ESCUELA TÉCNICA SUPERIOR DE INGENIERÍA (ICAI)

MASTER IN THE ELECTRIC POWER INDUSTRY

An Investment Decision Model for Renewable Projects in the Mexican Regulatory Framework

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Abstract

The purpose of this thesis is to analyze the undergoing liberalization process of the Mexican power sector and understand how the deregulation of the generation activity impacts investment decisions. In addition, a financial spreadsheet model is presented as the traditional methodology to evaluate investment opportunities under such context. Finally, a system dynamics (SD) model is proposed to investigate what contributions it can add on top of the traditional approach. The reason for this research goes beyond analyzing the Mexican power sector, by providing a robust model to support decision makers.

The thesis is composed of eight chapters, each of them dealing with different aspects of an investment decision context, including the regulatory environment, forms of financing projects, power plant technologies, financial models widely adopted by the market and SD modeling methodology. The first chapter is introductory and defines basic terminology and methodology used in the thesis.

Chapter Two examines relevant studies carried out about the Mexican energy reform, project finance of energy projects in developing countries and system dynamics models used for energy projects evaluations. Due to the recent liberalization process, not much has been developed about Mexico and no relevant papers targeting the use of system dynamics from a single investor perspective were identified.

Chapter Three goes deep investigating the main aspects of the Mexican power sector deregulation, especially focusing on the generation activity. In the last section of the chapter, an overview of the first power auction and PPA terms are presented and used as base case to develop the financial models highlighted in the following chapters.

In order to provide financial models with realistic approaches, chapter Four concentrates on elaborating a theoretical solar power plant project, detailing the technology adopted, expected investment expenses and operating costs in the context of Mexico. All the data presented is used as inputs to both models.

In chapters Five and Six, the traditional financial spreadsheet and SD models are discussed, respectively. Both models are equivalent and provide the same outputs such as the equity IRR,

assumed in the thesis as the main parameters investors use to support their decisions. Chapter Seven is dedicated to the results and findings of the proposed SD model, including several sensitivity analyses performed that would be difficult to be developed, under same circumstances, in the spreadsheet methodology.

Conclusions are drawn in chapter Eight. The main objectives of the thesis are first to highlight the complexities present in the Mexican PPA terms that increase the level of uncertainty decision makers have to deal with. Secondly, discuss how the traditional modeling approach addresses such uncertainties and, in most of the cases, conclude it is not able to provide a statistical representative range of outputs, which would improve investors' evaluations. The PPA's complexities and lack of statistical tools may make room to erroneous decisions, leading projects to not be materialized. Finally, the proposed SD model confirms the hypothesis that there are alternatives able to enhance the decision making process, especially running as many scenarios as needed be to convince investors they are better supported.

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1. Introduction

Electricity sectors in most countries historically evolved with vertical integrated and geographic companies that were owned by the state and subjected to a regulation of price, quality of service and entry access. Also known as natural monopolies, as they hold a primary and essential service to the population that in the case of competition would not bring higher welfare, the utility companies were also called vertical integrated businesses because they grouped all the components of electricity supply, i.e. generation, transmission, system operations, distribution, and retail. The regulated monopolies performance differed significantly across countries, raising the question if the model adopted so far was the most efficient and if there would be other regulatory frameworks to produce better outcomes. In addition, higher operating costs, construction cost overruns on new facilities, high retail prices, and falling costs of production from new facilities driven by low prices for natural gas and the development of more efficient generating technologies, such as CCGT, endorsed the pressures for changes targeting a reduction on electricity generation costs and, subsequently, retail prices (Joskow, 1998; 2000).

Nowadays several countries have adopted a, so-called, liberalized regulatory framework, in which competition is possible in determined electricity activities (generation and retail). The process of liberalization is stepwise, aiming at the unbundling and segregation of the vertically integrated utilities. In other words, separating activities possible of competition from the ones that should be kept regulated as a natural monopoly. The reform target is to develop institutional conjunctions for the electricity sector that provide long-term benefits to society and to ensure that an adequate share of such benefits are carried forward to consumers through prices that reflect the efficient economic cost of supplying electricity.

When it comes to electricity generation liberalization, the economic signal provided by the regulatory bodies aims to introduce new competitors and investors that would cope with generation risks. The shift of risks (e.g. technology choice, construction cost and operating mistakes) from the end consumers to investors, imposed the investment decisions to be more refined and accurate. The decision to invest on a new generating unit relies on translating operational parameters and variables into financial terms and evaluating different scenarios, as there are several exogenous factors and uncertainties. Shareholders are interested to know the level of risk their investments will have and what would be the trade off in terms of financial project returns. An investor can either finance a project from cash available on its balance sheet (corporate financing) or exclusively on the presumed income of the generation asset to be constructed. The latter is called “project finance”. In other words, project financing is a loan structure that relies primarily on the project's cash flow for repayment, with the project's assets, rights, and interests held as secondary security or collateral. Project finance is especially attractive to the private sector because they can fund major projects off balance sheet. In order to evaluate if a project is applicable to project finance, several requirements must be fulfilled. The common ones are stability and predictability of cash flows, project profitability, legal and regulatory stability and possibility to assign risk between all stakeholders (constructors, insurance, offtaker etc.).

Mexico is one of the countries currently facing liberalization process of the generation activity. On its first power tender, more than 69 companies participated totaling a 500MW of additional installed capacity and 6,361,250 MWh to be operational before March 2018 (CMS, 2016). Most of these companies are international developers expanding their portfolio. Several of them consider project finance as the main approach to raise funds for the construction phase of the new generation units. The traditional tool used to raise such funds is a spreadsheet financial model to evaluate the cash flows of the project and construction and operational expenditures. Potential lenders and other investors will rely heavily on financial models to determine whether a project is financially feasible by estimating future cash flows, profitability, and the ability to service debt under different financial structures and under a range of downside assumptions. The spreadsheet approach has been adopted by utility companies and advisors for years. Excel is the main software considered when studying investment feasibility. Even though several other modeling techniques are used in the academia for policy analysis and decision making, those do not seem to be largely adopted by the industry when it comes to evaluating investment decisions of power plants. The aim of this thesis is to detail the traditional approach and propose a new perspective using system dynamics in the Mexico liberalization context.

1.1 Project motivation

As an EMIN student, I have covered several interesting courses throughout the two-year period of my master program. My motivations, when defining my thesis topic, considered the following:

- Apply the decision making techniques and tools I have studied in TU Delft
- Cover a topic in line with the courses I have had in Comillas, i.e. the electric power industry
- Spend part of my research in cooperation with a company involved with the power sector
- Take advantage of my professional background
- Expectation that the output/results of my thesis may help me in my future professional life

After spending some months looking for a relevant topic and researching several papers about decision making in the power industry, I have realized that industry and academia have a large and successful history of developing optimization techniques to support utilities companies and investors in the power market. There are several fundamental and statistical models for decision making in the electric power system (EPS), from generation to retail – regarding marginal production, feed-in and offtake. On the other hand, I could not find as much material when considering simulation techniques using agent based modeling (or system dynamics). Even fewer when considering a one company perspective to decide for a generation investment, i.e. not a marginal production but a full investment decision based on system dynamics. Fewer if the investments in generation would have to be made as a non-recourse project finance (as further defined below).

I was introduced during the course of Electricity Industry Financing (Economy of the Electric Power Industry) to the project finance world. I also recall a lecture/discussion about it with a Comillas/EMIN alumnus and, at that moment, decided it would be very interesting to develop my thesis in cooperation with a company involved in the project finance niche. The main reason of this decision is due to the fact I would not only have the academic perspective of the topic, but also its applicability in the market.

1.2 Research objectives

Analyzing the feasibility of a renewable investment requires an understanding of the environment in which the project will be built. This includes the regulatory framework, renewables support schemes, a country's regulatory risks, macroeconomic condition, financing situation and many other topics to be explored throughout the planning and development phases of a project. After gathering all relevant information, investors expect to make a decision based on financial returns.

In other words, facts should be translated into monetary terms to be evaluated. Furthermore, an investor can either finance an investment from funds available on its balance sheet. Alternatively, a specific project can be financed – without recourse to the owner – based solely on the expected cash flows of the generation asset to be built. This latter form is generally referred to as "project finance".

Most of the financial evaluation studies are supported by financial models, i.e. excel spreadsheets with economic indicators subjected to different scenarios and sensitivity analysis. Based on these financial models, investors will decide whether or not an investment will be undertaken. One of the goals of this thesis is to show that a system dynamic model can be a better basis for investment decisions than a standard financial model, which is widely used in the industry today.

My objectives are, first to research and understand the main characteristics of Mexican electricity regulatory framework before and after generation liberalization (to be used as reference to a project investment decision environment), including past, present and expected scenarios for the development of renewable installed capacity, capacity mechanisms, structure of the electric power system, stakeholders, and power purchase agreement (PPA) terms. Secondly, a theoretical renewable project scope will be defined, in order to understand how the regulatory framework of Mexico affects the investment decisions. And finally, an agent based model will be constructed to evaluate the investment with a different methodology. Additionally, to the use of excel sheets, a system dynamic model will be the tool adopted to evaluate if an investment would make sense, and if so, under which conditions. The aim is to study what extra insights a system dynamic model adds to the well-developed spreadsheet approach.

1.3 Research questions

This paper focuses on the identification of main changes on the Mexican electricity market regulation. These changes are targeting more efficient generation investments, that would be converted in lower electricity supply costs. In order to evaluate this new framework from a developer point of view, a theoretical renewable project will be analyzed under a financial perspective. In addition, the last objective is to better explore the advantages of using a system dynamic model to evaluate the same renewable project neglecting the use of the traditional spreadsheet approach. Given the explanation above, the research questions to be conducted and intended to be answered in this paper are:

1. *What are the main characteristics of the Mexican electricity regulatory framework before and after generation liberalization?*
2. *How does the regulatory framework affect the investment decision of a renewable project from a financial perspective?*
3. *What insights do a system dynamic model add to the well-developed spreadsheet approach to support the investment decision of a renewable project?*

The questions are, on purpose, introduced in such order because it's necessary to obtain the answer of the previous one to use as an input for the following.

1.4 Methodology

The methodology applied to answer the research questions follows four stages. First, I will provide a full description of the Mexican regulatory frameworks of the energy markets based on a desk research. In other words, I will start with a general overview of the whole electric power system and will go into detail on each activity of the industry: generation, transmission, wholesale market (if applicable), distribution and retail. Given the main purpose of this paper is to evaluate investment decisions on the generation side, I will put more effort into analyzing the market structure, possible policies promoting renewable generation support, capacity and quantity mechanisms, PPA terms, and electricity offtakers.

The reason of selecting Mexico as the regulatory framework, under which the theoretical renewable project is going to be evaluated, is the historic undergoing reform of the country's energy sector, turning it into a very interesting and complex country to research with limited studies available so far.

The second stage consists of detailing the theoretical renewable project in terms of installed capacity, technology considered, research about investment and operational costs of such a plant and some benchmarking with existing renewable generation units' technicalities. The reference will be the recently installed plants in Mexico and the kind of projects that participated in the first energy tender of Mexico on March 2016. This will provide a realistic and update approach considering the specifications. For the sake of this thesis, several assumptions will be detailed later on.

The third stage is to develop a spreadsheet financial model based on the information provided by the prior sections and my own professional experience working on Green Giraffe, a specialist advisory boutique focused on the renewable energy sector. The target is to replicate the most used tool adopted by the market when it comes to evaluating investment decisions from a project finance perspective. This implies on building a model that considers both the technical production parameters and its translation to financial terms. The content of such model developed in Excel consists of using inputs to determine the construction and operational costs, revenue streams, Capex financing, tax calculations, depreciation and amortization of assets etc. These calculations will provide the outputs –financial statements (income statement, cash flow and balance sheet), which are the basis for an investment decision making process.

The fourth stage is about developing the system dynamics model from scratch. This is the last phase, because all the input variables, parameters and constraints will be provided by previous stages. The steps of this phase will be based on research of references of similar models, define the scope considered (to what extent the model will simulate or consider external variables), construction of the model using VENSIM software, simulation, sensitivity analysis, uncertainty analysis, verification, validation and, finally, the results. At the end, the expectation is to demonstrate how an investment decision can be supported by a system dynamics model, what is the applicability, what are the constraints and how this technique adds value to the current tools used in the market.

1.5 Thesis structure

This paper is conducted as a combination of desk research, two different modeling techniques and a few interviews to support some modeling assumptions. Limitations of information are expected because of the lack of interviews with the regulatory and Mexican gubernatorial bodies, which could provide an inside perspective of the stakeholders. Another limitation is the fact that liberalization is something taking place at the moment this paper is being written and future happenings can evidence new factors not considered when answering the research questions.

The thesis structure initiates in chapter 2, dedicated to present the results of a survey of the literature on the three areas that are relevant to the research questions: Mexican regulatory electricity framework, the use of project finance in developing countries to energy projects and system dynamic models for renewable energy projects investment decisions. Additionally, conclusions and shortcomings are identified and addressed in the following chapters.

Chapter 3 goes deeper into the Mexican regulatory framework. It begins pointing how the structure of the market was modified after the generation liberalization, and then it focuses on numerical data about macroeconomic parameters, main stakeholders and how the regulatory bodies are organized. Following that, the renewable energy support schemes are detailed to demonstrate how Mexico is moving towards a cleaner energy generation mix. Finally, a summary of the first Mexican power tender is elaborated.

A theoretical electricity generation project from solar sources is described on chapter 4. This project will be the basis to build the spreadsheet and continuous system models of the Mexican regulatory environment under the PPA terms. The sections of this chapter cover briefly the technology considered and its capital and operational expenditures (Capex and Opex, accordingly).

Chapter 5 describes the main sections of the spreadsheet financial model (the traditional approach). Some financial terms are introduced and described in this chapter already considering the Mexican financing environment, PPA terms and the theoretical project described on chapter 4.

Chapter 6 is the translation of the spreadsheet financial model into a system dynamic model point of view. A brief introduction of the VENSIM software is presented followed by a succinct mathematical theory. Furthermore, the main feedback loops and polarities of the model are explained and its impacts of the outputs. The chapter ends with a brief verification and validation of the suggested model.

Finally, the numerical results are exhibited on chapter 7 with a comparison of the two modeling techniques explaining the limitations and advantages of each. The conclusions, answers to the research questions and recommendations are presented in chapter 8.

2. State of the art

The goal of this chapter is to introduce a literature review. Three sections are dedicated, first to review what have been produced regarding the Mexican electricity regulatory framework. Secondly, a brief survey is made to highlight the main studies about project finance in developing countries. Finally, the main system dynamic papers related to renewable projects are presented and analyzed. These sections are important to support answers to the proposed research questions and identify shortcomings that may be overcome with this thesis.

2.1 Mexican electricity regulatory framework

Mexico is carrying out the final details of a reform of its electric sector. The debate of such reforms goes back to the nineties with the foundation of the country's energy regulatory commission to evaluate and plan the sector's performance. The main objective of the energy reform, supported by the New Electricity Law is to grant expanding participation of the private sector in the generation, transmission and distribution of Mexican electrical power system (Breceda, 2000).

Rodriguez et. al. (2003) discusses the historical structure of the Mexican electricity sector and defends the stepwise process that led the regulatory bodies structure changes. As many liberalization processes, it has components of legal, political and economic matters. This study emphasizes the importance of the Energy Regulatory Commission (CRE) foundation as the first step towards the sector's deregulation. The role of CRE (created in 1993) was to design and implement an electricity market. In 1995, CRE became an independent agency in charge of regulating natural gas and electricity industries. Rodriguez et. al. mention that the last reform allowed CRE to perform crucial tasks targeting a full liberalization in the future. Some of them were issuance of permits to generate electricity, participation in the setting of tariffs for wholesale and final sale of electricity and verification that entities responsible for the public electricity service purchase electricity at the lowest cost taking into account stability, quality and safety parameters.

Breceda (2000) highlights the importance of President Ernesto Zedillo's mandate, during which he proposed a reform of the Mexican electric sector that was denied by the chamber of deputies. The proposal was to curtail the public sector participation in the electricity market. The state-owned companies, Federal Electricity Commission (CFE) and Luz y Fuerza del Centro (LFC), that during the year 2000 provided more than 90 percent of the country's generation, would have their activities limited by privatization and an opened market to private utilities. Additionally, the transmission and dispatch activities would remain in the hands of the State. President Zedillo's project targeted the issues that were holding back the country's economic growth: the growing electrical power demand and insufficient public funds to expand Mexico's power installed capacity. As demonstrated in the following chapters, this initiative, even though not approved by that time, is much in line with the current reform. The reasons of the project denial in the year 2000 will not be analyzed in this thesis as they involve, public opinion, extensive historical events, and political parties' interests, among others.

Watson et. al. (2015) present a review of the New Electricity Law enacted in 2014. The current energy reform is considered the most significant change to its sector in 80 years. The main goals of the reform are to unbundle the vertically integrated and state owned utility CFE and to implement a wholesale electricity market as of January 2016. Before this reform CFE had full responsibility for planning the National Electricity System (SEN) and held 67 percent of the electricity generation. The rest was spread among independent power producers (IPP), which had to sell their power to CFE. Private sector participation was only allowed through special permits for cogeneration, generation for export purposes or self-supply power generation. CFE was also responsible for all of the transmission and distribution activities. Other substantial contributions of the energy reform to the sector are the creation of intraday and spot wholesale electricity markets, establishing new transmission planning and implementing clean energy incentives.

Understanding how the energy sector is organized in a particular country is not an easy task. The complexity increases when such country is undergoing a deregulation process. The literature reviews presented above detail the factors precedent to the liberalization and the achievements expected in the post implementation period. Most modifications in the regulation framework targets the increase of efficiency and this is not different in the Mexican reality. However, not much is highlighted in the literature about expected economic gains with such improvements. Additionally, a scheme presenting the scenario before and after regulation is necessary to classify and better explore the role of the sector's stakeholders. An effort is made on chapter 3 to bring the described information and provide comments, numerical data and terms about the energy reform main shifts as well as highlights of the first Mexican power tender in history.

2.2 Project finance of energy projects in developing countries

The importance of project finance in infrastructure investments in developing countries is major. One of the reasons is due to the regulatory risks of such countries. The projects broadly mediate a clear allocation of risks among public and private stakeholders. Investors and lenders generally assume risks for completion and performance of the constructed assets. Public authorities take on substantial risks in nearly all projects, regarding areas in which they have control, such as electricity prices, term, currency convertibility, fuel costs, inflation, offtaker and political events. In the power sector, risks are explicitly allocated under the PPA terms. The objective of this literature review is to research and examine the financing and governance structure called Project Finance that typically funds large scale, capital intensive, infrastructure investments in developing countries. The choice of selecting developing countries instead of only Mexico is to avoid narrowing down the number of literatures available.

Contrary to common belief, project finance is not a new trend of modern finance. Tinsley (2000) concludes that the modern history of project finance began with production payment financing in a Texas oilfield project in the 1930s. A driller funded the well-drilling costs in exchange for a share in future oil revenue. This technique was imported to Europe to finance large projects such as the North Seas oilfields in the late 1970s. After some years, project finance grew up significantly and spread worldwide having a significant impact in large scale projects in developing countries. These include the Ras Laffan LNG project in Qatar and the Petrozuata heavy oil project in Venezuela (Hauswald, 2003), as well as many independent power projects (IPP) in South America. One of the most important reasons for the implementation of this financing form is the need to fund major projects of infrastructure while dealing with different levels of risks, cost of capital, stakeholders and a diversity of sectors and countries.

Many are the studies that emphasize the need to develop energy projects worldwide to deal with the electricity demand increase. This is particularly relevant to developing countries as the lack of energy and installed capacity expansion are limiting factors to economic growth. In Latin America this was an ordinary event of last decade in Brazil, Chile and Venezuela to mention a few energy crisis that led those countries to forced blackouts and electricity consumption rationing. Gatti, S. et al. (2013, 12) mentions that the geographical distribution of countries that use project finance ranges from developed countries to developing ones. Regarding the developing countries, about 49.4% of the total number of loans granted to projects finance belongs to the Asian borrowers, with projects in Taiwan, Australia, China, and Indonesia, with a value that ranges from 32 to 55.9 billion dollars. Western European borrowers are the third largest recipient of funding projects, after Asia and North America. Latin America still has considerable room to grow the use of project finance on its infrastructure investments. The main reasons of constraint, are the financing environment and bankability limitations due to skepticism of the local market and low experience compared to Europe or North America.

The following paragraphs present a brief literature review highlighting some of the main project finance theories, advances and applicability.

Williamson (1975) and Klein, Crawford and Alchian (1978) proposed a theory based on the mechanisms of a particular economic structure, as well as financial and organizational governance (with the creation of SPV – special vehicle purpose). Managers would have the advantage to control the economic performance of the firm and may transgress it if these assets are characterized by the yield of substantial volumes of cash flows. This theory was highlighted and supported by Esty (2003). He stated that the assumption that the unique vehicle that features the project finance reduces the costs of hold – up problem between parties of a deal who have invested in a particular project. Those theories brought forward the idea of a project relying only on its cash flows to be financed.

Jensen and Meckling (1976) were one of the former authors who investigated and evaluated agency costs emerging from misalignments between project's managers and principal shareholders, i.e. the lenders and sponsors. Esty (2003) supported the assumption that project finance shortens agency costs from conflicts between managers and shareholders due to how the project's structure is organized, characterizing this mechanism.

Shah and Thakor (1987) in their research proved that the structure of project financing decreases the cost of capital, particularly for the ones classified by high risk exposure. The main hypothesis is supported by the symmetric information between the participating parties. This is in accordance with the prevailing of an actor intermediating unbiased information among stakeholders, especially the project's managers and sponsors.

Chemmanur and John (1996) investigated the floating of the project from the perspective of benefits of managers appearing from the gains that they have over acquaintance and command of the project and the matter of close auditing and due diligence processes over the project's phases.

An accurate definition of this form of financing is not simple, and it was first introduced by Nevitt (1979). Given the different types of projects that use this technique, he defined project finance as "a special purpose entity in which lenders of the project have mainly cash flows guarantees and the income generated by the project, as the main source of repayment of the loan and as collateral for loan, its assets." This definition is independent of the sector the project is introduced.

After presenting the main literatures about project finance, much can be concluded. As opposed to corporate finance, project finance consists of very special elements. Four of these elements are the establishment of a separate entity (SPV), non-guaranteed debt (or non-recourse debt to finance the project) that will rely only on the cash flows that will be generated by the project, the sharing of risks between the parties participating in the project and low volatilities of the revenue streams.

From the succinct literature review, not much is discussed about project finance in renewable electricity generation projects and how the PPA terms are essential to meet a fruitful debt raising environment. In other words, the bankability of such projects in the developing countries is something to be deeper explored in this thesis, particularly in the Mexican reality. Another point of attention is to discuss, in detail, the model techniques used to support evaluation of investment decisions under the project finance scope. Every investment approval requires, a previous model to explicit the costs, revenues and the real returns to investor and lenders, as well as an evaluation of the robustness and risks involved in the operation. Such model is subject to, due diligence by the lenders (in most cases, commercial banks requirement). In chapter 5, the most used modeling technique will be presented and implemented to a theoretical renewable project (to be detailed in chapter 4) into the Mexican electricity regulatory framework after its generation liberalization.

2.3 System dynamics models for energy projects

System dynamics is a method for modeling, simulating and analyzing complex systems. A system is characterized as a group of elements in which interactions are modeled as flows between variables in time steps, and in which the rate of change depends on the value of the parameters that define the system. Therefore, the main objective of system dynamics (SD) is to understand how a given system develops, and even more importantly, to comprehend the sources that guide its evolution. The basis of SD has been reanalyzed in detail in Radzicki and Tauheed (2009). The applicability of SD methodology for the realization of complex environmental systems has increased significantly. It has been used to study climate change policies, evolution of the economy and to comprehend energy markets (Fiddaman, 2002; Nordhaus and Yang, 1996; Naill et al., 1992; Feng et al., 2012).

Teufel et al. (2013) developed one of the most relevant and detailed reviews about the main system dynamics models applied to electricity generation markets and energy sources, from single to multi agent perspective. This literature review emphasizes the main findings, applicability of such models and common shortcomings. The models are presented and commented in the following paragraphs, starting from the macro and more aggregated models to the specific ones that will support the research questions of this thesis. The decision to survey the broad models presented is to provide a background and context about the use of SD in energy systems.

One of the first substantial studies about the development of strategic planning practices in the energy sector, called “Limits to the Growth”, was performed at the Massachusetts Institute of Technology (MIT). Its outcomes were two famous models, WORLD2 and WORLD3, as well as several publications about the results obtained from the models (Forrester, 1971). The MIT group study targeted at forecasting the long term progress of the energy sector, analyzing the socioeconomic interactions that were causing global population and industrial production to expand, even considering possible natural resources unavailability (Meadows and Meadows, 1973).

Following the same methodology, Naill (1972) built one of the first models focused on a specific natural resource - natural gas. His research was based on the life cycle theory developed by Hubbert (1950). Hubbert based his theory on the objective of simulating future US oil production scenarios and was able to forecast the production curves between the years of 1966 and 1971. This impressive result caught the attention of energy modelers to determine the impacts of energy production constraints on US economic growth. Naill, on 1976, proposed a new model, called COAL1. His model took into account all north American energy resources and consumption to simulate several scenarios in the short and long term. COAL1 was later on used as the basis of the FOSSIL1 model (Budzik and Naill, 1976; Backus, 1977). FOSSIL1 was used to assess the new National Energy Plan by the president Carter Administration (Naill and Backus, 1977). Naill, years later, adapted the model to turn into the evaluation work adopted by the US Energy Department for decades. The use and outcomes of such model were mainly policy testing, taxes effects forecasting, renewable resources investment and CO2 reduction policies evaluation (Armenia et al., 2010).

