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Energy Planning in Humanitarian Context: Proposal for Practical Guidelines and Application to Goudoubo Refugee Camp

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Mas tudo bem

O dia vai raiar

Pra gente se inventar

De novo

Aknowledgement

A mia madre, forte e gentile, e mio padre, buono e testardo, per aver stravolto la loro vita per me, per avermi insegnato ad essere sempre curiosa e mai stanca, per avermi appoggiata nelle scelte più folli, per aver sopportato la distanza e per dimostrarmi, nonostante le mie insicurezze, quanto incredibilmente renda loro ogni giorno orgogliosi.

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Abstract

The purpose of this thesis work is to face the sensitive energy issue in Humanitarian Response system, whereby it has not been sufficiently addressed yet, with the aim to support humanitarian stakeholders in identifying the most suitable and sustainable solutions to provide energy services within humanitarian relief.

The need to achieve the 7 SDG and deliver effective energy strategies inclusive of Renewable Energy Systems - which are not often adopted by humanitarian actors - have led to the proposal of a comprehensive and viable step-by-step guideline developed by adapting the already existing Comprehensive Energy Solution Planning (CESP) methodology to humanitarian settings.

In order to tailor the procedure, which is based on matching the energy demand with the local available renewable energy sources, novel multi-sector surveys have been developed to explore the context and the needs of the affected populations and intevene then with a bottom-up approach, at household, community and productive level. In addition, a two-dimensional taxonomy has been proposed for the definition of the strategy intervention in order to manage the energy both in terms of electric and thermal supply. For what concerns electric case reference to off-grid small-scale electricity generation systems has been made, while referring to thermal energy mainly cooking technologies have been taking into account. This enables to the identification of the most suitable energy systems and, among the whole range of possible options, to the selection of the most cost-effective energy technologies combination to ensure an adequate, sustainable, affordable and clean Access to Energy to all the beneficiaries.

With a view to showing the importance and practicality of the presented manual, the final part of the elaborate is dedicated to the case study of Goudoubo refugee camp, located in the desertic Sahelian region of Burkina Faso. The example served as a proof of practical implementation of the guideline and highlighted the impact, both economical – through the definition of new energy bills – and environmental, which the transition from traditional fuels to renewable energy sources implies, even in humanitarian settings.

Keywords: Humanitarian Response, Access to Energy, Energy Planning, Renewable Energy Technologies, Sustainability

Sommario

L'obiettivo di questa tesi è affrontare la delicata questione dell'energia nel sistema di Intervento Umanitario, a cui attualmente non viene ancora rivolta particolare attenzione, con il fine di supportare gli operatori del suddetto contesto nell'identificazione di soluzioni di fornitura di servizi energetici che siano adeguate e sostenibili.

La necessità di raggiungere il 7° SDG e di offrire strategie di intervento energetico che includano Sistemi a Energie Rinnovabili – raramente considerati dagli attori umanitari – hanno portato alla presente proposta di una linea guida completa che, passo dopo passo, è stata sviluppata adattando la già esistente metodologia del CESP (Comprehensive Energy Solution Planning) al settore umanitario.

Con l'intento di consegnare la nuova procedura, basata sulla corrispondenza tra la domanda energetica e le fonti di energia disponibili in loco, è stato di conseguenza sviluppato un sondaggio multisettoriale volto ad analizzare il contesto e gli essenziali bisogni delle popolazioni affette e intervenire con un approccio bottom-up a livello domenstico, comunitario e produttivo. Inoltre, è stata proposta una configurazione bidimensionale per definire la strategia di intervento e gestire l'approviggionamento energetico sia in termini di elettricità che di energia termica. Per quanto riguarda il caso elettrico, sono stati considerati sistemi small-scale di generazione off-grid, mentre per il termico è stato fatto riferimento principalmente alle tecnologie per la preparazione del cibo. Ciò permette l'identificazione dei più plausibili e adottabili sistemi energetici e in seguito, tra tutti i possibili scenari ipotizzati, consente la selezione della più appropriata ed economicamente vantaggiosa combinazione di tecnologie per garantire a tutti i beneficiari un adeguato, sostenibile e conveniente Accesso all'Energia.

Allo scopo di mostrare l'importanza e praticità del manuale, la parte finale dell'elaborato è dedicata al caso studio del campo di rifugiati di Goudoubo, situato nella desertica regione del Sahel in Burkina Faso. L'esempio, utilizzato come prova di applicazione pratica della linea guida, è servito ad evidenziare l'impatto sia economico – grazie alla definizione di nuove tariffe energetiche – sia ambientali che la transizione da combustibili tradizionali a fonti di energia rinnovabili comporta, anche in contesto umanitario.

Parole Chiave: Intervento Umanitario, Accesso all'Energia, Pianificazione Energetica, Tecnologie a Energie Rinnovabili, Sostenibilità

Introduction

The seventh goal of the 2030 agenda of Sustainable Development Goals, adopted by United Nations in 2015, commits the world to provide "affordable, reliable, sustainable and modern energy for all".
This also applies in humanitarian settings where access to energy is even more challenging.

The world is now witnessing the worst humanitarian crisis ever recorded: by the end of 2017, the number of forcibly displaced people have reached 68.5 millions and it expected to grow further.
The priority of the humanitarian community consists in providing these populations with basic services such as shelter, food, water and protection while access to energy has been historically disregarded among their needs, despite its relevance and cross cutting impacts.
This thesis work wants to enhance the response capacity of humanitarian actors in the identification of the potentially most suitable solutions for energy intervention within humanitarian relief.
Despite in literature there are already accessible manuals and available tools concerning energy intervention, they seem to be overly technical or, most of times, not sufficiently complete. In this regard, following the already existent structure of the CESP – Comprehensive Energy Solution Planning developed by UNESCO Chair at Politecnico di Milano – Department of Energy, a comprehensive step-by-step energy intervention guideline is here delivered by the author who tailored and adjusted the above mentioned framework to the humanitarian settings.

In this way, it can be showed how energy access intervention within humanitarian response is an effective tool for improving the health, safety and livelihoods of beneficiaries, while also having wider environmental benefits.

Chapter 1 aims at giving a general overview of humanitarian crisis and the always increasing number of forcibly displaced populations in the world. It also describes the humanitarian actors' role, their priorities in delivering support to humanitarian relief camps and the energy issue in such contexts.

Chapter 2 is dedicated to the introduction of the original CESP - Comprehensive Energy Solution Planning framework which the whole guideline has been based on. It has been here described the already existent five-step structure, the actual applications and all the adjustments the author carried out for the purpose of this work.

Chapter 3 explores in depth the CESP methodology analysing each phase separately, describing the new configuration proposed and presenting the new tools developed. In particular, the work focuses on the first four phases namely *Priorities*, *Diagnosis*, *Strategy* and *Comprehensive Design* while the last *Impact Evaluation* step has been only introduced. A Tools Box with a list of existent tools, original manuals and surveys is provided to the reader in attachment at the end of each chapter.

Chapter 4 consists in an example of practical application of the developed manual: it is here presented the case study of Goudoubo refugee camp, located in the desertic Sahel region of Burkina Faso. Thanks to the collaboration with Practical Action NGO that provided the author with field evaluations, it has been possible to have access to data essential to have an insight into the camp energy situation. Once context and population needs have been identified, a range of possible energy scenarios have been suggested, according to the availability of local resources and typical energy demand.

C*hapter 5* is devoted to the comparison of the different scenarios proposed for Goudoubo in the previous chapter. A discussion of the results has been included with the aim of justifying the choice of the most suitable and cost-effective scenario. Lastly, conclusions about energy intervention in humanitarian context and possible future developments have been drawn.

1. The Energy Issue in the Humanitarian Context

Over the last decades, bad governance, violence, conflicts, persecutions but also natural or mad-made disasters and deseases have driven an always increasing number of people from their homes and even to flee their country to stay alive. They have been so far defined as forcibly displaced populations and include refugees, internally displaced people (IDPs) and asylum-seekers.

By the end of 2017, according to UNHCR (United Nations High Commissioner for Refugees), 68.5 millions of people have been forced to leave their homes and seek refuge in other from conflicts, violence, human rights violations, persecutions, and natural disasters [1] calling for major humanitarian assistance worldwide. Globally in 2017, 40 million people were internally displaced as a result of conflict and persecution, while 25.4 million were refugees and 3.1 million were asylum-seekers.

Today, the world is actually witnessing the highest levels of displacement on record: according to UNHCR one person becomes displaced every 2 seconds, that's 30 people who are newly displaced every minute. While the Syrian conflict, now in its eighth year, contributed significantly to this increase being the world's biggest producer of refugees ever, there have been other major displacements throughout the world over the last five years, notably in and from Burundi, Central African Republic, the DRC, Iraq, Myanmar, South Sudan, Sudan, Ukraine, and Yemen [2].

The forced displacement has been depicted as a developing world crisis with implications for sustainable growth [3]: 95 percent of the displaced live in developing countries and over half are in displacement for more than four years. Their ensuing poverty condemns generations (mostly women and children) to a life on the margins, in challenging and uncertain environments, denying them the benefits of global progress enjoyed by so many others.

Focusing on displaced populations' vulnerabilities, the priority of the humanitarian community's mandate has always consisted in trying to meet their basic needs guaranteeing them access to food, water, shelter and medical care. However, having access to energy is another very important factor for refugees even if it has, in the past, not received a lot of attention.

The United Nations' Sustainable Development Goal 7 (SDG7) commits the world to providing "affordable, reliable, sustainable and modern energy for all by 2030". Humanitarian organizations are then becoming increasingly concerned about energy issues in communities,

camps, or settlements where internally displaced persons or refugees are settled temporarily in order to ensure not to leave them out of this commitment.
In fact, affordable access to sustainable energy is a key element for a self-reliant and dignified life for households in refugee camps and host communities alike. Sustainable energy access positively impacts food security, health, education and economic activities of households while, at the same time, protecting the environment.

Despite the increment of displaced populations around the world have also incremented the energy demand and pressure on resources in the hosting countries, as well as the efficient use of budget by the international community, refugee camps are still regarded as temporary establishments. Therefore, long term investments, such as connecting the camps to the grid or providing them with expensive energy solutions are often discouraged. However, on average, people spend 17 years in a refugee camp [4]. During this time, they usually have to rely on energy sources, such as biomass or kerosene for cooking and lighting which are mostly used in an unsafe, unhealthy and inefficient way: actually, the current energy supply schemes in refugee camps focus primarily on the electrification of humanitarian institutions as well as basic camp infrastructure and mainly depend on inefficient diesel generators. Replacing these energy sources or devices with sustainable energy solutions in camps would have numerous advantages for refugees as well as for the host community and the environment.

In this situation, a shift towards self-sustaining, cheaper, environmentally friendly and sustainable way of energy provision in refugee settings is indicated. In most camp locations, household energy challenges are both acute and interlinked. This is most obvious in the context of livelihood-related problems. It appears that most of the other challenges are root causes or consequences of the lack of sustainable livelihoods and the dangers linked to energy-dominated income-generating activities. A comprehensive approach is therefore essential to finding sustainable energy solutions.

The following work presents a manual which should be implemented with the aim of enhancing the response capacity of humanitarian actors in identifying the potentially most appropriate solutions for energy intervention in refugee camps and informal settlements.

2. Comprehensive Energy Solution Planning Framework

Comprehensive Energy Solutions Planning is a step-by-step methodology developed by UNESCO Chair at Politecnico di Milano – Department of Energy. It is an essential element for strengthening the effort toward energy access and sustainable energy systems, in order to extend or improve the energy services in a sustainable and efficient way.

The energy plan issue is not trivial: according to the literature, it is based on sound research on the national energy consumption and energy supply, energy prices, demand and supply technologies, population growth, environment and social impacts, success of an energy harnessing technology and influence of political situation [5].

Looking at the case of developing countries, rural energy planning often ignores socio-cultural and political issues, mainly, in most cases, focusing mainly on the techno-economic aspect: this affects the sustainability of technical interventions. In fact, when taking together both socio-ecological, technological and political interactions of rural energy solutions, the longevity of energy interventions may be determined [6].

For this reason, inclusive participation of local stakeholders in planning and access to human capital have to be considered since the earlier phases of any energy programmes [7] helping in searching for information about the suitability of a given technology based on geographical, cultural and ecological considerations [8]. In this way it is possible to intervene with a bottom-up approach and develop in each context the most suitable and adequate response for better meeting local demand and population interests.

Nevertheless, to ensure long-term sustainability of energy intervention, many determinant factors have to be taken into consideration, as regards system reliability and lifetime, as well as success in terms of acceptability and number of users.

Starting by delivering training programmes to users and stakeholders involved in the operation of the energy systems, it is possible to provide local entity with sufficient skills to face systems utilization and eventual related faults as well as allow them to guarantee the development of continuous monitoring and technical support system. In this way, a sense of ownership and a high rate of acceptance of the proposed technologies can be developed among the crisis-affected populations also by means of a tailored design of the systems reflecting their needs while supporting field-based actors become then directly involved in the assessment and management of natural resources and their availability in order to ensure a continuous supply. As a result, through the adoption of suitable and innovative financial and business schemes also incorporating in the planning process activities beyond the energy access, a clear identification of the baseline situation can be developed to understand the context and to allow the qualification of project outcomes after implementation.

Some of such determinant factors are frequently put in place during the planning of energy projects, but on the other hand, it is also evident that very few projects have been planned considering all the factors together. This consideration gives evidence of the lack of a comprehensive energy planning procedure addressing the peculiar characteristics of developing countries. In fact, energy planning has been widely addressed from different perspective in the case of the developed world.

Based on all these considerations, the Comprehensive Energy Solutions Planning (CESP) frameworkhas been introduced, with the aim of suggesting a complete overview of the energy planning process by integrating all the main above-mentioned relevant aspects into a clear and simple step-by-step procedure with a specific focus on energy access in rural areas of the developing world supporting researchers, practitioners and policy makers with a clear identification of the different phases that characterize the energy planning process from the earliest needs assessment to the final impact evaluation.

3. Methodology: CESP Phases In-Depth Analysis

The Comprehensive Energy Solution Planning framework is articulated into five key sequential phases. The first phase of CESP is the context assessment and identification of the *Priorities* (CESP 1), which allows to understand the context and the main needs of the local population. The *Diagnosis* phase (CESP 2) follows, where the main needs are correlated and/or translated into an energy demand and load profiles, the assessment of the available energy resources paves the way for demand-resources matching[1]. During the *Strategy* phase (CESP 3), the energy strategy is fully defined by defining the boundaries and the approach of the intervention and purposing and comparing different possible scenarios ranging from distributed to decentralized or grid connected energy systems. The C*omprehensive Design* phase follows (CESP 4) where a general techno-economic overview of each of the different configurations previously shown is presented, in order to find an optimal solution. Finally, in the *Impact Evaluation* phase (CESP 5) an evaluation of the expected impact is carried out by means of tools and monitoring activities [9].

In the following paragraphs, an in-depth analysis of each step of the procedure is presented in order to have a clear understanding of the energy response in humanitarian context as a whole.

This work has been mainly developed with a focus on the phases from *Priorities* identification to *Comprehensive Design* presentation, excluding the in-depth analysis of the *Impact Evaluation* step.

[1] It is worth noting the original CESP framework, this phase needs to be also dedicated to the exploration of policy and regulation in order to understand opportunities, threats and barriers which are determined by the surrounding political and regulatory framework. In the presented novel procedure, the author decided not to focus on this stage.

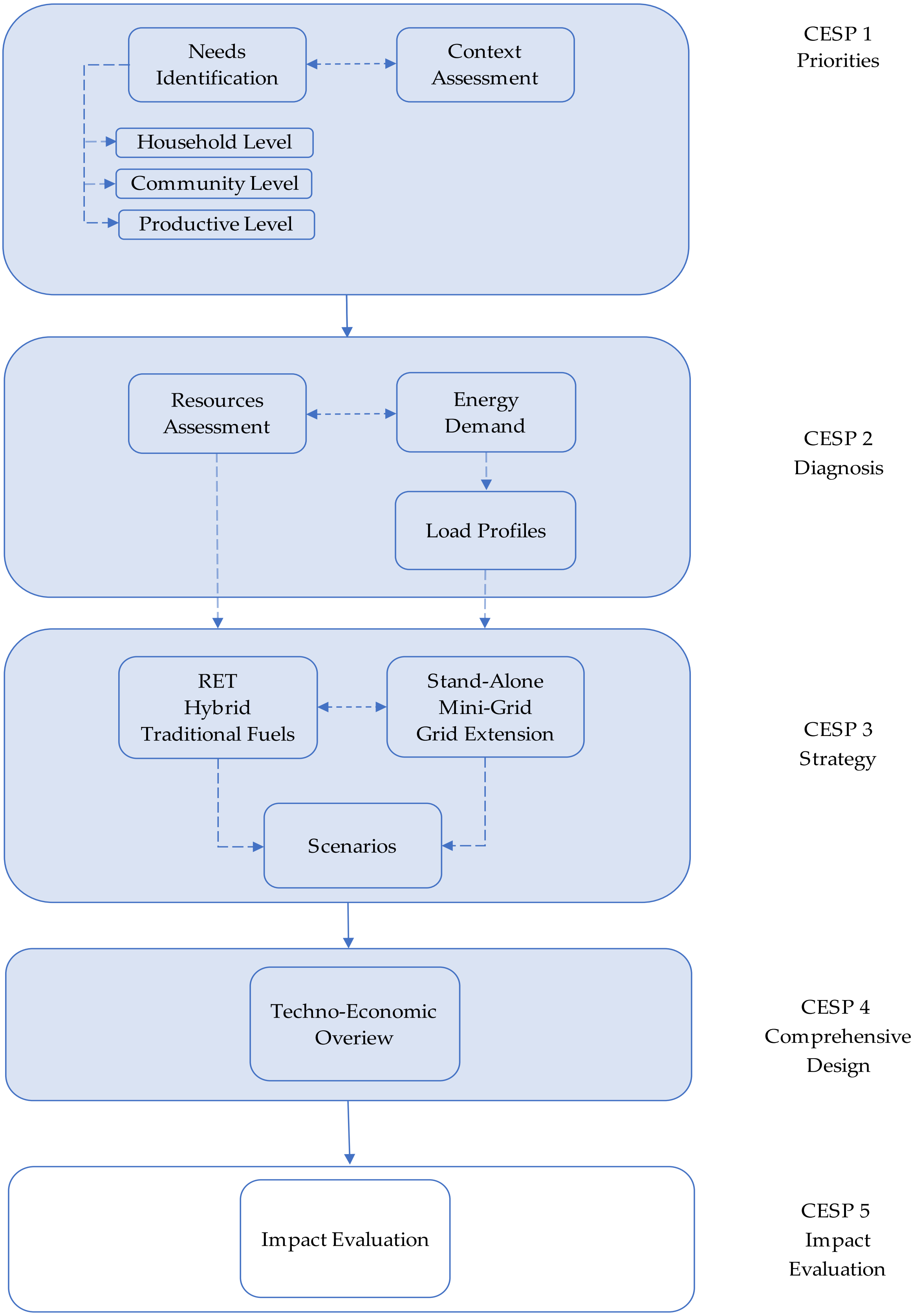


Figure 1 - CESP Structure. Source: Author

3.1 Priorities

In order to define priorities for energy intervention in the humanitarian context, the first phase of the procedure deals with the definition of the baseline situation of the targeted setting, starting by a general context assessment and including in particular a focus on the population needs identification. Aiming at gathering information about specific socio-cultural and socio-economic situation, a multi-sector analysis needs to be conducted by means of different both qualitative and quantitative data collection tools such as structured questionnaires and surveys but also direct observations and focus discussion groups with the involved stakeholders as well as meetings with local partners and organizations.

Starting by already existing and available tools and questionnaires provided by humanitarian agencies as well as other organizations, in the following chapter, novel structured and practical tools have been proposed. In particular, three comprehensive surveys have been developed for the purpose: one for each intervention level which usually need to be considered in humanitarian settings. Each one has been divided in sections according to the category of users and consumers class and their related energy needs and supply. In a bit more detail:

Table 1 - Surveys Index. Source: Author

Context Assessment	
Section 0HH (Q1 to Q8)	General Context Information
Household Survey	
Section 1HH (Q9 to Q17)	General Household Information
Section 2HH (Q18 to Q39)	Household Cooking
Section 3HH (Q40 to Q55)	Household Lighting
Section 4HH (Q56 to Q62)	WASH - Water Treatment, Supply and Sanitation
Section 5HH (Q63 to Q79)	Access to Electricity
Community Facilities Survey	
Section 1CF (Q1 to Q10)	General Community Facilities Information
Section 2CF (Q11 to Q30)	Lighting
Section 3CF (Q31 to Q40)	ICT&Enterteinment
Section 4CF (Q41 to Q55)	Motive Power
Section 5CF (Q56 to Q70)	Heating
Section 6CF (Q71 to Q84)	Cooling
Productive Uses Survey	
Section 1ES (Q1 to Q11)	General Enterprise Services/Productive Uses Informatior
Section 2ES (Q12 to Q31)	Lighting
Section 3ES (Q32 to Q39)	ICT&Enterteinment
Section 4ES (Q40 to Q54)	Motive Power
Section 5ES (Q55 to Q69)	Heating
Section 6ES (Q70 to Q83)	Cooling

In the following paragraphs, an in-depth presentation of the sections of each survey is introduced, in order to better understand how to conduct the priorities evaluation.
It is worth noting, while the first *Household Survey* has a proper structure more specific for the individual needs evaluation of each family, the others show same structure .
In particular, once in their earlier sections, respectively the kind of facility in the *Community Survey* and the kind of enterprise or productive activity for the *Productive Survey*, have been correctly chosen among the given options, all the other following sections have been developed according to the same configuration.
The full-text surveys can be found in Appendix D.

3.1.1 Context Assessment

The first *Section 0* (Question ID from Q1 to Q8) of the *Household Survey* is intended to understand the size of the problem and the general characteristics of the area of intervention as well as the level of integration and the acceptability of interaction and collaboration among persons. In particular, the information gathered from this are meant to give an idea of the topography of the area, of the typology and size of the community/camp/settlement under consideration including the type of shelter adopted and their constructive type, but also to outline characteristics about the status and origin of each group living, whether they are IDPs, refugees, asylum seekers or host communities members and how long they are expected to stay in the location of interest. The aim consists in providing the history of the camp or the evolution of the targeted population's presence weather conditions that may affect the intervention program.

In the *Section 1* (Question ID from Q9 to Q17) social organization, size and composition of each household have to be investigated, including information about their employment and their role in such household in order to have a better understanding about the local population. In addition, also questions about livelihood activities and other source of income or support provided by external organizations are included, so that it is possible to have data about the local economy situation.
This information will help to plan the size of the intervention and identify security and logistical concerns that may affect the choice of the accurate technologies to be adopted. For example,

shelter types and weather conditions will later help determine which stove models may be appropriate for local conditions, while the stability and longevity of the camp/settlement have implications for production and dissemination strategies, as well as for monitoring the performance/impact of the response activities.

