What economic model for a sustainable and affordable domestic lighting in suburban and rural areas in the Democratic Republic of the Congo?

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WHAT ECONOMIC MODEL FOR A SUSTAINABLE AND AFFORDABLE DOMESTIC LIGHTING IN SUBURBAN AND RURAL AREAS IN THE DEMOCRATIC REPUBLIC OF THE CONGO?

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SUMMARY

GLOSSARY

- **AC**: Alternative current
- **ADA**: "Auto-développement Afrique"
- **BMC**: Business Model Canvas
- **CFA**: "Communauté Financière Africaine" or "African Financial Community"
- **CPR**: Common-pool resources

  "A common pool resource is a resource that benefits a group of people, but which provides diminished benefits to everyone if each individual pursues his or her own self-interest. The value of a common pool resource can be reduced through overuse because the supply of the resource is not unlimited and using more than can be replenished can result in scarcity. Overuse of a common pool resource can lead to the tragedy of the commons problem." (Investopedia, 2018, first paragraph).

- **CSR**: Corporate social responsability
- **DC**: Direct current
- **DRC**: Republic Democratic of Congo
- **ISF**: Ingénieurs sans Frontières
- **"North" & "South"**: When speaking about development cooperation, we generally refer to the developed countries as being part of the "North" as opposed to the least developing countries which are part of the "South". This denomination has nothing to do with geographic location.
- **OECD**: Organisation for Economic Co-operation and Development
- **RDC**: "République Démocratique du Congo"
- **SMBC**: Social Business Model Canvas
- **WOM**: Word of mouth

INTRODUCTION

Africa possesses countless resources: precious stones, rare ores, a singular fauna and flora and much else. But it is also where 1.2 billion of people live (Energies pour l'Afrique, 2015). This population sits on maybe the most astounding treasures in the whole world. And despite this, Africa figures among the poorest continents (Observatoire des inégalités, 2013). The continent only consumes 3% of all the energy produced in the world and more than 620 million of people in Africa live without access to electricity. There are a lot of disparities on this continent. The most preoccupying is the situation in Sub-Saharan Africa where the electrification rate in rural areas can go below 10% (Energies pour l'Afrique, 2015).

Hard to believe, when we know all the energetic potential the continent has: hydroelectric power, solar, wind, fossil fuels… All are underexploited. The African population is expected to double within 30 years and when we consider all the social, environmental and economic impacts lack of electricity access can have[1], this is definitely a major issue. And within this general African and Sub-Saharan context, there is the special case of the Democratic Republic of Congo (DRC).

The DRC is a country whose population reached almost 79 million in 2016. More impressive is its population growth rate over the last fifty years – 3% against 0.35% for Belgium[2] (La Banque Mondiale, 2017)[3]. The country faces dramatic issues in the field of electricity supply. In 2011, only 9% of the population had access to electricity and with a mediocre quality of service. Worse, in rural areas, the supply does not reach 1% of the population. The situation is such that, at the moment, the DRC is the least electrified country in the whole world! (Munga, 2017).

The authorities are aware of the situation and took measures, in an attempt to fill the gap. The Congolese government also recognizes its lack of power in solving the electricity access issues across the country. That is why, in 2014, they began liberalizing the electricity sector with the aim of galvanizing it (Munga, 2017). However, it will be long before real effects will be seen, and it is very likely that the first beneficiaries of the measures will be urban populations. Remote and rural communities will have to wait even longer.

[1] Deforestation, health, food security, economic electricity dependent activities, waste of time, communication, living conditions and much more.

[2] Compound annual growth rate formula: = ((End Value/Start Value) ^ (1/Periods) -1

[3] Data retrieved (February 13, 2018) from https://donnees.banquemondiale.org/pays/belgique?view=chart & from https://donnees.banquemondiale.org/pays/CD

Access to energy is considered as a keystone for economic, political and social development by the "Fourth international forum on African perspectives" (Quatrième forum international sur les perspectives africaines, 2004). The access to quality energy has a lot of impact: fighting against hunger, education development, improvement of sanitary conditions, lengthening of working hours, production improvement, rise in employment, economic diversification, better information flow and democracy reinforcement to name but a few. All these elements are related to the three main interconnected poles that are the living conditions, the economic activity development and the effectiveness reinforcement of public interventions (see Appendix I). All are dependent on access to energy. The main concern of this paper is the access to energy with respect to education.

In Sub-Saharan Africa and specifically in the DRC, those children with access to education cannot entirely benefit from it, because they do not have access to electricity at home. As a result, they do not have decent conditions to do their homework in the evening. They usually resort to oil lamps, which are inefficient and represent a danger to health due to gas emissions, but also represent a significant cost for the household in the long run (fuel being the main factor), not to mention other dangers, such as fire (*Solarly, 2016*).

The present paper investigates and analyzes the feasibility of a project and the underlying economic model whose purpose is to provide solar lamps to schoolchildren. By providing them with solar lamps, the goal is to permit them to do their homework in decent conditions and avoid the use of oil lamps that slowly kills them.

Firstly, we will present the project and the context in which it will take shape, as well as the methodology we followed to answer the question of this thesis. The project has two main concerns that need to be explored. These are the governance and the economic aspects.

Secondly, we will present the governance issues and see how we can deal with it by using the groundbreaking work and findings of the Nobel Prize winner in economics, Elinor Ostrom.

Afterwards, we will present the economic aspects of the project. First, our general economic model using the "Social Business model Canvas", followed by an explanation and comparison of the different potential lamp suppliers for the project, as well as the financing possibilities.

Third, another chapter will present the technical feasibility of certain scenarios, as well as other technical aspects of the project.

We will end this paper with a small chapter about the link between project management and the writing of a thesis.

1 GENERAL PRESENTATION

1.1 PRESENTATION OF "INGÉNIEURS SANS FRONTIÈRES"

"Ingénieurs sans Frontières (ISF)" is a Belgian non-governmental organization (NGO) based in Brussels, whose purpose is to aid disadvantaged communities around the world through engineering projects. It has two main geographical areas of activity:

- In the North, ISF focuses on education with the aim of raising awareness about the role the engineers have in technological development. ISF emphasises those technologies that serve the population, whilst being ecologically aware.
- In the South, ISF provides support to aid projects instigated by local communities that face a technical problem. They concentrate on three main areas: solar electricity, access to water and waste management.

ISF consists of 3 members, including one remunerated employee and two unpaid workers.

The organization regroups more than 300 volunteers of many different profiles (types, ages, experiences, trainings and skills). All together, they represent a very interesting panel that forms one of the most important strengths of the organization.

In their projects, ISF emphasizes the empowerment of the communities in the South. ISF wants to make them aware of their responsibilities, that they need to take things in hand themselves for their future. They criticize the development cooperation that provides resources to the South without involving the beneficiaries. They especially condemn the resulting behaviors that can appear in the South, where people start to see western aid as their due and wallow in their situation as helpless persons.

Indeed, ISF has a policy that we consider to be a "non-fish giver", a reference to the maxim: *"Give a man a fish, and you feed him for a day. Teach a man to fish, and you feed him for a lifetime".* ISF is against projects that gather resources and then give them away for free to its beneficiaries. Its members defend long term visions regarding cooperative projects. Therefore, they requested that the scheme be economically sustainable. They want it to remain, even if ISF needs to withdraw from the project for whatever reason.

1.2 PROJECT PRESENTATION

The general purpose is to establish an economic model, which will provide access to a sustainable light source for the rural and/or suburban populations in the Democratic Republic of the Congo. The project will pay particular attention to the school children with the aim of providing them with decent conditions to do their homework.

The solution presented here is a 3-year project. It has recourse to solar lamps to provide such a source of light. The project aims to provide these lamps, primarily to the families of school children, through the creation of a parents' association and a partnership with a financing organization. The project will consider 250 lamps at first. This figure comes from the number of families with children studying in Sindi's school.

Regarding the solution provided, ISF has made some requests. As mentioned, the project should be non-fish giver. Therefore, the project has been developed to be profitable and sustainable. The customers will have to pay for the use of their lamp and the community of Sindi will be largely involved. The project is made to last, socially and economically.

The idea of doing this project comes from another project that ISF had carried out before. ISF helped to electrify a school in a suburban area of the city of Boma in the Democratic Republic of the Congo called Sindi. This electrification allowed the population to teach courses at night and improved the quality of the education. However, one issue persisted: once back home, children struggled to do their homework. The reason was a lack of access to sufficient light. Either they had recourse to oil lamps or did not have access to light at all. Oil lamps are expensive, the light they provide is poor and the gas emanations they generate kills thousands of people every year! The school electrification project was thus incomplete. It is in an attempt to completing it that the idea the present project saw the light of day.

At the beginning, the focus was not especially on Sindi which is a suburban area of the city of Boma in the Democratic Republic of the Congo. The project and the economic model claimed to be general but choosing Sindi was so obvious that we could not have avoided it. We contacted Roger Pholo, the contact person ISF had for the school electrification project, who directly showed his interest and enthusiasm for the new project. Roger Pholo is the priest of Sindi's community and is in charge of the management of the school he built with citizens and which ISF electrified (C. Jussiant, personal communication).

Thus, although it can be generalized, and we will do so later in this paper, the economic model presented here has been developed regarding the context and the environment of Sindi as well, as through the information provided by Roger Pholo.

During the study of the project we did not have the chance to go on site and meet the key persons who are concerned with the project. It would have been very interesting, but we did not have the time nor the money to make it possible.

Therefore, to insure the feasibility of the project, it is necessary to have a complementary study on site before being implemented. This project, mostly theoretical, might be adapted if some information collected from here is different from that collected on site.

1.3 METHODOLOGY

In this section, we will develop the methodology we have used and the main steps we have followed to answer the question of this thesis.

1.3.1 Getting to know the context: general research

Before the start of our internship, we had no information or knowledge about the issue we were asked to solve. We were and still are very interested in the project. The project is totally aligned with our values. We are also concerned with the fate of people in the South and especially with people from the DRC regarding the history Belgium has with the Country.

The first part of our work consisted in making some research about the global context on the internet and discussing with our mentor about the objectives. He shared with us the information he already had from previous research and past experiences. We also had the occasion to speak with Myriam Kresse, member of ISF, who is experienced with the African context. The objective was to understand the concern, the situation, the energy sector in Africa and the living conditions of the people targeted by the project.

The second objective, more practical, was to search for similar projects that have already been done for inspiration, but also to take a first look at the lamp market and the different possibilities available to carry out the present project. We obtained this information through online research and exchanges with our mentor, who had already effected some research on the subject. We were also advised and guided in our research by Myriam Kresse and by two members of the “Solarly” association, Maxime Dolberg and Julien Riat, who shared documents and information with us.

This first step was extremely important. It allowed us to obtain a general vision of the topic, to structure our work and moreover, to raise the important questions that are to be assessed to solve the thesis question.

1.3.2 Theoretical framework

There are two important aspects in the project that are critical: the modelling of the project and its governance. To take these two subjects up, literature was required to provide us with the necessary theoretical framework to guide and support our work.

Regarding the modelling, we mainly used two papers to construct the economic model and guide our reflections: the book from Alexander Osterwalder and Yves Pigneur entitled "*Business Model Generation*[4]" and the one from Ingrid Burkett entitled "*Using the business model canvas for social enterprise design*[5]."

The first book presents the business modeling tool developed by its authors called "*Business Model Canvas (BMC)*". Multiple variants, such as the "*Social Business Model Canvas*" or SBMC, have been developed by other authors. According to them, the BMC was not complete enough, more specific businesses such as social businesses. Ingrid Burkett is one of these authors. She developed her own version of the SMBC thanks to her experience in the social business field.

To tackle the governance aspect of the project, we were recommended by our mentor to study, and follow if relevant, the recommendations and findings presented in Elinor Ostrom's book: "*Governing the Commons, the Evolution of Institutions for Collective Action*." Rewarded with the economic Nobel prize in 2009, Ostrom presents governing and structure conditions under which Common-pool resources have been successfully or unsuccessfully managed or preserved through historical communities and empirical data. We also followed the recommendation of interviewed resource persons. Nathalie Rucquoy from "Auto-développement Afrique" (ADA), who is used to create "solidarity communities" among very poor communities in Africa, shared her past experiences with be and provided us with good advice. We completed our information through online research to get inspiration from existing similar projects.

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[4] Osterwalder, A., Pigneur, Y. (2010). *Business Model Generation*. John Wiley & Sons, Inc., Hoboken, New Jersey.

[5] Burkett I. (n.d.). *Using the business model canvas for social enterprise design,* Retrieved (April 30, 2018) from http://cscuk.dfid.gov.uk/wp-content/uploads/2016/07/BMC-for-Social-Enterprise.pdf

1.3.3 Getting on the field: data collection

The next step was about gathering the data needed to go further in the model. The aim was to make it more tangible and more practical. To do this, we required data from both sides, the customers and the suppliers.

Nevertheless, before everything, we had to know where the model would be implemented. It was important since the information we could obtain from the customers greatly depended on the location, as well as the transportation costs of the merchandise. That is when we agreed, with our mentor, to consider Sindi, the location where ISF carried out the school electrification project that inspired the present project, a perfectly suited place. Moreover, ISF still had good relations with the on-site organization in the person of Roger Pholo (C. Jussiant, personal communication).

We presented the project to Roger Pholo who directly shared his interest and accepted to collaborate with us. Roger Pholo provided us with the information we needed, regarding the customers and the environment of Sindi and answered the questions we had about different aspects of the model.

The other data we needed, more critical, was the supplier of the lamps, as well as their costs. We made research on the internet to find potential partners according to their offers (products, prices, locations). A lot of suppliers exist, that is why we used certain criterion to reduce and better target the most interesting ones. The most interesting responses we had were from Lagazel, Total and Ecozoom with who we went further into the details.

- Lagazel is a French company, present in various African countries[6], that sells solar lamps made in France and Africa[7].
- Total is present on the African solar lamp market through its project called Awango. The "Awango by Total" solar lamps are part of a broader project launched by Total: "Total access to energy" which carries the will of Total to give everyone access to energy (Total, n.d.)[8].
- Ecozoom "is a social enterprise and certified B Corporation dedicated to bringing ecological products to the world (Ecozoom, n.d.)[9]." Their main products are cookstoves, but they also produce solar lamps (Ecozoom, n.d.)[10].

[6] http://www.lagazel.com/contact

[7] http://www.lagazel.com/produits

[8] https://www.total.com/en/our-expertise/renewable-energies/solar/infographics/awango-total-facilitating-access-energy-least-advantaged

[9] https://ecozoomstove.com/pages/about-us

[10] https://ecozoomstove.com/pages/solar

Each of these suppliers have different offers with their own advantages and disadvantages that we will present further (cf. “The suppliers and offers” chapter).

We interviewed resource persons to help us assess the costs of financing of the project and the possible means of doing so.

- Jean-Baptiste Bokoto from Africa Synergie, who has launched his business and has already carried out projects in Africa and in the DRC.
- Rudi Verheyen, relationship manager for the non-profit sector at CBC Bank. He gave us information concerning a potential micro-financing through credit institutions.

1.3.4 Retrieving the information: data analysis and results

Once we had the information we needed, it was time to analyze the data. We performed calculations with the data from the suppliers in order to make enlightened comparison of the offers. We also used the contextual data Roger Pholo gave us, to analyze the feasibility and potential profitability of the project. We were also able, through the information and recommendations we had concerning the governance, the financing and the form of the on-site organization, to evidence and compare the different possibilities for the project in these different fields.

2 GOVERNING THE COMMON GOODS

The present project would not make any sense if it did not include the suitable management and governance aspects allowing its sustainability. The purpose of this chapter is to find the right governance and management tools permitting the project to be sustainable.

When speaking about the governance of common goods, it is difficult to avoid referring to Elinor Ostrom's book, published in 1990, entitled "Governing the Commons, the Evolution of Institutions for Collective Action[11]." Her work aimed at understanding why and how individuals were able to manage common goods, without using the traditional frameworks of the public (the State) and private sectors. She based her paper on many other publications treating governance issues of common goods and on communities, who across history, proved to be capable of managing their common and rare resources over a long period of time. In 2009, the paper was rewarded the economic Nobel prize in economic sciences (Bottollier-Depois, 2012).

The literature about the governance of the commons is not plentiful and Elinor Ostrom's work seems to be the best one on this topic. That is why we mainly based our work on this paper to tackle the governance issues of the present project. The following chapter presents the main findings from Elinor Ostrom's paper and how they can be applied to our specific situation.

2.1 CONNECTING THEORY AND PRACTICE

2.1.1 Definition of a common good

Elinor Ostrom defines the commons as follows: "*The term "common-pool resource" refers to a natural or man-made resource system that is sufficiently large as to make it costly (but not impossible) to exclude potential beneficiaries from obtaining benefits from its use.*" (Ostrom, 1990, p30).

In her definition, Ostrom refers to resources such as fishing grounds, parking garages, grazing areas, groundwater basins, etc. (Ostrom, 1990). All resources from which benefits can be obtained and that are easily accessible to the public, as opposed to private resources. Common resources differ from private resources in that the beneficiaries of private resources are limited by the owners of the resources, while commons are not. As a result, it can be very costly to prevent individuals from

[11] Ostrom, E. (1990). *Governing the Commons, the Evolution of Institutions for Collective Action*. Cambridge, England: Cambridge University Press.

overexploiting common resources while they can obtain important benefits from it (Bottollier-Depois, 2012).

Ostrom (1990, p30) also introduces the notion of stock and flow: "*Resource systems are best thought of as stock variables that are capable, under favorable conditions, of producing a maximum quantity of a flow variable without harming the stock or the resource system itself."* Commons goods are those for which an overexploitation of their flows causes a decrease of the stock and may end in their destruction. (Bottollier-Depois, 2012). Thus, the concept of sustainability can be expressed as follows*: "As long as the average rate of withdrawal does not exceed the average rate of replenishment, a renewable resource is sustained over time*." (Ostrom, 1990, p30).

The distinction can also be made between common goods, that are subject to overexploitation, and *"[…] public goods (like street lighting) for which the use does not affect in anyway the use that can be made by other people* [12]*."* (Bottollier-Depois, 2012, p8, personal translation).

2.1.2 "The tragedy of the commons" and the traditional approaches

The fate of the commons is not really a new topic. Economists and philosophers have been trying to understand and solve these issues for centuries. In most analyses, the individuals are considered as being rational, which leads to the conclusion that any commons will eventually end up overexploited and thus, deteriorated. With Garett Hardin's work came the expression "the tragedy of the commons."

"The tragedy of the commons" can be summarized by using the example of herders having access to a pasture where their cattle can graze. Each herder directly receives benefits from their animals and are considered to act rationally. Thus, in the aim of maximizing their profits, each herder will tend to graze as many animals as possible; even if this behavior leads to overgrazing and a deterioration of the pasture and later, to lower or inexistent profits. Why? Because the herders only bear the costs of overgrazing later in time. Because they are rational, they act such that they maximize their short-term profit. If they do not do so, someone else will. Therefore, we talk about the "tragedy of the commons", because according to this point of view, any common resource is condemned to be overexploited and destroyed by rational individuals (Ostrom, 1990).

In her book, Elinor Ostrom also mentions other theories related to the commons' issues: the prisoner's dilemma game and the logic of collective action. In the first theory, which considers a noncooperative

[12] Original text: "*[…] un bien public (comme l'éclairage public) dont l'utilisation par une personne n'empêche pas une autre personne de l'utiliser"*

game in which all participants are in possession of complete information, players will always choose the dominant strategy, which is to defect. And in the second one, it is considered irrational by its author (Mancur Olson) to participate in a collective action. Because according to him, if the individuals receive benefits whether they take part in the collective action or not, they will not take part in it as it is more efficient for them. (Bottollier-Depois, 2012). As this is not the aim of this paper, these theories will not be discussed further[13]. But what is interesting is that both theories arrive to the same conclusion: acting rationally, individuals are prompt in taking decisions leading to inefficient and unsustainable uses of common resources.

Much research seems to have been done on the commons topic and this conclusion represents quite well the dead-end it has always represented and the general representation most people still have about common goods. That is why Elinor Ostrom's work and findings are so interesting; she seems to have found possible solutions applicable to cases commonly thought as being without solution issues. It contrasts with the pessimistic vision about the commons that have been prevailing for centuries, showing that it is possible to exploit commons in a sustainable and profitable way.

2.1.3 Solar lamps as commons?

Can the lamps be considered as common goods according to Ostrom's definition?

This is the first question to answer, if we want to apply Ostrom's findings to the project. At first glance, we might think that the lamps do not correspond to Ostrom's definition. But going further into the analysis, there are characteristics that permit us to consider them as common goods.

As explained, the project aims to create and put in place an economic model that allows people in need to obtain lamps at an affordable price. The model entails the creation of association. Why? Because the association, and its management body, permit relationships with the supplier who has a person to refer to and interact with for the logistics, the warranty, or any problems that can occur. It enables to create the financial buffer between the customers and the supplier, allowing customers to spread their payments over time. As financial buffer, the association will borrow the money necessary (with the help of a third-party as we see further, cf. "Financing and profitability of the project" chapter) to purchase the lamps and then will sell them to the customers. Therefore, the association and its partner will be the owners of the lamps, until these are completely paid. And most of all, the

[13] For more information about these two theories, cf.: Ostrom, 1990, p2-7

creation of an association avoids the project to be simply a one-shot project. It allows it to sustain over time through this association, reach more individuals and improve services provided.

This being pointed out, here is why the lamps can be considered as common goods regarding Ostrom's definition:

In her definition, Ostrom qualifies common resources as being *"sufficiently large as to make it costly (but not impossible) to exclude potential beneficiaries from obtaining benefits from its use."* (Ostrom, 1990, p30). In the case of this project, the resource that is put in place is sufficiently large in the sense that any interested individual can take part in it (while stocks last). Moreover, the number of lamps is substantial enough to make it costly to control the uses that are made of the lamps. Customers receive lamps while they only have paid a fraction of it. Thus, they could obtain important benefits if they just sold the lamps once obtained or use them to make money. They could also use them improperly, by not taking care of them and slowly deteriorating them, reducing their lifespan. These elements support the vision of the lamps as common goods.

However, the lamps cannot be seen as stocks capable of providing a certain flow of units. They are more like stocks that are constantly reduced as the lamps are used. The lamps' lifespan is mainly constrained by their components that wear out when the lamps are exploited. Thus, regarding the definition made above, the lamps cannot be considered as renewable resources.

Obviously, the lamps in this case cannot be considered as public, since their use indeed prevents others from using them. They also are subject to possible overexploitation as are the commons according to Ostrom.

2.2 WHAT SOLUTIONS?

In this part of the chapter:

- First, we will consider the traditional ways of solving common goods issues.
- Second, we will analyze the most relevant solutions from Ostrom's book regarding the project.
- And third, we will go further by presenting how these solutions can be applied to the project, in order to stack all the odds in our favour to make the project successful.

2.2.1 Traditional solutions

Before considering the solutions presented by Ostrom, let's look at the traditional solutions to the problems presented above (cf. "The traditional approaches" subsection).

Since people are not capable of behaving in a collective and rational way, we need to put in place elements that will make them to do so. There are two common ways to achieve this purpose.

- The first one is privatization. In this scenario, the solution considered is to remove from the resource that which makes it common. The individual rationalities are supposed to create the collective rationality leading to a sustainable and efficient way of exploiting the resources.
- The second solution is the opposite: called the "Leviathan". The creation of a strong State able to constrain the individuals to behave such that profits can be made from the resource, while not harming its sustainability. (Bottollier-Depois, 2012).

These theories seem viable so why does Ostrom reconsider them? Because according to her, these theories are certainly simple and easy to understand and picture, but actually too simple and too far from reality. They are valid theoretically speaking, but only under particular hypotheses and conditions, which are very unlikely to be present all together in real situations. Every situation is different and possesses its own characteristics. The reality is vague and complex, much more than what these models are based on. Moreover, she doubts that these are the only possible solutions to the commons issue. (Bottollier-Depois, 2012).

Since the reality is complex, the model and the underlying hypotheses should be more complex and closer to reality. "*Particularly, the information possessed by the individuals are never perfect: individuals never know the state of the resource, they do not know when it will be exploited, neither they know its exact productivity, etc*[14]." (Bottollier-Depois, 2012, p10-11, personal translation). Therefore, the reality is less important than the perception individuals have about the potential benefits and costs as summarized by Ostrom (1990, p33): "*An individual's choice of behavior in any particular situation will depend on how the individual learns about, views, and weighs the benefits and costs of actions and their perceived linkage to outcomes that also involve a mixture of benefits and costs*."

The problem is thus to find the right institution that will be able to face the following three main challenges.

[14] Original text: "*En particulier, l'information n'est jamais parfaite: les individus ne savent pas quel est l'état de la ressource, ils ne savent pas à quel moment elle sera surexploitée, ils ne connaissent pas leur productivité, etc.*"

First, the supply, in other words, how and why an institution is created, and what will be the incentives that will lead to its creation.

Second, the commitment, or how to make sure that the rules that have been fixed will be followed, that the benefits of following them will be greater than infringing them.

And third, the mutual monitoring, that is, how to organize a surveillance among and through individuals within the institution.

2.2.2 Ostrom's theoretical solution

In the solutions developed by Ostrom, individuals are still considered as rational. However, the important difference is that this rationality is biased by incomplete information. They are also considered as part of a complex system, which can have effects and influence their behaviors. (Bottollier-Depois, 2012).

The biggest contrast between Ostrom's work and more classical approaches is that Ostrom's method is inductive. Her rules and results are based and inferred on multiple observations and real cases. This represents the real strength of her paper, as opposed to the more classical approaches which start from more general and theoretical (arbitrary) assumptions, from which they deduce rules and assume behaviors. (Bottollier-Depois, 2012).

Now let's dive into the "Design principles" as they are called by Ostrom (1990, p90): these are "*essential elements or conditions that helps to account for the success of these institutions [the institutions analyzed by Ostrom] in sustaining the CPRs [Common-pool resources] and gaining the compliance of generation after generation of appropriators [the ones who benefit from the commons] to the rules in use*." These principles are not presented as "necessary conditions for achieving institutional robustness in CPR settings." (Ostrom, 1990, p90). Ostrom humbly estimates that more studies should be carried out before being able to make strong assertions, but she remains confident in the acuity of her results and the potential of the principles listed below.

Design principles illustrated by long-enduring CPR institutions. (Ostrom, 1990, p90).

1. **Clearly defined boundaries:** Individuals or households who have rights to withdraw resource units from the CPR must be dearly defined, as must the boundaries of the CPR itself.
2. **Congruence between appropriation and provision rules and local conditions:** Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local conditions and to provision rules requiring labor, material, and/or money.

3. **Collective-choice arrangements:** Most individuals affected by the operational rules can participate in modifying the operational rules.
4. **Monitoring**: Monitors, who actively audit CPR conditions and appropriator behavior, are accountable to the appropriators or are the appropriators.
5. **Graduated sanctions:** Appropriators who violate operational rules are likely to be assessed graduated sanctions (depending on the seriousness and context of the offense) by other appropriators, by officials accountable to these appropriators, or by both.
6. **Conflict-resolution mechanisms:** Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials.
7. **Minimal recognition of rights to organize**: The rights of appropriators to devise their own institutions are not challenged by external governmental authorities.

For CPRs that fire parts of larger systems (irrelevant to our context, but for information):

8. **Nested enterprises:** Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.