Sterman, who made contributions to the development of the FOSSIL models, focused later on a new model to understand the relations and flows between economic and energy sectors (Sterman, 1981). His work fulfilled the shortcomings left by FOSSIL models, such as economic growth, interest rates applied to projects, renewable energy technologies costs and important parameters treated previously as endogenous variables. Sterman main contributions were the analysis of US energy transition technologies and financial terms impacting the US energy matrix developments.

Arango et al. (2002) developed a model named "Micro world". The goal of this model is to analyze the electricity generation capacities in terms of investment decisions in Colombia. "Micro world" is not only a system dynamic model, but also a game. The model is based on periodic investment decisions made by a potential investor within a defined scenario. The set of investment decisions allows an evaluation of the results of the electricity generation capacity expansion. The user or investor is able to notice how system evolves on a regularly basis and define if and when the investment decision in generation is worth. In this model an uncertainty analysis is considered with regards to capacity expansion. Uncertainty is implemented by variables modeled stochastically such as electricity price, demand evolution and the levelized cost of energy (LCOE) of several technologies. The main output of the model is the estimated project cash flows of the investment cycles.

Another model focused on the investigation of investment cycles is the one proposed by Gaidosch (2007). In his model, the scope of analysis is the German electricity market. The model considers a long term analysis frame of 30 years looking for investments schedules in additional power plants. Even though the model is focused on investment cycles from a macro perspective, it provides insights to support investors on the decision process. Thus the model supports the analysis of the impact of various politico-economic measures. The main simulation conclusion of the model emphasizes that the current German electricity market structure does not prevent from the existence of investment cycles with high price volatility and it suggests a range of policies to cope with that.

A SD model in line with the research field of the previous one is suggested by Sanchez et al. (2008). He also investigates investment dynamics, but combines it with financial variables that are crucial to investment decisions such as credit risk and game theory. He suggests and confirms with his model that the cost of capital when taking a new loan is directly proportional to the volume of investments made in the market. Hence, higher credit costs result in a decreasing net present value of a project. This is the first model of this literature review considering aspects relevant to a project finance modeling study.

Kadoya et al. (2005) adds to the study of investment cycles an important context, which is the deregulation of electricity markets. He investigates how the liberalization of generation influences the cyclical investment behavior. This model is market specific to the realities of Pennsylvania-New Jersey and Maryland Interconnection (PJM) and Independent System Operator-New England (ISO-NE). Two considerable additional features of this model are the input of electricity prices as forward curves and the detailed profitability statements used by companies for investment decisions. The simulation conclusions reinforce that deregulation is a supplementary source for cyclical investment behavior. This model is one step towards to the project finance environment as the main parameters considered for investment decisions are provided in the financial statements.

The model proposed by Olsina et al. (2006) enhances the mathematical floor behind cyclical investment mechanisms. The model takes the perspective of companies and regulatory bodies to develop elaborated scenarios in order to provide a pool of insights affecting investment decisions. One feature considered, among several improvements, is the risk of delay in the commercial operation date (COD), which affects investment decisions significantly. This feature is played in the model as a sensitivity analysis. One output provided by the model is the generation technology optimal mix under a competitive environment. Therefore, there is a competition between different technologies on top of competing market participants.

In contrast to most of the previous models that focus on the operation of the electricity sector, Bunn et al. (1993) are the first ones to go deep in the cost of capital to evaluate investment opportunities.

The model was developed to consider the effects of changing the expected return of investment, cost and acquisition conditions of capital, and sensitivities about the taxation laws. The focus is to analyze the impacts of competition, the way the market is organized and risks involved in the investment decisions. The study suggests that given the financial environment and conditions, price may be not enough to indicate installed capacity expansion needs. This could be an explanation of why utilities have a risk averse profile and tend to invest in technologies with lower fixed costs, such as renewables (Teufel et al., 2013).

Tan et al. (2010) model evaluates investment alternatives considering the example of wind turbines. The study mixes system dynamic with decision trees. Such combination enables to deal with a higher complexity level, taking into account the Monte Carlo analysis done in SD with the decision making process flexibility based on the decision trees methodology. The outputs of the simulation are cash-flows of the projected periods.

This literature review concludes that the system dynamics methodology is largely adopted to model the electricity sector, more precisely the generation side. The use of SD can be to support a relatively simple investment decision or to plan the whole energy sector of a country for the following 30 years, considering the large number of interactions between several variables, prediction of consequences, compensation effects and implementation of policies. The main advantages highlighted in the previous paragraphs are the ability the methodology provides to explore complex scenarios with several uncontrollable variables, helping to understand past events and predict future ones. SD is not only a simulation technique and can be deeply used as a communication tool to increase stakeholders' awareness. Given the dynamics and complexity of the energy sector, this tool seems to be extensively applied and widely approved.

When it comes to evaluate investment decisions of energy projects under the scope of project finance, not many studies have been developed. It is interesting to discuss the important support SD may provide to a project finance context during investment decisions. Project finance is the current reality of most developing power plants worldwide and both IPP and utilities have been adopting it when considering new investments. The objective of the following chapters is to, first, contextualize the use of SD to a single perspective investment decision, using project finance, on a liberalized Mexican environment. In addition, finally, conclude what contributions it can bring to the traditional spreadsheet modeling approach.

3. Mexican electrical power system liberalization

Lately, Mexico is considered to be one of the most valuable markets for investments in the energy and power sector by several investors worldwide. The number of foreign developers present in the country has grown significantly in the last years. The factors leading the considerable growth are based on the macroeconomic situation. Mexico is among the world's most progressing developing markets with a total GDP of USD 1.3 tn in 2014 (World Bank, 2015). At the same time, Mexico's membership of the North American Free Trade Area (NAFTA) provides its companies access to an economy with a total GDP of USD 20 tn in 2014 (Government of Canada, 2016). Additionally, its economy has grown by 3.3% p.a. on average from 2010 through the end of 2014 and further economic growth is expected to average 4% p.a. until 2029 (World Bank, 2015). Other topics supporting the good investment environment are the control of inflation averaged at 3.9% per year in 2014 (considered high to European level, but significantly lower than Mexico's historical data) and the investment grade awarded by major rating agencies due to improved fiscal policies.

The power market and, particularly, electricity generated by renewable sources are now facing a liberalization process that is calling attention of domestic and international investors. Changes are due to the major market reform expected to create favorable investment environment in the power sector, peak power demand projected to grow from 43 GW in 2015 to 64 GW in 2025 (World Bank, 2015), renewable installed capacity and generation energy targets introduced as part of recent market reforms and propitious wind and solar resources across the country.

Even though many factors support a shift in the Mexican economy power sector, Mexico suffers from problems that may put away potential investors, just as many other Latin American countries. Drug dealers' cartels and corruption are still issues to be addressed by the government to make room for new investors. Another downside is related to the energy reform being recent, since uncertainty may raise investors distrust. Time is necessary for the reform to prove itself regarding auctions, level of transparency, and electricity prices. Despite those issues, Mexico can be considered a favorable investment environment and certainly offers above average growth potentials in the renewables sector.

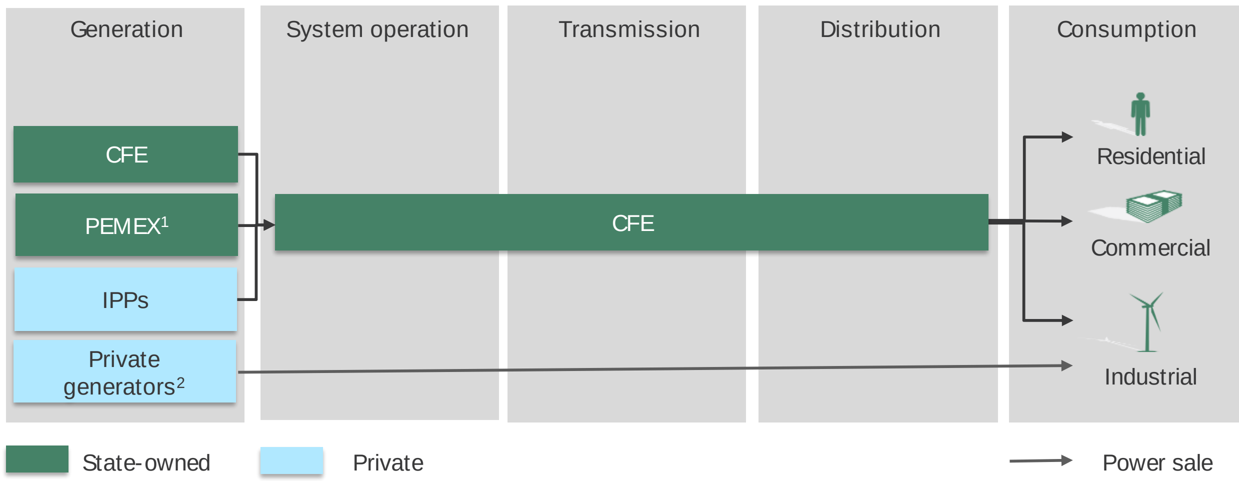
3.1 Market framework

In 2014, the Mexican government approved a process that initiated in the last decade, the important reforms of Mexico's energy and power markets. Prior to the reforms, the power market had been dominated by the CFE, the state-owned utility. The utility was regulated as a natural monopoly holding the activities of electricity generation, transmission and distribution. Whilst CFE's position has initially been unbundled as part of the reforms, there is still significant gubernatorial backing towards CFE, so that market participants continue to consider CFE as government counterparty.

Although CFE held a monopolistic position in the electricity sector until 2014, IPPs were part of the market structure since 1990. Those producers were suppliers to CFE under the PPA terms awarded in special public auctions. The reason of calling it special is due to the tenders being technology specific – only thermal power producers. In the case of other technologies, particularly to renewable sources, there were only two alternatives to be part of the Mexican market:

- The first option was limited to projects up to 30 MW nameplate capacity that could sell their energy to CFE under a 20-year PPA. However, very few of these PPAs were actually signed. The PPA was essentially not bankable as it had no floor price, hence not many projects were in operation under this small producer scheme.
- The second alternative targeted companies that were able to generate electricity for other self-supply activities. Industries with intensive energy consumption, as steel companies, would be allowed to have its own power plant projects. In this system, the electricity transaction was organized under a bilateral PPA regulated by the government. This alternative proved to be more successful than the first option, but there was no room for small developers and energy could not be traded among different offtakers.

The limitations of the Mexican market to small developers were clear and impeditive to enter PPAs. Figure 1 shows a schematic representation of the power market before full implementation of the energy reform. One of the reforms initiative was to amend this and bring more stakeholders to the electricity sector. This has changed fundamentally since major laws and regulations regarding the reform of Mexico's electricity market came into effect in 2013, late 2015 and early 2016. After the new electricity law implementation, producers will have two options to sell their output to the market. The first one is via bilateral contracts (PPA) with qualified offtakers. The second alternative is by PPA public auctions with the main suppliers (as CFE). The latter will be discussed in the last section of this chapter in detail. Another point of the reform that is especially relevant for renewable sources is the clean electricity generation target of 35% by 2024. Even though clean technologies, in the Mexican context, include nuclear and hydro, more opportunities and incentives for renewables sources are expected.



1 Petróleos Mexicanos cogeneración
2 Produce energy for self-supply under self-supply schemes

Figure 1 - General overview of the power market (before full implementation of the energy reform)

As discussed previously, the aim of the reform is largely to attract private investment. The first step towards the investment attraction targets was done by the new electric industry law (Ley de la Industria Electrica). This law created the national center of energy control (CENACE). Besides the operational control of the national grid and wholesale power market, CENACE is the body in charge to publish and evaluate the public PPA auction offers. Another contribution of the law was to reestablish the role of two important public bodies, CFE and CRE. The former was already discussed and targets the vertical unbundling of the state owned utility. The later has its scope redefined under the Energy ministry hierarchy. Electric tariffs in Mexico were set by the Department of Finance and not by the Energy Regulatory Commission (CRE), the industry regulator, resulting in a tariff regime more responsive to political considerations than economic realities.

According to the new electric industry law, the Energy Secretary (SENER) will be responsible to publish the basis of the electricity sector and operational arrangements of the wholesale electricity market. The basis of the sector describes how the market is organized, define the stakeholders, the framework of the tendering processes regarding capacity, electricity and clean energy certificates.

CENACE, as described above, will hold such tenders, in order to allow CRE's obligations to supply energy to regulated consumers as well as comply with the clean energy targets. Figure 2 explains what is the regulatory bodies in the Mexican energy sector:

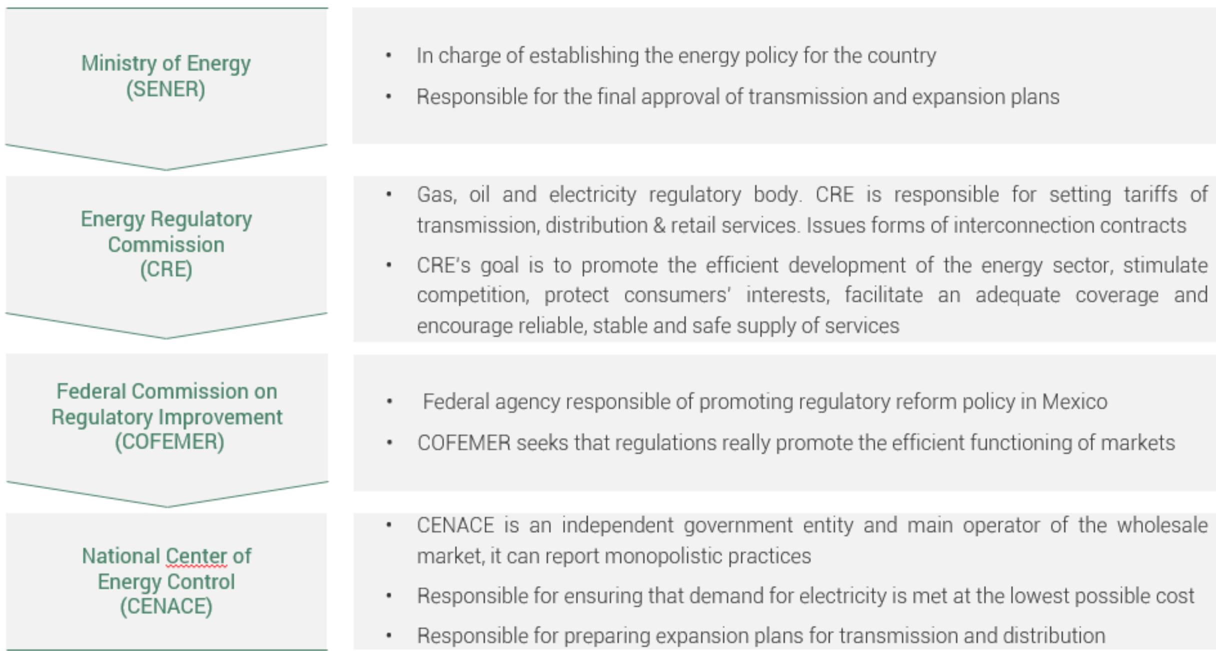
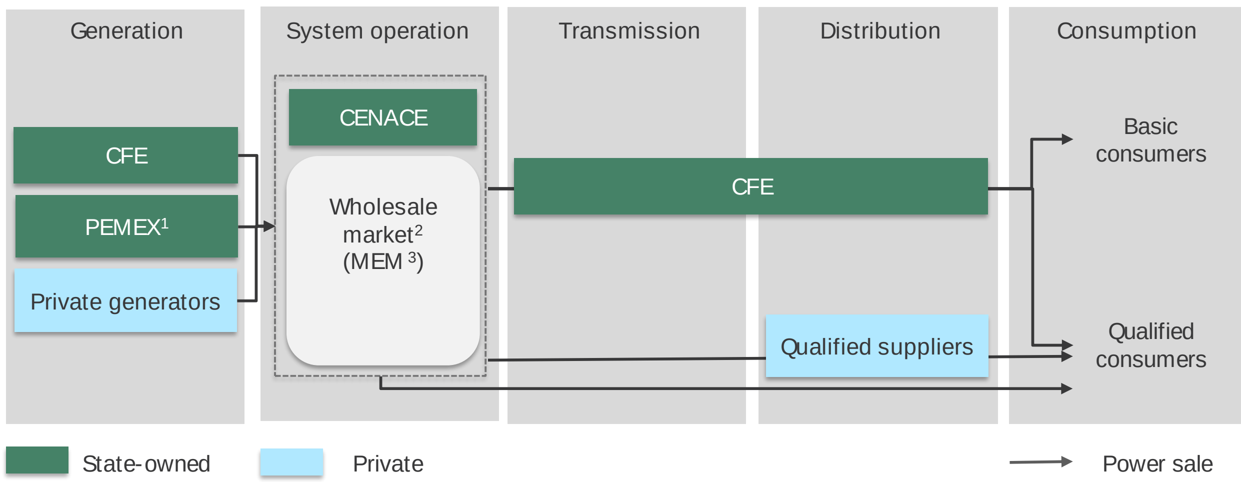


Figure 2 - Regulatory bodies in the energy sector

The regulated or basic consumers, mentioned in the paragraph above, refer to end users with a peak demand lower than 5 MW, usually residences and commercial consumers that pay regulated prices. The other classification is for qualified consumers (above 5 MW peak demand). Those can contract electricity supply from a producer under the bilateral PPA. At this stage, not much attention has been paid to the bilateral contracts as they are seen as an alternative to the public tenders. Much focus is given to the first auctions to be held in the beginning of 2016, with the expectation of achieving interesting electricity prices. Figure 3 shows a schematic representation of the power market after full implementation of the energy reform.



1 Petróleos Mexicanos cogeneración
2 Onwards 2018 - after scheduled tests starting in December 2015 (first phase), and 2017-18 (second phase - hour ahead market)
3 Mercado Eléctrico Mayorista

Figure 3 - General overview of the power market (after full implementation of the energy reform)

One aspect of the reform that is not completely defined is the agents that can apply to be a basic supplier. By definition, basic supplier are the distribution companies that supply electricity to regulated consumers. So far, there is only one company classified as so, which is CFE. However, regulation describing the qualification criteria for other basic suppliers was released in January 2016. The analysis of such criterion is not under the scope of this thesis, but no other players have yet applied to be a basic supplier.

The PPAs are tendered by public auction having as offtakers the basic suppliers. The new tender process, under the scope of CENACE, has some risks due to the fact of being a completely new mechanism to the Mexican regulator. The main risk to the auction participants is determining the price level given no historical data and quite complex mechanisms for the offers evaluation process. On the other hand, this price uncertainty may create higher prices for the first tenders and become more stable in future ones. Another risk is due to bid guarantees might be outstanding for a longer period of time than anticipated in case the bid evaluation is delayed.

Despite the complexity of the PPA terms tendered publicly, the Mexican energy reform provides important characteristics not seen in many other markets. The stable and predictable pipeline of public tenders is one example. This provides incentives and good visibility to attract developers and at the same time promote domestic agents. Another relevant example is the stepwise process of segregating CFEs activities in the generation side. Open the market to other basic suppliers is an essential and successful feature already seen in other Latin American markets as Chile. The details of PPA terms, the Mexican electric industry data and financial aspects of power projects are discussed in the following sections.

3.2 Market by numbers

The goal of this section is to present the main macroeconomic indicators of Mexico and detail the energy sector, presenting the current organization of the market, main players, generation mix, and main suppliers. The information provided will be supported by data and graphs to ease the reading of this thesis and serve as reference basis to the models developed later on.

Mexico is currently facing a favorable macroeconomic environment. As opposed to its past, there is political stability, low inflation (below central bank's target), large and growing domestic market (second in Latin America) and an expected economic growth from 2015 to 2029 to be around 4% on average per year. As discussed by many academic papers, GDP growth and electricity demand are highly correlated. This, in addition to the energy reform, brings a potential environment for investors to a market with 54.4 MW of installed power capacity.

The renewables share of installed capacity (excluding hydro) in 2014 was 5.8%, more than five times lower than the 35% target of electricity generation from clean sources (including hydro and nuclear) established by the reform. Figure 4 resumes the annual investment in clean energy in Mexico between the years 2009 and 2014. As it shows there is a wind technology predominance. One point of attention of the intermittent generation technologies as wind and solar is the necessity of having a grid adapted to that. This is a problem to Mexico and the government already estimated a pipeline of investments between 2015 and 2029 of USD 7 billion to accommodate future plants, expand coverage, reduce losses and modernize the grid.

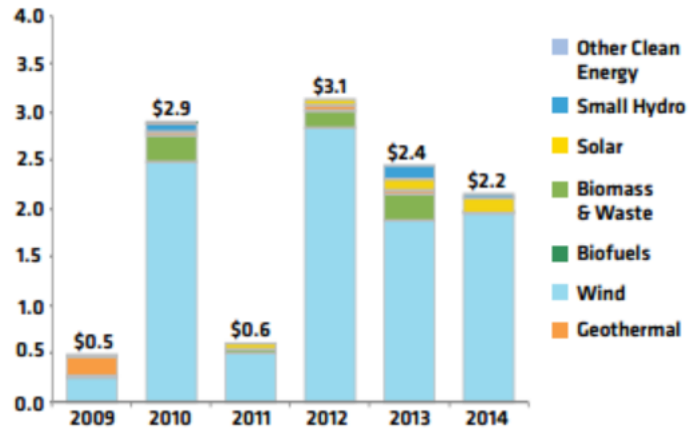


Figure 4 - Annual investment in clean energy 2009-2014 (M USD)

One aspect particularly relevant to regulators when establishing the volume of energy of the auctions is the reserve margin. In the case of Mexico, reserve margins required to be over a certain level to cover for potential lower availability of resources. The government established a minimum reserve level threshold of 13% by 2020. As show in the figure below, there is an expected increase of reserve margin with the first auctions after the generation liberalization and a decreasing tendency afterwards.

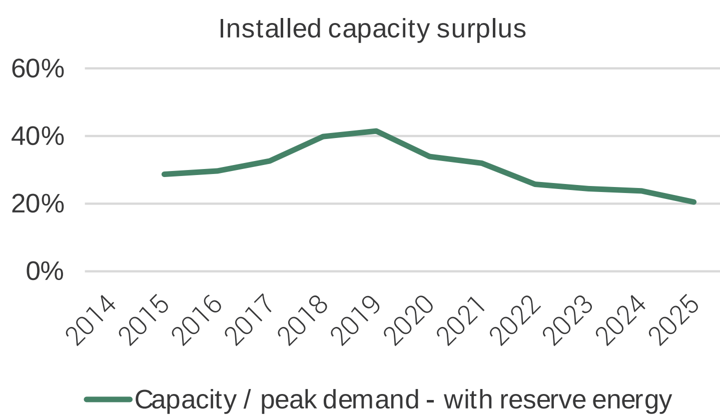


Figure 5 – Installed capacity surplus

Another important parameter to the regulator is the peak demand tendency to better plan the electricity sector. This is even more relevant when the country is facing a stable economic growth in the near future. As discussed before, GDP growth and electricity demand are highly correlated. According to CFE, peak hours in week days are from 8 to10 pm from April to October and from 6 to 10 pm the rest of the year and 57% of peak demand is concentrated in the west, center and northeast of the country (cities and industrial zones). The peak demand foreseen for 2016 is around 45 GW.

Given the vast reserves on natural gas present in Mexico, the country's generation mix was expected to be mainly of thermal sources, which represented 78% of the 251 TWh generated in 2014 (reference). The second dominant technology is hydro as show in the figure 6 below. All those technologies supply a market, whose larger consumption category is industrial (58%), followed by residential (26%), commercial (7%), agricultural (5%) and services (4%).

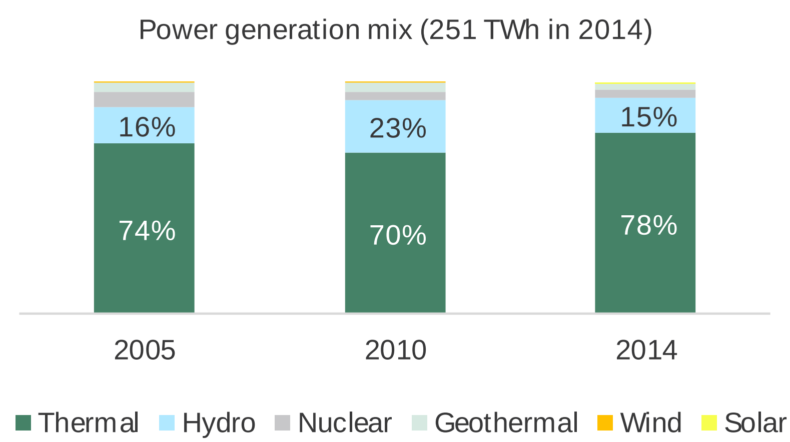


Figure 6 – Power generation mix

As explained in previous sections, the Mexican generation activity, besides its deregulation, has still the state-owned utility as the main player. In 2014, CFE dominated generation with 76% of installed capacity, which represents 41 GW, leaving 12 GW or 24% to the IPPs, that currently only sell their generation to CFE. Regarding renewable sources installed capacity, Mexico counts only for 2.5 GW of which 92% is wind and 8% solar. Although CFE dominates the total installed capacity, when it comes to renewables it is only the third main player (239 MW), behind Acciona (541 MW), the Spanish company and Enel (477 MW), the Italian utility.

This section provides an overview about how the market is organized and serves as a reference of changes to come with the deregulation process. This is important to measure if the new electricity law will indeed attract more players, increase the installed capacity, achieve the clean energy targets and result in a reduction of electricity prices to end users. Next section focuses on how the deregulation process is aiming renewable sources with a support scheme.

3.3 Renewable support scheme

Mexico has favorable solar and wind resources for renewable energy production. However, given the numbers of installed capacity provided in the previous section, this has not been enough to promote the generation from such sources. On the other hand, the regulator is aware of the situation and is addressing it with new laws targeting the development of renewable energy projects.

The first legal framework change for renewable energies was established in 2012 by the Mexico's climate change law that sets a target of 35% of electricity generation by 2024 from clean energy sources. Clean energy in the Mexican context, as detailed previously, considers, besides renewables sources, hydro, nuclear and low carbon emission thermal plants.