3.1.2 Needs Identification

According to recent UNHCR reports and reviews, when analysing a refugee situation, should move away from using "minimum emergency standards" as a benchmark for progress [4], and focus instead on the more elastic concept of "essential human needs". Such an approach enables to conceptualize a situation in a comprehensive and needs-based manner.
Essential basic needs are those elements required to lead a safe and dignified life. They both comprise and go beyond minimum standards and are time and context elastic. While at the start

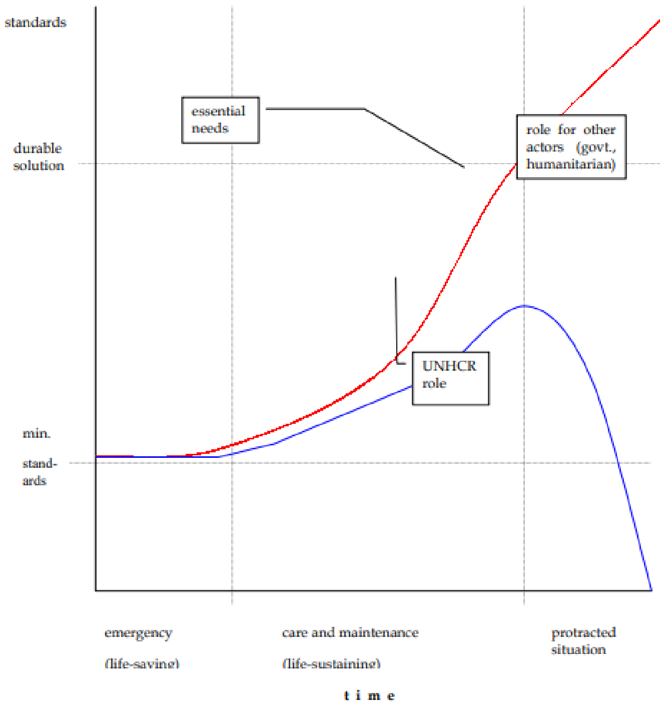


Figure 2 - Essential needs over time: an idealized representation. Source: UNHCR

Figure 4- Woman during her daily cooking practices in South Sudan. Source: Oxfamblogs.orgFigure 2 - Essential needs over time: an idealized representation. Source: UNHCR

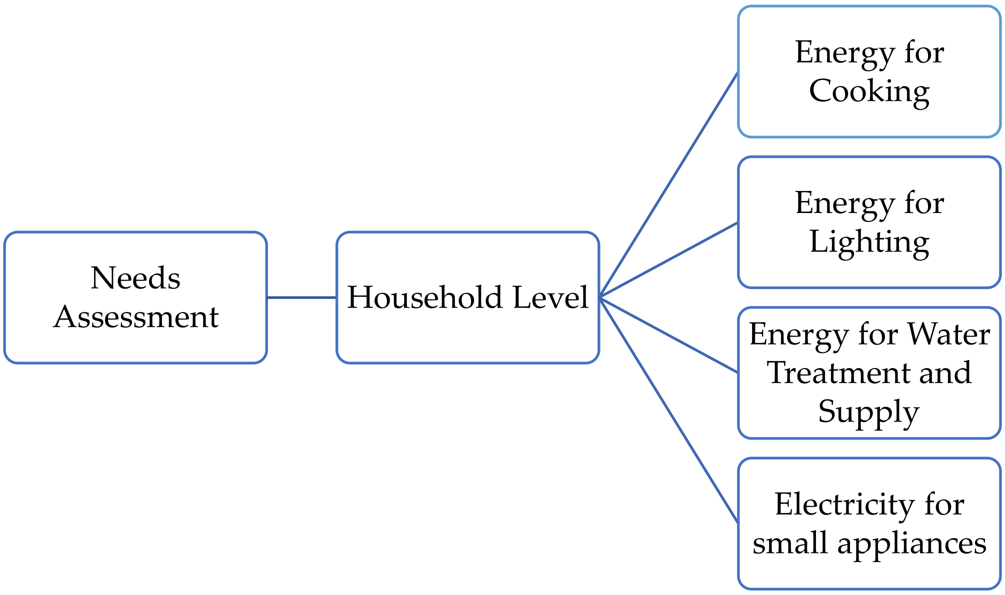
of an emergency essential needs may be congruent with minimum standards, over time essential needs will grow, as refugees' lives become increasingly intolerable unless they are able to enjoy a wider range of human rights and are enabled to develop their human functions and capabilities (Chatam House, 2016).

Developing an essential needs profile of a refugee population provides a full spectrum picture of it. Through having this picture in front of it, it is possible to develop comprehensive plans that account for current refugee needs and look towards a durable solutions future, highlighting the existing gaps in attaining them.

Depending on the focus of the action and context, beneficiaries' energy needs can be explored:

- At the household level
- At the community level (community services)
- At the productive level (energy for agriculture, artisanal activities, rural industries)

3.1.2.1 Household level



The household basic energy needs of displaced people in camps are those related to cooking, lighting, water treatment and supply and electricity devoted to small appliances operation. In particular, the most relevant need for preserving a decent standard of living, in refugee camps and informal settlement, is food security. Humanitarian actors usually try to address them focusing on food availability and access, while food utilization is often neglected. As a matter of fact, access to cooking energy is important for refugees as 95 per cent of the food that is supplied in refugee camps is raw and has to be cooked before it can be eaten and the amount of fuel – principally firewood and charcoal– required to fulfil these needs is typically greater than that provided by aid agencies [11]. To meet the rest of the demand, refugees must therefore use local natural and human resources to supplement their fuel allowance, collecting firewood from the areas nearby the camp or buy firewood from the host community.

The most common practices for cooking and strictly related activities, such as water boiling for food preparation, are based on the use of traditional fuels such as firewood or charcoal. Most of the times, firewood is burned in traditional three-stone fires stoves: this system is highly inefficient (efficiency rate is lower than 15 per cent), causing a high consumption of fuel, and in turn the emission of large quantities of smoke, i.e. particulate matter, carbon monoxide and other pollutants. The utilization of charcoal in traditional stoves poses as well severe threats in terms of pollutant emissions. Moreover, the traditional method that is in general used to produce charcoal from wood is energy costly wasting over half of the available energy in the wood and it is characterized by very low efficiency. As a consequence, when considering also the production phase, in some cases cooking with charcoal can result in the consumption of even more resources than three stone fires.

The lack in technologies for appropriate and safe food utilization leads to malnutrition and weak health, enhances causes of mortality creating a status of permanent emergency. Nevertheless, the issue of access to cooking energy in humanitarian contexts is also at the core of other challenges, such as protection, relations between hosts and displaced people, environmental damage, household energy-related natural resource restrictions and livelihood related challenges. In addition, the Inter-Agency Standing Committee (IASC) Task Force on Safe Access to Firewood and Alternative Energy in Humanitarian Settings (SAFE) identified other issues related to household energy. As a matter of facts, in many cases, women and children must cover long distances to collect firewood and have to carry heavy loads back to the camps. This puts them at risk for physical and sexual attack, physical injuries, and other problems. Women and children are also exposed to health risks, especially asthma, pneumonia, or other respiratory infections due to the smoke produced by inefficient cooking systems. Recently the issue has been tackled through the use of more fuel-efficient woodstoves, which are both affordable and easy to use, cutting the number of risky trips for firewood and allowing more trees the opportunity to grow. Subsequently, burning smaller amounts of wood fuel means less smoke will engulf their homes and their lungs, reducing health-related problems too.

Moving on food preservation, adverse environment conditions, such as high levels of temperature and humidity fasten the process of food degradation. The natural moisture in many foods becomes a breeding ground for organisms like bacteria and fungi, which can be harmful if eaten. The consequent food losses worsen a situation which is typically characterized by food scarcity. Therefore, the lack of appropriate means of food preservation may contribute to malnutrition. Appropriate preservation processes can constitute a solution to directly inactivating bacteria, yeasts, molds or enzymes, avoiding food contamination before or after the cooking process.

Another essential basic need is the access to safe water for cooking and drinking. It is essential for refugees to receive an adequate quantity of good quality water because water has an impact on so many vital sectors of society, including nutrition, health, education and sanitation. The UNHCR estimates that more than half of the refugee camps in the world are unable to provide the recommended daily water minimum of 20 liters of water per person per day [10]. Ensuring that the refugees receive an adequate quantity of water is an important public health issue because lack of clean water is correlated with the presence of diseases such as diarrhea and cholera. Though it is important to provide adequate quantities of water, the water quality and hygiene is also of the utmost importance. Even if the water that is provided is not contaminated, the transfer of water between vessels, the storage of water in the home, and touching the inside of water vessels with the hands are risk factors for contamination. In this sense, a lack of energy a lack of energy may act as a barrier to water procurement and treatment: energy is fundamental to pump water from underground or surface reservoirs, and it plays a major role also in many systems for water purification.

Energy also plays a fundamental role to ensure the satisfaction of further needs through the provision of other important services, such as lighting, for operating small domestic appliances and for entertainment and information and communication (charging phone mobiles). Often as sources of light three-stone fire is adopted as well as kerosene lamps and candles, due to the lack of any alternatives, although they are not so efficient and have a poor light quality. Such solutions expose people, in particular women and children, to the emission of smoke again, and to the risk of severe burnings and poisoning. In other cases, electricity is available around the settlements, but people can’t afford it, or is not entitled to use it. As a consequence of this, informal connections are a frequent practice, which means getting electricity by installing an illegal connection. Obviously, illegal connections do not comply any safety standard, with consequential increase in the risk of electric shock, short circuit, and fires. In addition, illegal connections can constitute a cause of conflicts with owners of legal contracts in the surroundings.

Lastly, electricity is often needed by local and international agencies assisting refugees, and, more in general, for camp management operations. In many cases, power is supplied by outdate, inefficient, noisy diesel generators, which emit significant amounts of pollutants, and consume large amounts of fuel.

Section by section, all the already introduced energy needs and uses are going to be investigated by means of a multi-sector survey.

Cooking

In the *Section 2* (Question ID from Q18 to Q39) of the proposed *Household Survey*, cooking practices and correlated habits have to be investigated. In order to get information about the topic, the surveys presented household by household contain questions concerning access to

Figure 3 - Group of Women during their cooking practices. Source: The Solution Journal

Figure 4- Woman during her daily cooking practices in South Sudan. Source: Oxfamblogs.org

cooking source, stove typology and fuel consumption. In particular it is necessary to collect data about the fuel that each group of household usually choose according to the typology o stove they own; the purchase place and in turn the fuel cost or the collection place and in case the time spend to get it; possibility of having difficulty with access to cooking fuel during the year and what is the reason of it; how much time the responsible person for cooking meals spend time in cooking; the place they used to cook in and level of air pollution due to the fuel employed.

Lighting

Talking about energy for lighting purpose at household level, practitioners need to submit to the local population an assessment of the light utilization, mainly getting information about the lighting source used, which systems, appliances and activities it is needed for.

Figure 5 - Children using Solar Portable Lanterns. Source: D.Light

The questions concerning the topic can be found in the *Section 3* (Question ID from Q40 to Q55) of the *Household Survey*.

In order to later develop the electric load profile curve, it is necessary to know the electricity utilization time devoted to lighting use, investigating habits of each group of households. Improved lighting system can change the life of any community, thereby allowing people to perform activities such as self-studying, sewing and other night-time tasks as well as to ensure their safety. Finally, it has to be known whether the lighting systems operate thanks to a grid extension or to the installation of off-grid systems or if they have no access to electricity at all.

Water Treatment and Supply

As already stated, access to safe water for cooking, drinking and sanitation is one of the essential need that has to be met in humanitarian context. Therefore, the *Section 4* (Question ID from Q56 to Q62) of the *Household Survey* explores the topic asking questions about the water point, its distance from each household, the time spent in collecting water. In addition, focusing on sanitation and hygiene, people should answer questions about their habits in using toilet and latrines to have a general understanding of the average amount of water usually consumed in hand-washing, excreta and solid waste management in order to attempt to improve water-correlated facilities. Moreover, gathering further information about existing pumping and storage systems allows practitioners and technicians to analyse and improve them, so that it is possible to guarantee an adequate access to water.

Figure 6 - Women drawing water by an installed pump in Bangladesh. Source: UNICEF

Electricity for small appliances

Access to electricity has to guarantee also the operation of other small electric devices such as phone chargers, radios, fridges, fans, TVs and other appliances devoted to communication and information eventually including access to internet.

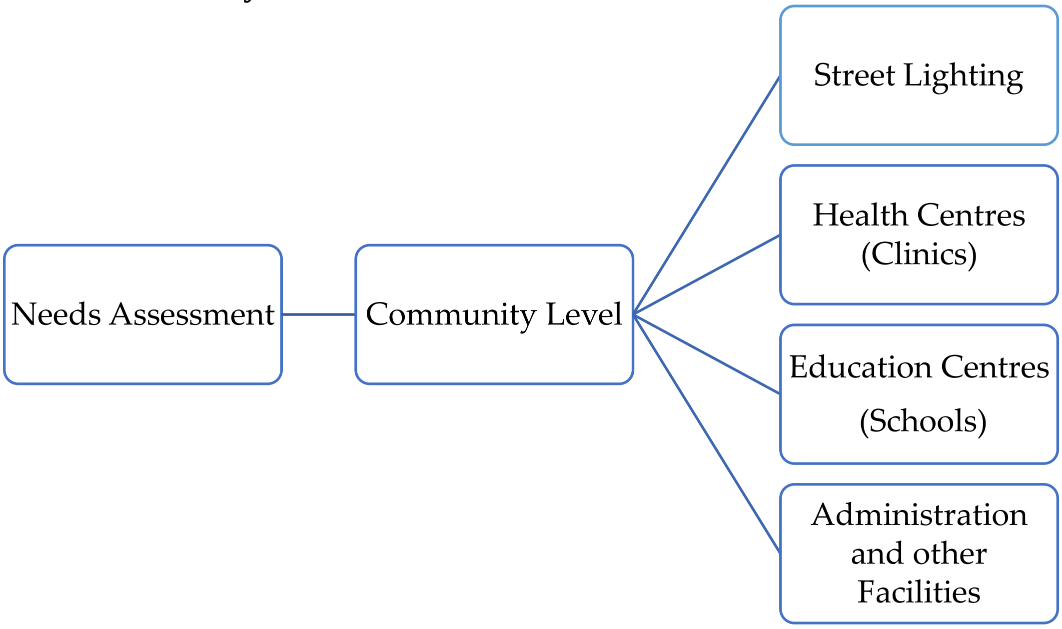
Therefore, the above introduced multi-sector *Household Survey*, in the last *Section 5 – Access to Electricity* (Question ID from Q63 to Q79) contains questions about the energy source exploited for this kind of operations and their utilization time in order to have an initial idea to later develop the electric load curves of a typical month or year. This part of the questionnaire is comprehensive of the sub-section *Section 6.1 -Mobile Phone and Internet Access* (Question ID from Q71 to Q79).

A table containing a list of the most common appliances and their typical power demands has shown below.

Table 5 - Nominal power of typical electrical appliances

Appliance	Power Demand [W]
Phone Charger	5
Toaster	800-1500
Blender	300
Microwave	600 - 1500
Table Fan	10 - 25
Stereo	10 - 30
Radio	5
TV 25'' Color	150
Iron	1000
Sewing Machine	100
Refrigerator/Freezer	475

3.1.2.2 Community level



At the community level, most frequent needs include street lighting, water pumping, fuels and electricity for schools, health clinics and social centres. In fact, energy is a key factor for improving access to education, health, and other social services.
The lack of public street lights creates safety and mobility issues: in the 58 per cent refugee households no one leaves the house after dark. In particular, women's mobility after dark is almost completely inhibited, presumably because of fears of gender-based violence: this fact limits opportunities to socialize with friends, or to participate in group income-generating or educational activities. In addition, also in rural schools after-dark study requires illumination. In health clinics, the lack of electricity and illumination, together with the daily drudgery, the physical burden of fuel collection and the poor transport means, all contribute to poor sanitary response. Increased availability and affordability of energy within a community, and a shift toward modern energy services, also trigger positive feedback on other social issues such as gender equality and women empowerment, and reduction of the digital divide.

The *Community Facilities Survey* reported in Appendix D.2 is organized in sections according to each kind of activity dealing with community services (from *Q1 to Q10*). Once the final use of each facility has been identified in the devoted *Section 1CF*, questions about needs and supply (electrical or non-electrical source) are presented. In particular, Questions ID from *Q11* to *Q30* regard *Lighting*, followed by *ICT & Enterteinment* from Question ID *Q31* to *Q40*, *Motive Power* from ID *Q41* to *Q5*5, Heating from ID *Q56* to *Q70* and finally questions about *Cooling* from ID *Q71* to *Q84.*

Street Lighting

As already mentioned, a reliable access to energy may also provide an adequate public street lighting. Installing streetlights allows refugees to reduce their vulnerability to insecurity, violence and personal attacks as well as allows them to pursue outdoor night-time tasks and activities trivially including going out to latrines or washing areas.
So far, the most adopted solution chosen for streetlight installation above facilities and alongside the pathways has been the connection to the grid. But it can perform eventually blackouts due to the weakness of the national network, extreme weather conditions and other correlated issues. In order to overcome such problems, innovative public lighting solutions began to be considered: integrated solar streetlight systems are the prime example of plug-and-play, durable, affordable, totally self-sufficient, with no technical maintenance solutions. In this section, the survey contains questions about street public light situation of the camp or settlement taken into consideration: it aims to evaluate the condition of camp daily life, in order to propose an improvement by means of more innovative energy solution.

Health Centres (Clinics)

At community level, clinic centres have to face unexpected challenges on a daily base. For this reason, selecting an appropriate source of reliable and sustainable energy can help to mitigate any kind of challenge inherent in operating a health facility. In fact, in this context access to electricity ensures the operability of the cold chain by means of the refrigerators devoted to the conservation of vaccines, blood and other medicines but especially available sources of light allow patient to receive care all day and night long. It is then investigated an average value of the energy demand on a typical daily/monthly basis, evaluating or estimating the energy consumption of each kind of device involved. In addition, for what concern this communitarian facilities, questions about food preparation and preservation issue, since patients have to be fed during the hospitalization as well as questions about energy spent for internal and external communication and information.

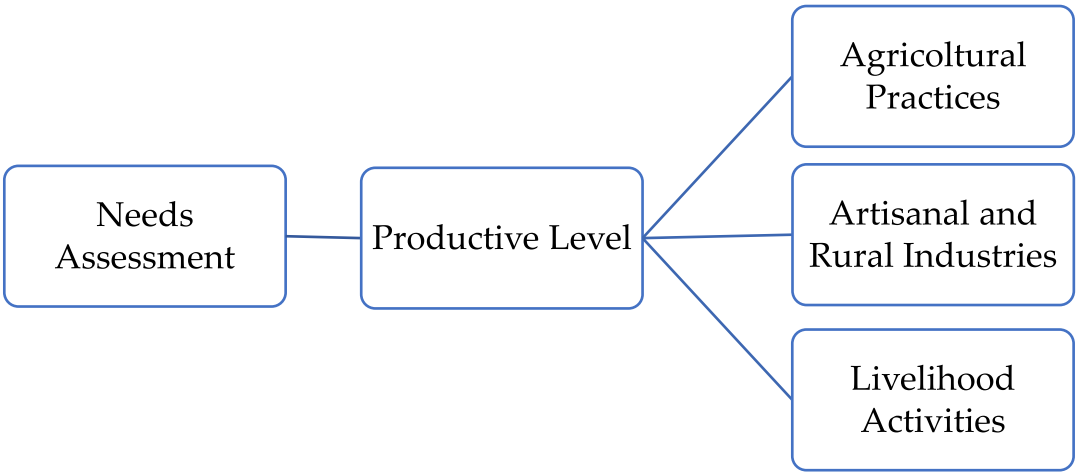
Education Centres (Schools)

Basic schooling has emerged as a humanitarian right just like water, sanitation, food, security and shelter [8]. With the aim of supporting education in refugee camp, it is possible to provide electricity and IT equipment by means of the provision of sustainable energy, such as solar power, to educational facilities currently without or not appropriate electricity supply. In this sense it is important also exploring this issue, investigating about the existent access to energy, the typical needed devices and their daily/monthly utilization.

Administration and other facilities

NGOs, local partners and all the humanitarian agencies have dedicated structures where to carry out their camp management and organization activities. In this sense also they contribute to the energy utilization so that it is necessary to take into account their consumption and demand and explore by means of this section of the survey how to guarantee them a reliable access to energy.

3.1.2.3 Productive level



In simple terms, productive uses of electricity are those that increase income or productivity. Typical productive uses can be found in agro-processing: an increased use of modern energy services can contribute to add value all along the food supply chain and to move away from subsistence agriculture. In particular, direct usages of energy for land preparation, cultivation, irrigation, harvest and post-harvest processing, storage, and transportation, are essential for moving from human and animal labour-based agriculture to a more productive mechanization.

The development of artisanal and rural industries is another essential component of rural economic transformation, which require heating, cooling and cooking processes and the utilization of ICT and mechanical devices.
Moreover, at productive level, it has to be taken into account energy uses designed to manufacturing industries such as carpentry, tailoring, welding and looming, and in the service sector and livelihood activities, e.g. in shops, bar, restaurants that use electricity for lighting, sound systems and refrigeration, as well as for charging mobile phones.

The *Productive Uses Survey* reported in Appendix D.3 is organized in sections according to each kind of activity dealing with enterprise services or productive uses (from *Q1 to Q11*). Once the final use of each enterprise or productive activity has been identified in the devoted *Section 1ES*, questions about needs and supply (electrical or non-electrical source) are presented. In particular, Questions ID from *Q12* to *Q31* regard *Lighting*, followed by *ICT & Enterteinment* from Question ID *Q32* to *Q39, Motive Power* from ID *Q40* to *Q5*4, Heating from ID *Q55* to *Q71* and finally questions about *Cooling* from ID *Q72* to *Q83.*

Livelihood and rural activities

In order to have a global understanding about energy demand and utilization in humanitarian context, at productive level, electrical and thermal energy devoted to agriculture practices, rural industries and other livelihood activities has to be taken into account. In particular, it refers to structures where shops or market are located also including any other kind of income generating activities: they are necessary to create a self-sustainable economy by means of a market-based approach. Since access to energy is fundamental for their operation, both from electrical and thermal energy point of view, the multi-sector needs assessment survey, also present a section devoted to this topic.

TOOLS BOX – Priorities

SURVEYS and TOOLS

- *SET4Food – Assessment form: Descriptive Aspects*
  http://www.set4food.org/images/Assessment_form_descriptive_aspects.pdf
- *USAID Step 3 Tool A: Site Survey Template*
- http://www.energytoolbox.org/cookstoves/FES_Programs_in_Humanitarian_Settings.pdf
- *USAID Step 3 Tool B: Household Survey Template*
  http://www.energytoolbox.org/cookstoves/FES_Programs_in_Humanitarian_Settings.pdf
- *D-Lab Toolkit – A2 Household tablet survey*
  https://docs.google.com/spreadsheets/d/1uD2Wl8mgsr3vT7oqFVAOq_SAn_eCubZ1z0ehadNz_Io/edit#gid=1084117619
- *Questionnaire for households – General Information of households* (Multi-sector, it could be considered in case of Emergency Response)
  http://kth.diva-portal.org/smash/get/diva2:626362/FULLTEXT01.pdf
- *REACH Multi-Sector Needs Assessment + FDGs*
  http://www.reachresourcecentre.info/system/files/resource-documents/reach_ssd_msna_maban_report_dec17_0.pdf

MANUALS and GUIDELINES

- *WASH Manual*
  file:///C:/Users/sara/Downloads/UNHCR%20WASH%20Manual.pdf
- https://www.lightingglobal.org/products/?view=grid
- http://www.poweringhealth.org/Pubs/PNADJ557.pdf
- *Energy for Agriculture*
  http://www.fao.org/docrep/003/x8054e/x8054e05.htm#P795_76970

3.2 Diagnosis

The second stage of the CESP framework deals with the *Diagnosis* phase*:* it allows to translate needs into energy demand and to assess potentialities and constraints in terms of local resources; it also concerns the analysis of the policy and regulatory framework.
The activities carried out in this part produce essential data for the following phases, paving the way for the definition of a proper strategy and the comprehensive techno-economic design.

In particular, the first part consists in the analysis of the data gathered from the questionnaire of the previous *Priorities* phase: starting from the current energy situation deducted from the collected information, baseline or forecast energy demand can be here evaluated or estimated as energy flows and only later translated in turn into load profiles.

The second part deals with a general assessment of local natural resources which is a critical factor in developing successful projects. It consists in the characterization of the range of renewable resources across a given region, evaluating their availability and exploitability both from spatial and temporal distribution point of view.

In the following paragraphs, it can be found the methodology and the correlated tools which have to be adopt in order to successfully carry out the phase.

3.2.1 Energy Demand and Load Profile

As already stated, when the data regarding the energy needs expressed by the population of a given humanitarian context have been analysed, they can be seen in term of energy demand and then evaluated as energy flows.
Through the analysis of energy flows, it is possible to show how energy resources are actually used to meet various energy services. In this context, Sankey diagrams could be useful to graphically represent the general energy balance including both electric and thermal energy components. Once the interactions between primary energy sources, energy drivers and final energy users have been clearly and visually identified, the existent local energy supply chains can be deduced.

On the other hand, the characterization of load profiles, in which the energy flows have to be translated in, is essential to proceed with the sizing of power sources and storage systems, to analyse and/or optimize energy fluxes and to define how to control the systems. In fact, load profiles capture the variation in the energy load over a specific time and are not only based on the total amount of energy consumptions, but they also refer to the amount of energy the targeted users require in given time steps.
Specifically, in order to perform load profiles estimates, in addition to define the same input data required to compute energy consumptions, it is also required to define the periods in the day each appliance works. It follows that different energy utilization leads to different load profiles which in turn affect the design process of the adoptable energy system.
Indeed, storage sizing and dispatch strategy optimization particularly depend on load profile features (e.g. peak values, hour of the day when power peak occurs, total daily energy, share of energy in the night hours). The estimation of load profiles in such studied context is particularly critical, not only because they vary along the year due to seasonal factor (e.g. ambient temperature variations, sunrise/sunset time), but also because most of the times there is a complete lack of quantitative information about energy consumptions.

In many cases, especially in rural and humanitarian context, historical data are not even available because of different reason. For example, in the case of electricity, the intervention could bring electricity to an area where electricity was not used before; diesel generators are used in the area, so that no data are available about peak power and energy consumption; users were using illegal connections.

On the other side, for what concern energy devoted to heating and cooking, in most cases energy needs are satisfied by using traditional biomass which is directly collected by end users or traded out of the official markets: for this reason, directly gathering this data may be difficult.

Different methods are found in the literature for the estimation and forecast of load profiles in less critical contexts, including top-down approaches (based on economics at a macro level) and bottom-up approaches (based on technological and local factors). However, at the very local level, demand projections are typically traced back to a function of a limited number of key parameters (such as population density, location, and target energy access levels), while at the country or regional level, a variety of methods are used to project total energy demand. In particular, the development of the actual energy consumption trends as a function of time can be carried out by means of software or calculated manually, always aiming at idenitfying the profiles associated to the current energy situation of the camp or settlement before any kind of intervention.

