 3 factors. The possibility of suboptimal tilt (β) was ruled out by running the MTY model at $\beta_{optimal}$ + 10° and $\beta_{optimal}$ - 10°. No significant improvement resulted. Therefore, lower than expected POA radiation for MTY is due to the particular path the sun follows throughout the year with respect to that location and/or irradiance components and their interrelationship. An industry parameter that describes the interrelation of irradiance components is the daily *clearness index* (K_T) throughout the year. It factors in the nature of the sky as a dynamic cover with its air mass composition changing over time, most visibly in the form of clouds. Simply put, CA outperforms MTY in the technical arena not because of higher insolation but because of clearer days (on average) throughout the year.

There are four solely *economic* outputs in

Table **4**: net savings over electricity cost, simple payback, present value of insurance and property tax, and weighted average cost of capital (WACC). CA outperforms MTY in the 4 *economic* outputs. Net savings over electricity cost and simple payback are proportional to annual energy output, where CA amounted to 10% more. However, it is not a direct proportionality and other factors like electricity costs and incentives have an influence. Else, this 10% lead in annual energy produced would directly translate into a 10% lead in net savings over electricity cost. As seen in

Table **4**, CA's net savings over electricity cost are only 5% better than MTY's. The present value of insurance and property tax is listed to show how influential is the risk perception of solar technologies on project economics, a topic of discussion in a later section. This results in the present value of insurance payments in MTY being 62% higher than those in CA even though the initial system cost is 47% lower. Finally, the weighted average cost of capital (WACC) in CA is only 48% that of MTY due to three factors: competitive financing (7.5% interest rate), lower inflation rate (2.5% in CA vs. 4.8% in MTY), and the fact that deals in MTY were modeled as cash-only resulting in a WACC solely depending on inflation rate and real discount rate.

The *integrative techno-economic* outputs in

Table **4** are real levelized cost of energy (LCOE) and net present value (NPV) as a percentage of total system cost. The real LCOE is the inflation-adjusted present value of project costs per kilowatt-hour of electricity generated by the system over the period of analysis[9]. It is an *integrative* metric both cash flows (economic) and energy production (technical) are included in its calculation. Equation 2 is the formula to calculate real LCOE, which is more appropriate than nominal LCOE for long (N = 20 years) periods of analysis and more widely used in the solar PV industry. The main difference between LCOE and NPV is that "LCOE is a measure of the cost of installing and operating the system without accounting for benefits like the value of electricity purchases avoided by the system"[9]. The ratio between NPV and total system cost is analyzed as opposed to just NPV to permit "apples to apples" comparison of projects differing in size and total capital required.

$$LCOE_{real} = \frac{-C_0 - \frac{\sum_{n=1}^{N} C_n}{(1 - d_{nominal})^n}}{\frac{\sum_{n=1}^{N} Q_n}{(1 - d_{real})^n}}$$

Equation 2

Q_n (kWh)	Electricity generated by the system in year *n*. Based on weather data & system performance parameters.
N	Analysis period in years.
C_0	The project's initial cost.
C_n	The annual project costs in Year *n*.
d_{real}	The real discount rate. This is the discount rate without inflation.
$d_{nominal}$	The nominal discount rate that accounts for inflation.

The LCOE of the system in CA is almost a third lower than that of the system in MTY. Partly as a consequence of this, the NPV in CA amounts to 98% of total system cost vs. 82% for the project in MTY. CA outperforms MTY by 16% on the basis of scaled-NPV.

After a techno-economic comparison of the benchmark cases, it is evident that the project in CA is more favorable despite its higher initial cost. The major difference seen in

Table **4** between both projects is insurance payments (ΔMTY Rel. To CA= + 62%). That and more expensive cost of capital (ΔMTY rel. to CA= + 52%) both lead to differing LCOEs (ΔMTY rel. to CA= + 27%) and *scaled*-NPV (ΔMTY rel. to CA = -20%). Therefore, the following sections show the results of sensitivity analyses of each of these dominant factors driving solar.

Bottleneck: A Fundamental Access To Capital Problem

Mexico is a developing nation. For economic and cultural reasons, solar energy generation is still categorized as innovation in Mexico. Access to capital presents itself as the bottleneck preventing accelerated development of the industry. Almost 80% of the capital raised by SMEs comes from personal savings and family loans. These are limited sources of capital and do not require the due diligence to ensure success other financers submit businesses to. For these and other reasons, relying on family and friends is problematic within the framework of new venture finance.

Recalling the funding gap from the "What is Crowdfunding?" background section (p.7), evidence across CF platforms places crowdfunding as a natural solution to fill this gap because the amount of capital needed per venture and the return expected by the capital provider match those of the funding gap. Figure 4 presents how the 5%-9% expected return of American equity crowdfunding fits in with the return of other investment instruments.

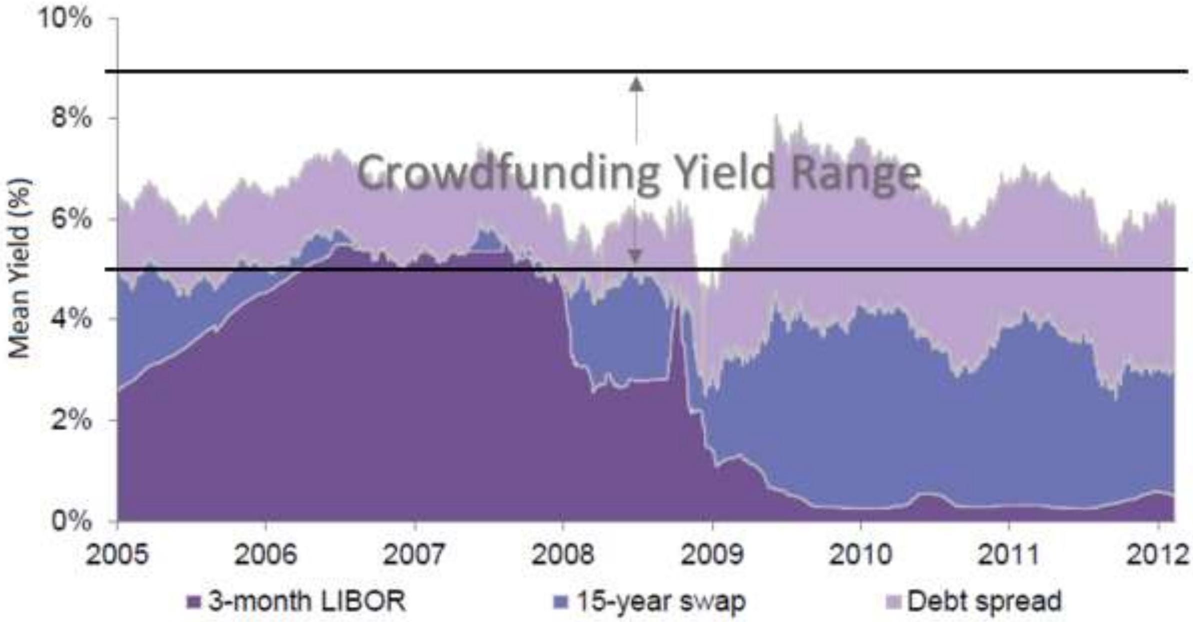

Figure 4. Cost of Capital: Crowdfunding vs. Other Investment Vehicles. Data is unavailable for the (hypothetical) return of Mexican equity crowdfunding so this graph is based on American figures. At 9% expected return, "crowdfunded debt would be pricier than US utility-scale wind debt financing today" [2].

The natural fit in the funding gap is the reason why the crowdfunding industry has been experiencing growth up to 80% in recent years (refer to Figure 5). Different types of crowdfunding are growing at different rates, based on the relative complexity of each type: from straightforward rewards-based crowdfunding (a $1.4 billion market) to equity crowdfunding with complex legal and regulatory implications (more modest 30% annual growth) (Figure 6).

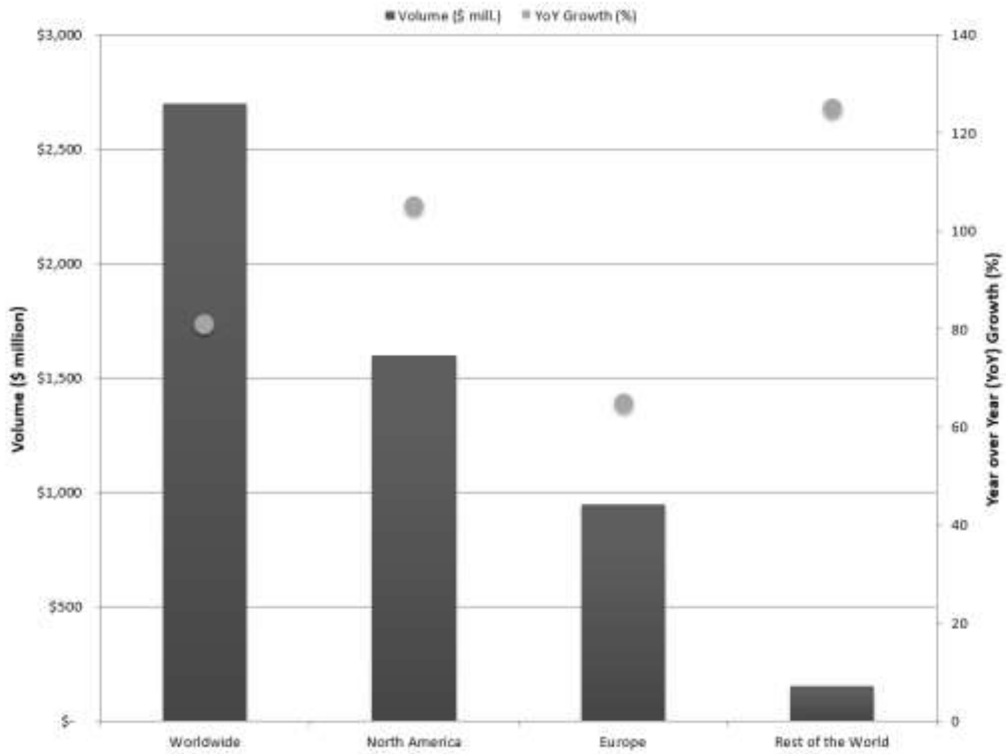

Figure 5. Recent global growth of crowdfunding by region.

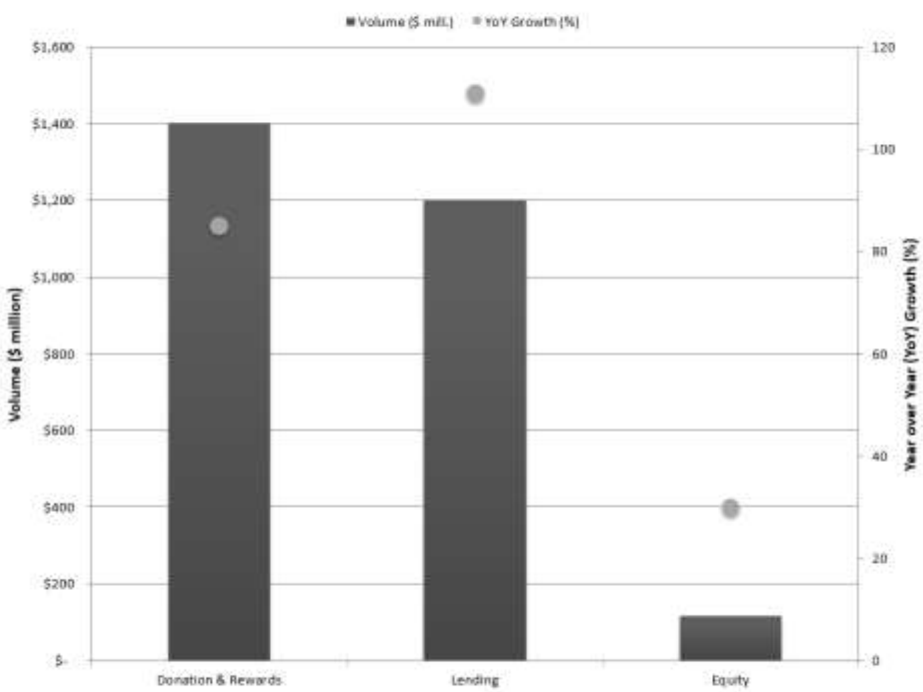

Figure 6. Recent global growth of crowdfunding by type.

So why specifically crowdfund solar energy ventures in Mexico if filling the capital gap benefits all industries with a solid entrepreneurial base? Because renewable energy financing is nowadays a niche market: big name banks and tax equity players are among the few injecting capital into renewable energy and they leverage this to their advantage in the negotiations. This results in more expensive capital, longer project development timelines, and a bottleneck preventing even faster deployment of renewable energy technologies. In addition to this, the timing is right: in its 'industry-agnostic' report on crowdfunding in Mexico, Massolution identifies renewable energy as a perfect fit for crowdfunding innovation: "The recent opening of investment opportunities in the (formerly state-controlled) energy markets will require capital to take advantage of growth opportunities"[10]

If the people of Nuevo Leon are comfortable with crowdfunding all kinds of ventures, this comes as an advantage to crowdfund solar projects in particular. Along those lines, research was done on how active were the people of Nuevo Leon in the national crowdfunding industry. *Fondeadora.mx*, the leading crowdfunding platform, provided some answers. 1,870 people from the state of Nuevo Leon have invested on average $600 MXN (est. $39 USD) per person in their platform. As capital seekers, entrepreneurs from Nuevo Leon have pitched 14 projects of which 9 met their funding goals and channeled around $700,000 MXN (est. $45,650 USD) towards their ventures. As capital providers, the in-state community has invested $450,000 MXN (est. $29,350) through *Fondeadora.mx*. The amount raised by entrepreneurs in Monterrey plus the amount pledged by entrepreneurs from Monterrey ($1,150,000) represents around 3% of the grand total invested through the platform. Eduardo Suarez from *Fondeadora.mx* comments that although the people from Monterrey are much familiarized with crowdfunding, they turn their eyes and their money to platforms in the U.S. given the city's proximity to the United States (see Figure 7). Capital flow from wealthy Mexicans to the U.S. is not insignificant: $27.9 billion USD in 2012, up 11% in relation to 2011[10]. On another hand, adds Suarez "the northern part of the country has not been our focus. So whatever has been raised in Nuevo Leon up to date has been organic growth"[11].

Figure 7. Geographical location of Nuevo Leon in relation to other Mexican states and the U.S. Monterrey is its capital.

Challenge: Cost of Capital

As the name implies, *weighed average cost of capital* (WACC) is the average cost of financing a project based on the expected returns of the different sources of capital (equity investors, lending banks, *crowdfunders*). The WACC is the minimum return that the project must earn to cover financing costs[9]. The tax shield that results from financing with debt (tax-deductible interest) as opposed to equity is included in WACC calculations. In these simulations, the project is financed either with 100% equity or 100% debt. For 100% debt projects, WACC is lower than the interest rate set by the lender due to the tax shield. Equation 3 and Equation 4 show how SAM calculates WACC from other financial parameters:

$$\text{WACC} = \textit{Real Discount Rate} \times (100\% - \textit{Debt Fraction}) + (100\% - \textit{Effective Tax Rate}) \times \textit{Loan Rate} \times \textit{Debt Fraction} \qquad \textbf{Equation 3}$$

$$\textit{Effective Tax Rate} = \textit{Federal Tax Rate} \times (100\% - \textit{State Tax Rate}) + \textit{State Tax Rate} \qquad \textbf{Equation 4}$$

In the case of Monterrey, the effective tax rate is fixed at 30%.