Another important supportive aspect to renewables is the clean energy certificates (CELs) to be introduced in the future auctions. This is the mechanism adopted by the regulator to achieve the 35% target. Those certificates are issued by CRE with a price and 20-year duration to be traded between all parties in the electricity market. One CEL is equivalent to 1 MWh. Generation companies that produce energy through renewable sources or clean technologies shall be eligible to receive tradable clean energy certificates.

According to CENACE ‘s expansion plan (2015-2029), 54% of new capacity (60 GW) will come from clean technologies. Wind is expected to be the 2nd most important source of new installed capacity with 12 GW to be added in the next 15 years. This tendency is in line with past investments in renewable energy in Mexico, as presented in the figure below.

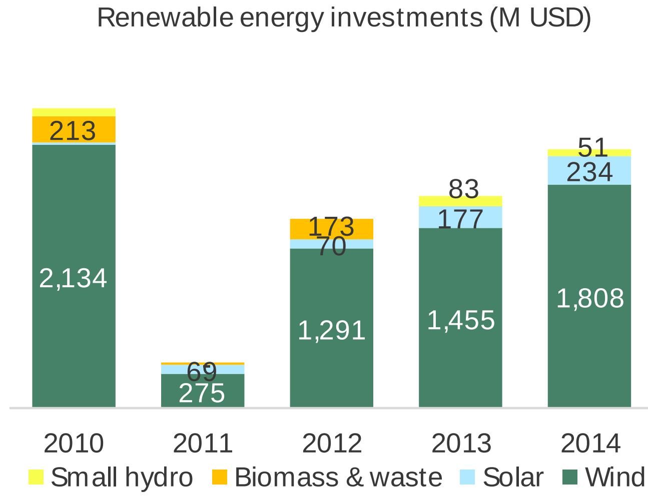


Figure 7 – Renewable energy investments (M USD)

Compared to other Latin American countries, Mexico do not set specific RES, especially when it groups it with other technologies as nuclear and natural gas. One particularity about renewable production is the intermittent generation. This is not fully addressed in the energy reform and is considered a downside. Chile, for instance, implemented in their regime hourly blocks of production to incentivize technologies that do not have stable availability as solar and wind.

3.4 First Mexican power tender and PPA terms

After the energy reform, the first and historic power tender issued by CENACE under the new regime was announced on 30 November 2015. The plan of CENACE is to hold one tender per year, exception is made for the first year, which will have two tenders. Every tender will have three products: electricity, CELs (clean energy certificates) and capacity. The latter cannot be bidden by intermittent generation. Given that, any participant following the auction rules, is allowed to bid any combination of the three products.

In this first tender, there is a timeline to be followed by all participants. The deadlines are pre qualifications and mandatory requirements for the well-functioning of the auction. The timeframe of the first auction is summarized and presented on table 1. The only basic supplier participating is CFE. As a buyer, CFE must submit its offer to buy the products before mentioned to CENACE. The offer to buy includes the quantity and price ranges (minimum and maximum) per product. At the same time, bidders are obliged to submit the bid bond requirement, a form of guarantee of participation. This serves to classify the bidder assuming technical, financial and legal qualifications. The ones qualified, first provide, via an online platform, the volume they are interested per product and weeks later, submit the overall price to the whole package. The results are expected to be published by CENACE days after the bidders' price submission.

Activity	Date or Period
Publication of the bidding rules	November 30th, 2015
Acquisition of the bidding rules	November 30th, 2015 to December 10th, 2015
Receiving questions	November 30th, 2015 to December 10th, 2015
Clarification meeting	December 14th, 2015 to December 17th, 2015
Publication of the final version of the bidding rules	December 22nd, 2015
Submission request for registration as a potential buyer	December 23rd, 2015
Notification of quantity, price and parameters of the accepted purchase bids	January 26th, 2016
Buyer seriousness guarantees submission	March 17th, 2016
Prequalification certificate issuance	March 18th, 2016
Reception of the economic sales offers	March 28th, 2016
Evaluation of the economic sales offers	March 28th, 2016 to March 30th, 2016
Realization of additional iterations of the economic sales offers	March 30th, 2016
Contracts subscription	May 12th, 2016

Table 1 – Timelines for the first tender

The participation in the tender is allowed to any company or legal entity subject to qualification requirements, fee payments and submission of bid bonds. Bidders can be operating or to be constructed power plants as long as framed under a clean energy technology (this includes renewable sources, nuclear, hydro and low carbon emission thermal plants) and so, be eligible for CELs. After the tender results have been published, projects awarded have 25 working days to establish, if applicable, a special vehicle purpose (SPV) in Mexico.

The technical parameters required to be presented by the bidder according to the tender manual consists of the participant proving that has already constructed or operated power plant projects, in the last 10 years, of at least one third of the total amount of his bid. Additionally, it should be submitted a detailed description of the technology adopted to the expected project, determine the location and interconnection zone, provide the operational dates and, in the case of selecting capacity as one of the products, the participant who has a project already in operation, should guarantee the remaining life of his power plant of a minimum of 15 years.

Regarding the financial parameter requested by CENACE, the participant must evidence its ability to raise capital to its past projects and the amount raised should be at least as large as the proposed project of the tender. In addition, the bid bond requirement will be returned in the case of the project not been selected or reduced progressively if accepted (considering milestone as financial close, construction reports and so on) to 50% at in service date. The construction reports must be provided 10 working days after end of each month. If seller fails to perform under this obligation, buyer has right to call performance bonds.

The tender manual defines three power zones (zonas de potencia – Sistema Nacional, Baja California and Baja California Sur). These zones are specific to the capacity product. The idea is to deal with transmission line constraints and guide the necessity of extra capacity in the specific interconnections. Projects bidding capacity can only do so in the power zones they are connected to, so there is no competition of capacity proposed between zones.

There are also zones to electricity and follow the same bidding rules as the power zones. The, so called, generation zones (zonas de generacion) are compound of export zones (nine areas that have limited need for additional electricity with a range of 66 to 7,550 GWh per year), interconnection zones (87 areas with limits to add extra capacity within a range between 0 and 1200 MW) and the price zones (which reflect the 50 areas with different electricity prices due to transmission constraints – also called zonal prices). The price zones have to purposes. The first one is to compensate the original bid price of a project to the average price and make all projects bids comparable at the national level. In other words, a project located on a zone with higher prices would deduct to its bid price a factor. This is only done for evaluation matters and has no impact of the final bid price awarded. The second purpose is to introduce the hourly factor adjustments (factores de ajuste de horario or FAHs) which takes into account incentives to produce more electricity when prices were historically higher, therefore reduce peak prices. FAHs are zone specific. Differently than the bid factor adjustment to price zones, FAHs do impact the revenues of operating projects (CENACE, 2016).

The paragraphs above try to address the complexities faced to the tender process and how projects should prepare their bids in respect to all the adjustments applicable depending on the zone they are or planned to be located. The following paragraphs highlight dynamics and main terms of the

PPA. The information also serves as a reference to the financial models developed to support investment decisions.

The PPA terms, as published by CENACE, define that all payments will be done in Mexican Pesos (MXP). However, participants have the option to index the PPA prices to, either US dollars (USD) or MXP rates. Although payments are in MXP, the prices are partially indexed (70%) to a USD/MXP ratio. The goal is to avoid severe volatilities of the FX rates. In the case of PPAs signed under USD, the remaining indexation is split to 20% US production price index (PPI) and 10% Mexican PPI. If PPA is under MXP, the remaining 30% indexation is all to MXP PPI. The reference date of all indexes is as of 30 days before COD. There is also an indexation considered between the bid date and COD in the same criteria.

Regarding the service periods and dates, the PPA period for electricity and capacity products is 15 years and 20 year-period for CELs. There is a standard service date considered, which is 2 years after the reception of the economic offers. In the case of the first tender, it would be 28th March 2018. On the other hand, projects have some flexibility to determine their own commercial operation date, which can be between one year prior to and up to two years after the standard in service date. The risk of delay in the PPA is fully allocated to the project and in the situation of not fulfilling those dates, there are penalties (5% of the value of the undelivered energy and pay/receive the difference between PPA price and spot price for the non-delivered electricity) to be paid to the basic supplier (offtaker) and the PPA period is shorted. If the project does not manage to be in operation in the 2 years after the standard service date, the offtaker has the right to terminate the PPA and draw the project's bid bonds.

During the PPA period, parties are allowed to modify the quantities of any product sold if mutually agreed and increased up to a limit of 10% of the contracted volumes. The committed volumes during operation may not be achieved, in case of a generation deficit, seller can add capacity once a year subject to certain conditions. Electricity payments has monthly adjustments to balance such volume volatilities and another one on the yearly balances to capture deviations between PPA price and spot market price. CELs are balanced only in the annual basis considering annual surpluses or shortfalls and PPA price and CEL market price. The revenue streams and its adjustments will be better detailed in the following chapters when building the spreadsheet model to the theoretical renewable project.

4. Description of a theoretical solar power plant project

In order to provide a deep understanding of the traditional spreadsheet financial models and investigate the contributions SD can add to the investment decisions, a theoretical renewable electricity generation project is necessary. The objective of this chapter is to introduce the scope a project that will be used as a reference in the following sections to be analyzed as an investment opportunity under the Mexican regulatory context and PPA terms. The description of the project's framework is based on literature review and personal professional experience. The decision of having a theoretical project is to give this thesis a realistic approach to what have been done in, both, energy markets and project finance environments.

This chapter begins with a section dedicated to describe the operational parameters and technology adopted. The following sections are dedicated to list the inputs of costs to be considered in the financial models as well as in the system dynamic method. Assumptions and simplifications will be discussed in all sections.

4.1 Technology

The choice for a solar project, besides personal interest, is due to the Mexican irradiation potential to accommodate such technology. On top of that, the International Energy Agency (IEA) estimates that solar energy's share of global energy generation will increase significantly up to 2035. This energy source alone is expected to generate more than 2% of total energy generated, whereas wind energy is expected to contribute 7%. This reflects an expected total capacity of solar photovoltaic (PV) assets of 600 GW in 2035. Since the solar PV market has grown at high speed and growth is expected to continue, it appears to be interesting to examine how the energy reform in the Mexican is able to accommodate solar PV investments.

Mexico is one of the top three most attractive countries in the world to invest in PV solar power projects, only behind China and Singapore. The potential of solar energy in Mexico is one of the highest in the world (SENER, 2003). This is because the country is located in the so called "solar belt" with radiation exceeding 5 KWh per square meter per day (EPIA, 2010). Furthermore, Mexico has the largest PV module manufacturing base in Latin America (PROMEXICO, 2012).

Within Mexico, the solar energy potential is highly accumulated in the north-western part of the country. Figure 8 shows the annual global solar radiation in Mexico that goes from 5.6 to 6.1 KWh/m2-day (IIE, 2010). In comparison, despite the recent significant growth in solar energy production in the European Union, the potential of solar energy in Europe is far lower.

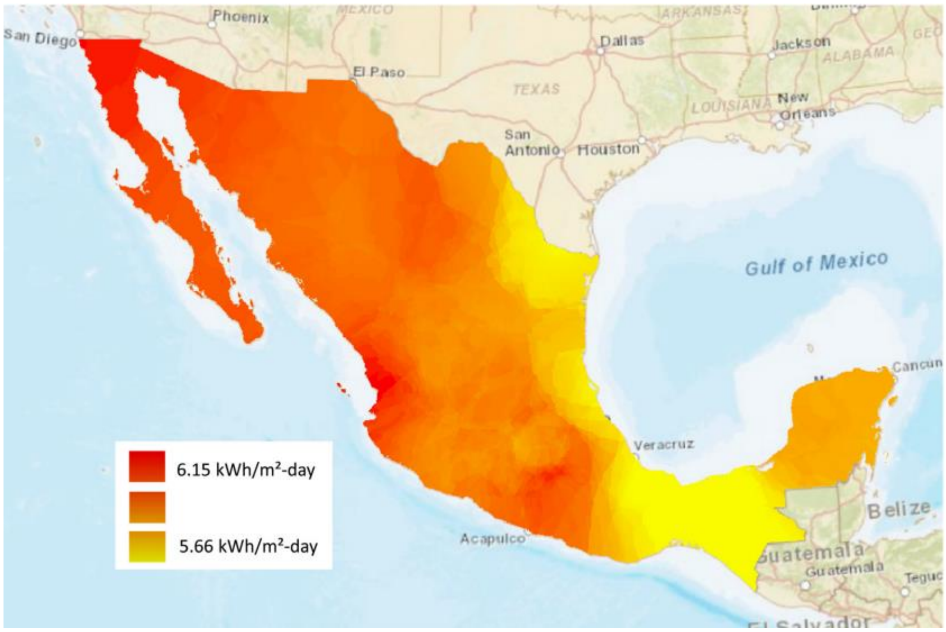


Figure 8 – Atlas of solar source potential

After the technology choice motivation and a succinct background, the goal in this chapter is to briefly describe the main parameters to be used as inputs in the following two chapters. The parameters are commented below:

Project's location – Baja California Sur

This location is selected due to existing solar PV projects in the region. The importance of determining the location is to determine the irradiation parameters considered for the solar panels that determine the electricity generation, the hourly adjustments (FAHs), costs related to grid access and the average electricity price in the area.

Installed capacity – 30 MWp

Installed capacity, sometimes termed peak installed capacity or rated capacity, describes the maximum capacity that a system is designed to run at. If for example, a solar farm has an installed capacity of 30 megawatts as the one assumed in this thesis, the system will have the ability – the components and hardware – to produce a maximum of 30 megawatts with optimal sun exposure. If a system with an installed capacity of 30 megawatts has optimal sun exposure for one hour, it will produce 30 megawatt hours of electricity. Installed capacity relates mainly to calculating the cost of solar panels. Looking at how many watt hours an installation will generate produce is used for assessing how many solar panels are required – comparing solar energy production to existing electricity usage.

Irradiation in module plane P50 – 3,000 kWh / m²

In order to predict the solar resource over the lifetime of a project, it is necessary to analyze historical data for the site. These data are typically given for a horizontal plane. The assumption is that the future solar resource will follow the same patterns as the historical values. Historical data may be obtained from land-based measurements or from information obtained from satellite imagery as described in figure 8. Data in hourly or sub-hourly time steps are preferred. The value assumed is an approximation of numbers identified in Baja California Sur. No statistical or historical research was done to determine such number. The P50 is the scenario selected considering a probability of reaching a higher or lower annual energy production is 50:50. There are other scenarios as P90, the risk that an annual energy production of P90 is not reached is 10%. Both values are widely used by banks and investors as base in their financing decisions.

Performance ratio – 80%

The performance ratio, often called quality factor, is independent from the irradiation and therefore useful to compare systems. It takes into account all pre-conversion losses, inverter losses, thermal losses and conduction losses. It is useful to measure the performance ratio throughout the operation of the system, as a deterioration could help pinpoint causes of yield losses. The value assumed is, again, based on observation of several other projects without any significant statistical approach. The figure below shows the main losses of PV systems.

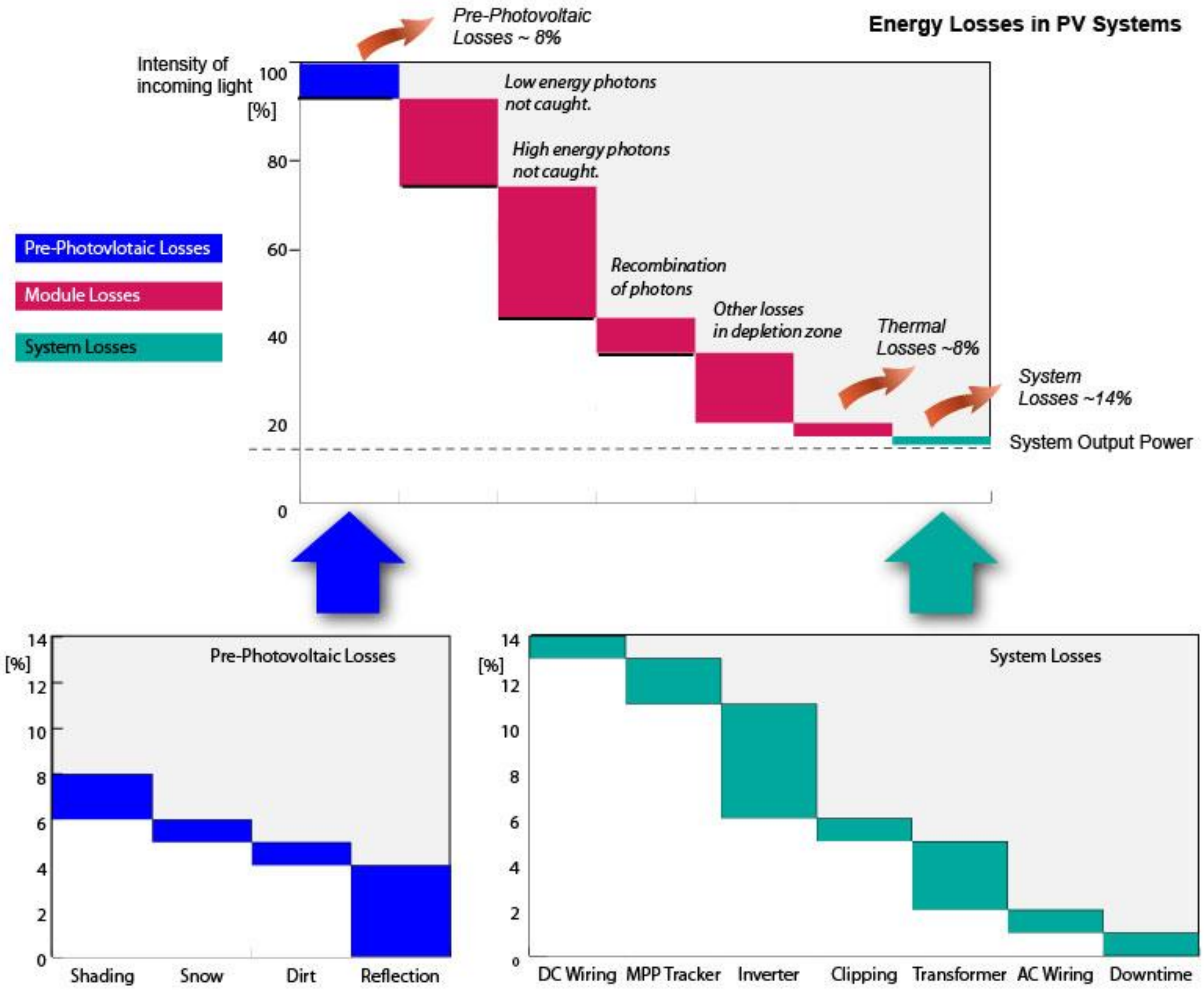


Figure 9 – Energy losses in PV systems

Technical availability – 98%

Availability can be defined as the degree to which a system is in a specified operable and committable state at the start of a mission, when the mission is called for at an unknown, i.e. a random, time. The technical availability or availability factor of solar power plants depends on periods when the plant is operational, even when there is no sunlight, are counted as available. If they are only counted as available during favorable times, photovoltaic plants have an availability factor approaching or equal to 100%. However, solar plants have relatively low capacity factors, which considers periods without sunlight. Solar capacity factors on average are about 20%. This makes solar availability factors much lower if times when sunlight is not available are taken into account.

Yield annual production – 47,040 MWh / year

The energy yield prediction provides the basis for calculating project revenue. The aim is to predict the average annual energy output for the lifetime of the proposed power plant (along with the confidence levels). The level of accuracy required will depend on the stage of development of the project. Its calculation is the product of the irradiation in module plane, performance ratio, technical availability and the plant installed capacity.

Annual degradation – 0.50%

Annual degradation is a key cost driver to determine how yield annual production changes over time. An accurate quantification of power decline over time, is known as degradation rate. This rate is essential for investment decisions, because a higher degradation rate translates directly into less power produced and, therefore, reduces future cash flows.

4.2 Investment costs

Below is provided a list of the main lines of investment costs necessary in a solar power plant business venture. Also defined as capital expenditure (Capex), it has an expectation of income to recover such expenditures through earnings generated by the business over several years. It is generally understood to be used for capital expenditure rather than for day-to-day operations (working capital) or other expenses.

Project development – 50 USD / kWp

Project development is essential to creating valuable power plant assets and includes activities prior to construction, such as securing a power purchase agreement (PPA), establishing site control, project permitting and project financing. As it varies according to the projects complexity and size, it is usually measured as a cost per kWp of planned installed capacity.

EPC contract – 1,400 USD / kWp

Engineering, Procurement, and Construction (EPC) is a particular form of contracting arrangement used in some industries where the EPC Contractor is made responsible for all the activities from design, procurement, construction, to commissioning and handover of the project to the End-User or Owner. Under an EPC contract a contractor is obliged to deliver a complete facility to a developer who need only turn a key to start operating the facility, hence EPC contracts are sometimes called turnkey construction contracts. In addition to delivering a complete facility, the contractor must deliver that facility for a guaranteed price by a guaranteed date and it must perform to the specified level. Failure to comply with any requirements will usually result in the contractor incurring monetary liabilities.

Interconnection – 1,250,000 USD

Interconnection expenditure is met at three stages in the project development. The first is the application submission, which involves processing fee and application charges. The second is the System Impact Study (SIS), that allows the developers to study the feasibility of solar power plant on the distribution network. This cost, of course, depends on the size of the project. And finally, the system installation, that depends on the equipment's needed for inter-connection. The cost of line upgrades, reclosers and other hardware needed to ensure safety.

Permits and registration costs – 10,000 USD

The permits for the solar power plant vary from place to place and depends on the local regulations and nodal agencies. These costs are incurred on time and materials basis which depends on the permits required, size of the project and the bureaucratic work involved in getting the permits. The breakdown of such costs are land conversion, bore well, pollution and waste disposal, connectivity to grid substation and immediacy to adequate transmission and distribution.

Insurance (CEAR + ALOP) – 180,000 USD

CEAR stands for Construction/Erection All Risks and those include policies designed to cover the risk of loss arising out of the erection and installation of machinery, plant and steel structures, including physical damage to the contract works, equipment and machinery, and liability for third-party bodily injury or property damage arising out of these operations. ALOP, which stands for Advance Loss of Profit, is an insurance policy that provides coverage for financial losses due to delays in construction and infrastructure projects. It provides a payout to companies that face higher costs or lost profits when a project takes longer than expected to complete.

4.3 Operational costs

Regarding the costs necessary to keep the solar power plant operational, a brief list of parameters, its costs and explanation is considered below.

O&M costs – 20 USD/kW

Operations and maintenance costs vary widely between different forms of power generation but form an important part of any power plant's business case. These ongoing costs - both fixed and variable - include day-to-day preventative and corrective maintenance, labor costs, asset and site management, maintaining health and safety, and a host of other important tasks. Large-scale PV installations are among the cheapest power generation technologies for O&M. Of course, the relative simplicity of solar PV is the defining factor here - cleaning and removing debris from PV cells along with careful monitoring of inverter units and AC subsystems are the primary maintenance tasks.

Land lease – 200,000 USD / year

A land lease, also called a ground lease, is a lease agreement that permits the tenant to use a piece of land owned by the landlord in exchange for rent. Land leases work very similarly to the way traditional property leases operate, and tenants can enter into both residential and commercial agreements. Most land leases are vacant, allowing the tenant to construct a temporary (or in some arrangements, permanent) structure at his own cost. However, some land leases do already have structures, partial structures or other objects on them for the tenants use. This does not apply in the case of this theoretical solar power plant.

Management fee – 50,000 USD / year

The management fee is divided into two categories: asset management and operations management. The first is related to the plant performance supervision, performance reporting, warranty administration, financial /commercial management as billing, payments, tax preparation, insurance administration and so on. The operations management is focused on plant supervision (service dispatch, security monitoring interface, energy forecast, grid operator interface, plant maintenance supervision etc.).

Insurance – 150,000 USD / year

Insurance premiums make up approximately 15% of a PV system's annual operating expense. Annual insurance premiums typically range from 0.25% to 0.5% of the total installed cost of a project depending on the geographic location of the installation. PV developers report that insurance costs comprise 5% to 10% of the total cost of energy from their installations, a significant sum for a capital-intensive technology with no moving parts.

The table below summarizes all the assumptions made in this chapter to this theoretical solar PV project:

Parameter	Unit	Value
Installed capacity	MWp	30
Irradiation in module plane P50	kWh / m²	3,000
Performance ratio	%	80
Technical availability	%	98
Yield annual production	MWh / year	47,040
Annual degradation	%	0.50
Project development expenditures	USD / kWp	50
EPC contract	USD / kWp	1,400
Interconnection	USD	1,250,000
Permits and registration costs	USD	10,000
Insurance (CEAR + ALOP)	USD	180,000
O&M costs	USD / kW	20
Land lease	USD / year	200,000
Management fee	USD / year	50,000
Insurance during operation	USD / year	150,000

Table 2 – Theoretical solar PV project assumptions

5. Description of a theoretical spreadsheet financial model

After introducing on chapters 3 and 4 the main impacts of the Mexican energy reform in the generation activity, providing the rules for the first Mexican power tender in history, analyzing the PPA terms for awarded power plants projects and describing a solar theoretical power plant project, this chapter focus on investigating the main analysis an investor would do based on a proposed financial model to decide if it's worth or not investing in Mexico.

The project financial models objectives are to translate the PPA terms into monetary ones and calculate the indicators that developers, lenders and sponsors base their investment decision. Such decision is referenced on the project economics from several perspectives. The point of view this thesis is considering is the investor's perspective main indicator – the equity internal rate of return (IRR). The IRR is compared to the investors historic projects references and should be always higher than the weighted average cost of capital (WACC). Moreover, the investment should generate a premium associated with the perceived risk levels of the project, as the ones highlighted in Mexico.

Solar projects are usually financed with equity and debt components. As a result, the IRR for the equity component can be calculated separately from the IRR for the project as a whole. The developer's decision to implement the project or not, will be based on the equity IRR.