We will not develop these principles further, because it would be too long to do so here (Ostrom develops these over 10 pages[15]). Furthermore, in our opinion, as formulated above, they are explicit enough to be understood. In the next section, we will develop these relevant principles to the project and provide some more explanation as needed.

2.2.3 In practice

Now that we have understood Ostrom's general guidelines for the common goods management, it is time to see how they can be applied and connected to the project.

Clearly defined boundaries: The customers must be clearly identified. In the case of the project, there are 2 types of customers. The first ones, targeted here, are households that have (a) scholar child(ren). They are the heart of the project, the parents who are part of the association, and will be involved in the lamp and organization management. The second type customers are "outsiders" that are interested in purchasing lamps but are not involved in the school's life and will not be involved in the management organization.

[15] For more information, cf. Ostrom, 1990, p90-102

This principle is also about establishing the boundaries for using the lamps. The lamps should be properly used to avoid their premature obsolescence. In other words, only used to light houses at night or other related purposes, that is with due diligence. These boundaries for using must be determined by the association members.

Congruence between appropriation and provision rules and local conditions: It is important that rules governing the association, its management and its members, access to the lamps, as well as the uses made of the lamps (to name but a few) are tailored to local culture and conditions. That is why we are not capable of determining these, as we do not have sufficient knowledges about the local conditions and culture. This aspect will have to be developed on site during the establishment of the project.

Collective-choice arrangements: As previously addressed, and in relation to the above point, the individuals that are mainly concerned with the lamps (1st type customers) must take part in defining and modifying the rules. Because they interact with one another and with their surrounding world, they are best placed to modify the rules over time, so that they best fit their environment, culture, conditions and reality. Including them will make the organization more resilient to disturbing events and be more adapted and flexible. But one condition is that the cost of changing rules must remain relatively low. In our situation, this condition should easily be reached through membership assemblies since members are likely to live close to the association's location (school). Still, these hypotheses will need to be confirmed on site.

As Ostrom says (1990, p93), "*institutions that are characterized by these first three principles […] should be able to devise a good set of rules*." But even with good rules, none can assure that everybody will follow them, that is why the following two points are important.

Monitoring: In our case, the monitors will be the association members and the management body of the lamps. Here, an important proximity of the actors is assumed and will have to be corroborated, but remains feasible, given the information that we have. If possible, some should be designated, in turns, as responsible for the monitoring. The proximity of the actors is important for the information of potential deviances to circulate among appropriators. Why assign the responsibility of the monitoring in turn? To minimize individual's from gaining personal power or benefits from their position and avoid tacit arrangements (like briberies, favors, etc.). This concept should be considered for all important posts inside the management organization. Moreover, each important post, including the monitors will be accountable to the rest of the association members, and more precisely, the other management organization members.

Graduated sanctions: It is hard for us to define or even recommend adapted sanctions because we do not sufficiently know the context and culture to do so. Thus, our suggestions would likely be inappropriate. Therefore, our recommendation is to generate debate amongst members about the most appropriate sanctions regarding possible offenses as a preventive action, but also when unexpected offenses occur subsequently and most of all, to consider the cultural and social context.

Conflict-resolution mechanisms: The already existing school structure is a real opportunity. It represents a place where the association members can assemble to discuss conflicts. Our proposition of conflict-resolution mechanism, simple and cheap (mostly time consuming) is largely inspired by case studies presented in Ostrom's book (1990). It consists in establishing a court-like assembly whose responsibility is to arbitrate conflicts. Judges would be elected by community members; whose mandates are only effective for one conflict resolution. The election would be carried out with show of hands before the beginning of the assemblies. The purpose is to avoid possible conflicts of interests between the judges and the parties. The assembly can thus elect the individuals they consider best to arbitrate whichever conflict. The parties would afterwards defend themselves and expose their arguments to the assembly, that will once more vote with show of hands to decide which sanction should or should not be applied.

An abusive use of this mechanism must be avoided. This mechanism should be used only for relatively important conflicts among the community, or when a sanctioned member or customer wants to contest a penalty that he considers as inappropriate, unfounded or unjustified.

Minimal recognition of rights to organize: The administration must approve, be aware and be included in the project as soon as it is launched, especially in the DRC. We were informed[16] that the DRC administration can represent a real threat to projects of this kind. It is common in the DRC administration for representatives to try taking personal advantages of such projects by arbitrarily fining it. Moreover, delivering energy to citizens is one of the services that is supposed to be provided by the Congolese administration. That is why it is important to include the administration and gain its approval. Particularly so the project is not seen as a threat by the administration, but as an opportunity. Regarding the little means the administration may have, it can work in concert with the association to improve the impact and share the costs of some services (energy, but also education

[16] (C. Jussiant, personal communication); (N. Rucquoy, personal communication, April 13, 2018); (J. Defourny, personal communication, April 18, 2018); (J-B. Bokoto, personal communication, April 16, 2018)

where members could decide that some of the organization's profits would be used to improve education).

All the elements developed above are to be debated, defined and decided within the school's community. Once more we reiterate that the recommendations we make are not to be blindly followed. We do not have sufficient knowledge of the culture and social context in Boma to do so. They are just ideas for further inspiration. What is critical is that the concepts above are understood and that one will see how to put them properly in practice.

2.3 CRITICISMS

As we already discussed, Ostrom prodded somewhat the traditional way of doing economics. She worked in an inductive way, starting from real life examples from which she retrieved models. This is opposed to the more traditional methods, using deduction where models are built and only valid under hypotheses that are not really "natural" or are too simplistic. Such as the vision that individuals are purely rational and always seeking maximization.

Reality is more complex and diversified and cannot be summarized with such restrictive hypotheses. (Bottollier-Depois, 2012). This is why Ostrom's work is an attempt to open new ways of thinking and modeling economics. Her work, although groundbreaking, is not perfect and can be criticized. In this section, we only focus on the negative criticism. Many positive ones exist but the aim here is not to defend or justify the use we made of her work – her Nobel prize, the quality and credibility of her work does not need further discussion and online research can quickly corroborate our point.

Nonetheless, her work is not perfect, nor it is complete and further research is still required (she was the first to admit it and to present her work more as a starting point of further research (Ostrom, 1990)).

Yet, we can put things into perspective considering our framework. We struggled to find critical reviews relating to similar contexts, that is why our criticism is certainly not complete but still permits to cover the main lines that tell us why we need be cautious about Ostrom's recommendations.

According to Bottollier-Depois (2012), some hypotheses underlying her model are not developed or highlighted enough. "*Her model mainly depends on the analyzed data: these ones contain a certain*

number of bias which constitute the limitations of the model."[17] (Bottollier-Depois, 2012, p17-18, personal translation). Bottollier-Depois (2012) considers the three following characteristics, which are all present in the Ostrom case studies and thus represent hypotheses of her model.

The discount rate in Ostrom's case studies is low, that is, individuals in her examples do not give too much importance to the present, they are aware that the existence of institutions preserving their commons could result in being profitable for them.

On the opposite, if people were living in very poor conditions where the use of the commons is vital, their discount rate would be much higher (Bottollier-Depois, 2012). Yet, this is the case in the environment of Sindi. Even if compared to other communities, people in Sindi are not the poorest, they still live in very poor conditions with a relatively high discount rate (R. Pholo, personal communication, April 2018). Without this low discount rate hypothesis, one could say that the model would not work in our situation or might but with less certainty then Ostrom could argue.

However, even though people are poor, they are not in a vital situation. We have discussed with Nathalie Rucquoy from ADA, who is used to work with way poorest communities. From her experience, there are reasons why the model could still work here. With the right incentives to group the community, such as a meaningful purpose like Sindi's school and the education of their children, it is likely that they will perceive the future benefit of the project. Therefore, their discount rate around the project would be reduced. It already has worked with the poorest communities, so it is reasonable to consider that it could still work here (Nathalie Rucquoy, personal communication, 13th of April).

"*The individuals in the case studies have a high level of mutual trust. We can make the hypothesis of strategic behaviors developing and thus we can expect that the neighbors adopt a strategic and manipulating strategies. In these conditions, mutual trust is impossible*[18]*."* (Bottollier-Depois, 2012, p18, personal translation).

In the DRC, where people are reputed to be opportunistic and individualist, this element is critical and represents one of the most challenging points of the present paper. But challenging is not impossible. Once again, Nathalie Rucquoy explained that they achieved to build a "solidarity community" with ADA and reestablish trust in the poorer and more individualistic communities.

[17] Original text: "*Son modèle est fortement dépendant des données analysées: ces dernières comportent un certain nombre de biais, qui constituent donc les limites de validité du modèle*."

[18] Personal translation: "*Les individus ont un fort niveau de confiance mutuelle. […] On peut même faire l'hypothèse que la présomption de comportement stratégique se développe, c'est-à-dire que l'on s'attend de plus en plus à ce que son voisin se comporte de façon stratégique (donc manipulatoire). Dans ces conditions, la confiance est impossible*."

They succeeded by gathering people together around significant projects and objectives. She recommended that we consider Sindi's school as a convening element for the project and this is why the school will be central in our project. It represents a pre-existing structure and a meaningful project for Sindi's community around which a community can be built and mutual trust be restored.

The third hypotheses presented by Bottollier-Depois is the small scale of the common-pool resources, and in our case, this hypothesis is respected as no more than 300 people should be concerned.

2.4 CONCLUSION

In conclusion, we will say that although Ostrom's work cannot be seen as totally prescriptive, it still represents a good base for reflection and provides guidelines on which we can lean to reflect and structure the governance of the project. No one can predict the success of a project in advance, especially with such a highly contextual one as ours. The most we can do is to stack all the odds in our favor to reach success which we believe we have achieved through Ostrom's work and through advice and remarks from more experienced persons, such as Nathalie Rucquoy.

3 DESCRIBING THE MODEL: THE "SOCIAL BUSINESS MODEL CANVAS"

"*A business model describes the rationale of how an organization creates, delivers, and captures value*" (Osterwalder & Pigneur, 2010, p14).

The "*Business model canvas*" is a business modeling tool developed by Osterwalder & Pigneur (2010) in their book entitled "*Business model generation*" or BMC (see Appendix II). The BMC is a concept which purpose is to provide us with "*a shared language that allows us to easily describe and manipulate business models*". (Osterwalder & Pigneur, 2010, p15).

The BMC consists in nine building blocks which cover the four main areas of a business: customers, offer, infrastructure, and financial viability. Put all together, the building blocks allows to present the most complex models in a very simple way. Its main strength is its flexibility. It provides a very good overview of a model and permits to easily interact and adapt it to new information.

In their book, Osterwalder & Pigneur argue that their BMC can be used for modeling social companies. However, some practitioners thought that adaptations needed to be made to the BMC in order to better fir the specificities of the not-for-profit sector. That is why came up the new concept of "*Social Business Model Canvas*" or SBMC.

A lot of "social adaptations" of the BMC exist, all derived from the original and with their specificities. One of these is the SBMC developed by Ingrid Burkett (n.d.) in her book entitled "*Using the business model canvas for social enterprise design*". We chose to work with Burkett's SBMC (see Appendix II) because her book provides complete explanations about her BMC's vision, it is simple, understandable and because according to us, it was appropriate to our situation.

We also adapted a bit her canvas by adding two building blocks called "*Surplus*" and "*Impact measures*" which were largely inspired from the Business Model Toolbox's canvas (Business Model Toolbox, n.d.)[19]. We chose to incorporate these two in the original canvas because according to us, they complete and provide interesting dimensions to our SBMC. These two are a bit apart from the other building blocks, that is why they will be discussed in the "*Epilog*" section below.

[19] http://bmtoolbox.net/tools/social-business-model-canvas/

We have thus built our economic model using Burkett's "*Social Business Model Canvas*", but why did we choose with this modeling tool?

The first reason, is because these tools are very easy to use, understand and present. Since the model is meant for the people from ISF, that do not necessarily have economic knowledge, it must be easy to describe and be accessible (understandable) to the general public. That is why we believe that using the BMC and SBMC as modelling tools represents a real asset to the project.

The second reason is the popularity and reputation of the BMC. Its use is recommended by many specialized companies and organizations such as the "Venture Lab" of the University of Liège (Surlemont, 2017), the consulting company "Strategyzer" [20], the business media company "Forbes[21]", the "Stanford Social Entrepreneurship hub[22]" and many others.

The last reason is that we were already used to it. We had the opportunity to use it in the framework of other courses during our cursus in HEC-Liège[23]. We personally think that we performed better, spared precious time and was more confident and effective in our work than if we had been using another tool that was unknown to us.

Now that we have presented the origins of the SMBC, the BMC, the reasons why we used them and the papers from which they came, let's have an insight about this chapter's content. This chapter will present the SBMC as applied to the project, where each section of the canvas will be explained in detail. Little by little, with each additional section, the economic model will take shape. At the end, the reader will have a global and detailed vision of the model.

The BMC, as well as the SBMC, can be presented as a "story" that narrates the different parts ("*building block*") of the model. With each additional block, the model takes shape and making the way it delivers value more and more understandable to third parties (Strategyzer, 2013). In her version of the SBMC, Burkett (n.d.) separates the commercial segment from the social impact part of the model. In our canvas (see Appendix III), the commercial aspects are presented by yellow sticky notes and the social impacts by red ones. Let's now get into the story of the model (We recommend reading the canvas one box at a time).

[20] https://strategyzer.com/canvas/business-model-canvas

[21] https://www.forbes.com/sites/tedgreenwald/2012/01/31/business-model-canvas-a-simple-tool-for-designing-innovative-business-models/#1410c36816a7

[22] https://sehub.stanford.edu/pro-1

[23] Including the course of "Strategy and Sustainability – Seminar (GEST1076)" conducted by Nathalie Crutzen and Marc Deschamps.

3.1 PROLOG

The form of the organization that will be created by the project has been a long topic for discussion. Will the organization be non-for-profit, a company, a cooperative or an organization without legal entity? After consideration, it appeared that the organization should be either non-profit or a cooperative.

We developed a comparison between both in our internship report where we concluded by saying that no decision could be made at that time (Bosseloir, 2018). However, given the progress we have made since, it appears that the cooperative model should be the most appropriate. Indeed, in the project, we would like the members to actively take part in most of the project's activities – main decision-making, rules' establishment, monitoring activities, sanctions system as well as conflict resolution system – as recommended by Ostrom's findings and as presented in the preceding chapter (cf. "Governing the commons" chapter) and in the following sections.

Most of these elements are similar to the operating model of a cooperative. This conclusion is subject to different interpretations, the project could be successfully undertaken through another form – with some necessary adjustments. However, our findings would suggest that the cooperative option is the best model.

Until our meeting with Nathalie Rucquoy (2018 April 13, personal communication), we believed the project should start with the creation of a cooperative with its own legal personality. Yet, even if the cooperative model seems to be the best option, the creation of a such an organization in the early stages of the project might be difficult.

In light of her experience, Nathalie Rucquoy advised us against doing so. According to her, creating a cooperative for such a small project is not necessary and could represent huge investment in time, money and effort considering the importance of the project. Instead, she advised launching the project without creating a legal entity in the first place. The necessity of doing so should be assessed later in the project.

The other possibility would be to use a local organization. This organization could thus serve as anchor point and provide the necessary structure for the project. Such an organization already exists. The Sindi's school is managed by a non-profit organization called "Œuvres pour l'enfance défavorisée". Of course, its status do not mention solar lamp projects as presented here, but the 5th article, in which are mentioned its object, stipulates: the organization "*is mainly created in the aim of supporting children […] in their need of education and health […]: giving them a chance for a good*

education and a total fulfillment." ("Œuvres pour l'enfance défavorisée" – Status, 2014, p2, see Appendix IV). Given this description, our solar lamp project can be considered as respecting the organization's object.

"Œuvres pour l'enfance défavorisée" is a real asset for the project, especially as Roger is this organization's president. Using its structure, its members, and its influence, it could serve as a support for the project during its incubation phase. Once mature, the project can become independent and create its own legal entity. This procedure will only start once the project will be well-proven, autonomous and ready to take the plunge.

Thus, the advice given by Nathalie Rucquoy is to first begin the project without creating the cooperative. We should put everything in place, see how it goes and wait for the project to be firmly in place, before considering the cooperative creation. And then, if this is possible and represents an added value to the project, the cooperative can be created.

Therefore, in the presentation of the model below, we do not refer to the members as being part of a cooperative. The model refers to an association that would be created by the parents who have children in Sindi's school. In any case, considering an association instead of a cooperative does not change the fundamentals of the model. All the recommendations made in this paper remain valid. The association would not have the legal character a cooperative would have, but its operations continue the same as for the cooperative. The only real difference comes from the financing. Because the association does not have a legal personality, it cannot take out a loan. The project will need an initial financing; this one will need to be provided by other means (cf. "Financing and profitability of the project" chapter).

In Africa, projects should not start out too big. This is advice coming from our mentor's experience[24]: "When starting a project in Africa, do not dream it too big too fast". Better to get one small project working well than one big project that does not work. That is why the project begins with the solar lamps, instead of considering the creation of an entire mini-grid for example.

As we will see further in the present chapter, the project can be generalized and thus, potentially duplicated. We really think that it can be applied to other communities. Of course, not in its current form, but with the necessary adaptations to the community's specificities.

[24] Claude Jussiant, personal communication, n.d.

3.2 VALUE PROPOSITION

The value proposition block in a BMC represents the value that is created for the customer segments (Osterwalder & Pigneur, 2010). The commercial value proposition is to provide a sustainable, clean and affordable lighting solution. It aims at replacing polluting, expensive and inefficient light sources by cleaner, cheaper and more efficient ones. The use of this new light source will have different positive effects.

First, it will prevent the population from using oil lamps that poison themselves and their environment with fumes emanating from petrol combustion (Le Figaro, 2012). In Africa, especially in countries with poor energy access like the DRC, the main light source is oil lamps and the electric domestic production mainly comes from oil-driven electric generators (Radio Okapi, 2015).

Second, these widespread oil lamps have become expensive compared to other cleaner technologies like solar panels. The present project will allow households to make cost savings on their domestic (cf. "Financing and profitability of the project" chapter, "Purchasing power" subsection). The lamp price will also allow people who cannot afford oil lamps to start lighting their households, increasing their quality of life.

Third, solar lamp runtimes allow their use for more than 12h (Lagazel, n.d.). Moreover, the efficiency of batteries powered lamps like LED's, allows a better visibility, increased comfort and can benefit several persons performing multiple tasks at the same time.

But the created commercial activity is, before anything else, a social project. Its main social value proposition is to serve as a starting point for the development of a stronger community and the creation of a "solidarity community[25]". The project has the potential to create a more empowered, united and developed community. It will seek to empower it by providing the community with great development opportunities and tools, such as a structure to collectively take decisions and means to undertake other projects in the future. A solidarity can be built around a common project, objective. We will come back to the "solidarity community" aspect in the following section (cf. "Customer segments" section below).

The project has the benefit of giving power to its customers by allowing them to reduce their cost of living, increase their quality of life and make savings. In poor communities, like Sindi's, such savings

[25] Nathalie Rucquoy, personal communication, April 13, 2018.

can be really empowering. It increases their purchasing power, allowing them to spend money for other more important things like education, food, health, water, …

The empowerment can also simply come from being able to light at night. Given the hour at which the sun sets in the DRC, it can be hard for Western people to imagine how much of the active part of the day is lost due to lack of light. It can be really incapacitating. Without light at night, it is hard, if not impossible, to work. No economic activities are possible, interactions are difficult and walking around at night is not safe.

Another social value proposition, and the main social impact of the project, is to provide the school children with what they need to properly do their homework and improve their education: light.

3.3 CUSTOMER SEGMENT

The customer segment block describes the groups of people that are targeted by the model and its value proposition (Osterwalder & Pigneur, 2010). Generally speaking, the targeted populations, the commercial customer segment, are communities living in suburban and/or rural areas in the DRC where access to electricity is very low or non-existent and where electrical production is expensive and polluting. Yet, in practice, the present project targets Sindi's population and put the emphasis on Sindi's school children and their families who represent our impact customer segment. The project will reach them through the already existing parents' committee. This committee, voted by the parents' general assembly, insures the collaborative interactions between the school and the parents[26]. The existence of such a parents' association is a real asset for the project to succeed.

The reasons for choosing Sindi as a location have already been presented (cf. "General presentation" chapter). But why focus the project on the school children in Sindi?

At first, with our mentor, we were thinking the project as separate from the school environment and were only considering the added values of the lamps and the creation of economic activity. When we presented the project as it was to Nathalie Rucquoy, she communicated her skepticism.

According to her, to only rely on the economic aspect of the project and the advantages provided by the lamps would not be enough to attract members, to insure their involvement and the durability of the project. Nathalie Rucquoy has immense experience and is very familiar with creating "solidarity communities" as she calls them. She has worked with far poorer communities than Sindi's and where

[26] Roger Pholo, personal communication, May 1, 2018

the mutual trust among the population was far lower. Based on her experience and past successes with these communities, she advised us to build the project around a stronger, more meaningful purpose in the eyes of the population. For example, the education and future of their children, that is Sindi's school[27]. We decided to follow her advice, supported by other positive opinions from our supervisor, Jacques Defourny and from Jean-Baptiste Bokoto[28].

This is why the project focuses on Sindi's school children and their parents. The lamps will allow the schoolchildren to do their homework and to do so in decent conditions, improving their working conditions and their education. The children's education will serve as a powerful incentive to the project. Moreover, the project can take advantage of the already existing community and the management structure of the school such as the parents' association and "Œuvres pour l'enfance défavorisée" which, as mentioned, could be used as a facilitator for the project.

3.4 CHANNELS

The channels block in the BMC represents how an organization can reach its customer segments. It includes the way they communicate and how they deliver value (Osterwalder & Pigneur, 2010). Several means will be used to communicate about the project.

First, at the project's launch, a general presentation of the project should be made to the parents' general assembly, with the help of the parents' committee. The purpose will be to expose the project to the parents, its implications, its nuts and bolts, its ins and outs and its potential; but also, to obtain the parents' approval and involvement, without which the project would be at risk. The event could also be used to obtain the first interesting feedback from parents: new ideas, interesting remarks and questioning will most probably come up. Taking these into account in the project will largely improve its chance of success.

Second, making the logical assumption that people inside Sindi's community interact and know each other, the word of mouth (WOM) will do its job. The parents present in the general assembly will talk about the project. This will be another opportunity to get feedback, from parents that were not present to the assembly but particularly from Sindi's school outsiders.

[27] Nathalie Rucquoy, personal communication, April 13, 2018.

[28] Jean-Baptiste Bokoto is the representative of Africa Synergies and EMF Energy, a group purchase platform, who knows well the environment and context of the DRC.

Third, once the feedback has been considered and integrated as appropriate, time will be required to communicate and present the project to the administration. The administration's approval is also critical to avoid any inconvenience further down the line. Providing the population with electricity is one of the services incumbents upon the administration. In a way, the project encroaches on the administration's mission[29]. The project must be presented as it is, that is an opportunity for the administration to fulfil its mission as opposed to a possible rivalry. Convincing the administration of the project's merit could lead to an involvement with a strong ally.

The communication means described above (WOM, general presentation and personal communication), will be very useful to raise awareness among the community before and during the launch of the project. But the once the project is launched, communication will still be important. WOM should still do its work. People will have the possibility to come to the project's physical location if they need information, have issues, remarks or anything else. They will have the possibility to talk directly with one of the management committee's members that should be instituted (cf. "Key resources" section below). General assemblies should be held on a regularly basis (cf. "Key activities" section below) and will permit to exchange, debate and communicate. Whatever the means, the management committee in charge of the lamps must always be open to the feedback they have from members, customers and other parties and take it into account.

The project will deliver its commercial value through its physical location where the lamps will be provided and stored. Its social value will mainly be delivered through the general assemblies and throughout the project's implementation and development.

3.5 CUSTOMER RELATIONSHIP

The customer relationship, as its name suggests, describes the connection the project wants to establish with its customers, and specifically for this project, with its members (Osterwalder & Pigneur, 2010).

The aim is to create a close relationship with the main (impact) customers: the parents of the school children. The families, and thus the parents are the project's core. Those who want to participate will be asked to register to be a part of the project's association. Being a member of the association will provide benefits. The members will have the opportunity to take part into the important decision making. They will be invited to participate in the general assemblies, elect the management

[29] Claude Jussiant, personal communication, n.d.

committee's members, approve project's management, make propositions, remarks and recommendations, express their opinions, debate, … In short, they will be asked to fully contribute to the project's life. They are important to the project and need to feel so and feel involved.

They will also be asked to join the monitoring system (cf. Key activities). They can also benefit from discounted prices compared to commercial customers (school's outsiders) but we will return to these points later in this chapter.

The relationship with the commercial customers is a long term one. Loyalty and mutual trust must be established between them and the project through good communication and presentation of the project and its objectives. They should respect feel concerned by and the social impact of the project.

3.6 REVENUE STREAMS

"Revenue streams are what enables social enterprises both to run the business and generate the impact" (Burkett, n.d., p21).

The main source of income comes from the payment received for the lamps rental. The payments should be paid in advance, this is at the beginning of each month of use. The users will also pay a fixed starting price to rent the lamp. For example, twice the monthly price (cf. "Financing and profitability of the project" chapter) as advance payment. This amount should be assessed by the stakeholders.

By paying at the beginning of each month as well as a fixed starting price to start renting the lamps, people will not see themselves given the lamps for free. The objective is in the first place to raise awareness among customers, make them understand that the lamps are not given away but deserved. Moreover, it will also gather a certain amount of money at the start of the project that could be useful for the initial operation expenses. The amount payed every month will serve to reimburse the credit taken out to begin the project (cf. "Financing and profitability of the project" chapter).

A possible revenue stream can come from subsidies. The association can ask for subsidies from its administration or seek donations. That, of course, is not the philosophy of the project as considered here, but the association do retain the right to do so. This may be helpful to carry out future projects.

3.6.1 Payment methods

What payment method will be used to perceive these payments? There is one payment method that is commonly used in Africa: mobile payment. People pay by sending text messages. It represents a

safer method than paying by cash or card considering the insecurity in these regions. It is interesting for the project as well – 80% of Sindi's population have access to a mobile[30]. The project could handle a significant amount of money on a regular basis given the economic context (cf. "Financing and profitability of the project" chapter). Relying only on cash would be dangerous for both the people manipulating it and the project's success. In addition to the security, such a system facilitates the payments – customers do not have to move to pay – but also the management of the payments – ease of monitoring which customer has paid, less risks to lose money or the money to be stolen or embezzled. Unfortunately, we were not able to obtain information about the costs of such a system. Its use should then be assessed once these costs will be known. The project will try to mainly use mobile payment, but cash will be allowed. Even if most have access to a mobile, it is not necessarily the case for everyone and the project cannot be unfairly biased on this condition.

3.6.2 What prices?

The price paid each moth by the customers should be between 1 and 1.5€ every month for a three-year period. We will explain further where these figures come from in the "Financing and profitability of the project" chapter. For now, it's sufficient to understand that the amounts come from data provided by Roger Pholo, as well as from his recommendations. The amounts paid for the lamps must be affordable and allow the project to generate some profit.

Why should it generate profit while customers could just pay for the cost price?

The first reason is simple, the profit generated represents a security – if some customers do not pay or cannot pay, the association will still be able to reimburse the loan and handle bad payers, insuring the continuity of the project.

The second one is that it provides the association with means to undertake other projects for the school, the community or extend the services provided (generating new revenue streams).