Electric Loads

In general for the case of electricity, it is common practice considering all the electrical appliances used in each category, their typical nominal power and their time of use, namely the number of hours per day they typically operate. The load profile of each class are then daily identifiable and, summing all them up, the total electric load curve of the studied area can be graphically obtained.

The following structure in Table 4 reflects the already introduced camp or settlement level organization and it shows the above mentioned categories as *User Classes.* In the humanitarian context three main *User Classes* can be identified, one for each level of intervention: Household, Community and Productive. Each *User Class* contains different kinds of *Consumer classes* with their own specific *Type of Appliances* which usually daily operate in order to meet the required energy demand.

It can serve as model to calculate manually the typical daily energy demand of most of the humanitarian settings. It contains the most typical appliances owned by a specific population.

Table 6 - User Classes, Consumer Classes and Typical Appliances. Source: Author

User Class	Consumer Class	Number of Users	Type of Appliance
Household	Households		Phone Charger Radio TV/Laptop Indoor Light Outdoor Light
Community	Health Center		Phone Charger Refrigerator Dry Heat Sterilizer Ceiling Fan Blood Chemistry Analyser Oxygen Concentrator Indoor Light Outdoor Light
	School		Phone Charger TV Laptop Indoor Light Outdoor Light
	Education Center		Phone Charger TV Indoor Light Outdoor Light
	Camp Organization Center		Phone Laptop TV Satellite Dish/Receiver Indoor Light Inkjet Printer
	Street Lighting		100 solar lights - 6 metri LED
Productive	Agricolture		Irrigation Pump
	Drinking Water Supply		Water Pump
	Hospitality (restaurant, bar, hotel)		Phone Charger Refrigerator Indoor Light Outdoor Light
	Grocery		Phone Charger Refrigerator Indoor Light Outdoor Light
	Tailor		Phone Charger Sewing Machine Indoor Light
	Retail Shop		Phone Laptop TV Satellite Dish/Receiver Inkjet Printer Indoor Lights

As alternative, according to Mandelli et al [31], the problem could be faced by means of a novel methodology for the estimation of load profiles in such cases, based on a stochastic bottom-up approach. It is implemented in the *LoadProGen* software, developed by Politecnico di Milano, which allows to outline load profiles of different classes of users present in any given context or area.

On this basis, if the energy consumption refers to the amount of energy (Wh) the targeted users require in a day, therefore the daily energy consumption (EC) for several users having several electrical appliances can be estimated as follow:

$$E_{C,el} = \sum_{j}^{User\ Class} N_j * \left(\sum_{i}^{Appliance} n_{ij} * P_{ij} * h_{ij} \right) \left[\frac{Wh}{day}\right]$$

where:

- *i* refers to the type of electrical appliances (e.g. light, mobile charger, radio, TV);
- *j* refers to the specific user class (e.g. household, school, stand shop, clinics);
- *Nj* refers to the number of users within class *j*;
- *nij* refers to the number of appliances *i* within class *j;*
- *Pij* refers to the nominal power rate [W] of appliance *i* within class *j;*
- *hij* refers to the duration of the period the appliance *i* within class *j* is on [h] (i.e. functioning time).

The previous ones are the basic input data to be introduced in the software: it can be easily noticed the inputs are the same as before with the exception of the *hij* functioning time values which are the trickiest required inputs data which have to be considered. They are typically defined based on experiences about appliances usage habits in the specific context or by defining specific targeted amount of supplied energy. Substantially, *LoadProGen* software just helps in avoiding manual calculations also allowing the energy consumption estimate at annual, monthly or seasonal level, producing multiple profile series.

If electricity is generated using local gensets, the energy carrier consumption $C_{C,el}$ (diesel or petrol) in general can be easily and precisely estimated using the average consumption or ottherwise, a broad estimation can be obtained as follows:

$$C_{C,el} = E_{C,el} * f$$

Where *f* is the average specific fuel consumption [kg/kWh].

Thermal Loads

LoadProGen software has been developed exclusively for the definition of the electric load profile, so that is not directly adoptable in case of thermal loads characterization.

About thermal energy, as previously stated, mainly refers to cooking and heating purposes. Accordingly, for the case of thermal energy, the best way to understand the daily energy consumption is to directly collect data about the consumption of the different energy carriers.

Such energy carriers in the developing world context are intended as kerosene, diesel for vehicles, firewood, charcoal. Unfortunately, in most cases the consumption of traditional fuels such as firewood or charcoal is not easily tracked, especially in the frequent case where refugees collect fuel autonomously in the surroundings.

As already stated, when direct data are lacking, it is necessary to make an estimation. In this case, it is necessary to estimate the daily consumption K_{th} of each different energy carrier k:

$$K_{th} = \sum_{j}^{User\ Class} N_j * \left(\sum_{i}^{Appliance} n_{ij} * C_{ij} \right) \ [unit/day]$$

where:

- i refers to the type of thermal appliances (e.g. three stone fire, Improved Stove, oil lamp);
- j refers to the user class (e.g. household, school, clinic);
- N_j refers to the number of users within class j;

- n_{ij} refers to the number of appliances i within class j;
- C_{ij} refers to the average energy carrier consumption rate of appliance i within class j [unit/h] (the unit can be kg or liters of fuel);

In terms of energy, $E_{C,th}$ is evaluated as follows in Eq. :

$$EC_{th,k} = \sum_{k}^{Energy\ carrier} K_{th,k} * LHV_k \quad [Wh/day]$$

where LHV_k is the calorific value of the energy carrier k.

3.2.2 Local Resources Assessment

The assessment of resources is the second activity that is carried out in the *Diagnosis* phase. This step is complementary to the definition of load profiles and it aims at determining the availability of renewable or traditional energy resources.
The resources evaluation is necessary in order to establish the spatial distribution and temporal availability patterns over different periods of a given resource.

Moreover, the assessment provides information about the cost of resources harnessing, in particular as regards biomass and hydro. Moreover, within this step further information may be obtained such as proximity to users, ease of access to the resources, and adequacy of the resources given the current and future demand for energy.
Several approaches and methods exist, depending on the resource, context, and cost-benefit ratio such as the following ones:

- International GIS databases
- National GIS databases
- Data from local meteorological or airport stations
- Data collection on the field

In general terms, the best approach for the evaluation of local resources and their availability, consists in direct observations and field data measurements and collection. Thanks to the existing meteorological or airport stations and eventually by installing direct measurement instruments, of course it is possible to collect reliable and accurate data of a study area. Nevertheless, not only such direct collection methods can be both costly and time consuming but also the extrapolation of these data is not always straightforward. In fact, when dealing with local available energy sources (typically renewables) sometimes metering stations are often unavailable or weather conditions do not allow practitioners to carry out measurements; in other context the installation of measurement devices and consequently data collection and elaboration request an excessively long period of time for the purpose of the intervention while it is not actually feasible.

On the other hand, international and national GIS databases allow easy access to datasets, which however can result in different levels of accuracy. In particular, solar radiation databases provide quite accurate information in every area of the world, while data as regards wind, hydro and biomass should be carefully verified.

In the following sub-paragraphs, the resources assessment methodologies have been reported focusing on renewables organized according to each different energy source.

The *TOOLS BOX – Diagnosis* which summarizes any mentioned and usable database or manual – and the related consultable direct links – referred to the whole range of energy sources, can be found at the end of the chapter.

Solar Potential

Solar energy is so far the most diffused and adopted renewable source. The assessment of solar resource provides the means to accurately determine the availability of solar radiation resources for developing, deploying, and operating cost-effective solar energy technologies.

The producibility of any given solar power system depends on the amount of solar radiation reaching the absorbent surface of the plant itself, be it a solar panel or a solar collector. Solar radiation measurements as well as other meteorological parameters such as ambient temperature and relative humidity have to be taken into account in order to evaluate the solar power potential of a certain area during a given period of time.

Since insolation is the most influential parameter to forecast the power output of a future solar plant, in case of direct measurements:

- Direct Normal Irradiation (DNI) can be measured by a pyrheliometer on a sun-following tracker;
- Global Horizontal Irradiation (GHI) can be measured by pyranometer with a horizontal sensor;
- Global Tilted Irradiation (GTI) can be measured by pyranometer installed tilted as solar panel;
- Diffuse Horizontal Irradiation (DHI) can be measured by a shaded pyranometer under a tracking ball.

But as already stated, the evaluation of the available solar irradiance may be carried out consulting on-line available databases which allow give a reliable record of long-term solar resource intensity and variability. Differently from data usually recorded for the other renewable sources (wind, hydro, biomass), the international and national solar GIS databases allow access to datasets which provide quite accurate information of solar radiation in every area of the world so that it is not always necessary to integrated further on-site observation analysis by means of weather modelling and forecasting of PV systems operation (radiometers).

Most commonly solar radiation values databases are:

- Global Solar Atlas;
- PVGIS;
- Irena Global Atlas;
- RETScreen from NASA

Wind Power Potential

Wind power turbines generate electricity from wind energy. Since the general formula for wind power in given by:

$$P = \frac{\rho * A * v^3}{2}$$

where:

- ρ density of air;
- A area of swept
- v speed of wind,

for what concern wind resource assessment, beyond the consultation of the information provided from the on-line available databases, the wind speed measurements play vital role as input parameter, which is initial step for the verification of modelling predictions of wind resources.

Wind speed fluctuates, which has an impact on wind electricity generation capacity and operating characteristics. In general, wind speeds are as follows [38]:

- 8 kph (2 m/s) minimum is required to start rotating most small wind turbines.
- 12.6 kph (3.5 m/s) is the typical cut-in speed, when a small turbine starts generating power.
- 36–54 kph (10–15 m/s) produces maximum generation power.
- At 90 kph (25 m/s) maximum, the turbine is stopped or braked (cut-out speed).

The speed of the wind is constantly changing. This is due to various factors such as land topography, the altitude, and nearby trees, all of which influence the turbulence of the wind and therefore its speed. An area with trees or buildings will produce more turbulence than a smooth surface such as a lake. Trees and buildings disturb the flow of the wind reducing the energy that can be captured by a turbine. An increased level of turbulence causes wind speed to become more changeable from second to second. As well as wind speed changing constantly wind patterns vary on daily and seasonal bases. There is a wide range of measurement equipment that can be used to record information of wind speed in a specific area. Some instruments are used with data loggers that record wind speeds over long periods of time.

The most commonly used measuring device is the cup anemometer, although other methods include:

- Propeller anemometers
- Drag devices - ERA gust anemometers
- Air pressure devices – pilot tubes
- Sonic devices – speed of sound in air
- Doppler devices – laser and sonar
- Calibrated kites
- Tatter flags
- Trees and other plants

Due to possible variations of average speed along the year, data should be collected during significant periods of time (ideally for a period of one year).
However, many available wind manuals, databases are:

- Irena Global Atlas;
- National Renewable Energy Laboratory online available database;
- Wind Global Atlas.

Hydropower potential

Hydro power is power derived from the energy of falling or running water, such as rivers. Micro and pico-hydro turbines are small-scale devices devoted to the production of energy. They do not cause as much impact to the surrounding ecosystems and landscape as larger hydro developments, but can provide electricity to people for domestic use such as lighting and can also improve income through greater business activity.
Since the resource is site specific and it is affected by seasonal variability , for hydro power design it is very important to have flow data over as many years as possible to be sure how much water (in rainy and dry season) is available to run a turbine. The exploitable potential in this case is given by the combination of the flow rate and the height of water fall (head), according to:

$$P = Q * H * g$$

Where:

- P exploitable hydro potential [W]
- Q minimum available flow [l]
- H head, difference in height [m]
- g gravitational acceleration [m/s2]

Also in case of hydro resource, useful data are provided by national and international databases such as:

- InfoHydro, a database provided by the World Meteorological Organization;
- SmallHydroWorld, proposed by UNIDO;
- ECOWAS providing a database mapping hydro resources in West Africa.

Otherwise, when online information are not available, onsite observations and measurements should be carried out.

The flow measurements have to be taken every day during one full year and, depending on the size of the river or stream there are different method to measure the flow [21]:

1) *Bucket method*: the method, which is suggested only in case of small water flow until 20 l/s, consist in measuring the time the water flow takes to fill the volume of a big tank with drain plug at the bottom and dividing the volume of the tank by the filling time.

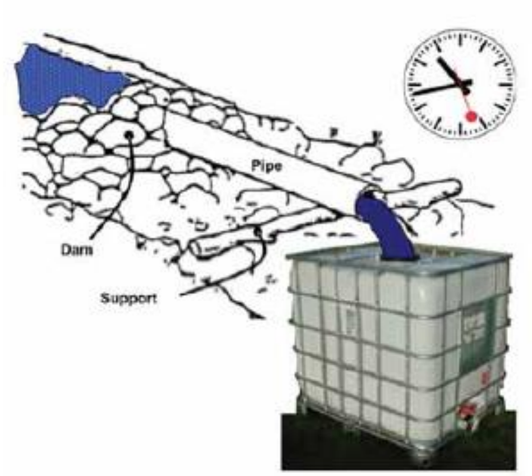


Figure 7- Illustrative Example of Bucket Method Measurement. Source: [21]

2) *Float method*: it consists in measuring the flow velocity of the stream cross-section. For a known length of a stream, an average cross section should be available, where a half filled plastic bottle of water has to be timed over a measured length. By multiplying cross section area with average flow velocity, an estimation of flow rate can be made.

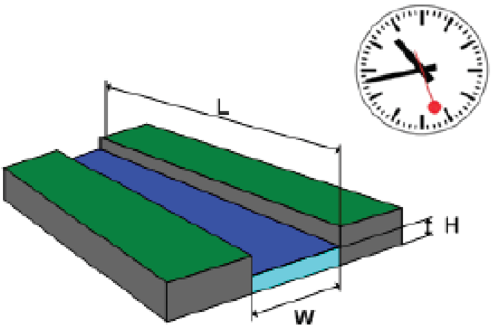


Figure 8 - Illustrative Example of Float Method Measurement. Source: [21]

3) *Current meter method (Velocity-area method):* the method, which is suitable for flow velocity ranging from 0.2 - 0.5 m/s, consists in measuring the cross-sectional area of the river and average velocity of the flow. The velocity can be measured at different depths and at any point of the river's cross section by a current meter. After averaging the values of the collected data, they can be used to calculate the actual flow.
4) *Weir method*: it measures the difference on the level between the surface of the water upstream and the bottom of the dam. The method provides for not easy installation which need a lot of skill and experience so that the measure can be carried out only by a trained person with proper equipment.

Instead, for what concerns data about the value of the head, it can be evaluated by means of the following measurement method:

- By level
- By water level
- By pressure gauge (a plastic hose is needed): calibrate the gauge scale, check size and length of the hose (water-filled hose must be carried around the entire length from intake to tailrace) and record all data
- By barometer/altimeter, short time evaluation during stable weather conditions, only for the first quick measurement

- By level instruments

Biomass Potential

Biofuels and biomass are energy products derived from organic sources such as wood, crops, and crop residues. These can be made into solid, liquid or gas fuels. Such organic fuel sources are easier to obtain for those living in poor rural areas. However, they are non-renewable sources of energy so come with drawbacks such as deforestation and health effects of burning.

In the humanitarian context, most of the population rely on traditional biomass as first source of energy. The purpose of an assessment is to identify resource potential within a given area for a particular end use. The level of detail also varies between biomass resources assessments. High-level, aggregated information - such as assessments at national, regional, and state/province level - are usually required by policy makers, whereas more detailed information at a county/district or site-specific level is required by energy planners and project developers. The purpose of a biomass resource assessment and the required level of detail should dictate the method for assessing resources. The current evaluation methods include geospatial technologies (geographic information systems and remote sensing), field surveys, and modelling (linear, statistical, geospatial, etc.). These products can be presented in a different format: tabular, graphic (charts or graphs), geographic (maps), or as analytical tools and software products. The most common and useful tools for the assessment of biomass resource are collected in the *Bioenergy Assessment Toolkit* proposed by the National Renewable Energy Laboratory [22], which also includes:

- FAOSTAT, which provides time-series and cross-sectional data related to food and agriculture for some 200 countries;
- The BioEnergy Atlas which includes two interactive maps, BioPower and BioFuels. These interactive geospatial applications allow users to view biomass resources, infrastructure, and other relevant information, as well as query the data and conduct initial screening analyses.

In addition, FAO also developed the very useful *Safe Access to Fuel and Energy (SAFE) toolbox* [12] by means of an excel tool to support field actors and researchers, which combines the assessment of biomass (woodfuel) resources and the assessment of energy needs for cooking in displaced settings. The tool is supplied with a user guide consisting in a step-by-step procedure where the user interface is organized as a sequence of Excel worksheets for data input.

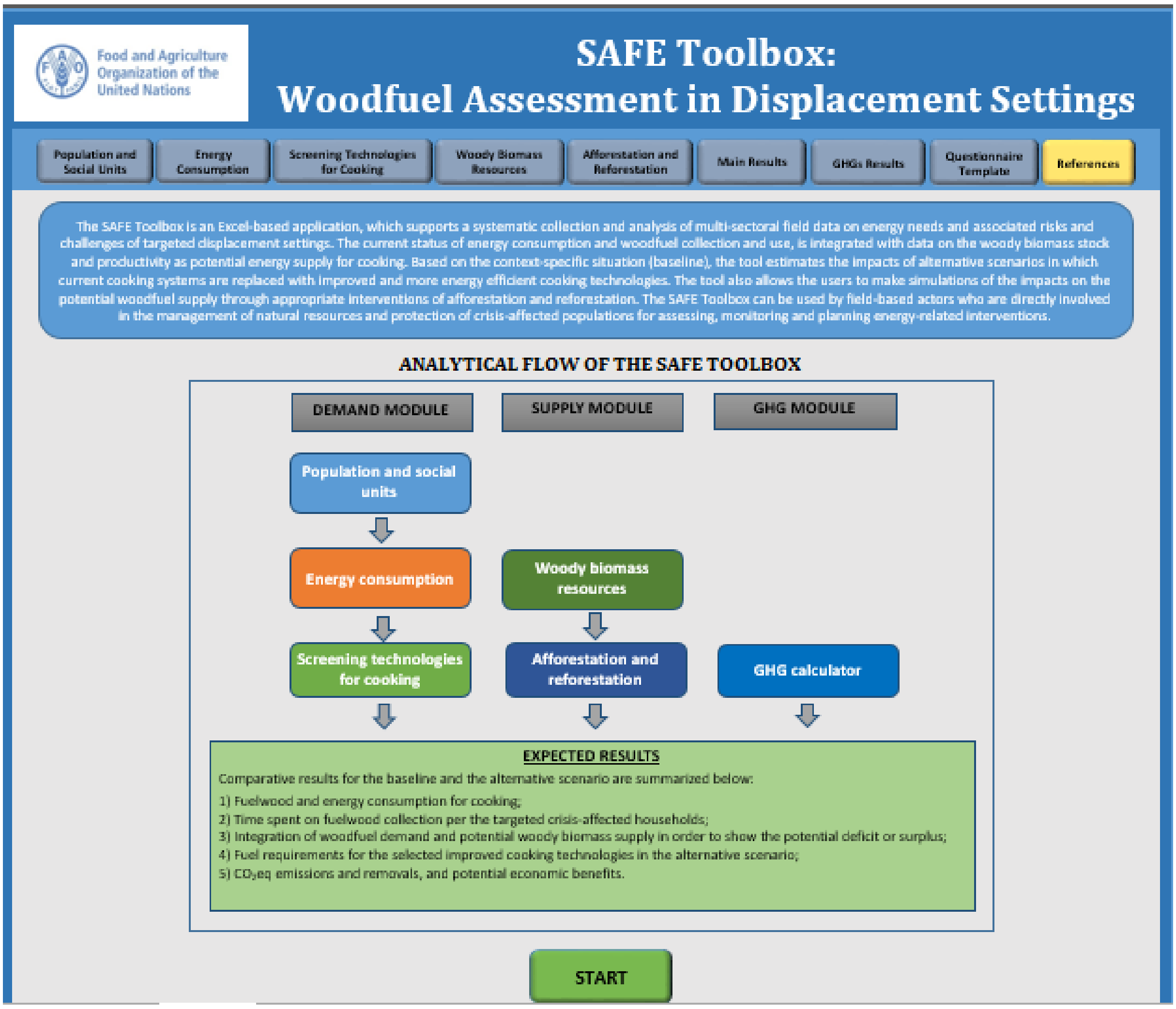


Figure 9 - Analytical Flow of the SAFE Toolbox. Source: SAFE Toolbox

The figure above shows the layout of the analytical flow of the toolbox. In detail, the structure can be summarized as follows:

1) Definition of population and social units of the targeted displacement setting;
2) Assessing energy consumption at the baseline;
3) Screening technologies for cooking at the baseline and alternative scenario(s);
4) Woody biomass resources at the baseline (stocks and productivity);

5) Afforestation and reforestation interventions in the alternative scenario(s);
6) Comparative results for the baseline and alternative scenario(s);
7) Estimation of GHG emissions and removals;
8) Questionnaire template to collect data through interviews and focus group discussions.

The user can launch the tool once the Start button has been clicked. Thanks to the provided tutorial contained in the guide and available in the *TOOLS BOX - Diagnosis* in the end of the chapter, the user can carry out each stage of the already mentioned procedure.

TOOLS BOX – Diagnosis

Solar Potential

- http://globalsolaratlas.info/
- https://eosweb.larc.nasa.gov/sse/RETScreen/
- PVGIS
- IRENA Global Atlas (Wind and Sun)

Wind Power Potential

- IRENA Global Atlas (Wind and Sun)
- https://www.adb.org/sites/default/files/publication/42032/guidelines-wind-resource-assessment.pdf
- http://www.wasp.dk/wasp#details__wind-resource-mapping
- WindPro
- https://www.nrel.gov/rredc/wind_resource.html
- https://globalwindatlas.info/

Hydropower Potential

- http://www.smallhydroworld.org
- http://www.ecowrex.org/smallhydro

Biomass Potential

- *SAFE toolbox* http://www.fao.org/3/a-bo563e.pdf
- FAOSTAT http://faostat.fao.org/site/291/default.aspx
- Bioenergy Atlas http://maps.nrel.gov/bioenergyatlas/

3.3 Strategy

Once essential needs have been assessed in the first *Priorities* section and energy demand and load profile have been identified during the *Diagnosis* phase, in addition to the local available energy resources and capabilities evaluation, all the initial phases of the framework have been completed: now all the information are available in order to proceed with the definition of a proper planning strategy.

The following *Strategy* step is the crucial and essential section of the whole procedure. The output data extrapolated from the *Diagnosis* phase have to be translated into useful inputs for the following part, with the aim of identifying the most viable and appropriate energy solutions for any given area or situation.

First of all, in order to the easily define any possible and adoptable scenario of energy intervention, a two-dimension scenarios classification scheme has been developed: it shows by energy source, how to identify different available technologies according to the size/scale of the desired plant to be installed. In this way, it is possible to have an understanding about the whole range of eligible technology solutions.

The *Strategy* scheme has been tailored taking into account both the already mentioned energy uses categories (i.e. energy for households, energy for community services, energy for productive uses) and the off-grid small-scale generation systems classification.

In rural electrification context, electricity main-grid connection in rural areas is generally limited to those towns and villages along major roads or near cities. When it is available, often only in high-income households, a few SMEs and community services can afford connections, since electricity may cost as much as 10 times more than in urban areas [38]. Off-grid small-scale electricity generation represents one of the most appropriate options to face this issue, both as a first step in the electrification process or as a building-block for future grid development [37].

In this framework, Mandelli et al [31] have proposed a comprehensive taxonomy resulting in the Off-Grid Matrix systems structure shown in Figure 12. According to the scientific literature, off-grid small-scale electricity generation systems can be divided in:

- *Decentralized systems* which are composed by autonomous units where conversion and distribution have no interaction with other units. Such systems are locally-based and need-oriented: they are usually tailored to specific local energy needs and they often rely only on local energy sources (i.e.renewables). This concept includes systems which supply electricity to nearby single consumers or a number of consumers. Using the consumer number category this leads to distinguish between stand-alone systems and micro-grid systems.

- *Distributed systems* which are made by more than one decentralized conversion unit which are connected and interact each other through a distribution grid. This results in a virtual power plant consisting of several generation points and equipped with a central brain for centralized control, that receives data about the operational status of the system and determines how to manage it. It is possible to refer to these systems as hybrid micro-grids. Hybrid micro-grids embrace several conversion units which can rely on several different energy sources and which supply electricity to single of several consumers, comprising the latter even different energy consumer typologies. It is worth noting that in this classification micro-grids are different from hybrid micro-grids since the former are not constitute by more than one conversion unit and they rely on one single source.