From the point of view of lenders, the concern is around the project's ability to meet the debt service requirements. The first one is the debt service coverage ratio (DSCR), which can be calculated as the cash flow available for debt service (CFADS) divided by the debt service requirement (principal repayment, interests and agency fees). The Average DSCR represents the average debt service ability of the project over the debt term. A higher DSCR results in a higher capacity of the project to service the debt. Minimum DSCR represents the minimum repayment ability of the project over the debt term and in case this value is lower than one, it indicates that the project is unable to service debt in at least one period.

The funding of solar PV projects is usually arranged by the developer or sponsor and it comprises two parts: equity and debt. Both the equity partners and project finance partners typically conduct an evaluation of the project covering the legal aspects, permits, contracts (EPC and O&M), and technical issues prior to achieving financial closure. Another key aspect of a project containing debt under the scope of project finance is the due diligence, which focus on identifying the risks and methods of mitigating any risks prior to investment. Where the project has inherent risks, the exposure to these risks will be negotiated between the parties and reduced wherever possible with insurance.

The equity part, provided by the developer or from equity partners that sign agreements or letters of intent to purchase the projects from the developers, is typically around 15-30% of the total project investment cost or Capex. The sponsors are usually individual firms, developers or equity funds managed by management firms, bank equity fund managers or pension fund managers. The equity funds can be used as the seed capital to start the construction of the project, following completion of the design and environmental studies, legal analysis, permit applications and grid connection applications.

In project finance, equity partners and developers form a special purpose vehicle (SPV) to develop the project. This is the equity vehicle which owns the project and plant when constructed. The SPV signs the EPC and O&M contracts, and the project revenues are paid to the SPV. The working capital requirements and debt servicing are taken from the revenue to determine the returns for the equity partners from the projects, typically in the form of dividends. A schematic figure is presented below to comprehend the stakeholders and actions surrounding the SPV (or project company).

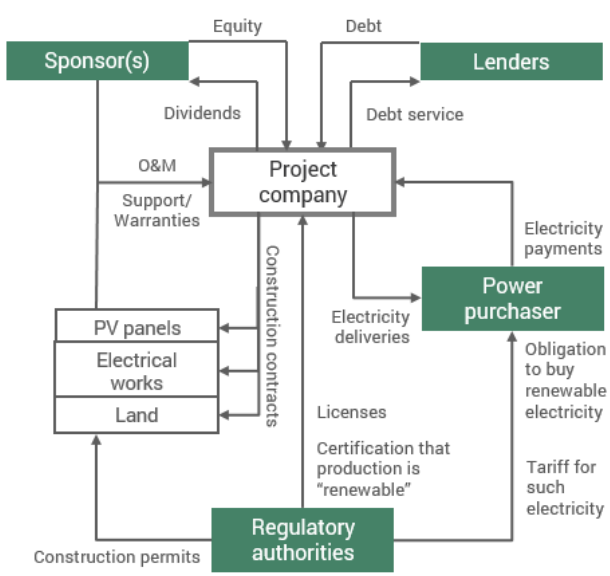


Figure 10 – SPV structure of a typical solar PV power plant

5.1 General description of the model

In order to build the financial model of the theoretical solar power plant project under the Mexican regulatory framework, the first step is to explain how the proposed model is structured. The model aggregates in an excel sheet the scope of the SPV that can be translated in financial terms and simulate them. Those include contractual structure, financial structure, accounting & tax Mexican rules, operational data as described in the previous chapter and so on. The purpose and analysis of a model varies according the perspective: equity valuations (sell-side, buy-side), bank – debt sizing, tender model (target bid price, IRR driven) and contractual negotiations.

The financial model of this thesis is structured in cluster of sheets: **outputs** (financial statements – Balance Sheet, Profit & Losses and Cash Flow; ratios – debt ratios, equity returns and project return; and Sum tab – a summary with the main information of the project such as key dates, profitability, leverage and operating cash flows profile), **calculations** (Constr – detail of all capital expenditures; Op – information about the operating revenues and operating costs; FinC – Capex financing requirement; FinOp – debt repayment profile given the project's cash flow; Tax – taxes according to Mexican laws; and D&A – assets depreciation and amortization), **inputs for the calculations** (Input – assumptions that do not vary over time; and InputT – inputs that vary over time). The target is to use the information of inputs tabs to calculate the financial statements and derive some metrics summarized in the Sum tab to be presented in this chapter.

The three financial statements of the outputs (BS, P&L and CS) are interrelated and have different uses. The purpose of P&L is ultimately to calculate taxes – it references all invoices (amounts to be paid & to be received and depreciation of assets). The Cash Flow is the SPV's bank account – it references all cash movements and the Balance Sheet references all assets (what the SPV owns) and liabilities (what the SPV owes to 3rd parties) – the two should always match. The financial statements sheets are linked to one another: BS and P&L link is the net earnings, the only direct link between BS and CF is the money (cash) on accounts and P&L works on invoicing basis and CF on real basis (as a bank account).

The first sheet of calculations is the Constr. It aggregates all expenditures during construction following a payment schedule. Given the Capex described on previous chapter, the cash out of such costs are determined in contract with suppliers. The FinC tab details the financing requirement of the Capex and segregates it between equity injection and senior debt drawdown following gearing and DSCR constraints imposed by lenders. In addition, it also calculates the senior debt facility total financial expenses (interests, upfront and commitment fees. The Op sheet contains the most relevant information regarding revenues and O&M costs. In the case of the Mexican framework, the revenue lines were very challenging to translate all the PPA terms due to the indexation rules, monthly and annual adjustments of electricity and CELs produced different than the committed amount. The FinOp sheet objectives is to determine (in order of priority) the senior debt repayment profile given the cash flow available from the project's revenues, the shareholder loan repayment (interests and principal), the cash available for share capital repayment and, finally, the dividends distribution. Lastly, Tax and D&A sheets are the technical calculations followed by the Mexican laws that impact the financial statements.

The inputs for the calculations consider all the assumptions of the project. In addition to the theoretical parameters presented on chapter 4, there are several other data necessary to run this investment decision model. Those include key dates of the project (construction and operation stages), inflation considered to index all costs, the electricity and CEL prices considered as well as their indexation factors detailed in the PPA, the imposed financial constraints (gearing and DSCR levels), equity assumptions (share capital percentage, shareholder loan interest rate, etc), senior debt facility assumptions (debt term, agency fee, upfront fee, commitment fee, commercial margin to be summed to the Libor rate to determine the total interest rate etc.), hedging rates and proportion to reduce debt interests volatility and tax and accounting inputs. Not all of these assumptions will be detailed in this chapter due to time limitations, but it is important to notice that most do not differ from common financial models and all of them will be used in this thesis to determine the equity IRR of the theoretical solar power plant project.

Besides determining the equity IRR, the model calculates the amount of debt necessary to the project. To raise debt, banks impose several constraints to the project performance. The two principal ones, as highlighted previously, are gearing constrain and debt service coverage ratio (DSCR). Gearing is the percentage banks accepts to fund the Capex. This percentage is determined by market general behavior and may be influenced by cash flows constraints. Banks do not fund entirely the capital expenditures to have commitment and involvement in the project operation from the equity side (investors).

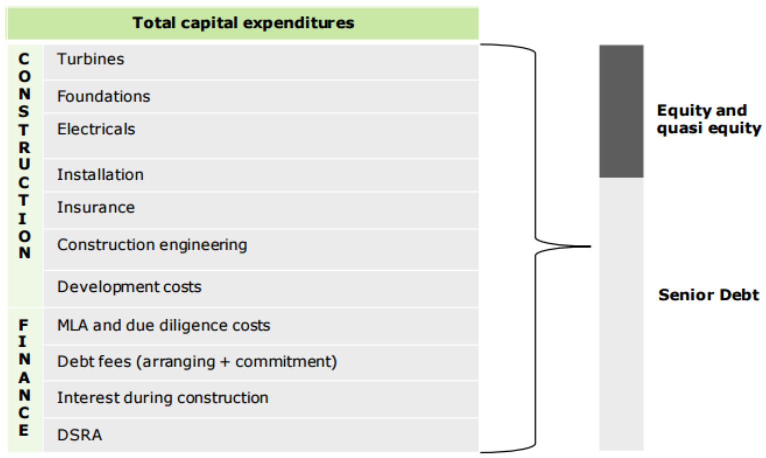


Figure 11 – Example of Capex constraint (gearing) for an offshore wind project

The second constraint, DSCR, limits the percentage allowed of the cash flow available for debt service to repay the debt facilities (principal, interests and agency fees). The objective of this constraint is to size debt not on all cash flows available and keep a percentage of it as a buffer in case of negative scenarios. This buffer guarantees flexibility to banks when dealing with unexpected risks.

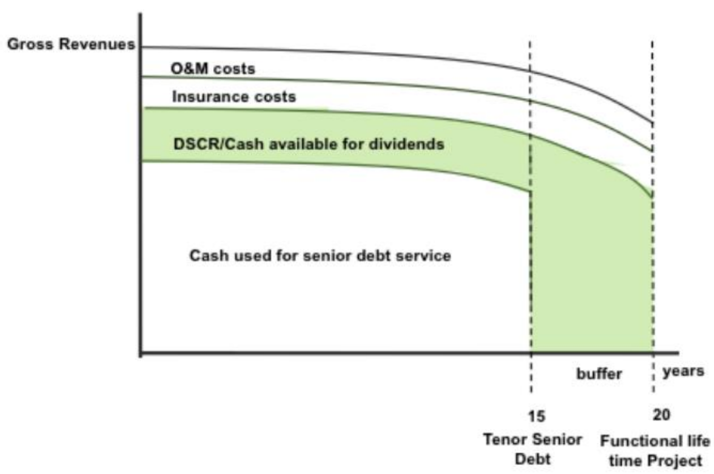


Figure 12 – Revenue side constraint (DSCR)

The model has two stages. The first one aims to determine the debt profile given several assumptions and the second one is to determine the impacts on equity IRR, given the debt profile determined on previous stage, performing sensitivity analysis of several parameters such as interest rates, solar irradiation, degradation rate, cost overruns and many others. Both stages can be performed by the traditional financial model approach. However, this thesis proposes to develop the second stage on chapter 6 (system dynamics method). The idea is to evaluate the limitations of performing a sensitivity analysis with several variables in Excel and how this could be addressed in a continuous system modeling technique. The hypothesis is that Excel is not able to deal with several variables at once, whilst SD can perform it easily and provide results to test the model's robustness and inform investors the impacts of such changes in the equity IRR.

5.2 Assumptions and parameters considered

Besides the assumptions and inputs listed on chapter 4, this section is devoted to describe the additional inputs necessary to calculate the equity IRR and determine the debt profile to be used in the SD model. These parameters are briefly explained and values are based on professional experience and market assumptions.

Solar power plant construction period – 7 months

According to the IFC report of Utility-Scale Solar Photovoltaic Power Plants (2015), solar installations can be built relatively quickly, often in 6–12 months, compared to hydro and fossil fuel projects that require more than 4–5 years to complete. This presents a major incentive in rapidly-growing, emerging markets, as Mexico, with a high unmet demand and urgent need for power. The construction period, of course, varies depending on the plant's installed capacity and location. For the Mexico context, its considered 7 months the sufficient time to make a green field plant project operational.

Solar power plant operation period – 30 years

Again, there are several factors that determine a solar plant life cycle. O&M plays an important role on that. Developers argue that photovoltaic systems modules typically last 25 to 40 years. Additionally, the life cycle considered is greater than the PPA term. It means that after the 15-year period for electricity and 20-year period for CELs, the project will only rely on market prices. Determining the spot market prices of such products in the long term is very uncertain and cause great impact on the economic indicators of the project.

Irradiation solar scenario considered – P50

From the equity perspective, sponsors usually consider the P50 scenario to determine the economic parameters. Banks, on the other hand, impose the P90 scenario to calculate the amount of debt allowed for a certain project. P50 can be considered as more optimistic and the figure from David Park's report (2011) below explain the reason.

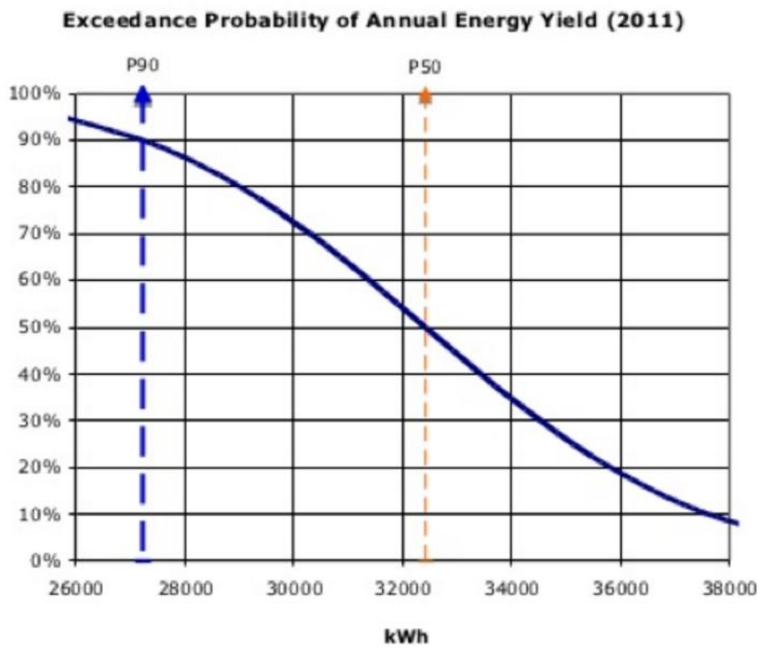


Figure 13 – Exceedance probability of annual energy yield

Committed electricity generation declared – 62,500 MWh / year

In the case of the first Mexican power tender, projects had to submit an envelope of revenues from CELs and electricity generation. In order to that, bidders had to estimate the volume of both products they would like to commit on an annual basis. This committed volume would be the reference for any production deviation and apply of monthly and annual adjustments according to PPA terms. The volume of electricity assumed is lower than, both, P50 and P90 scenarios of the theoretical solar PV power plant.

Committed CEL production declared – 62,500 CELs/ year

One clean energy certificate is equivalent to 1 MWh, thus the same volume is assumed. Plants, though, could determine different levels for different strategies. There was no constraint imposed by CENACE about it.

CEL market price – 20 USD / CEL

In the case plants do not fulfill the committed levels or produce an excess of it, they can go to the sport market and acquire/sell the shortfall/surplus. Additionally, they would have to consider an annual adjustment of the PPA price to the CEL market price as an impact in the revenue line. For the sake of simulating, the 20 USD per CEL is considered as of 2018 and indexed onwards based on the Mexican production price index (PPI).

Initial electricity price as per PPA – 829 MXP / MWh

As described previously, the tender awarded projects had to submit an envelope of revenues and the PPA terms clarify how should the electricity and CEL prices should be derived from that. The prices are in Mexican pesos and to achieve the described value, it is necessary to use the forex rate at bid date, apply the committed volume levels and consider a project awarded for a 65 USD / MWh offer price. The formula to determine the notional price of electricity is:

$$\mathbf{PNUEE_m} = \frac{\mathbf{PAM_m}}{(\mathbf{\#MWh} \times \mathbf{40}) + (\mathbf{\#CEL} \times \mathbf{20})} \times \mathbf{40}$$

Where, PAMm is the offer price (at bid date in MXP) adjusted monthly according to PPA indexation rules; #MWh is the committed volume of electricity per year; #CEL is the committed volume of CELs per year.

Initial CEL price as per PPA – 415 MXP / CEL

As explained above, this price (called notional price) is derived from the following formula presented in the PPA terms:

$$\mathbf{PNCEL_{PC}} = \frac{\mathbf{PAA_{PC}}}{+(\mathbf{\#MWh} \times \mathbf{40}) + (\mathbf{\#CEL} \times \mathbf{20})} \times (\mathbf{\#CEL} \times \mathbf{20})$$

where, PAApc is the offer price (at bid date in MXP) adjusted annually according to PPA indexation rules; #MWh is the committed volume of electricity per year; #CEL is the committed volume of CELs per year.

Maximum gearing – 75 %

As described previously, it is the level of a company's debt related to its equity capital, usually expressed in percentage form. Gearing is a measure of a company's financial leverage and shows the extent to which its operations are funded by lenders versus shareholders. The maximum gearing imposed by lenders varies from market to market and type of project. The value assumed should reflect Mexico's context.

Minimum DSCR – 1.35

The second constraint for lenders, DSCR drives the debt sizing of the project. DSCR measures how many times the CFADS (cash flow available for debt service) can repay the scheduled debt service. Identification of the minimum DSCR is the primary method to identify a period of weak CFADS to service the debt obligations. The 1.35 can be read as a maximum of 74% of the CFADS can be used to pay debt service.

Distribution DSCR lock-up – 1.10

After determining the debt amount and debt repayment profile, every month the project evaluate the CFADS and its remaining is used to pay shareholders. However, senior lenders are able to prevent equity distributions by the DSCR lock up, i.e., avoid the remaining of CFADS after paying debt to be distributed to shareholders because the project is very close to the boundary of not having sufficient funds for debt service. This lock up is used for the next period as a buffer to lower cash flows scenarios and eventually complement the debt repayment.

Percentage of equity as share capital – 20 %

Share capital consists of funds raised by issuing shares in return for cash or other considerations. The amount of share capital a company has can change over time because each time a business sells new shares to the public in exchange for cash, the amount of share capital will increase. On the other hand, this is defined beforehand when determining the equity structure of a project finance model.

Percentage of equity as shareholder loan – 80 %

The shareholder loan is the complement of share capital to form the equity structure that will determine the project's equity injection. Shareholder loan has (as debt) an interest rate, however in the cash waterfall is on a junior position.

Shareholder loan interest rate – 10 %

Shareholder loan is a debt-like form of financing provided by shareholders. Usually, it is the most junior debt in the company's debt portfolio, and since this loan belongs to shareholders it should be treated as equity. Maturity of shareholder loans is long with low or deferred interest payments. This can be limited by governments as it has impact on taxes paid.

Senior debt repayment period – 17 years

Also called maturity, it is the period of time for which a financial instrument remains outstanding. Maturity refers to a finite time period at the end of which the financial instrument will cease to exist and the principal is repaid with interest. In project finance it ends usually before the PPA period to create an additional buffer for lenders.

Agency fee during construction – 20,000 USD / year

Agency cost refers to the cost incurred by a firm because of the problems associated with the different interests of management and shareholder and the information asymmetry that exists between the principal (shareholders) and the agent (management). The information asymmetry directly affects the agency costs: the higher the information asymmetry, the greater will be the agency costs.

Agency fee during operation – 10,000 USD / year

There is a segregation between operation and construction due to the quantity of information and relevancy is greater during construction than operation which is more stable.

Senior debt facility commercial margin – 2.0 %

Senior debt commercial margin is the rate added to Libor (benchmark rate that some of the world's leading banks charge each other for short-term loans) to determine the final interest rate. It can be seen as the margin banks make when lending money to the project.

Senior debt facility upfront fee – 2.0 %

It is the fee paid by a borrower to a syndicate of banks for making a loan. The fee is often tiered, with the agent bank receiving a larger amount as a consideration for structuring the loan and/or underwriting larger amounts and thereby assuming greater risk. Upfront fees paid to syndicate members are almost always a function of commitment size. The upfront fee is structured as a percentage of the sum committed to the loan.

Senior debt facility commitment fee – 0.8 %

It is the fee charged by a lender to a borrower for an unused credit line or undisbursed loan. A commitment fee is generally specified as a fixed percentage of the undisbursed loan amount. The lender charges a commitment fee as compensation for keeping a line of credit open or to guarantee a loan at a specific date in future. The borrower pays the fee in return for the assurance that the lender will supply the loan funds at the specified future date and at the contracted interest rate, regardless of conditions in the financial and credit markets.

VAT debt facility commercial margin – 1.5 %

The VAT facility is used to finance the VAT deficit incurred during the construction period of the project. Interest and financial costs on the VAT facility are capitalized during the construction period. Banks charge lower rates to VAT debt because there are lower risks involved as the VAT reimbursement is guaranteed by the government. This debt is addressed to deal with working capital restrictions.

VAT debt facility commitment fee – 0.8 %

The commitment fee is usually the same as the senior debt facility. This rate is not related to the operation risks, but to banks secure the commitment amount to the project.

Interests earned on debt service reserve account – Libor (USD) - 0.3 %

The purpose of a debt service reserve account (DSRA) is to provide a cash buffer during periods where cash available for debt service (CFADS) is less than the scheduled payments. The balance of the DSRA should never be negative and balance should be zero at the end of the loan life, and should gradually decline in the periods leading up to that time. During the periods that there is a positive balance, it is acceptable to obtain interests of the amount and usually is considered as a reference the Libor rate minus an assumed percentage.

Hedging senior debt swap rate – 3.25 %

The hedging mechanism is largely used on project finance. The idea behind is to guarantee stable and predictable cash flows throughout the projects life cycle. The hedge is used to “substitute” the senior debt interest rate volatility caused by the Libor rate. To explain the dynamics of a floating rate loan, a borrower would enter into a contract with a swap provider under which the borrower would be liable to pay the counterparty a "fixed" payment (calculated by applying a fixed rate to a notional amount) and the counterparty would be liable to pay the borrower a "floating" payment (calculated by applying a floating rate to the same notional amount). Thus, if the interest rate basis increased, the fixed payment from the borrower to the counterparty would not increase but the floating payment from the counterparty to the borrower would.

Hedging senior debt swap margin – 0.15 %

Similar to the senior debt facility, the hedging swap rate is analogous to the Libor rate and the swap margin to the commercial margin.

Hedging proportion during construction and operation periods – 75 %

The hedge ratio is a ratio comparing the value of a position protected via a hedge with the size of the entire position itself.

Mexican corporate tax – 30 %

In Mexico, the Corporate Income tax rate is a tax collected from companies. Its amount is based on the net income companies obtain while exercising their business activity, normally during one business year. The rate is established by law and stands at 30 percent.

Mexican interest rate tax gross up – 4.9 %

Interests paid from Mexico to foreign entities are subject to taxation. The income tax withholding determine by the government is 4.9%.

Mexican VAT rate – 16 %

The value added tax is a based consumption tax assessed on the value added to goods and services. It applies more or less to all goods and services that are bought and sold for use or consumption in the Mexico. Mexico introduced a Value Added Tax regime in 1980. Locally, it is known as Impuesto al valor agregado (IVA). It is administered by the Ministry of Public Finance and Credit stand at 16 percent.

Depreciation period for EPC expenditures – 30 years

Depreciation period for other Capex – 20 years

Accelerated depreciation period for project development expenditures – 10 years

The Mexican Income Tax Law (MITL) establishes the depreciation rates that apply to investments in Mexico, depending on the kind of good or activity that is carried out. Specifically, the MITL establishes the depreciation rates according to the activity that is carried out by certain equipment. For the sake of simplification, the cluster of EPC expenditures has 30-year period depreciation followed by 20 years for other Capex and an accelerated depreciation of 10 years for the project development expenditures line.

The table below summarizes all the parameters and assumptions made for values that should not vary over time:

Inputs	Unit	Value
Solar power plant construction period	Months	7
Solar power plant operation period	Years	30
Irradiation solar scenario considered	-	P50
Committed electricity generation declared	MWh / year	62,500
Committed CEL production declared	CEL / year	62,500
CEL market price	USD / CEL	20
Initial electricity price as per PPA	MXP / MWh	829
Initial CEL price as per PPA	MXP / CEL	415
Maximum gearing	%	75
Minimum DSCR	-	1.35
Distribution DSCR lock-up	-	1.10
Percentage of equity as share capital	%	20
Percentage of equity as shareholder loan	%	80
Shareholder loan interest rate	% / year	10
Senior debt repayment period	Years	17
Agency fee during construction	USD / year	20,000
Agency fee during operation	USD / year	10,000
Senior debt facility commercial margin	% / year	2.0
Senior debt facility upfront fee	%	2.0
Senior debt facility commitment fee	%	0.8
VAT debt facility commercial margin	% / year	1.5
VAT debt facility commitment fee	%	0.8
Interests earned on debt service reserve account	%	Libor (-) 0.3 %
Hedging senior debt swap rate	%	3.25
Hedging senior debt swap margin	%	0.15
Hedging proportion during construction and operation periods	%	75
Mexican corporate tax	%	30
Mexican interest rate tax gross up	%	4.9
Mexican VAT rate	%	16
Depreciation period for EPC expenditures	Years	30
Depreciation period for other Capex	Years	20
Accelerated depreciation period for project development expenditures	Years	10

Table 3 – Additional inputs fixed over time

There several other parameters considered in the model that vary over time. The main ones are succinctly presented below.

Solar irradiation seasonality

The amount of solar radiation reaching the earth's surface varies greatly because of changing atmospheric conditions and the changing position of the sun, both during the day and throughout the year. During the day the variation is irrelevant to the model, due to the time frame adopted. However, the changes on solar irradiation throughout the year is of great importance. The relevancy of the amount of irradiation will first affect the total electricity generation and secondly the revenue when multiplying it to the electricity price of that month. In this model, its considered a seasonality which represents the percentage of the annual production in one specific month. As expected, summer months produce more electricity than winter ones.