Third, the earned money can be used to take charge of the lamps that need to be replaced depending on the supplier and the organization put in place.

Last but not least, preferential tariffs can be applied. All families with children at school do not have necessarily the means to buy the lamps, in addition to the price they pay each quarter to the school[31].

[30] Roger Pholo, personal communication, April 16, 2018

[31] Each family pays around 20 euros each quarter per child for the school costs (Roger Pholo, personal communication, March 26, 2018).

With the profit generated, the members' general assembly can determine to reduce the price paid by certain families for whatever criteria they determine as a group. This possibility greatly improves the potential impact of the project and can contribute to a spirit of solidarity.

There is also the possibility to charge higher prices for non-member customers – the school outsiders. The profit generated from this policy can thus benefit the association and its members by reducing the price they pay, finance projects, etc.

3.6.3 Once the lamps are paid

The lamps are expected to be reimbursed after a 3-year period. After these three years, should the customers continue to pay and for what?

At first glance, there is no reason for the customers to keep paying something to the association, but the fact is that the lamps are not endless. There will be a moment when they will need to be maintained or replaced. The replacement lamps will need to be financed. In order to avoid complications and/or costs of taking out another loan, the association can finance these lamps itself through the tontine system.

The tontine concept considered here is very simple. People join their economic forces to jointly purchase goods. Nathalie Rucquoy[32] described the manner in which they use this system as follows. Let's say that 10 participants want to buy 10 cookstoves. Each cookstove costs 100€, but they cannot afford to pay the 100€ up front. Therefore, they decide to create a tontine system, in which each participant gives 10€ every month to the communal fund. Which means that every month, 100€ are collected, that is the price of one cookstove. Every month, a participant will receive its cookstove, even if it may not have paid the whole price yet. The participant who has received its cookstove will continue paying 10€ a month. Ten months later, every participant will have received its good. Another method is where all participants receive their cookstove at the same time, but at the end of the 10-month period.

Once the project will be well-proven with well-functioning systems, mutual trust and solidarity established, such a system can show to be very useful. To replace the lamps once they are obsolete, we can use the tontine system to buy new ones or maintain the old ones. The advantage is that all the lamps will not expire at the same time, a progressive replacement will thus be possible. The choice of who should benefits first from the system can depend on the lamps' expiration. When too many

[32] Nathalie Rucquoy, personal communication, April 13, 2018.

need to be replaced at the same time, the association will define how to decide who will be prioritized. Up to the association whether it would be random prioritization, a vote or other objective elements. Thus, the association will not have to have refinance another loan to obtain its lamps. But why not use this system directly at the start of the project?

Because according to us, it is risky. The first persons to receive their lamp may stop paying once they have it. At the beginning of the project, the association and the community created around the project will be new. It may take time for the solidarity and mutual trust to take shape and be stronger among the members. It is less risky to try the tontine system after 3 years than at the beginning when nothing is in place. It might take time for the project to be fully effective and create a real "solidarity community".

These risks are smaller if the lamps are all distributed at the same time. The project includes a very large number of persons (more or less 250). It might be difficult to implement the tontine system with as many people. It is harder to install the mutual trust this system needs with 250 people than with 20 or 30. Moreover, if there are cases of default payments, it is likely that they will occur at the beginning of the project, when the benefits of halting payments are the highest. If the first beneficiaries stop paying, the other participants might refuse to continue paying and the system would then collapse. If the lamps are all distributed at the same time, default of payment can still occur, but the system will be more resilient to these disruptions.

Say we assume a 10% default of payment rate. In the tontine case, these 10% are likely to occur at the beginning. As a result, the other 90 per cent will probably withdraw and the project will fail. In the other case, the system, through the profit margin, will be able to absorb these default payments, allowing the project to continue. Moreover, let's assume that the lamps are paid after 2 or 3 years. In that case, it means that some of the customers would have to pay during all that period without taking any advantage from the system.

The other reason is logistical. Depending on the supplier, it could be costly to transport the lamps to Sindi. It is less expensive to buy them all at the same time, leveraging on the economies of scale. Small amounts of lamps will still be a problem when the tontines will be used further in the project. Except that the association will have the means to foresee the need for lamps in advance and purchasing a more lamps at a time.

The last reason is the timing and the affordability. Imagine a tontine system to purchase 250 lamps. These lamps cost roughly 7000 euros (lamps price & shipping costs, cf. "Suppliers and offers" chapter). The price paid by the customers each month must stay affordable.

Take 1€ each month to simplify the example, which is roughly the same if all the lamps were distributed at the same time (cf. "Suppliers and offers" chapter). Let's make the hypothesis that every participant will always pay their due. Under these assumptions, it would take 2 years to pay for all the lamps[33]. Meaning that some participants will have to pay for 2 years before taking any advantage of the project. For such goods, it is too long.

Besides, under these unrealistic hypotheses, the association would not make any profit and thus, would lose the benefits listed above and furthermore would not have any funds to finance the possible operating costs. To reduce the duration, the participants should pay twice the price a month (2€/month), which becomes a bit expensive for the customers. Getting all the lamps at once, at the start of the project, allows every member to enjoy the use of their lamp from the beginning, while being affordable in the short term.

We will not develop the model beyond 5 years after its start. Because thinking beyond the tontine system, that is 5 or 6 years after having started the project, is very difficult. There are so many things that could happens by then, that it would even be irrelevant to do so. Any conclusion we might come up with is very unlikely to still be true at that time. The association will hold all the cards to endure.

3.7 KEY RESOURCES

"*The Key Resources building block describes the most important assets required to make a business model work*" (Osterwalder & Pigneur, 2010, p34).

The project will need a physical location to operate. This location is needed to store and distribute the lamps, provide the services, but also to make the project tangible, and put a name and a location on the project. To us, it is important to have a place to which customers and members can refer. The premises will also be a place where the management committee can conduct the daily operations of the project and gather all the operating material like money, member files, customer files, records, furniture, etc.

[33] 6,000€/(250*1€/month) = 24 month, that is 2 years.

Roger Pholo told us that they had a free apartment that would be perfect for the project[34]. We were not able to see it, thus the feasibility of the project using this apartment will have to be assessed and confirmed on site.

The project will need financial resources. These resources will serve mainly to buy the lamps from the supplier. This first purchase will represent an important initial investment. The funds should be obtained through financial institutions and reimbursed over time as the project progresses. More information about the project financing will be provided further (cf. "Financing and profitability of the project" chapter)

Of course, the project will need solar lamps and maybe some technical skills depending on the supplier and the product. What is more, basic management skills will be necessary, such as basic accounting, financial management, customer management, supply management and so on.

Finally, the project cannot work without human resources. The core of the project management: the management committee. It will be responsible for running the daily operations – cash payments, manage the accountability, the accounts, the stocks, the lamps and more. The association will be free to choose the committee's members and their functions.

However, we would recommend the committee be composed of at least three members where each one has (a) well-defined function(s) distinct from each other. The aim is to avoid conflicts of interest and permit the monitoring of one's action by its peers. For example: a president in charge of, and representing the committee, a treasurer and a "lamps' manager". The committee will be responsible for presenting the results, the accounts, their management and how the project progresses to the members' general assembly to who they will be accountable.

The involvement of the population in the project is important. Otherwise, the project is more likely to fail. The project needs the population's approval and if not their direct involvement, to at least insure nobody will interfere with the project or want it to fail.

At the beginning, the project will need support staff to present the project to the persons concerned and guide them, at least during the early stages.

[34] Roger Pholo, personal communication, April 16, 2018.

3.7.1 KEY ACTIVITIES

"*The Key Activities building block describes the most important things a company must do to make its business model work*." (Osterwalder & Pigneur, 2010, p36).

The most important, obviously, is the rental services for the lamps. These services include not only the rental itself, but also the after-sale services. The lamps that are damaged, do not work properly or do not work anymore will need to be changed or repaired. In the same way, at the end of the lamps' life, the association will need to take care of their replacement – contact the supplier, return the lamps, have them refurbished if possible and purchase new ones if need be. The manner in which these will be undertaken will depend on the chosen supplier and the services it can offer.

The monitoring and sanctioning activities are there to avoid customers from distorting the project for they own benefit. The monitoring system is simple. All the association members are part of the monitoring system. When a member suspects someone is using the lamp improperly, he can report the suspicion or the evidence to somebody. One or more persons are elected to be responsible for gathering these accusations. The "principal monitor(s)" is part of the management committee and is the reference person(s) for the members to report the abuses they witness. He will be charged with confirming the accusations, and if they reveal to be true, to report his findings to the other members of the management committee, for possible sanctions.

The possible sanctions must be commensurate with the offense, that is respect Ostrom's recommendations (cf. "Governing the commons" chapter, "Ostrom's theoretical solution" subsection). We cannot tell what appropriate sanctions could be, given the lack of knowledge we have about Sindi's context and culture. That is why the different possible sanctions should be discussed and debated by the members during the members' general assembly.

As mentioned before, the management committee must report their activities to the members' general assembly. These must be held on a regular basis, at least once a year, to present the project situation to the members. The members' assembly will then renew its confidence in the committee or call for a new, partial or complete, election. The assembly is a great opportunity to gather opinions from its members. It can also be used to generate debates about the project, possible changes to make, discuss about new project ideas, etc.

Following Ostrom's recommendation about conflict resolution system and inspired by case studies from her work, a court-like assembly should be established (cf. Governing the commons, Ostrom's theoretical solution).

3.8 KEY PARTNERSHIP

"*The Key Partnerships building block describes the network of suppliers and partners that make the business model work*" (Osterwalder & Pigneur, 2010, p38).

The main partner in the model is the lamps supplier. This partnership is crucial to the project. It is essential that the supplier provides good material and assists in handling issues that can occur with the lamps. A good after-sale service at an affordable price is critical. Without trustworthy supplier, the model can collapse. The different suppliers and their offers will be presented and discussed further (cf. "Suppliers and offers" chapter).

The other essential partnership is with the microfinancing institution. It goes without saying that without an initial investment to purchase the lamps and a good financial model, it will be difficult to carry out the project. Again, the different ways of financing the project will be presented and discussed further (cf. "Financing and profitability of the project" chapter).

The mentor(s) is (are) the person(s) from ISF that will go on site to launch it. They will present the project to the community and help them set up the project with the help of this paper and other resource persons they might need. The mentor(s) will act as the intermediary(ies) between the project in its theoretical and its practical form. Of course, the project cannot be implemented without them.

As stated in the "channels" section above, it is very important to get the administration's support to avoid it from interfering with the project.

Finally, there are the key partners who are central to the project: the parents and community members. We repeat ourselves here, but it is very important that the parents feel involved in the project and its aims. Otherwise the project will not stand a chance to reach all its objectives. An appropriate approach to communicating and presenting the project is necessary. We will recommend talking with Roger Pholo, once on site, to determine which approach will be best and how to organize the first presentation.

3.9 COST STRUCTURE

"*The Cost Structure building block describes all costs incurred to operate a business model*" (Osterwalder & Pigneur, 2010, p40).

The management committee's members should be volunteers and thus not represent costs for the association, however some remunerations are not excluded if it appears to be interesting. For these as

well as the association's members, the project will mainly be a question of dedicating time. The members will be requested to spend time on attending the general assemblies and the management committee will have to spend time managing the project. In either case, the time "lost" participating in the project should not be too significant. The members will assemble between one to five times a year perhaps.

The management committee, for its part, should at least assemble one a month to check the payments and the status of the project – if other circumstances do not force them to do so more often. The work done by each committee member will also depend on the number of persons composing the committee. The more members there are, the less work there will be for each one.

The project will surely incur necessary operational costs such as files, registers, furniture, etc. It hard for us to tell exactly what will be needed and the costs they represent. Yet, we think that for the most part, these operational materials can easily be found and thus their costs should not be expensive.

The physical location should not cost anything, since it will be at the disposal of the project for free. Still, it represents an opportunity cost for the owner.

We shall not go more into the details of the costs structure in this section, as almost every element has either already been discussed, or will be in a later chapter (cf. "Financing and profitability of the project" chapter).

3.10 EPILOGUE

3.10.1 Propositions: the "Surplus" building block

If the project is successful, the association should obtain benefits depending on the prevailing prices and possible complications. The business model has been made and thought as it belongs to the association. Therefore, the community will be the only judge in deciding what the benefits should be used for and what activities should be organized. We will still present some possibilities, tracks which the association may or may not follow, for them to decide what is the best.

The association can offer another service like phone charging. The school's solar installations are oversized and are large enough to handle cell phone charging (cf. "Technical study" chapter). According to Roger[35], 80% of Sindi's population possess a phone. They usually go to the city to

[35] Roger Pholo, personal communication, April 16, 2018.

charge them at a cost of approximately 2 euros a month[36]. Since the school can handle phone charging, the association could, with school's permission, provide this service to the population; for free or for a fee. If they sell the service, the gathered money could benefit the school or the project. It can help the school to meet its expenses, start a new project or increase the revenue streams of the project. If they provide it for free, the association would contribute to the increase of purchasing power.

Another possibility would be to light the street. In fact, solar street lamps exist that are totally autonomous. The suppliers do not lack in Africa, a quick online research can find a supplier[37]. At night, Sindi is dark, it is hard to perform activities at night. Lighting up the streets can greatly benefit the community by allowing people to meet and by increasing the security at night. Some solar street light can even create, little by little, a mini-grid that could benefit everyone. But this should be the topic of another project or paper (track: Greenpeace, 2014)[38].

The profits can finance the purchase of another set of lamps, which would permit to reach and benefit more people. It can also focus on more vulnerable people and sell the lamps under cost to people who cannot afford them.

The money can also help finance the school, making it accessible to more children. The cost is relatively high for the population. As mentioned, the parents are asked to pay 20 euros per quarter per student while the average wage is of 20 euros a month[39]. The profits from the project can be used to reduce the amount paid, finance registrations or finance educational projects or material.

Economic hubs can also be created. Thanks to the solar installations of the school, an economic activity can be set up using the school electricity. The benefits can also finance the installation of additional panels and material that would be needed. Such projects should be carried with a technical support, ISF for instance. Calculations must be done to assess the capacity of the installations to make sure the additional charge the activities represent are not too big for the solar installations. Otherwise, these could malfunction or be damaged. And if needed, additional material could be installed.

These possibilities are only suggestions that the association can follow or not. As we said, the association is the only one able to decide, collectively, what to do with the possibilities this project

[36] Roger Pholo, personal communication, May 6, 2018.

[37] AptechAfrica (see more on: http://aptechafrica.com/service/solar-street-lights/); Sustainable.co.za (see more on: https://www.sustainable.co.za/); HomeEnergyAfrica (see more on: http://www.homeenergyafrica.com/solar-light.php); Philips (see more on: http://www.lighting.philips.com/main/products/solar#)

[38] Greenpeace. (2014, December 10). *Sustainable Street Lighting: Delhi*. National Institute of Urban Affairs, India. Retrieved from https://www.greenpeace.org/india/Global/india/2015/SSL/FinalReport_SSLP_NIUA.pdf

[39] Roger Pholo, personal communication, March 26, 2018.

provides. We are also sure that other good ideas will come from the members. No doubt the community has other preoccupations and needs of which we cannot conceive. Up to the association to receive, analyze and present the different possibilities to the members as they arise.

3.10.2 Summary and conclusion

The economic model presented above has been considered in accordance with the context and specific features of Sindi. Yet, that does not mean that it cannot be expanded elsewhere. To conclude this chapter, we will summarize and at the same time, phrase a generalization of the model.

The principle is to gather people around a topic related to domestic lighting (in this project, children's education). This topic must have meaning for them and act as a driving force and as an incentive (the future of their children). The participants create and become members of an association (parents' association) and elect a management committee. Then, the association, finds the necessary financing with the help of a third-party. The third-party purchases the lamps from the supplier and entrusts the association with them. The association is responsible for distributing the lamps and collects the payments to pay back the third-party. Once the lifespan of the lamps has fallen expired, the tontine system can be used to replace them.

The association should also respect the Ostrom's recommendations. The members need to clearly set up the rules together regarding who can benefit from the lamps, what to use them for and under which conditions. These rules must take the local conditions into account. The members, who are affected by the operational rules, can participate in their modification. The monitors are chosen by the members and are accountable to them. All members are part of the monitoring system. Members who do not respect the rules, set up by the association members, are sanctioned. The sanctions, if possible, are established among members and are graduated depending on the transgression and the context of the transgression. (Ostrom, 1990). The association creates a court-like assembly to manage conflicts. The association makes sure that its administration is aware and consents to the project.

4 THE SUPPLIERS AND OFFERS

In the present chapter, we will describe the different suppliers we have found and contacted, that might be suitable for the project. The selection is based on those found on the internet or through recommendations, and as such may be biased. Others with potentially more interesting offers may be found elsewhere in the DRC, Africa or world and if needed a similar analysis to the one being made in this chapter should be carried out. A lot of suppliers exist in the solar lamp market with many different offers. Our selection is mainly based on price and on the suitability of their products for the project. Other selection elements are more subjective but were discussed with our monitor Claude Jussiant and will be highlighted.

4.1 A LOT OF OFFERS

4.1.1 The budget

When browsing the internet, we rapidly realized that many offers and actors were present on the market. To even out the selection, we directly excluded the lamps that were too expensive. We determined the price limit thanks to a little analysis of the data Roger Pholo provided us[40].

At first, Roger Pholo emitted the demand that the lamps should not cost more than 2€ a quarter. Considering a 3-year project, the lamps' purchase price should thus be 24€ each (including purchasing price, shipping cost per lamp and customs clearance costs – if purchased outside of the DRC). A 24€-budget seems to be a little bit small if we want to include the shipping costs and customs clearance costs – the lamps would be approximately 40% more expensive because of the custom clearance in the DRC[41]. We increased Roger Pholo's demand to 1€ a month, so that the total purchasing price of one lamp would be 36€ which is a more realistic budget. We asked Roger Pholo's approval who confirmed that it would still be an interesting price[42]. We were therefore able to sort the suppliers by price and thus reduce the offers to analyze.

[40] Roger Pholo, personal communication, March 26, 2018.

[41] Claude Jussiant, personal communication, n.d. & Alain Bosseloir, personal communication, n.d.
Alain Bosseloir is the CEO of Zentech, "a Belgian biotechnology company specialized in the development, production and marketing of IVD solutions dedicated to diseases occurring at an early stage of life." (http://www.zentech.be/). There are used to work with the DRC and confirmed the figures.

[42] Roger Pholo, personal communication, April 11, 2018.

4.1.2 The lamps

Putting aside the price, the product itself was an important criterion. More specifically, regarding the different offers, the question was whether the lamps should have their own solar panel or not. And if so, should the solar panels be separated from the lamps or not.

Integrated panel?

With our mentor, Claude Jussiant, we quite quickly put aside the lamps with an integrated solar panel.

The first reason being the risk of theft. The customers would have to leave their lamps outside for a long period of time. In a suburban area like Sindi, we thought that this would be dangerous. We cannot certify that this could done safely, and in the absence of supporting information, it was more appropriate to consider the safer solutions.

The second reason was because of the lamps' lifetime. Exposure to high temperatures reduces the lifespan of batteries and is thus not recommended. The batteries in lamps with integrated panels, would be subjected to high temperatures for long periods of time for these to charge sufficiently; thus, reducing their lifetime. (Battery University, 2017).

With or without separated panel?

Lots of lamps are provided with a little solar panel that can be plugged in to charge them (for example see, see technical sheets in the Appendix V). For a long time, we questioned whether the lamps should be furnished with their panel to the customers or not. The answer is not that easy. Both possibilities have advantages and disadvantages.

The lamps could be purchased, by the association from the supplier, with their solar panels. These solar panels could be provided to the customers or kept at a central location where the lamps would be charged by the association.

If we provide the customer with their own solar panel, it would allow them to stay at home to charge their lamp. This solution is less time consuming then if they had to come at the store on a regularly basis to charge it.

Keeping the solar panels at a central location has the advantage of creating a sort of dependence on the association. Without their panels, the lamps would be useless once discharged. This would force the customers to come to the store to charge them, allowing the managers to better monitor payments and the lamps' condition. The customers would not be able to charge their lamps if they do not pay their due. A good incentive to avoid default of payments. On the other hand, providing the customers

with their own panel allows them to use their lamp even if they stop paying for it. If there are default of payments, the monitors will need to go meet the concerned customers without being sure to obtain the due amounts. If a lot of customers must be visited, this can be time consuming.

A great advantage of letting customers have their own solar panel is that the lamps would be available for use inside during the day which would not be the case in the other scenario as the lamps would not be at the home.

Another aspect to consider here is the potential multifunction of the lamps. Some lamps can also be used to charge a phone, for example. The risk of not furnishing the panels could be that the customers first charge the phone, and then use it for lighting the children's study. Charging a phone in this manner uses the battery much more; shortening its lifetime. On the other hand, if the customers have access to a solar panel at home, they would be able to charge their phone at the same time as the panel charges the battery, this one would thus not be used, maintaining the lifetime of the battery. Moreover, the lamps are more likely to be used for the main purpose which is lighting the children's study.

Some suppliers also accept to sell the lamps without their panels and at a better price. But it would mean that the lamps should be charged using another power source. The lamps could be charged using the school's solar installations that are large enough to support the additional charge this would represent. Additional material and installations would be required, so their cost should be assessed as well as a cost-benefit analysis should be made (cf. "Technical study" chapter").

Charging a large quantity of lamps could be difficult and/or too complicated. This would require space, well designed facilities, as well as a good management system. And this in both cases where the lamps are charged at the store – through school solar installations or little solar panels.

The problem is also that charging the lamps at the store would require someone to be present at least twice a day at the store. Someone would be requested to receive the lamps, manage their charging and return them. If we assume that the managers will volunteer, this option would be time consuming and binding for people who would not be paid. It is true that solutions could be found. Several persons can split the work for example, or the store can be open every 2 days – depending on the lamps' autonomy. But still, that would make the model more complex. People can also be paid, but this can be costly for the association.

Providing the solar panels would be much more convenient for the customers as opposed to not doing so. If the panels are not provided, the customers would be forced to come every 2 or 3 days to the store to charge their lamp and at least twice that day. Once to get the lamp charging and once to get

it back. This would be easy for people who live close to the school, but not for those living farther away.

A possibility could be that children bring their lamp with them when coming to the school, let them charge during the day and take it back home after school. But some raised the point that this would be risky. Young children are more likely to damage, break, lose or have the lamp stolen on their way to school or home.

Regarding the advantages and disadvantages (see summary table in Appendix VI), we would tend to say that the panels should be furnished with their lamps. Moreover, this opinion is shared by Roger Pholo. For us, the question is not as simple as with or without the panels. The choice should be made after having studied the project on site. It is impossible to say, from where we are, what would be the best solution. The question should be assessed with the help of the different stakeholders inside the community. The answer could also be neither one nor the other, but a combination of both.

We will just add that the monitoring aspect should not carry too much weight in making this decision. Indeed, insuring that the customers will respect the rules, pay their due, respect the lamps and so on, is supposed to be taken into account by using Ostrom's work and findings.

4.2 POTENTIAL SUPPLIERS

Once our selection criteria were defined, we were able to more easily target the suppliers. We intended to contact all the interesting ones. However, some did not answer, other were not interested or were not able to supply us. Hence, we have discussed further with the ones who responded and were interested. We will now present them and compare their offers.

As mentioned in the introduction, the project primarily concerns the 250 families of the school. This amount can evolve depending on the market research that should be made on site but still represents a good estimation. Therefore, we contacted the suppliers to have the data concerning a potential purchase of 250 lamps.

4.2.1 The suppliers

Regarding the selection criteria specified above, three suppliers stand out from the others. These are Lagazel, Ecozoom and Awango by Total that we already briefly presented in our methodology. We will reintroduce and compare them here below:

- **Lagazel** is a French company, present in various African countries[43], that sells solar lamps made in France and assembled in Burkina Faso (Le Monde, 2016). We were in contact with Lagazel by email through Jean Delattre who transmitted us the information we needed.
- **Ecozoom** "is a social enterprise from Kenya. They are certified B Corporation and dedicated to bringing ecological products to the world (Ecozoom, n.d., first paragraph)[44]." Their main products are cookstoves, but they also produce solar lamps (Ecozoom, n.d.)[45]. In the case of Ecozoom, we corresponded with Ronald van Harten.
- **Total** is present on the African solar lamp market through its project called Awango. The "Awango by Total" solar lamps are part of a broader project launched by Total: "Total access to energy" which carries the desire of Total to give everyone access to energy (Total, n.d.)[46]. We communicated with and obtained our information from Awango through Karl Gupa, commercial team leader & solar coordinator at Total DRC[47].

The lamps' origins differ from one supplier to another. As mentioned, except for some of the lamp components (the battery and one component of the panel), Lagazel lamps are made in France and assembled in Africa, creating employment on the continent (Le Monde, 2016). Ecozoom lamps are imported in Africa from China where they are produced[48]. Awango is a retailer and thus does not produce its lamps itself. The lamps are made by the "Global Leader in Solar Power for Off-Grid Families[49]", D.light. The d.light S10 lamps are made in China (KenRockwell, 2013) as well as the S300B lamp (Kopernik, n.d.).

The locations of these suppliers are also different. Awango is the only one present in the DRC, in Matadi[50] while Lagazel and Ecozoom would need to ship their lamps by plane[51]. Another interesting information and potential opportunity is one of Lagazel's projects. We were told by Jean Delattre that Lagazel intends to open a new workshop in the DRC and potentially in the city of Kinshasa. The project is still in its investigative phase but could see the day next year. Needless to say, the presence of suppliers in the DRC would be a real opportunity for the project. It would facilitate the shipping

[43] http://www.lagazel.com/contact
[44] https://ecozoomstove.com/pages/about-us
[45] https://ecozoomstove.com/pages/solar
[46] https://www.total.com/en/our-expertise/renewable-energies/solar/infographics/awango-total-facilitating-access-energy-least-advantaged
[47] Karl Gupa, personal communication, March 29, 2018.
[48] Ronald van Harten, personal communication, March 28, 2018.
[49] Dlight, page title, http://www.dlight.com/
[50] Karl Gupa, personal communication, March 29, 2018.
[51] Ronald van Harten, personal communication, April 2, 2018 & Jean Delattre, personal communication, March 29, 2018.

and potential returns of the lamps as well as save the shipping costs and the custom clearance costs – generally, big companies have agreements with the administration to reduce or even avoid these costs[52].

4.2.2 The models of lamp

Let's now dive more into the details of these offers. Each supplier has presented 2 lamps to us in accordance with the project specificities or with their availabilities.

In the Table1 (see Appendix VII) are presented the costs in euro for the different lamp models. You will find the technical sheets of these lamps we were given in the Appendix V. The prices that we were given were for the whole order, that is 250 lamps. From there, we calculated the lamps' unit price to make the comparison easier between the lamps and the budget of 34€ per lamp (in total) we have defined above. The price of the imported lamps must be inflated by 40% to take into account the customs clearance costs. All prices were not given in euro. We made the conversion to euro using the figures specified in the footnote – the CFA franc is the currency used in countries from West and Central Africa, including the DRC and Burkina Faso (CFA franc, n.d.)[53].

The lamps from Awango do not need to be shipped. Moreover, Awango is able to deliver the lamps from Matadi to Sindi, free of charge. On the other hand, the ones from Ecozoom and Lagazel would have to be shipped by aircraft – since Lagazel's DRC project is not certain, we consider the lamps to be shipped from Burkina Faso. The shipping costs are listed in the Table 2 (see Appendix VII). To these must be added the transportation costs from Kinshasa to Sindi. This service could be performed by a private individual and would approximately cost 500€[54]. Just as for Table 1, Table 2 presents the costs in their original currency as well as their conversion in euros and the total shipping cost per lamp in euro.