Table 7 - Off-Grid Systems Matrix. Author's adaptation from Source [27]

OFF-GRID SYSTEMS MATRIX

	Decentralized		**Distributed**
Rural Energy Uses	Stand-Alone Systems	Micro-Grid Systems	Hybrid Micro-Grid Systems
Household Basic Needs	Home-Based Systems	Systems including a distribution grid	Systems including a distribution grid
Community Services	Community-Based Systems		
Productive Uses	Productive-Based Systems		
Consumer Number	Single	Multiple	Single OR Multiple
Energy Sources	Single	Single	Multiple

Taking into account the above presented approach (which has intended to be applied when treating electric loads) and the already introduced context, for the purpose of this work, the *Strategy* scheme has been then tailored.

In detail, the scheme follows the already introduced classification treating the technologies which contribute to the definition of the electric load separately to those concerning the thermal load.
The columns report the generation systems at size/scale level organized considering the available technologies as follow:

- for the electric loads, which includes lighting, pumping, refrigeration and other electric appliances, the classification includes off-grid small-scale stand-alone solutions, mini-grid installations and, when possible, grid extension configurations;
- for the thermal loads, which involve cooking and heating solutions, the classification considers the technologies from a household vs community/institutions point of view.

While the rows report energy sources include from RET solutions as solar, wind and hydro power systems, to hybrid solutions (e.g. RET + diesel) in addition to liquid/gaseous fuels and traditional biomass.
In this way, once the availability of the local energy resources has been evaluated, it is easy to identify all the related energy systems which are in turn divided on the base of their application scale.
The choice has fallen on such a configuration in order to rapidly recognize which technology may be more accurate for any examined context: for example, when considering a particular location where is not suggested to adopt wind power systems due to the scarcity of the resource, all the related solutions may be eliminated from the strategy planning in order to narrow down the selection.

Table 8 - Strategy Scheme: Electric Load. Source: Author

	ELECTRIC LOAD											
	Lighting			**Pumping (Water Supply/Distribution)**			**Refrigeration**			**Electricity for Other Appliances**		
	Stand Alone	Mini-Grid	On-Grid	Stand Alone	Mini-Grid	On-Grid	Stand Alone	Mini-Grid	On-Grid	Stand Alone	Mini-Grid	On-Grid
Solar	SPL PPS SHS	SRS	Rooftop PV Solar Power Telecom Towers	PV water pumping	PV water pumping Centralized PV	PV - Grid Extension	Solarchillers			SPL (with phone charging outlet) PPS SHS	SRS	Rooftop PV Solar Power Telecom Towers
								Centralized PV				
Wind	WHS	WCS SWT	Wind Power Plant		WEPS Mechanical Wind Pumps	Wind Power Plant					WCS SWT	Wind Power Plant
Hydro		MGHS MHS	SHP				SHP				MGHS MHS	SHP
Hybrid	RET + Diesel		Diesel+PV Diesel+Hydro Grid connected Wind-Diesel	RET + Diesel		PV+Wind				RET+Diesel		Diesel+PV Diesel+Hydro Grid connected Wind-Diesel
Liquid/Gas Fuels	Diesel Generator			Engine Pumps			Diesel Generator			Diesel Generator		
Biomass (Firewood)												

Table 9 - Strategy Scheme: Thermal Load. Source: Author

THERMAL LOADS

	Heating		**Cooking**	
	Household	Community/Istitutional	Household	Community/Istitutional
Solar	Solar Water Heater		Solarcookers	
	Electric Heaters		Electric Stoves	
Wind	Electric Heaters		Electric Stoves	
Hydro	Electric Heaters		Electric Stoves	
Hybrid	Electric Heaters		Electric Stoves	
Liquid/Gas Fuels		Indirect Oil Heaters	Gas Modern Fuel Stoves	
Biomass (Firewood)			Istitutional Cooking Stoves	

3.3.1 Electric Loads

Focusing on the electrification, lighting, pumping, refrigeration and other appliances must be included as energy uses. The strategy scheme suggests for each energy source a distinction between the top-down, on-grid approach, i.e. grid extension, the bottom-up, off-grid approach, i.e. the development of new systems not interconnected to the main grid, and a combination of both top-down and bottom-up. More in detail, bottom-up electrification strategies are based on distributed (hybrid mini-Grids) and/or decentralized systems (stand-alone and mini-grid systems). Grid extension is recommendable only where costs are reasonable, while micro-grids in villages where the expenditure for the grid extension is too high, and stand-alone systems in scarcely populated areas with weak demand [31].

Lighting

For what concern lighting technologies, a wide range of solutions can be adopted. At household level, in the humanitarian context, individual needs have to be firstly met. The simplest available lighting systems are the free-of-charge/delivered items, such as solar lamps, lanterns or dry cell battery torches, which are mainly adopted in case of emergency and provided by external humanitarian organizations. They are not only considered as the most rapid and cost-effective energy response, but their utilization also reduces the hazard caused by kerosene lamps. While for the long-term intervention, in order to ensure a more reliable and sustainable energy supply, the small-scale technologies adopted consist in stand-alone renewable energy or hybrid systems at household level although diesel generator are still wrongly considered as the best solution, resulting instead in high fuel costs and environmental pollution.

At community and camp level, when grid extension is possible, then it is adopted, especially for street lighting, but national grid connection is not always a viable solution in refugees' context. This is due to their classification as temporary structures and also because, since there are usually based in remote locations, a grid connection would be extremely expensive. However, also at this level, solar power can be a very good option for bringing lighting by means of solar street light or PV systems. It is worth noting that in this way, these technologies provide long term fuel savings [32].

Pumping (Water Supply/Distribution)

*I*n order to meet refugees' water needs, various mechanisms and technologies can be employed for lifting water from the ground water sources such as wells and boreholes, rivers and springs. Preference is given to mechanism which can reduce risk of contamination and those which facilitate the extraction of adequate water quantities as per the population needs. In this way, manual systems such as hand pumps are used in many supply systems, even if they can serve only a restricted distribution system as the rate at which water can be pumped manually is low. When stronger water extraction is needed, powered pumping system are suggested. Solar water pumping systems have been often introduced in refugee camps and settlements. In some cases, solar power is enough to solely pump water, while in other operations, it has involved a combination of solar and fuel powered systems. Among powered pumping technology can be also included wind powered systems.

Refrigeration

For what concern this section, it has been taken principally into account the electricity need for refrigerators in community kitchens and clinic centres which are devoted to the conservation of food, vaccines and other medical or not items. At household level many food preservation techniques exist, also by means of particular devices, so that refrigeration can be not strictly included as essential basic needs.

Other Appliances

In this case, electricity use devoted for small appliances has to be considered. USB phone chargers, radio, TV and other electrical devices are included and their operation is usually viable by means of the same technologies adopted treated in the *Lighting* section in addition to electricity home systems.

3.3.2 Thermal Loads

Energy technologies devoted to cooking and heating purpose have been considered as thermal energy utilization.

Cooking

In this section cooking solutions options are suggested at household and institutional level. In the humanitarian context, as already stated, populations mainly rely on biomass including firewood, charcoal and kerosene which they used to adopt as the most common cookstoves' fuel. In order to purpose a more sustainable and cost-effective cooking solutions, according to the RET technologies, the scheme show the possibility of considering solar cookers and other improved cookstoves. The catalogue attached in the following *Design* section show all the existent cooking systems.

Heating

For what concern energy devoted to heating, it has been considered only hot water heating neglecting the space heating component. This choice is justified by the fact the space heating in such a context is not usually expected as one of the main essential need. Among the technologies, electric heaters have been individuated as the most suggested solutions mainly fuelled by renewable sources.

TOOLS BOX – Strategy

- *GIZ PV appliances for micro enterprises*
  https://collaboration.worldbank.org/servlet/JiveServlet/previewBody/20766-102-1-26833/GIZ%20(2016)%20Catalogue%20PV%20Appliances%20for%20Micro%20Enterprises_low.pdf
- *GIZ HERA Cooking Energy Compendium*
  https://energypedia.info/wiki/GIZ_HERA_Cooking_Energy_Compendium

3.4 Comprehensive Design

By means of the above-mentioned strategy scheme, it is possible to have an understanding of the most viable and appropriate energy solutions which might be adopted in order to achieve the best energy response.
The aim of the following *Comprehensive Design* section consists in providing a technology overview of each of the already identified solutions. This allows to finally identify the preferred scenario among all the suggested ones, basing the choice not only on both technical and economic point of view but also always considering it has to be geographically and socially suitable and adequate.

The section must be organized then as follow:

- General economic and technological presentation and assessment of all the suggested scenarios aiming at introducing a broad sizing of the energy solutions;
- Comparison of the proposals: new Sankey diagrams and load profiles are presented including load demand forecast or evaluation which allows optimal sizing of plant and battery associated to the new energy solutions;
- Selection of the most suitable and viable option, according to the already discussed criterion

This part of the guideline only contains an overview on the known and adoptable energy technologies.

While from a practical point of view, this must be intended as the stage in which a general energy demand has been estimated according to the needs related to the suggested scenarios so that new load profiles may be defined. It is possible to carry out the phase adopting again the tools above mentioned in the *Diagnosis*.
In this way, it will make easier the selection of the most suitable scenario.
In the *Comprehensive Design* section of the later presented case study, an example of practical application of the guideline can be found.

In general, for micro-grid and distributed generation power system design and optimization, the use of existing sizing software (e.g. HOMER Energy) is highly recommended.

Nonetheless, this section outlines various considerations concerning rough sizing guidance of the technologies.

3.4.1 Technologies overview

The following sub-sections are intended to provide a description of the layout and the main components of the proposed energy technologies, including a brief techno-economic feasibility analysis.
The energy technologies are organized and analysed by energy source as introduced in the *Strategy* classification scheme: they are firstly presented in general while later illustrated in detail at size and application level.

3.4.1.1 Solar Photovoltaic Systems

Photovoltaic (PV) solar technologies have been used for off-grid electrification for several decades. While the major share of the total global installed PV capacity is grid connected, off-grid PV systems have an important role to play in meeting energy access targets. Nowadays, several countries world-wide have some off-grid solar capacity installed or programmes in place to support solar off-grid applications. PV is a highly suitable and economical technology for addressing energy access challenges in developing and emerging economies, as well as remote and rural areas.

Any solar photovoltaic system includes different components that should be selected according to system type, site location and applications. The major components which it is composed by are:

- Photovoltaic module, which converts sunlight into DC electricity;
- Solar charge controller, necessary to regulates the voltage and current coming from the PV panels going to battery and prevents battery overcharging and prolongs the battery life;
- Inverter aiming at the conversion of DC output of PV panels into a clean AC current for AC appliances or fed back into grid line;
- Battery bank where energy is stored for supplying to electrical appliances when there is a demand;

- Load, consisting in all the electrical appliances that connected to solar PV system;
- Auxiliary energy sources, present in case of hybrid systems such as diesel generator or other renewable energy sources.

According to the technical configuration of the system, a first-step sizing of solar PV technologies' components can be conducted following these stages:

1) Rough estimation of the accumulation system
2) Power Output Estimation
3) PV Module Selection
4) Inverter Sizing
5) Solar Charge Controller Sizing

PPS (Pico Photovoltaic Systems)

A Pico Photovoltaic System is a PV system which may help in providing essential energy services for remote houses. It is defined as a small PV-system with a power output of 1 to 10Wp, mainly used for lighting and therefore able to replace unhealthy and inefficient sources such as kerosene lamps and candles. Depending on the model, small ICT applications (e.g. mobile phone charger, radio) can also be added.
PicoPV systems are powered by a small solar panel and use a battery which can be integrated in the lamp itself.

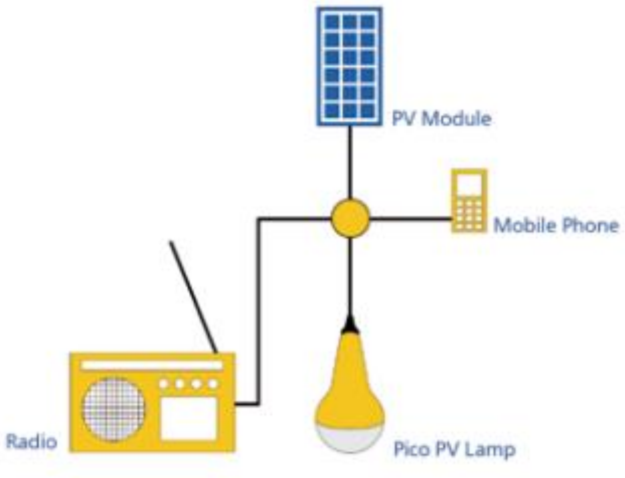


Figure 10 - Example PicoPV system. Source: [40]

PicoPV systems offer a wide range of advantages: easy installation (Plug & Play), user-friendly application, low investment costs, little maintenance required, high degree of expandability and flexible use. The prices are generally within the payment capacity of most rural people in developing countries.

SHS (Solar Home Systems)

Solar home systems (SHS) are stand-alone photovoltaic systems that offer a cost-effective mode of supplying amenity power for lighting and appliances to remote off-grid households. In rural areas, where there is no connection to the grid, SHS can be used to meet a household's energy demand fulfilling basic electric needs. Globally SHS provide power to hundreds of thousands of households in remote locations where electrification by the grid is not feasible. SHS usually operate at a rated voltage of 12 V direct current (DC) and provide power for low power DC appliances such as lights, radios and small TVs for about three to five hours a day [44]. Furthermore, they use appliances such as cables, switches, mounts, and structural parts and power conditioners / inverters, which change 12/ 24 V power to 240VAC power for larger appliances. SHS are best used with efficient appliances so as to limit the size of the array. A SHS typically includes one or more PV modules consisting of solar cells, a charge controller which distributes power and protects the batteries and appliances from damage and at least one battery to store energy for use when the sun is not shining.

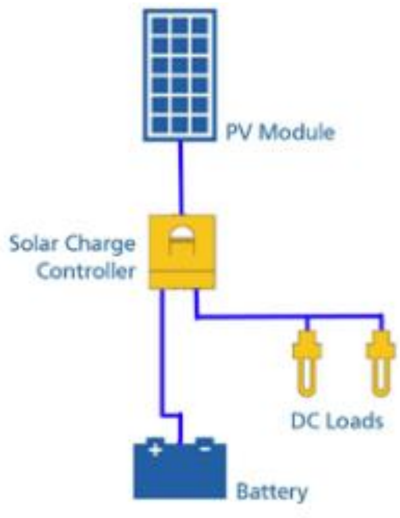


Figure 11 - Example of DC Solar Home System. Source: [40]

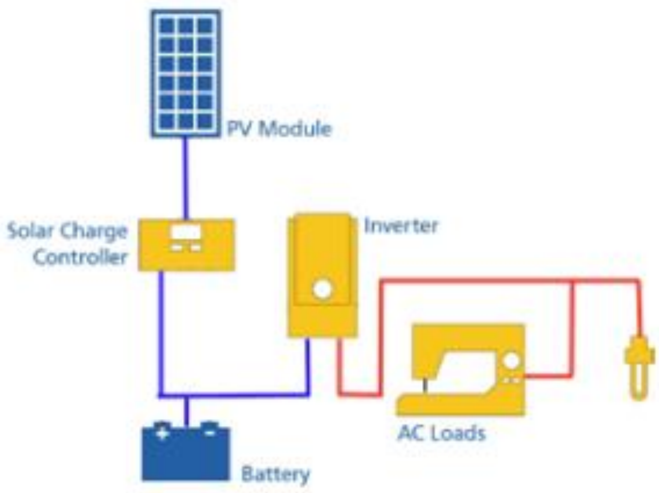


Figure 42 - Example of AC Solar Home System. Source: [40]

SRS (Solar Residential Systems)

Larger stand-alone PV systems called Solar Residential Systems (SRS) have also been installed in many different places around the world including developing countries.

Solar residential systems are usually able to provide electricity to large individual installations like hotels, hospitals, schools, factories etc. and offer a wide range of applicable loads.

For this reason, in the studied humanitarian context, this system typology could be considered in case of intervention at community level.

At the same time this type of systems are still relatively easy to operate and maintain. They generally include an inverter allowing the use of AC loads. The use of AC power has certain advantages, but th AC power (e.g. larger working instruments and machines). With a typical range from 500W to 4000W output power, SRS usually integrate 12V and 24V battery voltage, even if bigger systems work with higher voltage (48V).

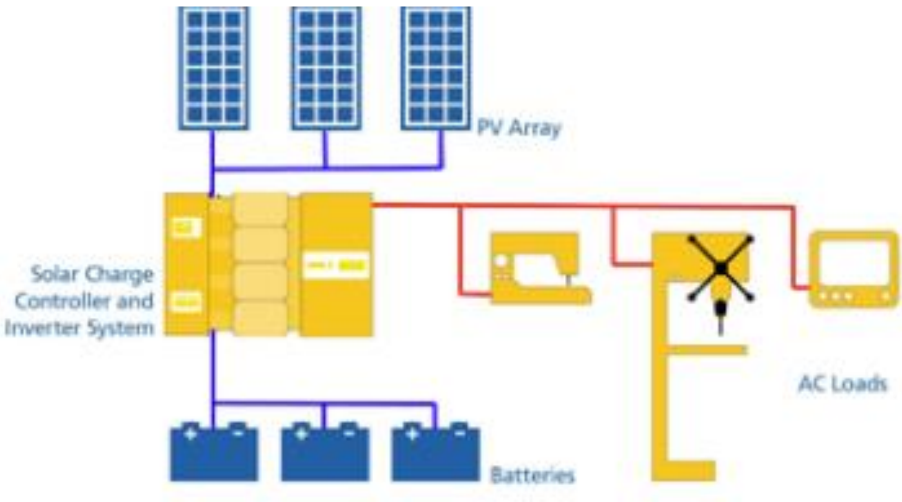


Figure 13 - Example of Residential Solar System. Source: [40]

3.4.1.2 Wind Systems

Developing countries can take advantage of wind power on a small scale, both for irrigation (wind pumps) and for generation of electricity (wind generators) for remote application. Therefore, according to different size and application it is possible to decide to choose different type of wind installations.

SWT (Small Wind Turbines)

Small wind turbines are turbines with a diameter of less than 15m and with a power output below 50kW. Most SWT however have a diameter of around 7m or less and a power output ranging between 1kW and 10kW. For very small installations for instance for a remote household, wind turbines below 2m diameter and with a 1kW output can be used [44].

WEPS (Wind Electric Pumping Systems)

Wind-electric pumping systems (WEPS) combine high reliability, low maintenance small wind turbines and "off-the-shelf" alternating current (AC) electric centrifugal pumps to provide a simple and robust remote water delivery system. In a WEPS system the 3-phase AC motor for a centrifugal electric water pump is directly powered by the variable voltage, variable frequency AC electrical output from the wind turbine's alternator. Unlike mechanical wind pumps, these new systems require no scheduled maintenance and can operate autonomously for periods of years between inspections. For areas with even modest wind resources (4 m/s or greater), WEPS can provide a cost-effective alternative to small diesel pumps for both drinking water and small plot irrigation.

3.4.1.3 Hydropower Systems

A hydroelectric power plant consists in civil and hydraulic works. According to the nominal power, hydropower systems could be divided in:

- Pico-hydro: power < 5 kWp
- Micro-hydro: power < 100 kWp
- Mini-hydro: power 100 kWp – 1 MWp
- Small-hydro: power 1 – 10 MWp
- Medium-hydro: power 10-100 MWp
- Large-hydro: power > 100 MWp

For what concern hydropower plant installed in remote rural areas, reference is mostly made to small-scale projects for understandable reasons of energy demand and grid connection.

The main components which can be recognized in each hydropower plant and whose sizing has to be taken into account are:

- Weir and intake
- Turbine
- Silt Basin
- Channels
- Penstock

According to the location, the context and the availability and potential of the hydric resource, different typology of hydro power plant can be proposed.

PHS (Pico Hydro Installations)

Pico hydro Systems are hydro power installation with a maximum electrical output of five kilowatts (5kW). Hydro power systems of this size benefit in terms of cost and simplicity from different approaches in the design, planning and installation than those which are applied to larger hydro power

3.4.1.4 Other Solar Technologies

Solar portable lamp

Single light source with or without mobile phone charging outlet; Entry level products with solar panels of 0.2 – 2 W; Price ranges from $10- to $40 (average $25) [44]. These typically consist of a complete in-build unit, comprising a battery, solar panel, wiring, power regulation and lighting bulbs or diodes, most often LED’s. These units are designed to be versatile and very tough to survive in remote and hostile conditions without requiring significant on-going maintenance.

Solar Water Pumping

Solar photovoltaic water pumping (SWP) uses energy from solar photovoltaic (PV) panels to power an electric water pump. Nowadays, the highest demand related to the technology is within rural off-grid areas, currently underserved, or served by costly fossil fuel-driven pumps. The potential applications include potable water supply for institutions (traditional market for

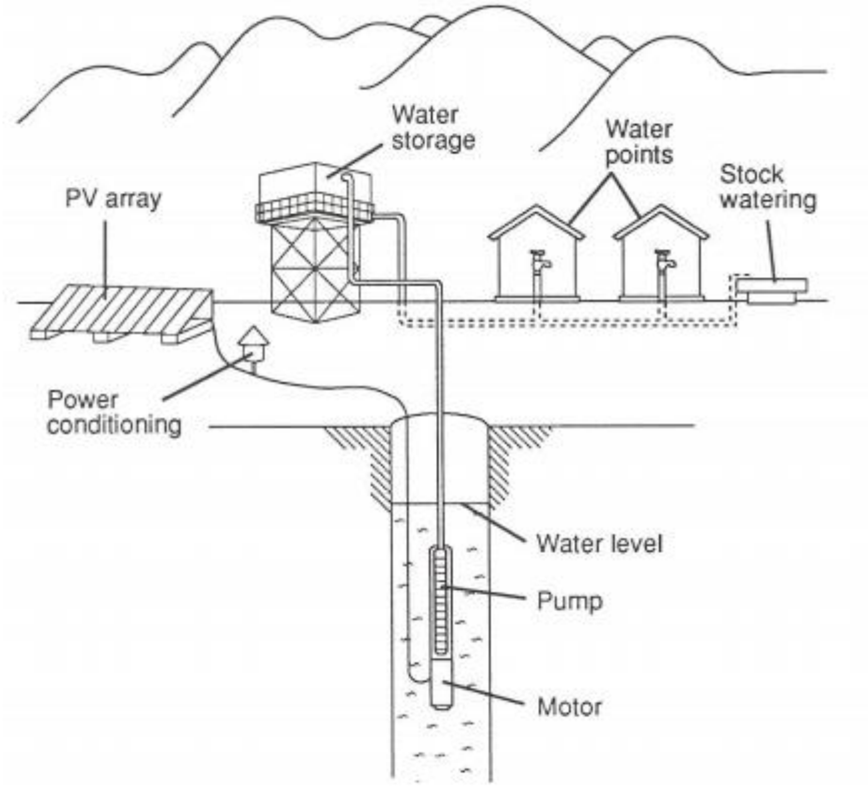


Figure 14 - Village Water Supply. Source: Practical Action

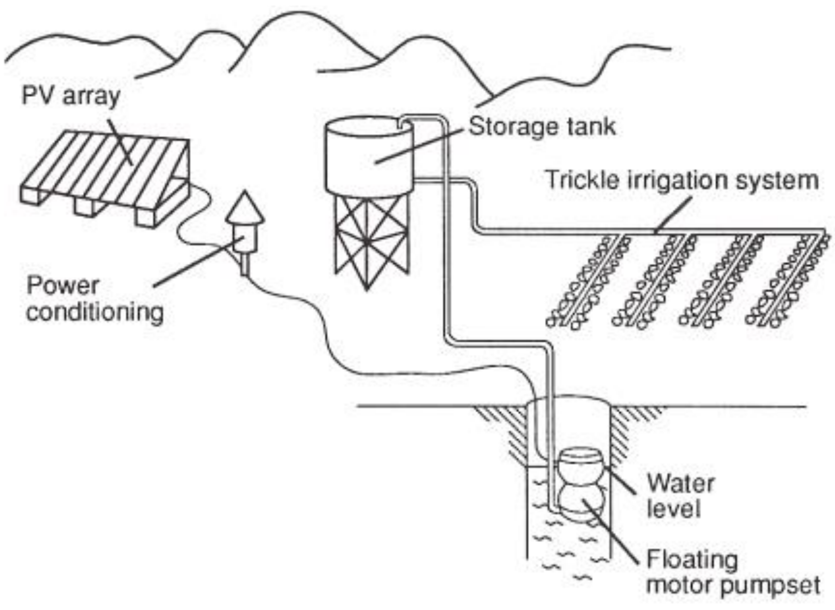


Figure 15 5– Solar Water Pumping. Source: Practical Action schools and health clinics), community-scale water supply schemes (larger village schemes), livestock water supply (individual or communal), small-scale irrigation (individual farmers or cooperatives).

Design of a solar PV water pumping system needs to follow the consideration given below [37]:

- Quantity of water requited on a daily basis
- Calculation of helpful hydropower
- Available solar energy
- The month with the minimum solar radiation
- Sizing of solar PV generator or PV array

Solar Water Heater

Solar thermal water heating systems consist of solar thermal collectors and a hot water storage tank. The solar panels collect and convert the heat from the sun into useable hot water that can be used for tap water preparation and/or space heating.