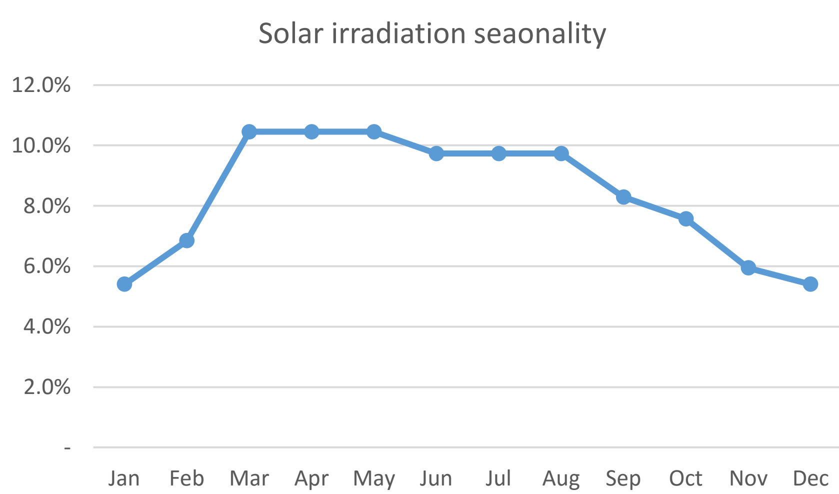


Figure 14 – Solar irradiation seasonality for Baja California Sur

PPA monthly price adjustment indexation

According to the PPA terms, electricity and CEL's prices are indexed monthly following three parameters. The first one, accounting for 70% of the indexation, is the FX rate between US dollars and Mexican pesos. It considers as a reference the FX at bid date and this value is used as the denominator to the rate at the end of every month. The second is US production price index (PPI) which accounts for 20% of the total indexation and follows the same calculation as the first one.

The third is the Mexican PPI completing the 10%. To forecast the PPA revenues, assumptions must be made to all the three mentioned parameters curves.

Monthly capex payment schedule

This input is relevant to impact the cash flow statements and determines when the equity injection and debt drawdown occur. Consequently, it impacts the senior debt facility interests and fees calculations and in the end the project's equity IRR determination. For each line of the Capex presented previously, its determined when the cash disbursements happen.

Monthly hourly adjustment factors (FAHs)

This input, already detailed on previous chapters, is provided on a monthly basis during the electricity PPA term (15 years) by CENACE. Each zone has its unique FAHs, which impact positively or negatively the revenues of a specific month depending on the power plant generation month and time. Its unit is USD / MWh.

Electricity market price

This is the most uncertain parameter and has great impact on the model's result. To calibrate such parameter in the Mexican context is something extremely difficult due to its recent liberalization and no historical data of electricity prices on the recently founded spot market. Several are the existing models that try to predict market prices with a fundamental approach. The electricity prices are significant in the model during the PPA term in case of electricity production surplus or shortfall and, after the 15-year period, to determine the main revenue stream once the PPA has ended. As the purpose of this thesis is not to predict market prices or study the use of any fundamental model, the data considered is provided by market consultants and treated confidentially.

5.3 Model's outputs

Given the inputs provided on previous sections and the explanation of the main calculations of the model, several are the results after the simulation. Those results are presented and briefly explained below.

Uses & sources

This section summarizes all the information to the expenses of the project and the sources necessary to fund such expenses. Hence, the uses and sources values should match as a balance sheet statement. The expenses comprise the total capex in nominal terms, the interests due during construction, the bank fees, the DSRA funding requirement (necessary fund at the end of construction to service debt in the first period of operation) and the VAT paid during construction. The table below presents the total uses.

Uses	Value (in kUSD)
Total capex - nominal terms	44,942
Interests during construction	442
Bank fees	870
DSRA funding requirement	1,011
VAT paid	7,191
Total	**54,457**

Table 4 – Uses during construction

The sources detail the amount of financing necessary from each investor stakeholder, i.e. equity, senior debt and VAT debt facility as presented below:

Sources	Value (in kUSD)
Equity injection	15,263
Senior debt total facility	32,003
VAT debt facility	7,191
Total	54,457

Table 5 – Total sources

Operating cash flows

This output is the projected cash inflows and outflows during the project's life span. It contemplates on the inflows side all the revenue streams, which are the electricity revenues, during and after the PPA term, and the CELs revenues. The peak on revenue curve, starting on 2032, is due to the end of the PPA and switch from electricity PPA prices to spot market prices, which in the model, is considered significantly larger. On the operating cash outflows, the graph below presents them by seniority level, i.e. ranking them by priority of payment. The highest priority are the operating costs that are essential to the projects continuity.

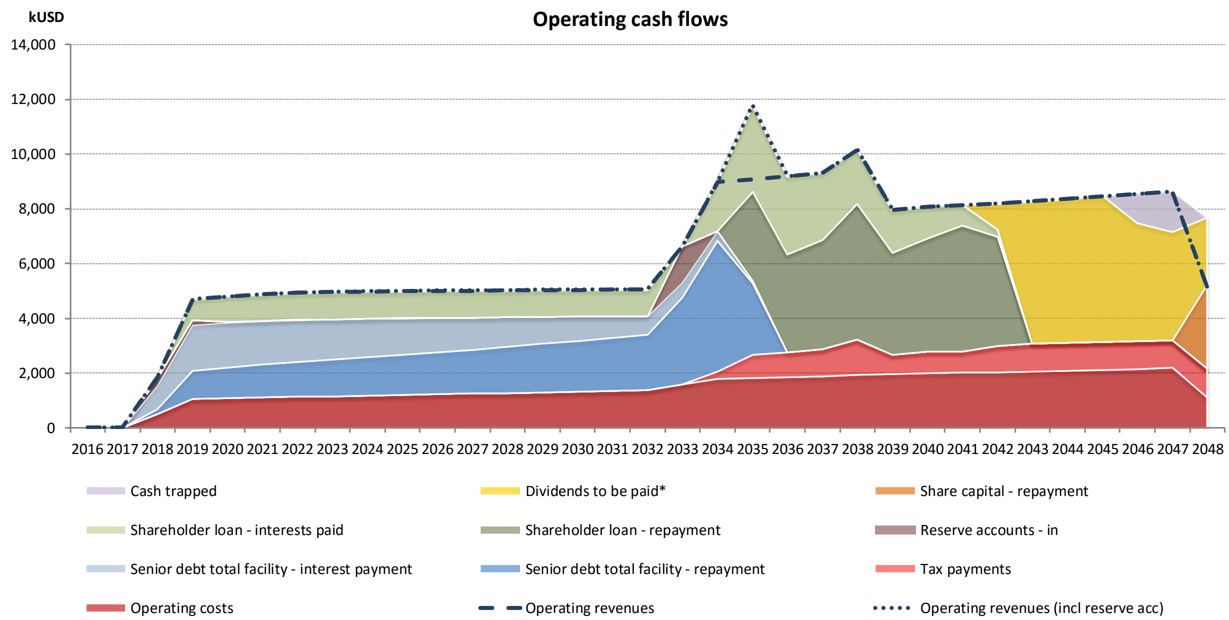


Figure 15 – Theoretical solar power plant project's operating cash flows

The second highest are the tax payments due to the Mexican authorities. Following are the senior debt facility principal repayments. The importance of paying the principal parcels first is to reduce the total amount due and, consequently, diminish the interests, which is next on the priority rank. The DSCR constraint, in the case of the forecasted ratio is below the 1.35x level, will trigger the reserve accounts – in, which secures the debt service for the next period. This is identified in the graph during the year of 2033.

The equity, as discussed previously, faces higher risks than debt. The trade off of it is to receive higher returns. As shown on figure 15, the shareholder loan (principal and interests), dividends and share capital are the last ones to be paid.

Financing

The financing comprises the total funds to finance the construction of the project and how it is divided between equity and debt after following the DSCR and gearing constraints. After running the model, the final values are 15,263 kUSD of equity and 32,003 kUSD of debt, resulting on a 67.7% gearing, which is lower than the maximum 75% imposed by banks. This result is due to the

DSCR limitation which restricts the maximum amount to be financed by lenders based on the cash available for debt service.

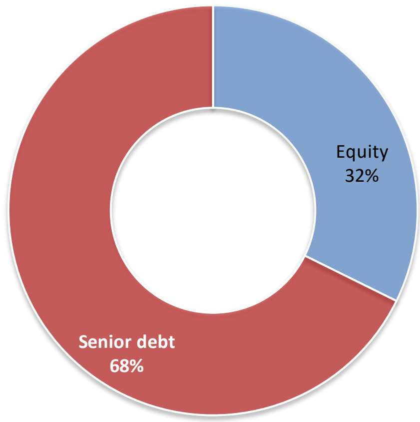


Figure 16 – Leverage level

Senior debt ratios

The senior debt ratios consist of the calculating DSCR ratio of the period, the historic six months, historic twelve months and projected twelve months. These ratios are, usually, requirement of banks to comprehend the project's behavior under different time frames. For our purpose, the important parameter is the minimum DSCR ratio achieved during the 17-year period (debt service duration). Given that in the previous section, the resulting gearing is lower than the maximum permitted, the DSCR constraint is the limiting parameter. Indeed, the minimum DSCR achieved of the project is 1.35x, which is the minimum imposed by banks. In other words, the project is not funding more debt due to cash flows boundaries.

Debt profile

The debt profile consists of the principal repayment, agency fees and the incurred interests. This debt service is defined given the inputs considered on previous chapter and is based on expected revenues. Banks sign the loan contract approval after an extensive due diligence process of the financial model, stressing parameters to understand the project's economic behavior on downside scenarios. Once the behaviors are studied and banks define the inputs to be considered, the debt profile is "frozen" and the project reaches financial close. Such debt service will be the one considered during the project's operation and any deviation of the forecasted scenario will mostly affect the sponsors' returns, the equity IRR.

The debt service profile after the simulation is presented on figure 17, where agency fee remains stable throughout the debt term, the interests decrease and consequently, the principal increases. The peak on years 2033 and 2034 is due to the higher cash flow available for debt service from the operating revenues, more specifically, the electricity revenues given the end of the PPA prices and switch to forecasted larger spot market prices. The numbers are negative, because it is a representation of the SPV's cash outflows.

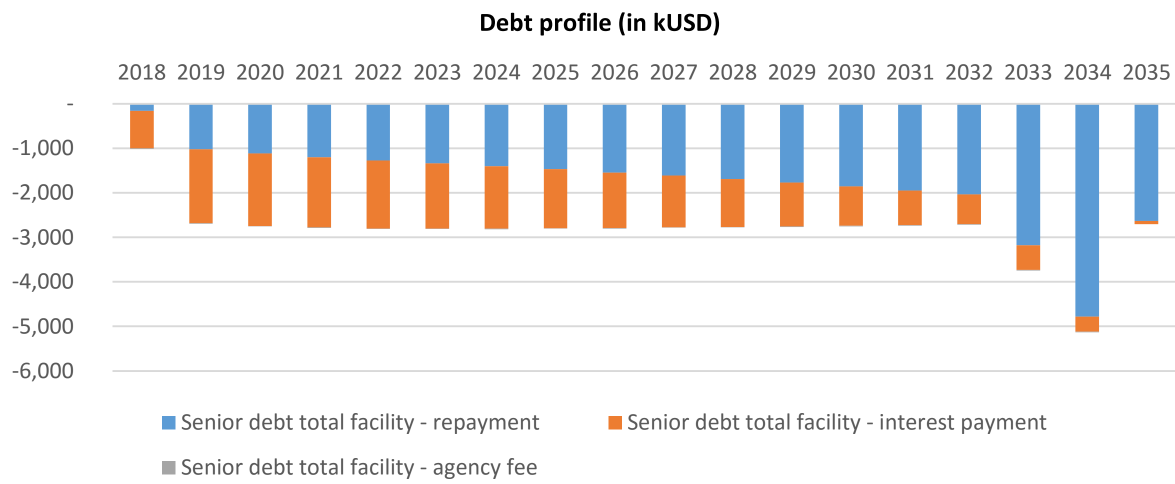


Figure 17 – Debt service

Profitability

From the perspective of sponsors, the profitability is the main parameter to measure the project's performance and support the investment decision. Shareholders expect that the internal rate of return is higher than they could get from other investments and pays off the risks they are exposed to. The IRR is just a form to measure on annual basis what is the yield on the equity injection. For the theoretical solar power plant, the equity IRR's output of the model is 10.08% per year. Figure 18 details the shareholders' profitability profile including repayment, interests paid on the shareholder loan, dividends and share capital.

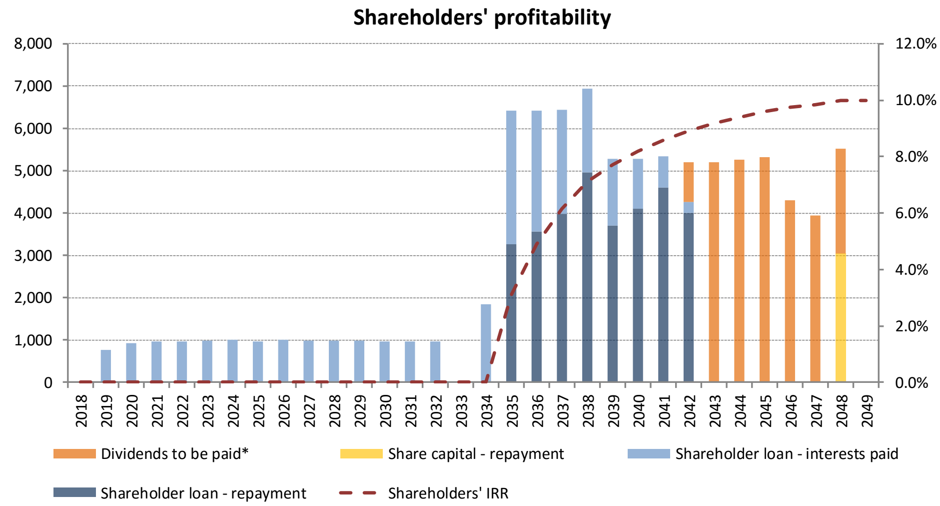


Figure 18 – Shareholders' profitability

After determining the equity IRR for a given debt profile and the project reaches financial close, sponsors (shareholders) may be interested to perform sensitivity analysis under exogenous variables, specially focusing on downside scenarios, to evaluate the impacts on the IRR. This step is usually performed before financial close to support the investment decision using several debt profiles. For the sake of simplification, the decision of this thesis is to perform such sensitivities with a unique debt profile, considering it as given for this second stage. This analysis is relevant, because as long as downside scenarios appear and the DSCR level continues to be above one, the lenders will not suffer any economic impact. However, the equity side may face significant decrease on its profitability. The idea of the sensitivity analysis for the lenders is to check the model's robustness and the range of equity IRR they may encounter due to project's uncontrolled parameters.

Performing this sensitivity analysis in Excel is very limited because of the software restrictions and memory usage. The scenarios would be determined by different inputs and simulating the model every time for a single value. It would be of great advance if the input, instead of a single value, were a range plus the interval assumed. To optimize the process, a macro can be developed to run the several scenarios and store the results of each scenario. However, this process is time consuming and leads to a limitation on the number of parameters to be varied. Hence, the range of results would not be statistically significant and the overall equity IRR range and robustness would be hard to determine. Most of the cases, this sensitivity analysis is performed indeed in Excel to a certain number of conditions pre-determined by the sponsor or suggested by the financial advisor. Usually, ten scenarios and a dozen of parameters are simultaneously simulated.

To address those limitations, a system dynamic modeling approach is suggested to evaluate the benefits and restrictions of such tool on chapter 6. The objective is to take advantage of the VENSIM software to perform the sensitivity analysis in a dynamic mode, inserting instead of single values inputs, an interval and step pre-established of several variables and observe the equity IRR fluctuation.

6. Proposed system dynamics model

System dynamics, as extensively discussed in this thesis, is a mathematical modeling technique developed to support decision makers to frame, understand, and discuss complex issues and problems. SD origins goes back to the 1950s when mathematical differential equations were formulated targeting to support managers to improve their understanding of industrial processes (Taylor, 2008). Nowadays the application of SD has a wider range, being used throughout the public and private sector for policy analysis, design and communication.

The main advance of system dynamics usage occurred around the 1990s, when graphical user interface system dynamics software developed into user friendly versions and have been applied to diverse systems. SD models solve the problem of mutual causation by updating all variables in small time steps increments with positive and negative feedbacks and time delays structuring the interactions and control. The best known SD model, presented on chapter 2, is most likely the 1972 The Limits to Growth who helped spread the advantages of using SD to understand the behavior of probable future scenarios. The model forecasted that exponential growth would lead to economic collapse during the 21st century under a wide variety of growth scenarios.

System dynamics is one aspect of systems theory as a methodology to comprehend the dynamic behavior of complex and hard-to-predict systems. The foundation of the method is the acknowledgement that the structure of a system, its many circularities, interlocking, sometimes time-delayed relationships among its components, is often just as important in determining its behavior as the individual components themselves. It is also vindicated that because there are often properties of the overall system which cannot be found among the properties of individual elements, in some cases the behavior of the whole cannot be explained in terms of the behavior of the parts (Jorgen, 1980).

The main components of system dynamics diagrams are causal links, feedback loops, accumulation of flows into stocks and time delays. Causal links represent the mathematical impact of one parameter into another that results on a different value than previous iteration. A causal loop diagram is a simple map of a system with all its constituent components and their interactions. By capturing interactions and consequently the feedback loops (see figure below), a causal loop diagram reveals the structure of a system. By understanding the structure of a system, it becomes possible to ascertain a system's behavior over a certain time period.

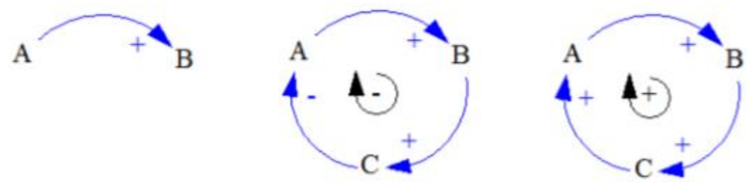


Figure 19 – Causal link and feedback loops

The third group of elements, stocks and flows, supports the causal loop diagrams performance in a more detailed analysis. The feedback is transformed to a stock and flow diagram. A stock and flow model, as shown on figure 20, helps in studying and analyzing the system in a quantitative way. Such models are usually built and simulated using computer software. A stock is the term for any entity that accumulates or depletes over time. A flow is the rate of change in a stock. Usually system dynamics models are composed of all the described elements.

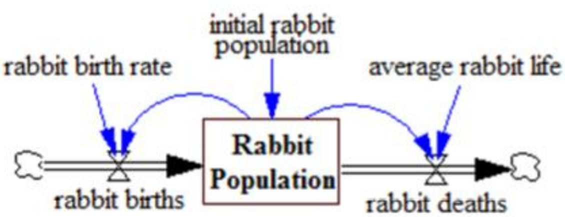


Figure 20 – Example of a stock flow diagram

Pruyt (2013), summarizes the steps involved in a simulation as:

- Define the problem boundary
- Identify the most important stocks and flows that change these stock levels
- Identify sources of information that impact the flows
- Identify the main feedback loops
- Draw a causal loop diagram that links the stocks, flows and sources of information
- Write the equations that determine the flows
- Estimate the parameters and initial conditions using statistical methods, expert opinion, market research data or other relevant sources of information
- Simulate the model, perform sensitivity analysis and comment the results

The true leverage of system dynamics is availed through simulation. Although it is possible to perform the modeling in a spreadsheet, there are a range of software packages that have been optimized for this and provide contributions to the traditional approach. Computer software is employed to simulate a system dynamics model of the stance being investigated. Running distinct scenarios simulations to examine certain policies or uncertainties on such a model can deeply assist in understanding how the system varies over time. System dynamics is much related to systems thinking and sets up the same causal loop diagrams of systems with feedback. However, system dynamics typically goes further and capitalize simulation to research the behavior of systems and the impact of alternative policies (Pruyt, 2013).

In the case of the model investigated in this thesis, the choice of using a system dynamics approach to contribute to the traditional modeling front and enhance the investment decision clarity considers several reasons. The first one would be the use of SD as a communication tool to explain what is behind the functioning of an investment decision model. Continuous system modeling has the advantage of adopting visual and intuitive tools that helps the audience to follow, step by step, the interactions of the model. Secondly, the ease to track errors, debug and validate when compared to the spreadsheet due to the visibility of the parameters relations in one diagram. Another advantage is the ability to perform a Monte Carlo analysis with several parameters without the need of hard programming. Ideally, other advantages and limitations of using the SD approach will be highlighted throughout this and the following chapters.

The selected software to develop and continue the investment decision model is VENSIM, which is an icon-based program to support the construction and testing of system dynamics models. VENSIM is one of the manifold commercially available packages that facilitate the construction of continuous simulation models. It has an interactive software environment that allows the development, exploration, analysis and optimization of simulation models. It was created to increase the capabilities and productivity of skilled modelers and has several functionalities that improves the quality and understanding of models.

The reason of choosing VENSIM among the various continuous system modeling software packages available in the market is due to the opportunity of having a student license provided in cooperation with the Delft University of Technology. Most of techniques and diagrams adopted in this thesis can be applied to any other simulation interfaces as well.

6.1 General description

The proposed SD model for the theoretical solar power plant follows a similar structure presented on chapter 5. The main objective of such model is to calculate the equity IRR, provide a visual effective communication tool and perform sensitivity analysis to determine the economic performance robustness of the possible investment opportunity.

Given the extension and complexity of the developed model, this section is focused on presenting the model by parts and explain the simulation functioning behind it. The idea is to start exploring the model from a high level approach and step by step detailing the particularities and role of each cluster of variables. All the parts are linked between one another and do not run independently.

For the sake of clarification of the diagrams to be presented, arrows represent a causality relation between variables, the signal determines if this causality influences positively or negatively the receiving parameter and light grey variables are the ones calculated in other parts of the model, but the resulting value of its calculation is used on a specific diagram. In this chapter, only the structures, causal links and equations are discussed, while on chapter 7 results are presented and succinctly commented.

Shareholder cash flow

The equity IRR is determined by the shareholder cash flow profile. The latter is negatively influenced by the project's required equity injection to be used during the construction phase. The negative impact means a cash outflow. The remaining four variables that positively impact the cash flow profile are, in order of seniority, the shareholder loan repayment and interests paid, share capital repayment and dividends.

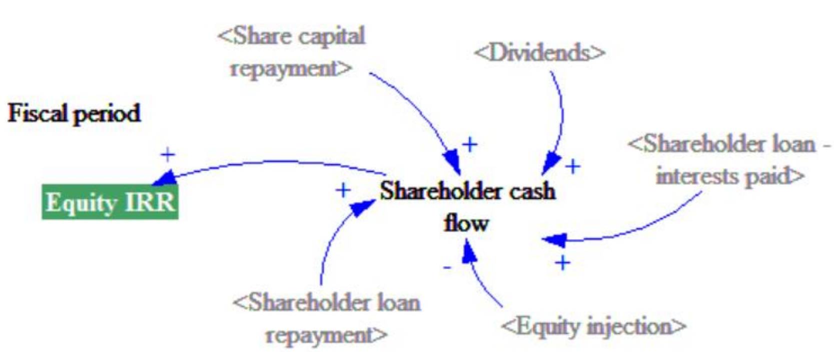


Figure 21 – Equity IRR calculation diagram

The calculation of the equity IRR is determined by the internal rate of return of the shareholder cash flow, considering a fiscal period of 12 months.

Shareholder loan – principal repayment

The next layer to determine the shareholder cash flow profile, is to explain how each of the five variables are modeled. Starting with the shareholder loan principal repayment, the remaining four are explained in their own sections.

This diagram presents the first feedback loop of the proposed model which could also be modeled as a stock flow diagram. This loop calculates how the shareholder loan evolves over time, calculating on each time step what is the loan drawdown (used for Capex), the repayment profile and the remaining part to be paid. The light grey variables highlight that there are external variables to this diagram boundary influencing the principal repayment.

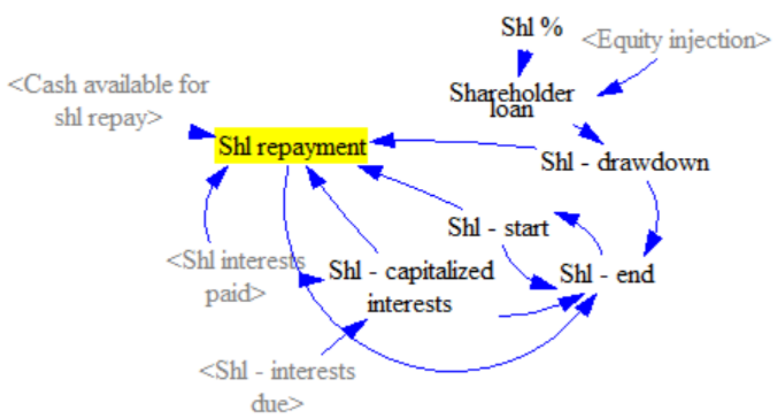


Figure 22 – Shareholder loan calculation diagram

The main parameter constrained the shareholder loan repayment is the cash available for shareholder loan repayment. This variable is explained in detail in one of the following sections, but briefly, it is the cash available in the distribution account (once the senior debt is already serviced and all constraints fulfilled)

Shareholder loan - interests paid

The interest paid due to the shareholder loan is the second variable contributing to the shareholder cash flow profile. Similarly, to the previous one, it calculates for a give shareholder loan interest rate (in this case 10%) and once the principal at a given period is paid, what is the amount of interests due and how much can actually be paid considering the cash available for shareholder loan repayment.

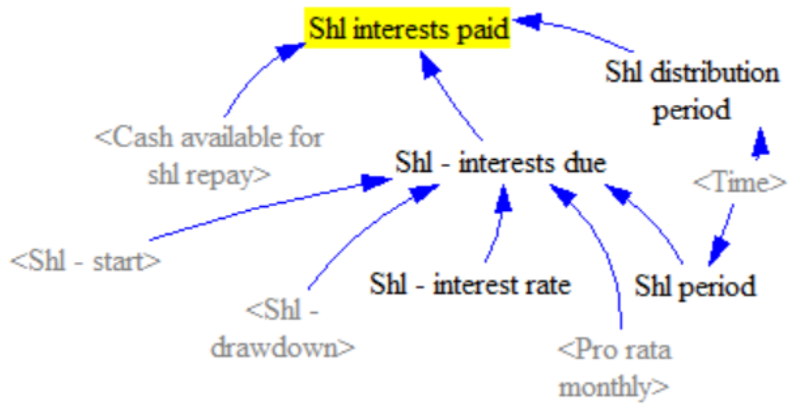


Figure 23 – Shareholder loan – interests paid calculation diagram

This diagram has a special parameter, the pro rata – monthly, to decompound the annual shareholder loan interest rate in to a monthly basis.