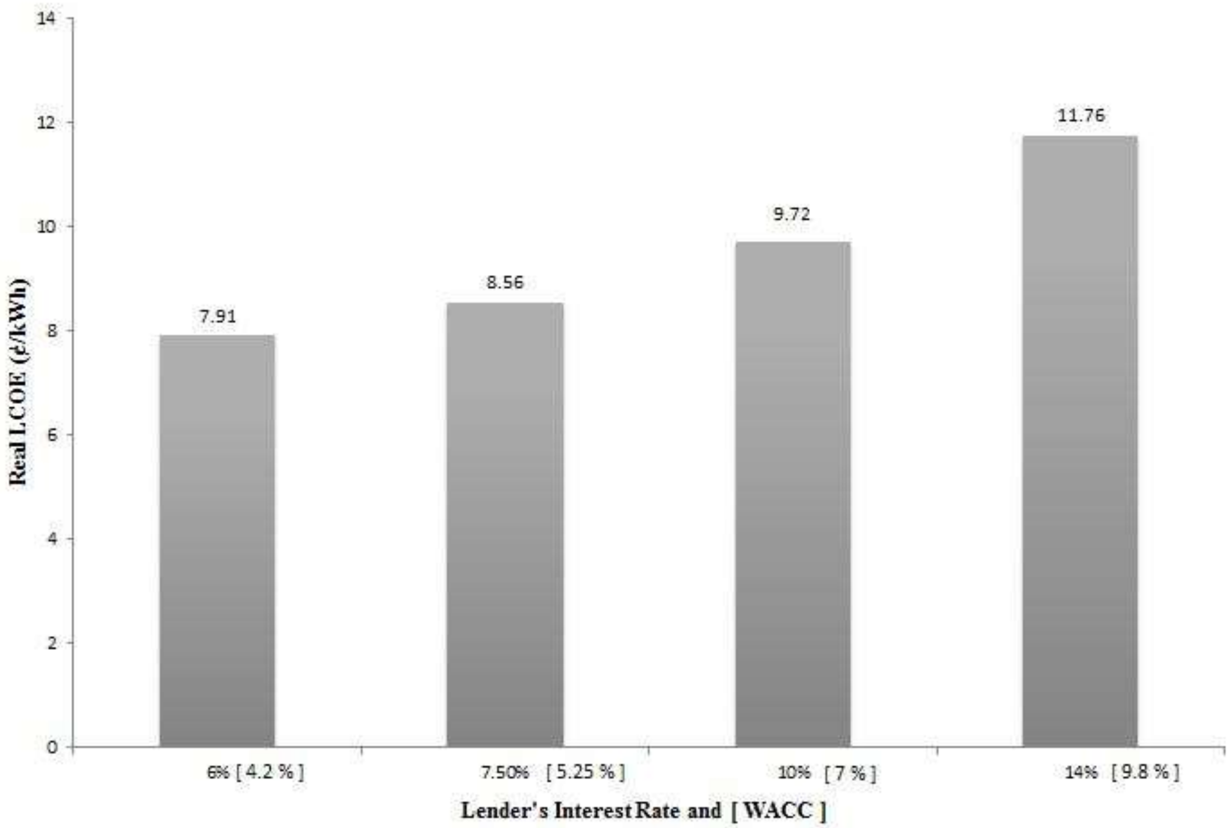

Figure 8. Sensitivity analysis of the cost of capital. The effect of an increasing interest rate in 100% debt financing on project's LCOE.

Figure 8 shows the effect of an increasing cost of capital on levelized cost of energy (LCOE). The interest rates chosen for the model represent the rate of return of American equity crowdfunding as per Figure 4: 6% is the lower bound of *crowdfunded* debt's yield, 10% is the upper bound, 7.5% equals the rate of the benchmark system in California, and 14% is that suggested by Mexican solar industry participant Álvaro Briceño[12].

Figure 9 shows the progression of increasing NPV as a percentage of total project costs as the lender's interest rate decreases. The first conclusion drawn is that debt financing as opposed to all-equity deals enhances project profitability given the conditions in place. Even a 14% interest rate has a higher NPV than a 100% equity cash deal. Nonetheless, cash deals are common place in Monterrey[12]. Customers under the DAC electricity rate can afford upfront payment of solar systems and usually chose ownership over long term financing or leasing. DAC is more thoroughly discussed in the section titled "Driver: Rising Grid Electricity Prices". For reasons as to why customers prefer ownership over hassle-free leases or PPAs, refer to Appendix D.

A second conclusion is that even if *crowdfunding* lenders ask for the upper bound 9% yield (plus

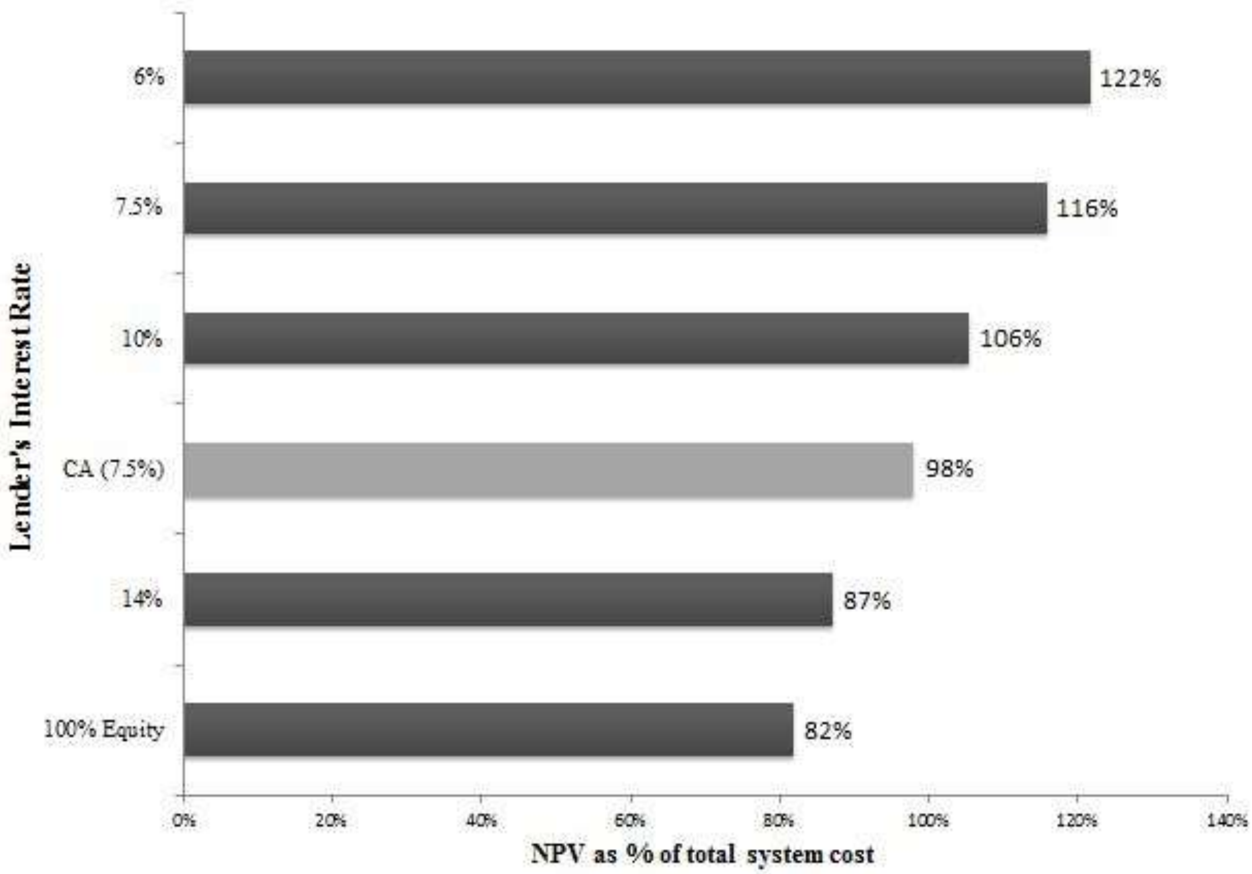

Figure 9. Optimizing project financing to maximize utility: the effect of decreasing the lender's interest rate on NPV as a percentage of total project costs.

1% transactional costs = 10% interest rate), the project in MTY outperforms that in CA as shown by *scaled*-NPV outputs[†]. Setting the interest for MTY equal to the lower bound *crowdfunding* yield (6%) outperforms the benchmark in CA by almost 25%. This shows the importance of interest rates compared to other influencing parameters with respect to solar utility. One final thing to point out is that in real

[†] From here on, scaled-NPV will refer to the NPV over total system cost expressed as a percentage.

scenarios utility maximization comes at an optimal combination of equity and debt, not at the all-equity and all-debt extremes modeled in this experiment.

Driver: Decreasing Solar Costs Across The Board

In an interview with Adam James from GreenTech Media, he mentioned that the two main factors that would promote accelerated solar adoption were 1) rising grid electricity prices and 2) the decrease in the cost of installing solar. Figure 10 is the photovoltaic industry's equivalent to Moore's Law in the computer technology industry. Moore's law states that the size of transistors halves every 18 months with a proportional cost reduction. Comparatively, Swanson's law, named after Richard Swanson, the founder of SunPower, states that the cost of PV cells falls by 20% with each doubling of global manufacturing capacity. Industry has yet to falsify Swanson's law[13–16].

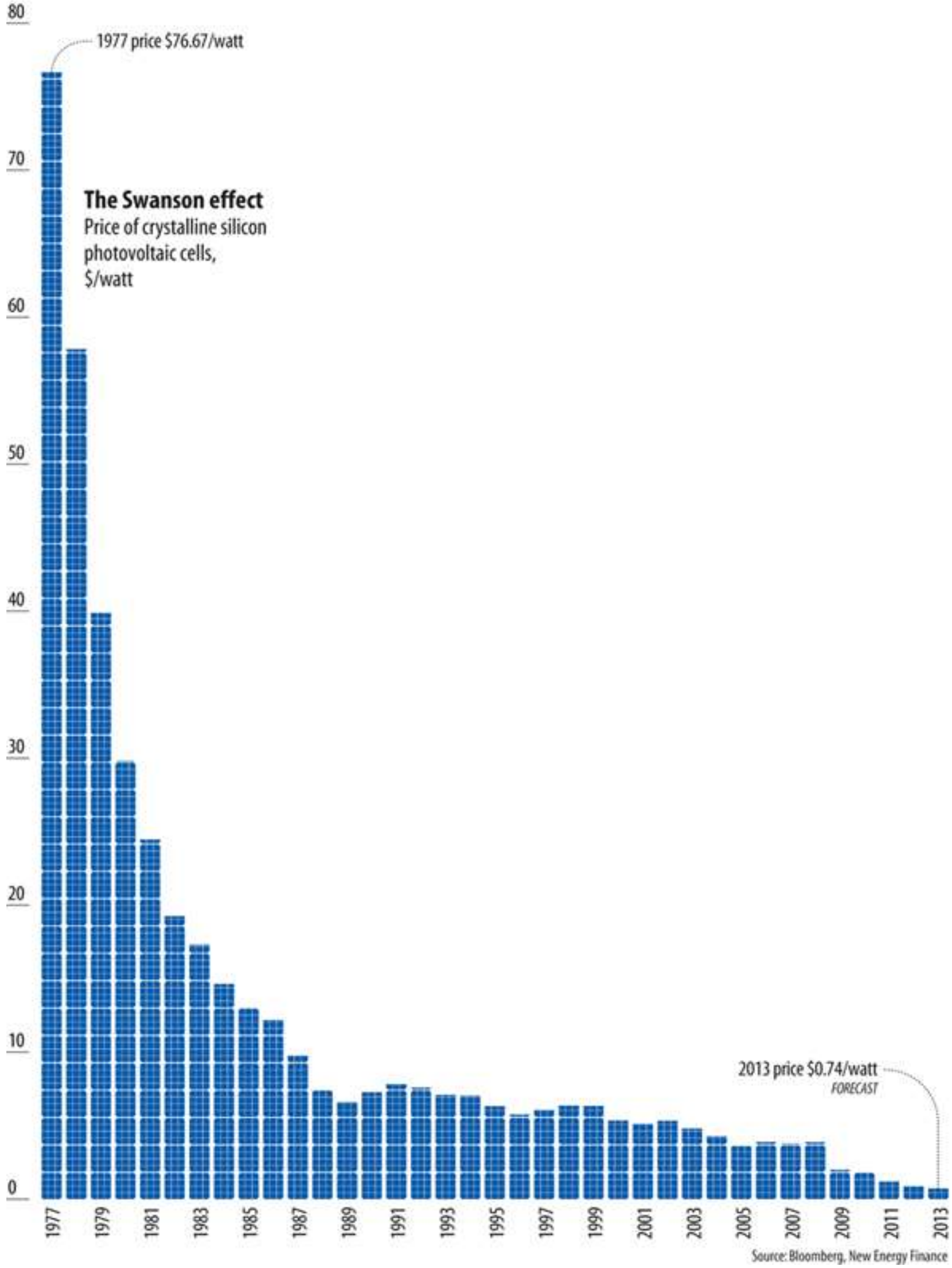

Figure 10. Swanson's Law: the cost of the photovoltaic cells needed to generate solar power falls by 20% with each doubling of global manufacturing capacity.

That said, modeling the effect of halving system costs for the benchmark systems in Monterrey and California is modeling a realistic scenario for the next decade. “Grid parity”, beyond being a buzzword, is becoming a reality in more and more regions around the world. Table 5 summarizes the results of installation cost-related runs #1,1A,2A, & 9.

Table 5. Absolute & relative effect of halving total system cost on 3 economic metrics: real LCOE, NPV, and payback period.

	Initial cost	Real LCOE (¢/kWh)	% Rel. To Benchmark(*)	NPV	% Rel. To Benchmark(*)	NPV/original initial cost	NPV/total system cost	Payback Period (yrs)
CA(*)	$677,558	8.98		$664,317		98%	98%	5.9
CA HALF-PRICE	$339,822	4.96	55%	$846,179	127%	125%	249%	**3.1**
MTY(*)	$460,477	12.35		$377,295		82%	82%	6.4
MTY HALF-PRICE	$230,238	6.66	54%	$612,085	162%	133%	266%	**3.3**

The first thing to point out in Table 5 is that neither LCOE nor payback are directly proportional to system costs. The effect of system costs reduction on both metrics is one of diminishing returns. That is, the more costs are driven downward the smaller the benefit per unit of change as reflected on LCOE and payback period. Cost reduction from 100% to 99% of benchmark cost has a bigger impact on these metrics than cost reduction from 25% to 24%. The larger increase in NPV in MTY versus CA (162% rel. to benchmark vs. 127%) signals that the economics of the system in MTY are largely driven by low costs and not other factors like incentives, competitive financing, and electricity prices. Additionally, upfront cash payment of the system in MTY is driving this higher relative improvement. Just as the financial burden is augmented for an individual paying for a product upfront compared to one paying through long term financing, the benefit of a 50% cost reduction is augmented for the individual paying upfront. In Table 5, the NPV over original cost ratio and NPV over new total system cost ratio are just different ways to represent this effect.

