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MÁSTER UNIVERSITARIO EN INGENIERÍA INDUSTRIAL

TRABAJO FIN DE MÁSTER

FINANCIAL ANALYSIS AND BUSINESS MODELS FOR MINIGRIDS IN EMERGING ECONOMIES

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Madrid

Declaro, bajo mi responsabilidad, que el Proyecto presentado con el título

FINANCIAL ANALYSIS AND BUSINESS MODELS FOR MINIGRIDS IN EMERGING ECONOMIES

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Autor: Valcarce Barbosa, Alejandro.
Director: Dueñas Martínez, Pablo; Díaz Pastor, Santos.
Entidad Colaboradora: IIT

RESUMEN DEL PROYECTO

Las minirredes se han convertido en la solución más económica para la electrificación de una gran parte de las áreas rurales o remotas, con una tecnología probada y una implementación rápida. Sin embargo, la viabilidad financiera de estos proyectos rara vez se logra. En esta tesis, se ha desarrollado un modelo financiero detallado para proyectos de minirredes, que produce resultados cuantitativos del rendimiento financiero. Este modelo se aplica a dos marcos regulatorios: una tarifa desregulada donde los consumidores pagan según su disposición a pagar (*willingness top pay)*, y una tarifa regulada mucho menor. Los resultados muestran que la tarifa desregulada está muy cerca de recuperar los costes para una minirred de alta calidad con un 95% de fiabilidad, con una subvención inicial del 50% de CAPEX, se puede lograr una TIR sobre el capital privado del 10% al 14%. Con la tarifa regulada, existen dos opciones para la viabilidad financiera: subsidios anuales en la tarifa que llegan a 3 veces la inversión inicial o reducir la calidad de la minirred a alrededor del 50% de fiabilidad, manteniendo las subvenciones iniciales sobre el CAPEX.

Palabras clave: Minigrids, acceso universal, modelo financiero, financiación, regulación de minirredes.

1. Introducción

Según las Naciones Unidas (ONU), más de 700 millones de personas en todo el mundo carecen de acceso a la electricidad. Este problema adquiere una especial relevancia en África, donde el 43% de la población todavía vive sin luz eléctrica. Sin embargo, los esfuerzos actuales de electrificación no son suficientes para alcanzar el objetivo del acceso universal en 2030. Según las políticas actuales, la Agencia Internacional de Energía (AIE) prevé que alrededor del 40% de la población seguirá sin acceso en 2030 en África subsahariana [1]. Aunque ha habido un progreso impresionante en la electrificación en los últimos años, el crecimiento se está desacelerando, ya que las regiones restantes sin acceso a la energía eléctrica son cada vez más difíciles de alcanzar. El camino hacia la electrificación completa en 2030 tiene diferentes herramientas, a algunos clientes llegará la red principal, y otros recibirán electricidad a través de minirredes (aisladas o conectadas a la red) u otros sistemas independientes. Las minirredes son la solución óptima para poblaciones rurales con baja demanda, aunque por encima de un mínimo, y que están lo suficientemente alejadas de la red principal de distribución. La AIE estima que las minirredes son la solución óptima para aproximadamente la mitad de la población rural.

Las minirredes son sistemas de generación pequeños (de 10 kW a 10 MW), que suministran a un número limitado de clientes. Esta red puede operar desconectada de las redes de transmisión y distribución nacionales principales. Estos sistemas de generación tienen varias ventajas: pueden proporcionar energía de alta calidad y con seguridad de suministro; y se instalan de manera rápida y relativamente sencilla.

Hay suficiente capital interesado para financiar estos proyectos, siempre y cuando haya un modelo de negocio sostenible y rentable. Sin embargo, la industria de las minirredes todavía está lejos de consolidarse, y para lograr el desarrollo deseado de acceso a la energía a un ritmo rápido, el sector privado y público deben cooperar. Es esencial que se implementen políticas adecuadas, así como subsidios, para lograr la escala necesaria de modelos de negocio sostenibles. El ritmo actual de implementación es de menos de 1000 minirredes al año. Se necesitará un aumento de dos órdenes de magnitud para finales de esta década si se quiere lograr un acceso universal. Para desbloquear el capital privado necesario para alcanzar el ODS7, se necesita un modelo de negocio viable. Los inversores privados todavía consideran las minirredes como una inversión de alto riesgo y baja rentabilidad.

2. Definición del proyecto

El proyecto se divide en tres etapas:

Primero, una revisión bibliográfica para comprender el estado de la industria de las minirredes y obtener los datos necesarios para desarrollar el modelo financiero.

En segundo lugar, el desarrollo de un modelo financiero detallado para evaluar el rendimiento de los proyectos de minirredes. Este modelo consta de tres bloques: flujos de caja, cuenta de resultados y estructura de financiación. Mediante la incorporación de variables de entrada de costes y tarifas, el modelo genera información sobre los flujos de efectivo generados por los activos del proyecto. Esto, a su vez, facilita decisiones informadas sobre la estructura de financiamiento óptima que abarca subvenciones, capital y deuda. Además, el modelo sirve como plataforma para derivar índices críticos de rentabilidad, como la Tasa Interna de Retorno (TIR) y el período de recuperación.

En tercer lugar, con el modelo desarrollado, se prueban dos escenarios regulatorios diferentes: una tarifa regulada y baja para los consumidores, y una configuración de tarifa desregulada, donde los clientes pagan su máxima disposición a pagar. Se calculan las subvenciones necesarias, y se analiza la rentabilidad para los accionistas.

Con los resultados de estos estudios de caso, se extraerán conclusiones y recomendaciones de políticas y regulación.

3. Descripción del modelo

El modelo está desarrollado en Excel y puede dividirse en entradas, cálculos y salidas:

Entradas: variables macro como inflación, cambio de divisas y tipo impositivo; ratios operativos para el capital circulante; costes: CAPEX y OPEX; ingresos: tarifas, demanda y crecimiento de la demanda; estructura de financiación: fondos propios, subvenciones y deuda, con sus condiciones.

Resultados: flujo de caja, saldo de tesorería cada año, pérdidas y ganancias, medidas de rentabilidad (TIR).

Los datos para los estudios de casos proceden del Reference Electrification Model (REM) del MIT-IIT, de la revisión bibliográfica de la normativa en India y de una estimación de la disposición a pagar de los consumidores, así como de otras fuentes, como el Fondo Monetario Internacional y el Banco Mundial para las condiciones de financiación.

4. Resultados

Caso I: Minirred de alta fiabilidad, tarifa desregulada, se cobra a los consumidores lo que están dispuestos a pagar [2]. El proyecto es solvente todos los años, con saldos positivos de tesorería e ingresos netos positivos. Se pueden pagar dividendos la mayoría de los años, con una TIR final sobre la inversión privada del 10,7%, o del 14% si el proyecto se vende el último año. Para obtener estos rendimientos es necesaria una subvención del 50% de la inversión inicial.

Tabla 1. Resumen de los resultados

	Case I	Case II-1	Case II-2
Project is viable	Yes	Yes	Yes
Minigrid reliability	95%	95%	50%
Tariff	22Rs - $0,264	7Rs - $0,084	7Rs - %0,084
Grant	$1,000,000	$6.693.000	$2,630,000
Equity IRR	10,7% - 14%	10.4%	8.7%

Caso II-1: Red de alta fiabilidad. Tarifa regulada (7Rs) y subvención pública del 60% del CAPEX, según la regulación actual [3]. Sin más subvenciones anuales, el proyecto quiebra. Con significativas subvenciones adicionales sobre la tarifa, se puede conseguir una rentabilidad similar a la del Caso I.

Caso II-2: Minirred de baja fiabilidad. Tarifa regulada y subvención pública del 60% del CAPEX. El proyecto es viable desde el punto de vista operativo y mantiene saldos de caja positivos. La rentabilidad para los inversores privados es significativamente menor que en los otros dos casos.

5. Conclusiones

Las principales conclusiones de este estudio en relación con el modelo financiero son las siguientes:

1. Un modelo financiero completo es crucial para evaluar la viabilidad de los proyectos de minirredes, atendiendo a diversas partes interesadas como consumidores, inversores, fondos de desarrollo y responsables políticos.

2. La viabilidad financiera de un proyecto de minirred depende en gran medida de la estructura tarifaria. Cuanto mayor sea la diferencia entre la tarifa y los costes reales de

la minirred, más difícil será que el proyecto prospere. Incluso pequeñas diferencias en la tarifa pueden tener un impacto acumulativo sustancial a lo largo de la vida del proyecto.

Con respecto a los casos de estudio

3. Una tarifa no regulada que refleje la disposición a pagar del cliente se acerca mucho a la recuperación de costes para una minirred de muy alta calidad (95% de fiabilidad). Con una subvención de la mitad de las inversiones iniciales, el proyecto es viable y rentable para los accionistas (TIR del 10% al 14%).

4. La tarifa regulada de la India, a pesar de las subvenciones estatales y locales para CAPEX, es inviable desde el punto de vista financiero para una minirred de alta calidad sin subvenciones tarifarias anuales adicionales, debido a la importante diferencia entre la tarifa y los costes. Con subvenciones sustanciales (en torno a 3 veces la inversión inicial), el proyecto llega a ser rentable con un resultado similar al de una tarifa no regulada.

5. Aunque las subvenciones anuales hacen que el proyecto sea rentable, depender tanto de las subvenciones prometidas añade un riesgo muy importante a la minirred, ya que cualquier cambio en la regulación podría provocar la quiebra inmediata.

6. La baja tarifa regulada puede funcionar a corto plazo para una minirred de baja calidad, con conexiones inferiores para los clientes. Sin embargo, no es viable a largo plazo cuando se necesitan inversiones de mantenimiento sin subvenciones adicionales o refinanciación.

7. Las minirredes de menor calidad no son intrínsecamente más rentables que las redes de alta calidad en términos de (LCOE). La viabilidad de estas redes de menor calidad depende en parte de que los clientes compren menos energía de la que en realidad demandarían debido a su menor fiabilidad, lo que amplifica el impacto de las diferencias entre costes e ingresos.

6. Referencias

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Collaborating Entity: IIT

ABSTRACT

Minigrids have become the most cost-effective solution for a great fraction of the electrification of rural or remote areas, with a proven technology and fast deployment. However, the financial viability of these projects is rarely achieved. In this thesis, a detailed financial model for minigrid projects has been developed, that outputs quantitative results of the financial performance. This model is applied to two regulatory frames: a deregulated tariff where consumers are charged their willingness to pay, and a low regulated tariff. The results show that the deregulated tariff is very close to cost recovery for a high quality 95% reliability grid, with an initial grant of 50% of CAPEX, equity IRR of 10% to 14% can be achieved. With the regulated tariff there are two options for financial viability: annual subsidies on the tariff that sum up to over 3 times the initial investment or reducing the quality of the minigrid to around 50% reliability, keeping initial grants on CAPEX.

Keywords: Minigrids, universal access, financial model, financing, minigrid regulation.

1. Introduction

According to the United Nations (UN), over 700 million people worldwide lack access to electricity. This problem takes especial importance in Africa, where 43% of the population still live in the dark.

However, current electrification efforts are not near enough to reach the United Nation's objective of universal access by 2030. Under the current policies, the International Energy Agency (IEA) predicts that around 40% of the population will still lack access in 2030 in Sub-Saharan Africa [1]. Although there has been an impressive progress in electrification in the past years, the growth is slowing down in recent times, as the remaining regions without access to electric energy are becoming harder to reach.

Many institutions have shown that the path towards complete electrification in 2030 has different tools, some clients will be reached with extensions of the main grid, and others will be supplied electricity with mini grids (either isolated or connected to the grid) or other standalone systems. Mini grids are the optimal solution for rural populations with low, but enough demand, and that are far enough from the main distribution grid. The IEA estimates that approximately half of the rural population would be best served with minigrids.

Minigrids are small generation systems (10kW to 10MW), that supply a limited number of customers. This grid can operate disconnected from the main national transmission and distribution networks. These generation systems have a number of advantages: they can provide high quality and reliable power; and they are fast and relatively easy to install. There is supposedly sufficient interested capital to fund these projects, as long as there is a sustainable and profitable business model.

However, the minigrid industry is still far from consolidated, and in order to accomplish the desired fast-paced development of energy access, the private and public sector must cooperate. It is essential that appropriate policies be implemented, as well as subsidies, to achieve the scale necessary for sustainable business models.

The current deployment pace is less than 1000 minigrids a year. A two order of magnitude increase will be needed by the end of this decade if universal access is to be achieved. To unlock the necessary private capital to reach the SDG7, there is a dire need for a viable business model. Private investors still consider minigrids as a high risk-low return investment.

2. Project definition

The project is divided into three steps:

First a literature review to understand the state of the minigrid industry, and to obtain the necessary data to develop the financial model.

Second, the development of a detailed financial model to evaluate the performance of minigrid projects. This model consists of three blocks: cashflows, P&L and finance structures. Through incorporation of input variables, encompassing costs and tariff considerations, the model generates insights into cashflows generated by project assets. This, in turn, facilitates informed decisions regarding the optimal financing structure encompassing grants, equity, and debt. Furthermore, the model serves as a platform to derive critical profitability indices such as the Internal Rate of Return (IRR) and payback period.