By combining Table 1 and Table 2, we obtain the Table 3 and the budgets in Euros each lamp would represent.

[52] Alain Bosseloir, personal communication, April 26, 2018.
[53] For more information about the CFA franc currencies, please visit: https://en.wikipedia.org/wiki/CFA_franc
[54] This estimation was made with Claude Jussiant (personal communication, April 2018) based on past projects.

Table 3: Budget per lamp.

	Lagazel[55]		Awango[56]		Ecozoom[57]	
	LK1500	LK3000	S20	S300B	Single Solar	Single Solar +
Total budget / lamp[58] (10)	28.12 €	43.92 €	11.06 €	29.92€	21.11 €	29.72 €

We decided to directly rule out the Single Solar + model from Ecozoom. The reason is because the only differences between the Single Solar and Single Solar + is a power bank and a 4Watt panel instead of a 3Watt one. The power bank, although potentially useful, appears superfluous to us as well as a 4W solar panel. It does not seem to be essential here.

The S20 model from Awango is an integrated solar panel model. But it is evident that its price is very attractive. Although it does not allow to charge a phone, it has a decent battery life – see Appendix V.

To stay consistent with the selection criteria we made, we will rule this possibility out for now. However, we think that the possible use of this lamp can be assessed during the on-site market research and the life of the project regarding the possibilities its price provides.

4.2.3 Comparison of the models

We will now compare the remaining 4 models based on their specificities to help make a choice between them[59]. The 4 remaining models are: the LK1500 and LK3000 models from Lagazel, the S300B from Awango and the Single Solar model from Ecozoom.

The price

In the first place, the price. We can see from the Table 3 that only the LK3000 does not respect the 34€ budget defined above. The Solar Single is the cheapest of the 4 (roughly 7/9 € cheaper) and the

[55] The figures come from a cost estimation we were given by Jean Delattre, personal communication, March 29
[56] Figures were given by Karl Gupa, personal communication, March 29, 2018.
[57] Figures were given by Ronald van Harten, personal communication, April 2, 2018.
[58] (10) = (4) + (9)
[59] The comparison will mainly be based on the information available in the technical sheets of the lamps. These technical sheets are available in the Appendix V

2 remaining have similar prices – the LK1500 being roughly 2€ cheaper than the S300B. If we only consider the price, the Single Solar is clearly the best product. However, as we will see, the specificities of the lamps are not equal, and a nuance must be made concerning the prices given for Lagazel's lamps.

By the beginning of the project, there is a possibility that Lagazel will have opened a production workshop in the DRC. We do not know the impact it could have on the lamps' prices, but in the hypothesis where the lamps are sold at the same ones, this would save the 40% additional costs from the customs clearance as well as the shipping cost by aircraft.

If this is the case, assuming the transportation from Kinshasa would still be made, the LK1500 price would be 17.24€ and the LK3000 would cost 27.91€[60]. Under these hypotheses, the LK1500 would became the cheapest model – roughly 4 euros cheaper than the Single Solar model and almost 13€ cheaper than the S300B. For its part, the LK3000 model would respect the budget and be competitive – 2€ cheaper than the S300B model. The project cannot be based only on the fact that Lagazel will or will not be present in the DRC but regarding these figures, this scenario must be taken into account.

Technical specificities

Let's have a look at the battery life. It is not an easy task to compare the runtimes of the different models. Each have different runtimes for different brightness levels. Moreover, the runtime varies depending on whether the battery is fully charged or if it is only partially charged after a full day's exposure to the sun.

To tackle the comparison, we can begin by comparing the capacity of the batteries. The battery is a common element and easily comparable that can give us a first general idea on the different runtimes of the lamps. The different capacities of the batteries are listed in the Table 4. The data are retrieved from the technical sheets in the Appendix V.

[60] = (3) + (7) / 250

Table 4: Batteries capacity

	Lagazel		Awango[61]		Ecozoom	
	LK1500	LK3000	S20	S300B	Single Solar	Single Solar +
Battery capacity (mAh)	1500	3000	400[62]	1800[63]	2200	2200

By far, the LK3000 model has the best battery capacity. Taking into account its price, the Single Solar model is very good. The LK1500 and S300B models are again comparable here. The S300B is a bit more expensive but has still has a decent battery capacity too. However, the runtimes of the lamps also depend on the lamps' outputs.

We will compare the runtimes of the different model based on the probable duration of their use. We consider the lamps to be used from the sunset to midnight. The DRC is close to the equator, so the setting of the sun is around 6pm. We make the hypothesis that no use of the lamp is made in the morning since the sun comes up around 6am (Ephemeride, 2018). Which gives us a comparison base of at least 6 hours of use. To improve comparison of the models, we will add the lighting power associated with the runtimes. The runtimes are given for a full charge of the battery.

Table 5[64]: Runtimes and lighting power

	Lagazel		Awango		Ecozoom	
	LK1500	LK3000	S20	S300B	Single Solar	Single Solar +
Runtimes	8h	7h	8h	8h	8h	6.4h
Lighting power in Lumen (lm)	70 lm	130 lm	17 lm	50 lm	75 lm	75 lm

[61] The battery capacity is not given in the technical sheets in the given Appendix V for the S20 and S300B models. To overcome this absence, the figures are based on other data sheets. In these, the data vary a bit compared to the ones given by Awango, but it allows to make a reasonable estimation.

[62] Lighting global. (2018). *Solar Lantern S20*. Retrieved from https://www.lightingglobal.org/wp-content/uploads/2013/12/LG_SSS-dl-S20_AR.pdf

[63] Lighting global. (2018). *D.light S300*. Retrieved from https://www.lightingglobal.org/wp-content/uploads/2013/12/LG-SSS_dl-s3001.pdf

[64] Data are provided in the Appendix V

Briefly, from the table 5 above, we can see that the best model is, without a doubt, the LK3000 model. It has 7h of runtime but its lighting power is almost twice as big as the others. The S300B model has the lowest runtime/lighting power relation and the LK1500 and Single Solar models are almost identical with a slight advantage to the Single Solar one.

We will end this section by mentioning the little extras and differences of the models. Except the LK1500 and S20, all the models can charge a phone. Comparing the solar panels is irrelevant here because the panels are designed to fit the lamps requirements. Except the S20 model in which the panel is integrated, all the lamps are provided with a sufficiently long charging cable – at least 4 meters. Lagazel's products have the advantage of easily replaceable batteries which is very interesting when we know that the component mainly limiting the lamps' lifespan is the battery. Ecozoom does not mention the resistance of its lamps while its competitors sing praises of their models on this aspect.

Given the shipping distance and to facilitate the respect of the 2-year warranty, Ecozoom proposed to provide 10% more lamps without their panels for free. Regarding Awango and Lagazel, the warranty and after-sale services could be managed through their location in the DRC. Lagazel did not provide any solution if their project does not turn out well. In that case, some additional lamps would need to be purchased or negotiated.

What is the best model?

We now have all the necessary information to make an informed choice. According to us, the best product is the LK3000 lamp: best runtime/lighting power relation, best battery capacity, solid, phone charging and easy battery replacement. Nevertheless, if Lagazel does not open a facility in the DRC, this model is too expensive. The best price-quality ratio is the Single Solar but has to be shipped from Kenya or China and is potentially less robust than its competitors. The LK1500 model is not bad but does not allow to charge a phone while the S300B does. The S300b seems to represent a good compromise, it is robust and easily accessible. But its price-quality ratio is quite low. The S20 is in a very different category, it can be useful due to its price but offers much less opportunities. The Single Solar+ is by far the least interesting product.

4.3 CONCLUSION

In conclusion, the choice is not easy between the 4 models – LK1500, LK3000, S300b and Single Solar. Each model has its advantages and disadvantages, better in some aspects and less performing in others. The final choice should be taken while considering the local conditions. We cannot definitively recommend one lamp or another. First, due to the lack of information we have on the local conditions and second, because the choice is highly subjective. No model really stands out from the others. However, we do think that this chapter allows one to make an informed and judicious choice once additional information from the field collected.

5 FINANCING AND PROFITABILITY OF THE PROJECT

This chapter will be discussing the financing the project needs as well as the profitability of the project. We will first estimate the amount to be financed for the project and present some direction. Then, based on data provided by Roger Pholo, we will present the potential profitability of the project.

5.1 INITIAL FINANCING

Although economically profitable, the project needs an initial investment to begin. The lamps need to be purchased, as well as the possible shipping costs financed. Taking the 40% custom clearance costs, we can obtain an estimation for each lamp model by combining the 4th element from Table 1 with the 8th element from Table 2. Then, we obtain the results in Table 6 below:

Table 6: Total budget for 250 lamps

		Lagazel		Awango		Ecozoom	
		LK1500	LK3000	S20	S300B	Single Solar	Single Solar +
Financing estimations (11)	[65]	7,029.61 €	10,980.10€	2,764.2€	7,479.67 €	5,276.4€	7,430.9€

From the above, we can conclude that the initial financing would need to be roughly between 5000 and 7000 euros. The amounts were calculated using the hypothesis that Lagazel's products would need to be shipped from Burkina Faso.

[65] = (4) * 250 + (8)

5.2 WHAT FINANCING MODEL?

Now that we have estimated the amount needed to start the project, let's study the ways we can finance it. Two main questions need to be answered: who will take out the loan and who will grant it.

5.2.1 Who will grant the loan?

The necessary financing can come from various origins: from credit institutions, sponsor(s), subsidized loans or from donations and subsidies. Donations and subsidy possibilities are not considered here. Remember the maxim: *"Give a man a fish, and you feed him for a day. Teach a man to fish, and you feed him for a lifetime*[66]*".* To respect the project's philosophy, the money must be lent, not given.

The money can be borrowed from credit institutions. This solution is may be the simplest one. A lot of these institutions exist in Belgium and in the DRC but taking a loan from credit institutions is costly. A comparison of the different offers will have to be carried out. We contacted Congolese and Belgian institutions to get a first idea about cost differences.

The only response we received was from CBC Bank in Belgium in the person of Rudy Verheyen[67]. He gave us an estimation about what the loan would cost if we considered a loan of 7,000€ spread over the duration of the project – that is 36 months. Given administrative costs of 250€ and an annual rate of 1.5%, in total, the gross cost would be 413.05€[68].

Although perfunctory information, it gives us an idea that we can integrate in our model, concerning loans from Belgium. Unfortunately, we did not have any responses from the DRC. Yet, we were told that it is very likely the cost of a loan in the DRC would be higher[69], which is something to consider. Further information research would need to be carried out in the DRC to better compare Congolese and Belgium loan conditions and costs. If a Congolese loan is financially viable, it should be preferred to the Belgian one. The aim is to respect the philosophy of the project; "By the Congolese, for the Congolese".

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[66] Chinese proverb

[67] Rudy Verheyen, personal communication, May 4, 2018. Rudy Verheyen is the relationship manager for non-profit organizations at CBC Bank.

[68] This amount is calculated as follow:

- Monthly payment = 198.97€ = C x i/1-(1+i)$^{-n}$ where C is the loan amount (7,000€), i is the monthly rate (1.5%/12 = 0.125%) and where n is the duration of the loan in months (36 months).
- **Total cost =** 250€ + (198.97€ * 36) – 7,000€ = **413.05€**

[69] Jean-Baptiste Bokoto, personal communication

The loan can also be subsidized, reducing its cost. The principle is to obtain a loan at a lower rate than the one in effect on the market, thanks to government of institutions aids. We did not research on this topic, but we think that it is an interesting option to be pursued.

Financing can also come from private sponsors. Private companies can agree to lend money at no rate in the name of their corporate social responsibility (CSR). This approach is more likely to work with Western companies that have more interest in doing CSR than Congolese companies. Those Western companies with branches in the DRC should be targeted, especially the ones active in the energy sector.

ISF could also raise money, subsidies and/or collect donations from private individuals or companies. The money collected would allow ISF to grant a zero-rate loan to the project. The association would not be given the money but would have to reimburse ISF. Moreover, once the money is recovered, it can be used to launch another similar project. This solution can be more constraining for ISF but can facilitate the project and allow its duplication. In case of reimbursement issues, ISF can easily re-adapt the repayment. The fact that the association does not have a legal entity would not be a problem (cf. "Who will take out the loan?" section below). It avoids the risks linked to taking out a loan from a third-party entity – in case of failure. In our opinion, this is the best financing method and should be assessed first.

5.2.2 Who will take out the loan?

The problem regarding a potential loan is that the parents' association that will manage the lamps does not have any legal personality. Hence, it cannot legally take out a loan and will need to have resort to a third-party entity to do so.

As a first solution, ISF could take out the loan, purchase the lamps and entrust them to the association. ISF can access more easily Belgian or Congolese loans.

In a second solution, "Œuvres pour l'enfance défavorisée", the non-profit organization managing the school, could be the one taking out the loan. The problem here is its financial accessibility. The organization has few assets to guarantee the loan. As a result, this may be more difficult. A solution could have third-parties or sponsors guarantee the loan. The best would be Congolese sponsors or Western companies with branches in the DRC, but Belgian ones are not excluded.

A final solution would be that a company, in the name of its CSR or because it wants to support the project, borrow the money and entrust it to the association. Again, Congolese companies or Western branches should be targeted first, to respect the project's philosophy.

The financing solutions presented above are not exhaustive, others can be found. The choice of the financing should consider cost and feasibility or complexity. Unfortunately, we have been unable to delve deeper into the subject due time constraints. However, the present chapter and paper contain all the information needed to present the project to potential financers.

5.3 PROFITABILITY

We already mentioned the reasons why the project should be able to generate a profit. We will now assess the potential benefit of the project, bearing in mind the purchasing power of the customers and potential costs that could be incurred.

5.3.1 Purchasing power

According to Roger Pholo[70], the average income in Sindi is about 20€ a month and people generally have 2 oil lamps at home. These lamps cost them around 6€ a month, that is 3€ per lamp, a third of their monthly income, which means that the purchasing power in Sindi regarding our lamp is potentially 3€ a month. Remember, we calculated our 36€ budget earlier on a 1€ per month basis. Three times less; that is a huge difference. And yet, we are not factoring in the cost of the lamp itself. Roger told us that an oil lamp costs around 1€ and has a lifespan of one year – which represents 0.08€[71] a month. These two numbers show us the commercial potential that is present in Sindi, and potentially in the DRC and Africa. People do not realize how expensive their lifestyle can be.

By cutting in half the price they pay each month, we can still provide them with a much better product while generating a profit in favor of the school children. Table 7 below shows the profit that could potentially be made with each lamp model. We assume 250 customers paying 1.5€ a month with costs spread over 3 years, the profit is calculated on a yearly basis.

[70] Roger Pholo, personal communication, May 5, 2018.
[71] 1€/12=0.0833€

Table 7: Financial aspects of the project

	Lagazel		Awango		Ecozoom	
	LK1500	LK3000	S20	S300B	Single Solar	Single Solar +
Total revenue[72] (12)	4,500€					
Total purchasing price (11)	7,029.61 €	10,980.10€	2,764.2€	7,479.67 €	5,276.4€	7,430.9€
Financing cost estimation (13)	413.05€					
Potential gross operating income[73] (14)	2,019.11€	702.28€	3,440.91€	1,869.09€	2,603.51€	1,885.35€

As we can see, the potential profit is substantial. The association could generate 6,000€ in 3 years while still allowing its customers to save 18€ a year. This almost represents a month's salary! Of course, the association could decide to lower the price if they consider it better to do so, keep it at 1.5€ or even increase it. It all depends on the association and its ambitions.

You will find a summary of the project profitability and financial aspects in the Appendix VIII.

5.4 CONCLUSION

The project needs an initial investment of around 7,000€. Multiple options are possible to obtain this financing. According to us, the most interesting one is where ISF provides the loan. It might be more difficult for ISF to find donors than investors, but it is the safest and cheapest solution.

Households spend way too much money on their oil lamps. The project would allow them to make savings, while still remaining profitable. It could generate up to 6,000€ over three years. An important amount which may represent a big opportunity for the association.

[72] (12) = 1.5€ * 250 * 12
[73] (14) = (12) – (11) / 3 – (13)

6 TECHNICAL STUDY

Earlier in this paper, we talked about the possibility of charging the lamps by using the solar installation already in place at the school of Sindi. This solution has been studied because some suppliers can provide their lamps at a lower price without their panels. This would represent a solution for people who cannot afford to buy the full package but are able to come charge their lamps at the school installations. As said, we think that a combination of both solutions – buying the lamps with their panels or without – would be best. The association should primarily highlight the selling of the whole package and reserve the second solution for those who are financially weaker.

The present chapter will present some technical specificities of the lamps and analyze the technical feasibility of charging these lamps through the solar installations at Sindi's school.

6.1 THE SOLAR INSTALLATIONS

Sindi's school is provided with 10 photovoltaic modules which function in 24 volts. We know from our mentor Claude Jussiant that the installations had been oversized regarding the energy consumption. However, we do not know to which extent. We have to make sure that the additional charge the lamps would represent can be handled by the installations and determine how many lamps can be charged at once.

To determine this number, we needed two pieces of information. The first one was the data of the solar installations. We needed to know what material is in place and what is the capacity. The second one was the additional charge a lamp would represent for the solar installations.

We had the data that had served to calculate the dimensions of the installations as well as the results (see Appendix IX). The problem was that we did not have the details of these sizing computations. To remedy this problem, we redid the calculations using a sizing software program created for ISF. In its computations, the program takes a lot of information into account: geographic position, solar panels and the batteries' characteristics, gradient of the panels and the radiance of the less sunny month of the year.

We entered the data into the program and we re-did the computations. These were made based on the daily consumption profile of the school – an estimation of the electric needs of the school – and on the solar and electric materiel – mainly the solar panels and batteries' characteristics. The program we used is different from the ones that had been used before to size the installations. Thus, the results

we obtained were different from the previous ones (see Appendix X). According to the new program and regarding the daily consumption profile, 8 solar panels would be required. Yet, 10 panels were installed in Sindi because the prior results recommended so. We were told that the installations were also oversized a bit on purpose in contemplation of possible future needs the school might have. All these elements confirm the fact that the installations are indeed oversized.

The simulations we made thereafter were based on an 8 solar panel installation. Therefore, even if the sizing we obtained was different, since the installations in Sindi have 10 panels, if our conclusions are valid under our hypotheses, they will still be valid for the installations in Sindi.

6.2 AN ADDITIONAL CHARGE

The program we used allows to fake disruptions and test the limits of the system. We used this tool to simulate the disruption the lamps would represent. In order to make our simulations, we had to estimate the additional charge of the lamp.

The LK3000 model from Lagazel is one of the model that would require the most power – its battery has the most important capacity (3000mAh) and the electric charge of its lamp is one of the most important (130 lumens during 7h). Since it is one of the models that requires the most power, again, if our conclusions are valid for this model, they will also be for the others.

We estimated the charge of charging the LK3000 using the information provided by its technical sheet. There it is mentioned that the battery works under 3.2 volts and has a capacity of 3000mAh. At maximum brightness and fully charged, the lamp can run for 7h, which means that the lamp consumes approximately 429mA[74].

These figures must be put into perspective here. First, in the calculations made above, the assumption is that the batteries are fully discharged after 7 hours. Yet, in practice, this is never the case. Batteries are designed to avoid this specific case. Batteries' charge never goes under a certain security percentage. The reason is because totally discharging batteries would greatly damage them[75]. Therefore, in practice, the current is a bit less important than 429mA. Since we do not know the security percentage, we will assume that the batteries are fully discharged. Our purpose here is to have a general idea about the number of lamps to be charged, not to have a precise number.

[74] If the battery is fully charged, the lamp can run at maximum brightness for 7h. Considering the fact that the battery has a capacity of 3000mAh, it means that the lamp consumes 3000 mAh / 7h = 429mA for 7 hours.

[75] Claude Jussiant, personal communication, May 24, 2018.

Second, there maybe is a current restrictor in the lamps, protecting the batteries from being damaged by a too high current. We do not have this information, so we will assume that there is not such restrictor to make our estimation. Further testing should be realized to confirm or infirm this hypothesis.

Since the battery works under 3.2 volts, the charge in Watts of the lamp is equal to 1.37 Watts[76]. However, as we will explain hereunder, it is more likely that the lamp is charged under 5 volts[77], not 3.2 volts. Under that hypothesis, the charge of the lamp would thus be 2.14 Watts.

Here we are making hypotheses, because we are not able to do testing to corroborate our assumptions. These tests will have to be carried out if the association wants to use the school's installations. The results we obtained, as well as the number of lamps the installations could deal with, may not correspond to the reality. However, even if different from reality, our computations still provide an order of magnitude and above all the procedure to follow, once the real data will have been collected.

6.3 DISRUPTIONS AND LIMITS OF THE SYSTEM

Now that we have estimated the electric charge of one lamp, the question is: given the electric charge of a lamp, how many lamps can be charged at the same time using the solar installations of the school?

We proceeded by trials and errors. We began by taking into consideration 250 lamps to be charged at the same time. Here we consider that the lamps' batteries are charged during the day, between 6am and 6 pm to use the power surplus of the panels. We ran the program for a disruption of 536 Watt between 6am and 6 pm and obtained the "Results 1" presented in the Appendix X.

From this first simulation, we can see that the power provided by the panels is almost sufficient to respond to the power demand. Almost, because we can see that at 11pm, the stability of the system is threatened; the power demand exceeds the power that is provided. From this first point of view, we can deduce that the charge is too important. As a reminder, the school in Sindi has 10 solar panels, not 8. Therefore, in practice, this charge might not be too important, but we operate under the 8 panels hypothesis.

The problem is that the additional charge the lamps represent during the day prevents the batteries to from charging. The energy surplus of the day does not charge the installations' batteries anymore, but

[76] 1Watt = 1 A * 1 volt. Therefore, we have 429mA * 3.2 = 1.37 Watts

[77] It is very likely that the USB technology would be used to charge the lamps, it is cheap, convenient. The USB technology is a standard that works under 5 volts.

the lamps' ones. As a result, at the end of the day, the school's batteries are not charged enough to be able to face the night's demand, hence the instability at 11pm.

If we only consider the power supply, the problem is not too important. However, this is not the case for the inverter. We can see that the inverter is clearly not sized to face such a demand, and we will see that the inverter will be the most constraining element of the system. If the project needs to charge a substantial number of lamps, the inverter would have to be changed or another one added.

We ran several simulations to find the maximum power the system can accept. While we were progressively reducing the disruption, we were constantly facing the same problems. According to the program, the inverter would not be able to manage the power demand, especially between 11am and 12am where the demand is the highest. The other problem occurs at 11pm where the power demand is more important than the supply. At the end, we estimated the maximum authorized by the system to be more or less 135 Watts which represents 63[78] lamps.

However, when we calculated the charge of one lamp, we considered a current that would charge the lamp in 7 hours. Therefore, the lamps would only need 7 hours to be fully charged which is not the case in our simulation – where we consider them to charge for 12 hours, from 6am to 6pm.

Instead of disturbing the system for 12 hours, if we disturb it during the 7 hours where the panels provide the most energy and if we avoid the 2 problematic hours (11 am and 12am) during which the lamps would not be charged, we can estimate a possible additional electric charge of 345 Watts – see Appendix X. These 345 Watts would allow to charge 161 lamps at once which more than doubles the capacity of the previous results.

However, the solution formulated above can be criticized on two points. First, this solution would require someone to unplug the lamps at 11am and reconnect them at 1pm. Given the cultural context, the respect of these instructions is not guaranteed. Second, charging the lamps at full power for 7 hours is not good for the lamps' batteries. It would be better to reduce the charge current at maximum and spread the charge over time. This could be achieved by acting on the charge current of the charger. We could thus spread the charge over the 12 hours of sunlight – from 6 am to 6pm. The current would thus be 250mA[79]. With a voltage of 5 Volts, the charge of one lamp would then be 1.25 W[80]. Under

[78] 135W / (2.14W/lamp) = 63 lamps
[79] = 3000 mAh / 12h = 250mA.
[80] = 0.250A*5 volts = 1.25 W

this configuration and with adaptations to improve the inversion capacity, up to 225 lamps can be charged at the same time (see Appendix X).

However, the conclusions above must be handled with kid gloves, because there are a lot of unknowns. As we said, charging the lamps at full power for 12 hours is not good for the lamps' batteries. It is likely that the manufacturer of the lamps has placed a security that cuts the charge once the batteries are fully charged, but we do not have this information. We do not know the actual current of the charger, nor if it would be possible to easily reduce the charge current and at which cost; thus, we do not know the actual charge duration. We do not know the lamps' batteries discharge either. In any case, charging the lamps' batteries with material that is not designed for the lamps introduces a lot of unknowns. Therefore, the discussion here is purely theoretical and further testing will have to be carried out.

6.4 CHARGING MATERIAL

We have determined the quantity of lamps that could potentially be charged by the school's installations. Yet, these installations, as they are, are not conceived to charge solar lamps. If we want to charge lamps, we need additional material we will call charging material. The following section will discuss and present the different elements that are necessary for being able to charge the lamps using school's power supply.

The school's solar panels provide direct current (DC) under 24 volts while its intern grid provides alternative current (AC) under 230 volts (see Appendix X), but the lamps batteries work under 3.2 volts (see Appendix V). We basically have 2 solutions. Either we connect directly to the panels or we connect to the grid. The first solution might seem better but, reveals to be more difficult to set up. The reason is because it is easier to go from 230 volts to 3.2 volts through AC, than from 24 volts to 3.2 with DC. We will thus consider the case where the lamps are charged using the 230 volts grid, but before going further, let's make a precision. The lamps' batteries work under 3.2 volts. However, such connectors may be difficult to find. We would recommend using the USB technology which works under 5 volts and easier to find and cheaper. Moreover, USB chargers are generally capable of providing current up to 500mA, which is sufficient in our case (Quechoisir, n.d.). According to Claude Jussiant, the voltage difference is not important enough to pose a problem. Moreover, it is probable that the lamps are equipped with necessary components to lower the input voltage. We make this hypothesis based on the Single solar model's technical sheet, from which we observe that the battery works under 3.7 volts while the solar panel's power supply is 6 volts (see Appendix V).

Unfortunately, we do not have this information for the other models, but it still support our assumption.

So, the goal is to switch between 230 volts in AC and 5 volts in DC. To be able to do so, 3 elements are necessary: a transformer 230/5V, an AC/DC converter and a Zener diode in parallel (see diagram in the Appendix XI).

The transformer allows to switch between the two voltages through the characteristics of the AC. The converter straightens up the AC current into DC using 4 diodes and a resistor or a self (see Appendix XI). Last, the Zener diode in parallel, joined with a resistor in a series, is used to smooth the voltage variations. A Zener diode in parallel in a circuit is used to always provide the same output voltage at its bounds, whenever the input voltage is higher than its breakdown voltage – if not too important, otherwise the diode could be damaged. For example, if a Zener diode has a 5 volts breakdown voltage and has a 6, 7 or 8-input tension, the circuit will still have 5 volts of voltage at the diode's bounds. However, if the input voltage is lower than the breakdown one, the diode will block the current and thus will not affect the tension at its bounds. That is why, to insure a constant output of 5 volts, more than 5 volts should be present at the diode's bounds.