Challenge: High Risk Perception Leads to High Insurance Rates

Whenever banks provide capital, it usually comes with a high interest rate due to a lack of knowledge about solar technologies. Sometimes, the ignorance is severe: Briceño from Powerstein tells of a time the insurance company was offering them equipment insurance at more expensive terms than typical automobile insurance[12]. How can an inanimate commodity like a solar panel be more risky than a constantly moving car? Especially with car accidents being in the top 10 global leading causes of death[17]. Developers face the same issues with national lending companies.

Figure 11 presents a scatter plot of the effect of varying the annual insurance rate on levelized cost of energy and net present value in Monterrey. NPV is used as opposed to scaled-NPV because analysis is only performed on the system in Monterrey and total system costs are a constant $460,477. As insurance rate increases, energy produced by the system becomes more expensive (increasing LCOE) and the NPV of the project decreases. Which metric does insurance rate impact the most? This is inconclusive. When going from 1% to 4% insurance rate, LCOE increases by 28% and NPV decreases by only 23%. However, when modeling a change from 4% to 7.35%, NPV decreases by 33% and LCOE increases by only 24%. From one extreme to the other, 1% to 7.35%, LCOE takes a bigger hit: it increases by 58% while NPV only decreases by 48%.

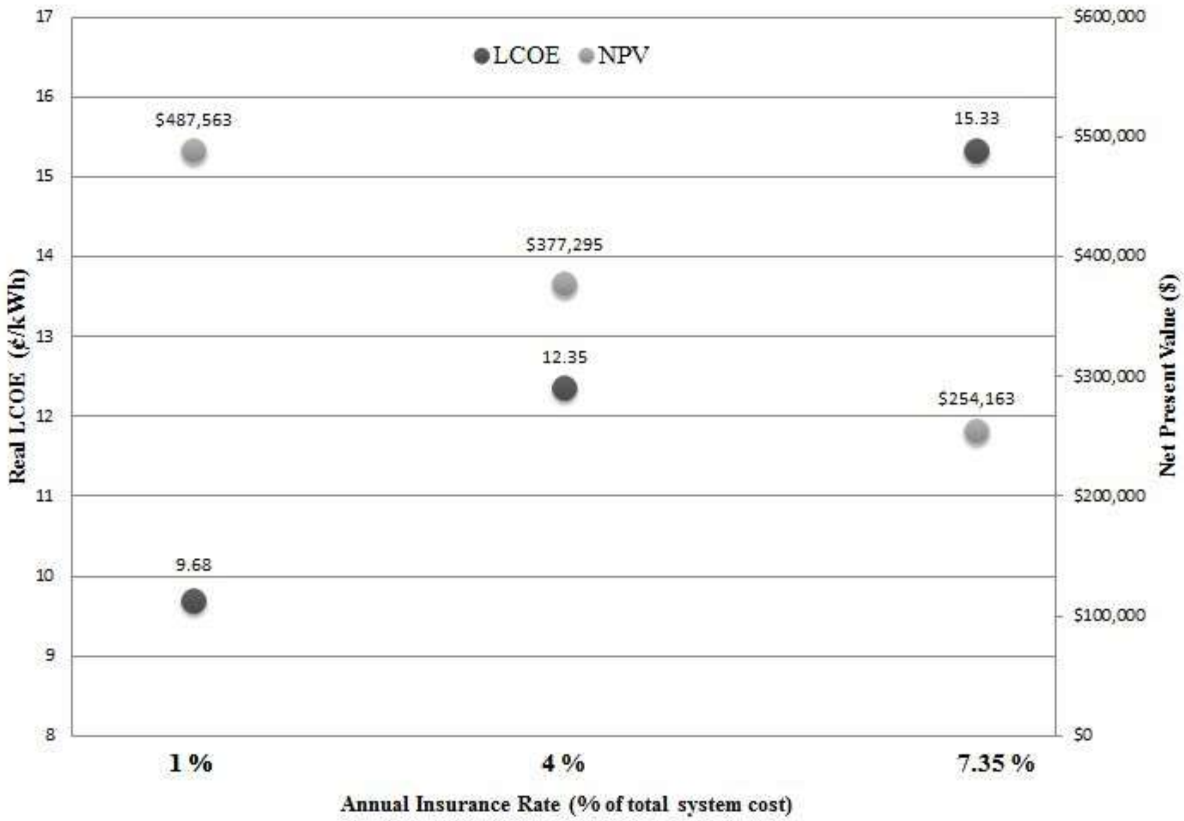

Figure 11. The effect of varying the annual insurance rate on project LCOE and NPV.

One way to reduce the simple payback period is by decreasing operating expenses like annual insurance payments. In Figure 12 one can see the effect of higher annual insurance payments on the project's simple payback period and the present value of this cumulative expense. Intuitively, payback period increases as the insurance rate rises. More in-depth analysis, of interest to project developers in Monterrey, is the fact that in the range studied (1% ~ 8%), a 1% increase in insurance rate results in the payback period extending approximately 4 more months into the future. Similarly, at a discount rate of 5.5% and an inflation rate of 4.8% in Mexico, a 1% increase in insurance rate doubles the present value of cumulative insurance expenses. Another perspective of the severity of the issue is that the ratio of PV of insurance payments over total system cost for CA amounts to **12% vs. 46%** for MTY.

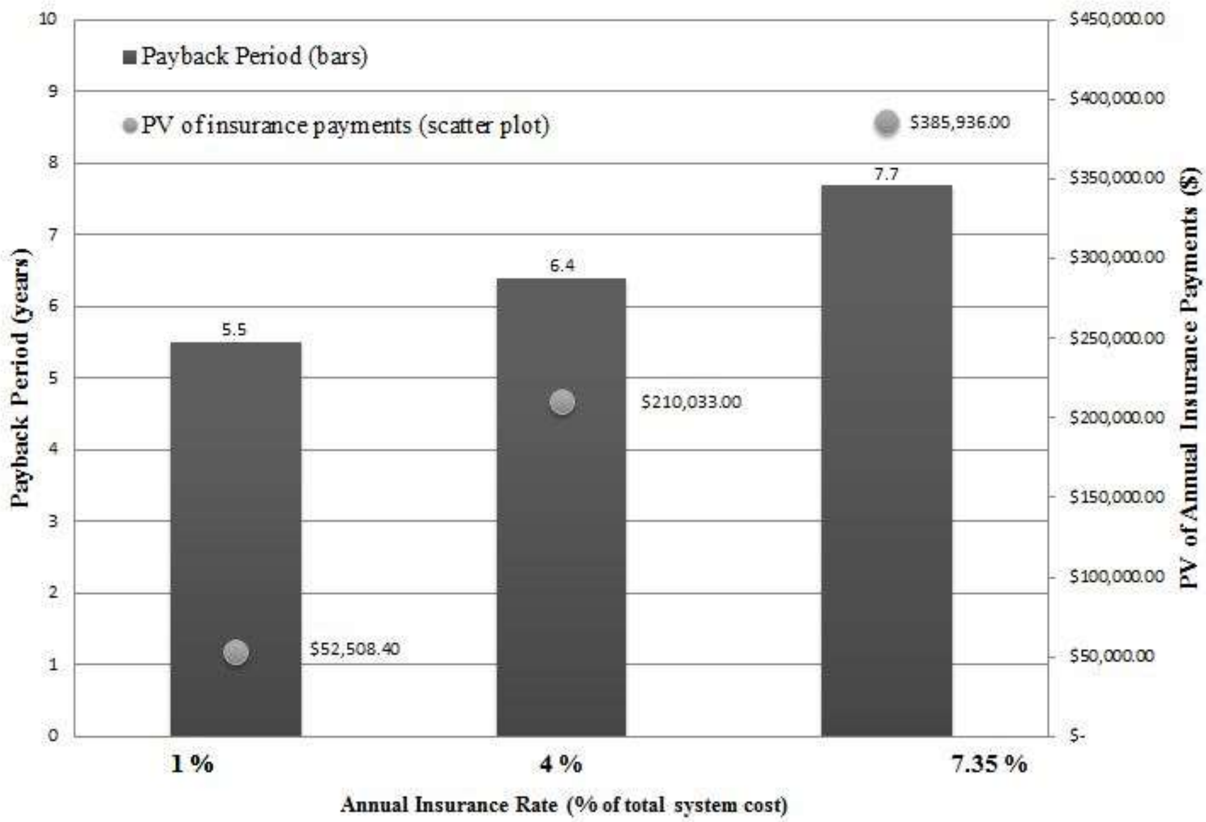

Figure 12. The effect of varying the annual insurance rate as a percentage of total system cost on payback period and the present value of cumulative insurance expenses.

Driver: Rising Grid Electricity Prices

Solar engineering researcher Dr. Jeffrey R.S. Brownson, senior analyst at GreenTech Media Adam James, and Director of Commercialization at Powerstein Alvaro Briceño all agree that the main driver for solar adoption nowadays is electricity costs. The Metropolitan Area of Monterrey is the 3rd largest city in the country. According to the 2011 national census, the state of Nuevo Leon has 4.7 million inhabitants and 1.2 million households[18]. An estimated 16,000 households in the city pay the residential high consumption electricity rate, DAC[12]. These homeowners have been the target customer for the local residential solar industry, which doubles in size every year. Why target DAC customers so aggressively? Because they are paying between $0.20-$0.30 USD per kWh, depending on seasonal pricing and the climate region they are located in. All residential rates with the exception of DAC are subsidized. Named from 1A to 1E, 1E is the most subsidized one; in some places and during certain times of the year, 1A & 1B are paying more than the average U.S. residential electricity price just like DAC[19].

The benchmark escalation rate of 5.29% per year used in the simulation was extracted from the national Energy Information System (SIE) run by the Mexican Department of Energy (SENER). Adam James, Álvaro Briceño, and many experts agree that the energy reform will cause electricity prices to rise in the next 5 years[12,19]. The reform was accompanied by political propaganda to convince the general population to believe that electricity prices were going to decrease in the near term due to the structural changes in the energy and electricity markets[19]. This disincentivizes people to look at solar alternatives. Experts at GreenTech Media and other research hubs however, publicly report prices will increase. Their explanation is logically sound[19]:

1. Historically, some retail electricity prices have been heavily subsidized. This has caused two things: other customer classes (commercial, DAC, etc.) to offset this degree of subsidization and Comisión Federal de Electricidad (**CFE)** to lose money for decades past. CFE was the state-owned, vertically integrated utility up until the reform.
2. The old state-owned CFE can lose money. However after the reform, CFE will have to be financially viable on its own. The company has to figure out a way to be profitable, and the only viable solution identified by experts is to increase prices.
3. On top of that, CFE has to meet very high pension obligations in coming years. It has to find a way to make even more money.

CFE cannot keep the subsidies and make money at the same time. It has to raise and restructure the way their retail rates look. Thus, Briceño proposed an 8.5% escalation rate. In Monterrey, the modeled annual load of 1,796,270 kWh resembles that of an average commercial building as found by researchers at NREL when studying *community solar* models[20]. Corresponding to this size, electricity costs without a solar system for year 1 are $399,146. A constant 13.3% year-over-year increase accounts for the inflation rate (4.8%) as well as the escalation rate (8.5%). At this 13.3% YoY growth, electricity costs amount to $4,280,550 in year 20. This shows the prominent role of electricity price escalation rates and inflation rates when the analysis includes cash flows 20+ years into the future.

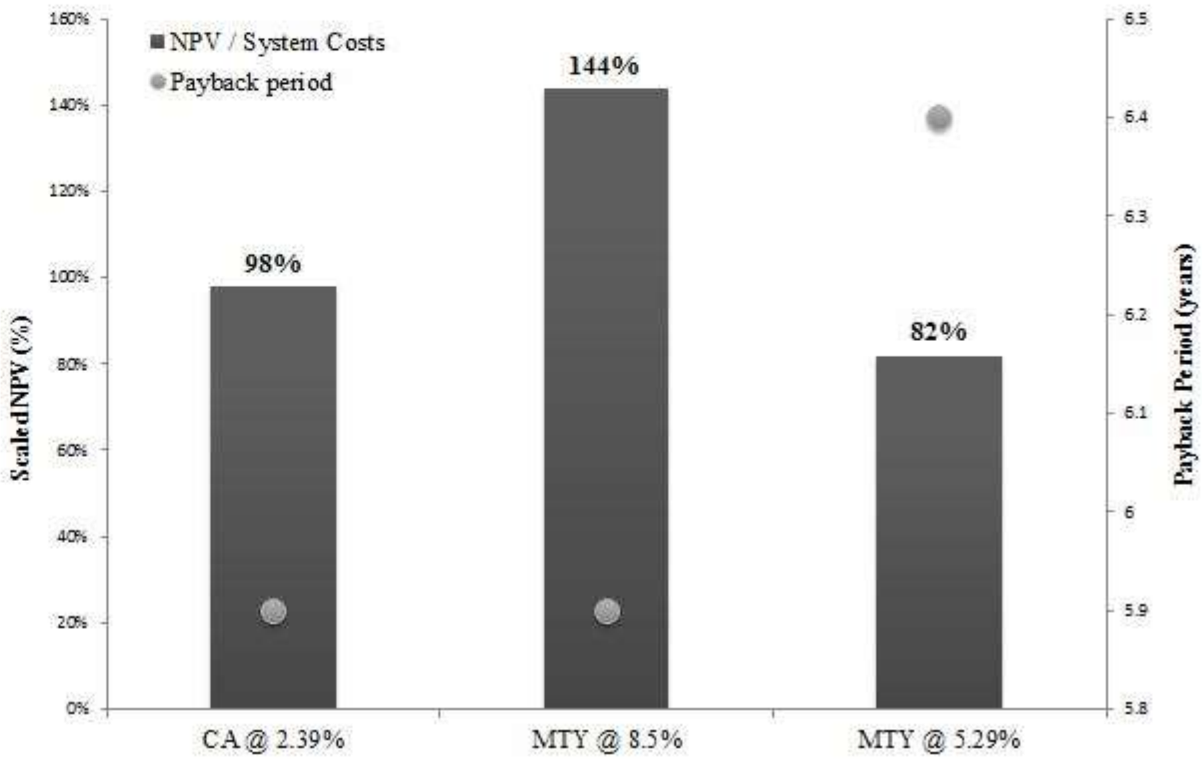

Figure 13. Electricity prices in Mexico are expected to increase after fundamental changes to the structure of CFE product of the energy reform. This graph portrays the effect of a higher electricity price escalation rate on project utility, as measured by scaled-NPV & payback period.

As seen in Figure 13, a higher escalation rate for grid electricity prices makes the solar alternative more attractive by increasing its scaled-NPV (%) and decreasing its payback period. Increasing grid electricity prices makes alternatives like solar electricity more attractive. In *Solar Energy Conversion Systems*, Dr. Brownson refers to this economic phenomenon as the *energy constraint response*[21]. The access to fuels for transportation and grid electricity generation can become restricted for a variety of reasons. Restricted access leads to actors throughout the energy value chain to look for energy alternatives like solar power. Brownson's main premise is the following: "During periods of increased fuel constraints, research into the use of solar energy is often socially advocated and the solar resource has been interpreted as ubiquitous and vast. In contrast, during periods in history when fuels were accessible, inexpensive, and unconstrained, [the solar resource] has been deemed diffuse and insufficient."