Third, with the developed model, two different regulatory scenarios are tested: a regulated, low tariff for consumers, and deregulated tariff setting, where customers are charged what they are willing to pay. The necessary subsidies and grants are calculated, and the profitability for equity holders analyzed.

With the results from these case studies, conclusions and policy recommendations will be extracted.

3. Description of the model

The model is developed in Excel, and can be divided into inputs, calculations, and outputs:

Inputs: macro variables like inflation, currency exchange and tax rate; operational ratios for the net working capital; costs: CAPEX and OPEX; revenues: tariffs, demand, and demand growth; financing structure: equity, grants and debt, with its conditions.

Outputs: cashflow, cash balance every year, P&L, profitability measures (IRR)

The inputs to the case studies are drawn from the MIT-IIT Reference Electrification Model, literature review for the regulations in India, and an estimate of consumer’s willingness to pay, and other sources, like the International Monetary Fund and the World Bank for financing conditions.

4. Results

Case I: Hight reliability minigrid, deregulated tariff, consumers are charged what they are willing to pay [2]. The project is solvent every year, with positive cash balances, and positive Net Income. Dividends can be paid most years, with a final IRR on equity of 10.7%, or 14% if the project is sold on the final year. A 50% grant on initial CAPEX is needed for these returns.

Table 1. Results summary

	Case I	Case II-1	Case II-2
Project is viable	Yes	Yes	Yes
Minigrid reliability	95%	95%	50%
Tariff	22Rs - $0,264	7Rs - $0,084	7Rs - %0,084
Grant	$1,000,000	$6.693.000	$2,630,000
Equity IRR	10,7% - 14%	10.4%	8.7%

Case II-1: High reliability grid. Regulated tariff (7Rs) and a government grant on 60% of the CAPEX, according to current regulations [3]. Without more annual subsidies the project goes bankrupt. With additional and significant subsidies on the tariff, similar profitability to Case I can be achieved.

Case II-2: Low reliability minigrid. Regulated tariff and a government grant on 60% of CAPEX. The project is operationally viable and keeps positive cash balances until the last year, where there is not enough built-up cash to reinvest in maintenance CAPEX. Profitability for private investors is significantly lower than on the other two cases.

5. Conclusions

The key conclusions from this study regarding the financial model are as follows:

1. A comprehensive financial model is crucial for assessing the viability of minigrid projects, catering to various stakeholders like consumers, investors, development funds, and policymakers.

2. The financial viability of a minigrid project is heavily influenced by the tariff structure. The greater the gap between the tariff and actual minigrid costs, the more challenging it becomes for the project to thrive. Even minor differences in the tariff can have a substantial cumulative impact over the project's duration.

Regarding the case studies:

3. An unregulated tariff that reflects the customer's willingness to pay is very close to cost recovery for a minigrid of very high standards (95% reliability). With a grant of half the initial CAPEX, the project is viable and profitable for equity shareholders (10% to 14% Equity IRR).

4. India's regulated tariff, despite government CAPEX grants, is financially unviable for a high-quality minigrid without additional annual tariff subsidies due to a significant gap between tariff and costs. With substantial subsidies (around 3x the initial investment), the project becomes profitable with a similar outcome as with an unregulated tariff.

5. Although continued subsidies make the project profitable, depending so heavily on promised subsidies adds a very significant risk to the minigrid, since any changes in regulation could result in immediate bankruptcy.

6. The low regulated tariff can work in the short term for a lower quality minigrid, with subpar connections for customers. However, it is not viable in the long term when maintenance investments are needed without additional grants or refinancing.

7. Lower quality minigrids aren't inherently more cost-effective than high-quality grids in terms of Levelized Cost of Electricity (LCOE). The viability of these lower-quality grids partially hinges on customers purchasing less energy than demanded due to lower reliability, thereby amplifying the impact of cost-revenue gaps.

6. References

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Chapter 1. INTRODUCTION

According to the United Nations (UN), over 700 million people worldwide lack access to electricity. This problem takes especial importance in Africa, where 43% of the population still live in the dark.

The international community decided to tackle this issue actively and it became the UN's Sustainable Development Goal 7 (SDG7), aimed at universal access in the year 2030: "Ensure access to affordable, reliable, sustainable and modern energy for all". Universal access to modern energy services is essential for achieving many other development goals, such as improving health and education, promoting economic growth, and reducing poverty and inequality.

However, current electrification efforts are not near enough to reach this objective. Under the current policies, the International Energy Agency (IEA) predicts that around 40% of the population will still lack access in 2030 in Sub-Saharan Africa. Although there has been an impressive progress in electrification in the past years, the growth is slowing down in recent times, as the remaining regions without access to electric energy are becoming harder to reach.

Many institutions have shown that the path towards complete electrification in 2030 has different tools, some clients will be reached with extensions of the main grid, and others will be supplied electricity with mini grids (either isolated or connected to the grid) or other standalone systems. Mini grids are the optimal solution for rural populations with low, but enough demand, and that are far enough from the main distribution grid. The IEA estimates that approximately half of the rural population would be best served with minigrids.

Minigrids are small generation systems (10kW to 10MW), that supply a limited number of customers. This grid can operate disconnected from the main national transmission and distribution networks. These generation systems have a number of advantages: they can provide high quality and reliable power; and they are fast and relatively easy to install. There is supposedly sufficient interested capital to fund these projects, as long as there is a sustainable and profitable business model.

However, the minigrid industry is still far from consolidated, and in order to accomplish the desired fast-paced development of energy access, the private and public sector must cooperate. It is essential that appropriate policies be implemented, as well as subsidies, to achieve the scale necessary for sustainable business models.

The current deployment pace is less than 1000 minigrids a year. A two order of magnitude increase will be needed by the end of this decade if universal access is to be achieved. To unlock the necessary private capital to reach the SDG7, there is a dire need for a viable business model. Private investors still consider minigrids as a high risk-low return investment.

1.1 PROJECT MOTIVATION

In this context of great need for electrification, and especially with the deadline of 2030 for the completion of the sustainable development goals, there is a lot of work and research to be done, to facilitate supranational entities, governments and private investors and societies the development of new, sustainable electrical infrastructure.

However, the successful implementation of minigrid projects requires overcoming various challenges, with financial viability standing out as a critical factor. Hence, the motivation for this final thesis is to develop a comprehensive financial model tailored to minigrid projects, empowering stakeholders with valuable insights to make informed decisions and attract investments in this transformative sector.

Minigrids have shown immense potential in addressing energy poverty, as they offer a viable and scalable solution that can be customized to suit the specific energy needs of each community. By designing a robust financial model for minigrids, this thesis aims to facilitate the implementation of financially sustainable projects, leading to greater energy access and promoting sustainable development in underserved regions.

In the work towards electrification, it is crucial that both private and public parties involved have access to a reliable and realistic financial model. Without a proper analysis of costs, revenues and macroeconomic factors, there can be no informed decision making.

Chapter 2. STATE OF THE QUESTION

Firstly, it is important to address the current state of the minigrid industry. The report by the Energy Sector Management Assistance Program (ESMAP), Minigrids for Half a Billion People [1], clearly illustrates the gap that has to be overcome to reach universal access by 2030. Currently, there are 47M people connected to minigrids, a number that has to increase ten-fold, to 490M people by 2030, if the universal access goal is to be reached. This will require an investment of $220 billion, between private and public institutions.

This same report highlights that there have been a very positive progress in the industry. Capital costs have been declining, while quality of service has increased. Projections reveal that the LCOE can be reduced by 70% by 2030. In addition, ESMAP states that the potential profits for private investors are large.

However, there are still many barriers to overcome in order to unlock the private capital needed to scale minigrids across the world. A report [2] by Husk, one of the largest private minigrid developers highlights these problems. The publication states: "Despite the urgency of scaling minigrids to achieve SDG7, the nascent industry is still struggling. After more than a decade of effort there is still no profitable minigrid developer. Some investors have withdrawn from the sector citing the "lack of a viable business model"."

The authors believe that what is needed is a sustainable business model. There have still been no experiences of consistently profitable business model.

The same report sets forth the main barriers to sustainability:

- The costs are too high. The combination of insufficient subsidies, and that most private companies do not have the size for the benefits of economies of scale.
- Quality. Power quality must be significantly better than that offered by national grids to justify the increased cost.
- Demand is too low. Without sufficient demand, mini grids cannot be profitable. Despite there being pent up demand, it will not automatically transform into

consumption. Lack of access or prior experience with it can lead to a low consumption rate. Potential consumers will not have appliances.

The report also states other interesting considerations towards a viable business model. Profitability at a local mini grid level is not enough. There must be a sufficient scale to cover administrative and other overhead costs. Local scale is required.

A publication by the UN [3] provides important conclusions on how to keep developing the minigrid sector. Among them:

1- Scale is fundamental for minigrids to be sustainable.
2- Policymakers must balance government control, financial subsidies, and consumer tariffs for minigrid deployment, as not all three are possible at once.
3- Electricity demand on rural areas is still very uncertain, it is important to consider demand risk mitigation to ensure viability of the projects.

Another paper [4] again brings to attention that the main problem to achieve scale is a sustainable business model, which can only be made possible with the appropriate regulation. The author highlights possibilities to cover the viability gap in these projects. This viability gap arises from the fact that electricity tariffs have to remain uniform across a country, or at least across the same distribution company. However, the tariffs designed to cover already electrified supply costs are lower than those needed to pay off the costs of what remains to be electrified.

To cover this viability gap, the paper proposes the solutions:

1- Direct subsidies to minigrid developers from government electricity access programs.
2- Direct subsidies to minigrid developers from cross-subsidization in other tariffs.
3- Direct subsidies to minigrid developers in a concession contract.

Aside from these solutions, it is also possible that anchor loads in the mini grid, such as telecommunication towers could cross-subsidize residential customers.

Another minigrid model to consider is that of undergrid minigrids. The Rocky Mountain Institute Report, Electrifying the Underserved [5], presents the basics of the undergrid minigrids. As mentioned before, undergrid minigrids are implemented in communities that are already served by distribution networks, but with unreliable supply. The minigrid acts as distributed generation resources, improving reliability. The combination of these two supply methods is beneficial both for the distribution company, that reduces losses, and to the customers. Access to reliable electricity is fundamental to enable local business creation and development.

This same report goes on to explain four business models for this type of minigrids, depending on the ownership and operation of the minigrid:

- Minigrid operator-led: developed by a private minigrid operator.
- Special purpose vehicle-led: developed by a special purpose vehicle (SPV), possibly formed by the distribution companies' investors.
- Cooperative led: developed by the community, in the form of a cooperative
- Collaborative SPV-led: shared between the operator, the community cooperative and the distribution companies' investors.

Each of these models has its advantages and drawbacks, and the circumstances of the community are what tell which model is more suitable.

This report highlights that the concept of undergrid minigrids remains largely untested. New projects are required to prove each business model. In this regard, it is important to note that this document does not go into detailed economic study of each model and provides no quantitative analysis or implementation examples of the business solutions.

Aside from these general studies on minigrids, for the development of this project, concrete information on consumer preferences, willingness to pay, macroeconomic factors and financing conditions is needed.

The practical cases studied in this project are based in India. To gain a better understanding of the electrification situation in this country, the report [6] on access to clean cooking and electricity by Council on Energy, Electricity and Water (CEEW) is of great help, especially determining the current quality of electricity service in rural India, with an average of 10 to 12 hours of service.

Another report [7], by the Centre for Science and Environment of New Delhi, summarizes the policies in place in the region of Uttar Pradesh, and gives information on the current tariffs paid by consumers of privately developed minigrids.

The United Nations Development Program also gives information about the average cost of equity for minigrids programs in India and other places of the world in a report with ETH Zürich [8]

Another paper of great importance to the crafting of the study cases is "Quality of service predicts willingness to pay for household electricity connections in rural India." [9]. This document draws attention on the importance of the quality of service when it comes to customer satisfaction and willingness to pay. This paper offers quantitative data on the tariffs that non-electrified households would be willing to pay for a connection, which will be used in this project's case studies.

This same paper also concludes that "the results suggest that improving the quality of connections is critical to improving access", and "our results show that improving the quality of service would allow distribution companies to connect more households and charge cost-recovering prices for electricity. Improvements in the quality of service would increase households' WTP for the service, and the revenue for prices that cover the real cost of generating, transmitting, and distributing electricity would in turn help pay for those improvements. India's recent rural electrification efforts (Palit and Bandyopadhyay, 2017) have neither emphasized service quality nor tried to target communities with high WTP. As household electrification continues to expand in the country, our results highlight the need to focus on service quality and the value of electricity service, as opposed to increased connectivity alone. As improving the quality-of-service increases WTP, then Indian policymakers may have a solution to the financial problems that rural electrification creates under heavily subsidized electricity prices."

This thesis will be proved in this project, applying both regulated tariffs and the consumer WTP, and the financial performance of these two models evaluated.

Chapter 3. PROJECT DEFINITION

3.1 JUSTIFICATION

As has been brough up in previous chapters, there is a great need for tools for an informed decision-making process regarding minigrid investment and regulation.

A detailed financial model is one of the main, if not the most important, pieces of this process.

I. Financial Viability Assessment: A detailed minigrid financial model serves as an indispensable tool for assessing the economic feasibility of electrification projects. It provides insights into the initial investment costs, ongoing operational expenses, revenue projections, and potential profitability of minigrid systems. By conducting rigorous financial analysis, policymakers, investors, and project developers can identify potential barriers, risks, and opportunities, enabling informed decision-making regarding resource allocation and project prioritization.