The water heating systems have both environmental and economic benefits. They use renewable energy to warm up water and they do not emit any pollution, contributing to a reduction in greenhouse gases emissions and the improvement of local air quality. Furthermore, SWH systems can reduce fuel consumption substantially.

SWH systems are fully mature technology and have been used for many decades to provide heat in household and industry. In most cases SWH will supply only a certain share of the required heat demand. A complementary heating system (usually a boiler) is therefore often installed to provide heat when the sun’s heat is not sufficient [45].

SWH is particularly applicable in rural homes and buildings, which often have more surface available for the installation of the solar collectors than those in urban areas.

3.4.1.5 Hybrid Technologies

A hybrid generation system is a system combing two (or more) energy sources, operated jointly, including (but not necessarily) a storage unit and connected to a local AC distribution network (minigrid). When power output (e.g. PV power output) is DC and minigrids operate in AC, the hybrid system need the multifunctional inverter devices able to convert DC and AC currents, control the generation and storage systems and set up the voltage and frequency of the minigrid [36].

PV/Diesel hybrid

The most typical hybrid generation system, consists in the configuration which include a PV component, a diesel genset and a battery bank, connected to a minigrid of various sizes. Taken separately both the technologies have their own limitations. In contrast to power supply systems using diesel gensets, and despite their higher initial cost, PV systems can be amortized in as little as four to five years, depending on the site and system size, and they have low operating costs. In addition, PV systems are flexible and can be expanded on a modular basis as the energy demand grows. Compared to pure gensets systems, a photovoltaic diesel hybrid system provides numerous advantages, i.e. lower fuel costs, reduced risk of fuel price increases and supply shortages thanks to optimized planning and minimal CO_2 emissions.

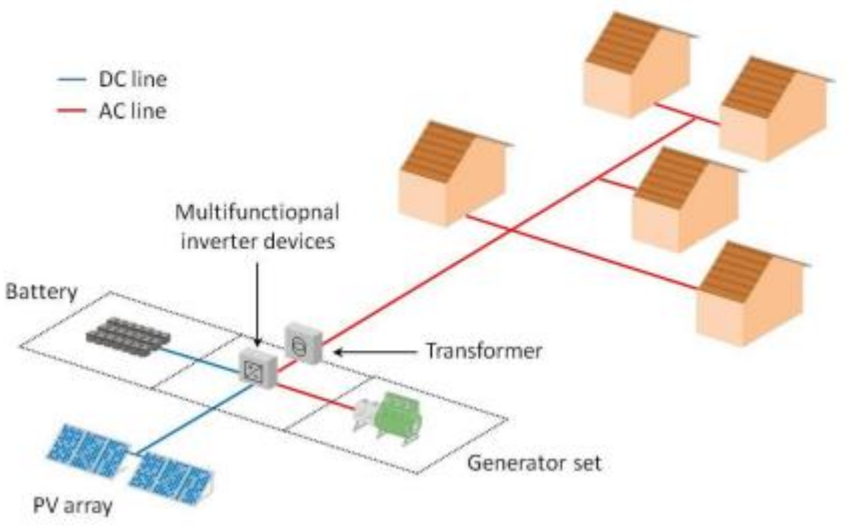


Figure 16 - Schematic view of a PV / diesel hybrid system for rural electrification. Source: [36]

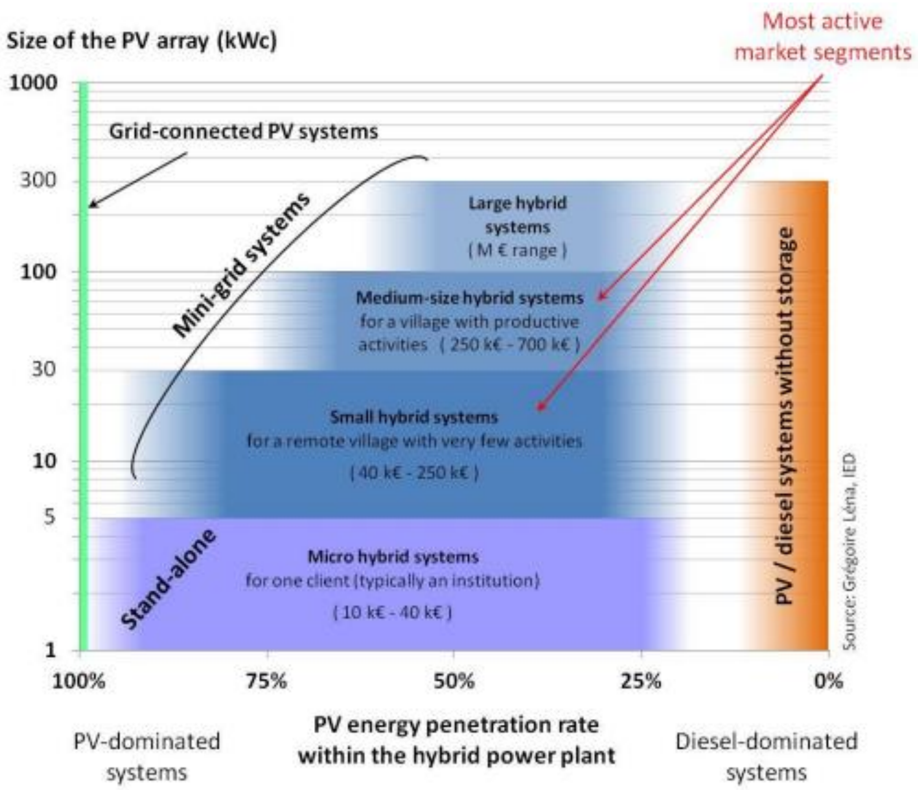


Figure 176 - Market segmentation for PV / diesel hybrid systems for rural electrification in developing countries. Source: [36]

3.4.1.6 Cooking Technologies

The variety of available cooking technologies reflects economic and sociocultural factors and energy requirements [46]. Within each category of stoves, there are a range of designs and performance.

In order to help the energy actors to select the appropriate device for a given context, this paragraph aims to introduce a classification of the existing types of cook-stove subdivided by the different fuels adopted. This criterion is reasonable since the selection of a suitable stove for a specific context mainly depends mainly on locally available fuels [34]. The most employed fuels and energy sources are:

- Wood and often residues, dung and other waste materials;
- Charcoal;
- Gaseous fuels, such as liquefied petroleum gas (LPG) and natural gas;
- Liquid fuels, such as kerosene (including paraffin), alcohols (such as ethanol and methanol) and biofuels;

- Solar energy;
- Electrical energy.

.

Here below, stoves are classified by fuel as already anticipated and then, in each category, stoves are subdivided according to their level of performance, from traditional to improved.

Wood

Since in developing countries, most of people still rely on traditional cooking practices exploting mainly firewood as fuel, the wood cookstoves are the most widespread ones. In order of increasing performance, the following technologies exist [46]:

- Three-stone Fire
- Traditional stove
- Improved Cook-Stoves
- Stoves with chimney or fan
- Gasifiers or wood-gas stoves
- Stoves with TEG modules

Charcoal

Traditional and improved stoves are available for using charcoal fuels. Generally, these technologies are similar to those using woofuel but in this kind of stoves heat transfer mechanism can occur in a smaller combustion chamber due to the higher heating value of the fuel.
Charcoal stoves performance evaluation does not take into account the charcoal-making process which is in turn highly pollutant [47]. Improving the efficiency of charcoal stoves can minimize these impacts. Burning charcoal tends to release a lot of carbon monoxide (CO), and some improved charcoal stoves are designed with the goal of reducing CO emissions. According to increasing performance order, it is possible to recognize:

- Traditional Charcoal Stoves
- Charcoal Improved Cook-Stoves
- Gasifiers

- Stoves with TEG modules

Liquid Fuels

Liquid fuelled stoves utilize kerosene (including paraffin), alcohols (ethanol and methanol), and biofuels, which are modern fuels. As a consequence, their thermal efficiency is generally high and pollutant missions level is very low even though the latter may be higher in case of oil from jatropha or in case of improper use of kerosene. For instance, there are hybrid stoves fuelled by kerosene and vegetable oil, paraffin and ethanol. However, these stoves are not adopted by the majority of people in developing countries due to the unavailability and the high cost of the fuels [47]. It is worth noting that an interesting option for developing countries is to use liquid fuels locally produced from agricultural residues.

Gaseous Fuels

Like liquid fuelled stoves, cooking devices fed with gaseous fuels present high performances, although sewage derived biogas stoves could generate significant pollutant emissions if not properly designed and utilized. Nowadays, even gaseous fuels are often not affordable and not available in developing countries' rural areas.

Solar Energy

Solar cookers are devices which utilize the energy from the sun to cook food; usually, they are not defined as stoves, since there is no combustion phase. A very wide range of solar cooker models exist, but most of them can be classified into three main categories [47]:

- Panel Cookers which can provide just a small amount of thermal power since it is generated simply by the sunlight concentration on the pot, which is eventually enclosed in a trasparent plastic bag;
- Box Cookers made up of an insulated box whose wals areusually black with the aim of maximizing the absorption with a glass cover. The mentioned structure is in turn rounded by reflective surfaces to direct subeams onto the pot;
- Parabolic Cookers which consisting in simple parabolic reflectors where the pot has to be located at the focus point in an adequate support system. This cooking technology is characterized by its excellent performance since it can rapidly reach high

temperature. At the same time, it can also lead to risks of scalds and of burning the food.

Electrical Energy

Electric stoves transform electrical energy into heat for cooking. Clearly, their use is confined to areas where electricity is available, preventing several communities from their adoption; particularly, rural areas are often excluded. Indeed, although these stoves are commonly employed in the developed world, they are scarcely diffused in developing countries.

Electric stoves do not produce any emissions, but electricity generation could do. However, since they have very high quality standards, they are considered modern cooking devices; consequently, their dissemination in developing countries should be fostered even if it depends on the availability of electricity.

TOOLS BOX – Comprehensive Design

- HOMER Energy www.homerenergy.com
- RETSCREEN www.retscreen.net
- Clean Energy Cooking http://cleancookstoves.org/technology-and-fuels/stoves/
- SET4Food DSS http://www.set4food.org/images/SET4food_DSS_handbook_ENG.pdf

3.5 Impact Evaluation

In this thesis work, the last CESP5 phase dealt with *Impact Evaluation* has not been treated in-depth as the previous steps of the procedure, nevertheless, the author undertakes to offer a brief description of it, providing the text with the already existent tools.

In general, impact evaluation phase consists in the assessment of the impact of an intervention on target beneficiaries or costumers after its implementation. Ideally, the evaluation should detect all the positive and negative long-term effects on identifiable population groups produced by a development intervention, directly or indirectly, intended or unintended. These effects can be economic, socio-cultural, institutional, environmental and technological. The importance of distinguish the impact assessment from more direct project results arises from the different methodological approaches that may be required. Impact should be detected in the long run and on a large scale, considering a number of relevant factors related to people and their development, which the project may affect. From this consideration, the need for a multidisciplinary and people-oriented approach emerges.

Recalling the objectives of CESP and indeed to present a planning process for energy access interventions in developing areas, the aim of this last phase of the planning process is limited to forecasting the expected impact that the intervention will have.

TOOLS BOX – Impact Evaluation

- *Measuring social impact in the clean and efficient cooking sector*
  http://cleancookstoves.org/resources/489.html
- *HERA Sustainability Assessment Framework*
  https://energypedia.info/wiki/File:HERA_Sustainability_Assessment_Framework_2014.pdf
- *Impact Evaluation Framework*

4 Case Study: Goudoubo Refugee Camp

In order to verify the usefulness of the developed manual, the planning process has been applied to a real case study.

Thanks to the collaboration with Practical Action NGO which has been studying the energy situation of refugee camps in the context of the so-called Moving Energy Initiative (MEI) projects, it has been possible to have access to essential data gathered in the Goudoubo refugee camp, situated in Burkina Faso, in the November of 2016. By means of field surveys, focus group discussions and other field evaluations presented to a sample of 129 households (about 10 per cent of camp population), the first *Priorities* phase can be carried out and successfully completed.

4.1 Priorities

Context and Demographics

Goudoubo Refugee Camp has been established in October 2012 to host refugees from camps located too close to the border. It is located 17 km north-west of Dori, capital of the Sahel Region in the central province but also far enough from the Malian border. Dori lies 270 km

Figure 187 - Localization of Goudoubo. Source: Open Street Map

north of Ouagadougou, capital of Burkina Faso.

An average of 30 Malian refugees continues to cross into Burkina Faso through Inabao and Markoye border points every month to arrive at Goudoubo.

The camp is one of the three permanent sites in the country (alongside Mentao and Saag-Nioniogo) and it currently hosts more than 10,000 refugees distributed in about 3000 households [29], more than 55 per cent of whom are below the age of 18, with a roughly even number of males and females.

According to the data gathered from the surveys, with an average number of 5 people per household, almost half of the population claims to have an occupation: most of them are engaged in keeping house or rising children all time, others work as volunteers for camp organizations or NGO, someone as daily/casual labourer, others study or are retired while only fews own a business or a rural or commercial activity. .

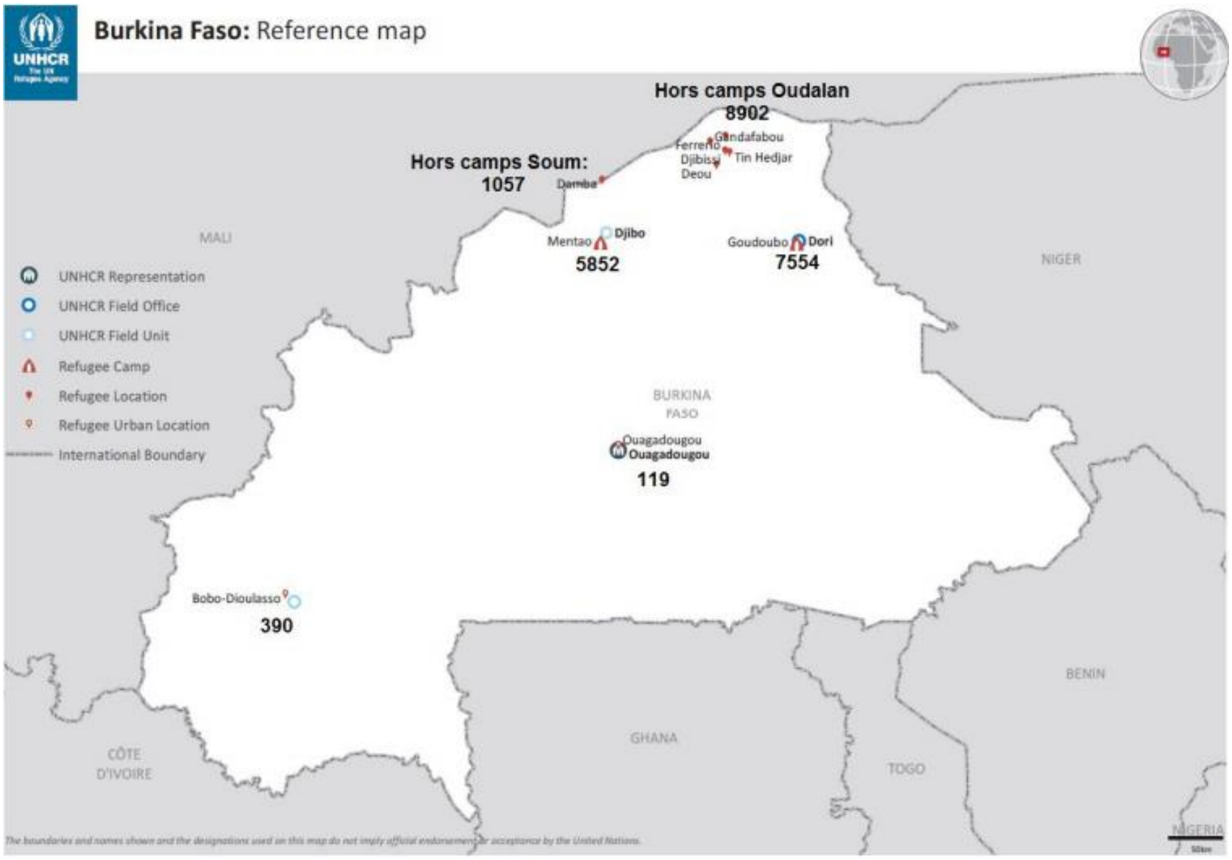


Figure 19 - Burkina Faso Displacement Map. Source: UNHCR

The camp has capacity for 21,000 refugees and it is organized in blocks, islets and lots and according to past reports, it is stated people used to live in UNHCR tents.

4.1.1 Household Level

After a brief background and general context assessment about Goudoubo camp situation, the survey aims to separately investigate, section by section, all the essential needs already introduced. When the access to energy is not guaranteed for meeting a particular need, the interviewer can directly shift to the groups of questions concerning the following need.

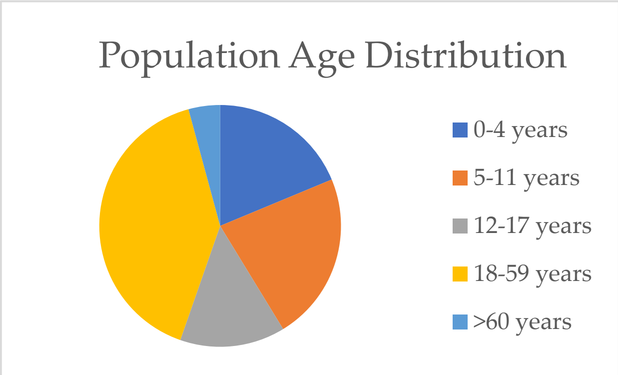


Figure 20 - Goudoubo Population Age Distribution

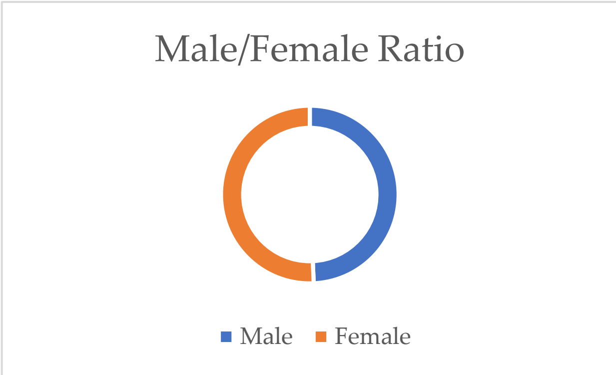


Figure 21 - Goudoubo Male/Female ratio

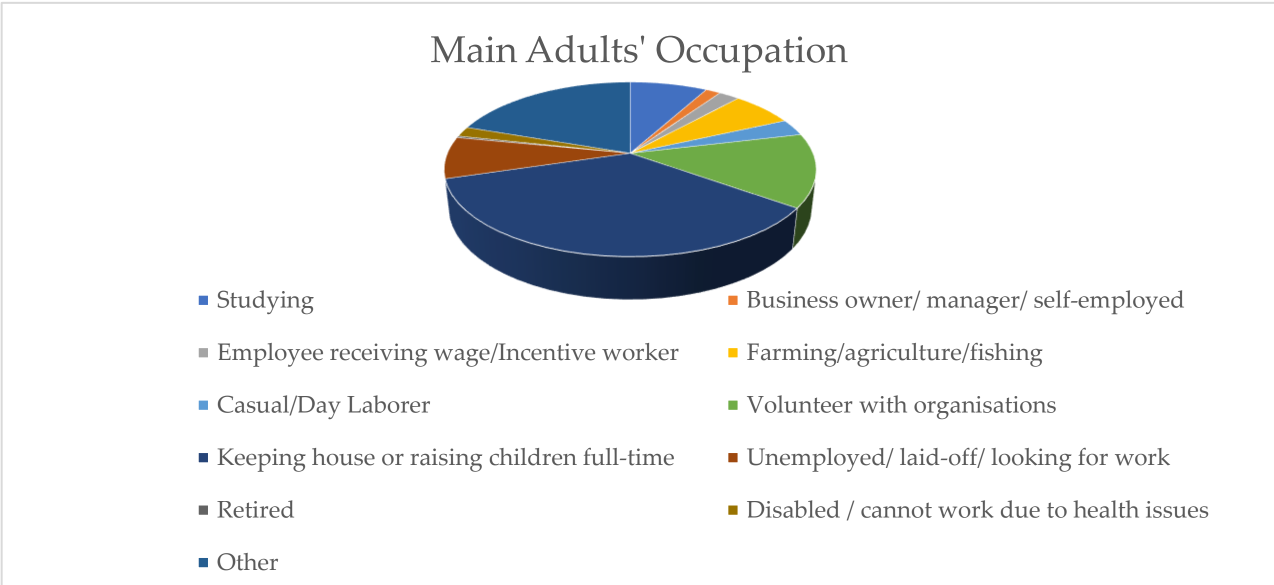


Figure 22 - Goudoubo main adults' occupation

Cooking

In Goudoubo camp, 35 per cent of refugees still rely on the three stone fire traditional cooking technology, but most of them adopted as main cookstove the local (fixed or portable) improved stoves. Woodfuel is currently the main cooking fuel with a utilization of almost 1000 kg monthly per household, considering both the amount collected, purchased or donated by humanitarian agencies. One-third of the population have access to a secondary cookstoves, usually fuelled by charcoal (resulting more than 30 kg purchased monthly per family), briquettes or by LPG. Only one family out of eight owns solar cookers as secondary cookstoves and they are the ones who received them by the camp institutions in order to test them. The respondents sustain the usefulness of the secondary cookstoves when finishing the fuel for the primary one or in case of particular weather conditions (e.g. very windy day). The major problems experienced during cooking appears to be related to weak combustion and smoke production. Cooking is done almost always by women and great part of the respondents state to prepare meals outdoors, spending an average period of 5 hours per day in cooking activities,

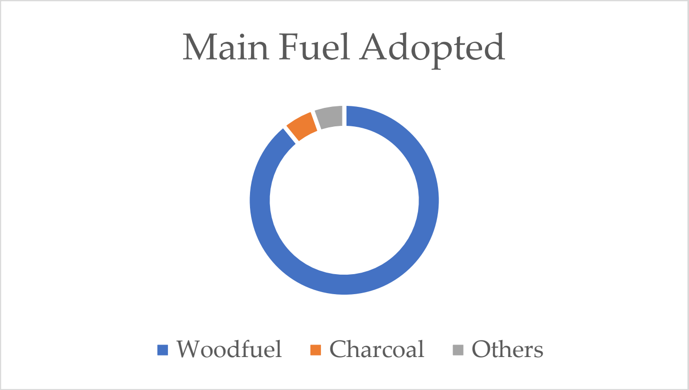


Figure 23 - Goudoubo Adopted Fuel Share

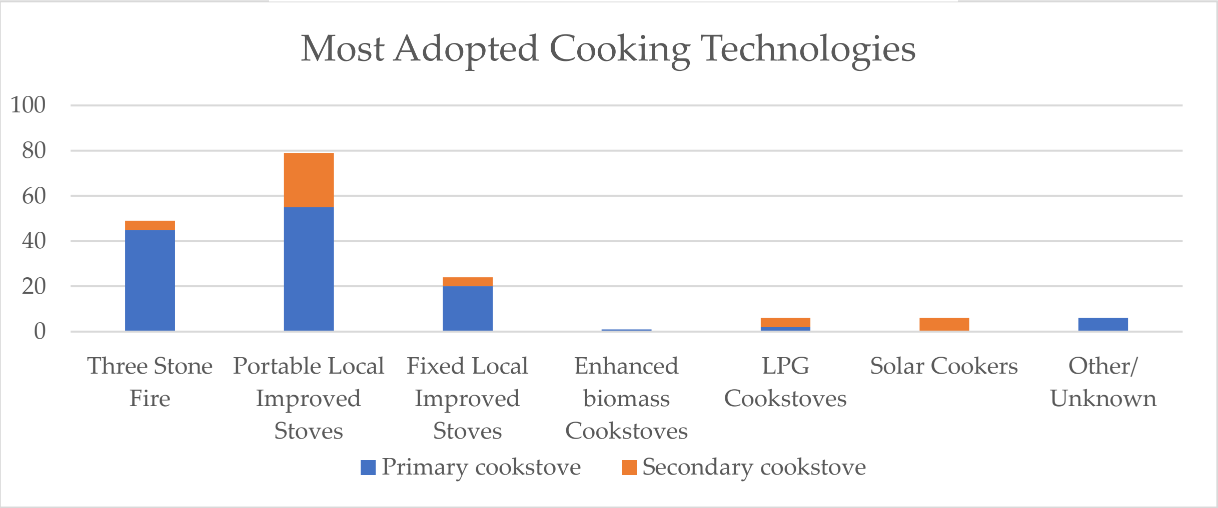


Figure 24 - Goudoubo Cooking Technologies

including boiling water, when they used to share space and eventually fuel and food.

Lighting

After cooking, as already stated, lighting is considered one of the most essential need in the humanitarian context. In particular, in Goudoubo refugee camp in question, the lighting situation is serious: in a typical month, 75 per cent of camp population use indirect lighting (e.g. street lights) as main lighting source while the remaining part of people make use of candles or solar lanterns. According to the largest part of respondents, having lights is fundamental in order to ensure safety and security as well as to do household chores or carry out night time tasks at home but they claim to have the possible to light their home only on average less than 4 hours after becoming dark outside.