The *energy constraint response* phenomenon is seen because solar electricity is, dispatchability and intermittency problems aside, a direct substitute of grid electricity. From the data for the system in Monterrey displayed in Figure 13 one can extract that for every 1% increase in electricity price escalation rate, the payback period shortens by almost 2 months. Additionally, at an 8.5% escalation rate, the scaled-NPV of the system in Monterrey is almost 50% higher than that of the system in California.

In addition to the data outputted by the SAM simulation, the Cobb-Douglas demand function study by Ramirez *et al.* concludes that the residential sector of the Monterrey Metropolitan Area presents a highly inelastic demand for electricity in the short term and an inelastic demand in the long term. A 1% increment in the price of electricity generates only a 0.165% decrease in residential demand in the short term and a 0.630% decrease in the long term[18]. The inelasticity of demand is expected as this public service has become a basic need. This tells solar industry players that customers will first look for grid electricity alternatives like solar energy before curtailing their demand.

According to Briceño, his current customers aren't sold on 10-15% savings. They will invest the time to look into solar and educate themselves on the promise of 50%-70% savings[12]. How does one achieve 50%-70% savings? If you are a high-consumption residential customer (DAC), this is feasible. After installing properly sized solar, the customer stops consuming the amount of grid energy (in kWh) to be classified as high consumption. After 12 months under the high consumption threshold, the CFE changes the tariff to one in the range from 1A to 1E. As previously mentioned, these tariffs are subsidized so the savings realized will have two components: reduced grid energy consumption and a reduced price on the balance of grid energy consumed.

Outside of the 'DAC population', solar recognition remains low. Since marketing has primarily been word-of-mouth since the industry in Monterrey was born, organic growth in the middle and low classes remains low. Developers don't market aggressively to the population paying rates other than DAC because project economics change. A solar proposal is not as attractive if paired with the 1C tariff as opposed to the DAC tariff. "[Developers] have been going for the low hanging fruits and that's what has worked for them" says Adam James from GreenTech Media[19].

Current Challenge, Future Driver: Policy, Legislation, & Incentives

It is helpful to know what incentives are currently in place for the Mexican solar industry prior to discussing the results of simulating different combinations of incentives in SAM. The Database of State Incentives for Renewables & Efficiency (DSIRE) in the United States is one of a kind. Information hubs like this one are not the norm around the world. Mexican solar industry players across the board complain about the lack of publicly available industry data. Policy instruments and incentives are not the exception. It is frustrating for companies and researchers alike that industry data is not at the tip of their fingers but rather bound to the know-how of those professionals who have been in the industry for a few years. Alvaro Briceño from Powerstein happens to be one of these professionals, and he provided the following list of policy instruments and incentives currently available for accelerating solar deployment in Mexico[12]:

1. Net metering: installation in certain states comes free of charge. In other states, bureaucracy and paperwork are major obstacles, requiring a government inspection of such a simple installation. The situation isfavorable in Monterrey.
2. Accelerated depreciation: similar guidelines as for the United States's Modified Accelerated Cost Recovery System (MACRS).
3. Clean Energy Certificates: the legislative framework is still under construction.
4. FIDE loans: FIDE loans are government loans. They are extremely bureaucratic and require a lot of paperwork. Interest rates are better than those offered by depository banks but not significantly.

Certain equipment (i.e. microinverters) can't be included when calculating the total amount of capital lent.

5. CIBanco's CIPanel Solar loan: this is the private sector's equivalent of FIDE loans. It is offered to DAC customers at a 15% interest rate. The loan term can range from 6 to 60 months and it requires a 35% down payment[22].
6. Agricultural support through FIRCO which stands for 'Shared Risk Trust' in Spanish: a matching program for the primary sector where the government matches up to $1 million MXN (est. $65,100 USD) in PV investments (for a total investment cap of $2 million MXN).
7. For interconnected PV systems under CFEs HM rate, excess generation is injected to the grid at peak power rate. Although HM rates are typically for commercial buildings, this is important in Monterrey because certain households (owned by wealthy individuals) have such a high consumption that they are priced at the HM and not the DAC rate. However, aiming for a solar fraction[21] that brings DAC customers a tier down to 1A-1E is still more financially attractive than getting peak pricing as a generator under the HM rate interconnected to the grid.

After reviewing this list, it is important to mention two important things: First, due to the more centralized nature of the government when compared to the U.S., most taxes in Mexico are collected at the federal level. This leaves states with limited ability to provide tax incentives in order to promote renewable energy deployment. The 2% state payroll tax is a minor alteration to consider to attract renewable energy investment[10]. Second, it is more useful for low-income housing owners to do efficiency upgrades than to install renewable energy; thus, most incentives and policies geared towards them are focused on efficiency and conservation[12].

A total of 10 runs were compared to study the effect of incentives on project economics: 2 benchmark runs (CA & MTY) and 8 additional runs for the system in MTY. Three fundamental project finance metrics were compared: real LCOE, *scaled*-NPV, and simple payback period. To facilitate a detailed analysis of the effect of incentives on these metrics, Table 6 presents a *qualitative* study at the onset of this sensitivity analysis. The table presents a ranking of each particular combination of incentives (each run): the uppermost row is the best alternative while the bottommost is the worst. Each run is ranked 3 times on the basis of LCOE, scaled-NPV, and payback period (columns 2-4). On the color-coding: the 1st ranking (LCOE) is arbitrarily used as the reference to compare how each run in the 2nd (NPV) and 3rd (payback) rankings moves up or down on the list. Yellow means the run is equally ranked in NPV or payback with respect to the LCOE ranking. Green means the run is higher ranked in NPV or payback with respect to the LCOE ranking. Red means the run is lower ranked.

Table 6. Qualitative ranking of the effect of different combinations of incentives on project 3 fundamental project finance metrics.

Ranking	Real LCOE	Scaled-NPV	Payback Period
1 - Best	ITC & PTC @10.09% escalation rate		
2	PTC @10.09% escalation rate	PTC @10.09% escalation rate	ITC & PTC @0% escalation rate
3	ITC & PTC @0% escalation rate	ITC & PTC @0% escalation rate	PTC @10.09% escalation rate
4	CA* 30% ITC	PTC @0% escalation rate	ITC & 30% cash grant that reduces ITC basis
5	PTC @0% escalation rate	CA* 30% ITC	PTC @0% escalation rate
6	ITC & 30% cash grant that reduces ITC basis	ITC & 30% cash grant that reduces ITC basis	CA* 30% ITC
7	30% cash grant as a non-taxable incentive	30% cash grant as a non-taxable incentive	30% ITC
8	30% ITC	30% ITC	$0.09/kWh PBI (like CA ReMAT)
9	$0.09/kWh PBI (like CA ReMAT)	$0.09/kWh PBI (like CA ReMAT)	30% cash grant as a non-taxable incentive
10 - Worst	30% cash grant		

Next, qualitative observations based on Table 6:

1. An incentive combination of a 30% Investment Tax Credit (ITC) and a Production Tax Credit (PTC) of \$0.09/kWh with a 10.09% annual escalation rate is always the best alternative, no matter which project finance metric is used as basis of comparison.
2. A 30% *taxable* cash grant only (and the trivial case of no incentives at all) is always the worst alternative, no matter which project finance metric is used as basis of comparison. The reason why this run is the worst performer is because 30% of the benefit is lost to taxes.
3. Benchmark run for MTY (30% ITC) and the run with the 30% ITC <u>and a</u> Production Based Incentive modeled after CA's ReMAT ranked equally on the basis of the 3 financial metrics. Thus, a PBI has no effect in this case because the solar fraction is F = 0.2 every month. This means the system never sells surplus solar electricity to the grid, condition needed to realize the benefits of a PBI.
4. With either LCOE or NPV as basis for the ranking, the only ways the system in MTY outperforms the CA benchmark is with an ITC/PTC combination or with only a PTC as an incentive. On the basis of payback period, a combination of an ITC and a 30% cash grant (ranked #4) also outperforms the CA benchmark (ranked #6).
    a. Given that LCOE and NPV factor in the time value of money and simple payback does not, a cash grant only incentive scheme outperforms an investment tax credit (ITC) only scheme on the basis of LCOE and NPV but <u>not</u> on the basis of payback period. Since inflation and the time value of money are fundamental economic concepts, Results are prioritized on a LCOE and NPV basis.
5. The LCOE and NPV rankings only differ in positions #4 and #5: the CA benchmark comes before a non-escalating PTC in MTY and vice versa. The cause of this minor difference becomes apparent when analyzing SAMs back-end cash flow table and how after tax costs (for computing LCOE &

NPV) and after tax cash flows (for computing NPV) are calculated. A detailed explanation of the cause is beyond the scope of this paper[‡].

Figure 14 shows how the different combinations of incentives perform against each other on the basis of LCOE. The run with a PTC at a 10.09% escalation rate was chosen as the reference point (1.00) and "LCOE multipliers" were generated for the remaining runs. For example, a run with a 2.00 LCOE multiplier corresponds to a LCOE twice as big (4.8 ¢) as that of the reference run (2.4 ¢). The run with a combination of an ITC & a PTC at a 10.09% escalation rate (-0.26 multiplier) is unrealistic. Essentially it presents the possibility of tax-deductible expenses, 20-year long production tax credits, and an initial investment tax credit outweighing all system costs throughout the 20 year period of analysis. Obviously, runs that combine an ITC with other incentives will outperform the ITC-only benchmark. What is not so obvious and one can attest in Figure 14 is that only a PTC at 0% escalation rate and only a 30% cash grant outperform the 30% ITC benchmark. On the topic of cash grants vs. ITC, Figure 14 supports many studies by renowned economists that claim the deadweight loss (DWL) (a.k.a. allocative inefficiency) of a direct cash incentive scheme is smaller than that of the prevalent ITC. On the topic of production-based incentives (PBI), they drove the rapid development of the German solar industry in the form of Feed-In Tariffs (FiT) but their effectiveness is currently a topic of debate.

[‡] More detail on this: "for the commercial building financial model, the after-tax cash flow is reduced by the income tax on the value of energy produced. This is because SAM assumes that without the solar system, the commercial entity would have treated electricity purchases as a tax-deductible operating expense."[9]

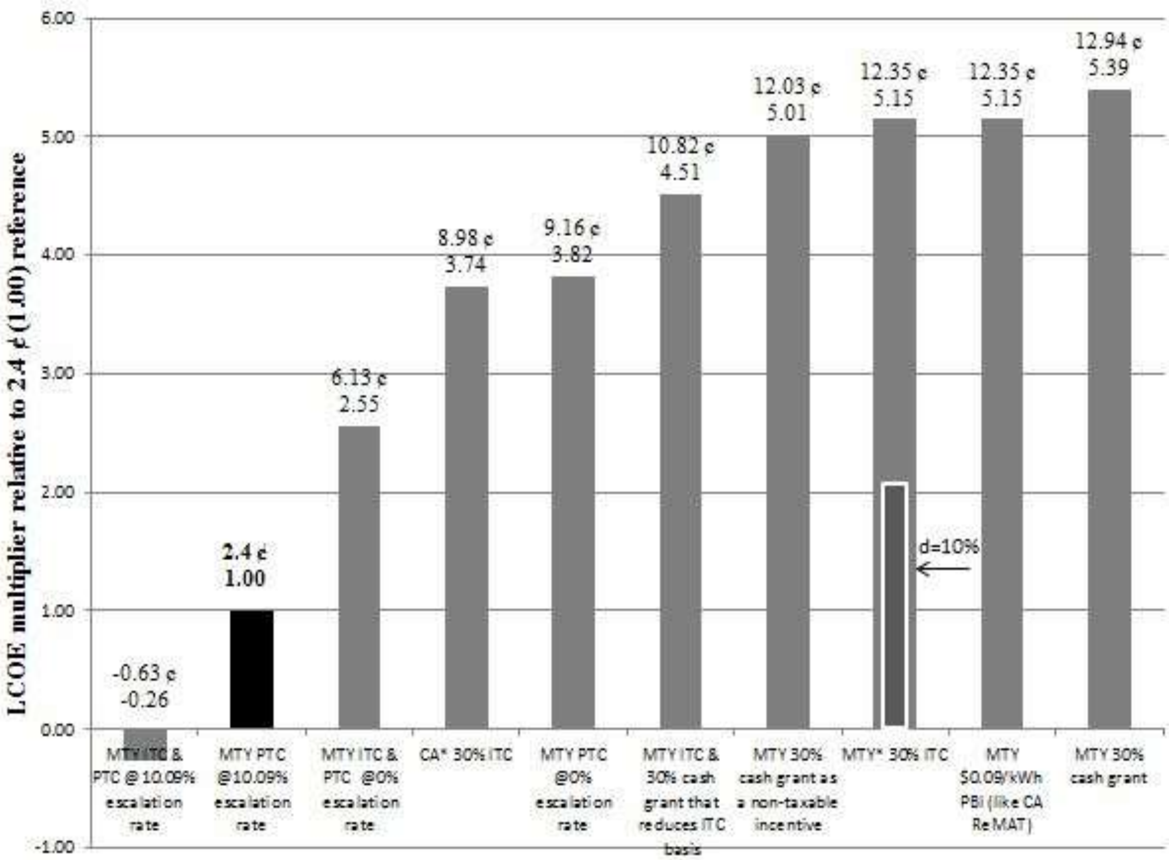

Figure 14. The effect of combining different incentives (tax & cash, investment-based & production-based) on levelized cost of energy using a PTC at a 10.09% escalation rate as a reference point.

How can a PTC at 10.09% escalation rate result in a real LCOE more than 5 times smaller than that for the prevalent 30% ITC. Two factors offer an explanation: the relatively high escalation rate (5.29% electricity escalation rate + 4.8% inflation rate = 10.09%) and the time value of money (5.5% discount rate). Figure 15 presents supporting evidence to these claims. The figure shows federal tax savings at the end of every year in the analysis period for a system with no incentives, one with a 30% ITC, and one with a $0.09/kWh PTC at a 10.09% escalation rate. In the case of the PTC plot, the effect of the high escalation rate is very clear: federal tax savings grow rapidly throughout the years. Although the project has no income because the building consumes all the solar electricity produced as opposed to selling it, the commercial entity surely has other sources of income to allocate these tax savings. SAM makes this assumption and therefore LCOE is impacted by tax money saved. In year 20, the case with no incentives and the one with a 30% ITC actually incur a tax expense. This is because the system is sold at salvage value, which in turn generates a taxable income. Taxes from selling the system also apply for the PTC case, however the production-based tax credit absorbs all this liability.