II. Attracting Investment: As has been brought up in the Introduction, investment is a cornerstone of successful minigrid deployment. Accurate financial models enhance transparency and credibility, making minigrid projects more attractive to both public and private investors. The financial model developed in this project showcases the potential returns on investment and repayment timelines, which are crucial elements in convincing stakeholders to allocate resources to electrification projects in underserved areas.

III. Policy Formulation: Informed policy formulation is contingent upon a clear understanding of the financial dynamics of minigrid projects. Policymakers require accurate financial models to assess the impact of subsidies, incentives, and regulatory frameworks on the overall viability of minigrids. Especially, a detailed financial model can help regulatory agencies see the effect of tariff regulation and can help establish cost reflective tariffs. These models can aid in designing effective support mechanisms that promote sustainable electrification, aligning policy goals with economic realities.

IV. Risk Management: Minigrid projects inherently involve various technical, economic, and operational risks. Although most minigrid projects take place in politically unstable countries, and have many non-financial risks associated with them, the financial model developed is of great help evaluating risks, like inflation, exchange rate, demand growth…

3.2 OBJECTIVES

I. Research into the state of the question regarding minigrid business models.

II. Development of a financial model for a minigrid project in Excel, taking into account: CAPEX, OPEX, inflation, demand growth, exchange rate changes, and financing.

III. Testing of the financial model with a case study, extracting conclusions.

3.3 ALIGNMENT WITH THE SUSTAINABLE DEVELOPMENT GOALS

The main objective of this project is to enable financial viability of minigrids, the main barrier that has to be overcome for the scaling of this industry needed to provide access to electricity in rural areas in developing countries. This aligns with several of the UN's Sustainable Development Goals.

Mainly, this project works towards **SDG7: Clean and Affordable Energy**. It is widely accepted by international agencies (IEA, World Bank) that this objective can only be reached in a reasonable time with the implementation and scaling of mini grids. Research towards a sustainable business helps unlock the private capital needed for the exponential growth in minigrid installations required to reach SDG7.

Affordable energy is also crucial for many other development goals. It is necessary to fight poverty (SDG1), provide clean water (SDG6), or climate action (SD13) among others:

- Clean water and sanitation (SDG6). Access to electricity is vital for powering water pumps and treatment systems.
- Climate action (SDG13). At present, diesel generators are one of the main ways for electricity access in rural areas in developing countries. Fossil fuels are necessary for many other uses, like cooking, lighting, and transportation. Minigrids that provide access to electric energy with renewable sources will be able to replace some of the consumption of these polluting fuels.
- Industry, innovation, and infrastructure (SDG9), which aims to build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation. Minigrids can be an innovative solution for providing energy access in remote or isolated areas and can promote sustainable industrialization by supporting local businesses. Aligned with this objective of promoting local businesses and jobs, access to energy will help fight poverty (SDG1).

3.4 METHODOLOGY

The first step to building a financial model of a minigrid will be a literature review and conversations with experts, to map all the necessary elements of the model. In this regard, was to review publications by the most prominent actors in the minigrid industry: The World Bank, United Nations, Africa Minigrids Development Association (AMDA), study groups like the Rocky Mountain Institute, the MIT-IIT Universal Access Lab as well as private developers like Husk Power.

The financial model will reflect to three main blocks: the Cashflows, P&L and the financing structure of the project. The objective of the model is that, when inputting the project costs and energy tariffs, the results are:

- The cashflows and cash balance from the assets of the project every year, and every possible negative cashflows that may compromise the viability of the project and cause bankruptcy.
- The profit and losses of the project, calculating the net income every year.

The financing structure of the projects, in terms of grants, debt and equity, will also be an input to the model. Once seeing the cashflows from assets every year, the necessary financing cashflows become clearer.

Also, with these two results, the possible dividends to the equity holders can be calculated.

With these three blocks, profitability measures can be extracted: the net present value of the investment and the internal rate of return. These numbers can help investors, policy makers and other stakeholders make informed decisions.

Once the model is built, it will be tested using real-world investment cases, with a regulated and deregulated tariff, and different amount of subsidies.

For the necessary data, a combination of research and minigrid design simulation models will be used. For instance, the REM model by MIT-Comillas will be run to get demand, CAPEX and OPEX data of minigrids in India.

That data will be inputted into the model. The financial performance of the project in the different scenarios will be analyzed and conclusions drawn.

3.5 PLANIFICATION AND ECONOMIC ESTIMATION

1. Dec 15 – Feb 25:

   Research into the state of the art of the minigrid industry, regulation, and business models. This will include scientific literature, publications by international agencies and private companies, and conversations with relevant players in the industry.

2. Feb 25 – May 1.

   Build the necessary infrastructure to evaluate the finance of different business models. This will include detailed spreadsheets with cash-flows, financing, risk, etc.

3. May. – June 1.

- Evaluate different business models using the spreadsheets. Optimize the models and propose changes to improve the financial performance, preferably using real world data.

4. June 1 – July 15

- Draw conclusions from the results obtained in the previous steps. Start writing the results.

5. July 15 – Aug 15

- Draft and edit the final thesis' document.

An estimation of the project's cost is:

Table 2. Estimation of the project's cost

	Amount	Cost	Total
Office License	1	100,00 €	100,00 €
GAMS License	1	1.000,00 €	1.000,00 €
Work hours	360	15,00 €	5.400,00 €
Total			**6.500,00 €**

The Trabajo Fin de Grado course, with 12 ECTS corresponds to 360 hours of work. The average pay of a junior ICAI engineer (22 to 25 years old), according to the Asociación de Ingenieros del ICAI, is 15 euros.

The total estimated cost of the project is 6.500€

Chapter 4. FINANCIAL MODEL

In this chapter, the model is described. It follows a traditional structure, with costs, revenues and inflation.

4.1 INPUTS

Each of the following is on an independent tab on the Excel model.

4.1.1 GENERAL PARAMETERS

The fist tab in the model is for general parameters:

I. **Corporate tax rate:** The local tax rate on profits for companies.

II. **Projected inflation:** estimated inflation each year for the duration of the project, in percentage, both for the local currency and for the USD

III. **Investment horizon:** duration of the project. Number of years for the evaluation of the project.

IV. **Ratios:** operational ratios

   a. **Days in inventories:** the average number of days it takes to convert inventory into sales. In the case of the minigrid, the only inventory is diesel. Depending on the frequency and reliability of fuel supply, this number can vary greatly.

   b. **Collection period:** the average number of days it takes for the operator to collect payment from clients.

   c. **Cash ratio:** the fraction of the current liabilities that is held in cash. Fixing this ratio allows the model to plan for a minimum amount of cash to be held every year.

   d. **Days to pay payables:** period to pay payables. In the case of minigrids, period to pay the fuel.

e. **Days to pay accruals:** period to pay accruals. In the case of minigrids, the O&M cost, mostly salaries of the operators.

V. **Required rate of return**: in percentage, discount rate that will be used to evaluate the profitability of the project, calculating the Net Present Value.

4.1.2 COSTS

The costs input tab in the model captures both capital and operational expenditure. For a minigrid, the CAPEX has to do with the initial investment, further growth capex for expansions, maintenance CAPEX to replace worn off P&E. On the other hand, the OPEX reflects mainly fixed costs.

4.1.2.1 CAPEX

I. Investment CAPEX

These first rows are for the investment. In a hybrid solar-diesel minigrid, the main investments are in:

a. Solar PV
b. Batteries
c. Diesel Generator
d. Charge Controllers
e. AC/DC converters

Aside from this equipment, another investment may be necessary, which is the building of the distribution network. This also has a place in the model, in case it would be necessary:

f. Distribution lines
g. Transformers

Each of these pieces of equipment have a different useful life, so the model also asks for this information, which is necessary for the depreciation calculations and to program the maintenance CAPEX.

II. Maintenance CAPEX

The minigrid equipment has to be replaced after a number of years. It is necessary to include a maintenance CAPEX in the model, that plans for this expense. In the following rows of the tab, the sheet reflects the planned reinvestments, according to the useful life of each category of equipment and adjusting the future cost with the predicted inflation.

This is, if there is an initial investment of $100.000 for batteries on year 0, and the batteries have a useful life of 7 years, on year 7, there will be a capital expenditure of $100.000 times the accumulated inflation of those seven years.

4.1.2.2 OPEX

Regarding the operational expenditures of running a minigrid, we can distinguish between fixed and variable costs.

I. Fixed Costs

These have to do with the cost of operation and maintenance labor. The minigrid equipment requires occasional and recurrent maintenance. All the expenses associated with O&M can be considered fixed. In the model, this cost is adjusted with inflation every year.

II. Variable costs

These represent mainly the cost of fuel in a hybrid mini grid. Depending on the available data, the way to enter this cost may vary, but a fair approximation can be done by adjusting this consumption yearly with the demand growth and inflation.

4.1.3 REVENUES

The revenue calculation for an electric grid is directly related with the energy sold and the tariff at which it is sold. The model developed considers five different consumer groups, and allows for a different tariff, demand, and number of connections, and each with a different growth rate.

The five groups proposed here are:

I. Residential I: for the bulk of consumers, with a standard demand
II. Residential II: a higher tariff for families with more electricity and/or reliability needs. This can be with a higher power, or prioritizing their supply.
III. Commercial: consumer group for stores, hair salons, restaurants…
IV. Industrial
V. Institutional: for government buildings, like schools, small hospitals, or anchor loads like telecom towers.

In the Revenues tab of the model, the following inputs are needed:

I. **Demand growth (%)**: for each year, the YoY demand growth is entered for each of the consumer groups. This number then multiplies the year's energy demand to calculate next year's.
II. **Tariff**: for each of the demand groups, a price per kWh in the local currency is entered for year 1. This tariff is automatically adjusted with inflation each year, but it is also possible to input different tariffs for each year, attending to a different criterion if needed.
III. **Number of connections:** for each of the groups, there is a number of connections parameter. This number can change over time due to population growth, new customer acquisition, newly created businesses or industries…
IV. **Demand:** The aggregated demand of the consumer group, in kWh, for the first year. This number is updated automatically with the parameter I, demand growth.

An example of how this data is inputted in the model can be seen in Figure 4.1.

	Year	0	1	2	3	4
	Inflation (INR)		*4,9%*	*4,4%*	*4,1%*	*4,1%*
	Population growth		*0,8%*	*0,8%*	*0,8%*	*0,8%*
Residential I	*Demand growth*		*3,6%*	*3,6%*	*3,6%*	*3,6%*
	# Connections		535	539	544	548
	Tariff		22,00	22,97	23,91	24,89
	Demand (kWh)		1.846.130,29	1.912.590,98	1.981.444,25	2.052.776,25
Residential II	*Demand growth*		*3,6%*	*3,6%*	*3,6%*	*3,6%*
	# Connections		60	60	61	61
	Tariff		25,00	26,10	27,17	28,28
	Demand (kWh)		112.568,92	116.621,40	120.819,77	125.169,28
Commercial	*Demand growth*		*3,6%*	*3,6%*	*3,6%*	*3,6%*
	# Connections		3	3	3	3
	Tariff		40,00	41,76	43,47	45,25
	Demand (kWh)		92.306,51	95.629,55	99.072,21	102.638,81
Industrial	*Demand growth*		*3,6%*	*3,6%*	*3,6%*	*3,6%*
	# Connections		1	1	1	1
	Tariff		40,00	41,76	43,47	45,25
	Demand (kWh)		5.628,45	5.831,07	6.040,99	6.258,46
Institutional	*Demand growth*		*3,6%*	*3,6%*	*3,6%*	*3,6%*
	# Connections		1	1	1	1
	Tariff		22,00	22,97	23,91	24,89
	Demand (kWh)		2.769,20	2.868,89	2.972,17	3.079,16

Figure 4.1. Example of the revenue inputs in the Excel model

There are two general inputs, inflation of the local currency and population growth. Then, each consumer group has its own inputs for demand growth, number of connections, tariff in local currency, and aggregated demand in kWh.

4.2 CALCULATIONS

4.2.1 REVENUES

With the information entered in the Revenues Input tab, the revenues are calculated. Quite simply, the revenue for a given year is:

$$Revenue = tariff \times demand$$

This is calculated separately for each of the consumer groups, since they can have different tariffs, these subtotals are then added into a total revenue for each year. The "number of connections" parameter that has been described above is not used for any revenue calculations, but it is added for convenience and tracking.

Since the tariff is in the local currency, the revenue has to be translated into USD, multiplying by the currency exchange rate.

4.2.2 Currency Exchange Rate

Since minigrid projects are targeted towards different countries, each with a different currency, and most Development Finance Institutions and investors work in US dollars, a currency exchange rate is needed.

To estimate the currency exchange rate in the years of the duration of the project, the following formula is used:

$$FX\ rate\ (t+1) = FX\ rate\ (t)\,\frac{1 + Inflation\ A}{1 + Inflation\ B}$$

A more accurate estimation of the future forex rates is outside of the scope of this project, but, given one, it can be inputted into the model.

4.2.3 Depreciation

Assets are depreciated linearly, within a period equal to the useful life. Therefore, each type of equipment's depreciation is calculated separately.