Share capital repayment & dividends

The third and fourth variables are presented together. Starting with the share capital repayment, the alternative form of equity, it is determined considering the cash available for share capital repayment. Previously, it was described the senior level of these variables and this can be explicitly visualized in this diagram, i.e. once the shareholder loan repayment and interests are serviced, the remaining cash is calculated under the cash available for share capital (scr), which determines the share capital repayment. The net of this operation defines the cash available for dividend payment. This structure confirms the first equity service is the principal repayment and the last one are dividends distribution.

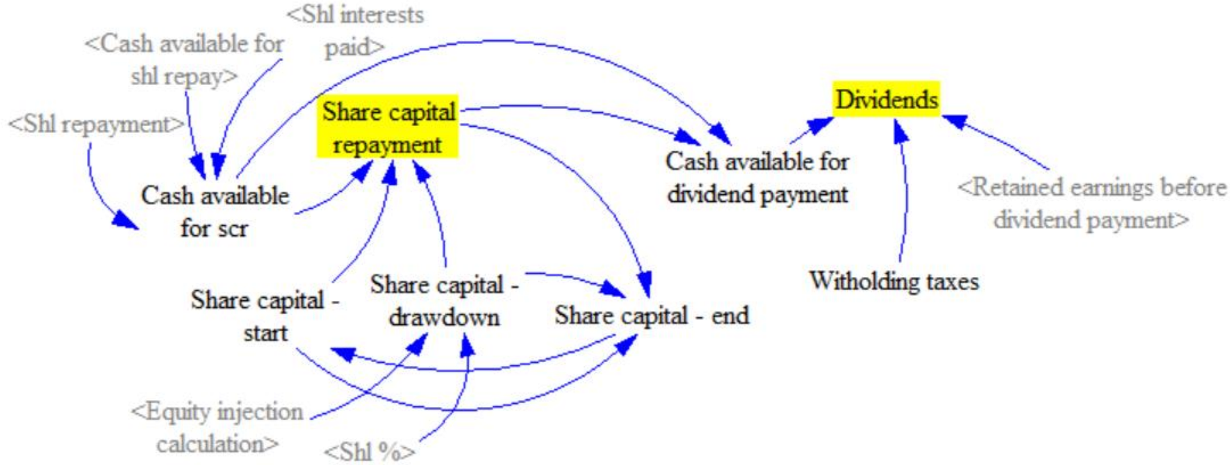


Figure 24 – Share capital repayment & dividends calculations diagram

On top of the cash available for dividend payment, there are withholding taxes deducted and the final amount is subject to retained earnings from the P&L statement.

Equity injection

The last variable determining the shareholder cash flow profile and the only one negative is the equity injection. This is the first structure adopting the stock-flow diagram as a solution to calculate necessary cumulative values.

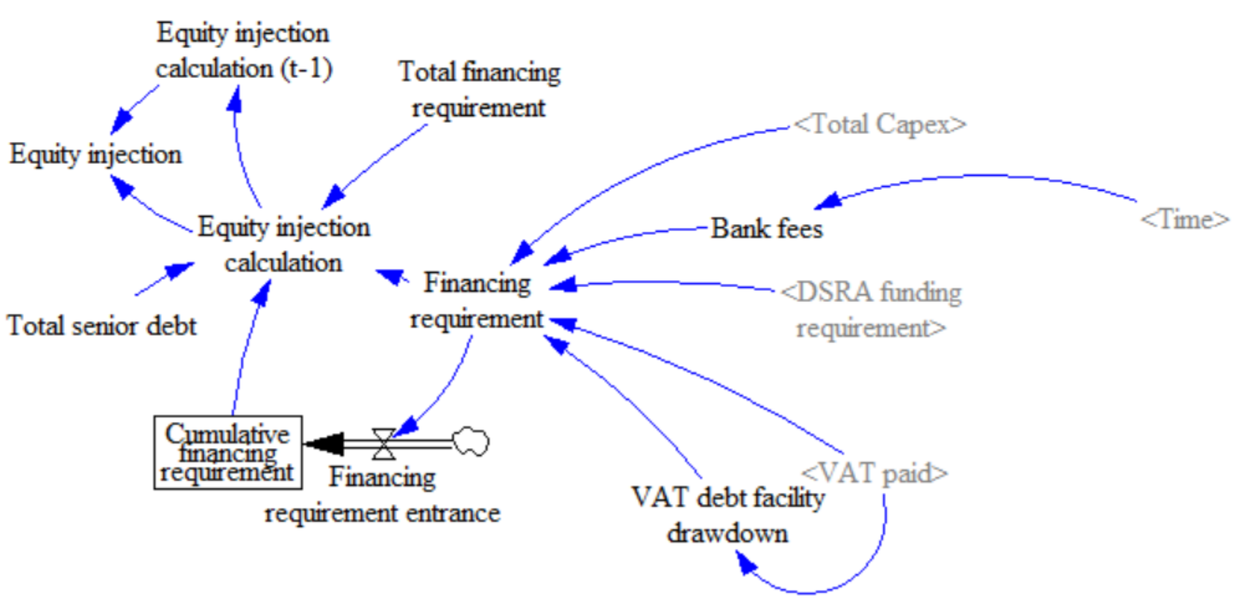


Figure 25 – Equity injection calculation diagram

Equity injection is determined by the total financing requirement of the theoretical solar power plant minus the total senior debt, considered is the model as an exogenous variable, i.e. outside of the defined simulation boundary. This is, therefore, the same for the bank fees curve.

The cumulative financing requirement, modeled as a stock, uses an integral equation to calculate it is value on every time step. Another worth mentioning structure is the equity injection calculation on t-1. The solution considered in the diagram is to use a “delay fixed” equation with a delay time of one time step and initial value to zero. The result seizes the value of the equity injection delayed one month.

Cash available for the proceeds account

The third layer of the proposed model refers to the simulation of the cash accounts used to distribute service according to finance constraints and seniority level. The first one is the cash available for the proceeds accounts or available for shareholders.

The DSRA or debt service reserve accounts, secures the cash necessary to service debt and the resulting amount is released to shareholders’ availability. The DSRA is determined by the cash flow available for debt service (CFADS; one section is dedicated to it). The model anticipates if the future CFADS are enough to service debt by considering the DSRA funding requirement, which is determined once the debt service profile is fixed when debt is raised (external input).

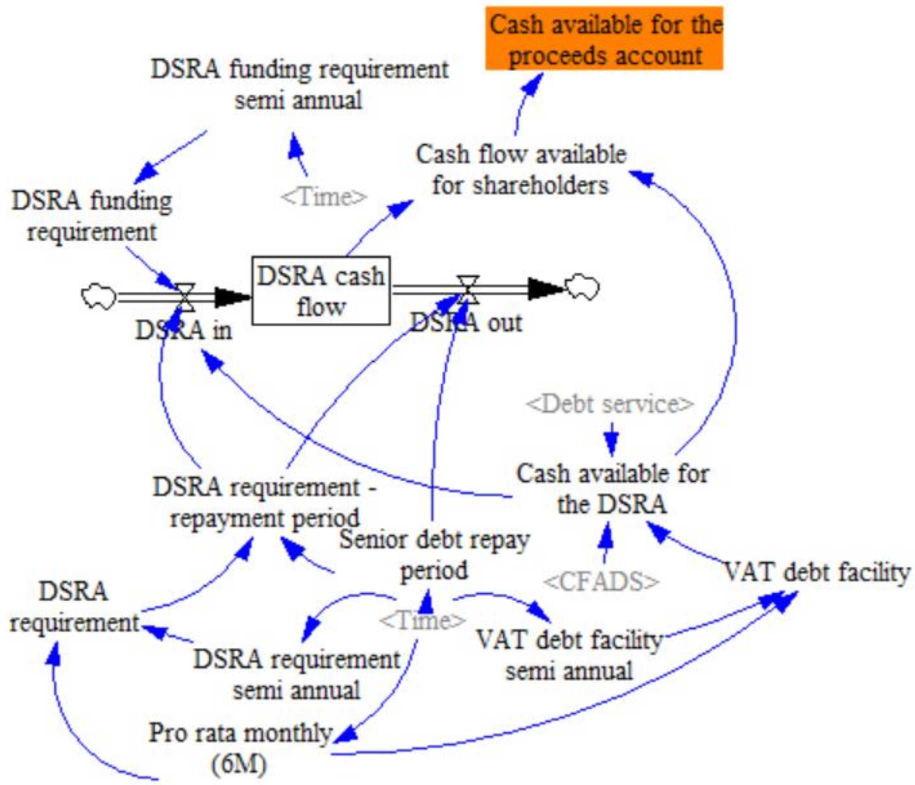


Figure 26 – Cash available for the proceeds account calculation diagram

Cash available for distribution account

The cash available for distribution account follows a similar structure of the previous one. The interesting point here is the fact that cash is only released if the DSCR (debt service coverage ratio) lock-up of the last 12 months' sum is above the 1.10x requirement. This is done to create an additional buffer to banks in case future revenues are not enough to service debt. The way this is calculated in the model is shown on the equation below.

"*Proceeds account* - *out*"=-("Proceeds account - BoP"+"Proceeds account - in")*Shl distribution period*IF THEN ELSE(Historic 12M DSCR>"Distribution DSCR lock-up", 1, 0)

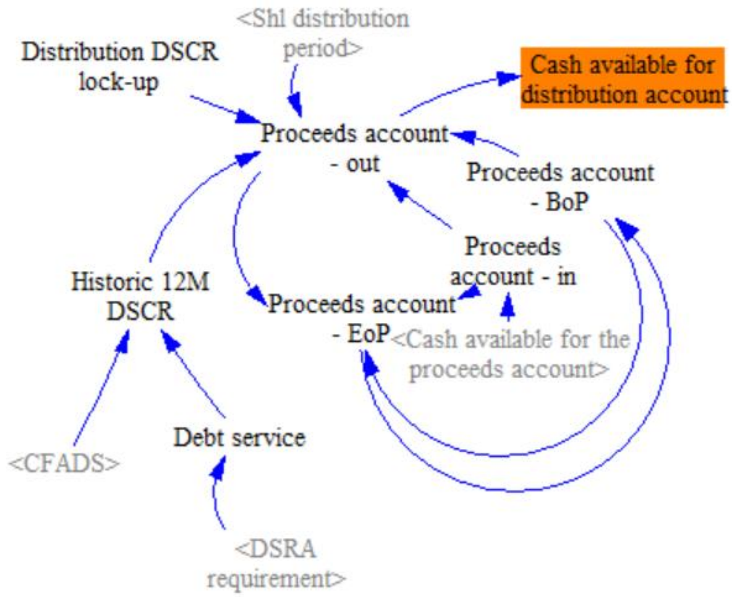


Figure 27 – Cash available for the distribution account calculation diagram

Cash available for shareholder loan repayment

The shareholder loan repayment is triggered by the cash balance of the distribution account and is the first priority on equity cash distribution. The other distributions, represented in the diagram by "light grey" variables, in order of priority are interests, share capital repayment and dividends. This diagram could also be modeled as a stock flow approach.

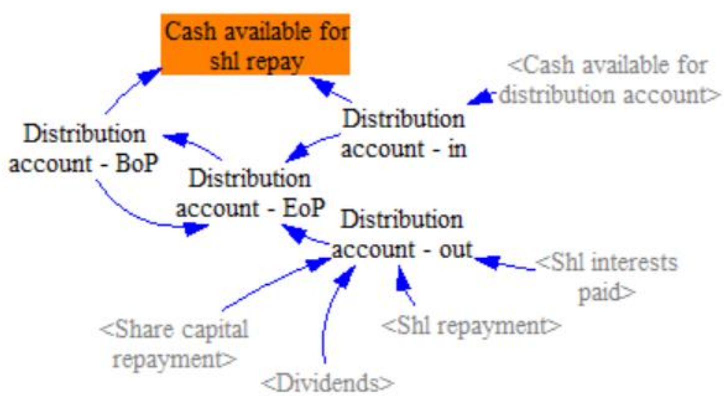


Figure 28 – Cash available for shareholder loan repayment calculation diagram

Cash flow available for debt service (CFADS)

The CFADS, project's cash flow available for debt service is analyzed by project lenders to determine debt sizes and repayment criteria. In this model, both are already pre-determined and any change on revenues or costs would affect firstly the equity IRR and in drastic cases, the debt service.

In a typical project finance model, the cash flow available for debt service is calculated by netting out revenue, total operating costs, capital expenditure, tax, interest income and working capital adjustments. Figure 29 shows how the model considers it and the following sections analyze each of the variables.

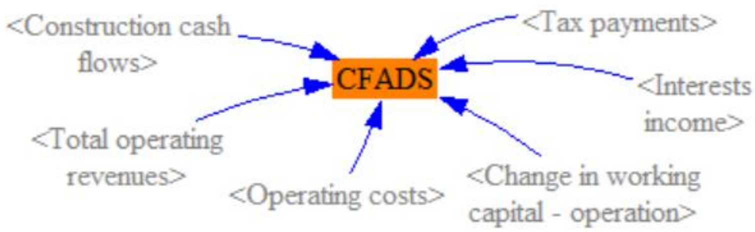


Figure 29 – CFADS calculation diagram

Construction cash flows

The first variable impacting CFADS, construction cash flows, introduces the fourth layer of the proposed SD model.

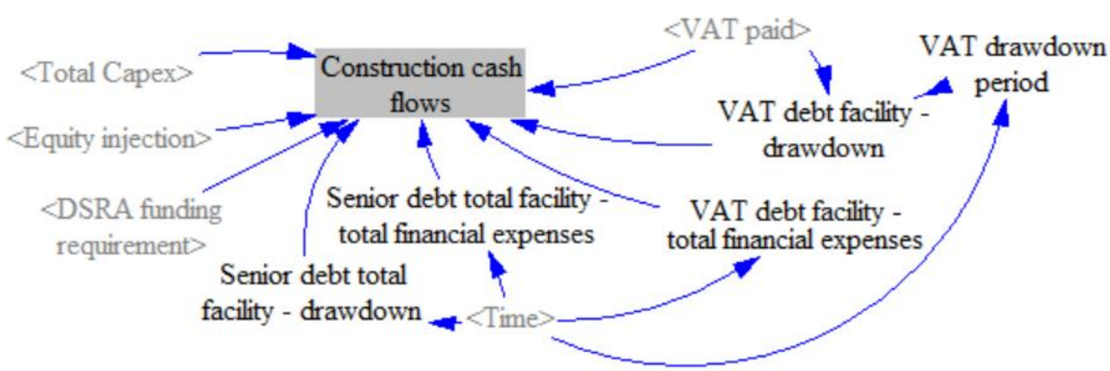


Figure 30 – Construction cash flows calculation diagram

The construction cash flows are modeled as a simple sum of the incoming arrows:

Construction cash flows=-Total Capex-VAT paid+Equity injection+"Senior debt total facility - drawdown"-"Senior debt total facility - total financial expenses"+"VAT debt facility - drawdown"-"VAT debt facility - total financial expenses"-DSRA funding requirement

Total operating revenues

The operating revenues follow the PPA terms of the Mexican first power tender. Given all the calculation complexity of the two products adopted to the theoretical project, this section is split into total energy revenues and total CEL (certificados de energia limpia) revenues.

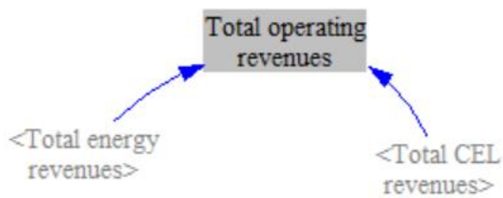


Figure 31 – Total operating revenues diagram

Total energy revenues

The energy revenues are a sum of revenues during the 15-year PPA period and after it. The after period is a product of the considered long term forecast of energy market prices and the net monthly production. The latter has an impact of the solar PV panels degradation factor, which reduces on a monthly basis the yield. Additionally, the net production follows the irradiation seasonality of the plant's location.

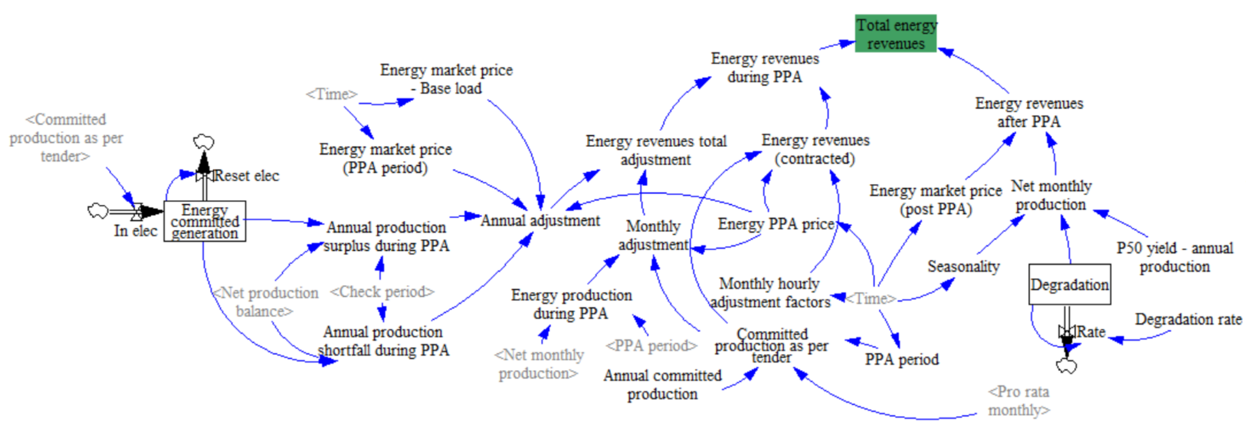


Figure 32 – Total energy revenues diagram

The energy revenues during the PPA period is determined by the volume of energy committed in the tender and the revenues total adjustments. The former is multiplied by the bid price (indexed according to PPA terms) and the hourly adjustment factors (FAHs). The latter is calculated by annual and monthly adjustments. Monthly adjustments are the difference of net monthly production and the committed amount times the spot market prices. Annual adjustments are calculated by electricity shortfalls multiplied by a base load market price and electricity surpluses times the spot market prices.

One challenging mechanism modeled which is worth mentioning is the stock of "energy committed generation". The model is run on a monthly basis and the annual adjustments require the calculation of electricity production deviation on an annual basis. The solution is achieved by modeling together with the stock, an outflow that resets the "energy committed generation" every 12 months as formulated below:

Energy committed generation= Integral (In elec-Reset elec,initial value zero)

, where *In elec*=Committed production as per tender;

> *Reset elec*=Energy committed generation*PULSE TRAIN(start month(42), duration 1 month, repeat period every 12 months, end month (420))

Total CEL revenues

CEL revenues are composed of "committed CEL revenues" and "CELs cash flow". The former follows the same mechanism as the "energy revenues contracted", by multiplying the "CEL PPA price" and the "committed production" as of the tender.

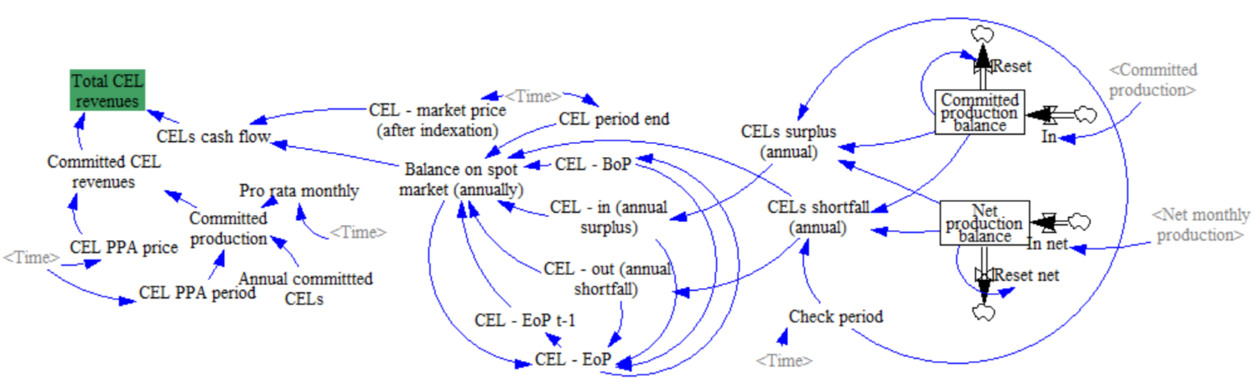


Figure 33 – Total CEL revenues diagram

The “CELs cash flow” is calculated as the annual balance of CELs on spot market times its market price. The balance considers possible surpluses and shortfalls. In the case of a surplus, the difference may be cumulated to the following year balance check. A similar solution to energy committed generation is built to calculate the volumes deviations on a yearly basis.

Operating costs

Despite the dense diagram, the operating costs are determined similarly to the spreadsheet approach. It comprises the elements considered on chapter 4. The “pro rata monthly” is used on most parameters as the inputs are determined as cots per year and the model runs on a monthly basis.

Transmission network charges is the only parameter directly affected by PPA terms. During the PPA period of 15 years (electricity), the charges apply only for electricity surpluses generation. Post PPA, the charges apply to the net production. Hence, the formulation is as follows:

Transmission network charges=((Annual production surplus during PPA*"Transmission tariff (indexed)")+(Net monthly production*"Transmission tariff (indexed)"*Post PPA period))/1000

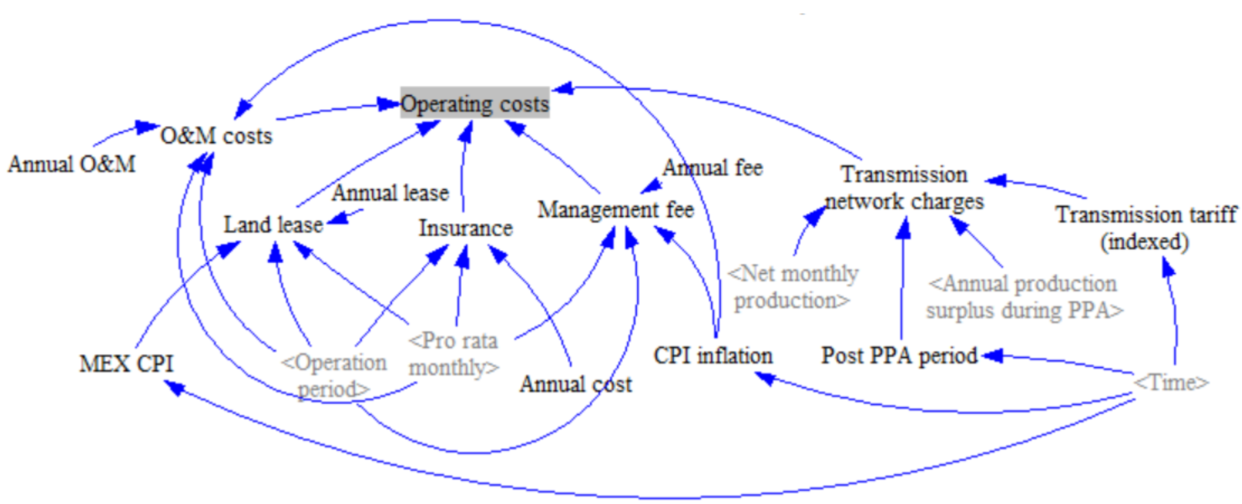


Figure 34 – Operating costs calculation diagram

Change in working capital during operation

The change in working capital is the difference of payables receivables of the project. Given that the project considers one-month period for both, the change should be close to zero with low deviations around it. In case of having different periods, the CFADS would be affected on specific periods positively or negatively depending on the net difference of days.

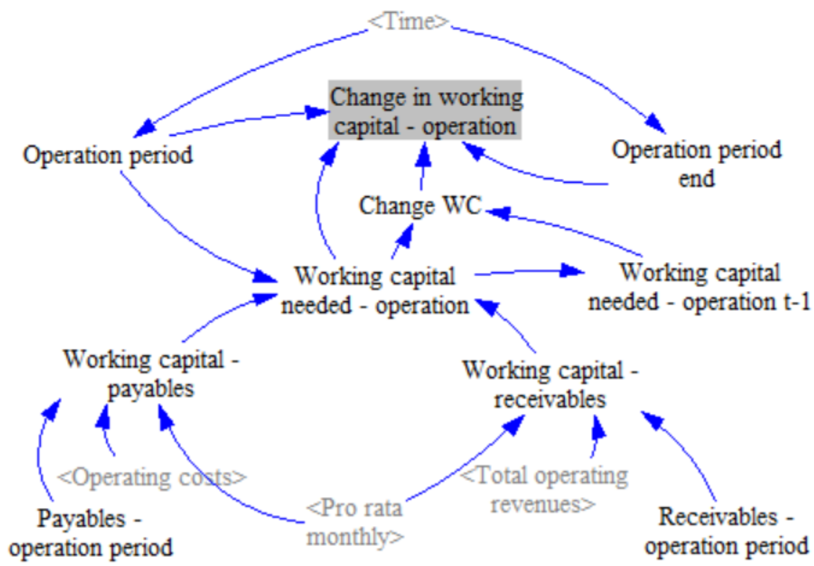


Figure 35 – Change in working capital during operation calculation diagram

Interests income

Interests income are calculated as the cash available on the reserve account considering a given interest rate minus the market LIBOR 6M rate.

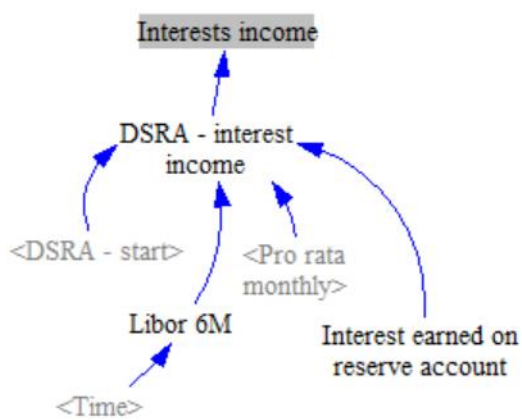


Figure 36 – Interests income calculation diagram

Tax payments

It is not the objective of this thesis study the complex Mexican taxation system. Therefore, a simplification of the taxes payments is done considering the product of the project's operating revenues and an approximated tax rate. This assumption does not consider the ten-year tax carryforward established by the Mexican laws, hence this proposed model may differ (not significantly) from the spreadsheet equity IRR result obtained.