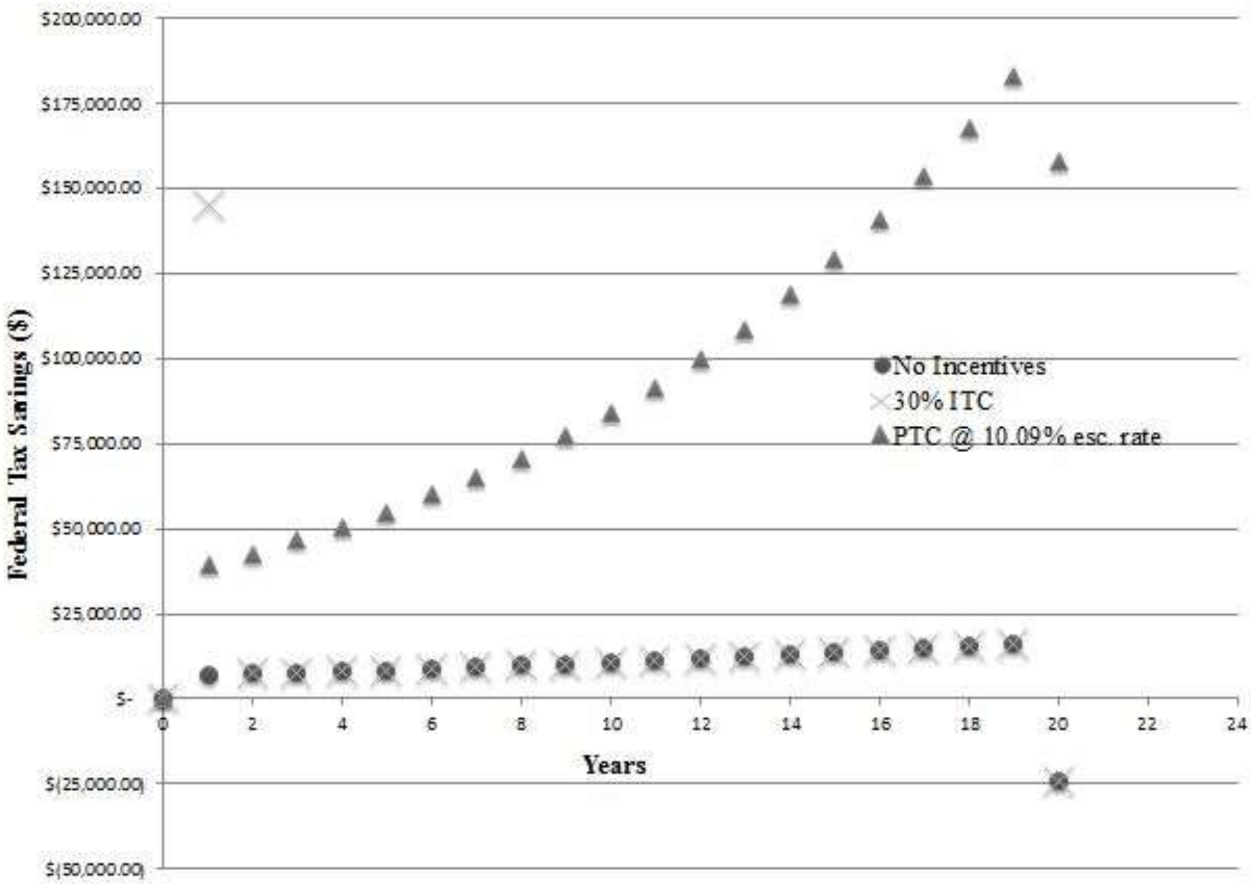

Figure 15. Annual federal tax savings for 3 modeled systems in Monterrey with different government incentives: no incentives, 30% ITC, and a $0.09/kWh PTC at a 10.09% escalation rate.

One more thing to note is the tax credit for the 30% ITC case in year one, almost amounting to $150,000. The effect of the time value of money on LCOE is not as clear in Figure 15 and thus we refer back to Figure 14. An additional bar in Figure 14 for the 30% ITC benchmark run shows the LCOE for a case at a <u>10% discount rate</u> as opposed to the default 5.5%. Instead of costing 5 times more than the PTC reference case, the 30% ITC now only costs <u>twice</u> as much. The lower the discount rate, the higher value future cash flows have. At a higher 10% discount rate, the federal tax savings in year 1 for the 30% ITC case (Figure 15) are relatively more valuable than the tax savings for the PTC case in years 2-20. One can further increase this discount rate to reduce the gap between the ITC case and the PTC case to zero. However, there comes a point where the discount rate is unrealistically high and the simulation becomes futile. The main takeaway for developers and other actors is to choose a discount rate carefully after much due diligence. Additionally, it is the author's judgment that the 10.09% escalation rate for the PTC is unrealistically high and should be reassessed.

CONCLUSION

First, key findings of the SAM simulation are summarized in bulleted lists. Then, based on the simulation, topics of strategic focus to solar project developers in Monterrey are recommended. Third, qualitative and quantitative results are holistically assessed to address the feasibility of a business model to crowdfund solar PV projects in Monterrey. Finally, the limitations of this work and suggested future research are presented.

Summary of Key Quantitative Findings

<u>Solar Resource & Comparison of Benchmarks</u>

- Solar resource is not a prohibiting factor for successful solar development in Monterrey. The dummy system in Monterrey produced 92% of the energy of the system in CA; comparatively, the system in the solar capital of the world (Freiburg) produced 62% of the energy.
- In 4 out of 5 outputs related to system performance, the benchmark in CA outperforms the one in MTY by a difference between 5% and 10%. This is mainly due to clearer days throughout the year (on average) and not higher insolation.
- The benchmark in CA outperforms MTY in 4 *economic* outputs: net savings over electricity cost, simple payback, present value of insurance and property tax, and weighted average cost of capital (WACC). The first 2 of these factors are proportional to annual energy output.
- The LCOE of the system in CA is ~30% lower than that of the system in MTY. CA's NPV is 98% of total system cost vs. 82% for the project in MTY.
- The major differences between both benchmarks are insurance payments (Δ=62%) and cost of capital (Δ=52%) that lead to differing LCOEs (Δ=27%) and *scaled*-NPVs (Δ=20%).

Cost of Capital runs:

- Due to current inflation rates in Mexico, debt financing as opposed to all-equity deals enhances project profitability. Even a debt financed deal at 14% interest rate has a higher NPV than a 100% equity cash deal.

Insurance Rate & Risk Perception

- Mexican banks and lending agencies incorrectly overestimate technology risk and charge an annual 4% of total system cost in insurance, while in CA these actors charge 1%. This results in the present value of insurance payments in MTY to be 62% higher than those in CA even though the initial system cost is 47% lower. Another perspective of the severity of the issue is that the ratio of the PV of insurance payments over total system cost for CA amounts to 12% vs. 46% for MTY.
- When observing the effect of insurance rate when going from one extreme (1%) to the other (7.35%), one observes a greater impact on LCOE than on NPV. This can be explained by the fact that LCOE is a metric based solely on costs (like insurance payments) whereas NPV also takes into account benefits.
- For the system in MTY, a 1% increase in insurance rate results in the payback period extending approximately 4 more months into the future. Additionally, a 1% increase in insurance rate doubles the present value of cumulative insurance expenses.

Electricity Price Escalation Rate

- For every 1% increase in electricity price escalation rate, the payback period shortens by almost 2 months.
- At an 8.5% escalation rate, the *scaled*-NPV of the system in Monterrey is almost 50% higher than that of the system in California.

- If grid electricity prices go up after the energy reform as predicted by James, Briceño, and other experts, solar electricity and other decentralized systems will become more attractive alternatives to grid electricity.

Global trend of decreasing costs of installing solar systems

- The effect of system cost reduction on LCOE and payback period is one of diminishing returns: the more costs are driven downwards, the smaller the benefit as reflected by LCOE and payback period.
- Halving system costs results in a 62% improvement in *scaled*-NPV in MTY vs. a 27% improvement in CA. This provides quantifiable evidence that the economics of the system in MTY are predominantly driven by low costs and not other factors like incentives and competitive financing.

Policy Incentives

- A 30% Investment Tax Credit (ITC) and a Production Tax Credit (PTC) of $0.09/kWh with a 10.09% annual escalation rate is the incentive combination that maximizes project economics out of 9 combinations modeled.
- The only ways the system in MTY outperforms the CA benchmark is with an ITC/PTC combination or with only a PTC as an incentive.
- On the basis of LCOE, a standalone PTC at 0% escalation rate and a standalone 30% non-taxable cash grant both outperform the 30% ITC, the current de facto incentive. This finding supports many studies that claim the deadweight loss (DWL) of a direct cash incentive scheme to be smaller than that of the prevalent ITC.
- A $0.09/kWh PTC with a high 10.09% escalation rate results in an LCOE more than 5 times smaller than that for a 30% ITC case due to the high escalation rate and the time value of money (5.5% discount rate)..

Strategic Focus: Recommendation to Key Industry Participants

To produce Table 7, the runs were grouped by type of driver being modeled and then averaged LCOEs relative to benchmark in each category. For example, the 8 runs modeling incentives, some outperforming the benchmark and others underperforming, collectively outperformed the benchmark with an LCOE 34% lower and an NPV 53% higher. The reason for doing this is to show industry participants, especially solar project developers, what drivers they should strategically prioritize and focus on. Refer to Appendix B

Table 9. The effect of different drivers on modeled project's LCOE & NPV relative to benchmark. for a breakdown of the components of these averages.

Table 7. Key drivers for enhanced development of the solar industry in Monterrey. Note that electricity cost does not apply as an LCOE driver since the LCOE calculation doesn't take into account electricity savings.

Type of Driver	Real LCOE rel. to benchmark	Type of Driver	NPV rel. to benchmark
Electricity cost	N/A	Electricity cost	176%
System Costs	54%	System Costs	162%
Incentives	66%	Incentives	153%
Cost of Cap.	77%	Cost of Cap.	131%
Risk perception	101%	Risk perception	98%

Based on Table 7, long-term investment in photovoltaic R&D and balance of system (BoS) equipment R&D is recommended, to drive the cost of solar down. This will result in grid parity in more regions and under more sets of conditions. As predicted by Brownson, James, and Briceño[12,19], the cost of grid electricity is the main driver for enhancing the development of the solar industry. However, grid electricity price is an external factor to solar developers, thus beyond their control. At the other end of the table lies risk perception as a driver. On this subject, every developer should have a budget to educate other industry participants like lending entities and customers to change their perception of technology risk. This budget shall resemble typical advertising budgets in amount of money allocated. It can be seen as an investment to create a solar culture that will eventually pay back by enhancing solar project economics. Finally, the main motivation for this research work was exploring a business model that would enable more competitive *crowdfunded* capital to fuel solar project development. In this study, 4 interest rates ranging from 6% to 14% were utilized. The effect of more competitively priced capital was significant on LCOE and NPV. The fact is that the 5-9% yield on crowdfunded capital structured as debt, as Bloomberg New Energy Finance suggests[2], would be a very attractive alternative to conventional sources of capital. Additionally, it would redistribute the power to finance renewable energy ventures more equitably and lessen the bottleneck currently in place.

A Business Model to Crowdfund Solar PV Projects in Monterrey, Mexico

At the time of this writing, July 2015, it is not possible to create an online platform that channels the funds of the general public towards photovoltaic projects in Monterrey, Mexico. The legal framework is not in place, and a business offering a return on these investments would be illegal. A main challenge to overcome in moving towards the creation of a legal framework and regulation is how do you protect individual investors with an average income from the risks associated with solar project development and financing. With a few exceptions in Europe, the global equity crowdfunding industry is still under construction and it will take a few more years until the rules of the game are in place and the first players begin operating.

In various instances of the Results & Discussion section and in Appendix D, additional reasons are provided as to why the market in Monterrey is not ready for this business model. These reasons are qualitative in nature and mostly pertain to the sociocultural context in that location at this time. Crowdfunding is not viable because the majority of the people don’t have credit/debit cards for online transactions. CF is not viable because E-Commerce penetration is low partly due to cybersecurity concerns by a big part of the population. CF is not viable because the average Mexican citizen is skeptical of investing and thinks it is too complex and shall be left for the wealthiest 5%.

Nevertheless, the quantitative study based on SAM simulations confirms the proposition that crowdfunded capital is a great solution for the new venture funding gap and could alleviate a bottleneck in the solar industry and accelerate deployment. With a cost of capital ~50% higher than that in California, the solar industry in Monterrey needs alternative sources of competitive financing. An additional benefit of bringing crowdfunding into the mix is that it creates awareness of solar technologies in the general public. It creates a solar culture with rippling effects, like lower costs to insure solar equipment, currently 62% higher in MTY when compared to CA.

Availability of capital, grid electricity prices, and incentives are the main drivers of solar adoption. Secondary drivers in Monterrey are in place, waiting for the 3 main drivers to align in order for the industry to explode. Due to the high levels of education, the city is the most environmentally conscious and educated in renewable energy. Its residents have participated in crowdfunding before, within Mexico and also in the U.S. Grid electricity prices are expected to increase, making solar electricity more attractive for compelling financial reasons. Globally, solar installation cost curves are leading to grid parity in an increasing number of nations under an increasing number of different conditions. In conclusion, other than a moderate lack of adequate incentives, the solar side of the equation in Monterrey is optimal. And for the crowdfunding side of the equation, the young industry will mature in a few years and allow the proposed business model to operate legally and flourish.

Limitations & Suggested Future Work

A major limitation of the quantitative portion of this work is that the small number of iterations (20 runs) make it statistically insignificant. Additionally, model input parameters were mostly single values provided by experts or reputable research hubs. Albeit their expertise, ideally these input parameters would be a statistical mean sourced from a data set of hundreds or thousands of projects. These two limitations apply to a lesser extent for the system in California given that the availability of "bankable" data in the U.S. is higher. With that, the simulation wouldn't rely so much on secondary data but rather on statistical treatment of primary data. The models can be improved by including depreciation, electricity sold to the grid through net metering, and all pertaining local, state, and federal incentives. Parameters impacting system performance can be studied more in detail and integrated into the simulation. An example of this would be replacing the default "no shading" assumption with more realistic shading schedules for both locations. One major limitation of the cost of capital sensitivity analysis is that only 100% debt and 100% equity financing were modeled. In reality, an optimal combination of equity and debt maximizes utility and the majority of real systems are financed through a combination of various sources of capital. More realistic financing schemes should be explored as part of future work. One major limitation of the incentives sensitivity analysis is that although the 10.09% PTC escalation rate was a straightforward addition of electricity escalation rate and inflation, The author believes it is unrealistically high and should be reassessed in future studies.

With the motivation for a business model for crowdfunding PV projects in Monterrey, a good proposition for future work is a statistically significant analysis of the cost of capital on project economics. The legal, regulatory, and financial complexities preventing crowdfunded PV projects to become a reality in Mexico encourage me to suggest future work in other academic areas to come up with appropriate legal documents (for example contracts with risk mitigation mechanisms), a regulatory framework, and financial models. If the main challenge the equity crowdfunding industry is facing is protecting average citizens from downside risk and a complete loss of the investment, The author suggests researching what has been done in the past to hedge risk, properly distribute it, and contractually transfer it to parties that can undertake it.

EXPERIMENTAL METHODS

Literature Review

The experimental methods can be described from the ground up: foundationally, this thesis is a literature review. On top of that, primary research in the form of interviews and simulations strengthen its core propositions. Here, the characteristics of the literature that to some extent shapes the ideas presented are described. Without counting the sources for the analysis in SAM and the interviews, 26 written works were used as direct sources of information. Figure 16 shows the relative composition of these sources of information by type. Reports were produced by for-profit companies and governmental agencies. They were the source of most qualitative data on crowdfunding and renewable energy development. At 27%, scholarly articles were the main component of this literature review and proved most useful in gaging what research had been previously published on innovative financing methods and renewable energy in Mexico.