What makes this circuit very interesting is the fact that it is very easy to find. Indeed, the circuit presented above is basically what is present in a classic USB charger which make it a very cheap solution.

6.5 CONCLUSION

We have determined the number of lamps that can be charged at the same time using the school's solar equipment, which is 225 under certain conditions. This number does not represent the number of customers who can potentially benefit from this solution. It is unlikely that all the customers would charge their lamps at the same time. Thus, even if the maximum number customers must be assessed, 225 lamps is not a limitation.

The advantage of the solution presented here is that it is very technically simple to implement. Some tests should be carried out before, but the material required (mainly sockets, chargers and an inverter) can be found easily.

However, we should still be careful about this solution. Let's repeat the raison d'être of this solution. The purpose was to obtain the lamps at a lower price by not purchasing them with their solar panel

and therefore, using the solar installations to charge them. The advantage of doing this was to reduce the lamps' price, making them more accessible to financially weaker people.

As mentioned, this solution requires additional material. Even though this material could be obtained at a cheap price, the material's price must be lower than the savings made by not purchasing the solar panels. Moreover, the price difference must be significant enough for this solution to be attractive. A cost-benefit analysis will have to be carried out!

However, the association should try to avoid this solution insofar as possible. We do not think that the model could be based entirely on the solution presented here. This solution is interesting if some financially weak customers are not able to buy the lamps with the panels, but for several reasons it should not be generalized – time consuming, difficult to manage, inconvenient, etc. By limiting the number of customers that benefit from this solution, we can also reduce its cost (sparing the inverter's costs) and make it more attractive for these financially weaker people. Furthermore, the charging material could be financed through the profit generated by the association with the other customers, gaining in attractiveness again.

7 PROJECT MANAGEMENT

In September 2018, students in Business Engineering were given a training course about project management. We will present in the present chapter how the tools and skills we were given during this training helped us or not to realize our project thesis.

A thesis is a substantial work. It is spread over a long period of time and represents an important part of the course. We were very conscious of the work it represented and determined to tackle it in the best possible way. We began checking in the toolbox we were given during the training course.

The first aspect of project management we considered was the importance of planning. The first thing we did was to establish the main steps to follow for our thesis, which we presented in our development plan. Then, we tried to define the different tasks to be done to complete these steps. At the end, we were in possession of a working structure to successfully undertake our thesis.

The next step was to estimate the time that would be needed to complete each task, in order to make a schedule and a Gantt chart – you will find the Gantt chart we made in the Appendix XII. We used a pre-programmed Excel sheet to do our Gantt chart, which we divided in 3 parts. One is dedicated to the search of information and development of our model. The second part was to plan our readings but since Ostrom was our only big reference, we did not need this schedule anymore. And the third part helped us to schedule our thesis writing.

We did not define the critical path of our schedule, because we thought that it would have been irrelevant doing so. For some parts we highly depended on other individuals. It took time sometimes to contact and obtain the answers and information we needed from resource persons, so we had to begin other tasks in advance so as to avoid losing time waiting for responses. Moreover, most of tasks were interdependent. The third task could influence the first one which could have needed to be done again. The non-linearity between the tasks made it irrelevant to try defining a critical part.

This scheduling was time consuming. But even so, it proved to be very useful. It allowed us to have a clear vision of what to do, when and how much time would be necessary. Most of all, it allowed us to structure our work and our thought process. The project is wide, and a lot of things needed to be tackled. When dealing with such a project, it can easily become confusing. We were able to focus and not to get ahead of ourselves by following the plan and Gantt chart we made.

When doing a large and long project, the time, days, the weeks goes by very quickly. The Gantt chart helped us realize this and to monitor where we were in our work, what had been done, what still

needed to be done and in what time frame. It avoided getting lost in the work and above all, being trapped by missing time, which we think is very common for this type of project. If we are on schedule, it is because we were able to monitor our time at the most critical moment, that is in the first weeks of the project.

We were able to follow the Gantt chart for a month, but then it became impossible to do so. All the estimations we made turned out to be wrong. The tasks to do, as well as their completion time. Some tasks were not necessary or not relevant anymore, others needed to be added or changed and we were systematically late. It was very useful for a while, but it became too constraining and time consuming to constantly adapt the schedule. To such an extent that we had to stop using it. As time went by, the project became more and more clear in our mind. Thanks to the Gantt chart which helped us structure our work, we had a clear vision of what to do and in which order. Once you have a clear vision in your mind of what to do, even if the tasks were changing, we were able to easily adapt our work. At this point, the Gantt chart became totally unnecessary.

Of course, we still had to manage our time. In order not to lose track, we were regularly checking the calendar and setting deadlines to force ourselves to progress and avoid stagnating. But we no longer felt the need to formalize this in the Gantt chart or any other planning tool.

In conclusion, we will say that for our part, it was very useful to make a schedule and structure our work at the beginning. But in our opinion, this tool was not appropriate for our project. Even if we tried to schedule our work, it was impossible to respect the schedule. The project was highly dependent on the information and data we were receiving. This information could have affected any dimension of the project, so trying to progress step by step did not really make sense later in the project.

We did not feel the need to use or follow other recommendations from the training course. The reason being that it was irrelevant to us. A simple costs-benefits analysis supported our feeling. The time we would have spent to review all the course to seek further useful elements would have been substantial. Moreover, we estimated that the benefits we would have reaped from doing so was poor regarding their costs.

Resource planning and management is irrelevant in our case since the only resource of our project was our working time. We could have tried to allocate our time to different tasks, but this was already done in the Gantt chart. Estimating that a task would take 5 days to be completed is equivalent to allocate 5days*8hours of our working time to this task.

A similar reasoning can be applied to costs management and planning. Our project-thesis did not involve any costs in the way it was presented in the training course.

A potentially useful tool would have been risk management. As we said, our project involved quite a lot of uncertainty. It depended highly on the information we were collecting, and one critical information could have turned the project upside down. But the project was not complex enough to require a full risk management. First, for most of the events/risks we could have thought about, it was very unlikely that these would come true. Second, we did not identify such a risk that would have put our project thesis in danger. Third, we trusted our mentor and supervisor. We knew that there was no issue for which we would not have found a solution. That is why we thought irrelevant to apply a complete and formal risk management to our project thesis.

In a project-thesis, communication is key and can be decisive. Especially when the project takes place in an important structure. The other students told us that it may be difficult to obtain the information needed. In a company environment, people are busy and have no time to grant to your project. Moreover, they have the tendency to see you as an intern to babysit, a burden more than an asset. Good communication can raise awareness about your project and prove its interest. It can also be useful to be seen less as an intern and more as a co-worker. In a project thesis, you are supposed to act and be considered as an advisor. You are there to help the company solving an issue. These are reasons why communication should be taken seriously while making a project-thesis.

However, in our case, the communication never was a concern. Firstly, because ISF is a small organization and secondly because our mentor was always available when needed. It would have been irrelevant to do communication management in our case, since communication never was an obstacle.

In conclusion, project planning and scheduling were very useful to us initially. It allowed us to tackle our project peacefully and in a structured manner. But at the end, it became too constraining and unnecessary. Other tools and techniques like communication management would have been relevant in the frame of a project-thesis but was not regarding the context of ours. Finally, we considered the rest of techniques and tools seen in the training course to be irrelevant.

GENERAL CONCLUSION

The situation regarding electricity access in Sub-Saharan Africa and especially in the Democratic Republic of the Congo (DRC) is grave. It greatly affects people's life in many ways and represents an obstacle to education, which is our main concern. Reality is stark, and people lack solutions, despite all the opportunities that exist.

The model we have developed is one solution which can be used to partially respond to this issue. Our model is not an absolute answer, but we truly believe in its potential and the impact it could have on people's everyday life.

Our model's main purpose is to provide rural/suburban communities with solar lamps. These lamps will allow children to do their homework in better conditions and will avoid households using oil lamps, which are expensive and polluting.

We used the special case of Sindi, a small suburban area of Boma in the DRC, as pilot environment to develop our model.

We have seen how to greatly increase the governance's durability of the project through Ostrom's 7 recommendations:

9. Clearly defined boundaries
10. Congruence between appropriation and provision rules and local conditions
11. Collective-choice arrangements
12. Monitoring
13. Graduated sanctions
14. Conflict-resolution mechanisms
15. Minimal recognition of rights to organize

Our economic model has been developed using the "Social Business Model Canvas" modelling tool. Even though the model is based on the special case of Sindi, it can still be generalized to other communities.

The model's principle is to gather people around a meaningful topic related to domestic lighting (in this project, children's education). The participants become members of an association that they create and elect a management committee. The association also creates a partnership with a third-party to help finance the lamp purchase. Once the lamps are purchased from the supplier, this third-

party entrusts the association with them. The association is then responsible for distributing the lamps and collects the payments to pay back the third-party. The tontine system can be used to replace the lamps once their lifespan has fallen expired.

A lot of lamp suppliers exist on the market. We defined criteria to guide our selection: price, the localization and lamps' characteristics. We analyzed and compared the different offers we were able to identify and reached the conclusion that 4 lamp models are more or less equivalent. Unfortunately, we lack too much information about the on-site situation to be able to make a definitive choice. We had to make estimations based on information we were able to collect from Belgium. Further studies should be carried out on the spot before starting the project, to make the best selection.

We explored the different financing possibilities for the project. Some have costs, other do not and some are easier than others. Regarding the project's nature as well as the elements we discussed, we think that ISF should finance the project by granting a loan to the association. This loan would be financed through donations and/or subsidies. This solution may be the most constraining for ISF, which will have to seek such support, but it is the safest solution, financially speaking. The decision is up to ISF. The other solutions we presented are also valid ones.

Sindi's school is equipped with solar installations. We emitted the idea that those could be used to charge the lamps, which may reduce costs. Furthermore, we analyzed the technical feasibility of doing so. Our results indicated that, under certain conditions, up to 161 lamps could be charged at the same time. We also defined the material required to charge the lamps. Classic USB chargers might perfectly be suitable, but some tests should still be made before to insure proper functioning. We discussed the pros and cons, and, in our opinion, this solution should be reserved for a limited number of customers, the financially weakest, who cannot afford the full package offer.

This paper represents the theoretical study of the project. A lot of work still needs to be done on site. A market study should be carried out before starting the project, information and hypotheses must be confirmed or disconfirmed, the project must put in place, be presented to the population, obtain their approbation and involvement, and so on.

We truly believe in the project and its impact on people's life. This paper contains all the elements for the project to be successful. We hope it will be launched and lessons drawn. This project can serve as pilot, allowing to perfect the model. Then, who knows, maybe we will be able spread it and improve hundreds, if not thousands of people's everyday life.

APPENDICES

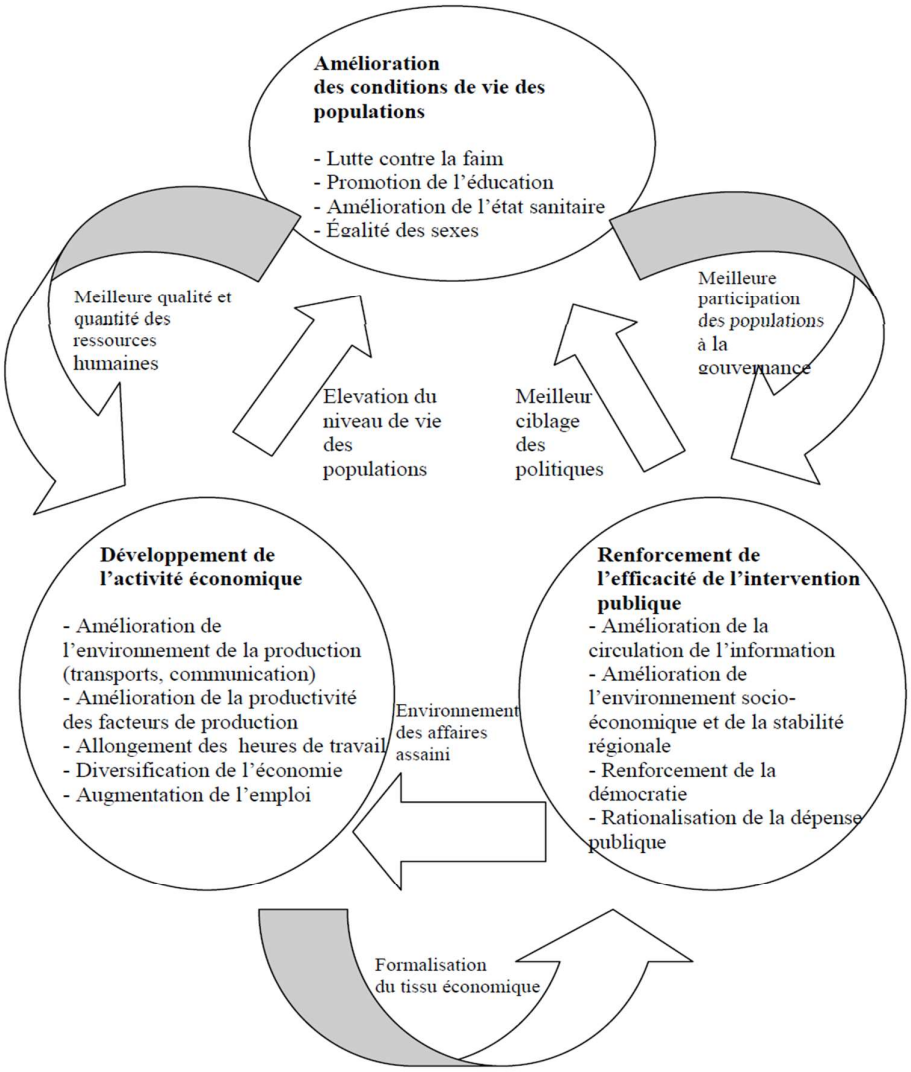
TABLE OF CONTENTS : APPENDICES

APPENDIX I: "ACCESS TO ENERGY, KEYSTONE FOR ECONOMIC, POLITICAL AND SOCIAL DEVELOPMENT"

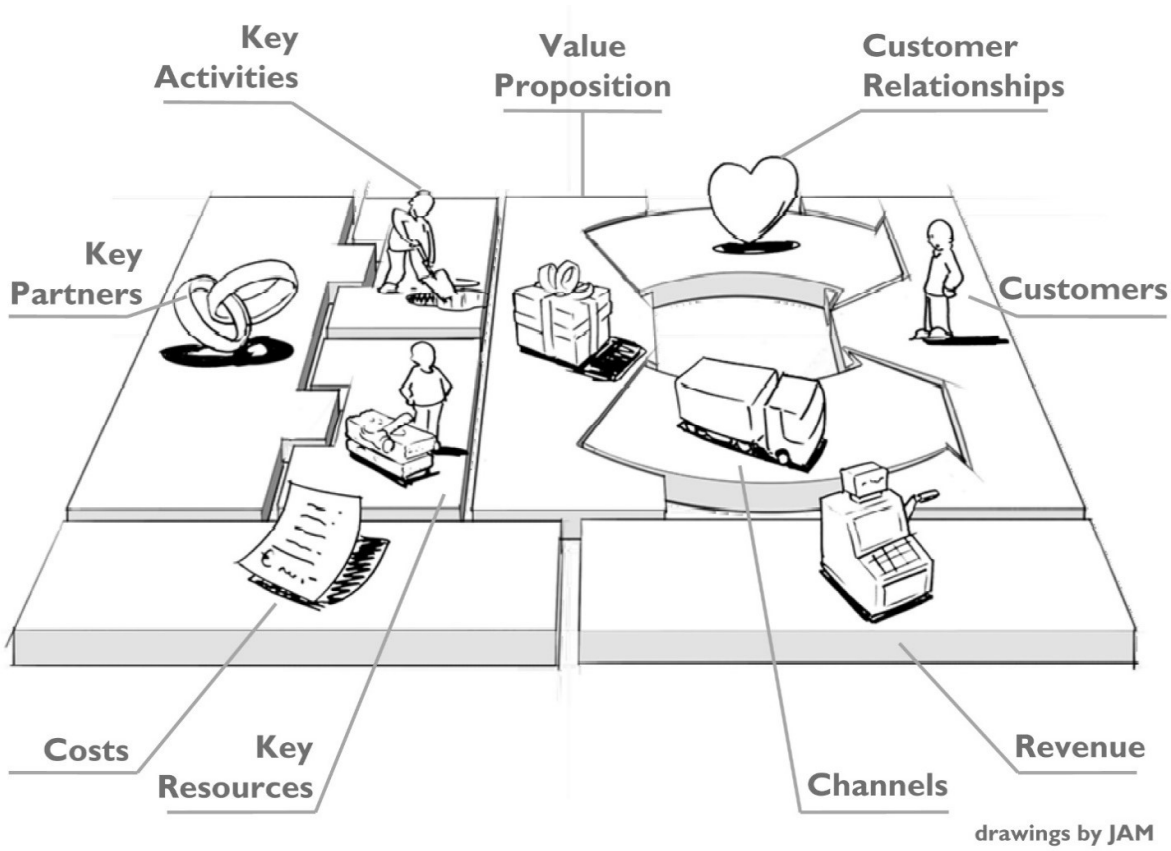
(Quatrième forum international sur les perspectives africaines, 2004)

L'accès à l'énergie, clef de voûte du développement économique, social et politique

L'accès à une offre d'énergie de qualité permet d'améliorer substantiellement les conditions de vie des populations car elle favorise la lutte contre la faim et la malnutrition grâce à la cuisson et la préservation des aliments par la réfrigération, à l'amélioration de la productivité au sein de la chaîne alimentaire et au développement de mode de production agricole modernes. Il constitue un élément essentiel de progrès sanitaire *via* l'amélioration de l'hygiène alimentaire et le perfectionnement des équipements médicaux.



APPENDIX II: THE "BUSINESS MODEL CANVAS" AND BURKETT'S "SOCIAL BUSINESS MODEL CANVAS""

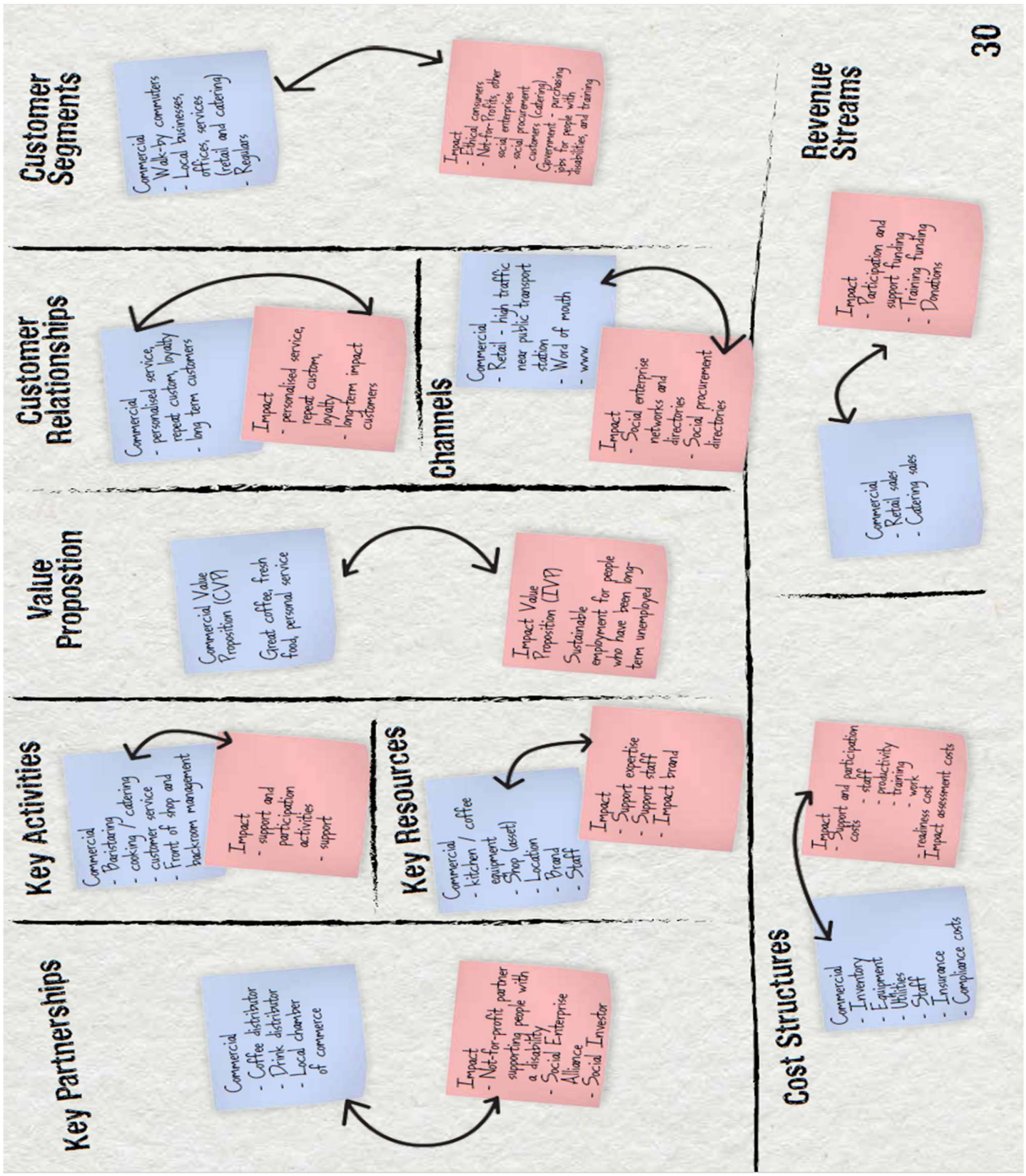


7.1.1 Osterwalder & Pigneur's "Business Model Canvas"

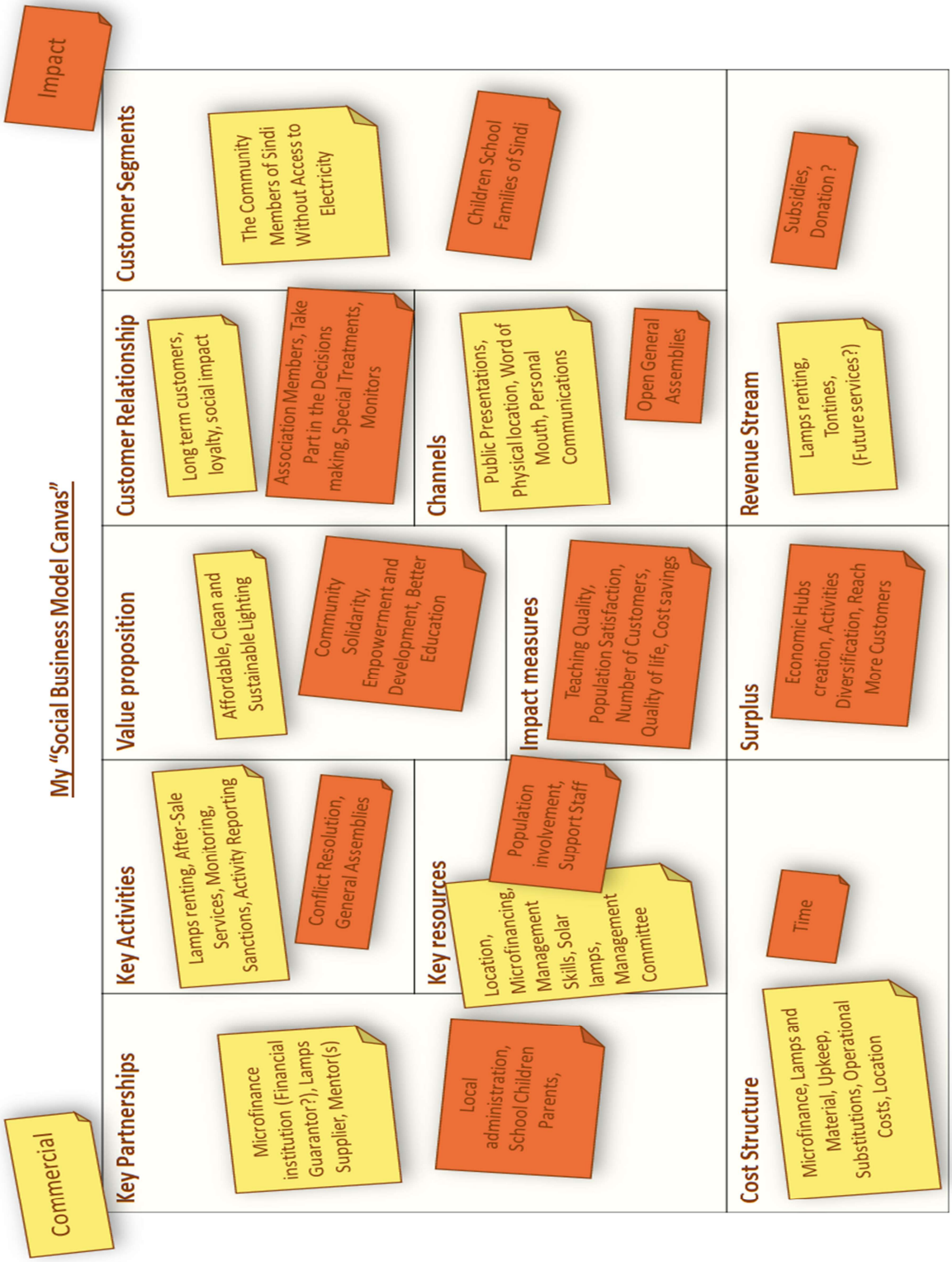
Debliquy, P. (2012, September 20). *Comment fonctionnent mes concurrents (Business Canvas Generation)?* Retrieved (May 24, 2018) from http://blog.euresis.com/index.php?/archives/930-Comment-fonctionnent-mes-concurrents-Business-Canvas-Generation.html

Burkett's "Social Business Model Canvas"

Burkett I. (n.d.). *Using the business model canvas for social enterprise design, p.30*. Retrieved (April 30, 2018) at: http://cscuk.dfid.gov.uk/wp-content/uploads/2016/07/BMC-for-Social-Enterprise.pdf

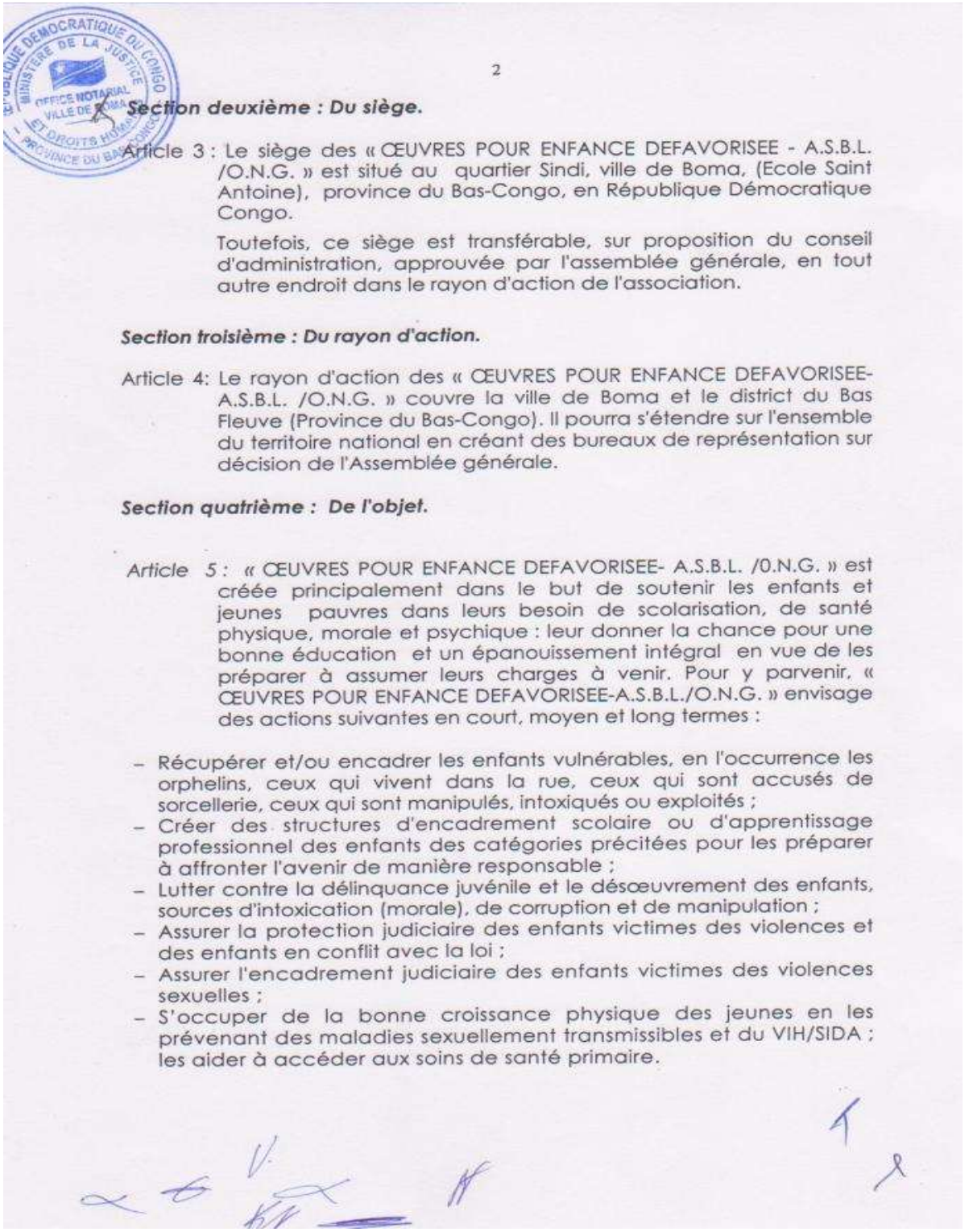


APPENDIX III: OUR "SOCIAL BUSINESS MODEL CANVAS"



APPENDIX IV: "ŒUVRES POUR L'ENFANCE DÉFAVORISÉE"'S LEGAL STATUS

Œuvres pour l'enfance défavorisée. (2014, July). *Legal Status, p2 [Official document]*. Boma, Democratic Republic of Congo.