The reinvestments are also depreciated at the same rate as the initial investment since it is the same type of equipment.

The depreciation tab also keeps track of the book value of the P&E, subtracting every year the depreciation to the previous year's book value, and adding whatever CAPEX might have taken place during the period.

In essence, it follows the formula:

$$Book\ Value\ (t) = Book\ Value\ (t-1) + CAPEX\ (t) - Depreciation\ (t)$$

Where:

t: period (year)

4.3 INCOME STATEMENT

Although the financial survival of the project is more urgently dependent on the cashflows, it is important to calculate the income statement. Especially, the figure of Net Income, since it is what any possible dividends will be based on.

For the calculation of the Net Income, we start form the EBIT, which has been explained previously in section 4.4.

For convenience, in the model developed in Excel, the calculations previous to the EBIT are repeated (Figure 4.2).

Income statement					
Year	**0**	**1**	**2**	**3**	**4**
Revenue		558.888,63	592.325,82	626.536,19	662.073,32
COGS		432.221,00	450.425,00	469.294,00	489.661,00
Gross Margin		**126.667,63**	**141.900,82**	**157.242,19**	**172.412,32**
Fixed Costs		19.452,00	19.899,40	20.317,28	20.723,63
EBITDA		**107.215,63**	**122.001,42**	**136.924,91**	**151.688,69**
Depreciation		131.893,76	131.893,76	131.893,76	131.893,76
EBIT		**(24.678,13)**	**(9.892,34)**	**5.031,14**	**19.794,93**
Interests		3.500,00	3.500,00	3.500,00	3.500,00
EBT		**(28.178,13)**	**(13.392,34)**	**1.531,14**	**16.294,93**
Taxes		(6.199,19)	(2.946,31)	336,85	3.584,88
Income (subtotal)		(21.978,94)	(10.446,02)	1.194,29	12.710,05
Deferred income due to grants		66.666,67	66.666,67	66.666,67	66.666,67
Net income		**44.687,72**	**56.220,64**	**67.860,96**	**79.376,71**

Figure 4.2. Example of Income Statement Calculation in the Excel Model

To the Earnings before Interests and Taxes, the Interests (also called financial expenses) are subtracted, arriving at the Earnings before Taxes (EBT)

$$EBT = \ EBIT \ - Interests$$

From the EBT, the Taxes are subtracted to arrive to the Net Income of the year.

$$Net\ Income\ (sub - total) = EBT - Taxes = EBT(1 - Tax\ Rate)$$

To this Net Income (subtotal), there is another addition needed. Grants are accounted as a deferred income every year, since they are destined to cover part of the initial CAPEX, and this CAPEX is depreciated through the years.

For simplicity, this extra non-taxable income is prorated among the years of the project and added to the Net Income (sub-total) (see Figure 4.2).

$$Total\ Net\ Income = Net\ Income\ (sub - total) + Deferred\ Income\ due\ to\ grants$$

4.4 CASHFLOWS FROM ASSETS (CFFA)

A project's cash flows from assets refer to the net cash inflows or outflows generated by the project's operational activities over its lifespan. These cash flows encapsulate the financial impact of the project's core operations, including revenues, expenses, taxes, and capital expenditures. Positive cash flows from assets indicate that the project is generating more cash through its operations than it is spending, resulting in a favorable financial outcome. Conversely, negative cash flows from assets imply that the project's operational expenses exceed its generated revenues, leading to a less favorable financial position. Evaluating and analyzing a project's cash flows from assets is essential for understanding its profitability, sustainability, and potential to create value for the stakeholders involved.

To arrive at the projects' CFFA, some intermediate calculations are necessary: The Net Operating Profit after Tax, the Operating Cashflow, the CAPEX, and the change in Net Working Capital. These are described below.

4.4.1 NET OPERATING PROFIT AFTER TAX (NOPAT)

NOPAT stands for "Net Operating Profit After Tax." It is a financial metric that represents the profitability of a company's core operating activities after deducting both operating expenses and taxes. NOPAT reflects the company's earnings before taking into account interest expenses and any non-operating income or expenses.

The first step in the Project Cashflow is to calculate the Earnings before Interests, Depreciation, Taxes and Amortization (EBIDTA).

$$EBIDTA = Revenues - Fixed\ Costs - Variable\ Costs$$

The EBIDTA is the first important financial measure of the project. It is an indicator of the operational performance of the minigrid. It only reflects the difference between the yearly revenues and the cost of these goods (in this case, energy) sold. It excludes the initial investment from consideration.

Next, the depreciation calculated in the tab "Depreciation" is subtracted, to get the Earnings before Interest and Tax (EBIT)

$$EBIT = EBIDTA - Depreciation$$

Next, the Taxes are subtracted to the EBIT, to get the NOPAT.

$$NOPAT = EBIT - Tax$$

Where the taxes are calculated as

$$Tax = EBIT * Tax\ rate$$

And the Tax rate is an input described in 4.1.1.

4.4.2 Operating Cashflow

Since the depreciation is not a cashflow, but a non-cash expense used to calculate profits (and taxes), it is added back to the NOPAT to get the operating cashflow (OCF).

$$Equation\ 4.1 \qquad OCF = NOPAT + Depreciation$$

4.4.3 CAPEX

Aside from the NOPAT, the next step in calculating the CFFA is knowing each year's capital expenditures. However, this needs no further calculation, as it is an input, described in 4.1.2.1. The total CAPEX is the sum of the investment and maintenance expenditure.

4.4.4 NET WORKING CAPITAL

Net working capital is a financial metric that represents the difference between a company's current assets and current liabilities. It reflects a company's ability to cover its short-term operational expenses and manage day-to-day business activities. In the case of a minigrid project, current assets include cash, accounts receivable and inventory. Current liabilities include accounts payable, and accruals.

The important measure towards the CFFA is the change in net working capital. When a company's current assets increase more than its current liabilities (an increase in working capital), it requires additional cash to fund these assets. Since these actions tie up cash, they result in a decrease in CFFA. On the contrary, a decrease in working capital results in an increase in cashflows.

In the minigrid model, the net working capital each year is calculated as:

$$NWK = Inventories + Cash + Receivables - (Payables + Accruals)$$

Where each of the terms are calculated using the inputs described in 4.1.1

$$Inventories = \frac{Days\ in\ inventories * Variable\ Costs}{365\ days}$$

$$Receivables = \frac{Collection\ period * Revenues}{365\ days}$$

$$Payables = \frac{Days\ to\ pay\ payables * Variable\ Costs}{365\ days}$$

$$Accruals = \frac{Days\ to\ pay\ accruals * Fixed\ Costs}{365\ days}$$

$$Cash = Cash\ ratio * (Payables + Accruals)$$

With this information, the change in net working capital each year is simply calculated as

$$\Delta NWC = NWC(t) - NWC(t-1)$$

4.4.5 CFFA

The final free cash flow, which in the case of this model, is also the Cashflows from assets are calculated as:

$$\boldsymbol{CFFA = OCF - CAPEX + \Delta NWC}$$

4.5 *FINANCING SOURCES*

The second main block of the financial model of a minigrid is financing. In this project, a combination of equity, grants, concessional and commercial debt are proposed.

4.5.1 EQUITY

Equity, as a source of funding for a project, refers to the capital raised by a project or company by selling ownership shares or ownership interests to investors. When investors purchase equity, they become shareholders or equity holders in the project or company. Equity financing involves obtaining funds without incurring debt or obligation to repay a specific amount at a future date. Equity financing offers investors a stake in the project's potential profits and value appreciation. In return for their investment, shareholders may receive dividends (a portion of the profits) and have voting rights in company decisions.

The equity each year is modelled as:

$$Equity\ (EoP) = Equity\ (BoP) + Capital\ increase\ \pm Net\ income - Dividends$$

Where:

EoP stands for End of Period (end of the year)

BoP stands for Beginning of Period (start of the year)

Dividends are a part (or the total) of the Net Income, paid to the shareholders every year. The amount of the dividends is discretionary.

Capital increase is the cash raised from investors. Typically, this will happen in the year 0.

Of these terms, only the capital increase and dividends will affect the financing cashflows directly.

4.5.2 GRANTS

In the context of minigrids, grants refer to financial contributions or funds provided by governments, international organizations, non-governmental organizations (NGOs), or other entities to support the development, implementation, or operation of minigrid projects. These grants are modelled as non-repayable.

4.5.3 CONCESSIONAL DEBT

Concessional debt refers to a type of financing that provides loans to support the development, implementation, or operation of minigrid projects at more favorable terms than those typically offered by commercial lenders. These loans are provided by governments, international financial institutions, development banks, or other entities with a focus on promoting sustainable development and addressing energy access challenges in underserved areas.

This debt usually has below-market interest rates and may have a grace period. A grace period refers to a specified period of time during which the borrower is not required to make any principal repayments.

4.5.4 Commercial Debt

Commercial debt refers to loans or financing obtained from private sector financial institutions, such as commercial banks or private lenders, to support the development, establishment, or operation of minigrid projects. Commercial debt is typically offered at market-driven terms and conditions.

4.6 Financial Expenses and Debt Repayment

As described in the previous section, concessional and commercial debt have interests associated with them.

4.6.1 Debt repayment

Every year, interest to be paid are calculated as a percentage (interest rate) on the debt outstanding.

In the model developed in this project, the debt repayment is constant every year, and only depends on the sum of the loan and the repayment period:

$$Debt\ repayment = \frac{Initial\ loan}{Repayment\ period}$$

This way, every year, the same amount is repaid. With this repayment, the debt outstanding is updated as:

$$Debt\ (EoP) = Debt\ (BoP) - Debt\ repayment + Debt\ increase$$

In the case of concessional debt, there is another parameter in play, the grace period. International Institutions that give out subsidized debt can include a grace period, a number of years at the beginning of the loan, where there is no debt repayment. This means that the repayment starts after the grace period.

4.6.2 INTERESTS

On top of the annual debt repayment, interests are calculated as a percentage (interest rate) of the debt outstanding. To model this, the average debt during the year is taken, and multiplied by the interest rate:

$$Interest = \frac{Debt\ outstanding\ (BoP) + Debt\ outstanding\ (EoP)}{2} * Interest\ rate$$

4.7 FINANCING CASHFLOW

Aside from the cashflows from assets, the other source of cash inflows and outflows is financing. The financing cashflows focuses on these transactions that affect the capital structure, such as raising debt or equity, loan repayments, interests and dividends. This balance is reflected in Equation 4.2

$$\begin{aligned} Financing\ Cashflow &= \\ &= Financial\ Expense + Debt\ repayment + Debt\ increase + Grants \\ &+ Dividends + Capital\ increse/reduction \end{aligned}$$

Equation 4.2

The Equation 4.2 has all the terms added, but each one will have a different sign, typically: Capital Reduction, Financial Expense, Debt repayment and Dividends will be negative terms, Debt increase, Capital Increase and grants will be positive.

4.8 PROJECT CASH BALANCE

Of utmost importance is the cash of the project at every year. If the cash falls below zero at any given period, the project is bankrupt.

To keep track of the cash at the end of every period, the model takes into account the addition of the Cashflow from Assets (4.4.5) , and the Financing Cashflow (4.7). Using all the numbers described in previous sections, the basic cash balance equation is:

$$Cash(EoP) = Cash(BoP) + Cash\ Movement$$

Where the Cash Movement is calculated as follows:

$$Cash\ Movement = CFFA + Financig\ Cashflow$$

An example of the cash calculations in the Excel model is presented in the Figure 4.3.

Year	0	1	2	3	4	5	6
CFFA	(2.110.240,73)	40.527,86	126.538,90	137.975,91	149.218,59	(39.485,82)	175.008,78
Financial Expense		(1.750,00)	(1.750,00)	(1.750,00)	(1.750,00)	(1.750,00)	(1.691,67)
Debt repayment							(46.666,67)
Debt increase	700.000,00						
Grants/Sub-debt financing	1.000.000,00						
Dividends							(42.921,13)
+/- Capital Increase/Reduction	500.000,00						
Financing Cash Flow	2.200.000,00	(1.750,00)	(1.750,00)	(1.750,00)	(1.750,00)	(1.750,00)	(91.279,46)
Cash movement	**89.759,27**	**38.777,86**	**124.788,90**	**136.225,91**	**147.468,59**	**(41.235,82)**	**83.729,32**

Cash BoP	0	89.759,27	128.537,13	253.326,03	389.551,94	537.020,53	495.784,71
Cash movement	89.759,27	38.777,86	124.788,90	136.225,91	147.468,59	(41.235,82)	83.729,32
Cash EoP	**89.759,27**	**128.537,13**	**253.326,03**	**389.551,94**	**537.020,53**	**495.784,71**	**579.514,03**

Figure 4.3 Example of the Cash balance calculations in the Excel Model

As it can be seen, the addition of the Cashflow from Assets and the Financing Cashflow gives out the cash movement for every year. This Cash movement is then used to calculate the Cash at the end of each period. In the example presented in Figure 4.3, all the financing takes place in the first year: $500.000 in equity, $1.000.000 in grants and $700.000 in debt.

In the following years, there is only a financial expense, interest on the debt, but no debt repayment until year 6 since there is an initial grace period. Also, in year 6 there is a dividend payment, which is reflected as a cash outflow.