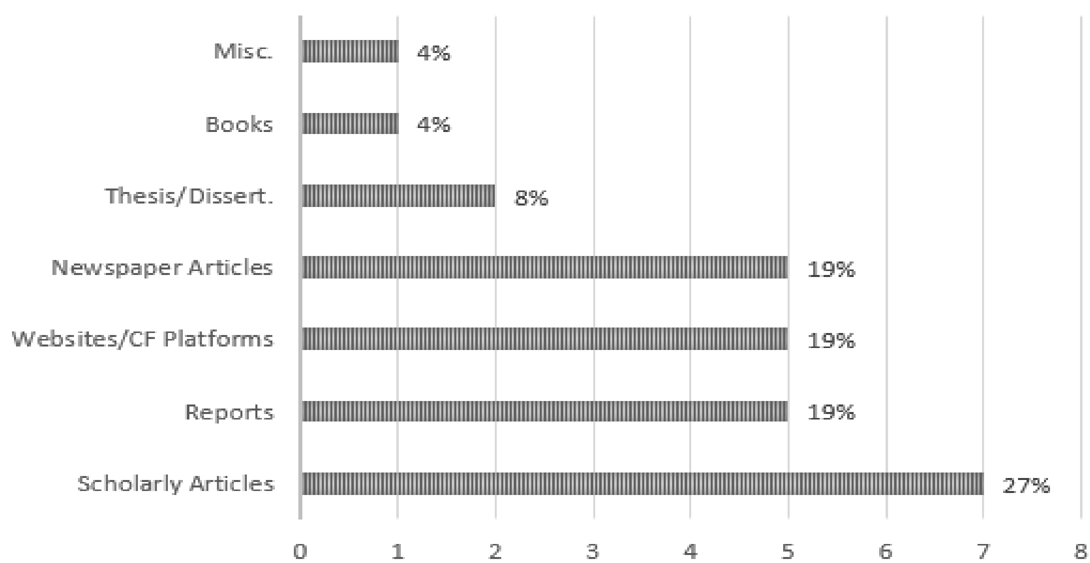

Figure 16. Overview of Types of Literature Reviewed.

SAM Simulation 1: Basic Solar Resource Assessment

The comparison of the solar resource of Monterrey (Mexico), Oakland (CA), and Freiburg (Germany) was carried out using the National Renewable Energy Laboratory's (NREL) System Advisor Model (SAM). SAM is free simulation software to model energy systems performance. SAM is a very robust environment with many inputs. Depending on the level of customization and analyst thoroughness, SAM can output basic solar assessment data or a more thorough analysis tying solar energy to project finance, policy incentives, and more. It is important to note that this first simulation is a basic assessment of the solar resource. Output data related to project finance will not be taken into consideration because factors affecting project finance metrics like governmental incentives were left as defaults. The independent variable in this simulation is location. The dependent variable is annual solar energy production and metrics that derive from this. The control variables and input parameters are outlined in the following bulleted list. If a variable is not explicitly mentioned, it is safe to assume the default value in SAM version 2015.1.30 was utilized:

- Module: SunPower SPR-210-BLK-U
- Inverter: SMA SunnyBoy 5000US 240V [CEC 2007]. Inverter capacity: 5 kW_{AC}
- System Design: 2 strings - 11 panels/string - 1 inverter
- Nameplate capacity: 4.735 kW_{DC}
- DC to AC ratio: 0.95, with typical industry values for residential installations between 1.1 and 1.25 (oversizing for future additions is a standard practice)
- Shading: no external shading or self-shading
- Losses, degradation, and any kind of financial parameters left as SAM defaults.

SAM Simulation 2: Robust Techno-Economic & Sensitivity Analysis

Table 8 in Appendix A

Table 8. Detailed listing of input parameters and their sources for techno-economic analysis using the *System Advisor Model* by NREL. is a detailed listing of the input parameters used for the robust techno-economic analysis in SAM (Simulation 2). It is meant for the average reader to skim through it and experimenters looking to reproduce these simulations to examine in detail. There, it is noted that these input parameters correspond to benchmark run #1. Control variables have the same value for both locations and sometimes correspond to SAMs default value. Some input parameters (highlighted in the table) are calculated by SAM from other input parameters. Finally, some input parameters will be changed in subsequent runs as part of sensitivity analysis. The following subsections will specify precisely which input parameter was varied in each run.

Sensitivty Analysis of Cost of Capital: Runs #1-5

The hypothetical community solar system in Monterrey underwent 4 different runs with 4 different interest rates to explore the importance of affordable capital relative to other factors. A 100% debt fraction model was adopted as opposed to the cash-only benchmark model. The interest rates inputted and the reasoning behind each choice are listed below:

1. 6% interest rate: according to BNEF, “debt and debt-like crowdfunded clean energy investments are expected to yield 5-9%”[2]. Therefore this interest rate corresponds to the lower limit: a 5% yield for the lender/investor (“the crowd” in this case) and a 1% return for the online crowdfunding platform

serving as intermediary. Mosaic, solar PV project crowdfunding platform in California[§], charged a 1% platform fee through April 2014 and then decreased it to 0.5%.

2. 7.5% interest rate: the average loan rate of the U.S. FHA PowerSaver Loan Program[22], financing incentive used for the California benchmark run.
3. 10% interest rate: upper limit of the crowdfunded debt expected yield range. Same explanation as for the 6% interest rate (#1.) above.
4. 14% interest rate: typical rate offered by banks in Mexico to residential installations, as provided by interviewee Briceño[12].

Sensitivity Analysis of Insurance Rate & Risk Perception: Runs #1,6,7

The system in Monterrey was simulated with two annual insurance rates as a percentage of installed cost in addition to the 4% insurance rate benchmark.

1. 1% annual insurance rate: typical insurance rate for residential rooftop systems in the U.S. This value was used for the benchmark run (1A) in California.
2. 7.35% annual insurance rate: Value equals auto insurance for a new 2014 standard-gear Volkswagen Jetta as quoted by GNP Seguros online pricing system. GNP Seguros is one of the largest insurance companies in Mexico. It was decided to model a rate equal to auto insurance after the interview with Álvaro Briceño (Director of Commercialization at Powerstein), where he expressed that insurance companies in Mexico see a solar system as a riskier asset than a car and price it as such[12].

The reason for sensitivity analysis on insurance rate is because this parameter reflects the risk perception of different actors in the solar industry. Here the actors in question are insurance companies in Mexico.

[§] From here on a.k.a. **CA** for short.

Sensitivity Analysis of Electricity Price Escalation Rate: Runs #1,8

The benchmark electricity price escalation rate for Mexico is 5.29% per year. This value was calculated with information from the national Energy Information System (SIE) run by the Mexican Department of Energy (SENER). However, when interviewing industry participants for model parameters, Briceño from Powerstein suggested an 8.5% rate that takes into account the short and medium-term changes post-energy reform. Beyond 5 years in the future, hopefully the national electricity provider (CFE) will have assimilated all the internal and market changes and the escalation rate will go back to normal. To keep the model simple, however, the 8.5% was used throughout the 20 years of analysis. Although the precision of this escalation rate cannot be asserted, it was used for modeling to assess its impact on project finance and compare it to other variable parameters.

Sensitivity Analysis of Decreasing Solar Costs: Runs #1,1A,2A,9

Note: Suffix "A" in the run number means that it corresponds to the system located in California and not Monterrey.

The total installed cost, $2.73/$W_{DC}$ for California and $1.85/$W_{DC}$ for Monterrey, was cut in half for these two additional runs. The way SAMs back-end calculations work, it doesn't matter whether one makes the 50% reduction solely on the module cost ($/$W_{DC}$) or one distributes the cut equitably among direct and indirect costs. It was decided that the 50% reduction would be equitably distributed among different components (module cost, inverter cost, labor, engineering, overheads, etc.) Refer to the subsection of the *Results & Discussion* section addressing this decrease in cost for an explanation to why a 50% reduction is realistic.

Sensitivity Analysis of Having Different Policy Incentives: Runs #1, 11-18

Beneficial for an industry in most cases, incentives are nonetheless artificial instruments created under a transient legislative and regulatory framework to align with specific policies. SAM allows for inclusion of 1) tax credits and 2) direct cash incentives in the simulation environment. Tax credits are further divided into 1.1) investment tax credits (ITC) and 1.2) production tax credits (PTC). Direct cash incentives come in the form of 2.1) investment based incentives (IBI), 2.2) capacity based incentives (CBI), and 2.3) production based incentives (PBI). Recall this numbering and acronyms when reviewing runs #1, 11-18 below for the sake of organization. Before listing the runs, Figure 17 graphically shows

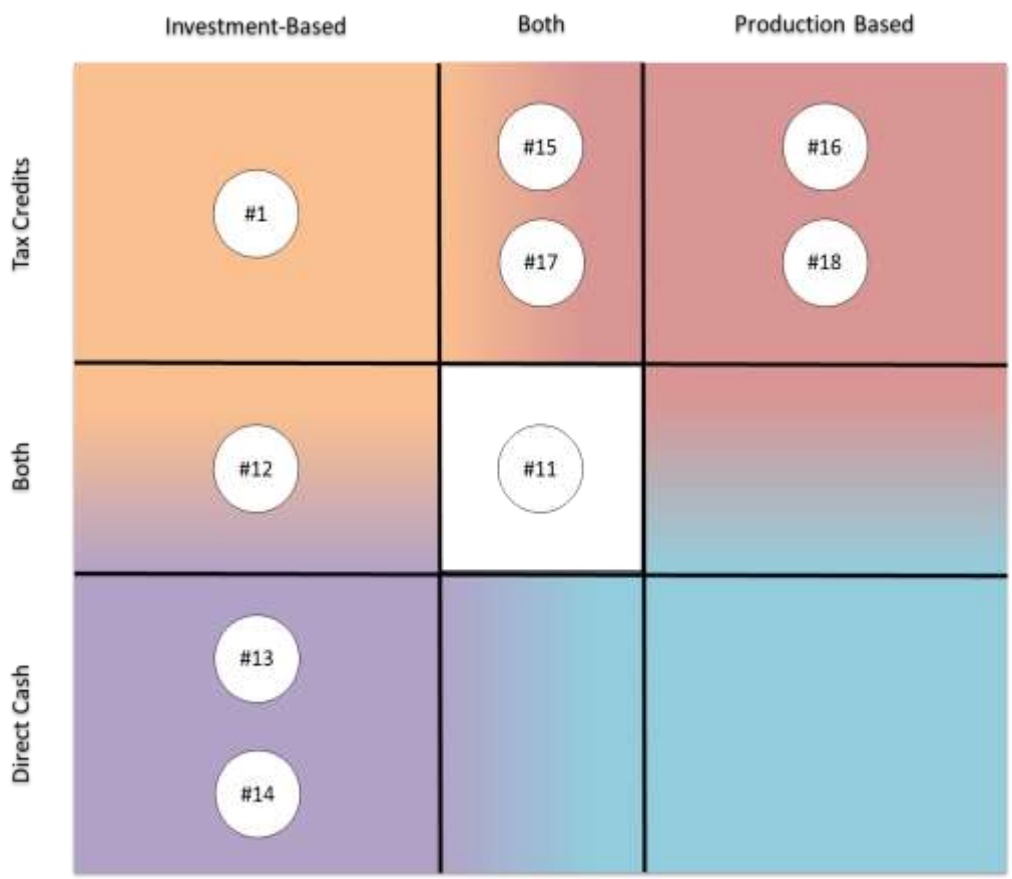

Figure 17. Incentive Type Grid. X-axis is the basis upon which the incentive is calculated (initial investment or energy production) while y-axis represents the means through which the benefit is granted (as a tax credit or a direct cash benefit).

which combination of incentives each run models by plotting them in 1 of 9 sectors.

#1. Benchmark: 30% federal ITC (1.1) of eligible total installed costs .

#11. 30% federal ITC (1.1) **plus** a $0.09/kWh PBI (2.3) with a 20 year contract. $0.09/kWh is approximately equal to the feed-in tariff for California's Renewable Market Adjusting Tariff (ReMAT)[22] program for technologies classified as intermittent and peaking. As per eligibility criteria, one cannot do net metering and ReMAT at the same time. However, as noted in the *Results & Discussion* section, due to the size of the electric load modeled, whether net metering is activated in the model or not does not matter.

#12. 30% federal ITC (1.1) **plus** a 30% cash grant (2.1 – IBI). The cash grant is a taxable incentive at the federal and state levels and reduces the depreciation and ITC bases. Note that the effect on the depreciation basis is irrelevant because the benchmark model and all subsequent ones have no depreciation.

#13. 30% cash grant (2.1 – IBI) **only** that does not reduce the depreciation and ITC bases. It is a taxable incentive.

#14. 30% cash grant (2.1 – IBI) modeled as a non-taxable incentive. Due to the absence of both an ITC and depreciation, bases reduction has no effect on the output.

#15. 30% federal ITC (1.1) **plus** a $0.09/kWh federal PTC (1.2) over the course of 20 years with a 10.09% escalation rate. The monetary incentive per kWh matches ReMAT, similar to run #11. The 10.09% escalation rate equals the electricity price escalation rate (5.29%) plus the inflation rate (4.8%).

#16. $0.09/kWh federal PTC (1.2) over the course of 20 years with a 10.09% escalation rate **only.**

#17. 30% federal ITC (1.1) plus a $0.09/kWh federal PTC (1.2) over the course of 20 years without an escalation rate.

#18. Only a $0.09/kWh federal PTC (1.2) over the course of 20 years without an escalation rate.

Appendix A

Table 8. Detailed listing of input parameters and their sources for techno-economic analysis using the *System Advisor Model* by NREL.