2

Section deuxième : Du siège.

Article 3 : Le siège des « ŒUVRES POUR ENFANCE DEFAVORISEE - A.S.B.L. /O.N.G. » est situé au quartier Sindi, ville de Boma, (Ecole Saint Antoine), province du Bas-Congo, en République Démocratique Congo.

Toutefois, ce siège est transférable, sur proposition du conseil d'administration, approuvée par l'assemblée générale, en tout autre endroit dans le rayon d'action de l'association.

Section troisième : Du rayon d'action.

Article 4: Le rayon d'action des « ŒUVRES POUR ENFANCE DEFAVORISEE-A.S.B.L. /O.N.G. » couvre la ville de Boma et le district du Bas Fleuve (Province du Bas-Congo). Il pourra s'étendre sur l'ensemble du territoire national en créant des bureaux de représentation sur décision de l'Assemblée générale.

Section quatrième : De l'objet.

Article 5 : « ŒUVRES POUR ENFANCE DEFAVORISEE- A.S.B.L. /0.N.G. » est créée principalement dans le but de soutenir les enfants et jeunes pauvres dans leurs besoin de scolarisation, de santé physique, morale et psychique : leur donner la chance pour une bonne éducation et un épanouissement intégral en vue de les préparer à assumer leurs charges à venir. Pour y parvenir, « ŒUVRES POUR ENFANCE DEFAVORISEE-A.S.B.L./O.N.G. » envisage des actions suivantes en court, moyen et long termes :

- Récupérer et/ou encadrer les enfants vulnérables, en l'occurrence les orphelins, ceux qui vivent dans la rue, ceux qui sont accusés de sorcellerie, ceux qui sont manipulés, intoxiqués ou exploités ;
- Créer des structures d'encadrement scolaire ou d'apprentissage professionnel des enfants des catégories précitées pour les préparer à affronter l'avenir de manière responsable ;
- Lutter contre la délinquance juvénile et le désœuvrement des enfants, sources d'intoxication (morale), de corruption et de manipulation ;
- Assurer la protection judiciaire des enfants victimes des violences et des enfants en conflit avec la loi ;
- Assurer l'encadrement judiciaire des enfants victimes des violences sexuelles ;
- S'occuper de la bonne croissance physique des jeunes en les prévenant des maladies sexuellement transmissibles et du VIH/SIDA ; les aider à accéder aux soins de santé primaire.

APPENDIX V: LAMPS' TECHNICAL SHEETS

Ecozoom: Single Solar +

ecozoom™

Single Solar +

With Power Bank

- 1 Solar powered lamp with 2 brightness settings
- 8 hours of lighting per bulb
- 2 year Warranty
- 3 year battery life
- Mobile phone charging

How to Use

No need for cables. you can use the lamp inside, outside or on the go

Easily move lamps from one room to another. No restrictive cables

Charge the lamps during day using solar panel

Technical Specifications

Solar Panel	4W 6V polycrystalline, plastic frame, 6M cable, 1 DC connector for charging light. One USB cable.
LED Lamp	One bulb, orange housing, with 2200mAh 3.7V lithium ion battery, two brightness settings, frosted glass.
Charging	5-in-1 mobile charging cable.
Brightness	Two brightness settings (150 & 75 lumens).
Solar run times (per bulb)	3.3 hours on 150 lumens, 6.4 hours on 75 lumens
Power Bank	Aluminium shell, 2,600 mAh capacity.
	*Please charge your new solar product for minimum 5 hours before use

Shipping Specifications

Shipping Weight	Box dimensions	20' Container Qty	40' Container Qty
1 kg/unit	(l) 23cm • (w) 10cm • (h) 20.5cm	4,880 units	11,000 units

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ecozoom™

Single Solar

With phone charging

- 1 Solar powered lamp with 2 brightness settings
- 8 hours of lighting per bulb
- 2 year Warranty
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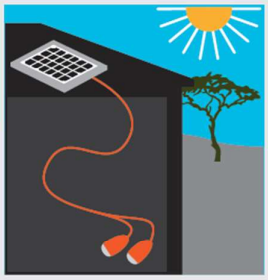
How to Use

No need for cables. you can use the lamps inside,outside or on the go

Easily charge lamps from one room to another. No restrictive cables



Charge the lamps during day using solar panel

Technical Specifications

Solar Panel	3W 6V polycrystalline, plastic frame, 6M cable, 1 DC connector for charging light. One USB cable.
LED Lamps	One bulb, orange housing, with 2200mAh 3,7V lithium ion battery, two brightness settings, frosted glass.
Charging	5-in-1 mobile charging cable.
Brightness	Two brightness settings (150 & 75 lumens).
Solar run times (per bulb)	4 hours on 150 lumens, 8 hours on 75 lumens

Shipping Specifications

Shipping Weight	**Box dimensions**
1kg/unit	(h) 25cm • (w) 23cm • (d) 9cm

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Lagazel: Kalo 1500

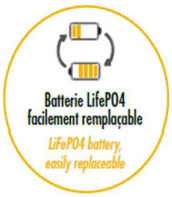
LAGAZEL KALO 1500

SPÉCIFICATIONS TECHNIQUES
TECHNICAL SHEET

	Dimensions / *Size*	Coffret / *Box* : 98 x 64 x 201 mm. Lampe seule / *lamp only* : 90 x 40 x 150 mm		
	Poids / *Weight*	Coffret / *Box* : 745 g. Lampe seule / *lamp only* : 450 g		
	Technologie d'éclairage *Lighting technology*	Plusieurs DEL haut rendement *Multi, high-efficiency LEDs*		
	Niveaux d'éclairage *Lighting modes*	Eco	Normal	Turbo
	Puissance d'éclairage *Lumen output*	15 lm	30 lm	70 lm
	Autonomie après un jour de charge *Daily solar runtime*	24 h	13 h	6 h
	Autonomie après une charge complète *Run time after a full battery recharge*	30 h	16 h	8 h
	Technologie de batterie *Battery technology*	Lithium fer phosphate *LiFePO4*		
	Capacité de la batterie *Battery capacity*	1 500 mAh - 3,2 V		
	Durée de vie batterie *Battery lifespan*	2000 cycles *2000 cycles*		
	Technologie panneau solaire *Solar panel technology*	Polycristallin *Polycristalline*		
	Puissance panneau solaire *Solar panel power*	1,2 Wp		
	Longueur câble *Cable length*	4 mètres *4 metres*		
	Matériaux coque *Hull materials*	Acier galvanisé ou laqué anti-choc, anti-corrosion *Stainless zinc-coated steel or laquered shockproof, withstand corrosion*		
	Matériaux hublot *Window materials*	Polycarbonate anti choc, anti-UV *Shockproof polycarbonate, anti-UV protection*		
	Garantie / *Warranty*	2 ans / *2 years*		
	Qualité Quality	Conforme aux normes de qualité Lighting Global *Meets Lighting Global Quality Standards*		
	Durée de vie *Lifespan*	Batterie : 5 ans, lampe et panneau :10 ans *Battery: 5 years, Lamp and panel: 10 years*		
	Accessoires / *Accessories*	Sangle d'attache / *Hanging strap*		

Énergie solaire gratuite
Free solar energy

Lampe en métal, robuste, résistante aux chutes
Metallic and sturdy lamp, resilient to chock



Batterie LifePO4 facilement remplaçable
LiFePO4 battery, easily replaceable

Conforme aux standards de qualité Lighting Global
Meets Lighting Global Quality Standards

Fabriquée en France et en Afrique
Made in France and Africa

LAGAZEL
Lighting Everywhere

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Lagazel: Kalo 3000

LAGAZEL KALO 3000

SPÉCIFICATIONS TECHNIQUES
TECHNICAL SHEET

	Dimensions / *Size*	Coffret / *Box* : 98 x 94 x 201 mm. Lampe seule / *Lamp only* : 90 x 40 x 160 mm		
	Poids / *Weight*	Coffret / *Box* : 1080 g. Lampe seule / *lamp only* : 520 g		
	Technologie d'éclairage *Lighting technology*	Plusieurs DEL haut rendement *Multi, high-efficiency LEDs*		
	Niveaux d'éclairage *Lighting modes*	Eco	Normal	Turbo
	Puissance d'éclairage *Lumen output*	15 lm	65 lm	130 lm
	Autonomie après un jour de charge* *Daily solar runtime* *	38 h	12 h	6 h
	Autonomie après une charge complète* *Run time after a full battery recharge**	44 h	14 h	7 h
	Port USB *USB port*	Compatible avec la majorité des téléphones *Compatible with most phones*		
	Technologie de batterie *Battery technology*	Lithium fer phosphate *LiFePO4*		
	Capacité de la batterie *Battery capacity*	3 000 mAh - 3,2 V		
	Durée de vie batterie *Battery lifespan*	2000 cycles *2000 cycles*		
	Technologie panneau solaire *Solar panel technology*	Polycristallin *polycristalline*		
	Puissance panneau solaire *Solar panel power*	2,4 Wp		
	Longueur câble *cable length*	4 mètres *4 metres*		
	Matériaux coque *Hull materials*	Acier laqué anti-choc, anti-corrosion *Laquered shockproof steel, whistand corrosion*		
	Matériaux hublot *Window materials*	Polycarbonate anti choc, anti-UV *Shockproof polycarbonate, anti-UV protection*		
	Garantie / *Warranty*	2 ans / *2 years*		
	Qualité *Quality*	Conforme aux normes de qualité Lighting Global *Meets Lighting Global Quality Standards*		
	Durée de vie *Lifespan*	Batterie : 5 ans, lampe et panneaux :10 ans *Battery: 5 years, Lamp and panels: 10 years*		
	Accessoires *Accessories*	Sangle d'attache - Pieds de lecture rétractables *Hanging strap - Extendable reading stand*		

Énergie solaire gratuite
Free solar energy

Lampe en métal, robuste, résistante aux chutes
Metallic and sturdy lamp, resilient to chock

Batterie LiFePO4 facilement remplaçable
LiFePO4 battery, easily replaceable

Conforme aux standards de qualité Lighting Global
Meets Lighting Global Quality Standards

Fabriquée en France et en Afrique
Made in France and Africa

* Recharger un téléphone diminue l'autonomie de l'éclairage / *Mobile phone charging can reduce the daily runtime of the lights*

LAGAZEL
Lighting Everywhere

www.lagazel.com - contact@lagazel.com

1

D.LIGHT S20B

instruction manual

Features

1 1 Solar lantern d.Light S20

Component plugging

1 Glow-in-the-dark power button
2 Integrated solar panel
3 5 V plug for Nokia 2 mm charger (not included)
4 Charge indicator
5 Metal hanging handle

Solar charging

Fully charge the lantern before 1st use.

Make sure d.light S20's solar panel faces sunlight directly throughout the day for best performance. The product will only be fully charged after 6 hrs of direct bright sunlight. The charging indicator is red if the battery is charging, and turns off when the battery is full.

This solar lantern is waterproof and can be installed outside permanently. On cloudy or rainy days, charging can still work but it will la longer.

For charging, do not install the lamp in a place shaded by trees or structures.

Note :
Wipe solar panel clean of dust and dirt to maintain charging performance.
Use Nokia 2 mm charger to charge the lamp on the grid (5 - 6 hours long).

D.LIGHT S20B

instruction manual

Use

Press the button:
1x to light on at a Low level (17 lm - 8 h).
2x to light on at a High level (25 lm - 4 h).
3x to turn off the lantern.

At high level, it is possible to read and work up to 0.6 m far from the lantern, within a 1m diameter circle (1 person).
Use the shape of the lantern and its handle to direct the light in several positions and for taking it away.

Maintenance

For an optimal use of the lantern for 5 years:
*Fully charge the lantern **at least once a year**.*
Wipe solar panel clean of dust and dirt to maintain charging performance.
After use, keep the lantern safe inside, protected from sun and rain, best between 0°C and 25°C.

Note :
If the lantern does not work, charge it one full day at sunlight (or on the grid) to reload it.

Warranty

This solar lantern is covered by the **Awango by Total 2 year warranty**. These conditions apply to warranty:
The warranty covers manufacturing defects, but not normal wear and tear or abuse.
The warranty is void if the product is tampered in any way, or if the case is opened by an unauthorized repair person.
The warranty does not cover under-performance related to improper installation (shaded panel, etc.).

1

D.LIGHT S300B

instruction manual

Features

1 1 Solar lantern d.light S300B
2 1 Solar panel
3 1 USB charging cable

Component plugging

1 Power button
2 5V socket for solar panel or Nokia2mm charger (not included)
3 Pin of the solar panel
4 USB socket
5 Battery indicator
6 USB cable and adaptors for mobile phone charging
7 Handle

Solar charging

Fully charge the lantern before first use.

Install solar panel straight up, facing open sky, all day long. During solar charging, the battery indicator may climb up, and light full when battery is full.

Do not install the solar panel in a place shaded by trees or structures.

Solar panel is waterproof and can be installed outside permanently. On cloudy or rainy days, charging can still work but it will last longer.

Do not expose the lamp to the sunlight while charging.

Note :
Wipe solar panel clean of dust and dirt to maintain charging performance.
Use Nokia 2 mm charger to charge the lamp on the grid (6 hours long).

D.LIGHT S300B

instruction manual

Use

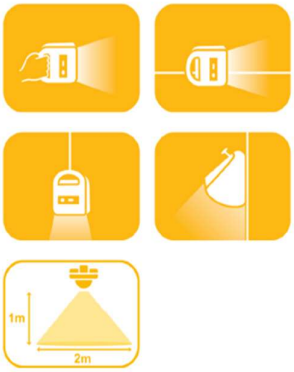
Press the button:
1x to light on at Bed light level (5 lm - 100 h)
2x to light on at Low level (25 lm - 16 h)
3x to light on at Medium level (50 lm - 8 h)
4x to light on at High level (100 lm - 4 h)
5x to turn off the lantern.

While in use, battery indicator displays battery power remaining.
At high level, it is possible to read and work easily up to 1m far from the lantern, within a 2m diameter circle (2 - 3 persons).

The lantern can be set down in several positions. Handles enable the lantern to be hung, or to be handled for mobile use.

Solar panel may be tied down using holes on solar panel frame.

Warning :
The lantern is designed for occasional use outside during rainy weather. If water enters the charging ports, leave the to dry indoors after use.



Mobile phone charging

1.Select the right adaptor for your phone.
2.Connect the phone to the USB cable, through this adaptor.
3.Connect the cable to the lantern through the USB port.

Warning :
Do not connect the solar panel directly to a phone. The phone may be damaged.

Note :
It is not necessary to connect the solar panel to the lamp to charge a mobile phone.
Phone charging may reduce the time of lighting of the lantern, until next lantern charging.
USB charging will be disabled when the battery is low (check for red low-battery indicator).

Maintenance

For an optimal use of the lantern for 5 years:
Fully charge the lantern **at least 1x a year**.
Wipe solar panel clean of dust and dirt to maintain charging performance.
After use, keep the lantern safe inside, protected from sun and rain, best between 0°C and 25°C.

Note :
If the lantern does not work, charge it one full day at sunlight (or on the grid) to reload it.

Warning :
Routinely exposing the lantern to direct sunlight or rain will damage the lantern.

Warranty

This solar lantern is covered by the **Awango by Total 2 year warranty**. These conditions apply to warranty:
The warranty covers manufacturing defects, but not normal wear and tear or abuse.
The warranty is void if the product is tampered in any way, or if the case is opened by an unauthorized repair person.
The warranty does not cover under-performance related to improper installation (shaded panel, etc.).

APPENDIX VI: ADVANTAGES – DISADVANTAGES, SUMMARY TABLE

	ADVANTAGES	DISADVANTAGES
WITH PANELS	• Lamps can be used during the day • Charging a phone without damaging the battery • More convenient for customers and management committee	• Less dependent on the association • More difficult monitoring • Less incentive to insure payments
WITHOUT PANELS	• Dependence on the association • Better monitoring • Incentive to avoid default of payments • "Potentially" cheaper	• Waste of time for customers • Lamps cannot be used during the day • Charging a phone reduce battery's lifespan • Complex management of the lamps • Receive and return the lamps, time consuming

APPENDIX VII: SUPPLIER COMPARISON TABLES

Table 1: Price of the lamps

	Lagazel[81]		Awango[82]		Ecozoom[83]	
	LK1500	LK3000	S20	S300B	Single Solar	Single Solar +
Prices (1) 250 lamps	2,500,000 CFAF	4,250,000 CFAF	3,400 $	9,200 $	3,125 $	4,875 $
Prices (€) (2)[84] 250 lamps	3,810.98 €	6,478.66 €	2,764.23 €	7,479.67 €	2,540.65 €	3,963.42 €
Prices / lamp (3)[85]	15.24 €	25.91 €	11.06 €	29.92 €	15.85 €	10.16 €
Prices / lamp *40%[86] (4)	21.34 €	36.28 €	11.06 €	29.92€	22.20 €	14.23 €

[81] The figures come from a cost estimation we were given by Jean Delattre, personal communication, March 29, 2018
[82] Figures were given by Karl Gupa, personal communication, March 29, 2018.
[83] Figures were given by Ronald van Harten, personal communication, April 2, 2018.
[84] (2) = (1) / Currency. Where 1€=1.23 $ & 1€=656 CFAF
[85] (3) = (2) / 250.
[86] (4) = (3) * 1.4

Table 2: Shipping cost of the lamps

	Lagazel[87]		Awango[88]		Ecozoom[89]	
	LK1500	LK3000	S20	S300B	Single Solar	Single Solar +
Shipping cost (5)	783,420 CFAF	924,945 CFAF	/	/	1,500 $	1,700 $
Shipping cost[90] (€) (6)	1.194,24 €	1.409,98 €	/	/	1,219.51 €	1,382.11 €
Additional 500€ (7)	500 €	500 €	/	/	500 €	500 €
Total shipping cost[91] (8)	1,694.24 €	1,909.98 €	/	/	1,719.51€	1,882.11€
Total shipping cost / lamp[92] (9)	6.78 €	7.64 €	/	/	6.88 €	7.53 €

[87] The figures come from a cost estimation we were given by Jean Delattre, personal communication, March 29, 2018.
[88] Figures were given by Karl Gupa, personal communication, March 29, 2018.
[89] Figures were given by Ronald van Harten, personal communication, April 2, 2018.
[90] (6) = (5) / Currency. Where 1€ = 1.23 $ & 1€ = 656 CFAF (Google currency converter, April 2018)
[91] (8) = (7) + (6)
[92] (9) = (8) / 250

APPENDIX VIII: SUPPLIERS COMPARISON AND FINANCIAL ASPECTS TABLE

	Lagazel		Awango		Ecozoom		
	LK15000	LK3000	S20	S300B	Single solar	Single solar +	
Period	3 ans						(9)
Number of lamps	250						(10)
Monthly price	**1,50 €**						(11) = (4) * (1-())
Yearly price	18,00 €						(12) = (11) * 12
Customs clearence costs in %	40%						(13)
Lamps cost	3.810,98 €	6.478,66 €	2.764,23 €	7.479,67 €	2.540,65 €	3.963,42 €	(14)
Lamps cost with customs clearence cost	5.335,37 €	9.070,12 €	2.764,23 €	7.479,67 €	3.556,91 €	5.548,79 €	(15) = (14) * (1 + (13))
Shipping cost	1.194,24 €	1.409,98 €	- €	- €	1.219,51 €	1.382,11 €	(16)
Total shipping cost	1.694,24 €	1.909,98 €			1.719,51 €	1.882,11 €	(17) = (16) + (3)
Total purchasing price	7.029,61 €	10.980,10 €	2.764,23 €	7.479,67 €	5.276,42 €	7.430,90 €	(18) = (17) + (15)
Price of one lamp	21,34 €	36,28 €	11,06 €	29,92 €	14,23 €	22,20 €	(19) = (15) / (10)
Shipping cost per lamp	6,78 €	7,64 €	- €	- €	6,88 €	7,53 €	(20) = (17) / (10)
Total purchasing price per lamp	28,12 €	43,92 €	11,06 €	29,92 €	21,11 €	29,72 €	(21) = (19) + (20)
Monthly cost of one lamp	0,78 €	1,22 €	0,31 €	0,83 €	0,59 €	0,83 €	(22) = (21) / ((9) * 12)
Yearly cost of one lamp	9,37 €	14,64 €	3,69 €	9,97 €	7,04 €	9,91 €	(23) = (21) / (9)
Reduction compared to oil lamps	**74,67%**	**60,43%**	**90,04%**	**73,05%**	**80,99%**	**73,22%**	(24) = 1 - ((22) / (4))
Reduction of the solar lamps' price compared to oil lamps'	**51%**						(25) = 1 - ((11) / (4))
Total loan costs estimations	**413,05 €**						(26) = (8)
Profit	2.019,11 €	702,28 €	3.440,91 €	1.869,09 €	2.603,51 €	1.885,35 €	(27) = (((12) - (23)) * (10)) - ((26) / (9))
Gross profit margin	47,93%	18,67%	79,52%	44,60%	60,92%	44,96%	(28) = 1 - ((22) / (11))
Total profit over the period	6.057,34 €	2.106,84 €	10.322,72 €	5.607,28 €	7.810,53 €	5.656,05 €	(29) = (27) * (9)

Data			
Currencies conversion	1euro =	1,23 dollars	(1)
		656 CFAF	(2)
Last Km transportation cost		500,00 €	(3)
Oil lamp cost per month		3,08 €	(4)=(5)+(6)/((7)*12)
	Fuel	3,00 €	(5)
	Lamp cost	1,00 €	(6)
	Lifespan	1 year	(7)
Loan cost		413,05 €	(8)

APPENDIX IX: SOLAR PANELS SIZING DATA FOR SINDI AND PREVIOUS RESULTS

	Input
	Output

Seules les cases input peuvent être modifiées

Données Batiments

Construit		
Classes	26	Lampes
	14	Prises
Guest	10	Lampes
	5	Prises
Cantine	3	Lampes
	3	Prises
	1	Frigo
Sanitair	2	Lampes
Extérieu	5	Spots
Matériel	1	TV
	2	PC
	1	Copieuse
	15	GSM

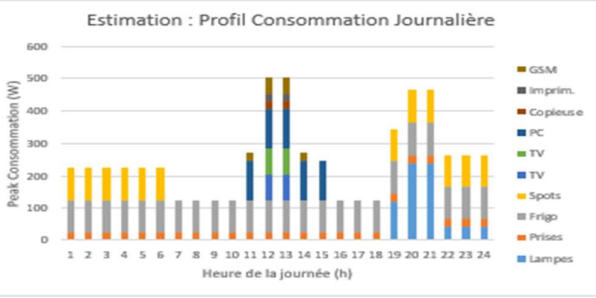
En construction		
Classes	26	Lampes
	14	Prises
Extérieu	5	Spots

En projet		
Classes	22	Lampes
	11	Prises
S. Poly	12	Lampes
	6	Prises
Santé	35	Lampes
	24	Prises
Extérieu	17	Spots

Sommaire : Consommation et nombre appareils

	Consommations		Nombres Présent	Const	Futur
Lampe	10	W	41	67	136
Prise	50	W	22	36	77
Frigo	100	W	1	1	1
Spot	10	W	5	10	27
TV	80	W	1	1	1
PC	60	W	2	2	2
Copieuse	25	W	1	1	1
Imprim.	25	W	1	1	1
GSM	10	W	15	15	15

Graphique de l'estimation du profil de consommation journalière



Résumé des consommations

Total	5930	W	Lampe	720	W
P max	465	W	Prise	600	W
P mean	247,1	W	Frigo	2400	W
			Spot	1200	W
			TV	160	W
			PC	600	W
			Copieuse	50	W
			Imprim.	50	W
			GSM	150	W

Consommation plus grande que la moyenne

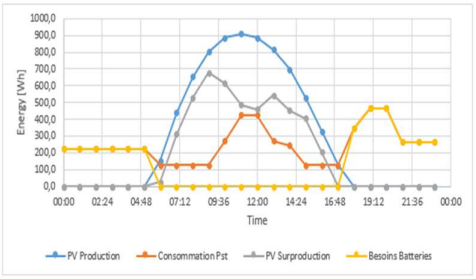
Tableau : Estimation des Consommation Journalières (Puissance)