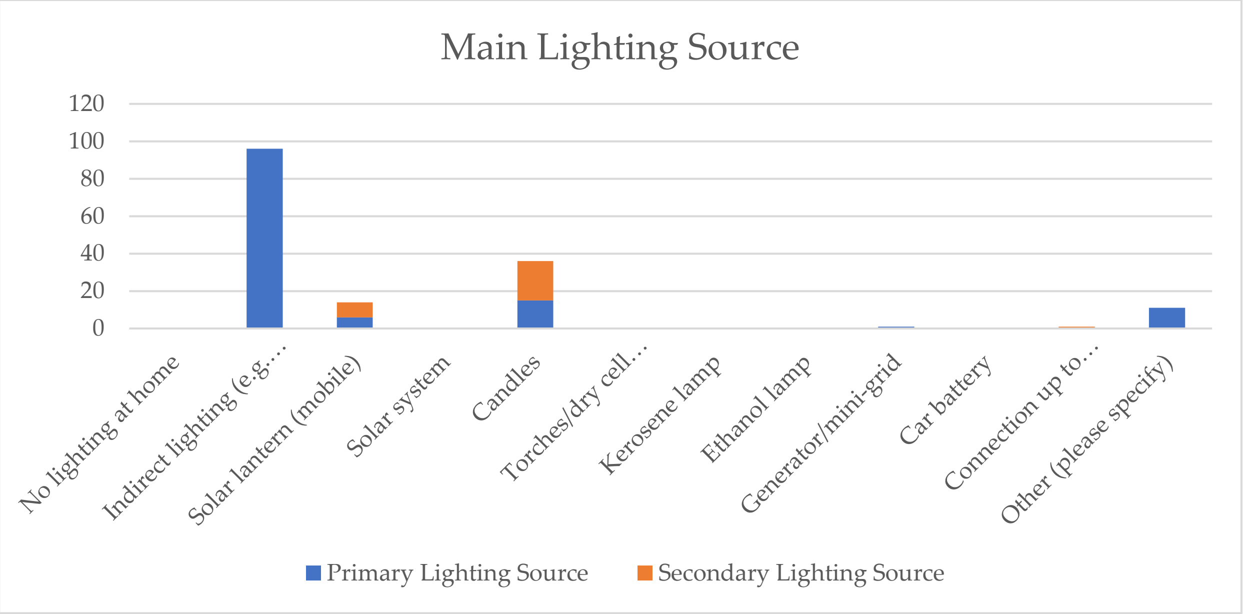


Figure 25 - Goudoubo Lighting Sources

Water Treatment and Supply

The survey presented by the interviewers seems not to contain a section with questions concerning water treatment and supply or any other information about WASH. Although, according to Corbyn and Vianello [30] and UNHCR 2013 report, it has known that in the north-western side of the camp fews latrines and showers are present thanks to the borehole well nearby. By means of water pipeline, it allows the population to have an access to water in correspondence of hand pump well and also tapstands randomly present around the camp.

Figure 26 - Hand pump well in Goudoubo. Source: UNHCR Drone Footage

Electricity for Small Appliances

In Goudoubo refugee camp, 5 per cent of population have no access to energy at all, neither the little amount needed for small appliances operations. For what concern the remaining part of refugees, 66 per cent of population rely on the utilization of solar lanterns, devices delivered (free of charge) to the household by the humanitarian agencies. They used to adopt them mainly as source of charging their phones (thanks to the provided USB port), which according to them is one of the most important small appliance they need. For the remaining part of the population, the most adopted technologies are dry-cell batteries or rechargeable batteries while the only 2 per cent of population own a small solar home system. In addition, most of respondents would like to have access to electricity for the operation of other basic home devices such as color TV, radio and eventually laptop or refrigerator.

4.1.2 Community Level

For what concern this section, interviewers presented a second survey to the refugees: it aims to gather information around energy use for the different types of community services like schools, clinics, vocational centres, camp offices, etc. active in the camp.

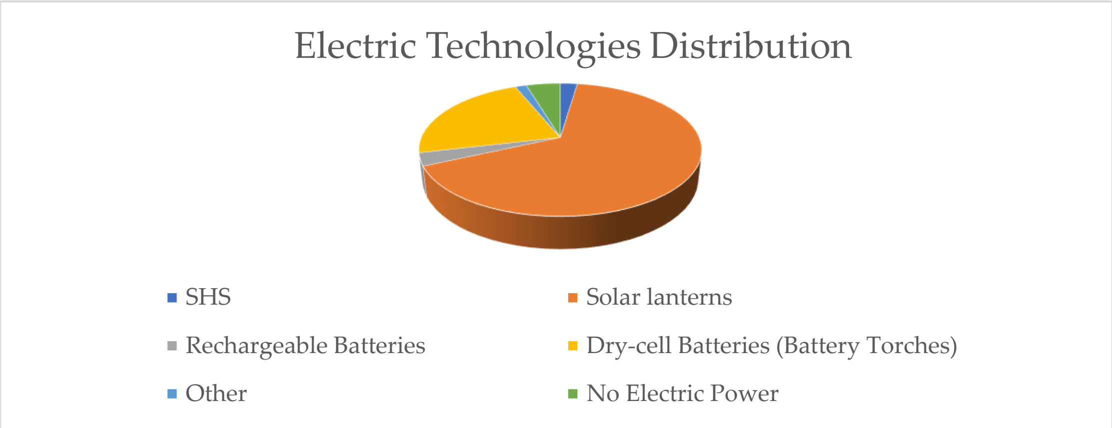


Figure 27 - Electric Technologies present in Goudoubo

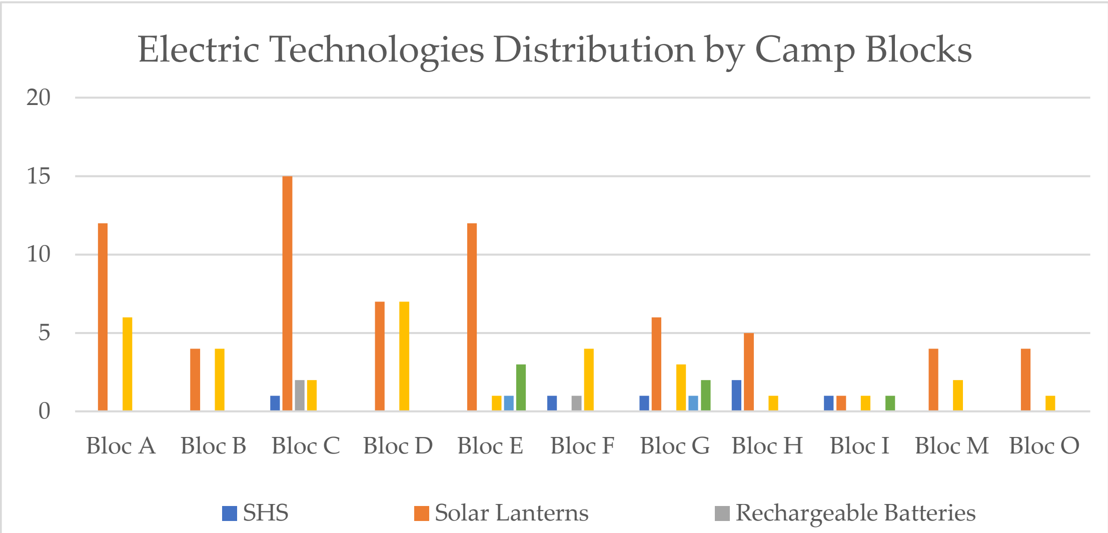


Figure 28 - Electric Technologies Distribution by Camp Blocks

Street Lighting

A great part of the whole sample of respondents reported the public lighting situation as not satisfactory. They claim the energy service devoted to street lights as one of the most essential in the camp: with a more adequate electricity supply for public lighting purpose, they could achieve safer living conditions, ensuring a greater security in the camp during the darkest hours after the sunset.

Although, from reports provided by Corbyn and Vianello [30], it has known that in 2016, 100 solar street lights (as shows in figure below) have been installed around the camp.

Figure 29 - Solar Street Lighting in Goudoubo Refugee Camp. Source: [30]

Health Centres (Clinics)

From the data gathered, in the sample interviewed in Goudoubo refugee camp, only one health centre is present. The building in which the clinic operates in is a 5-rooms UNHCR housing (non-tent), equipped with a total of 8 beds in order to provide hospitality to patients. With an average amount of 500 patients per week, the clinic should always guarantee its operations 12 months per year, 30 days per month and 24 hours per day but unfortunately it is daily prone to electricity interruptions which are not good for patients' safety and health.

In general the respondents state electricity supply is most of time available, in fact the centre currently can count on a roughly acceptable access to electricity provided by a 30 kW biofuel generator which allowed the operation of the essential device needed such as refrigerator for vaccines and medical items preservation, oxygen concentrator, blood chemistry analyser, dry heat sterilizer in addition to phone chargers, computer and ceiling fan. Also in this case, solar lanterns are adopted as main source of lighting and for ICT & Entertainment (including charging batteries) applications.

Education Centres (Schools)

From the data collected, among the community facilities one school and three education centres have been individuated (referring to the only interviewed sample). In general, both the typologies used to operate 5 days per week, 6 hours per day during the whole year but the access to energy is far from being satisfactory. The totality of the respondents claims to have no access to lighting because of inadequate or unavailable technology or energy and the only operating electrical appliances are solar lantern provided with built-in phone chargers. Only the school owns a solar stand-alone system devoted to the operation of ICT & Entertainment appliances – including charging batteries – but it is constantly subject to daily electricity interruption. In the structure only one room is provided by light, thanks to which teachers can prepare lessons at night [30].

Administration and other facilities

Of course, in refugee camps are always present facilities devoted to administration and camp management activities. In Goudoubo, according to the data gathered from the analysed sample, it is possible to recognize:

- One reception centre (gendarmerie) which operates during the whole year, 24 hours per day. It has a basic access to electricity, thanks to a diesel generator (8000 W), by means of which it is possible to provide energy to laptops used for the electronic submission of every refugee;
- Two community centres, one devoted to young refugees' formation, where they can learn tasks useful for mechanics and electronics practices and applications; the other consists in a religious centre;
- One structure devoted to the NGO or governmental institutions;
- Two camp security and operation centres.

In general, the respondents claim to have access to electricity for lighting and for ICT & entertainment, owning small appliances such as radios and TVs eventually provided by satellite dish.

4.1.3 Productive Level

A third survey has been presented to business owners, rural workers and other productive activities employers in the camp, in order to outline the general economic situation about energy use for the different types of enterprises and businesses active in Goudoubo.

Livelihood and rural activities

In this section, data about owners or employers of enterprises and facilities dealt with income generating activities have been collected. In general, in Goudoubo a low level of economic activity is reported. In the interviewed sample, most of the enterprises engaged in productive agricultural and livestock practices: they are carried out outdoors so that they do not use energy devoted to lighting or other appliances operations. Retails shops are quite diffuse including a tailor shop, phone-charger points and shops devoted to food (including meat) and beverages sale. The last ones cannot count on the availability of refrigerators for cold storage so that they have to adopt ice thanks to the only two ice suppliers of the whole camp who used to buy ice bags from the capital Dori. There also are present a mechanic where energy is necessary for motive power purpose, a blacksmith and many restaurants and boutiques where ceiling fan, colour TV and refrigerators are always desired. Instead they unfortunately have to settle for the presence of only phone chargers mainly fuelled by dry-cell batteries.

According to Corbyn and Vianello [30] at productive level, in the camp a solar-powered water pump (10 kW) has been installed, replacing a diesel-based generator, to provide clean drinking water for Goudoubo's 10,000 residents. Moreover, a solar-powered irrigation system (12 kW) for a vegetable production area has been installed to provide livelihoods for 150 households and an energy service centre has been set up to provide entrepreneurs with fully equipped solar systems facilities from which they can access electricity 24 hours a day for a fee.

4.2 Diagnosis

Once the gathered data in the previous *Priorities* section have been correctly analysed and sorted, the following *Diagnosis* phase aims to outline a picture of the total energy demand of Goudoubo camp.

4.2.1 Energy Demand and Load Profiles

Electricity

Starting from the actual energy consumption data corresponding to each energy use, different specific user classes have been identified: this step is fundamental when the already introduced *LoadProGen* software is used. For example, due to the heterogeneous access to energy of households and other facilities inside the camp, the chosen approach consists in traducing the data collected from the survey and classifying them in classes according to their consumption level and categories.

In particular, from the given sample behaviour it is possible to approximately assume the dynamics of the whole camp population as follows:

Table 10- Goudoubo Baseload Demand

User Class	Consumer Class	Number of Users	Type of Appliance	Number of Appliances	Nominal Power [W]	Total Nominal Power per Class [W]
Household	Low_Household	2388	Phone Charger	1	5	11940
	Medium_Household	597	Phone Charger	1	5	2985
			Radio	1	7	4179
	High_Household	81	Phone Charger	2	5	810
			Radio	1	7	567
			TV/Laptop	1	150	12150
	SHS_Household	136	Phone Charger	2	5	1360
			Radio	1	7	952
			Indoor Light	2	50	13600
			Outdoor Light	0	50	0
Community	Health Center (biofuel generator 30 kW)	1	Phone Charger	10	5	50
			Refrigerator	2	250	500
			Dry Heat Sterilizer	1	1000	1000
			Ceiling Fan	2	60	120
			Blood Chemistry Analyser	1	100	100
			Oxygen Concentrator	1	320	320
			Indoor Light	20	50	1000
			Outdoor Light	0	50	0
	School	1	Phone Charger	8	5	40
			TV	0	100	0
			Laptop	0	150	0
			Indoor Light	0	50	0
			Outdoor Light	0	50	0
	Education Center	2	Phone Charger	2	5	20
			TV	0	100	0
			Indoor Light	0	50	0
			Outdoor Light	0	50	0
	Camp Organization Center	5	Phone	2	5	50
			Laptop	1	100	500
			TV	1	150	750
			Satellite Dish/Receiver	1	25	125
			Inkjet Printer	1	100	500
	Street Lighting		100 solar lights			
Productive	Agricolture	1	Irrigation Pump	1		10000
	Drinking Water Supply	1	Water Pump	1		12000
	Hospitality (restaurant, bar, hotel)	3	Phone Charger	3	5	45
			Refrigerator	0	250	0
			Indoor Light	0	50	0
			Outdoor Light	0	50	0
	Grocery	5	Phone Charger	1	5	25
			Refrigerator	0	250	0
			Indoor Light	0	50	0
			Outdoor Light	0	50	0
	Tailor	1	Phone Charger	1	5	5
			Sewing Machine	1	100	100
			Indoor Light	0	50	0
	Retail Shop	7	Phone	2	5	70
			Laptop	1	100	700
			TV	0	150	0
			Satellite Dish/Receiver	0	25	0
			Inkjet Printer	0	100	0
			Indoor Lights	0	50	0
					Total Installed Power [W]	76563

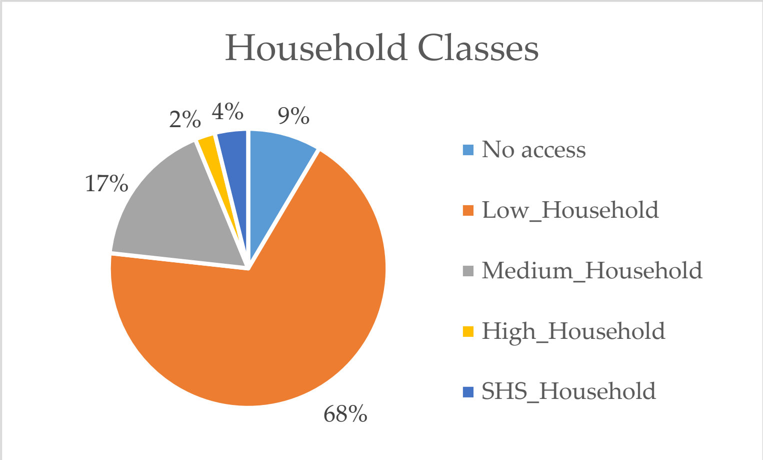


Figure 30 - Goudoubo Household Consumption Classes

The figure above shows the electric daily load profiles obtained setting as input data the information about the electric consumption and demand extrapolated in the previous *Priorities* phase. The daily windows of usage of each appliance have been roughly assumed attempting to remain as true as possible to the surveys output.

In particular, for the given case study, Load Profiles have been it presents the resulting total electric load curve together with the the partial electric load curves which refer to (I) each User Class or to (II) each single electric energy use reported in the camp.

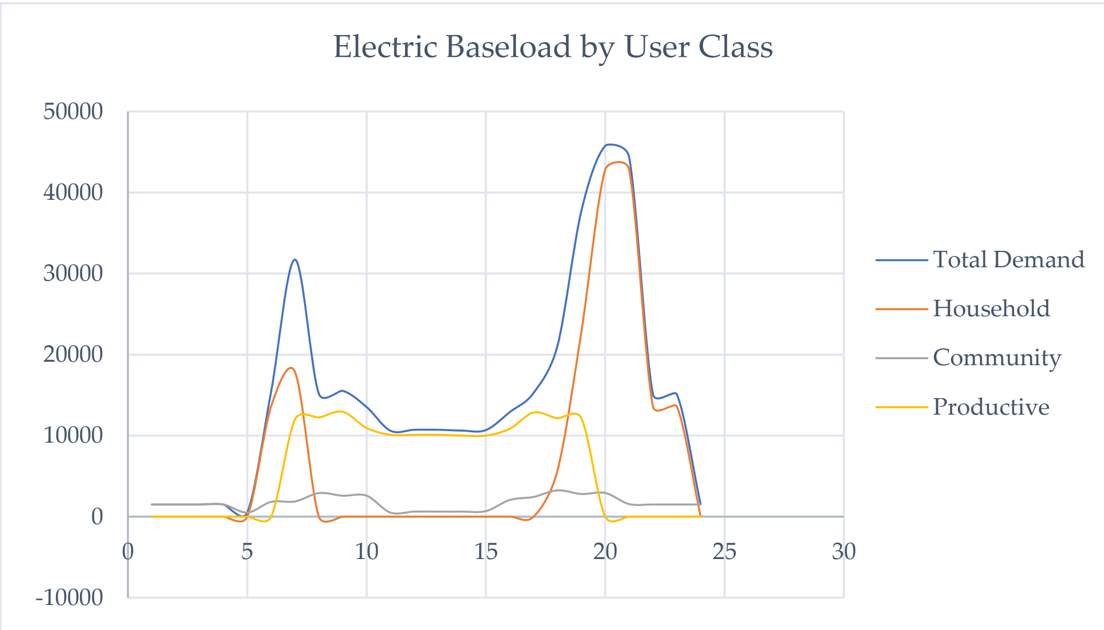


Chart 1 - Goudoubo Baseload by User Class

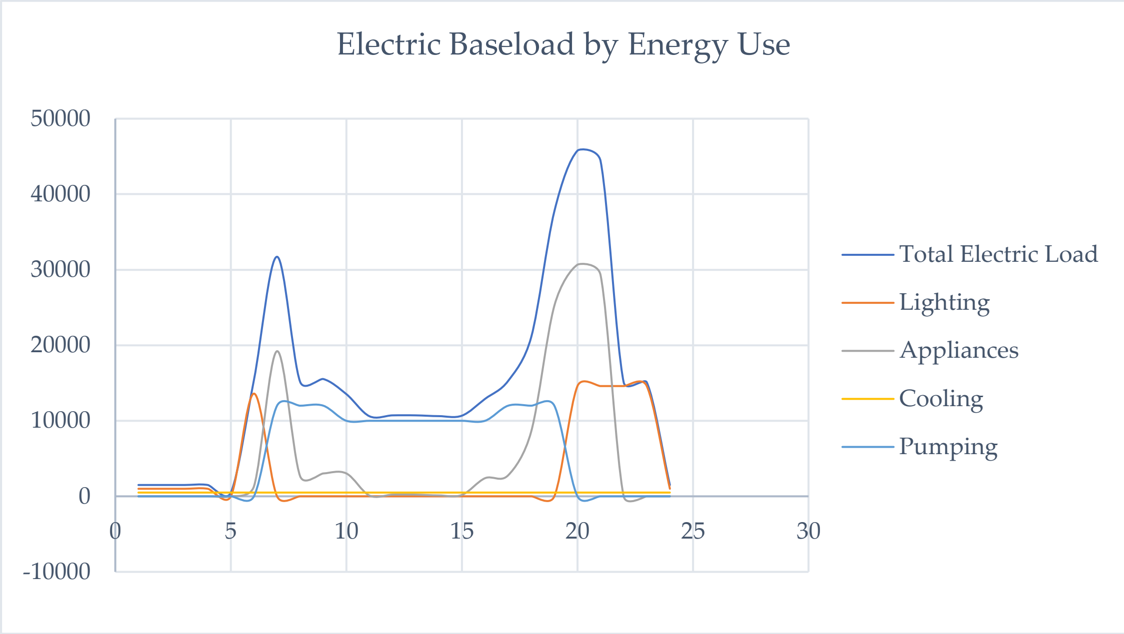


Chart 2 - Electric Baseload by Energy Use

Thermal Energy

According to the guideline, in this step the energy uses which contribute to the definition of the thermal energy demand have to be analysed. The component of energy devoted to cooking and heating purpose in the Goudoubo camp is here considered then.

From the analysis of the collected data, the only considerable thermal energy usage in Goudoubo camp is that concerning energy for cooking.

4.2.2 Resources Assessment

Since unfortunately it has not been possible to directly conducted field measurements of the local resources of the region where Goudoubo refugee camp is situated, the following application study and the consequent intervention proposals and selection have been developed on the base of the meteorological data available on the already mentioned databases and climatic reports.

When the camp under consideration has been localized according to its GPS coordinates, it is possible to evaluate the available and exploitable resources of the studied zone.

Solar Potential

As already stated, data concerning solar radiation are available by consulting one of the above-mentioned online portals. In this case, PVGIS database has been consulted in order to extrapolate geographic information of the specific site of Goudoubo. In particular, once entering the GPS coordinates in the online software, the monthly average solar radiation values can be evaluated, as well as the optimal orientation and the optimal inclination of the panels.

Table 11 - Goudoubo Monthly Irradiation. Data Source: PVGIS

Month	H_h	H_{opt}	DNI	I_{opt}	D/G
January	5550	6480	6000	42	0,32
February	6160	6840	6150	33	0,32
March	7110	7370	5970	18	0,38
April	6570	6400	5500	1	0,36
May	6550	6070	5490	-12	0,36
June	6210	5630	5110	-18	0,38
July	5940	5450	4840	-15	0,38
August	5720	5470	4460	-4	0,39
September	6080	6150	5090	12	0,37
October	6100	6580	5490	27	0,37
November	5790	6670	6200	39	0,31
December	5390	6430	6200	45	0,31
Year	6100	6295	5542	14	0,35

Where

H_h: Irradiation on horizontal plane ($Wh/m^2/day$)

H_{opt} : Irradiation on optimally inclined plane ($Wh/m^2/day$)

DNI: Direct normal irradiation ($Wh/m^2/day$)

I_{opt}: Optimal inclination (deg.)