Note: The input parameters below correspond to the benchmark Run #1.			
Color-code: value calculated by SAM using other input parameters or extracted from weather file.			
Input Parameter	**CA**	**MTY**	**Justification for value and/or source**
Analysis period (years)	20		Maximum loan term of the U.S. FHA PowerSaver Loan Program[22]
Location & Resource	Oakland CA Airport (TMY3)	McAllen TX Intl. Airport (TMY3)	McAllen is 2h30min away from Monterrey by car. It was the closest weather file found. Domestic and international weather files were considered.
Latitude	37.717° N	26.31 °N	
Longitude	-122.217 °E	-98.17 °E	
GHI (kWh/m2/day)	4.63	4.72	
DNI (beam) (kWh/m2/day)	4.55	4.53	
Average Temp. (°C)	13.9	22.7	
Module			
Module Name	Trina Solar TSM-305PA14		Module used in ASUs Parking Lot 59 S installation[23], project that matches the average size of shared solar projects[20]
Maximum power (Pmp)(Wdc)	305		
Nominal efficiency (η)(%)	15.876		
Inverter			
Inverter name	Advanced Energy Industries: AE 500TX-600 600V [CEC 2014]		Same rationale as module choice[23,20]
Nom. AC V (V)	600		

Max. DC i (A)	356		
Max. AC output power (kWac)	100		
System Design			
Desired array size (kW)	250		Average size of shared solar projects[20]
Nameplate capacity (kWdc)	248.861		
Number of modules	816		
Total module area (m2)	1567.5		
Number of inverters	2		
System Tilt (°)	32.717	24.31	From "Optimum fixed orientations…" by Lave & Kleissl [24]
System Azimuth (°)	188.5	187.5	From "Optimum fixed orientations…" by Lave & Kleissl [24]
Shading	None. Control variable.		
Losses	Default values. Control variable.		
System Costs			
Total installed cost ($/Wdc)	2.73	1.85	CA: from SunShot Initiative PV Pricing Trends[25], MTY: average of values provided by Adam James[19] & Álvaro Briceño[12]
Fixed O&M cost ($/W-year)	21	20	CA: Distributed Generation Renewable Energy Estimates of Costs by NREL[26], MTY: average of values provided by James[19] and Briceño[12] as in cell above.
Degradation	0.5%/year = Default value. Control variable.		
Financial Parameters			
Debt (%)	100	0	From interviews with industry participants (Briceño from Powerstein, Zambrano CEO at Galt Energy, James from GreenTech Media), most residential deals in MTY are cash-only deals, thus 0% debt.
Loan term (years)	20	N/A	Maximum loan term of the U.S. FHA PowerSaver Loan Program [22]

Loan rate (%)	7.5	N/A	Average loan rate of the U.S. FHA PowerSaver Loan Program [22]
WACC (%)	5.12	10.56	
Inflation rate (%)	2.5	4.8	CA: http://www.usinflationcalculator.com/inflation/current-inflation-rates/, MTY: National Institute of Statistics & Geography http://www.inegi.org.mx/sistemas/indiceprecios/calculadora inflacion.aspx
Real discount rate (%)	5.5		SAMs default value. Control variable. It is somewhat subjective and different experts use different values. The author did not calculate a discount rate of his own, recognizing his lack of expertise.
Nominal discount rate (%)	8.14	10.56	
Federal income tax rate (%)	30		
State income tax rate (%)	2.44	0	
Sales tax (%)	7.5	16	
Annual Insurance rate (% of installed cost)	1	4	**CA**: SAM default corroborated by https://www.allstate.com/tools-and-resources/home-insurance/solar-panels.aspx **and** http://solarenergy.net/solar-power-resources/10-things-to-know-before-going-solar/, **MTY**: value provided by interviewees in the solar industry in MTY. It is subject to sensitivity analysis in subsequent runs of Simulation 2.
Net salvage value (% of installed cost)	30		If 30% is salvaged after 20 years, that results in a system lifespan of 29.5 years, in line with NRELs estimates [26]
Depreciation	None		It is hard to model Mexican depreciation in SAM since it was developed with the U.S. in mind, primarily. Thus, depreciation became a control variable equal among both systems.
Incentives			
Federal ITC (%)	30	30	Other incentives are included as part of sensitivity analysis for other runs in Simulation 2.
Electricity Rates			
Service Provider	Pacific Gas & Electric (PG&E)	Comisión Federal de Electricidad (CFE)	

Rate Name	Residential Seasonal Schedule E-8	De Alto Consumo (DAC) in 1C climate region	
Type	5-tier consumption-based schedule for E-8 zone/territory (Oakland-SF area). Summer & winter distinction	High-consumption unsubsidized residential rate set on a monthly basis	**CA**: http://www.pge.com/tariffs/rateinfo.shtml, http://www.pge.com/tariffs/ResElecCurrent.xls, http://www.pge.com/tariffs/tm2/pdf/ELEC_SCHEDS_NEM.pdf, **MTY**: http://app.cfe.gob.mx/Aplicaciones/CCFE/Tarifas/Tarifas/tarifas_casa.asp?Tarifa=DAC2003&Anio=2015&mes=1&imprime=
Net metering	Disabled for benchmark. Irrelevant because of energy sink modeling in "Electric Load" tab.		
Electricity cost escalation rate (%/yr)	2.39	5.29	CA: avgprice_annual.xls at http://www.eia.gov/electricity/data.cfm#sales, MTY: 2005 to 2015, http://sie.energia.gob.mx/bdiController.do?action=cuadro&cvecua=IIIBC02
Electric Load	Constant F = 0.2 and monthly f = 0.2. An energy sink is modeled where the system produces 20% of the commercial building's monthly requirements and thus no surplus energy is left to sell back to the grid.		Average total load requirement met by shared solar projects on commercial buildings [20]

Appendix B

Table 9. The effect of different drivers on modeled project's LCOE & NPV relative to benchmark.

KEY for "Type of Driver" Columns:		I = incentives, EC = electricity cost, SC = system costs, CC = cost of capital, RP = risk perception			
	LCOE rel. to benchmark	**Type of Driver**		**NPV rel. to benchmark**	**Type of Driver**
MTY ITC + PTC @ 10.09% esc. rate	-5%	I	MTY ITC + PTC @10.09% esc. rate	242%	I
MTY PTC @10.09% esc. rate	19%	I	MTY PTC @10.09% esc. Rate	209%	I
MTY ITC + PTC @0% esc. rate	50%	I	MTY (8.5% electricity esc. rate)	176%	EC
MTY 50% total system costs	54%	SC	MTY ITC & PTC @0% esc. rate	168%	I
MTY (6% cost of cap.)	64%	CC	MTY 50% total system costs	162%	SC
MTY (7.5% = CA cost of cap.)	69%	CC	MTY (6% cost of cap.)	149%	CC
MTY PTC @0% esc. rate	74%	I	MTY (7.5% = CA cost of cap.)	141%	CC
MTY (1%=CA insurance)	78%	RP	MTY PTC @0% esc. rate	135%	I
MTY (10% cost of cap.)	79%	CC	MTY (1%=CA insurance rate)	129%	RP
MTY ITC & 30% cash grant that reduces ITC basis	88%	I	MTY (10% cost of cap.)	129%	CC
MTY (14% cost of cap.)	95%	CC	MTY ITC & 30% cash grant reducing ITC basis	117%	I
MTY 30% non-taxable cash grant	97%	I	MTY (14% cost of cap.)	106%	CC
MTY BENCHMARK*	100%	I	MTY 30% non-taxable cash grant	103%	I
MTY (8.5% electricity esc. rate)	100%	EC	MTY BENCHMARK*	100%	EC
MTY 30% taxable cash grant	105%	I	MTY 30% taxable cash grant	94%	I
MTY (7.35%=AUTO insurance rate)	124%	RP	MTY (7.35%=AUTO insurance rate)	67%	RP

Appendix C

Case Study: *Mosaic*

Mosaic is a crowdfunding platform headquartered in Oakland, CA. It is presented as a case study in addition to the main body of this thesis because it operates and connects investors to solar developers in a similar way to the business model explored in this paper. Founded in 2012 by Yale dropout Billy Parish, the company secured impressive amounts of start-up funding. For example, it won a $2 million grant from the SunShot Initiative, a program under the U.S. Department of Energy. Mosaic's strategy was to make customers comfortable with this innovative business model from day 1. To achieve this, Mosaic simplified the offerings of its first five solar projects as zero-interest investments to avoid the logistical and legal hassles of offering a return above face value. The projects were very successful in California and raised over $350,000 from hundreds of investors.

At present time, Mosaic is striding away from being a solar project crowdfunding platform. This is because the U.S. crowdfunding regulatory environment is in stand-by. It is currently focusing on being a financer for the residential solar market through its Mosaic Home Solar Loan. Additionally, it is working with inter-industry partners to standardize the way solar risk is evaluated[27]. The implications of understanding and measuring different kinds of risk are enormous. A discussion about risk is a thesis topic in itself and for this project it suffices to mention the primary types of risk: credit risk, technology risk, operational risk, and weather risk. Although currently inactive in that sector, it is still important to explain Mosaic's business model as a crowdfunding platform because this is still the vision of the company and it will likely return to it once the regulatory environment is more favorable to conduct this type of business. Figure C represents in simple flows of capital how Mosaic intended to connect individual investors to large residential and commercial solar projects.

As seen in Figure 18, first Mosaic negotiates loan terms with project developers. After this, it issues the Notes (a written promise to pay a specific sum of money over a fixed term) on the other side of the equation, that of the crowdfunders. Then, project owners set up contracts to sell the electricity generated to building owners or utilities. The revenues from selling the electricity enable project owners to pay back the principal and interest to their lender, Mosaic. The company then pays back the crowdfund investor (interest + principal) after taking its fee as an *aggregator*. As a 3rd party aggregator, Mosaic charges (as of May 2014) a 0.5% platform fee. In addition to this origination fee on the loan, it charges a small annual fee[27]. These fees are analogous to transactional fees charged by brokers in the traditional finance industry. Fundamentally, Mosaic is a middleman between disperse capital providers (individual investors) and capital seekers (solar developers).The advantages for solar developers of securing financing through Mosaic are more flexible capital involving less paperwork and shorter deal-closing times and cheaper capital than what banks typically offer.

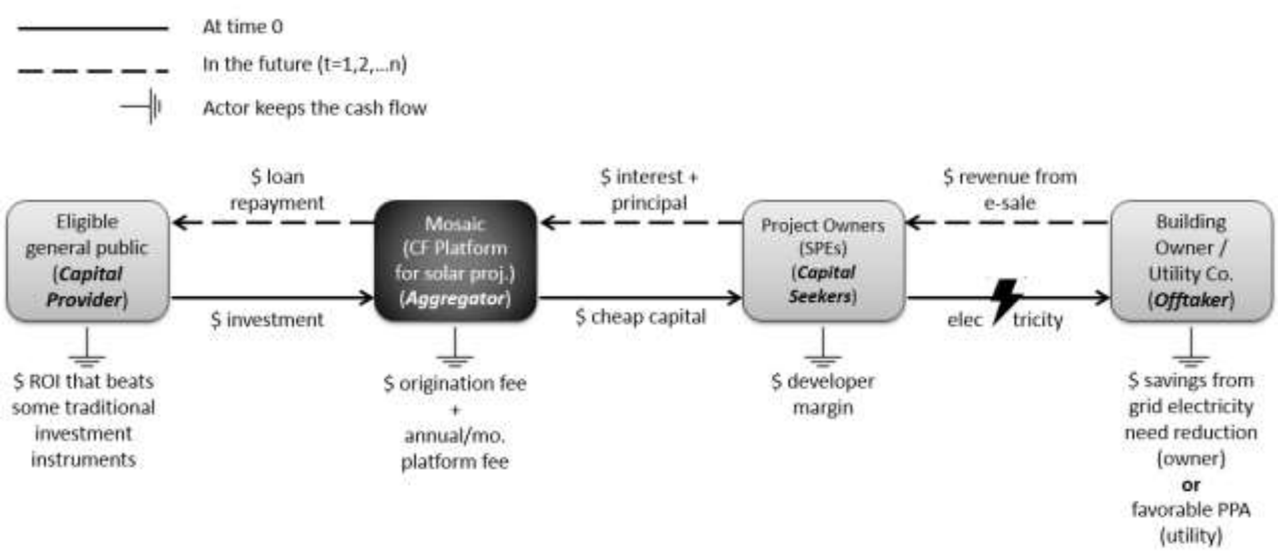

Figure 18. Mosaic's proposed business model as a solar project crowdfunding platform.

A major limitation of Mosaic's model (and other CF platforms and platforms to-be for what matters) is that eligibility requirements severely restrict who can participate as a capital provider. At the moment, only California residents who are 18 years of age or older with a valid Social Security Number can invest. Additionally, there are no investment opportunities available at the moment, with the last offering ending as far back as January 2015. As John Basile from Customer Service at Mosaic clarified, offerings for new projects on community buildings, schools, and churches do not come that often and sell out quickly. To add complexity to the matter, in order to comply with regulators, Mosaic cannot market its new offerings so there is no way to notify interested investors. Potential investors must visit Mosaic's website frequently and browse for new offerings[28]. The offering in January 2015 was $100 million in Notes, issued in series each corresponding to a different project financed by Mosaic. The interest rate was a function of the rate of the corresponding loan between Mosaic and the project developer. The Note term ranged from 12 to 120 months. On top of the other eligibility requirements, the following restrictions to invest in these Notes applied:

1. Investors who invest more than $2,500 in any 12-month period must have either (1) a minimum annual gross income of $70,000 and a minimum net worth of $70,000, exclusive of automobile, home and home furnishings, or (2) a minimum net worth of $250,000, exclusive of automobile, home and home furnishings.
2. In addition, no investor may invest more in this offering than an amount equal to 10% of the investor's net worth.

These restrictions and eligibility criteria for capital providers certainly make the business model less romantic. It is far from 'everyone' who can invest. In Mosaic's defense, the policy and regulatory framework on a global scale is not ready for equity crowdfunding.

Appendix D

Sociocultural Context

The following paragraphs are based off the literature review at the onset of this research. Given the variety of topics they cover, the author was unable to link them to the quantitative research in the main body of this paper. That said, these additional factors are as important as those presented earlier in determining the success of a solar project crowdfunding platform. Although qualitative in nature, they are sourced from documents from respectable government agencies and for-profit research hubs. According to Alvaro Briceño from Powerstein, undermining the importance of the local sociocultural context is one of the main reasons why no international solar developer has been able to dominate the Mexican market[12].

Local Societal Push for Renewable Energy

Various factors come together to make Monterrey the ideal place in Mexico for crowdfunded solar development. The Monterrey Metropolitan Area houses San Pedro, municipality ranked at different points in time as the most affluent in Latin America by different news agencies and development reports. Education comes hand in hand with economic affluence. In San Pedro and large parts of Monterrey, upper middle class and upper class families are significantly more aware of solar energy, the technology, and its financial and environmental benefits. “Monterrey is one of the best places in terms of consumer awareness and reception of solar power”, says GreenTech Media senior analyst for Latin America Adam James[19]. “Public perception [in Monterrey] is great and people want to own solar power” adds Alvaro Briceño, Director of Commercialization at Powerstein[12]. The majority of residential solar projects in Monterrey are for wealthy consumers that pay the High Consumption Rate (DAC) imposed by CFE. As

Briceño and James point out[12,19], the residential sector has developed on a referral basis among DAC customers. Outside the DAC niche market the circumstances are different. People distrust the unfamiliar technology. While solar developers see the solar panel as a commodity, the average Mexican citizen sees it as a high-tech, fragile product. Cost of ownership remains prohibitive to the vast majority of the people, and governmental incentives are lacking. The main factor driving the pro-solar societal push remains an economic one. Savings and disavowal towards an institution regarded as abusive (CFE, the sole electric provider) drive the industry much stronger than environmental awareness[12].

Financing Options for the End-Customer: Solar Leases & PPAs

The introduction of leases and PPAs as residential PV financing in Mexico produced some unexpected results for developers and shone a light on certain aspects of Mexican culture: the sense of ownership. Mexican citizens want to own. For example, in the U.S., the consumer buys a car on a loan with the mentality to replace it with a newer model and a new lending scheme 5 to 10 years down the road. In Mexico however, people want ownership. Developers offer customers convenient solar leasing of the type that has made SolarCity highly successful in the U.S., and they look concerned. It is hard for them to conceive someone else's equipment on their property, even though it is ultimately providing a highly beneficial service for them[12]. As most can't afford ownership, they incorrectly assume solar energy is for the wealthy. However, even in the underdeveloped Mexican market, there are options for low-income housing and the working class can afford small residential systems.