4.9 PROJECT PERFORMANCE MEASUREMENTS

4.9.1 NET PRESENT VALUE (NPV)

The net present value of a project is the current value of all cashflows less the initial investment. The current value is calculated by discounting future cashflows with a chosen discount rate. The present value of a series of cashflows can be easily calculated with Excel.

4.9.2 INTERNAL RATE OF RETURN (IRR)

The Internal Rate of Return (IRR) of a project is the discount rate at which the Net Present Value (NPV) of the project's cash flows becomes zero. In other words, the IRR is the rate at which the present value of future cash inflows equals the present value of the initial investment (or cash outflows).

In practice, the IRR represents the project's effective rate of return, reflecting the compound annual growth rate of the project's cash flows. If the calculated IRR is higher than the required rate of return (often referred to as the cost of capital), the project is potentially considered worthwhile, as it generates returns exceeding the required minimum.

Again, the IRR can be easily calculated with an Excel function.

More details on the mathematical formulation and explanation of the IRR and NPV can be found in [10]

4.9.3 LEVELIZED COST OF ELECTRICITY (LCOE)

The levelized cost of energy (LCOE) is a measure of the average cost of generating electricity from a power plant (in this case, a minigrid) over its lifetime. It is calculated by taking the total cost of building and operating the plant and dividing it by the total amount of energy that the plant will generate over its lifetime.

The LCOE can be calculated as:

$$LCOE = \frac{\sum_{t=0}^{T} \frac{CAPEX(t) + OPEX(t)}{(1+r)^t}}{\sum_{t=0}^{T} \frac{E(t)}{(1+r)^t}}$$

Where *t* is each year period of the minigrid lifetime, *r* is the discount rate and *E(t)* is the generated electrical energy in each of the periods.

The LCOE is calculated in $/kWh.

Chapter 5. CASE STUDIES

To test the model developed in this project, two case studies have been built, using real-world data of minigrid costs, projected inflation, concessional debt conditions…

The cases take place in India.

5.1 DATA

5.1.1 MACROECONOMIC FACTORS

- **Projected Inflation**: The International Monetary Fund provides estimates for the inflation in the next 5 years [11]. From then on, we estimate constant inflation and equal to the last year of available estimations for the rest of the project.
- **Tax Rate**: According to PwC [12], the basic corporate tax rate in India is 25%
- **Exchange rate**: As of August 2023, the USD INR exchange rate is 0.012.
- **Discount rate:** We will assume a risk-free rate of 4%, approximating the yield of a 10-year US treasury bond.

5.1.2 MINIGRID DESIGN

The cost structure of the minigrid is taken from the MIT and IIT-Comillas' Universal Access Lab's Reference Electrification Model (REM).

MIT and IIT-Comillas's Universal Access Lab's Reference Electrification Model (REM) utilizes geospatial and current electrical system data to optimize for the best form of electrification for regions without electricity.

The REM, given a reliability target for the minigrid and several other inputs, outputs the optimal minigrid design, in terms of investment in solar panels, batteries, diesel generator and other electronics. It also outputs the diesel cost during each year of operation.

The Reference Electrification Model (REM) enjoys the capability to design mini-grids by making use of heuristics rules and search algorithms, or optimization techniques. Whatever the case, as a rule, REM assumes that mini-grids have centralized generation and operate in island mode. The adopted general architecture for any off-grid system in REM is shown in Figure 5.1. This fairly common design meets the requirement of being able to provide an AC output, which will be necessary in case of a hypothetical connection to the main grid. REM does not include all the components in every generation design. For instance, if a mini-grid has only a diesel generator then converters and inverters will not be included.

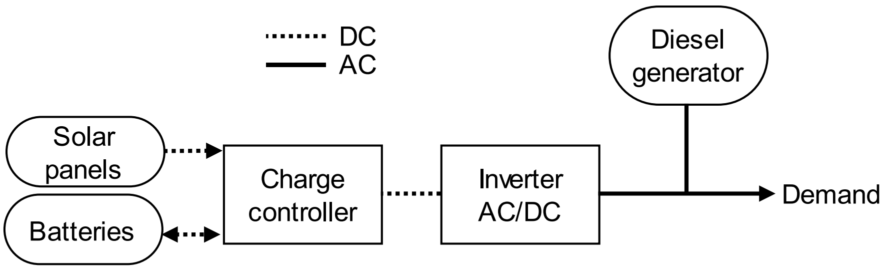

Figure 5.1. Minigrid configuration

The heuristic algorithm that REM uses to determine the generation design of a mini-grid is a variation of which starts by picking an initial point in the multidimensional space of the mini-grid design variables. Then, the search continues by calculating the value of the objective function for several points around the initial point and moving from the initial point along the minimum-cost direction. For each candidate point, which has as many dimensions in the search space as design variables –PV panels, batteries, and diesel generator sizes– of the mini-grid, REM performs an annual simulation of the operation of the mini-grid and calculates the total cost of that point. The simulation adopts a priority-list generation dispatch strategy, which are described below, while the total cost includes investment and operation costs plus a penalty for the non-served energy.

The REM also builds the demand profiles. In this case, the peak aggregated demand is around 360 kW in the first year (Figure 5.2). These have been built after some metering lectures that were shared by the Indian counterpart, so it is rigorously based on real-world data.

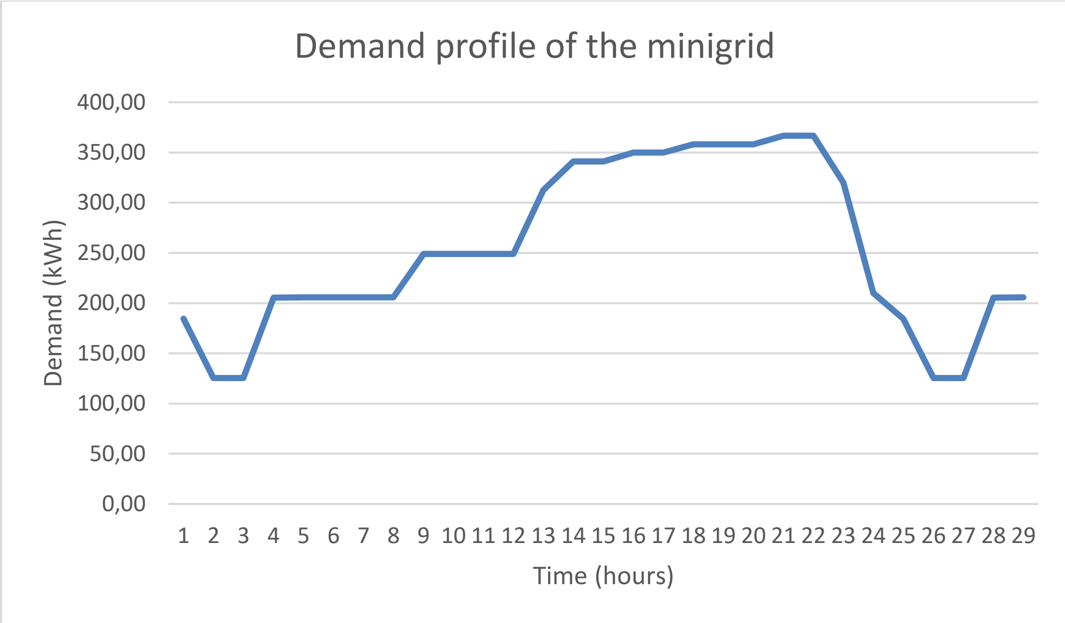

Figure 5.2. Minigrid demand profile

5.1.2.1 Demand growth

The chosen yearly demand growth for the model is 3.6%, this includes the growth due to new connections and to increased productive uses.

5.1.2.2 Costs

For that demand and 95% reliability target, and with the model's available catalogs, the initial investment is:

Table 3. Generation CAPEX

Useful life (years)	Generation CAPEX		
25	Solar Panel	$	1.575.700,00
7	Battery	$	121.140,00
5	Diesel generator	$	180.000,00
15	AC/DC converter	$	135.845,82
15	Charge controller	$	97.554,91

The REM also calculates the useful life of batteries and the diesel generator, taking into account how much they are used throughout the project.

The same model also provides the O&M and fuel costs for every year of the project. These are detailed in Annex I.

5.1.2.3 LCOE

For the calculation of the LCOE, only the costs and energy generated are necessary. With the minigrid design and outputs from the REM, and using a discount rate of 4%, as explained, the Excel model outputs a LCOE of **$0.329 / kWh** (27.41 Rs/kWh)

5.1.3 OPERATIONAL ASSUMPTIONS

For the calculation of working capital, the following assumptions are made.

Table 4. Operational ratios

Days in Inventories:	90 days
Collection period:	45 days
Cash Ratio:	15%
Days to pay payables:	60 days
Days to pay accruals:	30 days

This means that the company holds 90 days' worth of diesel at every time, that the average consumer collection period is 45 days, that diesel is paid every 2 months and salaries every month.

5.2 CASE I: CONSUMER WILLINGNESS TO PAY

In this first case, a minigrid with a 95% reliability is designed. The tariff is adjusted so that it matches a typical consumer willingness to pay (WTP) for a connection of this quality.

The objective of this case is to establish an upper bound on the revenues that can be accomplished electrifying a population in rural India, without a capped tariff, and only taking into consideration the consumers' preferences.

To get this number, the starting point for the willingness to pay of consumers in rural India is taken from a paper [9] that analyzes the impact of quality of service on a consumer's WTP for a connection. That study found that more that the average non-electrified rural household would be willing to pay 399 Indian rupees (Rs) for a good connection to a grid. It also found a statistically significant relation between quality of service and WTP. This is important because the minigrid proposed in this study is of a very high supply reliability (95%), vastly superior to the rural connection in India. According to a survey [6] across different states in India, the average electrified household reported receiving between 9 and 12 hours of electricity a day.

5.2.1 TARIFF

To arrive at a per unit tariff, the average consumption of a rural household, that was not previously electrified, is taken as shown on Table 5:

Table 5. Power requirements estimation for a basic connection. Source: author's calculations

	Number of items	Power [W]	Total Power [W]	Effective usage [hours]	Consumption per day [Wh/day]
Lightbulb	5	5	25	4	100
Phone charger	1	10	10	8	80
Fan	1	50	50	8	400
Total			**85**		**580**

This level of electrification is consistent with a Tier 2 access as described by the World Bank [13]. With the information from Table 5, and the willingness to pay from [9], we arrive to a per unit average tariff of 22.93 Rs/kWh. We round it down to a **tariff of 22 Rs/kWh.** This tariff is consistent with current tariffs charged to residential customers by several private minigrid developers in India, that range between 16 and 40 Rs/kWh [7].

In the case of commercial and industrial customers, the willingness to pay is even greater, since the alternative is a diesel generator. The price of a kWh of electricity produced with a diesel generator can vary greatly, but we will take an safe price around $0.40/kWh, which translates into approximately 33 Rs/kWh.

As has been described in the explanation of the model, this tariff will be updated every year according to the inflation of the local currency.

5.2.2 FINANCING

For the project financing, we take a typical structure of 50% grants, 20% equity and 30% concessional debt.

In the case of this project, since the initial investment is $2.110.240, and using round numbers, this turns into an initial capital structure as shown on Table 6, raising a total of $2.2M for the project.

Table 6. Initial Capital Structure of the minigrid project

Grants	$1.000.000
Equity	$500.000
Concessional Debt	$700.000

The concessional debt, given by a Development Finance Institution, such as the Asian Development Bank or the International Finance Corporation of the World Bank, vary on a case-to-case basis. We will take similar conditions to those offered by the Inter-American Development Bank, with an interest rate of 0.5%, a 5-year grace period and 15 years maturity.

5.2.2.1 Dividend Payments

The payment of dividends to shareholders is a decision of the company's management, always within the constraints of having a positive net income and having enough cash to pay them.

In this case study, dividends are paid every year since year 3. A part of the net income is distributed to the shareholders, considering that the necessary future reinvestments have to be financed with the project cash. This means that in year 15, no dividends can be paid, to pay for the maintenance CAPEX of ACDC convertors, charge controllers and the diesel generator.

The dividends paid have been adjusted so that the cash on the last year of the analysis is close to zero.

5.2.3 PROJECT PERFORMANCE

In this section, the project performance during the first 15 years of operation is analyzed: operational viability, IRR of the project and for the equity investors, payback period and survival of the project in terms of cash balance.

The detailed numbers are shown on Annex I

5.2.3.1 Income Statement

The first important result to outline is that the project is EBIDTA positive since the first period, and throughout the 15 years. This means that the tariff on energy is enough to cover the operational costs, variable and fixed. This EBIDTA grows every year, from $107k in year 1 to $399k in year 15.

Although the project is always EBIDTA positive, the Net Income sub-totals (without the income due to grants), are negative in the first two years of the project. However, adding the deferred income, the total Net Income is positive every year of the project.

5.2.3.2 Cash Balance

With the initial financing of $2.2M, the cashflow on year 0 is positive.

In the following years, the cash balance remains above zero. A few critical moments to remark are:

- During the first four years of the project, the CFFA are positive, and the only financing cashflow is the payment of interest on debt, which is small relative to the CFFA. This allows to build up cash reserves for the maintenance CAPEX needed on year 5.
- On year 5, there is a $200k CAPEX necessary to replace the diesel generator, this creates a negative CFFA of $46k. This negative cashflow is financed with the cash reserves.