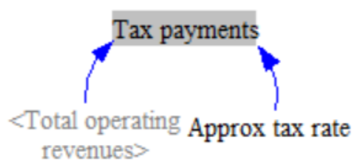


Figure 37 – Project taxes calculation diagram

Total capex

The last diagram of the proposed SD model is about the construction phase expenditures. This structure comprises all the expenditures forecasted to deliver an operational theoretical solar power plant in Mexico. The importance of having such detailed structure is not only to obtain the total capex, but also for sensitivity analysis purposes. Any infrastructure project suffers at some extent uncertainties during its development that mays significantly affect the final equity IRR.

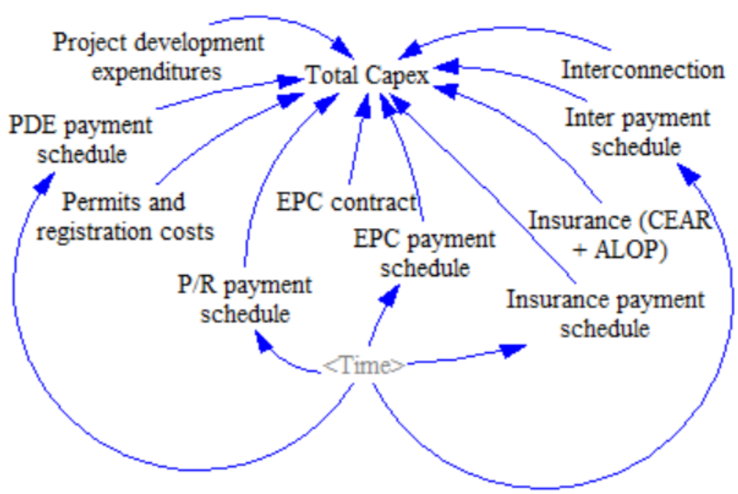


Figure 38 – Total capex calculation diagram

6.2 Assumptions

Several are the assumptions and simplifications considered for the proposed SD model. The first one is required before the modeling starts and refers to the time bounds of the simulation. One constraint SD packages have is the fact of running simulation environments do only work with one unit of time, which in this case is monthly basis. As described previously in this chapter, this constraint proved to be challenging as a range of inputs and parameters of the spreadsheet model are calculated on semi-annual basis. The solution was to consider a parameter called “pro rata monthly” to convert the necessary variables.

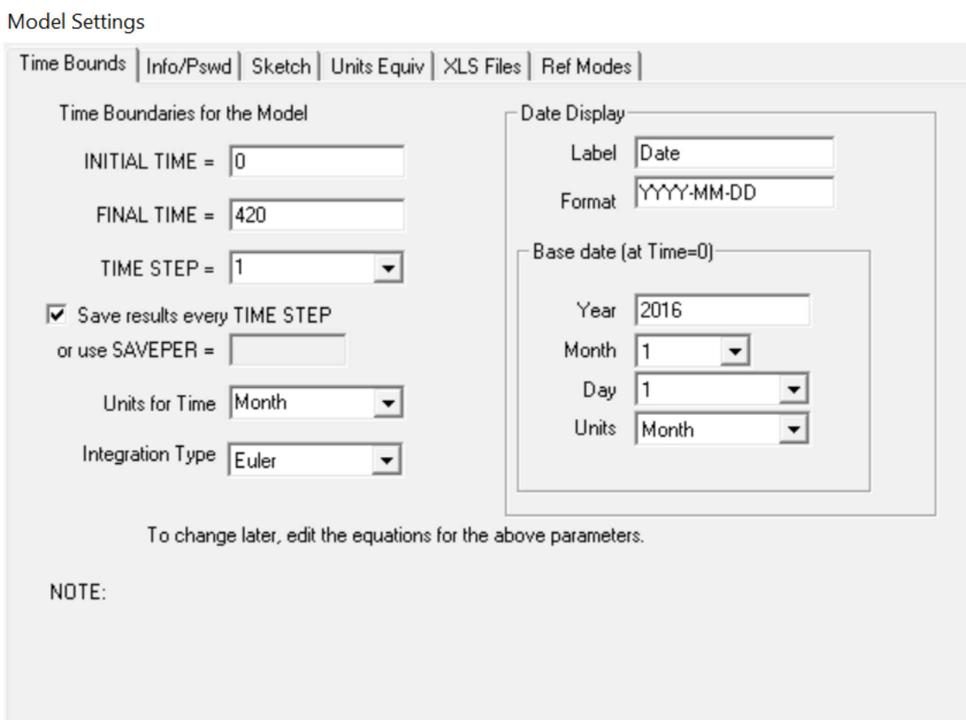


Figure 39 – Model settings

VENSIM provides the election to select what integration type the modeler would like to consider to simulations. The options are Euler, Runge-Kutta4 and Runge-Kutta4 auto. The latter suits best for continuous models with large variations in the speed of dynamics. Runge-Kutta4 fits better for continuous models with, possibly, oscillatory behavior without large changes in the speed of dynamics. Finally, Euler is best for models with very discrete functions, which is the case of the proposed model. There are many discrete functions such as the Capex payment schedule, the reset of the stock-flow diagrams, the monthly and annual adjustments of CELs and electricity revenues and so on.

The most relevant assumption considered in this model is the system boundary. The spreadsheet model has two calculation stages. The first one is to determine the debt amount and profile, and the second is to perform simulations to determine the equity IRR once the debt is "frozen". For the sake of simplification, this SD model focuses on the second stage interested to understand what are the impacts on equity IRR by performing sensitivity analysis trough Monte Carlo simulations on several parameters at the same time. Therefore, the debt profile is an input of the VENSIM model. This is considered given the difficulties and limitations of Excel to perform such sensitivities with statistical significance and the contributions SD can add to overall investment decision assessment.

Another simplification is regarded to tax calculations. The Mexican taxation system is not the aim of this thesis and in order to consider it in the model, but at the same time do not extent its complexity, a solution was to reflect the tax calculation as an approximated rate over the project's revenues. This rate is based on the spreadsheet model. The consequences of this decision is to neglect the tax payment schedule and therefore, impact the equity IRR. However, considering the amount of taxes paid, the deviation of the internal rate of return between model should not be significant.

6.3 Verification and validation

One step prior to interpreting the simulation results is necessary for the modeling flow. The model should be extensively tested to ensure that there are no structural mistakes, mathematical errors and if the model functioning reflects the modeler's intention. Model testing despite looking for errors, is a process to improve the model, learn and build confidence in its usefulness for a particular purpose. After this step, the modeler has a clearer idea regarding recommendations that follow from modeling studies. According to Sterman (2002), all models are wrong. However, model testing assures that the model is at least not erroneous, used incorrectly or useless for the intended purpose. SD models are supposed to be operational causal models. Hence, SD model testing comprises implanting techniques that guarantees whether SD models generate the right outputs for the right reasons.

The first model testing technique is denominated verification. Model verification is all about the analysis performed to check whether the model is incorrectly coded or simulated incorrectly. Codification refers to equations, functions adopted, sub-models' structures, units' consistency and numeric integration method selection. This step is performed visually checking all the parameters without simulating the model. Model verification focus on activities correspond to a large extent to model debugging. The difference is that in case of model debugging one knows there are bugs, whereas in case of model verification, one is looking for errors without knowing whether there are any.

Model validation, the second technique, refers to the whole diversity of tests to analyze if the model outputs match the goals of the modeling study. This technique is performed post simulation comparing inputs, structures and outputs. Validation is really about building confidence in its fitness for purpose. Hence, model users and experts should somehow be involved in model validation. Some of the topics covered during the validation procedures Pruyt (2013) lists, are:

- Boundaries, structures and parameters adequacy check
- Model generate behaviors for the right reasons
- Behaviors observed under extreme condition are plausible
- Check if the sensitivity of the model to changes in parameters, functions, boundaries, correspond to the sensitivity of the real system

Several are the validation tests performed. The most relevant ones are boundary and structure assessment tests, uncertainty analysis - extreme condition tests, and sensitivity analysis. Validation in many research areas corresponds largely to testing whether a model reproduces past real data, but this is not the case of this thesis topic. The applicable ones are sensitivity and uncertainty analysis, and structure assessment by comparing it to the spreadsheet model, used as reference base.

Model validation tests are applied in each step of the modeling process – from draft to final refinement. There is a diverse range of tests that supports the process of establishing confidence in the usefulness of a model or modeling process for its intended purpose. Such tests are categorized as (i) “direct structure tests”, in which the structure is tested without simulating the behavior, (ii) “structure-oriented behavior tests”, which allow to test the structure indirectly by running the model and comparing its behavior to real/anticipated behavior in order to find, again, errors in the model structure, and (iii) “behavior reproduction tests” which allow to statistically compare model output with past behavior of the real system or to other existing models.

Considering that the proposed SD model of this thesis is a spinoff of the spreadsheet approach, the validations and verifications are simplified by comparing the structures and results of both models. The first testing (and probably most relevant) is to identify if the equity IRR of both models, under same conditions, match. Furthermore, all the substructures and profiles can be easily traced and compared, and once deviations are identified, the analysis goes deep to fix possible errors. The results of verifications and validations are briefly presented in the next chapter that comprises all simulation results.

7. Results

In this chapter, simulation results from the proposed SD model will be presented and brief explanations are also provided in order give a more sensible understanding of the functioning of the model and how it applies to a solar power plant project under the undergoing Mexican energy reform.

The first section addresses the main relevant parameters discussed in chapter 5 under the framework of the spreadsheet approach, but from the perspective of VENSIM simulations. The second section of this chapter focuses on comprehending the contribution a SD model can add to sensitivity analysis and, therefore, support investors to base their decisions under a range of equity IRR scenarios.

7.1 Simulation

The first simulation output is the equity IRR. This is the main parameter referenced in this thesis, from the perspective of investors, supporting the decision making process. The profile presented in figure 40 matches the one of the spreadsheet model and results on an equity IRR of 10%. This result is interesting to, first perform a validation between model's approaches and, second confirm the usefulness of the SD model proposed.

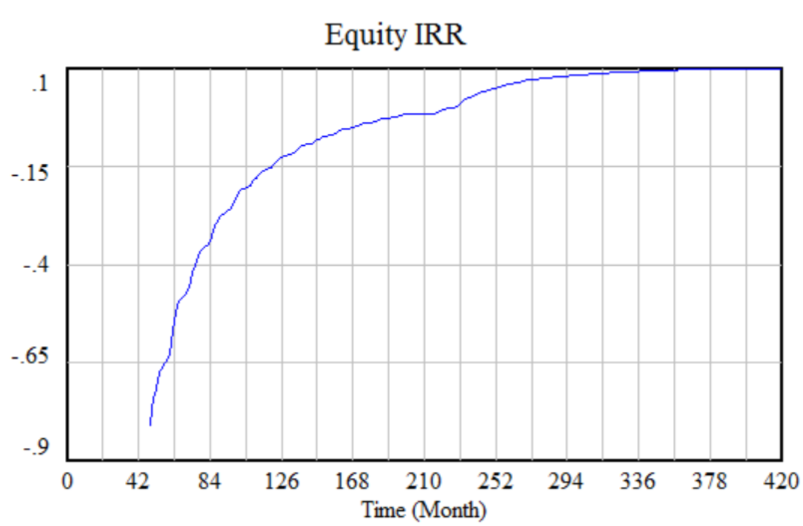


Figure 40 – Equity IRR profile of the SD model

As discussed previously, the equity IRR is determined by the shareholder cash flow profile, which is influenced by the equity injection and cash inflows during the project's lifespan. The simulation result below, acknowledges the cash outflow during the construction phase done by sponsors to partially fund the capex around month 20. Onwards, there are only cash inflows, both, during the PPA and post PPA periods. The former resulting on a stable profile and the latter having deeper variations due to the market price risk exposure.

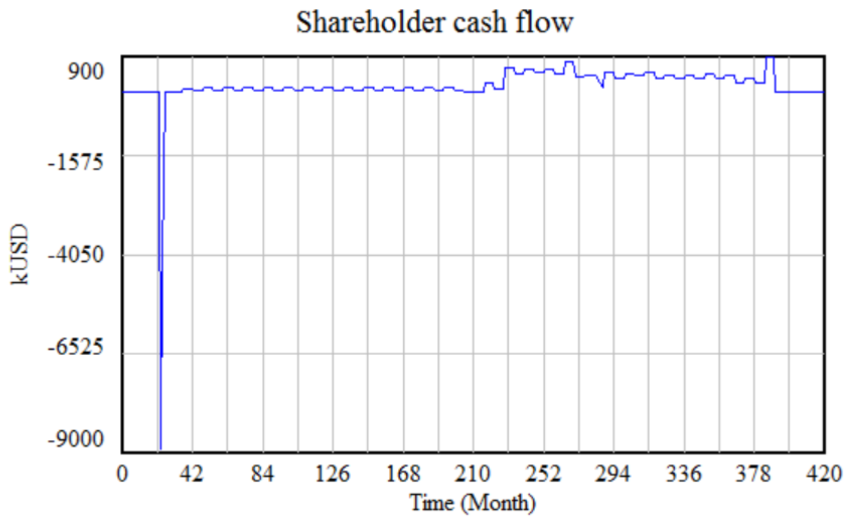


Figure 41 – Shareholder cash flow profile of the SD model

On the revenue's side, it is interesting to grasp the dynamics behind the Mexican PPA terms with regards to CELs and electricity generation. Figure 42 combines the total, electricity and CELs revenues' curves over the 30-year period. Given the assumptions considered for the model, it is possible to comprehend that the electricity revenues' curve has an oscillatory profile mainly due to irradiation seasonality over a year. Additionally, in the month 210 there is a break in the trend due to the end of the electricity PPA period. The stepwise increase is explained by electricity market prices adopted in the model, which differ from the PPA price.

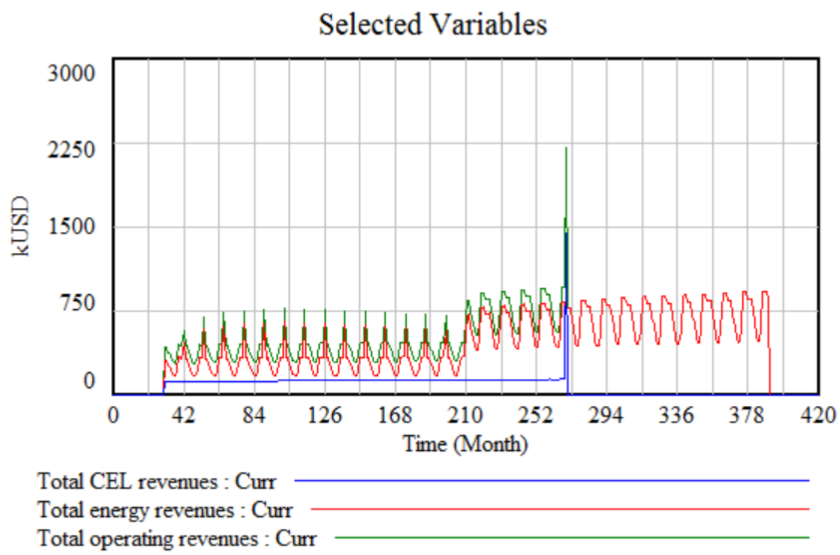


Figure 42 – Total revenues profile of the SD model

The behavior of CELs' revenues is, as defined by CENACE, different than electricity. First, the CEL PPA period is 5 years longer. Secondly, it follows a stable monthly remuneration. Finally, the model considers the CELs' surpluses to be stocked and used in case of shortfall periods. Additionally, at the end of the CEL PPA period, all the stocked CELs are sold following the spot market prices. Hence, the peak value in the month 270 is the release of the cumulated CELs over the 20-year period. After the PPA period there are no revenues from clean energy certificates.

The operating costs are also influenced by the PPA constraints. The transmission charges, during the 15-year electricity PPA period, apply merely to the generation flows above the committed electricity amount as of bid date. Afterwards, the total net monthly generation is considered to the transmission costs' calculation. Moreover, all operating costs are indexed either by consumer price indexes (CPI) or production price indexes (PPI).

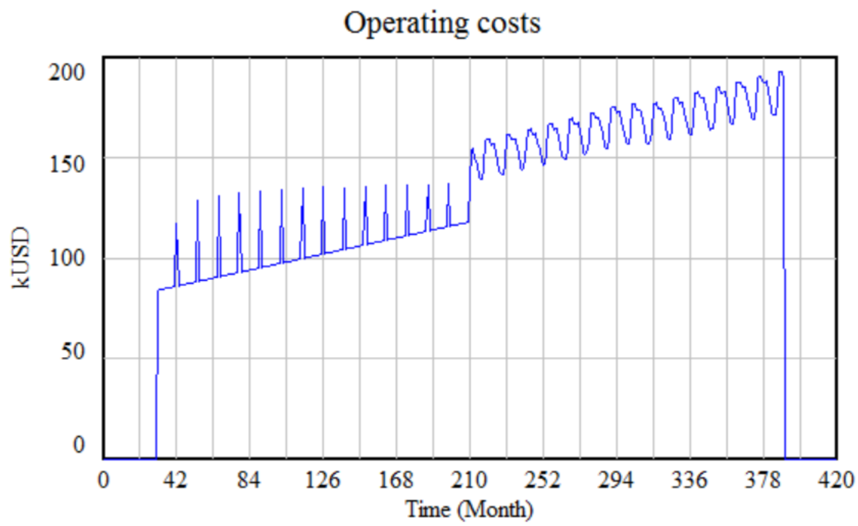


Figure 43 – Operating profile of the SD model

Part of the total capital expenditure is observed in the shareholder cash flow graph as a cash outflow. The total amount and the moment of cash disbursement is stated in figure 44. Again, the total values and the payment schedule of the SD and spreadsheet models match as expected for the base case.

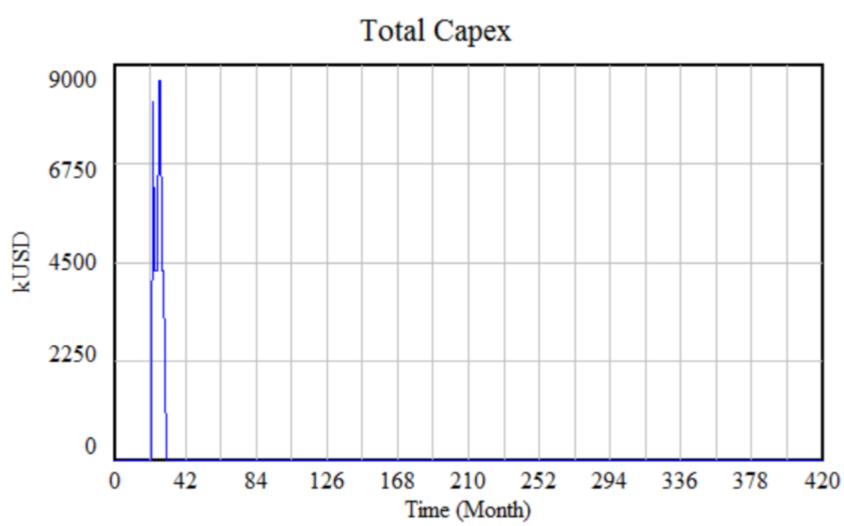


Figure 44 – Capex profile of the SD model

The last structure analyzed is the CFADS profile. It combines the construction cash flow, total operating revenues, operating costs, changes in the working capital during operation, interests' income from the DSRA and tax payments. Analyzing the profiles from each of the described profiles, the prevailing one is the total operating revenues. This is expected as is the most relevant cash inflow and its net value determines the cash flow available for debt service. This simulation result is representative to perform validation and verification modeling tests as it is a third layer structure of the proposed model. Therefore, if the achieved profile is in line with the spreadsheet model, it means that the fourth and fifth layers of the SD model are correctly calculated.

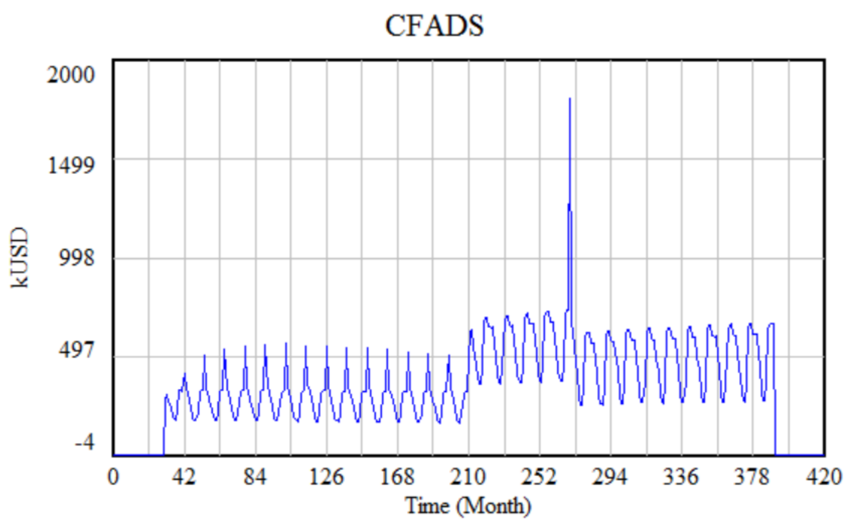


Figure 45 – CFADS profile of the SD model

Additional simulation results of several sublevels of the proposed SD model are part of the annexes and succinctly commented.

7.2 Sensitivity analysis

Sensitivity Analysis is the calculation of effects on the outputs due to changes in input values or assumptions, including boundaries and model functional forms (Morgan and Henrion, 1990). In other terms, Sensitivity Analysis (SA) accounts to the analysis of the outcome of small changes (usually maximum 20%) to values of parameters and functions on the behavior or preference for a particular policy, referenced to a base case. In system dynamics, the term SA is commonly employed and primarily points to a combination of Sensitivity Analysis and Uncertainty Analysis (UA). Some authors distinct UA as larger range of changes applied to input values of the model (above the 20% level). The applications of SA, as defined by Tank-Nielsen (1980), include:

- Searching for errors in models by testing a set of values to specific parameters and observing the simulation results

- Enhancing the comprehension of relationships between inputs and outputs, and in the case of SD, generate insights about the link between model's structure and behavior
- Identifying candidates for uncertainty reduction efforts, and hence, direct further work on parameters and structure, i.e. reduction of model's uncertainty by introducing more accurate parameters and variables' calculations
- Recognizing inputs for which the output is insensitive due to the possibility of dynamic limits reached or non-linear thresholds crossed
- Identifying inputs that create highly sensitive behaviors to the model's output
- Testing the local robustness of results in the proximity of a base case scenario

Both univariate and multivariate SA are performed in SD, both manually at many moments throughout the SD modeling process (Tank-Nielsen 1980) as in the spreadsheet approach and in automated mode by means of Monte Carlo sampling (Fiddaman, 2002), Latin Hypercube Sampling (Ford, 1990), and Taguchi methods (Clemson, 1995). All these methods are available on VENSIM and multivariate seems to be the best fit to the proposed model due to the ability to select various parameters to perform Monte Carlo sampling in parallel.

Sensitivity can be desirable as well as undesirable depending on the model's structure. High sensitivity is often undesirable in the case of lack of mechanisms to be controlled and could negatively influence key performance indicators, such as the equity IRR or covenants imposed by lenders. High sensitivity is, on the other hand desirable, whether it can be controlled and therefore opens up more desirable dynamics. SA is essential, both in model testing and in policy analysis. In model testing, one would like to know which small changes to the model lead to large changes in behaviors, whereas in policy analysis, one would like to know where the largest policy leverage can be found.

In the case of the project finance models, SA encompasses varying the inputs in the financial model (energy yield, operating costs and electricity prices) to examine how the economic performance of the project changes (measured using net present value, internal rate of return, or payback). Sensitivity analysis gives lenders and investors a larger comprehension of the consequences of changes in inputs such as O&M costs on the project's profitability. It assists decision makers (lenders and sponsors) understand the key risks associated with the project. Common results (outputs) monitored during sensitivity analysis embrace:

- Equity IRR
- Average DSCR
- Project returns
- Net effective interest rate

Typical inputs selected to the sensitivity analysis include parameters from different phases of the project under study:

- EPC contract costs
- O&M costs.
- Annual energy production.
- Degradation rate of solar PV panels
- DSCR lock-up
- Delays in completion

The main advantage of performing SA using a continuous system modeling package, such as VENSIM, is the ability to select as many parameters needed or asked by decision makers to determine the equity IRR robustness. There are no limitations with regards to inputs, number of simulations and random distribution functions. Those are constraints usually encountered while modeling on a spreadsheet tool such as Excel. More importantly, SA results of a SD model is statistically representative, while Excel needs considerable visual basic for applications (VBA) programming and simulation time to achieve results close to the ones provided by VENSIM.

The table below summaries the inputs selected, the range applied and distribution considered to perform the SA and analyze its results from the equity IRR perspective. The range and inputs selected have no intention to reflect a real project or plausible risks, but to contribute comprehending the applicability of the methodology.

Control parameter	Unit	Random distribution	Base case	Min value	Max value
EPC contract	kUSD	Uniform	42,000	42,000	46,000
Degradation rate	%	Gamma	0.5	0.5	0.6
P50 yield – annual production	MWh / year	Normal	70,560	68,000	70,560
Annual O&M costs	kUSD / year	Poisson	600	600	720
Interconnection	kUSD	Weibull	1,250	1,250	1,500
Project Devex	kUSD	Triangular	1,500	1,500	1,800
VAT tax rate	%	Exponential	16	16	18
Electricity prices post PPA	USD / MWh	Binomial	Profile	90%*Base case	Base case
CPI indexation	%	Beta	Profile	90%*Base case	110%*Base case

Table 6 – Sensitivity analysis's parameters

The values selected are representing only downside scenarios. The figure below is the output of the SA. The line in blue is the base case and defines the upper bound of the equity IRR range. The colors of the graph represent the probability of the equity IRR to be within the range of P50, P75 and P95.