D/G: Ratio of diffuse to global irradiation (-)

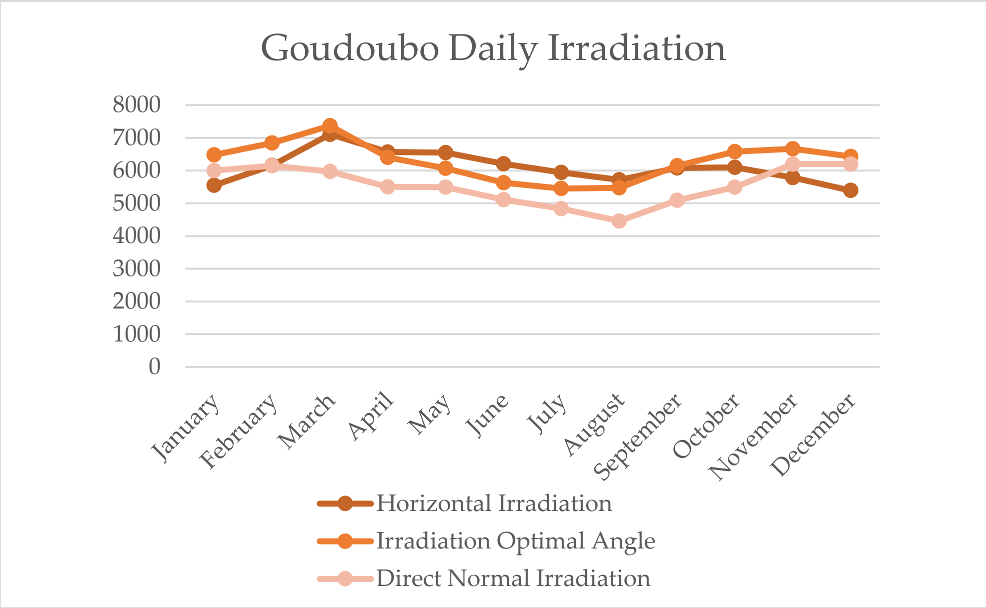


Chart 3 - Goudoubo Daily Irradiation. Data Source: PVGIS

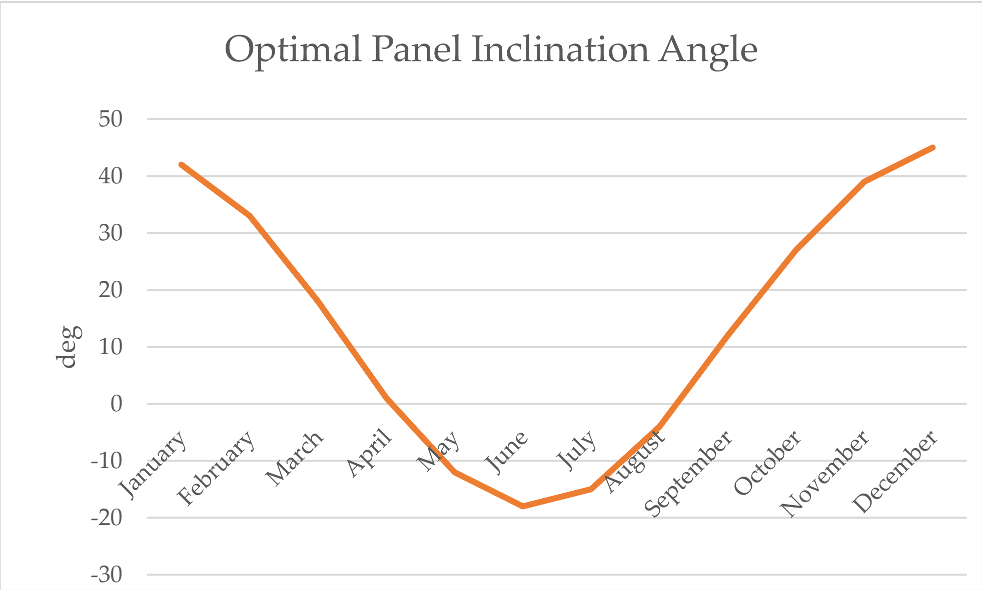


Chart 4 - Optimal Panel Inclination Angle. Data Source: PVGIS

Wind Power Potential

According to the data gained from the online available *Global Wind Atlas*, in the Goudoubo region an average wind speed of 4.34 m/s has been recorded during the years, with a power density of 83 W/m[2]. The average wind speed value basically exceeds the cut-in velocity value, which is necessary to the wind turbines

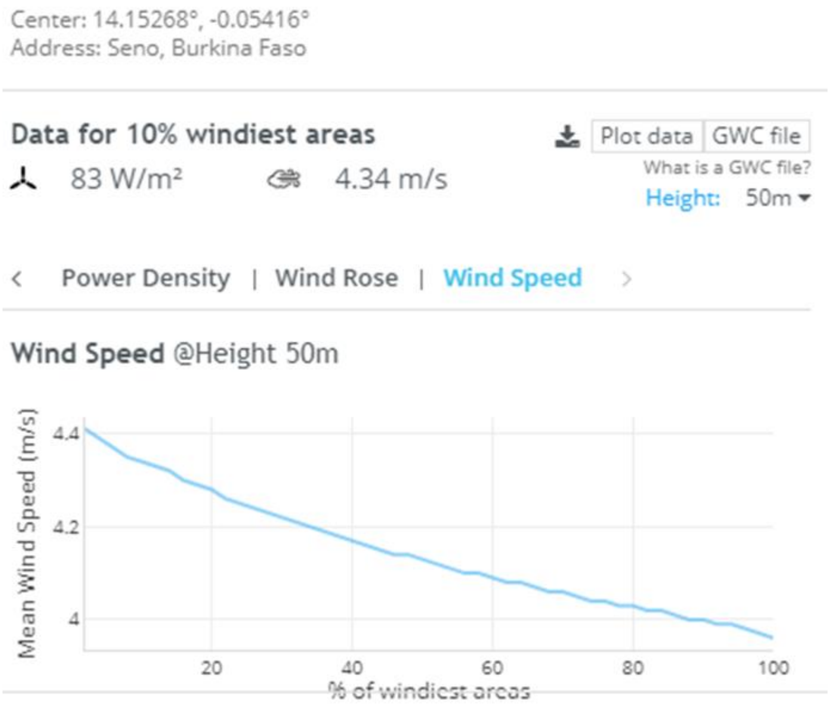


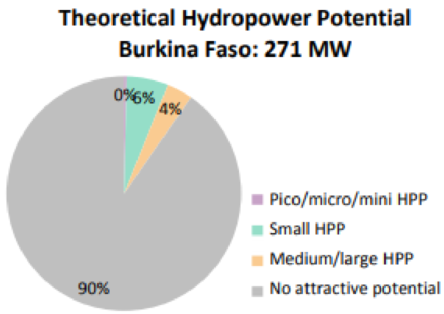
Chart 5 - Goudoudo Wind Data Outputs. Source: Global Wind Atlas

Hydro Power Potential

By consulting the report which can be found in the *Ecowrex* online database, according to the hydrologic characteristics of Burkina Faso, the theoretical hydropower potential[2] for the country is estimated to be 271 MW (reference period 1998-2014), which is the total of all rivers in the country [31]. There are five existing small hydropower plants, but there are no medium or large hydropower plants since most of rivers are classified with "No attractive Potential".

The region with attractive theoretical hydropower potential of river reaches are found in the south-west and south of Burkina Faso. Unfortunately, Goudoubo is located in the north-eastern

[2] The theoretical hydropower potential of a river is defined as the amount of power that would be produced if the full head of the river was used and if 100 % of the mean annual discharge was turbinated (i.e. no spillway losses or environmental flow constraints) [31].



Theoretical Hydropower Potential of Rivers in Burkina Faso	
Pico/micro/mini HPP	1 MW
Small HPP	16 MW
Medium/large HPP	10 MW
No attractive potential	244 MW
Total of all rivers in country	271 MW
Total of rivers with attractive theoretical potential for pico/micro/mini, small, or medium/large HPP	27 MW

Figure 31 - Theoretical Hydropower Potential of Burkina Faso from ecowrex report [31]

Sahelian region which is the driest one, receiving only an annual average of less than 500 mm. Therefore, despite the presence of the nearby Feildegasse watercourse, the installation of hydropower plants seems not to be the most viable solution for Goudoubo.

4.3 Strategy

As already mentioned in the guideline, once local resources potential has been assessed, it is possible to narrow down the scenarios selecting the most suitable ones.
In Goudoubo refugee camp, the level of the access to energy is currently quite low. As reported, most of population have only rough access to electricity to charge phones and just in few cases they own other small appliances, namely TV or radio. Then the intervention should be intended as gradual, in order not to generate a negative impact.

Goudoubo camp covers approximately an area of 750 squaremeters (750 m x 1000 m). The camp road marks the blocks in which the settlement it is organized: in each block 4, 8 or 12 communities can be individuated. Often a considerable part of the community structures are still unoccupied. The main provincial highway allows the access to Goudoubo from the central camp road to which the camp is distributed roughly symmetrically. The community services facilities and camp operations structures are situated in the northern side of the camp together with the school and the other education centres while the only one clinic can be found in the above mentioned central road. The camp structure organization could be significant to the energy strategy choice to be adopted.

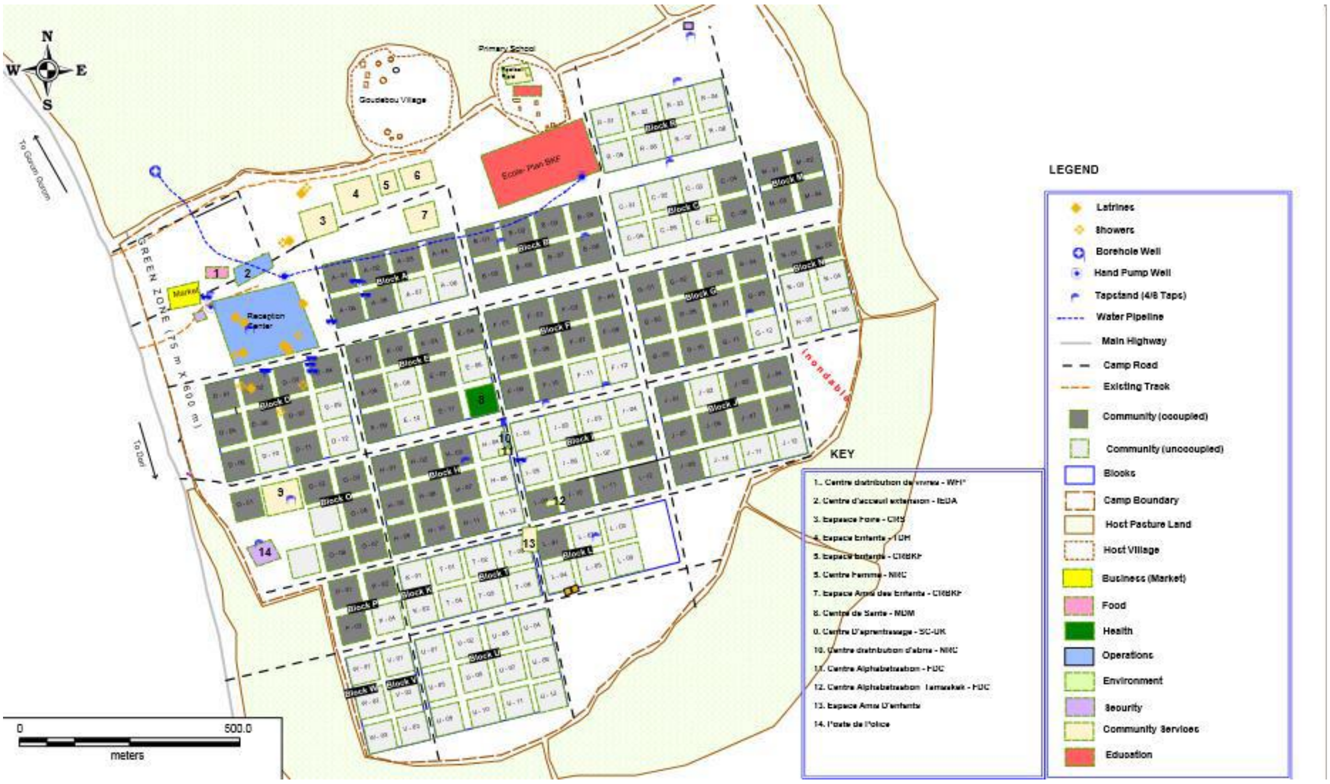


Figure 32 - Schematic of Goudoubo Camp. Source: UNHCR 2013

On the base of the *Total Energy Access minimum standards* proposed by UNHCR and Practical Action (tables reported in Appendix A), an idea of the new camp configuration can be outlined. First of all, a new electric energy demand has been proposed: currently Goudoubo camp cannot accomplish so many of the requirements which ensure a dignified life, so that it can be proposed the most plausible one in order to deliver to the camp population an adequate access to energy.

The following table contains the input data assumed to generate the new electric load profile which is instead presented below in comparison with the actual one previously illustrated.

Table 12 - Goudoubo Proposed Electric Demand

User Class	Consumer Class	Number of Users	Type of Appliance	Number of Appliances	Nominal Power [W]	Total Nominal Power per Class [W]
Household	Household_ Block	3500	Phone Charger	1	5	17500
			Radio	1	7	24500
			TV/Laptop	0	150	0
			Indoor Light	1	50	175000
			Outdoor Light	0	50	0
Community	Health Center (biofuel generator 30 kW)	1	Phone Charger	10	5	50
			Refrigerator	2	250	500
			Dry Heat Sterilizer	1	1000	1000
			Ceiling Fan	1	60	60
			Blood Chemistry Analyser	1	100	100
			Oxygen Concentrator	1	320	320
			Indoor Light	20	50	1000
			Outdoor Light	2	50	100
	School	1	Phone Charger	8	5	40
			TV	1	100	100
			Laptop	20	150	3000
			Indoor Light	8	50	400
			Outdoor Light	2	50	100
	Education Center	2	Phone Charger	4	5	40
			TV	1	100	200
			Indoor Light	2	50	200
			Outdoor Light	1	50	100
	Camp Organization Center	5	Phone	2	5	50
			Laptop	1	100	500
			TV	1	150	750
			Satellite Dish/Receiver	1	25	125
			Indoor Light	2	50	500
			Inkjet Printer	1	100	500
	Street Lighting		100 solar lights - 6 metri LED	100	35	3500
Productive	Agricolture	1	Irrigation Pump	1	10000	10000
	Drinking Water Supply	1	Water Pump	1	12000	12000
	Hospitality (restaurant, bar, hotel)	3	Phone Charger	3	5	45
			Refrigerator	1	250	750
			Indoor Light	3	50	450
			Outdoor Light	1	50	150
	Grocery	5	Phone Charger	1	5	25
			Refrigerator	1	250	1250
			Indoor Light	2	50	500
			Outdoor Light	1	50	250
	Tailor	1	Phone Charger	1	5	5
			Sewing Machine	1	100	100
			Indoor Light	1	50	50
	Retail Shop	7	Phone	2	5	70
			Laptop	1	100	700
			TV	1	150	1050
			Satellite Dish/Receiver	1	25	175
			Inkjet Printer	1	100	700
			Indoor Lights	2	50	700
					Total Installed Power [W]	259205

The number of appliances proposed for each category and consumer class have been assumed in order to give an adequate and roughly equal distribution of them around the camp.

The author decided to provide each household at least with a phone charger, a lightbulb and a radio while other electric appliances (i.g. for ICT&Enterteinment purpose) have been installed in the community facilities, for example the school have been equipped with 20 TVs and solar street lights are eventually equipped with phone charger stations. This configuration aims at making available at public/community level electrical devices which are not properly part of

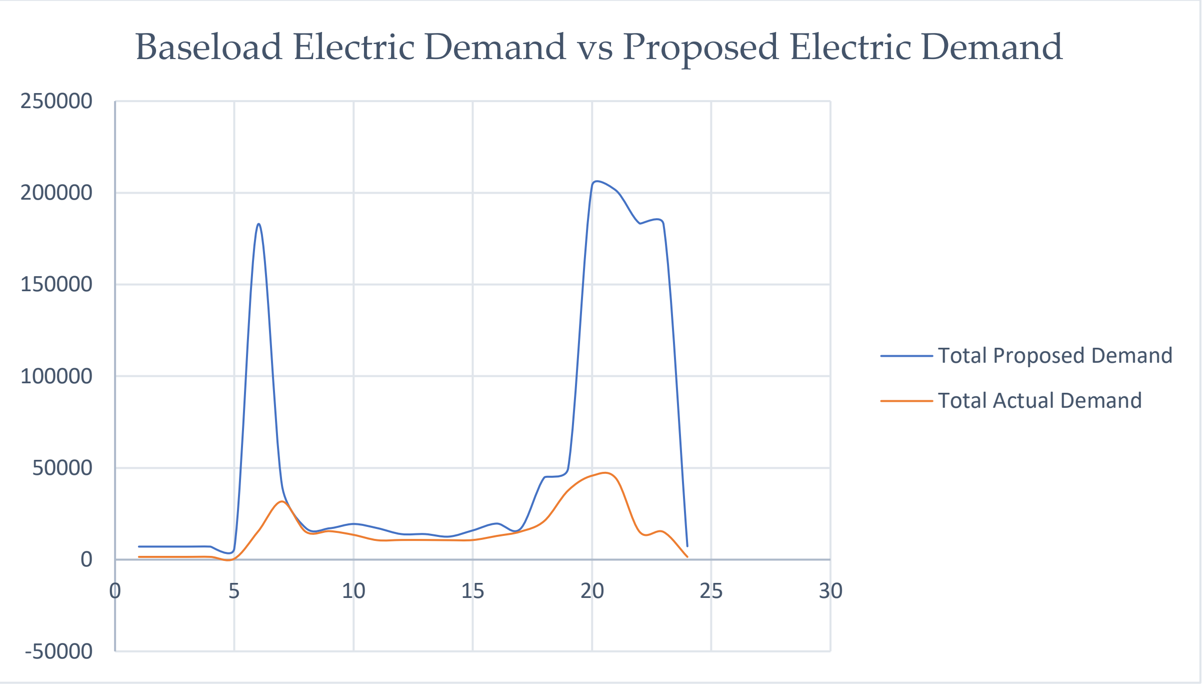


Chart 6 - Goudoubo Electric Demands Comparison

the essential needs and which would soar significantly the total energy demand if considered individually, i.e. one or more per household.

The chart above shows how the new total energy demand is clearly so much higher than the actual one but it can be justified by the attempt of guarantee an adequate access to energy to the whole camp.

In general, the consumption pattern reveals the highest energy demand corresponding to the typical morning peak (6AM – 8AM) and evening peak (8PM – 11PM), in both the situations. From the following Chart 6, it is worth noting the great part of the electricity demand would be due to the aim of providing the coverage of the energy needs for lighting purpose. Especially at household level, the demand soars shifting from the actual to the new proposed situation, since currently the access to energy for lighting in Goudoubo is almost totally absent. It can be reminded the only source of lighting for households is given by solar lanterns, kerosene lamps or candles.

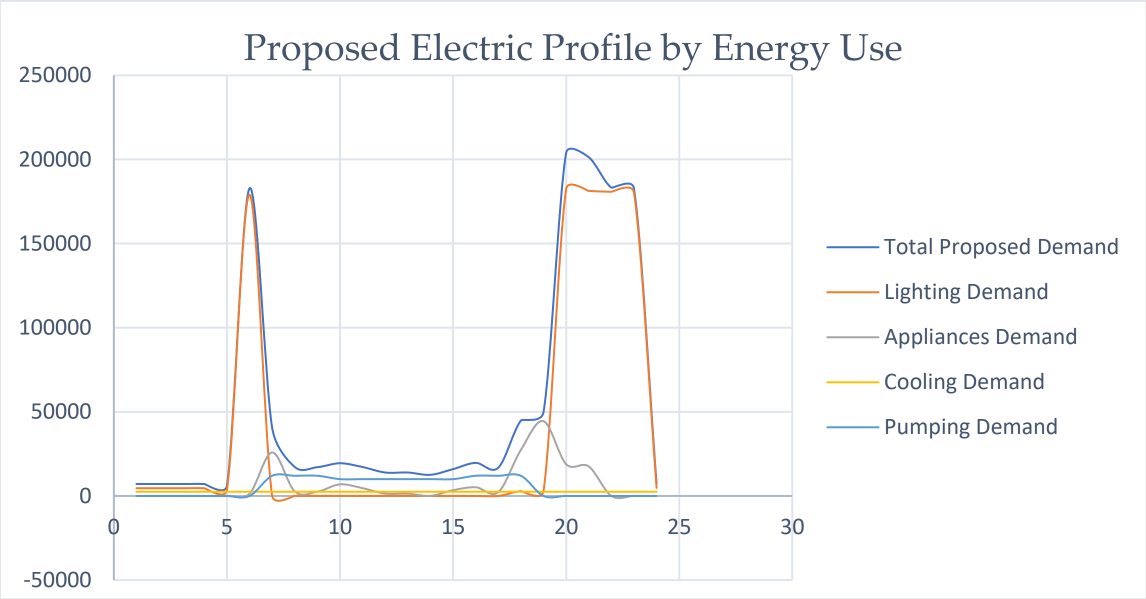


Chart 7 - Proposed Electric Daily Profile by Energy Use

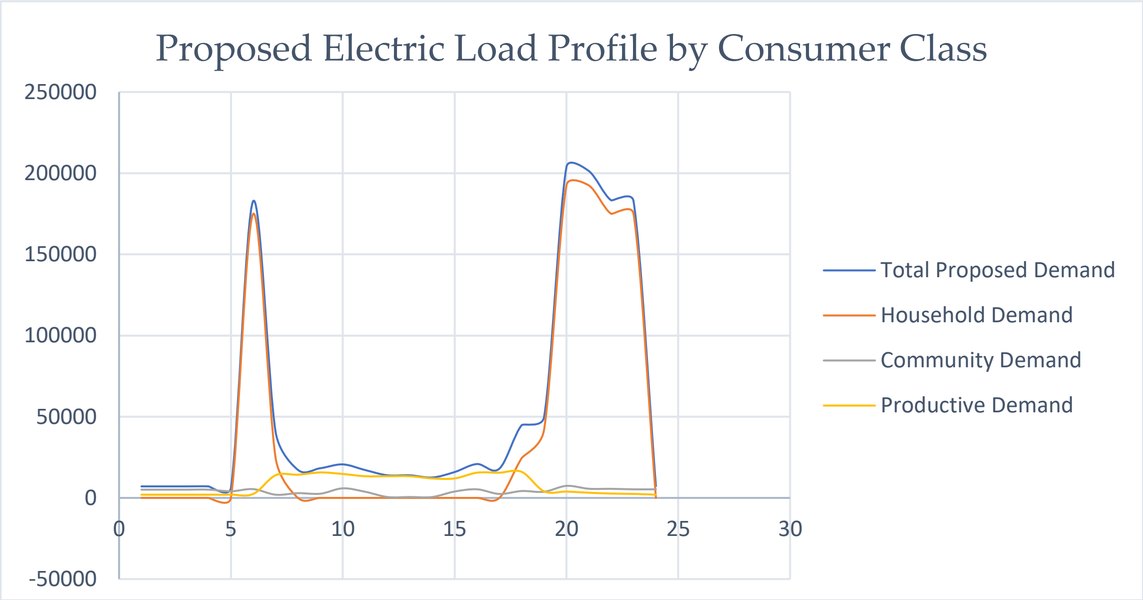


Chart 8 - Proposed Electric Load Profile by Consumer Class

It will be possible then to present a range of possible scenarios and only in the end opt for the most cost-effective solution.

Focusing on electric load, first of all, it should be reminded Goudoubo is located in a remote desertic area which is definitely not reached by the national grid: among all the condiserable technologies, the grid extension option can be brushed aside.

As result, considering only stand-alone and mini-grid options and the available energy resources, for the given case study, the different solutions proposed by the author can be summarized as the Table 11 shows:

Table 13 - Proposed Electric Scenarios for Goudoubo

	Electric Energy Demand		**Energy Resources**		
	Actual	New	RET	Traditional Fuels	Hybrid
Scenario 0	x			x	
Scenario 1	x		x		
Scenario 2		x			x
Scenario 3		x			x
Scenario 4		x			x

For what concern thermal loads, neglecting the energy devoted to heating purpose since it has not been recorded in Goudoubo, cooking technologies can be considered as the only thermal energy contribution in the camp. In particular, the attention has been rightly focused on the different adoptable cooking technologies, including traditional, improved and modern cookstoves.

As already deduced from the priorities assessment output, currently Goudoubo population mostly used to rely on biomass as fuel for cooking practices.In order to propose a range of different options even for thermal case, different scenarios can be considered to promote the most suitable and cost-effective transition from tradional to renewable and more sustainable technologies. The different solutions can be summarized as follows in Table 12:

Table 14 - Proposed Thermal Scenarios for Goudoubo

	Cooking Technologies		
	Three-Stone Fire	Improved Cookstove	Solar Cookers
Scenario 0*	x		
Scenario 0	x	x	
Scenario 1		x	
Scenario 2		x	x

4.4 Comprehensive Design

This paragraph is devoted to the techno-economic presentation and overview of the above proposed energy scenarios for the intervention in Goudoubo refugee camp, concerning both electric and thermal. Then, the final chapter will be dedicated to a comparison among all the options and the choice of the suggested combination to be adopted.

For the sake of simplification, the simulations for sizing and optimization of five electric scenarios have been carried out by means of HOMER Energy software. In parallel, four thermal options have been developed and the costs calculated manually.

All the calculations have been made considering the project intervention over a lifetime of 10 years.

4.4.1 Electricity Scenarios

Focusing on the electric energy, in all the simulations carried out by means of HOMER Energy software, the author adopting the same inputs aiming at maintaining a certain equivalence among all the scenarios. In the following Table 13, the components' techno-economic specifications have been presented.

Table 15 - Techno-Economic Specifications of Electric Scenarios Components

Project	
Project Lifetime	10 years
Discount Rate	4,25%
Inflation Rate	2,08%
Annual Capacity Shortage	10%
Diesel Generator	
Genset Lifetime	5 years
Cost of Genset [$/kW]	500
Flat Plate PV	
PV Lifetime	15 years
Cost of PV [$/kW]	2400
Converter	
Converter Lifetime	10 years
Cost of Converter [$/kW]	700
Wind Turbine	
Wind Turbine Lifetime	15 years
Cost of Wind Turbine [$/kW]	5000
Storage – 1kWh Lead Acid Battery	
Battery Lifetime	10 years
Throughout kWh	800
Cost of Storage [$/item]	300

Scenario 0 – Baseload Situation: Energy from Diesel

The configuration of the *Scenario 0* comes from the consideration of the actual energy situation of Goudoubo camp, where the current access to energy in the camp is far from being satisfactory for the population.