- On year 3, the Net Income allows for a first dividend payment, so all of this Net Income of $33k is paid to the investors. The built-up cash reserves are enough to make this payment as well.
- Also, year 6 is the first year after the concessional debt grace period, so there is also a negative financing cashflow equal to the principal payment of the debt.
- These dynamics of maintenance CAPEX, dividends, interests, and debt repayment are repeated in following years. However, the project's cash always remains above zero, so no financing adjustments are needed.

5.2.3.3 Project IRR

Taking into consideration the project's cashflows, the Internal Rate of Return is of -2.3%.

This is, however, only due to the cashflows from operations for the first 15 years of operation of the project. On year 15, the minigrid could be sold or kept in operation. For a more realistic return analysis, we can assume that the minigrid could be sold on year 15 for its book value (Assets – Liabilities). With this new cashflow in year 15, the **IRR is +2.4%.**

However, with current discount rates of approximately 4%, the net present value of the investment is still negative. **Nonetheless, for equity holders, this rate of return will be higher since there are grants and concessional loans well below market value**. This will be shown in the next section.

5.2.3.4 Returns on Equity

From year 3 onwards there is an increasing dividend payout to the project's shareholders. With these payments and the initial investment of $500k, we can calculate an IRR of 10.7%, and a payback period of 8.83 years (Table 7).

Although positive, this rate of return is well below typical required rates of private investors on minigrid projects, which are considered risky. According to a United Nations and ETH Zürich study [8], the average cost of equity for minigrid projects in India is around 21%.

Table 7. Equity returns - Case I

PV:	**235.115,02 €**
r:	21,0%
NPV:	**(264.884,98 €)**
IRR:	**10,7%**
Payback:	**8,83 years**

These returns, however, only take into consideration the dividend payments in the first 15 years of the project.

At the end of this period, the company has a positive balance, and could be sold, or kept in operation. For reference, assuming the project could be sold at its book value (Assets – Liabilities) on year 15 the **equity IRR goes up to 14.5%**.

Table 8. Equity returns. Selling at the end of the 15 years – Case I

PV:	**289.957,19 €**
r:	21,0%
NPV:	**(210.042,81 €)**
IRR:	**14,5%**
Payback:	**8,83 years**

5.2.4 CASE I CONCLUSIONS

Charging customers what they are willing to pay for a basic connection, and a high-quality, high-reliability electricity supply is enough to recover the operating costs of the minigrid and part of the investment costs.

However, this tariff is not enough to recover all the costs, as is shown with the LCOE calculation (LCOE is 27.4Rs and the tariff is 22Rs). In this stylized case, that gap is covered with an initial grant of around 45% of the initial CAPEX.

With this initial grant, concessional debt and the revenues from the operations, the project survives cash-wise through the 15 years of operation and pays and IRR between 10.7% and 14.5% to the equity shareholders, while making available electric power to the consumers.

5.3 *CASE II-1 – REGULATED TARIFF*

In Uttar Pradesh, India, the State Government offers a 30% capital subsidy, plus another 30% government subsidy. In turn, there is a maximum tariff of 7 Rs per kWh, and a minimum 8-hour supply [7]. In this case study, we will apply those conditions to the model, and observe the financial viability of the proposed tariffs.

5.3.1 TARIFF

The actual proposed tariff structure is a fixed payment for a connection of a certain power. This, as shown in [7] turns out to be a tariff of 6 to 7 Rs per kWh. We will choose the upper bound of 7 **Rs/kWh.**

5.3.2 FINANCING

The local and state governments give a total of 60% grant of the CAPEX. The other 40% will be completed with 20% equity and 20% concessional loan, with the same terms as in Case 1. Again, rounding up to have some cash margin, the financing structure the first year is:

Table 9. Financing structure - Case II-1

Grant	$1.266.144
Equity	$450.000
Concessional Loan	$450.000

Thus, raising a total of $2.166.144 to cover the CAPEX + some cash margin.

5.3.3 PROJECT PERFORMANCE BEFORE SUBSIDIES

With the minigrid designed to achieve 95% reliability, and the 7Rs/kWh tariff, the project is inviable by a large amount. The revenues due to the tariff are not enough even to cover the operating costs of fuel. The project is EBIDTA negative every year (Table 10).

Table 10. Income statement for the first years of operation. Case II-1

Year	0	1	2	3
Revenues		187.418,88	198.631,78	210.103,95
Variable costs		432.221,00	450.425,00	469.294,00
Fixed Costs		19.452,00	19.899,40	20.317,28
EBITDA		**(264.254,12)**	**(271.692,62)**	**(279.507,33)**
Depreciation		131.893,76	131.893,76	131.893,76
EBIT		**(396.147,88)**	**(403.586,38)**	**(411.401,09)**
Taxes		(99.036,97)	(100.896,60)	(102.850,27)
NOPAT		**(297.110,91)**	**(302.689,79)**	**(308.550,82)**

The project would go bankrupt in the first year of operation, with a negative cash at the end of the period of over $148.000.

If the quality conditions and the tariff cap are to be kept, more annual subsidies on energy sold are necessary.

5.3.4 NECESSARY SUBSIDIES

Since the operational revenues are not enough to cover OPEX, another influx of cash is necessary. A reasonable possibility is a tariff subsidy, a government payment on each kWh sold.

A subsidy of 10.8 Rs/kWh every year is enough to have a positive cash balance in the first years of operation, as well as a positive Net Income (see Annex II), while being able to pay dividends to equity shareholders, with an **Equity IRR of 10.4%**, similar to the one in Case I.

Grants & subsidies							
Rs/kWh		10,8	10,8	10,8	10,8	10,8	10,8
BoP	0	1.266.144,44	1.542.277,18	1.822.596,35	2.107.427,55	2.396.559,95	2.810.578,66
+ Increase (subsidies)	1.266.144,44	-	-	-	-	120.237,96	-
* Increase (grants)		276.132,74	280.319,17	284.831,20	289.132,40	293.780,76	298.796,50
EoP	**1.266.144,44**	**1.542.277,18**	**1.822.596,35**	**2.107.427,55**	**2.396.559,95**	**2.810.578,66**	**3.109.375,16**

Figure 5.3. Necessary subsidies and grants for the first year of operation

To achieve the financial profitability of the minigrid, as well as overcoming the risk of default, a considerable amount of subsidies has to be disbursed every year: around $250k/ $300k, which represents around 12% of the initial investment.

Throughout the life of the project, a total of **$6.693.493** have to be paid in subsidies and grants, or over 3 times the total initial investment.

5.3.5 Project Performance with Subsidies

With the described annual subsidies, the project achieves a positive net income every year of operation:

Income statement

Year	0	1	2	3	4	5
Revenue		187.418,88	198.631,78	210.103,95	222.021,05	254.294,24
COGS		432.221,00	450.425,00	469.294,00	489.661,00	511.357,00
Gross Margin		**(244.802,12)**	**(251.793,22)**	**(259.190,05)**	**(267.639,95)**	**(257.062,76)**
Fixed Costs		19.452,00	19.899,40	20.317,28	20.723,63	21.138,10
EBITDA		**(264.254,12)**	**(271.692,62)**	**(279.507,33)**	**(288.363,58)**	**(278.200,86)**
Depreciation		131.893,76	131.893,76	131.893,76	131.893,76	131.893,76
EBIT		**(396.147,88)**	**(403.586,38)**	**(411.401,09)**	**(420.257,34)**	**(410.094,62)**
Interests		2.250,00	2.250,00	2.250,00	2.250,00	2.250,00
EBT		**(398.397,88)**	**(405.836,38)**	**(413.651,09)**	**(422.507,34)**	**(412.344,62)**
Taxes		(99.599,47)	(101.459,10)	(103.412,77)	(105.626,84)	(103.086,16)
Net income (subtotal)		(298.798,41)	(304.377,29)	(310.238,32)	(316.880,51)	(309.258,47)
Deferred income (grants)		355.269,00	359.455,43	363.967,46	368.268,66	372.917,02
Net income		**56.470,59**	**55.078,14**	**53.729,14**	**51.388,15**	**63.658,55**

Figure 5.4. P&L for the first years of operation

There is a positive net income that grows from $56k in the first year to $68k on year 15. Cash wise, there is a significant margin of more than $50k at the end of every year, so all of the net income can be distributed as dividends.

5.3.6 RETURNS ON EQUITY

The dividends paid average **$62k** every year, which turns out to an **IRR of 10.4%** and a **payback of 7.68 years** (Table 11).

Table 11. Equity returns. Case II-1

PV:	**490.080,48 €**
r:	9,0%
NPV:	**40.080,48 €**
IRR:	**10,4%**
Payback:	**7,68 years**

5.3.7 CASE II-1 CONCLUSIONS

To keep the premises of a 95% reliability minigrid, and a very low regulated tariff, subsidies on the energy sold are needed. The government would have to complement the tariff paid by consumers with approximately another 150% to make the project financially viable and attractive to private investors. The total subsidies and grants paid amount to over 6.6 million dollars, or over three times the initial investment.

Although with these conditions the investment can be justifiable to the private sector, depending so heavily on continued government subsidies over time adds a great risk to the project, since any changes in regulation could make the minigrid go bankrupt immediately.

5.4 CASE II-2 – REGULATED TARIFF AND REDUCED RELIABILITY

It has been shown that the regulated tariff is not enough to make a 95% reliable minigrid viable. In this next case, the minigrid has been designed with a 50% reliability and no diesel, so that the initial expenditure in PV is greater, and later OPEX is smaller, since the CAPEX is subsidized.

5.4.1 MINIGRID DESIGN

To bring down the operational costs, the new minigrid is designed with a 50% reliability target. This means that half of the demand in the villages will not be met. Furthermore, the minigrid is designed with only PV, and no diesel generators. This turns to a greater initial investment, but no variable costs during the operation of the project.

This is a sub-optimal design in terms of total cost, but since CAPEX is subsidized, it makes more financial sense for investors.

This new minigrid has an initial CAPEX of

Table 12. Initial CAPEX. Case II-2

Generation CAPEX		
Solar Panel	$	3.174.325,00
Battery	$	874.800,00
Diesel generator	$	-
AC/DC converter	$	140.612,00
Charge controller	$	192.730,00

Totaling **$4.382.467,00**

5.4.1.1 LCOE

With this minigrid, the operational costs are much lower, and the initial investment much higher. A 50% reliability also means that only half of the demand is served, a lot less energy is generated through the life of the project. The LCOE for this minigrid is **$0.344/kWh**, very similar to the minigrid on Case I, with 95% reliability.

5.4.2 FINANCING

Following the same policy described on Case II-1, there is a 60% grant on CAPEX, 20% equity and 20% concessional loan, amounting to:

Table 13. Initial Financing Structure. Case II-2

Grant	$2.629.480,20
Equity	$880.000
Concessional Loan	$880.000

5.4.3 PROJECT FINANCIAL PERFORMANCE

The detailed numbers can be found on Annex III

5.4.3.1 Income Statement

The Net Income subtotal (before the incomes due to grants) is negative throughout all the project since the revenues from the sale of electricity are not enough to cover the CAPEX. However, after the grant, the total Net Income becomes positive.

5.4.3.2 Cash

The greatest problem of this case, with a large initial grant to finance the CAPEX but very low operational revenues, comes when a maintenance CAPEX is needed. In this case, the simulation gives a battery useful life of 15 years, so on year 15, they have to be substituted.

Although the project has a positive cashflow during the years of operation, all of the raised money is not enough to finance this necessary reinvestment on year 15. Even if no dividends are paid, it would need to be refinanced with a new grant, or the project decommissioned. With a new grant on 60% of the maintenance CAPEX; the project can continue.

In summary, the project survives during the first 15 years of operation, but when the first maintenance CAPEX is needed, the project is not sustainable, and a new grant would be needed.

5.4.3.3 Equity

Paying dividends close to the Net Income every year, the Equity IRR is 8.7% This is a low return rate for a minigrid project, which is considered very risky.

5.4.4 CASE II-2 CONCLUSIONS

In this alternative case, a new minigrid is designed, with a supply reliability of 50% (down from the 95% reliability of Case I), and the expenses are concentrated at the beginning, with no diesel variable costs throughout the project.

60% of this initial CAPEX is financed with government grants, amounting to over $2.6M. With this financing structure and the revenues from operations, the project survives cash-wise during the first years of operation, but it goes bankrupt when a maintenance investment is needed on year 15.

The investment is not sustainable without continued government financing. Customers will receive a very poor electric connection, with only 50% reliability, but in exchange the tariff is much lower than in Case I.

In fact, as shown by the LCOE calculations, the cost of a low-quality minigrid is not lower, in terms of $/unit, than that of a high-quality minigrid. **The viability of this case lies not in that the minigrid is cheaper, but in that the viability gap that arises from the difference in costs of the minigrid and the low tariff is multiplied by a low demand volume**. In other words, since there is a great viability gap associated with every kWh of energy sold, what is effectively being done in this minigrid, is allowing customers to buy less electricity, because every unit of power sold puts a strain on the financial survival of the minigrid. This regulated tariff effectively removes the power of choice from the customers.

5.5 ANALYSIS OF THE RESULTS

Two main scenarios have been analyzed:

Case I: a deregulated tariff, where customers are charged what they are willing to pay in exchange for a high quality, high reliability connection to a minigrid.