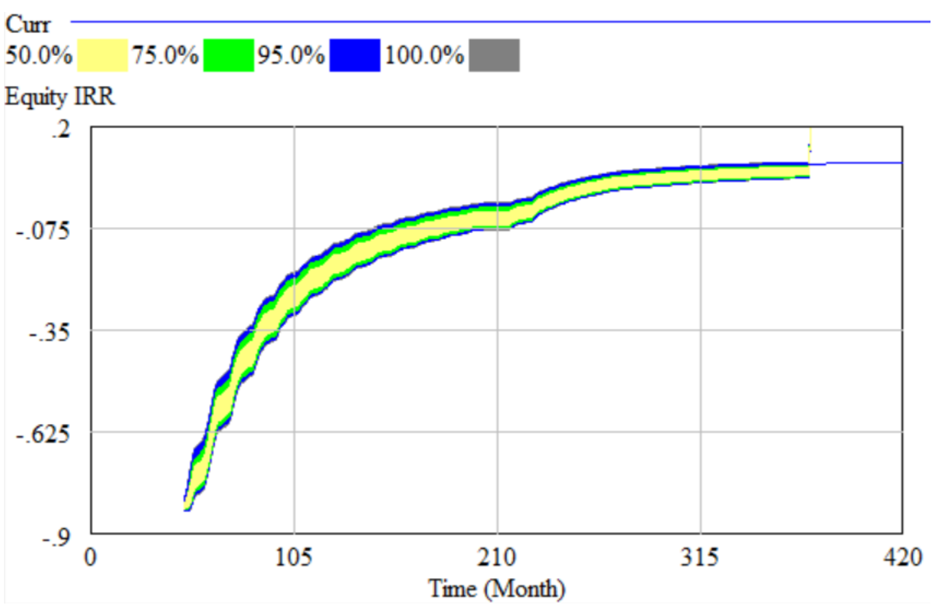


Figure 46 – Equity IRR sensitivity analysis

Figure 47 shows that after performing the SA of the inputs presented in table 6, the equity IRR lower bound is around 6% and the upper bound 10%, the latter is the base case value. This way, shareholders have the ability to test as many scenarios as needed to evaluate the risk exposure may be encountered throughout the project's life cycle. Instead of only base the investment decision on a single output, SA ensures investors a range which is statistically representative and provides the project's robustness in terms of its internal rate of return.

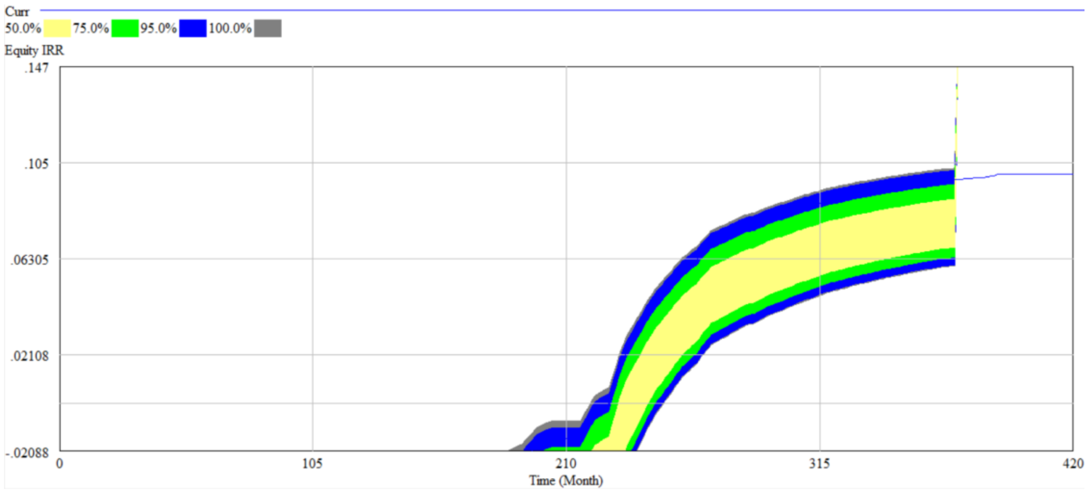


Figure 46 – Equity IRR sensitivity analysis (2)

The flexibility VENSIM enables with respect to random distribution choices, number of simulations and the possibility to obtain results of any of the model's variables with one click, confirms the great value this methodology adds to decision making processes of infrastructure investments, even when inserted on a complex context such as the Mexican regulatory framework.

8. Conclusions and recommendations

In the introduction of this thesis, the reasons of deregulating the electric power sector of a country were presented. Attempts were investigated throughout the paper to better understand the impacts of the liberalization process in Mexico and how these affect investment decisions. In order to comprehend the impacts, two financial models were presented. The first, called traditional approach, uses spreadsheet calculations to determine how PPA terms could be translated to provide an economic parameter to support investors' decisions. The second, a SD model, is an alternative to address drawbacks identified in the spreadsheet financial model. The data provided to those models come from a theoretical solar power plant project based on the Mexican context.

Three research questions guided the investigations and findings of the thesis. By reconstructing the steps towards the sector's liberalization process, while applying international benchmarks, some answers for the first research question were identified:

What are the main characteristics of the Mexican electricity regulatory framework before and after generation liberalization?

Before the liberalization, the main characteristics of the Mexican electric power system highlighted were:

1- CFE, the state owned utility company, holds a vertically integrated and monopolistic position among generation, system operation, transmission, distribution and retail.
2- Cogeneration and self-supply, along with exports, were the main mechanisms available to the private sector to sell electricity to clients other than CFE.
3- Inexistence of bilateral long term contracts between qualified users and suppliers.
4- Regulation of the energy sector was conducted from agencies within SENER, without a transparent demarcation between the authority responsible for designing the government's energy policy and the regulatory entities in charge of promoting an efficient and operation.

After the full liberalization process, according to the Energy Reform, the targeted characteristics are:

1- CFE will no longer have a regulatory function and will not manage the electric power system, which will belong to CENACE, granting it autonomy to serve as an independent and impartial dispatcher, and giving it the mandate to operate the wholesale market created.
2- The generation and wholesale of electricity will take place under a regime of free enterprise and open competition.
3- Large end users of power will be free to choose their suppliers and the terms and conditions of power supply.
4- Generators will now be able to enter into bilateral long term contracts with qualified users and qualified suppliers (i.e., the new private retail companies), as well as with CFE to power the public basic service via a transparent pipeline of auctions.

Following, the second research question covers the aspects an investor may encounter to analyze an investment opportunity considering the Mexican PPA terms:

How does the regulatory framework affect the investment decision of a renewable project from a financial perspective?

1- Three are the products offered via public auctions: capacity, electricity and clean energy certificates. However only the last two apply to renewable sources due to the intermittent generation characteristic of these technologies.
2- Absence of historical market prices' data hampers the accuracy of financial models testing project's IRR.
3- High complexity and innovative PPA terms with regards to operating revenues complicate considerably financial models that could lead to erroneous bidding strategies.

Finally, the last question investigates what contributions a system dynamic model could add to the decision making process:

What insights do a system dynamic model add to the well-developed spreadsheet approach to support the investment decision of a renewable project?

1- It serves as an effective communication tool as all the dynamics of the model can be visually comprehended by following the diagrams' causal relations. This is proven to be well suited to decision makers lacking financial expertise.

2- Perform sensitivity analysis using integrated Monte Carlo and optimization algorithms to obtain, instead of a unique result or tens of scenarios, a statistically representative range of scenarios, without limitations to random distribution functions, neither number of simulations.
3- SD avoids instabilities by running in discrete time and does work with calculation's circularities without the need of VBA programming.

Of course the use of SD does not substitute completely the spreadsheet model and the main reasons for that are:

- Excel is widely developed and adopted by the market.
- It has the ability of easy and effective comparisons of large amounts of data.
- Great chart's variety and user friendly interface.

On the other hand, a decision supported by both, spreadsheet and SD approaches, has the advantage of performing a wider range of sensitivity analysis, be accepted by the market, be an effective communication tool and, therefore, contribute, for instance, to reduce the volume of projects awarded on power auctions that do not materialize.

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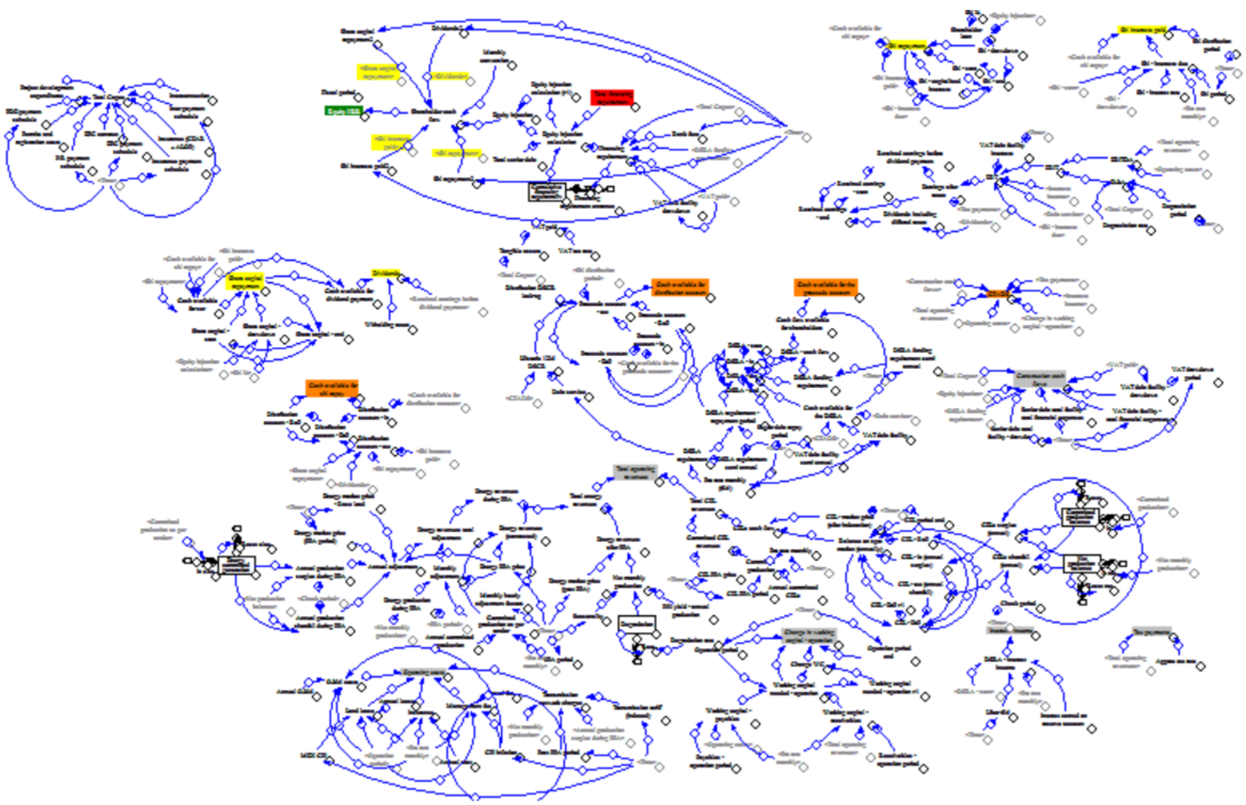
Annexes

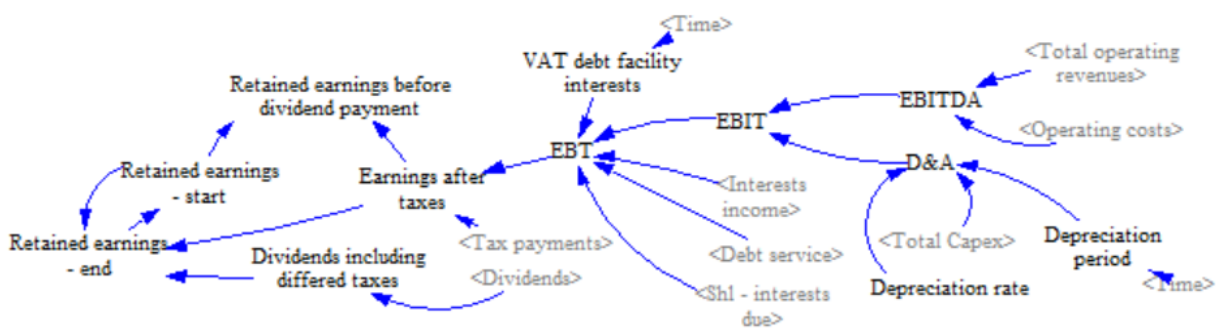
I – Additional simulation structures

Below is presented the model in one view, containing all the diagrams highlighted in the thesis, except one structure used to determine the P&L parameters, which is detailed after.

Model overview



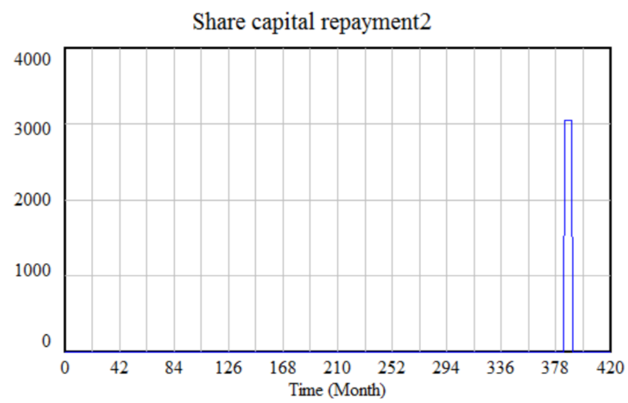
Profit & Losses calculation



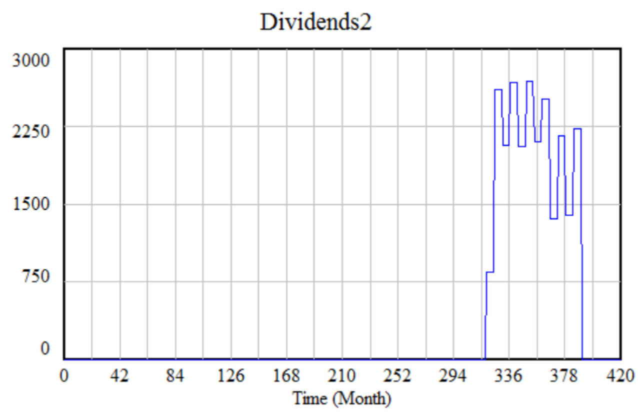
II – Other SD model's behavior

In this section are presented the simulation profile of other parameters supporting the calculation of the shareholder cash flow, and therefore, equity IRR.

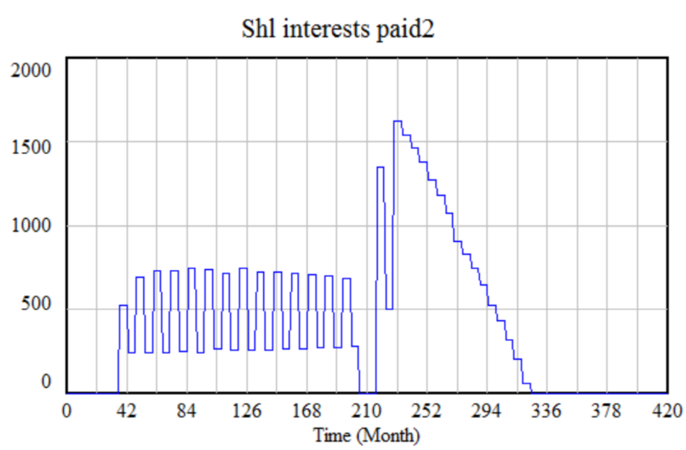
Share capital repayment profile



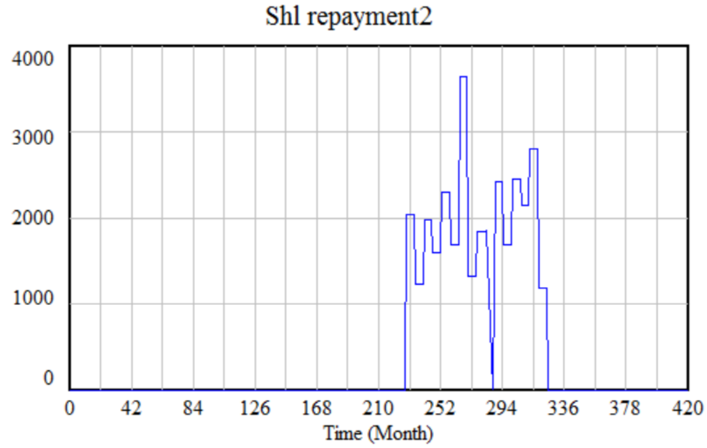
Payment of dividends



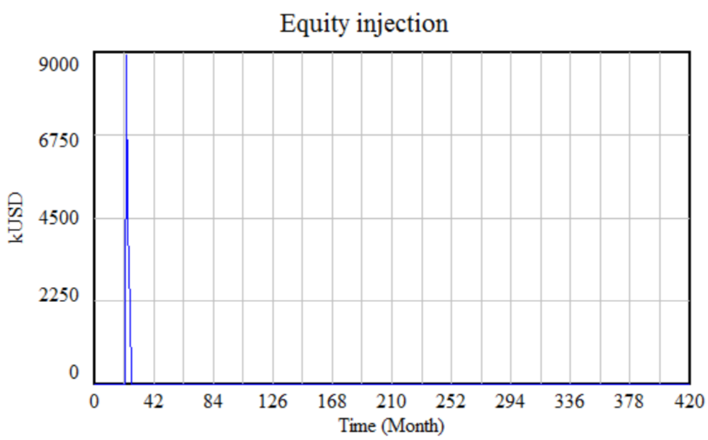
Shareholder loan interests' payment



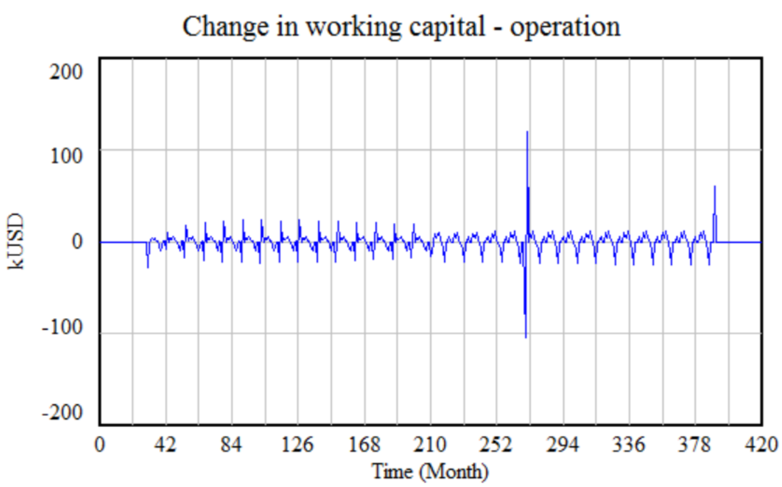
Shareholder loan principal repayment



Equity injection



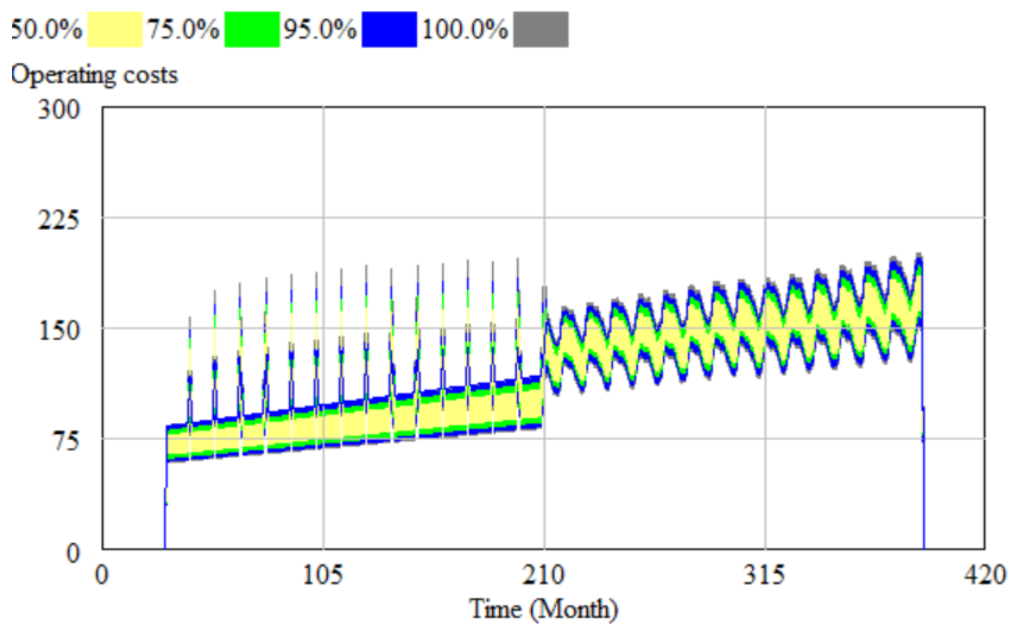
Changes in working capital during the operation phase



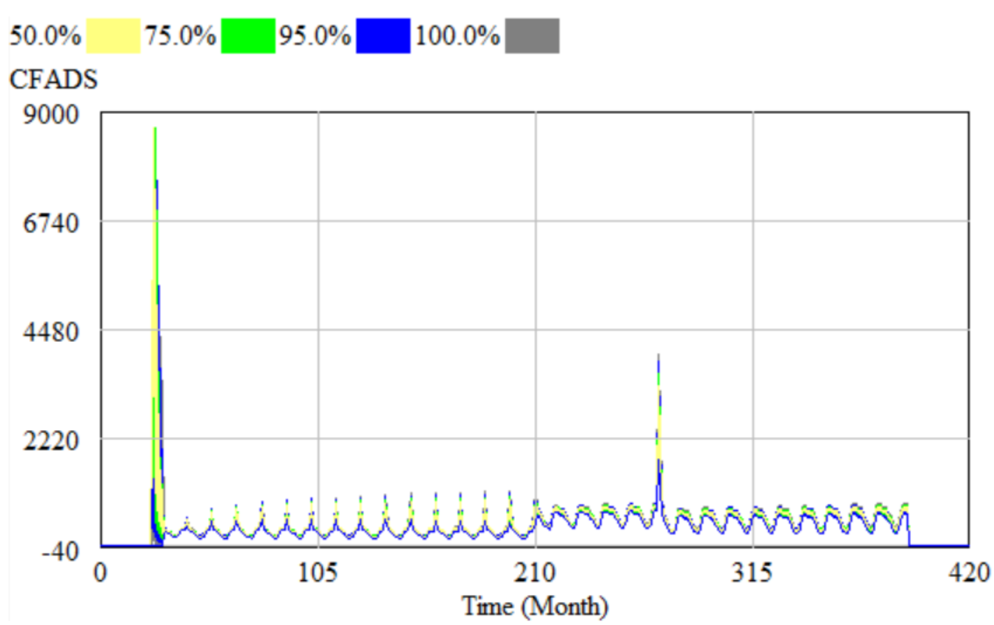
III – Sensitivity analysis of other parameters

Performing sensitivity analysis in other parameters serves not only as a validation tool, but also provides a better understanding of the model's behavior. Knowing how changes affect the main variables, enable the decision maker to develop more accurate policies. The figures below are sensitivities performed with the same control parameters presented on chapter 7.

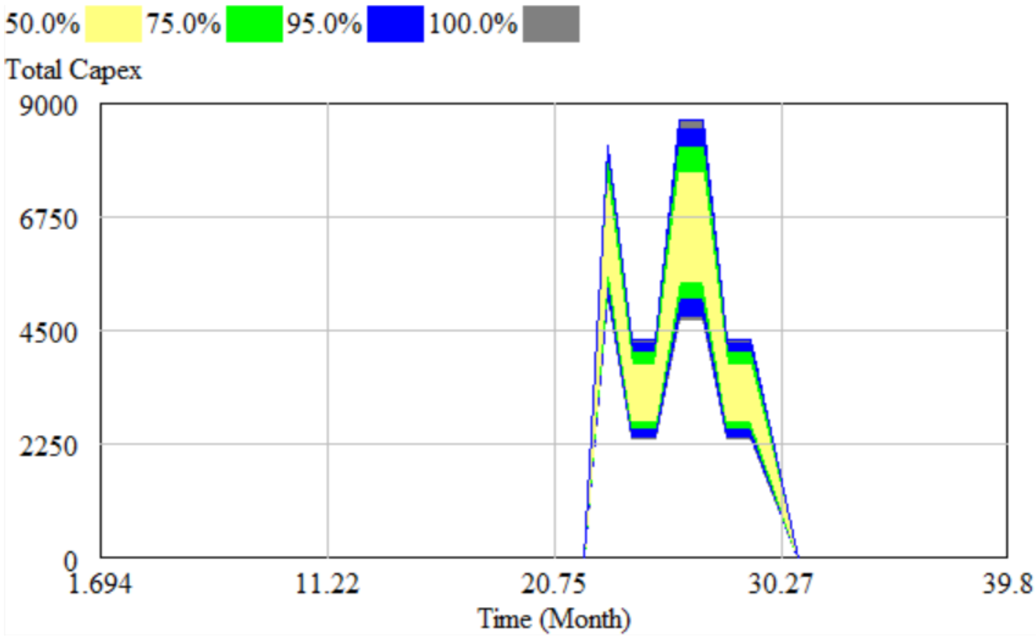
Operating costs



CFADS – cash flow available for debt service



Total Capex (reduced scale)



Equity injection (reduced scale)