Cybersecurity Considerations & the Proliferation of E-Commerce

Another matter to address is the relative confidence of the population in the security of personal information when participating in e-commerce. Figure 19 shows e-commerce sales per capita in the U.S. and Mexico from 2010 to 2016. As seen in the figure, the Mexican e-commerce industry doesn't remotely compare to the American one, with sales in 2014 being one order of magnitude bigger in the U.S. "One of the major challenges facing the development of this ecosystem to date – in developed and developing countries alike – has been the creation of rules and regulations needed to govern online financial transactions, including crowdfunding."[10]

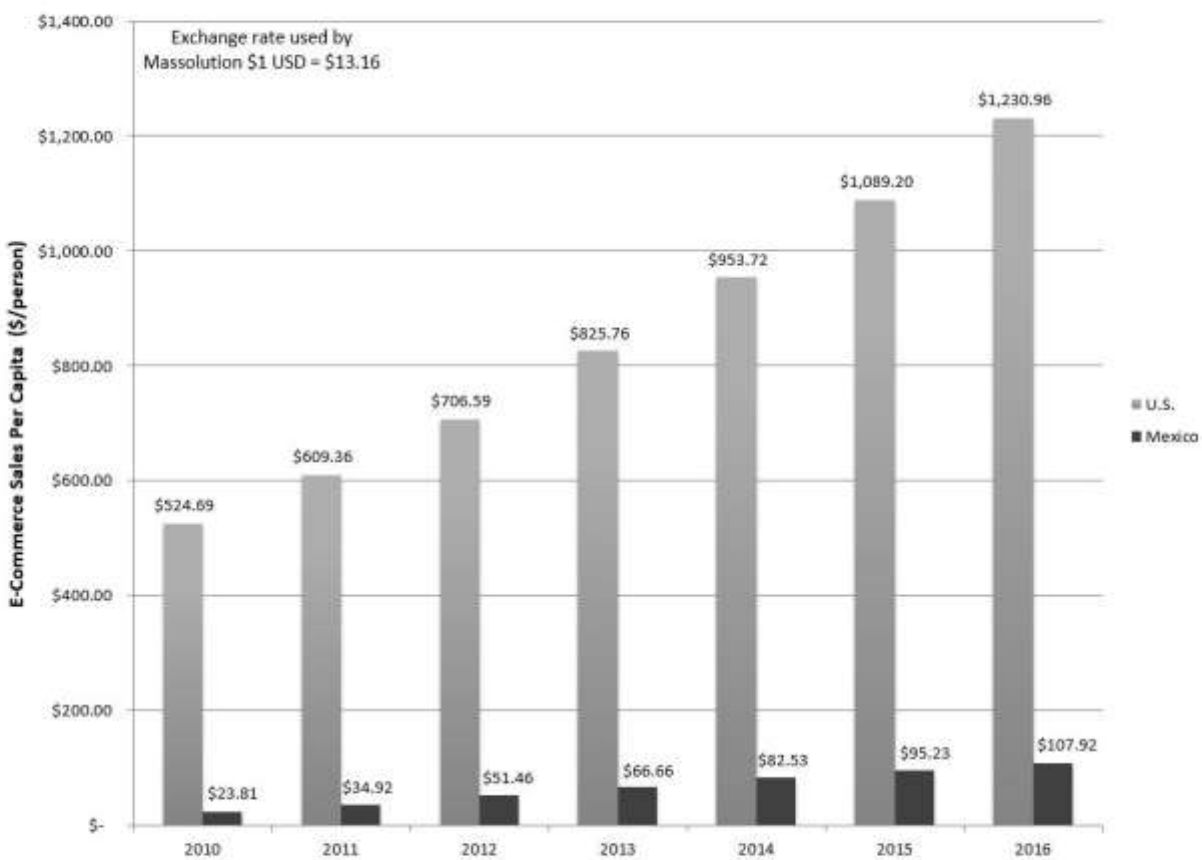

Figure 19. Business to Consumer E-Commerce Sales in Mexico & the U.S., 2010-2016. Prepared by author with data from Massolution[10].

The Investment Landscape for the Average Mexican

Putting solar energy aside for a moment, what investment options does the general public have in Mexico? Velia Valdes, analyst at Fitch Ratings in Monterrey, provided a list of the alternatives[29]:

1. High liquidity funds through the retail bank of choice. At low interest rates, most of the times the investor loses money after accounting for inflation.
2. Personal investment management through brokerage houses at the retail bank of choice. An example is Bancanet by Banamex. Through these one can invest in stock equity of companies listed in the Mexican Stock Exchange (BMV).
3. Investment funds like Vector Casa de Bolsa, GMB, and Skandia. The investor grants management rights to investment experts. The investment fund charges a management fee and a fee on capital gains.
4. CETES. Mexican Federal Treasury Certificates.
5. Corporate debt is out of reach for the average citizen. One requires a minimum investment amount of $2-3 million MXN (est. $130,000-$195,000 USD).

It is important to realize that the investment landscape in Mexico is underdeveloped when compared to that in the U.S. Investing in an instrument related to energy, be it fossil fuels or renewable energy, is extremely limited. Just recently, since February 2015, Mexican investors were granted the opportunity to trade in the main markets for oil futures on the Sistema Internacional de Cotizaciones (SIC) platform. An example of a future they can trade through the SIC is West Texas Intermediate (WTI) crude on the Chicago Mercantile Exchange. For cultural reasons discussed at the end of this section, most people don’t invest through the SIC, even though barriers to entry are, practically speaking, non-existent. SIC ‘requires’ investors to have a net worth of $2 million MXN (est. $130,000 USD). In practice however, there is no auditing involved and many people sign letters claiming to meet the requirement.

Granted, energy reform allowed PEMEX (the government-owned petroleum monopoly) for the first time in history to hold bidding rounds for the formation of public-private joint ventures for oil and natural gas exploration. However, obvious monetary restrictions and not-so-obvious regulatory restrictions prohibit most of the population from participating. The obvious restriction is that most people don't have millions and billions for fossil fuel exploration investments. The not-so-obvious ones require the bidding team to have 25+ years of experience in the industry and top tier exploration equipment[29]. Another alternative loosely tied to energy are CKDs, or Structured Equity Securities. CKDs are a new 'mezzanine' asset class, a mix between debt and equity in terms of risk and return. The capital goes to mainly infrastructure projects all across Mexico. The reason these can be considered energy investments is because there are CKDs focused on petroleum and natural gas projects. Grupo Bursatil Mexicano (GBM) Infraestructura even has CKDs tied to wind energy projects[29].

Just as investment opportunities in the U.S. increase enormously for the accredited investor or so-called "high net-worth individual", the CNBV (SEC-equivalent) gives plenty of investment flexibility to individuals in this category. Mexican Securities Market Law defines accredited investors as individuals and corporations that maintained during the previous year investments in securities of at least 1.5 million Unidades de Inversion (UDIS) (est. $450,000 USD) or with a gross income during the previous two years of at least 500,000 UDIS (est. $160,000 USD)[10]. This definition excludes the vast majority of the population from specific renewable energy investments and most private securities offerings of any kind.

The problem posed by the limited renewable energy investment opportunities for the average Mexican is exacerbated by cultural factors. Both the author's personal experience and the interviews with investment experts in Mexico point to the fact that the general public is skeptical to invest. People think it is overly complicated and shall be left to the wealthiest 5%. The closest thing to an investment for the average Mexican is money tied into pension funds (AFOREs) as required by law. The population has good reasons to believe national investing is complex: traditional investor protections are non-existent; law enforcement in intermediary markets is weak; and competition from the better established U.S. capital markets have kept the number of investors participating in Mexico's private capital markets at low levels[10]. To further hinder investment specifically through crowdfunding platforms, less than 25% of the population (29.6 million) has credit cards to invest through these online platforms. This is due to a combination of annual percentage rates (APRs) reaching over 40% and cybersecurity concerns[10].

Appendix E

Energy Policy & the Crowdfunding Industry in Mexico

Energy Reform & Renewable Energy Policy

The Mexican energy reform has been heavily covered by international multimedia companies since the presidential changes to the constitution were approved in December 2013. It is important to acknowledge a few important facts about the energy reform before addressing solar energy policy and legislation. Firstly, the vast majority of the energy reform impacts the hydrocarbon industry[19]. The reform was a package of changes across several industries and sectors: one part of it was implemented in the electricity sector; another, the biggest one by far, was implemented in the oil industry. In *absolute* terms, hydrocarbon reform vastly outweighed electricity reform let alone renewable energy reform. However in *relative* terms, the energy reform was significant for the smaller renewable energy[19]. The caveat is that in most fronts, the nation is still waiting for secondary legislature and a supporting regulatory framework. The original timeframe for this ended May 2015, but it is the rule for the Mexican government to miss deadlines, not the exception. Foreign investor interest is at an all-time high, and they similarly wait impatiently for regulation to clearly define the market and opportunity.

Forty-five percent of the electricity in Mexico is generated through natural gas-fired combined cycle generation. The official published plan, Energy Sector Prospective 2013-2027 estimates an increase in natural gas electricity generation to 66% [4]. This official estimates outright contradict the Climate Change Law (passed in 2012), which established a goal of 35% non-fossil fuel generation by 2024 and was reiterated in the Law for the Use of Renewable Energy and Financing of the Energy Transition (LAERFTE). Advances in the national renewable energy agenda have been minute and mostly led by the private sector. According to policy experts at the Global Sustainability Institute (IGS) at the EGADE Business School in Monterrey, the Peña Nieto government prolongs a breach between political discourse addressing clean energy and the adequate mechanisms to develop this kind of energy[4]. The government is even careful to address the topic within the frame of "clean" and not "renewable" energy, leaving the possibility open to include natural gas.

As in many other nations, fossil fuels are and historically have been subsidized in Mexico. Fossil fuel subsidies in the agricultural and residential sector averaged 1.7% of the GDP from 2005 to 2009, according to the Global Sustainability Institute (IGS) headquartered in Monterrey[4]. For example, in 2012, the R&D expenditure of the energy sector was of $10,863 million MXN. 50% was granted to the Mexican Petroleum Institute, 37.4% was for PEMEX, 7% for the Electricity Research Institute, and 6.4% to the Nuclear Research Institute[4]. Renewable energy R&D didn't make the budget. Additionally, the Hydrocarbon Fund is three times bigger than the Sustainability Fund. As of May 2014, two thirds of expenditure in energy R&D is concentrated on fossil fuels.

Community Solar & the Development of Crowdfunding in Mexico

Community solar in Mexico has happened unintentionally and sporadically. Neither of these is sustainable. On one front, it was unintentional because under the old regulatory structure there was the "self-supply" model: a private entity could build very large projects and have different off-takers consume the energy throughout the country. The so-called "energy bank" (virtual net metering equivalent) implemented by the government allowed the 'electrons' generated at the Independent Power Producer's site to be netted against those being consumed at the off-takers site. The energy reform abolished this regulatory regime and the framework for community solar is unclear at the moment and deprioritized in the energy reform agenda[19]. On the other front, community solar happens sporadically as neighbors convene for bulk purchasing power. As Briceño from Powerstein explains, it is usually an environmentally conscious neighbor with leadership traits that initiates collective action. However, this is not community solar because these are still individual systems on individual rooftops[12].

If community solar is unintended and sporadic, crowdfunded solar is non-existent. Regulation is even less clear than in the U.S, and there is nothing like the JOBS or the CROWDFUND Acts lined up to change the conditions in place. "As in other markets at early stages of crowdfunding development, interviews revealed a general lack of clarity regarding the scope of what is currently permitted today or what should be permitted under new regulations addressing crowdfunding."[10]

The sale of securities via online crowdfunding models is a new phenomenon and most governments have yet to study and understand it. In terms of equity crowdfunding, Europe is at the forefront of regulatory innovation. In countries like Italy and the U.K., equity crowdfunding is legal and regulated today. In Mexico, the National Institute for the Entrepreneur (INADEM) has established a working group to support the development of crowdfunding legislation. Existing crowdfunding platforms in Mexico are part of this working group. A word of caution for Mexico is that its public institutions have been historically complex and unable to effectively help the citizen with processes[10]. This can slow the development of policy and a regulatory framework to foster the development of the industry.

As of today, two actors can legally finance new ventures: institutional investors and qualified investors. On one hand, Mexican Securities Market Law defines institutional investors as any of the following organizations[10]: Mexican banks, foreign banks, broker dealers, insurance and bond companies, bonded warehouses, financial leasing companies, factoring companies, investment funds, private pension and annuities funds, and foreign pension and investment funds. On the other hand, qualified investors are individuals and corporations that maintained during the previous year investments in securities of at least 1.5 million Unidades de Inversion (UDIS) (est. $450,000 USD) or with a gross income during the previous two years of at least 500,000 UDIS (est. $160,000 USD) [10]. The vast majority of the population is thus excluded from funding new ventures. The National Banking & Securities Commission (CNBV, roughly SEC equivalent) must either expand the definition of 'qualified investor' (legislative change) or allow unqualified investors to invest in these new kinds of instruments at their own risk (no-action statements or exceptions).

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ACADEMIC VITA

FERNANDO FUENTES DE LA PARRA

Education

The Pennsylvania State University, University Park, PA
B.S. in Energy Engineering, B.S. in Energy Business and Finance
Schreyer Honors College

Design of Solar Energy Conversion Systems, PV System Design and Construction, and 2 other solar courses
Initial exposure to SAM & PVWatts and familiarity with NEC articles 690 & 705

Engineering and Business Experience

SunEdison, ***Solar Development Program Summer Analyst,*** San Francisco, CA — Summer 2015

CEMEX Energy & Sustainability, ***Energy Intern,*** Monterrey, MEXICO — Summer 2014

- Became acquainted with wind energy project finance (complex spreadsheets and VBA programming) at internal meetings with more senior team members.
- Shadowed direct supervisor in meetings with institutional investors and potential off-takers as part of the deal team for the wind farm project.

2014 Green Energy Challenge, National Electrical Contractors Association (NECA) — 2013-2014

- Part of multidisciplinary team that submitted the "Energy Retrofit Proposal of Penn State Berks Perkin's Student Center"
- Created preliminary design of a 50 kW PV system in AutoCAD and modeled performance and simple financial metrics in SAM.

Office of Physical Plant at Penn State, ***Energy Intern,*** University Park, PA — Jan-Sept. 2013

- Assessed on-campus solar project proposals with the System Advisor Model (SAM).
- Analyzed complex utility and campus energy systems data.

Solvay & CPC Monterrey , ***Engineering Projects Intern,*** Monterrey, MEXICO — Summer 2012

- Managed the implementation of a solar thermal system and an off-grid PV system.
- First exposure to AutoCAD by designing both solar systems to serve as models when pitching to management and coordinating with suppliers and installers.

LEED® Green Associate — As of May 2014

Languages Spanish, native speaker | English, fluent (+16 yrs. of learning) | German, C1 language level

Software Proficient: SAM/PVWatts | AutoCAD | MatLab | LaTeX | GAMS | @Risk/PrecisionTree

Leadership & Awards

Winner of the 2015 Senior Class Gift Design Competition by proposing a solar array distributed around campus on 6 different bus stops — May 2015

THON 2015, ***Dancer*** — Feb. 2015

Society of Energy Engineers (SEE), ***President*** — 2014-2015

Spark Clean Energy Fellow 2014 — 2014-2015

1000pitches Entrepreneurship Competition, ***1st Prize & Recipient of $1000*** — Dec. 2013