Case II: a regulated, very low tariff for customers, with two sub-cases:

- A 95% reliability minigrid
- A 50% reliability minigrid

Case I, with a typical financing structure for a minigrid project, turns out to be financially profitable for investors, with an **IRR between 10.7% and 14%** for the 15-year life of the project. Customers, in exchange, receive **24 hours of electricity connection**, a significant upgrade from a typical rural connection in India.

This project, however, still needs from assistance form Development Financial Institutions, since a 50% grant on CAPEX, and a subsidized loan are necessary for the success of the minigrid.

Table 14. Results Summary

	Case I	Case II-1	Case II-2
Project is viable	Yes	Yes	Yes
Minigrid reliability	95%	95%	50%
Tariff	22Rs - $0,264	7Rs - $0,084	7Rs - %0,084
Grant	$1,000,000	$6.693.000	$2,630,000
Equity IRR	10,7% - 14%	10.4%	8.7%

Case II initial approach clearly shows that **with the regulated tariff, a 95% reliability connection for consumers is financially inviable**, with the project going bankrupt on the first year. Further subsidies are needed. With annual subsidies on the tariff of 10.8Rs/kWh (more than the consumers pay), the project achieves similar profitability as in case I. The **total grants and subsidies amount to $6,7M**, more than 3 times the initial investment.

On the second subcase, to try to achieve a feasible minigrid with those tariffs and smaller subsidies, the grid reliability target is brought down to 50% and the projects costs concentrated on the CAPEX rather than the OPEX, bringing up the expenditure on PV and reducing it on diesel generators.

This revised configuration, coupled with promised government grants, renders the project financially feasible for the initial 15 years. However, the project becomes incapable of refinancing the necessary maintenance CAPEX in the 15th year to replace batteries and electronic components. An additional grant for CAPEX is e imperative in the 15th year. The government would be spending a grant in excess of $2.5M on a project that would only bring consumers a very poor reliability connection to the grid, with constant outages and power limitations. It is also hard to think that private investors would commit to a project with very low returns.

On case I, however, the tariff is established considering the customers' willingness to pay. With this approach, **the project turns out to be profitable and viable**, with the revenues being able to pay for OPEX, CAPEX and equity returns. In exchange for this **higher tariff, customers receive a very high-quality connection, and equity holders a significant**

return on investment. This is very important, since with no private equity investment there is no project to begin with.

On the side of the government, or other development institutions, the grant amounts to $1M, much less than on the second case, and this contribution is enough to make the minigrid viable, and to give the citizens an excellent electricity access.

Chapter 6. CONCLUSIONS

In this Master's Final Thesis, a financial model for the study of minigrids has been developed, taking into consideration initial and operating costs, financing sources, cashflows and financial profitability for private shareholders. With this model, two different approaches to electrification have been tested: deregulated and regulated tariffs, and the financial viability of these policies examined.

The main conclusions of this study relating to the financial model are:

1. A detailed financial model is essential for the analysis of minigrid project's viability, for consumers, private investors, development funds and policy makers.
2. The financial model must reflect the Income Statement, but more importantly, the cash balance every year, since this cash is the critical variable that determines bankruptcy or "survival".
3. In the same line, the payment of dividends to shareholders has to take into consideration the cash balance every year, and the necessary future investments in maintenance CAPEX.
4. The most critical variable in the financial viability of a minigrid is the tariff, the bigger the difference between the tariff and the actual costs of the minigrid, the more difficult it is for the minigrid project to survive. Small differences in the tariff, since there is a large amount of energy sold throughout 15 years of the project.

And with regards to the case studies:

1. An unregulated tariff that reflects the customer's willingness to pay is very close to cost recovery for a minigrid of very high standards (95% reliability). With a grant of half the initial CAPEX, the project is viable and profitable for equity shareholders (10% to 14% Equity IRR).

2. India's regulated tariff, even with government grants on CAPEX is in no way viable for a high-quality minigrid. The gap between the tariff and the costs is so large that more annual subsidies are needed.
3. With enough subsidies on the tariff (3x the initial investment), the project becomes profitable for shareholders (10.4% Equity IRR)
4. This regulated tariff can work in the short term for a lower quality minigrid, with subpar connections for customers. However, it is not viable in the long term without continued subsidies when maintenance investments are needed.
5. Although continued subsidies make the project profitable, depending so heavily on promised subsidies adds a very significant risk to the minigrid, since any changes in regulation could result in immediate bankruptcy.
6. These low-quality minigrids are not more affordable than the high-quality grids, in terms of the LCOE. In some sense, what makes this minigrids viable is that the 50% reliability is in fact allowing customers to purchase less energy than they demand, and thus the gap between costs and revenues for every kWh of energy is multiplied by a smaller volume of energy.

As a general conclusion and recommendation, we support the conclusion of the authors of [9], that "As improving the quality-of-service increases WTP, then Indian policymakers may have a solution to the financial problems that rural electrification creates under heavily subsidized electricity prices". The current regulation might be working against the electrification progress, since the gap between the regulated price and the actual costs is too large to overcome and are very far away from the actual consumers' willingness to pay, especially for a high quality-of-service connection, which actually makes minigrid projects viable in the long-term.

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ANNEX I – CASE I

Income statement

Year	0	1	2	3	4	5	6	7	8	9
Revenue		558.888,63	592.325,82	626.536,19	662.073,32	699.626,12	740.033,73	782.775,12	827.985,08	875.806,18
COGS		432.221,00	450.425,00	469.294,00	489.661,00	511.357,00	533.928,00	560.005,00	582.623,00	609.850,00
Gross Margin		**126.667,63**	**141.900,82**	**157.242,19**	**172.412,32**	**188.269,12**	**206.105,73**	**222.770,12**	**245.362,08**	**265.956,18**
Fixed Costs		19.452,00	19.899,40	20.317,28	20.723,63	21.138,10	21.582,00	22.035,22	22.497,96	22.970,42
EBITDA		**107.215,63**	**122.001,42**	**136.924,91**	**151.688,69**	**167.131,02**	**184.523,73**	**200.734,89**	**222.864,11**	**242.985,76**
Depreciation		131.893,76	131.893,76	131.893,76	131.893,76	131.893,76	135.973,08	135.973,08	138.732,10	138.732,10
EBIT		**(24.678,13)**	**(9.892,34)**	**5.031,14**	**19.794,93**	**35.237,26**	**48.550,64**	**64.761,81**	**84.132,02**	**104.253,66**
Interests		3.500,00	3.500,00	3.500,00	3.500,00	3.500,00	3.383,33	3.150,00	2.916,67	2.683,33
EBT		**(28.178,13)**	**(13.392,34)**	**1.531,14**	**16.294,93**	**31.737,26**	**45.167,31**	**61.611,81**	**81.215,35**	**101.570,33**
Taxes		(6.199,19)	(2.946,31)	336,85	3.584,88	6.982,20	9.936,81	13.554,60	17.867,38	22.345,47
Income (subtotal)		(21.978,94)	(10.446,02)	1.194,29	12.710,05	24.755,06	35.230,50	48.057,21	63.347,97	79.224,86
Deferred income due to grants		66.666,67	66.666,67	66.666,67	66.666,67	66.666,67	66.666,67	66.666,67	66.666,67	66.666,67
Net income		**44.687,72**	**56.220,64**	**67.860,96**	**79.376,71**	**91.421,73**	**101.897,17**	**114.723,88**	**130.014,64**	**145.891,53**

Income statement

Year	10	11	12	13	14	15
Revenue	926.389,24	979.893,78	1.036.488,53	1.096.351,96	1.159.672,86	1.226.650,93
COGS	639.074,00	667.949,00	697.498,00	731.307,00	764.103,00	801.233,37
Gross Margin	**287.315,24**	**311.944,78**	**338.990,53**	**365.044,96**	**395.569,86**	**425.417,56**
Fixed Costs	23.452,80	23.945,31	24.448,16	24.961,57	25.485,76	26.020,97
EBITDA	**263.862,44**	**287.999,47**	**314.542,37**	**340.083,39**	**370.084,10**	**399.396,60**
Depreciation	138.732,10	143.077,37	143.077,37	143.077,37	143.077,37	146.219,35
EBIT	**125.130,35**	**144.922,10**	**171.464,99**	**197.006,01**	**227.006,72**	**253.177,25**
Interests	2.450,00	2.216,67	1.983,33	1.750,00	1.516,67	1.283,33
EBT	**122.680,35**	**142.705,43**	**169.481,66**	**195.256,01**	**225.490,06**	**251.893,91**
Taxes	26.989,68	31.395,20	37.285,97	42.956,32	49.607,81	55.416,66
Income (subtotal)	95.690,67	111.310,24	132.195,70	152.299,69	175.882,25	196.477,25
Deferred income due to grants	66.666,67	66.666,67	66.666,67	66.666,67	66.666,67	66.666,67
Net income	**162.357,34**	**177.976,91**	**198.862,36**	**218.966,36**	**242.548,91**	**263.143,92**

Income statement

Year	0	1	2	3	4	5	6	7	8
CFFA	(2.110.240,73)	35.212,21	120.407,74	131.934,27	143.248,71	(45.383,58)	169.079,63	40.846,38	198.897,53
Financial Expense		(3.500,00)	(3.500,00)	(3.500,00)	(3.500,00)	(3.500,00)	(3.383,33)	(3.150,00)	(2.916,67)
Debt repayment							(46.666,67)	(46.666,67)	(46.666,67)
Debt increase	700.000,00								
Grants/Sub-debt financing	1.000.000,00								
Dividends				(40.000,00)	(50.000,00)	(50.000,00)	(60.000,00)	(80.000,00)	(120.000,00)
+/- Capital Increase/Reduction	500.000,00								
Financing Cash Flow	2.200.000,00	(3.500,00)	(3.500,00)	(43.500,00)	(53.500,00)	(53.500,00)	(110.050,00)	(129.816,67)	(169.583,33)
Cash movement	**89.759,27**	**31.712,21**	**116.907,74**	**88.434,27**	**89.748,71**	**(98.883,58)**	**59.029,63**	**(88.970,29)**	**29.314,20**

Cash BoP	0	89.759,27	121.471,49	238.379,22	326.813,49	416.562,20	317.678,61	376.708,24	287.737,95
Cash movement	89.759,27	31.712,21	116.907,74	88.434,27	89.748,71	(98.883,58)	59.029,63	(88.970,29)	29.314,20
Cash EoP	**89.759,27**	**121.471,49**	**238.379,22**	**326.813,49**	**416.562,20**	**317.678,61**	**376.708,24**	**287.737,95**	**317.052,15**

Income statement

Year	9	10	11	12	13	14	15
CFFA	214.106,19	7.826,63	249.330,25	269.585,49	288.948,86	149.450,62	(231.161,65)
Financial Expense	(2.683,33)	(2.450,00)	(2.216,67)	(1.983,33)	(1.750,00)	(1.516,67)	(1.283,33)
Debt repayment	(46.666,67)	(46.666,67)	(46.666,67)	(46.666,67)	(46.666,67)	(46.666,67)	(46.666,67)
Debt increase							
Grants/Sub-debt financing							
Dividends	(120.000,00)	(140.000,00)	(150.000,00)	(150.000,00)	(180.000,00)	(180.000,00)	
+/- Capital Increase/Reduction							
Financing Cash Flow	(169.350,00)	(189.116,67)	(198.883,33)	(198.650,00)	(228.416,67)	(228.183,33)	(47.950,00)
Cash movement	**44.756,19**	**(181.290,03)**	**50.446,92**	**70.935,49**	**60.532,20**	**(78.732,72)**	**(279.111,65)**

Cash BoP	317.052,15	361.808,34	180.518,31	230.965,22	301.900,71	362.432,91	283.700,19
Cash movement	44.756,19	(181.290,03)	50.446,92	70.935,49	60.532,20	(78.732,72)	(279.111,65)
Cash EoP	**361.808,34**	**180.518,31**	**230.965,22**	**301.900,71**	**362.432,91**	**283.700,19**	**4.588,55**

ANNEX II – CASE II-1

Income statement

Year	0	1	2	3	4	5	6	7	8	9
Revenue		187.418,88	198.631,78	210.103,95	222.021,05	254.294,24	268.981,26	291.596,83	308.438,30	331.326,39
COGS		432.221,00	450.425,00	469.294,00	489.661,00	511.357,00	533.928,00	560.005,00	582.623,00	609.850,00
Gross Margin		**(244.802,12)**	**(251.793,22)**	**(259.190,05)**	**(267.639,95)**	**(257.062,76)**	**(264.946,74)**	**(268.408,17)**	**(274.184,70)**	**(278.523,61)**
Fixed Costs		19.452,00	19.899,40	20.317,28	20.723,63	21.138,10	21.582,00	22.035,22	22.497,96	22.970,42
EBITDA		**(264.254,12)**	**(271.692,62)**	**(279.507,33)**	**(288.363,58)**	**(278.200,86)**	**(286.528,74)**	**(290.443,39)**	**(296.682,67)**	**(301.494,03)**
Depreciation		131.893,76	131.893,76	131.893,76	131.893,76	131.893,76	135.973,08	135.973,08	138.732,10	138.732,10
EBIT		**(396.147,88)**	**(403.586,38)**	**(411.401,09)**	**(420.257,34)**	**(410.094,62)**	**(422.501,82)**	**(426.416,48)**	**(435.414,76)**	**(440.226,12)**
Interests		2.250,00	2.250,00	2.250,00	2.250,00	2.250,00	2.175,00	2.025,00	1.875,00	1.725,00
EBT		**(398.397,88)**	**(405.836,38)**	**(413.651,09)**	**(422.507,34)**	**(412.344,62)**	**(424.676,82)**	**(428.441,48)**	**(437.289,76)**	**(441.951,12)**
Taxes		(99.599,47)	(101.459,10)	(103.412,77)	(105.626,84)	(103.086,16)	(106.169,21)	(107.110,37)	(109.322,44)	(110.487,78)
Net income (subtotal)		(298.798,41)	(304.377,29)	(310.238,32)	(316.880,51)	(309.258,47)	(318.507,62)	(321.331,11)	(327.967,32)	(331.463,34)
Deferred income (grants)		355.269,00	359.455,43	363.967,46	368.268,66	372.917,02	380.380,35	385.481,73	392.325,61	397.602,66
Net income		**56.470,59**	**55.078,14**	**53.729,14**	**51.388,15**	**63.658,55**	**61.872,73**	**64.150,62**	**64.358,28**	**66.139,32**