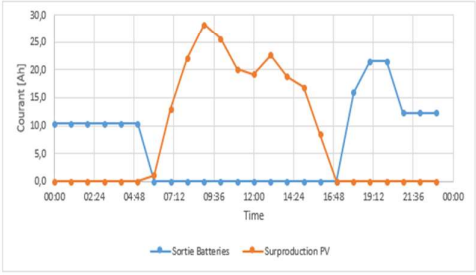
Heure	Lampes	Prises	Frigo	Spots	TV	PC	Copieuse	Imprim.	GSM	Total (W)
00:00	0	25	100	100	0	0	0	0	0	225
01:00	0	25	100	100	0	0	0	0	0	225
02:00	0	25	100	100	0	0	0	0	0	225
03:00	0	25	100	100	0	0	0	0	0	225
04:00	0	25	100	100	0	0	0	0	0	225
05:00	0	25	100	100	0	0	0	0	0	225
06:00	0	25	100	0	0	0	0	0	0	125
07:00	0	25	100	0	0	0	0	0	0	125
08:00	0	25	100	0	0	0	0	0	0	125
09:00	0	25	100	0	0	0	0	0	0	125
10:00	0	25	100	0	0	120	0	0	25	270
11:00	0	25	100	0	80	120	25	25	50	425
12:00	0	25	100	0	80	120	25	25	50	425
13:00	0	25	100	0	0	120	0	0	25	270
14:00	0	25	100	0	0	120	0	0	0	245
15:00	0	25	100	0	0	0	0	0	0	125
16:00	0	25	100	0	0	0	0	0	0	125
17:00	0	25	100	0	0	0	0	0	0	125
18:00	120	25	100	100	0	0	0	0	0	345
19:00	240	25	100	100	0	0	0	0	0	465
20:00	240	25	100	100	0	0	0	0	0	465
21:00	40	25	100	100	0	0	0	0	0	265
22:00	40	25	100	100	0	0	0	0	0	265
23:00	40	25	100	100	0	0	0	0	0	265

Sindi's previous sizing results

Données Input PV , Appareils et Batteries							
Données Input PV			**Données Pertes Appareils**			**Données Input Batteries**	
Irradiance Std	1000	W/m²	Pertes MPPT	10%	-	K temp	1 -
Pc module std	250	Wc	Pertes (ond.)	10%	-	K age	1 -
Rendement PV	15%	-	Pertes cables	3%	-	% fin de décharge	90% -
Rdmnt dégressif	6%	/°C	**Multiplicateur de consommation**				
Temperature	45	°C	0h ->6h	1	-		
Pertes cond clim	10%	-	18h -> 24h	1	-		
Aging PV (5 ans)	2,5%	-	6h -> 19h	1	-		

Graphique de production journalier : PV + Batteries + Consommation





Dimensionnement : Données Input PV et Batteries				
Valeurs à modifier en jaune pour le dimensionnement PV & Batteries			Nombre Module PV	10 -
			V batteries	24 V
			Nbre branches	2 -

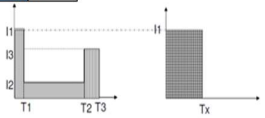
Dimensionnement : Données Output PV et Batteries					
Données Output PV			**Données Output Batteries**		
Nombre Module	10	-	V batteries	24	V
Surface totale	16,67	m²	Nbre branches	2	-
Surface Module	1,67	m²	**Décharge Batteries**		
Pc module std	250	Wc	Capacité nécess	79,2	Ah
Pc installée	2500	Wc	V fin décharge	21,6	V
La batterie doit être capable de délivrer			7,60	h	10,4 A
un courant équivalent pendant la durée			3,68	h	21,5 A
donnée			12,00	h	6,6 A
(ex: I (U17) pendant T (S17))			Autonomie		12 h

Dimensionnement Batteries par équivalence		
Capacité nécessaire		
Qtot	79,2	Ah
Min A	10,4	A
Max A	21,5	A
Temps de décharge équivalent		
TminA	7,6	h
TmaxA	3,68	h

Somme de tout les courants débité par la batterie en Ah = Qtot
En calculant le temps équivalent pour une décharge constante
Ceci pour le courant de décharge min et max

Bilan PV/Batteries		
Sur PV	4711,3	Wh
Util Batt	3420,0	Wh

Bien d'essayer d'avoir
La surproduction PV > Utilisation Batteries



Recharge batteries		
Temps de recharge disponible	12	h
Courant/h nécessaire pour recharge	6,6	A
Nbre d'heures de grande recharge	10	h

Valeurs Contrôle	
Surproduction PV	OK
Recharge Batteries	OK
Temps Recharge	OK

Dimensionnement onduleur		
V batteries	24,00	V
VAC	230	V
Pmax	465,00	W
Facteur surdim.	1,5	-
P onduleur	697,5	W

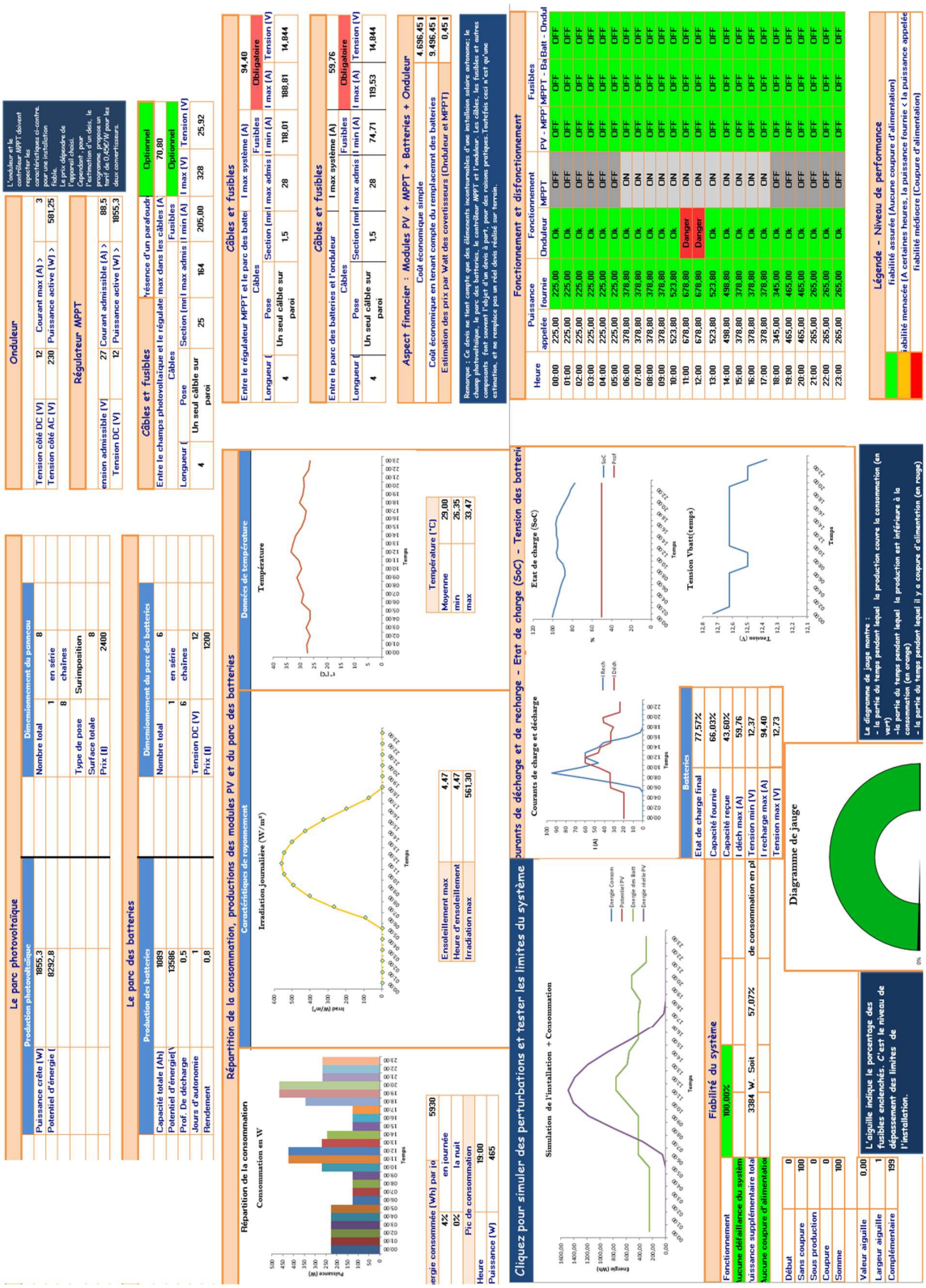
Dimensionnement MPPT		
Valeur de courant	43,3	A
Facteur de securité	1,5	-
Courant design	64,9566	A

Tableau : production PV + Consommation + Batteries pour dimensionnement

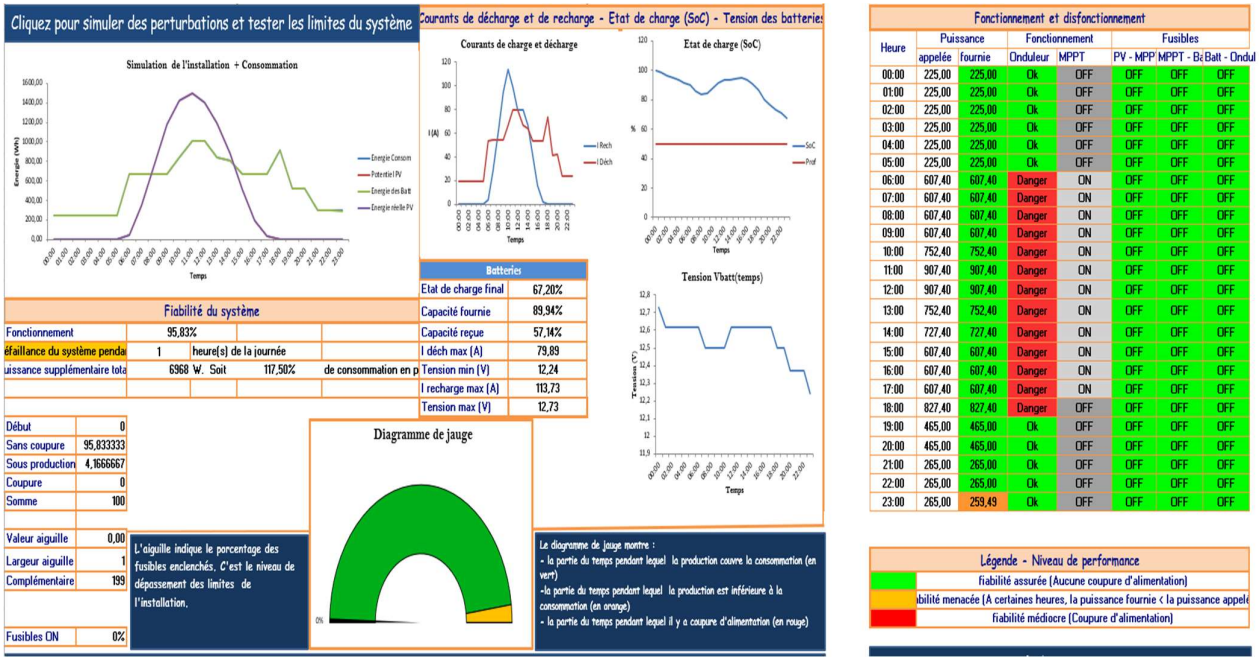
			Cons Pst	PV	Batteries		PV	
Octobre			AC	SurProd.	Besoin Batteries		SurProd.	Batt.
Time	Wh/m²	Prod Wh	Wh	Wh	Wh	Ah	Ah	Rech.
00:00	0,0	0,0	225	0,0	225,0	10,4	0,0	NOK
01:00	0,0	0,0	225	0,0	225,0	10,4	0,0	NOK
02:00	0,0	0,0	225	0,0	225,0	10,4	0,0	NOK
03:00	0,0	0,0	225	0,0	225,0	10,4	0,0	NOK
04:00	0,0	0,0	225	0,0	225,0	10,4	0,0	NOK
05:00	0,0	0,0	225	0,0	225,0	10,4	0,0	NOK
06:00	93,8	151,9	125	26,9	0,0	0,0	1,1	NOK
07:00	270,0	437,5	125	312,5	0,0	0,0	13,0	OK
08:00	404,0	654,6	125	529,6	0,0	0,0	22,1	OK
09:00	495,8	803,2	125	678,2	0,0	0,0	28,3	OK
10:00	546,0	884,6	270	614,6	0,0	0,0	25,6	OK
11:00	561,3	909,3	425	484,3	0,0	0,0	20,2	OK
12:00	546,3	885,0	425	460,0	0,0	0,0	19,2	OK
13:00	502,8	814,6	270	544,6	0,0	0,0	22,7	OK
14:00	430,0	696,7	245	451,7	0,0	0,0	18,8	OK
15:00	327,8	531,0	125	406,0	0,0	0,0	16,9	OK
16:00	202,0	327,3	125	202,3	0,0	0,0	8,4	OK
17:00	77,5	125,6	125	0,6	0,0	0,0	0,0	NOK
18:00	0,0	0,0	345	0,0	345,0	16,0	0,0	NOK
19:00	0,0	0,0	465	0,0	465,0	21,5	0,0	NOK
20:00	0,0	0,0	465	0,0	465,0	21,5	0,0	NOK
21:00	0,0	0,0	265	0,0	265,0	12,3	0,0	NOK
22:00	0,0	0,0	265	0,0	265,0	12,3	0,0	NOK
23:00	0,0	0,0	265	0,0	265,0	12,3	0,0	NOK

APPENDIX X: OUR SIMULATION RESULTS.

Sizing results of ISF's software for Sindi's school



ISF's software: 536 watts from 6am to 6pm simulation



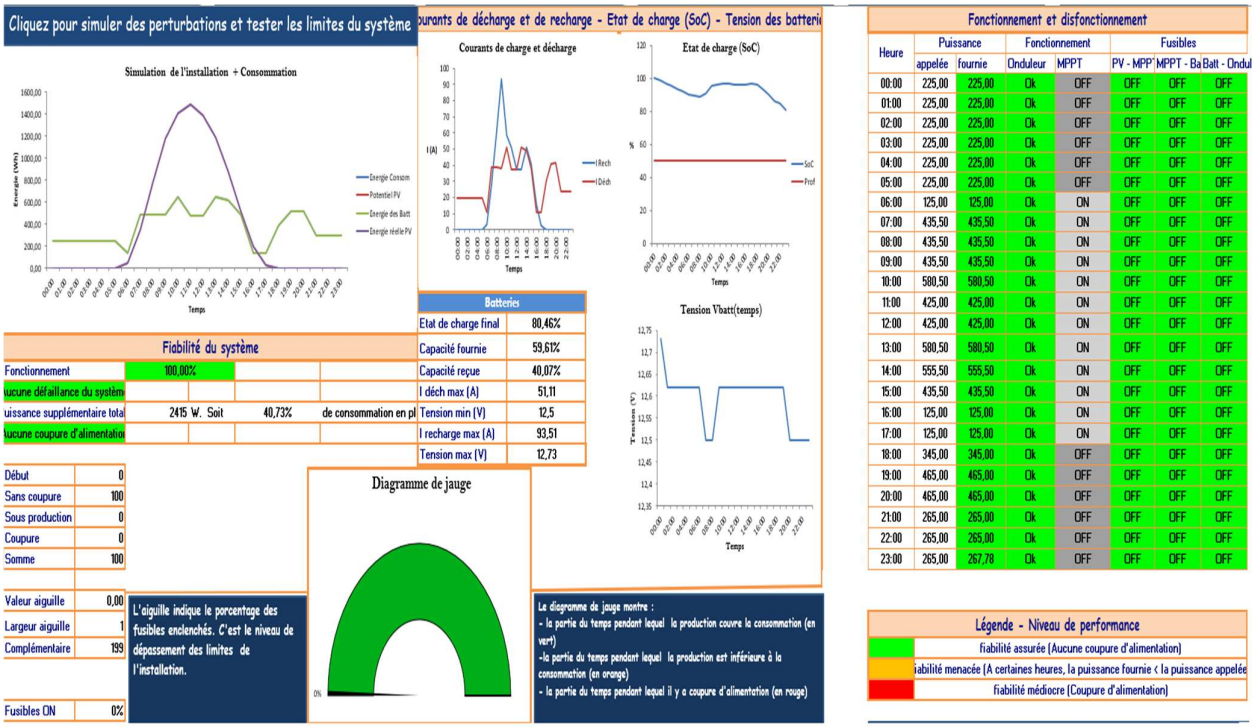
Fonctionnement et disfonctionnement

Heure	Puissance		Fonctionnement		Fusibles		
	appelée	fournie	Onduleur	MPPT	PV - MPPT	MPPT - Ba	Batt - Ondul
00:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
01:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
02:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
03:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
04:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
05:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
06:00	607,40	607,40	Danger	ON	OFF	OFF	OFF
07:00	607,40	607,40	Danger	ON	OFF	OFF	OFF
08:00	607,40	607,40	Danger	ON	OFF	OFF	OFF
09:00	607,40	607,40	Danger	ON	OFF	OFF	OFF
10:00	752,40	752,40	Danger	ON	OFF	OFF	OFF
11:00	907,40	907,40	Danger	ON	OFF	OFF	OFF
12:00	907,40	907,40	Danger	ON	OFF	OFF	OFF
13:00	752,40	752,40	Danger	ON	OFF	OFF	OFF
14:00	727,40	727,40	Danger	ON	OFF	OFF	OFF
15:00	607,40	607,40	Danger	ON	OFF	OFF	OFF
16:00	607,40	607,40	Danger	ON	OFF	OFF	OFF
17:00	607,40	607,40	Danger	ON	OFF	OFF	OFF
18:00	827,40	827,40	Danger	OFF	OFF	OFF	OFF
19:00	465,00	465,00	Ok	OFF	OFF	OFF	OFF
20:00	465,00	465,00	Ok	OFF	OFF	OFF	OFF
21:00	265,00	265,00	Ok	OFF	OFF	OFF	OFF
22:00	265,00	265,00	Ok	OFF	OFF	OFF	OFF
23:00	265,00	259,49	Ok	OFF	OFF	OFF	OFF

Légende - Niveau de performance

fiabilité assurée (Aucune coupure d'alimentation)
abilité menacée (A certaines heures, la puissance fournie < la puissance appelé
fiabilité médiocre (Coupure d'alimentation)

ISF's software: 345 watts from 7am to 3pm (except for 11am and 12am) simulation



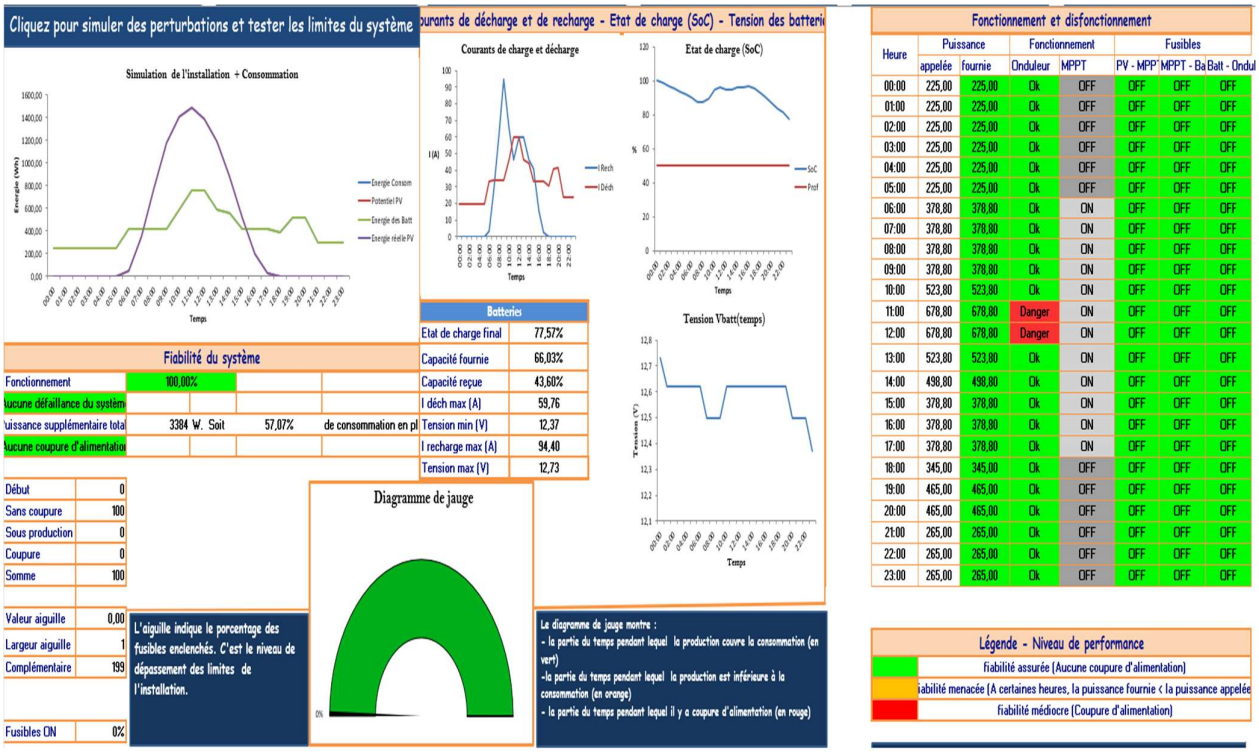
Fonctionnement et disfonctionnement

Heure	Puissance		Fonctionnement		Fusibles		
	appelée	fournie	Onduleur	MPPT	PV - MPPT	MPPT - Ba	Batt - Ondul
00:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
01:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
02:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
03:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
04:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
05:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
06:00	125,00	125,00	Ok	ON	OFF	OFF	OFF
07:00	435,50	435,50	Ok	ON	OFF	OFF	OFF
08:00	435,50	435,50	Ok	ON	OFF	OFF	OFF
09:00	435,50	435,50	Ok	ON	OFF	OFF	OFF
10:00	580,50	580,50	Ok	ON	OFF	OFF	OFF
11:00	425,00	425,00	Ok	ON	OFF	OFF	OFF
12:00	425,00	425,00	Ok	ON	OFF	OFF	OFF
13:00	580,50	580,50	Ok	ON	OFF	OFF	OFF
14:00	555,50	555,50	Ok	ON	OFF	OFF	OFF
15:00	435,50	435,50	Ok	ON	OFF	OFF	OFF
16:00	125,00	125,00	Ok	ON	OFF	OFF	OFF
17:00	125,00	125,00	Ok	ON	OFF	OFF	OFF
18:00	345,00	345,00	Ok	OFF	OFF	OFF	OFF
19:00	465,00	465,00	Ok	OFF	OFF	OFF	OFF
20:00	465,00	465,00	Ok	OFF	OFF	OFF	OFF
21:00	265,00	265,00	Ok	OFF	OFF	OFF	OFF
22:00	265,00	265,00	Ok	OFF	OFF	OFF	OFF
23:00	265,00	267,78	Ok	OFF	OFF	OFF	OFF

Légende - Niveau de performance

fiabilité assurée (Aucune coupure d'alimentation)
iabilité menacée (A certaines heures, la puissance fournie < la puissance appelée
fiabilité médiocre (Coupure d'alimentation)

ISF's software: 282 watts from 6am to 6pm simulation

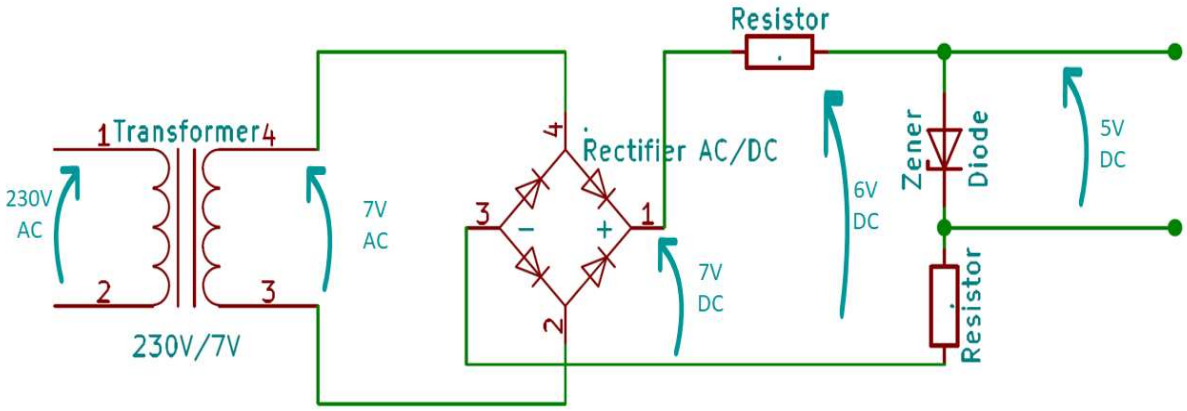


Fonctionnement et disfonctionnement							
Heure	Puissance		Fonctionnement		Fusibles		
	appelée	fournie	Onduleur	MPPT	PV - MPPT	MPPT - Ba	Batt - Ondul
00:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
01:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
02:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
03:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
04:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
05:00	225,00	225,00	Ok	OFF	OFF	OFF	OFF
06:00	378,80	378,80	Ok	ON	OFF	OFF	OFF
07:00	378,80	378,80	Ok	ON	OFF	OFF	OFF
08:00	378,80	378,80	Ok	ON	OFF	OFF	OFF
09:00	378,80	378,80	Ok	ON	OFF	OFF	OFF
10:00	523,80	523,80	Ok	ON	OFF	OFF	OFF
11:00	678,80	678,80	Danger	ON	OFF	OFF	OFF
12:00	678,80	678,80	Danger	ON	OFF	OFF	OFF
13:00	523,80	523,80	Ok	ON	OFF	OFF	OFF
14:00	498,80	498,80	Ok	ON	OFF	OFF	OFF
15:00	378,80	378,80	Ok	ON	OFF	OFF	OFF
16:00	378,80	378,80	Ok	ON	OFF	OFF	OFF
17:00	378,80	378,80	Ok	ON	OFF	OFF	OFF
18:00	345,00	345,00	Ok	OFF	OFF	OFF	OFF
19:00	465,00	465,00	Ok	OFF	OFF	OFF	OFF
20:00	465,00	465,00	Ok	OFF	OFF	OFF	OFF
21:00	265,00	265,00	Ok	OFF	OFF	OFF	OFF
22:00	265,00	265,00	Ok	OFF	OFF	OFF	OFF
23:00	265,00	265,00	Ok	OFF	OFF	OFF	OFF