Income statement

Year	10	11	12	13	14	15
Revenue	350.462,48	373.624,79	395.203,86	433.396,88	458.428,15	484.905,13
COGS	639.074,00	667.949,00	697.498,00	731.307,00	764.103,00	801.233,37
Gross Margin	**(288.611,52)**	**(294.324,21)**	**(302.294,14)**	**(297.910,12)**	**(305.674,85)**	**(316.328,24)**
Fixed Costs	23.452,80	23.945,31	24.448,16	24.961,57	25.485,76	26.020,97
EBITDA	**(312.064,32)**	**(318.269,52)**	**(326.742,30)**	**(322.871,69)**	**(331.160,61)**	**(342.349,20)**
Depreciation	138.732,10	143.077,37	143.077,37	143.077,37	143.077,37	146.219,35
EBIT	**(450.796,41)**	**(461.346,89)**	**(469.819,67)**	**(465.949,06)**	**(474.237,98)**	**(488.568,55)**
Interests	1.575,00	1.425,00	1.275,00	1.125,00	975,00	825,00
EBT	**(452.371,41)**	**(462.771,89)**	**(471.094,67)**	**(467.074,06)**	**(475.212,98)**	**(489.393,55)**
Taxes	(113.092,85)	(115.692,97)	(117.773,67)	(116.768,51)	(118.803,25)	(122.348,39)
Net income (subtotal)	(339.278,56)	(347.078,92)	(353.321,00)	(350.305,54)	(356.409,74)	(367.045,16)
Deferred income (grants)	402.969,81	411.035,76	416.587,74	422.234,52	427.977,70	435.704,11
Net income	**63.691,25**	**63.956,84**	**63.266,74**	**71.928,97**	**71.567,96**	**68.658,95**

Cashflows

Year	0	1	2	3	4	5	6	7	8
CFFA	(2.110.240,73)	(197.059,61)	(172.033,54)	(177.945,00)	(184.679,79)	(379.996,20)	(182.695,80)	(327.185,67)	(189.961,95)
Financial Income									
Financial Expense		(2.250,00)	(2.250,00)	(2.250,00)	(2.250,00)	(2.250,00)	(2.175,00)	(2.025,00)	(1.875,00)
Debt repayment							(30.000,00)	(30.000,00)	(30.000,00)
Debt increase	450.000,00								
Grants/Sub-debt financing	1.266.144,44	276.132,74	280.319,17	284.831,20	289.132,40	414.018,72	298.796,50	388.169,73	309.086,35
Dividends		(56.470,59)	(55.078,14)	(53.729,14)	(51.388,15)	(63.658,55)	(61.872,73)	(64.150,62)	(64.358,28)
+/- Capital Increase/Reduction	450.000,00								
Financing Cash Flow	2.166.144,44	217.412,15	222.991,03	228.852,06	235.494,25	348.110,17	204.748,77	291.994,12	212.853,06
Cash movement	**55.903,71**	**20.352,54**	**50.957,48**	**50.907,06**	**50.814,46**	**(31.886,03)**	**22.052,97**	**(35.191,56)**	**22.891,12**

Cash BoP	0	55.903,71	76.256,25	127.213,73	178.120,79	228.935,25	197.049,22	219.102,19	183.910,63
Cash movement	55.903,71	20.352,54	50.957,48	50.907,06	50.814,46	(31.886,03)	22.052,97	(35.191,56)	22.891,12
Cash EoP	**55.903,71**	**76.256,25**	**127.213,73**	**178.120,79**	**228.935,25**	**197.049,22**	**219.102,19**	**183.910,63**	**206.801,75**

Cashflows

Year	9	10	11	12	13	14	15
CFFA	(194.466,41)	(424.140,58)	(206.109,75)	(212.322,54)	(211.609,68)	(378.662,39)	(712.427,75)
Financial Income							
Financial Expense	(1.725,00)	(1.575,00)	(1.425,00)	(1.275,00)	(1.125,00)	(975,00)	(825,00)
Debt repayment	(30.000,00)	(30.000,00)	(30.000,00)	(30.000,00)	(30.000,00)	(30.000,00)	(30.000,00)
Debt increase							
Grants/Sub-debt financing	314.363,40	453.004,34	325.189,34	330.741,32	336.388,09	439.599,43	687.576,02
Dividends	(66.139,32)	(63.691,25)	(63.956,84)	(63.266,74)	(71.928,97)	(71.567,96)	(68.658,95)
+/- Capital Increase/Reduction							
Financing Cash Flow	216.499,08	357.738,09	229.807,49	236.199,58	233.334,12	337.056,47	588.092,07
Cash movement	**22.032,67**	**(66.402,49)**	**23.697,74**	**23.877,04**	**21.724,44**	**(41.605,92)**	**(124.335,68)**

Cash BoP	206.801,75	228.834,43	162.431,94	186.129,68	210.006,72	231.731,16	190.125,25
Cash movement	22.032,67	(66.402,49)	23.697,74	23.877,04	21.724,44	(41.605,92)	(124.335,68)
Cash EoP	**228.834,43**	**162.431,94**	**186.129,68**	**210.006,72**	**231.731,16**	**190.125,25**	**65.789,57**

ANNEX III – CASE II-2

Income statement

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Revenue		98.641,52	104.543,04	110.581,03	116.853,18	123.481,10	130.612,87	138.156,55	146.135,92
COGS									
Gross Margin		**98.641,52**	**104.543,04**	**110.581,03**	**116.853,18**	**123.481,10**	**130.612,87**	**138.156,55**	**146.135,92**
Fixed Costs		33.017,00	33.776,39	34.485,70	35.175,41	35.878,92	36.632,37	37.401,65	38.187,09
EBITDA		**65.624,52**	**70.766,65**	**76.095,33**	**81.677,78**	**87.602,18**	**93.980,50**	**100.754,89**	**107.948,83**
Depreciation		207.515,80	207.515,80	207.515,80	207.515,80	207.515,80	207.515,80	207.515,80	207.515,80
EBIT		**(141.891,28)**	**(136.749,15)**	**(131.420,47)**	**(125.838,02)**	**(119.913,62)**	**(113.535,30)**	**(106.760,91)**	**(99.566,97)**
Interests		(6.573,70)	(6.573,70)	(6.573,70)	(6.573,70)	(6.573,70)	(6.354,58)	(5.916,33)	(5.478,08)
EBT		**(135.317,58)**	**(130.175,45)**	**(124.846,77)**	**(119.264,32)**	**(113.339,92)**	**(107.180,73)**	**(100.844,58)**	**(94.088,89)**
Taxes		(35.472,82)	(34.187,29)	(32.855,12)	(31.459,51)	(29.978,40)	(28.383,83)	(26.690,23)	(24.891,74)
Net income sub-total		(99.844,76)	(95.988,16)	(91.991,65)	(87.804,82)	(83.361,51)	(78.796,90)	(74.154,35)	(69.197,14)
Deferred income (grants)		124.509,48	124.509,48	124.509,48	124.509,48	124.509,48	124.509,48	124.509,48	124.509,48
Net income		**24.664,72**	**28.521,32**	**32.517,83**	**36.704,66**	**41.147,97**	**45.712,58**	**50.355,13**	**55.312,34**

Income statement

Year	**9**	**10**	**11**	**12**	**13**	**14**	**15**
Revenue	154.576,14	163.503,84	172.947,17	182.935,91	193.501,56	204.677,43	216.498,78
COGS							
Gross Margin	**154.576,14**	**163.503,84**	**172.947,17**	**182.935,91**	**193.501,56**	**204.677,43**	**216.498,78**
Fixed Costs	38.989,02	39.807,79	40.643,75	41.497,27	42.368,71	43.258,46	44.166,88
EBITDA	**115.587,13**	**123.696,06**	**132.303,42**	**141.438,64**	**151.132,84**	**161.418,98**	**172.331,90**
Depreciation	207.515,80	207.515,80	207.515,80	207.515,80	207.515,80	207.515,80	207.515,80
EBIT	**(91.928,67)**	**(83.819,74)**	**(75.212,38)**	**(66.077,16)**	**(56.382,96)**	**(46.096,82)**	**(35.183,90)**
Interests	(5.039,84)	(4.601,59)	(4.163,34)	(3.725,10)	(3.286,85)	(2.848,60)	(2.410,36)
EBT	**(86.888,84)**	**(79.218,15)**	**(71.049,04)**	**(62.352,06)**	**(53.096,11)**	**(43.248,22)**	**(32.773,54)**
Taxes	(22.982,17)	(20.954,94)	(18.803,09)	(16.519,29)	(14.095,74)	(11.524,21)	(8.795,98)
Net income sub-total	(63.906,67)	(58.263,22)	(52.245,94)	(45.832,77)	(39.000,37)	(31.724,01)	(23.977,57)
Deferred income (grants)	124.509,48	124.509,48	124.509,48	124.509,48	124.509,48	124.509,48	124.509,48
Net income	**60.602,81**	**66.246,26**	**72.263,54**	**78.676,71**	**85.509,11**	**92.785,47**	**100.531,91**

Income statement

Year	0	1	2	3	4	5	6	7	8
CFFA	(4.382.467,00)	91.242,72	104.279,41	108.255,59	112.412,19	116.812,59	121.537,70	126.568,82	131.911,69
Financial Income									
Financial Expense		(6.573,70)	(6.573,70)	(6.573,70)	(6.573,70)	(6.573,70)	(6.354,58)	(5.916,33)	(5.478,08)
Debt repayment							(87.649,34)	(87.649,34)	(87.649,34)
Debt increase	1.314.740,10								
Grants/Sub-debt financing	2.629.480,20								
Dividends			(28.000,00)	(33.000,00)	(33.000,00)	(33.000,00)	(33.000,00)	(33.000,00)	(33.000,00)
+/- Capital Increase/Reduction	500.000,00								
Financing Cash Flow	4.444.220,30	(6.573,70)	(34.573,70)	(39.573,70)	(39.573,70)	(39.573,70)	(127.003,92)	(126.565,67)	(126.127,42)
Cash movement	**61.753,30**	**84.669,02**	**69.705,71**	**68.681,89**	**72.838,49**	**77.238,89**	**(5.466,22)**	**3,15**	**5.784,26**

Cash BoP	0	61.753,30	146.422,32	216.128,03	284.809,92	357.648,41	434.887,30	429.421,09	429.424,24
Cash movement	61.753,30	84.669,02	69.705,71	68.681,89	72.838,49	77.238,89	(5.466,22)	3,15	5.784,26
Cash EoP	**61.753,30**	**146.422,32**	**216.128,03**	**284.809,92**	**357.648,41**	**434.887,30**	**429.421,09**	**429.424,24**	**435.208,50**

Income statement

Year	9	10	11	12	13	14	15
CFFA	137.584,74	143.607,52	150.000,67	156.786,07	163.986,85	171.627,49	(1.474.388,59)
Financial Income							
Financial Expense	(5.039,84)	(4.601,59)	(4.163,34)	(3.725,10)	(3.286,85)	(2.848,60)	(2.410,36)
Debt repayment	(87.649,34)	(87.649,34)	(87.649,34)	(87.649,34)	(87.649,34)	(87.649,34)	(87.649,34)
Debt increase							
Grants/Sub-debt financing							992.473,50
Dividends	(33.000,00)	(33.000,00)	(33.000,00)	(33.000,00)	(33.000,00)	(33.000,00)	(33.000,00)
+/- Capital Increase/Reduction							
Financing Cash Flow	(125.689,18)	(125.250,93)	(124.812,68)	(124.374,44)	(123.936,19)	(123.497,94)	869.413,81
Cash movement	**11.895,57**	**18.356,59**	**25.187,99**	**32.411,63**	**40.050,66**	**48.129,55**	**(604.974,79)**

Cash BoP	435.208,50	447.104,07	465.460,66	490.648,65	523.060,28	563.110,94	611.240,49
Cash movement	11.895,57	18.356,59	25.187,99	32.411,63	40.050,66	48.129,55	(604.974,79)
Cash EoP	**447.104,07**	**465.460,66**	**490.648,65**	**523.060,28**	**563.110,94**	**611.240,49**	**6.265,70**