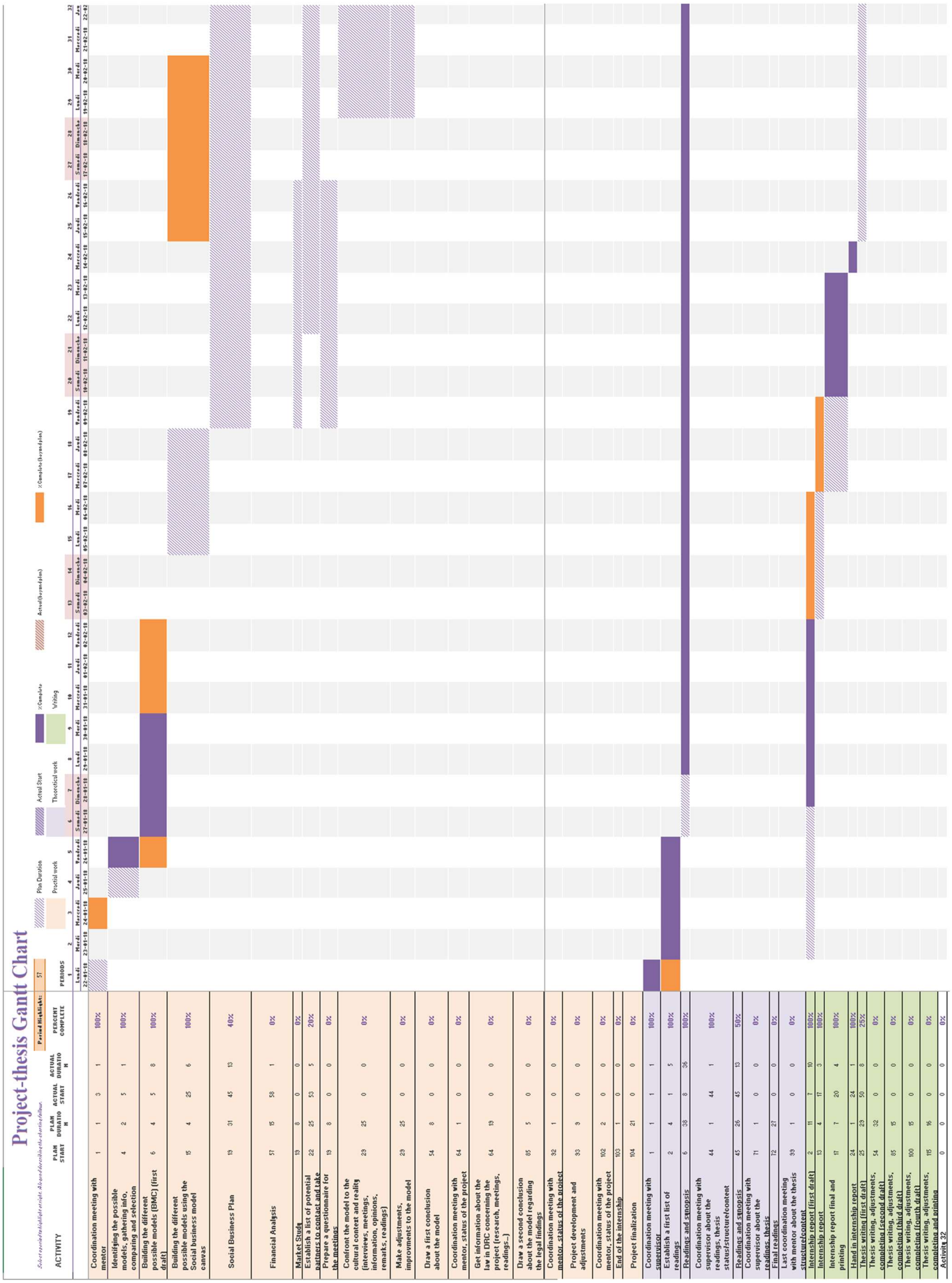
Batteries	
Etat de charge final	77,57%
Capacité fournie	66,03%
Capacité reçue	43,60%
I déch max (A)	59,76
Tension min (V)	12,37
I recharge max (A)	94,40
Tension max (V)	12,73

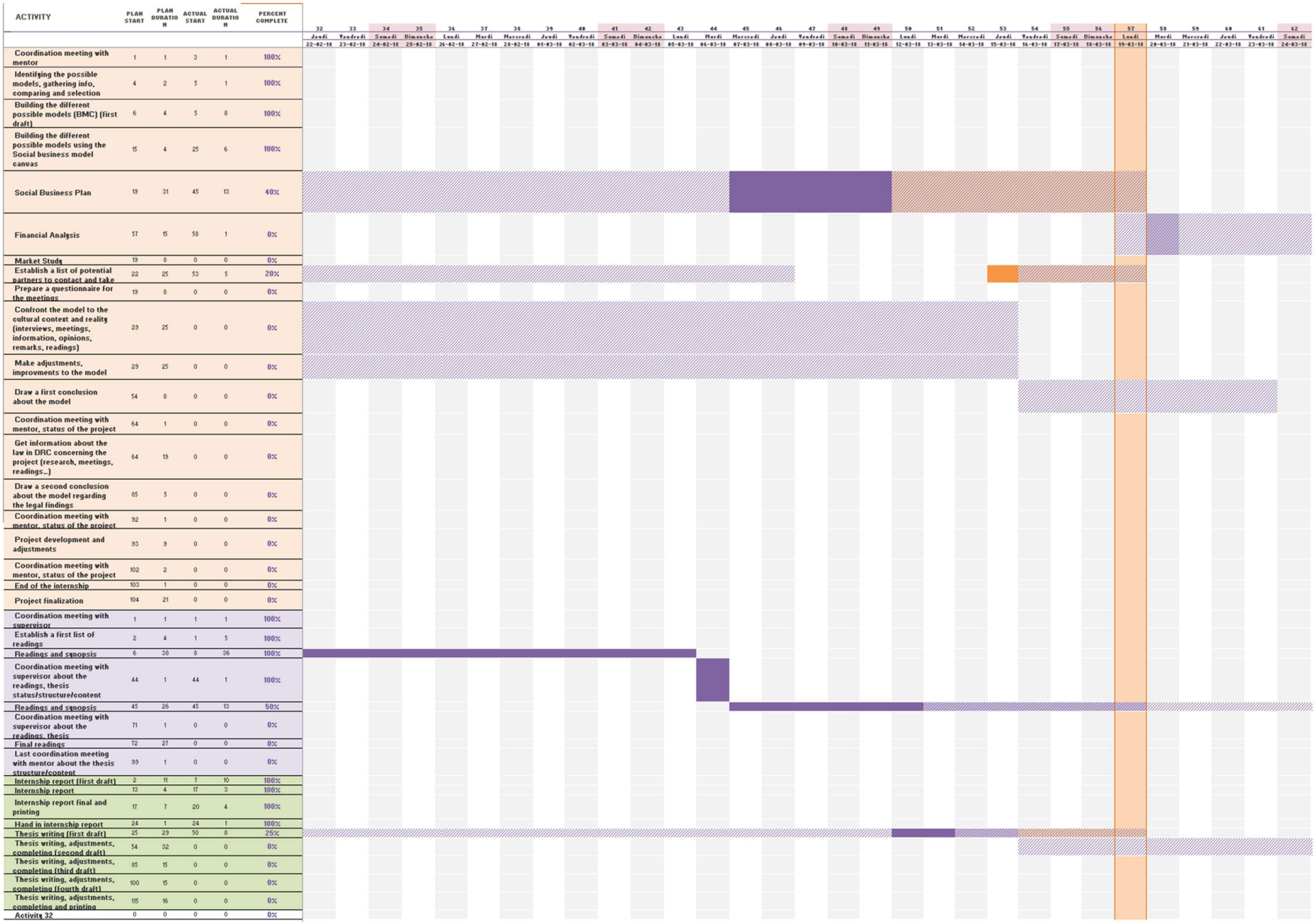
Légende - Niveau de performance
fiabilité assurée (Aucune coupure d'alimentation)
iabilité menacée (A certaines heures, la puissance fournie < la puissance appelée
fiabilité médiocre (Coupure d'alimentation)

APPENDIX XI: EXAMPLE OF CIRCUIT PLAN TO SWITCH BETWEEN AN AC 230V AND A DC 5V.



APPENDIX XII: OUR GANTT CHART





ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Coordination meeting with mentor	1	1	3	1	100%
Identifying the possible models, gathering info, comparing and selection	4	2	5	1	100%
Building the different possible models (BMC) (first draft)	6	4	5	8	100%
Building the different possible models using the Social business model canvas	15	4	25	6	100%
Social Business Plan	19	31	45	13	40%
Financial Analysis	57	15	58	1	0%
Market Study	19	8	0	0	0%
Establish a list of potential partners to contact and take	22	25	53	5	20%
Prepare a questionnaire for the meetings	19	8	0	0	0%
Confront the model to the cultural context and reality (interviews, meetings, information, opinions, remarks, readings)	29	25	0	0	0%
Make adjustments, improvments to the model	29	25	0	0	0%
Draw a first conclusion about the model	54	8	0	0	0%
Coordination meeting with mentor, status of the project	64	1	0	0	0%
Get information about the law in DRC concerning the project (research, meetings, readings...)	64	19	0	0	0%
Draw a second conclusion about the model regarding the legal findings	85	5	0	0	0%
Coordination meeting with mentor, status of the project	92	1	0	0	0%
Project development and adjustments	93	9	0	0	0%
Coordination meeting with mentor, status of the project	102	2	0	0	0%
End of the internship	103	1	0	0	0%
Project finalization	104	21	0	0	0%
Coordination meeting with supervisor	1	1	1	1	100%
Establish a first list of readings	2	4	1	5	100%
Readings and synopsis	6	38	8	36	100%
Coordination meeting with supervisor about the readings, thesis status/structure/content	44	1	44	1	100%
Readings and synopsis	45	26	45	13	50%
Coordination meeting with supervisor about the readings, thesis	71	1	0	0	0%
Final readings	72	27	0	0	0%
Last coordination meeting with mentor about the thesis structure/content	99	1	0	0	0%
Internship report (first draft)	2	11	7	10	100%
Internship report	13	4	17	3	100%
Internship report final and printing	17	7	20	4	100%
Hand in internship report	24	1	24	1	100%
Thesis writing (first draft)	25	29	50	8	25%
Thesis writing, adjustments, completing (second draft)	54	32	0	0	0%
Thesis writing, adjustments, completing (third draft)	85	15	0	0	0%
Thesis writing, adjustments, completing (fourth draft)	100	15	0	0	0%
Thesis writing, adjustments, completing and printing	115	16	0	0	0%
Activity 32	0	0	0	0	0%

32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
Jeudi	Vendredi	Samedi	Dimanche	Lundi	Mardi	Mercredi	Jeudi	Vendredi	Samedi	Dimanche	Lundi	Mardi	Mercredi	Jeudi	Vendredi	Samedi	Dimanche	Lundi	Mardi	Mercredi	Jeudi	Vendredi	Samedi	Dimanche	Lundi	Mardi	Mercredi	Jeudi	Vendredi	Samedi
22-02-18	23-02-18	24-02-18	25-02-18	26-02-18	27-02-18	28-02-18	01-03-18	02-03-18	03-03-18	04-03-18	05-03-18	06-03-18	07-03-18	08-03-18	09-03-18	10-03-18	11-03-18	12-03-18	13-03-18	14-03-18	15-03-18	16-03-18	17-03-18	18-03-18	19-03-18	20-03-18	21-03-18	22-03-18	23-03-18	24-03-18

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Coordination meeting with mentor	1	1	3	1	100%
Identifying the possible models, gathering info, comparing and selection	4	2	5	1	100%
Building the different possible models (BMC) (first draft)	6	4	5	8	100%
Building the different possible models using the Social business model canvas	15	4	25	6	100%
Social Business Plan	19	31	45	13	40%
Financial Analysis	57	15	58	1	0%
Market Study	19	8	0	0	0%
Establish a list of potential partners to contact and take	22	25	53	5	20%
Prepare a questionnaire for the meetings	19	8	0	0	0%
Confront the model to the cultural context and reality (interviews, meetings, information, opinions, remarks, readings)	29	25	0	0	0%
Make adjustments, improvments to the model	29	25	0	0	0%
Draw a first conclusion about the model	54	8	0	0	0%
Coordination meeting with mentor, status of the project	64	1	0	0	0%
Get information about the law in DRC concerning the project (research, meetings, readings...)	64	19	0	0	0%
Draw a second conclusion about the model regarding the legal findings	85	5	0	0	0%
Coordination meeting with mentor, status of the project	92	1	0	0	0%
Project development and adjustments	93	9	0	0	0%
Coordination meeting with mentor, status of the project	102	2	0	0	0%
End of the internship	103	1	0	0	0%
Project finalization	104	21	0	0	0%
Coordination meeting with supervisor	1	1	1	1	100%
Establish a first list of readings	2	4	1	5	100%
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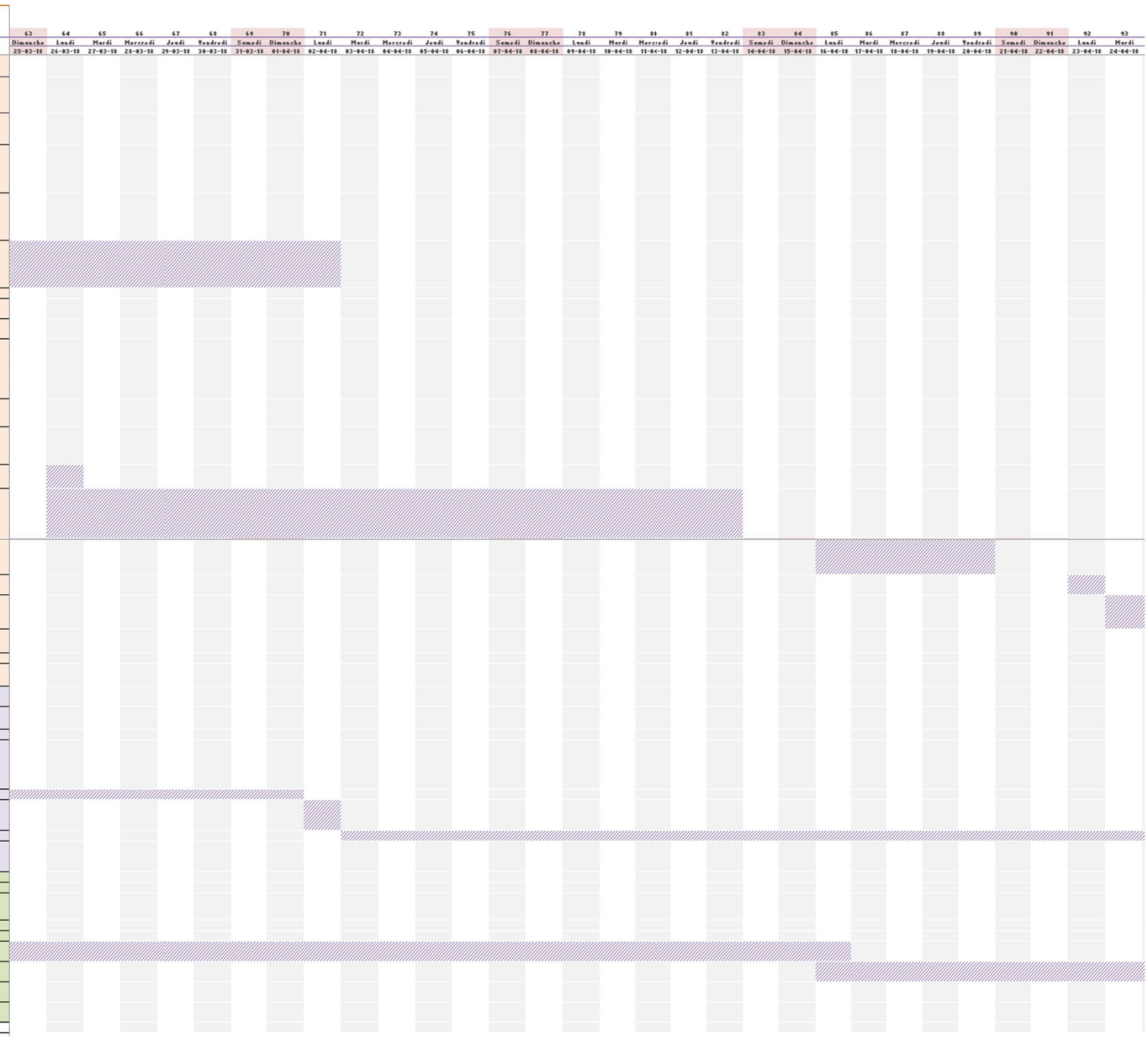
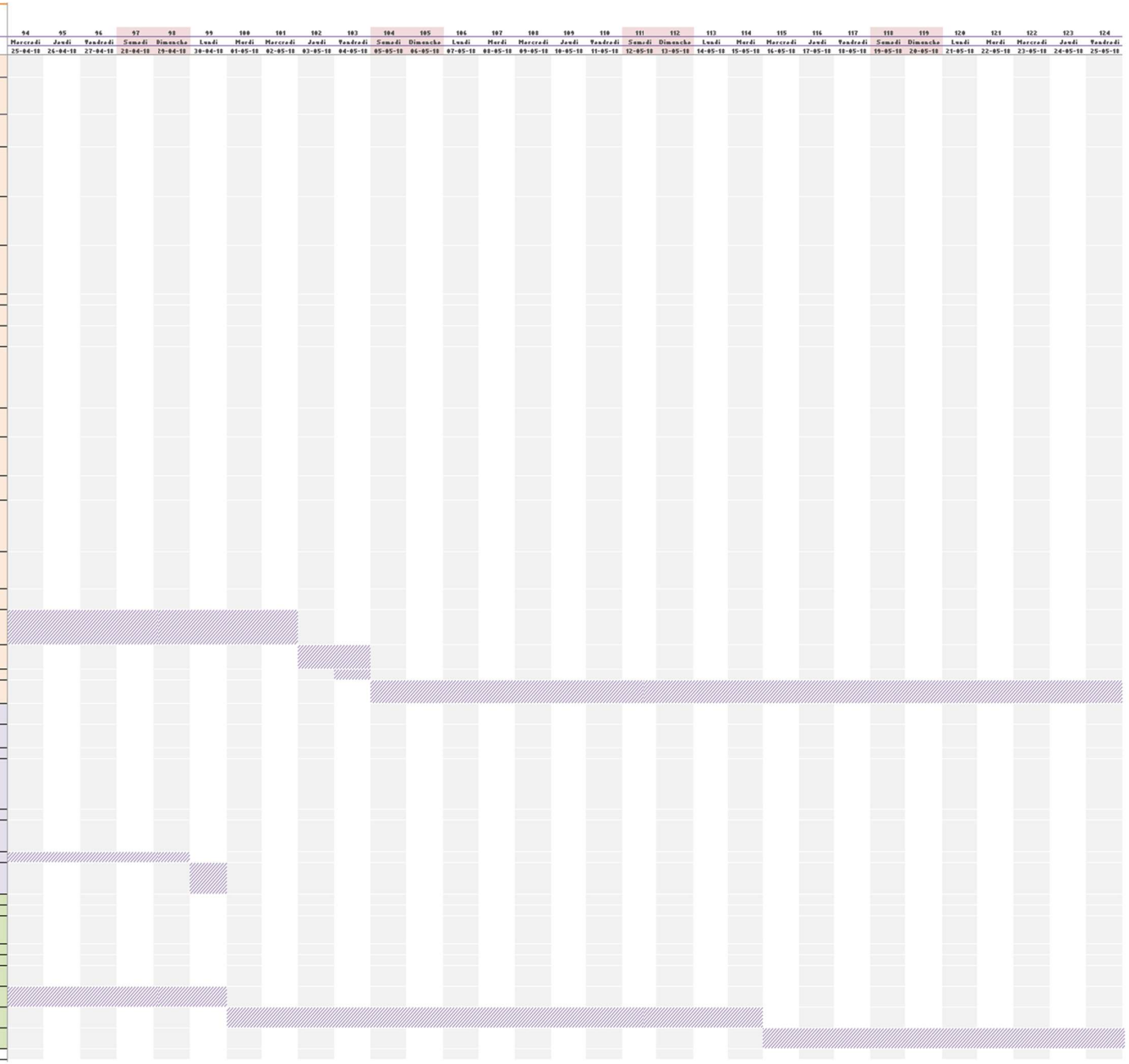
Readings and synopsis	45	26	45	13	50%
Coordination meeting with supervisor about the readings, thesis	71	1	0	0	0%
Final readings	72	27	0	0	0%
Last coordination meeting with mentor about the thesis structure/content	99	1	0	0	0%
Internship report (first draft)	2	11	7	10	100%
Internship report	13	4	17	3	100%
Internship report final and printing	17	7	20	4	100%
Hand in internship report	24	1	24	1	100%
Thesis writing (first draft)	25	29	50	8	25%
Thesis writing, adjustments, completing (second draft)	54	32	0	0	0%
Thesis writing, adjustments, completing (third draft)	85	15	0	0	0%
Thesis writing, adjustments, completing (fourth draft)	100	15	0	0	0%
Thesis writing, adjustments, completing and printing	115	16	0	0	0%
Activity 32	0	0	0	0	0%



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Coordination meeting with mentor	1	1	3	1	100%
Identifying the possible models, gathering info, comparing and selection	4	2	5	1	100%
Building the different possible models (BMC) (first draft)	6	4	5	8	100%
Building the different possible models using the Social business model canvas	15	4	25	6	100%
Social Business Plan	19	31	45	13	40%
Financial Analysis	57	15	58	1	0%
Market Study	19	8	0	0	0%
Establish a list of potential partners to contact and take	22	25	53	5	20%
Prepare a questionnaire for the meetings	19	8	0	0	0%
Confront the model to the cultural context and reality (interviews, meetings, information, opinions, remarks, readings)	29	25	0	0	0%
Make adjustments, improvments to the model	29	25	0	0	0%
Draw a first conclusion about the model	54	8	0	0	0%
Coordination meeting with mentor, status of the project	64	1	0	0	0%
Get information about the law in DRC concerning the project (research, meetings, readings...)	64	19	0	0	0%
Draw a second conclusion about the model regarding the legal findings	85	5	0	0	0%
Coordination meeting with mentor, status of the project	92	1	0	0	0%
Project development and adjustments	93	9	0	0	0%
Coordination meeting with mentor, status of the project	102	2	0	0	0%
End of the internship	103	1	0	0	0%
Project finalization	104	21	0	0	0%
Coordination meeting with supervisor	1	1	1	1	100%
Establish a first list of readings	2	4	1	5	100%
Readings and synopsis	6	38	8	36	100%
Coordination meeting with supervisor about the readings, thesis status/structure/content	44	1	44	1	100%
Readings and synopsis	45	26	45	13	50%
Coordination meeting with supervisor about the readings, thesis	71	1	0	0	0%
Final readings	72	27	0	0	0%
Last coordination meeting with mentor about the thesis structure/content	99	1	0	0	0%
Internship report (first draft)	2	11	7	10	100%
Internship report	13	4	17	3	100%
Internship report final and printing	17	7	20	4	100%
Hand in internship report	24	1	24	1	100%
Thesis writing (first draft)	25	29	50	8	25%
Thesis writing, adjustments, completing (second draft)	54	32	0	0	0%
Thesis writing, adjustments, completing (third draft)	85	15	0	0	0%
Thesis writing, adjustments, completing (fourth draft)	100	15	0	0	0%
Thesis writing, adjustments, completing and printing	115	16	0	0	0%
Activity 32	0	0	0	0	0%



LIST OF SPECIALISTS

- Alain Bosseloir, CEO at Zentech
- Jean Delattre from Lagazel.
- Jean-Baptiste Bokoto from Africa Synergie & EMF Energy.
- Karl Gupa, commercial team leader & solar coordinator at Total DRC.
- Maxime Dolberg, co-founder & tech developer, and Julien Riat, marketing manager, at Solarly.
- Myriam Kresse, member of ISF.
- Nathalie Rucquoy delegated administrator & project coordinator at "Auto-développement Afrique".
- Roger Pholo Sindi's priest and president of the association "Œuvres pour l'enfance défavorisée" in Sindi.
- Ronald van Harten, COO at Ecozoom.
- Rudi Verheyen, relationship manager for the non-profit sector at CBC Bank.

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RÉSUMÉ

L'accès à l'énergie est un élément clef pour le développement économique, politique et social. Malgré ses nombreuses ressources, l'Afrique vit une situation catastrophique. Dans ce contexte africain, la République Démocratique du Congo se démarque de par la gravité de sa situation : ce pays est aujourd'hui le moins électrifié au monde ! Le paradoxe est qu'il existe énormément d'opportunités de développement dans ces régions. Le projet présenté dans ce mémoire explore l'une de ces opportunités appliquée à la communauté suburbaine de Sindi, dans la banlieue de Boma en République Démocratique du Congo.

Le réseau électrique est tout simplement inexistant à Sindi et la majorité de sa population s'éclaire à l'aide de lampes à pétrole. Ces lampes sont un vrai fléau, elles sont excessivement chères, peu efficaces et polluantes.

L'étude de projet présentée dans cette thèse et le modèle économique sous-jacent visent à appuyer le système éducatif en place à Sindi en permettant aux élèves de faire leurs devoirs dans des conditions sanitaires et de travail décentes. Visant principalement les élèves et leur famille, l'objectif du projet est de fournir une alternative à ces lampes à pétrole, tout en permettant à ces familles de réaliser des économies. Celui-ci cherche à valoriser la communauté et à respecter la philosophie véhiculée par la célèbre maxime : *« Donne un poisson à un homme et il mangera un jour, apprend lui à pêcher et il mangera toute sa vie » (proverbe chinois).*

Pour atteindre cet objectif – maximiser les chances de réussite et assurer la pérennité du projet – l'étude propose un modèle de gouvernance coopératif grandement inspiré des travaux d'Elinor Ostrom, prix Nobel d'économie en 2009, sur la gouvernance des biens communs. Cette étude présente également d'autres aspects du projet comme la gestion de celui-ci, les lampes et leurs fournisseurs, ses aspects financiers, ainsi qu'une étude technique. Tous apportent des éléments qui permettront à « Ingénieurs sans frontières » d'effectuer des choix éclairés et de mener le projet à bien.

Le modèle économique consiste à regrouper une communauté sans accès à l'électricité autour d'un but commun, à créer une association qui sera en charge des lampes solaires autour de ce but et de doter cette association d'un système de gouvernance résilient et pérenne. L'association achète, grâce à une aide financière externe, des lampes solaires qu'elle revend aux consommateurs. Le prix de ces lampes est rendu abordable grâce à un étalement du paiement. L'association réalise alors un bénéfice qui lui permettra d'entreprendre d'autres projets pour le développement de la communauté.

Mots-clefs : Gouvernance, biens communs, modèle économique, lampes solaires, Afrique, République Démocratique du Congo, modèle coopératif, coopérative, coopération au développement, éducation.

EXECUTIVE SUMMARY

Access to energy is a keystone for economic, political and social development. Despite its numerous resources, Africa lives a dramatic situation. In this African context, the Democratic Republic of Congo stands out in view of the seriousness of its circumstances: it is the least electrified country in the whole world! A paradox regarding the number of development opportunities Africa has. The project presented in this paper explores one of these opportunities and its application to a practical case, the community of Sindi, Boma's suburb, in the Democratic Republic of Congo. No electrical grid exists in Sindi and most of the population uses oil lamps to light up at night. These are a curse, they are extremely expensive, inefficient and polluting.

The project study presented in this thesis and the underlying economic model aim at supporting Sindi's educational system by allowing school children to do their homework in decent health and working conditions. Targeting the school children and their families, the main objective of the project is to provide an alternative solution to oil lamps while allowing families to make savings. It seeks to empower the community and to respect the philosophy conveyed by the maxim: *"Give a man a fish, and you feed him for a day. Teach a man to fish, and you feed him for a lifetime" (Chinese proverb).*

To reach this objective, to maximize the chances of success and to insure the sustainability of the project, the study presents a cooperative governance model that is greatly inspired from the work of the 2009 Nobel prize in Economics, Elinor Ostrom, about the governance of the common goods. This study also tackles other aspects of the project like its management, the lamps and their suppliers, its financial aspects as well as a technical study. Each brings elements that will allow "Ingénieurs sans Frontières" to make informed choices and to complete the project successfully.

The economic model consists in gathering an off-grid community around a shared objective, creating an association around this goal to manage the solar lamps and providing it with a resilient and lasting governance system. Through an external financial assistance, the association purchases solar lamps and resells them to the customers. The price of the lamps is made affordable thanks to multiple payments spread over a defined period. The association makes a profit which allows it to undertake other development projects for the community.

Keywords*: Governance, common goods, economic model, solar lamps, Africa, Democratic Republic of Congo, cooperative model, cooperative, development cooperation, education.*