This proposal involves traditional fuels as unique energy sources: the adopted energy technologies will be diesel gensets. In particular, in this case the electric demand will only concern the energy needs of the health center and those of the two pumping systems, one for the drinking water supply and the other for the irrigation pump for agricultural use.

Table 16 - Energy demand for Scenario 0 and Scenario by Class

User Class	Consumer Class	Number of Users	Type of Appliance	Number of Appliances	Nominal Power [W]	Total Nominal Power per Class [W]
Community	Health Center (biofuel generator 30 kW)	1	Phone Charger	10	5	50
			Refrigerator	2	250	500
			Dry Heat Sterilizer	1	1000	1000
			Ceiling Fan	2	60	120
			Blood Chemistry Analyser	1	100	100
			Oxygen Concentrator	1	320	320
			Indoor Light	20	50	1000
			Outdoor Light	0	50	0
Productive	Agricolture	1	Irrigation Pump	1		10000
	Drinking Water Supply	1	Water Pump	1		12000
					Total Installed Power [W]	25090

The best solution for meeting these energy needs is the installation of 30 kW diesel genset able to cover the electric demand of the above mentioned loads. It is worth noting that in reality, due to the extension of the camp area, it would be impossible to take into account a unique genset for the whole electric demand since the hand-pump well and the land devoted to agricultural uses are not located quite close to the health center. Nevertheless, such a choice can be justified by the fact this scenario serves as baseline with respect to the others in order to understand the importance of an intervention.

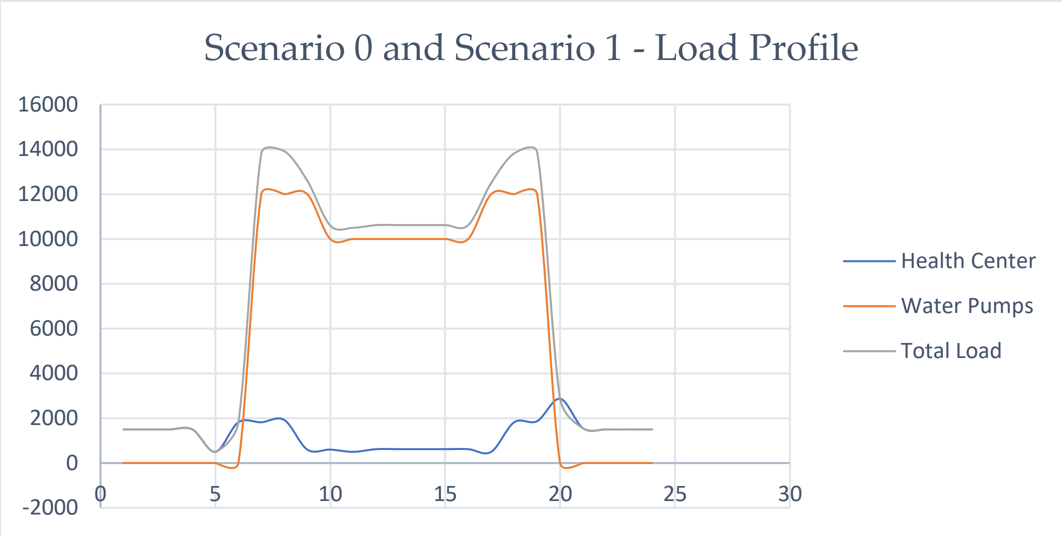


Chart 9 - Load Profile valid for Scenario 0 and Scenario 1

Table 17 - Scenario 0: Techno-economic characteristics

Scenario 0	
Genset [kW]	30
Cost of Genset [$]	15000,00
Converter [kW]	-
Cost of Converter [$]	-
PV [kW]	-
Cost of PV [$/kW]	-
Wind [kW]	-
Cost of Wind Turbine [$]	-
Storage [quantity]	-
Cost of Battery Bank [$]	-
NPC [$]	389851,00
Initial Capital Cost [$]	15000,00
Operating cost [$/year]	42006,00
Renewable Fraction	0%

Scenario 1 – Baseload Situation: Energy from Renewables

As first alternative, the author suggests to consider again the actual energy situation of Goudoubo in which only the health center and the water pumps are taken into account, but this time adopting renewables as energy sources. Therefore, the genset of the previous *Scenario 0* has been replaced by a solar-powered system.

In particular, in order to meet the previous electric needs, a pure 50 kW photovoltaic system could be installed. Additional characterics of the energy system can be found in the following Table 15.

Table 18 - Scenario 1: Techno-economic characterics

Scenario 1	
Genset [kW]	-
Cost of Genset [$]	-
Converter [kW]	60
Cost of Converter [$]	42000,00
PV [kW]	50
Cost of PV [$/kW]	120000,00
Wind [kW]	-
Cost of Wind Turbine [$]	-
Storage [quantity]	150
Cost of Battery Bank [$]	45000,00
NPC [$]	227904,00
Initial Capital Cost [$]	207000,00
Operating cost [$/year]	2343,00
Renewable Fraction	100%

Scenario 2 – New Situation: Energy from Hybrid PV-Diesel

The following *Scenario 2* consists in a new energy situation for Goudoubo camp based on the above introduced energy demand.

The intervention has to be intended at camp level by means of a unique centralized system which must meet the newest energy demand of the whole camp. Even this time, renewables have been considered as mainly energy sources with diesel back-up generator(s). In particular, simulation after simulation, HOMER Energy software suggests to adopt a 360 kW solar PV systems able to cover the energy demand of the whole camp extension with an additional 30 kW diesel genset. In the Table below have been reported the techno-economic characteristics of the energy system.

Table 19 - Scenario 2: Techno-Economic Characteristics

Scenario 2	
Genset [kW]	30
Cost of Genset [$]	15000,00
Converter [kW]	200
Cost of Converter [$]	140000,00
PV [kW]	360
Cost of PV [$/kW]	-
Wind [kW]	-
Cost of Wind Turbine [$]	-
Storage [quantity]	2000
Cost of Battery Bank [$]	60000,00
NPC [$]	2480000,00
Initial Capital Cost [$]	1620000,00
Operating cost [$/year]	96464,00
Renewable Fraction	82%

Scenario 3 – New Situation: Energy from Hybrid PV-Wind-Diesel

Similarly to the previous configuration, in the considered *Scenario 3* for Goudoubo, the new energy situation has been taken into account. Substantially this option is equivalent to the previous one but it aims at considering the hybrid PV-Wind System option.

According to the resources assessment, in addition to the particularly reliable solar energy, Goudoubo could also count on wind potential: it is worth noting, with the addition of a 10 kW wind turbine, clearly the initial capital cost would soar, nevertheless Operating Cost woul decrease.

Table 20 - Scenario 3: Techno-Economic Characteristics

Scenario 3	
Genset [kW]	30
Cost of Genset [$]	15000,00
Converter [kW]	200
Cost of Converter [$]	140000,00
PV [kW]	360
Cost of PV [$/kW]	864000,00
Wind [kW]	10
Cost of Wind Turbine [$]	50000,00
Storage [quantity]	2000
Cost of Battery Bank [$]	600000,00
NPC [$]	2520000,00
Initial Capital Cost [$]	1670000,00
Operating Cost [$/year]	95129,00
Renewable Fraction	82%

Scenario 4 – New Situation: Multiple Mini-Grid Approach with Energy from Renewables

In the last suggested option, a new energy situation for Goudoubo has been presented. In this case, the intervention has to be intended as a multiple mini-grid configuration: Goudoubo camp has been divided into three main blocks in order to split up its total energy demand. Renewables have been considered as mainly energy sources with diesel back-up generator(s).

In a bit more detail, according to the distribution of household, community facilities and enterprises and productive uses services, it has been chosen to subdivide Goudoubo as follows:

- *Block 1* which involves the health center and approximately 1000 households in the southern part of the camp;
- *Block 2* which takes into account the education centers located in the north-eastern part of the camp and about other 2000 households;
- *Block 3* which considers camp organization centers including retails shops, street lighting and agricultural practices and the 500 remaining households.

In this way three different load profiles can be individuated and three separated solar PV systems have been sized in order to cover the energy demand of each block. The following Table 18 below shows in details the allocation of the adopted electrical appliances.

Table 21 - Scenario 4: Energy Demand by Blocks

	User Class	Consumer Class	Number of Users	Type of Appliance	Number of Appliances	Nominal Power [W]	Total Nominal Power per Class [W]
Block 1	Household	Household_ Block1	1000	Phone Charger	1	5	5000
				Radio	1	7	7000
				TV/Laptop	0	150	0
				Indoor Light	1	50	50000
				Outdoor Light	0	50	0
	Community	Health Center	1	Phone Charger	10	5	50
				Refrigerator	2	250	500
				Dry Heat Sterilizer	1	1000	1000
				Ceiling Fan	1	60	60
				Blood Chemistry Analyser	1	100	100
				Oxygen Concentrator	1	320	320
				Indoor Light	20	50	1000
				Outdoor Light	2	50	100
Block 2	Household	Household_ Block2	2000	Phone Charger	1	5	10000
				Radio	1	7	14000
				TV/Laptop	0	150	0
				Indoor Light	1	50	100000
				Outdoor Light	0	50	0
	Community	School	1	Phone Charger	8	5	40
				TV	1	100	100
				Laptop	20	150	3000
				Indoor Light	8	50	400
				Outdoor Light	2	50	100
		Education Center	2	Phone Charger	4	5	40
				TV	1	100	200
				Indoor Light	2	50	200
				Outdoor Light	1	50	100
Block 3	Household	Household_ Block3	500	Phone Charger	1	5	2500
				Radio	1	7	3500
				TV/Laptop	0	150	0
				Indoor Light	1	50	25000
				Outdoor Light	0	50	0
	Community	Camp Organization (	5	Phone	2	5	50
				Laptop	1	100	500
				TV	1	150	750
				Satellite Dish/Receiver	1	25	125
				Indoor Light	2	50	500
				Inkjet Printer	1	100	500
		Street Lighting		100 solar lights - 6 metri LED	100	35	3500
	Productive	Agricolture	1	Irrigation Pump	1	10000	10000
		Drinking Water Supp	1	Water Pump	1	12000	12000
		Hospitality (restaurar	3	Phone Charger	3	5	45
				Refrigerator	1	250	750
				Indoor Light	3	50	450
				Outdoor Light	1	50	150
		Grocery	5	Phone Charger	1	5	25
				Refrigerator	1	250	1250
				Indoor Light	2	50	500
				Outdoor Light	1	50	250
		Tailor	1	Phone Charger	1	5	5
				Sewing Machine	1	100	100
				Indoor Light	1	50	50
		Retail Shop	7	Phone	2	5	70
				Laptop	1	100	700
				TV	1	150	1050
				Satellite Dish/Receiver	1	25	175
				Inkjet Printer	1	100	700
				Indoor Lights	2	50	700
						Total Installed Power [W]	259205

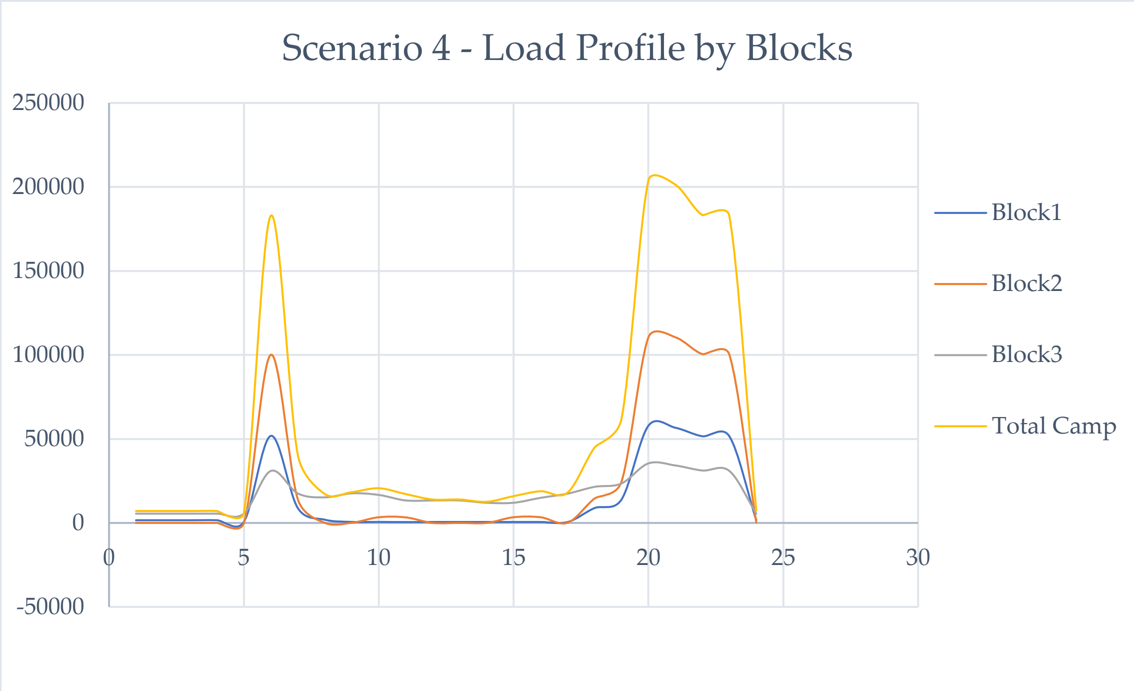


Chart 10 - Scenario 4: Load Profiles by Blocks

In detail, according to the simulations which have been carried out by means of HOMER Energy software, the suggested configurations can be considered as shown in the following Table 22.

Table 22 - Scenario 4: Techno-Economic characteristics

Scenario 4	**Block 1**	**Block 2**	**Block 3**	**Camp**
Genset [kW]	30	30	30	
Cost of Genset [$]	15000,00	15000,00	15000,00	45000,00
Converter [kW]	40	80	40	
Cost of Converter [$]	28000,00	24000,00	28000,00	80000,00
PV [kW]	50	100	80	
Cost of PV [$/kW]	120000,00	240000,00	192000,00	552000,00
Wind [kW]	-	-	-	
Cost of Wind Turbine [$]	-	-	-	
Storage [quantity]	500	1000	300	1800
Cost of Battery Bank [$]	150000,00	300000,00	90000,00	540000,00
NPC [$]	582680,00	1680000,00	545423,00	2808103,00
Initial Capital Cost [$]	313000,00	579000,00	325000,00	1217000,00
Operating cost [$/year]	30220,00	68397,00	24701,00	123318,00
Renewable Fraction	51%	69%	52%	

4.4.2 Cooking Scenarios

For what concerns thermal energy, the following four solutions have been proposed and developed under many assumptions, both for the sake of simplification and for highlighting fuel consumption. As already mentioned, what emerges from the analysis of the gathered data from the field surveys is that in Goudoubo camp population mostly rely on biomass as cooking fuel including firewood, charcoal, briquettes or LPG. The fuel is usually collected, purchased or donated. In this work, the calculations have been made assuming all the cooking fuel as firewood and taking into account it had been all purchased (30% by donors, namely UNHCR and WFP, and 70% directly by camp populations).

In addition, according to the averagely recorded 5 daily hours devoted to cooking practices, fuel is assumed as consumed during three different daily peaks correnspondi ng to breakfast (1 hour), lunch (2 hours) and dinner (2 hours).

Moreover, the cost of firewood has been assumed as $0.06 per kg[3] and all the data calculated annually. In the following table all the techno-economic specifications of the components implemented in the cooking scenarios have been reported:

[3] 1CFA = 0.002$; cost of firewood has been averagely calculated as 30 CFA per kg.

Table 21- Techno-Economic Spcification of Cooking Scenarios Components

Data	
Project	
Project Lifetime	10 years
Discount Rate	4,25%
Fuel - Firewood	
Cost of Fuel [$/kg]	0,60
Three-Stone Fire	
Fuel	Firewood
Efficiency	10%
Manufacturer	Self-built by population
Cost of Stove [$/item]	-
Lifetime	-
Improved Cookstoves	
Fuel	Firewood
Efficiency	45-50%
Material	Metal
Manufacturer	Roumdé
Commercial Name	Foyer Amelioré Ouaga Metallique
Cost of Stove [$/item]	5,00
Lifetime	2 years
Solar Cookers	
Fuel	Solar Energy
Material	Metal
Manufacturer	Solar Cookers International
Commercial Name	CooKit panel solar cooker
Cost of Stove [$/item]	25,00
Lifetime	2 years

*Scenario 0**

In this option, the configuration assumes three-stone fire as unique cooking technologies adopted in the camp. This scenario is worse than the real one and it has been presented with the only aim of highlighting the extremely low efficiency of the above mentioned traditional cooking technologies whose fuel consumption is definitely as high as also the annual economic expenditure devoted for the fuel.

The only costs which have to be taken into account in this scenario are those concerning fuel, which have been calculated year by year as operation costs.

Scenario 0

This scenario came as baseline: it reflects the actual situation in Goudoubo where 35% of the camp population use traditional three-stone fire as cooking technology, while the remaining 65% can count on improved cookstoves. According to the analysis of data, great part of respondents stated that they own metal improved cookstove: for the sake of calculations, the author referred to *Foyer Amelioré Roumdé Ouaga Métallique*, commonly adopted in Burkina Faso and typically consuming the 40% less than the traditional cookstoves.

As result, the fuel consumption is in this case lower than the previous due to the savings of the more efficients stoves. Nevertheless the improved technologies adopoted give a significantly contribution in terms of initial capital cost which in the previous scenario resulted equal to zero.

Scenario 1

With the aim of reducing costs and fuel consumption and with an eye towards more sustainable cooking practices, in this option it has been proposed to provide the total population of Goudoubo with improved cookstoves as unique cooking technologies. In this way, the total amount of firewood consumed around the camp has been clearly reduced with an obvious higher value of the initial capital cost.

Scenario 2

The author proposed as last solution for thermal energy, a scenario in which modern cooking technologies have been introduced, namely solar cookers. Due to the unpredictability of the solar potential, it could not be possible to adopt them as unique cooking devices, so that it has been suggested to introduce such a technology in people habits - as gradually as possible - in order to promote the transition from traditional cooking fuels to renewable resources.
In this regard, it has been suggested to shift only one of the three typical daily meals (lunch) to the modern food preparation with solar cookers. It has to be intended as if only during two out of five daily hours devoted to cooking practices, Goudoubo population make use of solar cookers. As result, fuel consumption can be seen decreased by the 40%. The remaining two meals continue to be covered by improved cookstoves usage, as in the previous solution. Each household own both an improve cookstove and a solar cooker.
Obviously, this scenario implies a clear increase both in the initial capital cost and in the maintanance cost due to the purchase and periodic replacement of the additional solar cooking technologies. In particular, for the purpose of this work, the author have chosen the *CooKit panel solar cookers* manufactured by Solar Cookers International, lightweight, compact and already diffused among Burkinabé.

Nevertheless, due to the lower rate of fuel consumption, as a consequence the operation costs are rightly reduced.

5 Results

Once all the possible scenarios have been presented, a comparison among them has been put forward. In this sense, the author can suggest the best combination of both electric and thermal options in order to finally propose the most cost-effective and sustainable energy intervention for Goudoubo refugee camp.

Today households spend on average more than US$10 per month on energy, counting regrettably on a weak, unreliable and not sustainable access to it.
In particular, from the electrical point of view, just a very limited share of population have access to lighting sources and in most of cases it is possible only thanks to the owning of solar portable lanterns or, in the very worst cases, of candles. In addition, only the owners of lanterns provided with USB port are able to charge phones at home. The only facility with access to electricity is the health center which has unfortunately to face continuous daily supply interruptions, due to the high electric load which has to be all covered by the diesel generator.

Instead, for what concerns thermal energy, camp population still used to rely mainly on firewood for their cooking practices. This approach has not only an economic impact due to the high expenditure caused by the low-efficiency and high-consumption adopted stoves, but also an environmental effect because of the elevate rate of emissions generated in addition to health-related problems.

Comparing the results coming both from technical and economic analysis, Table 21 and Table 23 have been attached below in order to present all the final calculations.

Table 23 - Electric Scenarios proposed for Goudoubo

Electric Scenarios Comparison		Genset [kW]	Converter [kW]	PV [kW]	Wind [kW]	Storage [quantity]	Renewable Fraction	Initial Capital Cost [$]	Operating cost [$/year]	NPC [$]
Scenario 0	Base Load	30	-	-	-		0%	$ 15.000,00	$ 42.006,00	$ 389.851,00
Scenario 1	Base Load 100% REN	-	60	50	-	150	100%	$ 207.000,00	$ 2.343,00	$ 227.904,00
Scenario 2	New_PV+diesel	30	200	360	-	2000	82%	$ 1.620.000,00	$ 96.464,00	$ 2.480.000,00
Scenario 3	New_PV+Wind+Diesel	30	200	360	10	2000	82%	$ 1.670.000,00	$ 95.129,00	$ 2.520.000,00
Scenario 4	Block1_PV+Diesel	30	40	50	-	500	51%	$ 313.000,00	$ 30.220,00	$ 582.680,00
	Block2_PV+Diesel	30	80	100	-	1000	69%	$ 579.000,00	$ 68.397,00	$ 1.680.000,00
	Block3_PV+Diesel	30	40	80	-	300	52%	$ 325.000,00	$ 24.701,00	$ 545.423,00
	Camp Total			230		1800		$ 1.217.000,00	$ 123.318,00	$ 2.808.103,00

Focusing on the electric cases and referring to the baseload, over a project lifetime of 10 years, it is clear that the *Scenario 1* is the best to be chosen. Despite of the rightly higher initial capital cost due to the investment for the adoption of the solar PV technology with respect to that of the cheaper diesel generator of the *Scenario 0*, it shows a deep decrease in the annual operating cost, result of the large fuel salvages. Of course, with the aim of covering the new demand, thanks to which the whole camp could count on an adequate energy supply for all, the provided options include investments far removed from the previous ones. The *Scenario 2* showed better performances with respect to the *Scenario 3*, in terms of both Net Present Cost and Initial Capital Cost. This is mainly due to the additional presence of the wind turbine which, even decreasing the annual Operating Costs, seems not to improve the Renewable Fraction. The matter could have already been deduced in advance due to the relatively limited potential of the wind resource in the studied location. At the same time, looking at the last *Scenario 4* suggested option where the new energy demand has been splitted in three separated camp blocks, although the total initial capital cost seems to be lower than that of the *Scenario 2*, both the NPC and Operating Costs are instead higher. This is due to the fact that in each block a 30 kW back-up diesel generator has been taken into account, tripling then the operating costs related to the total fuel consumption.

In order to allow the comparison and semplificate the choice, the Levelized Cost of Energy (LCOE) values have been taken into account. They have been calculated for all the scenarios by means of the equation below:

$$LCOE = \frac{Total\ lifetime\ Cost}{Total\ lifetime\ Output} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

where the numerator corrensponds to the NPC taking into account nvestment expenditures in year I_t t, operations and maintenance expenditures M_t, fuel expenditures F_t; while the denominator refers to electricity generation E_t over a project lifetime of n years. The term r is the considered discount rate.

According to the calculation which have been carried out, the Table 22 show the results confirming once again the *Scenario 2* as best option to be chosen. In this way, it is also possible

to highlight even the monthly household electric energy bill, computed considering the share of electric demand devoted to household supply in each scenario, with respect to the total camp demand.
It is worth noting, in the *Scenario 0* and *Scenario 1* does not make sense calculate the monthly energy bill, since in both these case there is no provision for any electricity supply for households.

For what concerns thermal energy and the related cooking scenarios proposed, drawing conclusions seems to be so much easier than in the electricity case. In fact, the results clearly highlight that, the less three-stone fire technologies are adopted for the cooking practices, the less is the value related to operating cost and the amount of fuel consumed in turn.

Table 24 - Household Electric Energy Bill

Electric Scenarios Comparison		LCOE [$/kWh]	Monthly Household Electric Energy Bill [$]
Scenario 0	Base Load	0,69	$ -
Scenario 1	Base Load 100% REN	0,40	$ -
Scenario 2	New_PV+diesel	0,58	$ 4,49
Scenario 3	New_PV+Wind+Diesel	0,59	$ 4,56
Scenario 4	Camp Total PV+Diesel	0,65	$ 5,20

In this regard, the assumed *Scenario 0** has been introduced in the comparison just with the aim of underlining the fuel expenditure in a situation in which all the households would adopt the traditional high-consumption devices of three-stone fire for their cooking practices. In fact the baseline situation in Goudoubo it is in reality reflected in the *Scenario 0*: thanks to the adoption of the improved cookstoves by 65% of camp population, the value of NPC has considerably decreased.

Table 25 - Cooking Scenarios proposed for Goudoubo

Cooking Scenarios Comparison	Three-Stone Fire	Improved Cookstoves	Solar Cookers	Initial Capital Cost [$]	Operating Cost [$/year]	NPC [$]
Scenario 0*	100%			$ -	$ 2.454.295,29	$ 24.542.952,93
Scenario 0	35%	65%		$ 11.375,00	$ 1.816.594,82	$ 18.210.170,29
Scenario 1		100%		$ 17.500,00	$ 1.472.198,72	$ 14.780.598,10
Scenario 2		60%	40%	$ 105.000,00	$ 883.319,23	$ 9.184.857,76

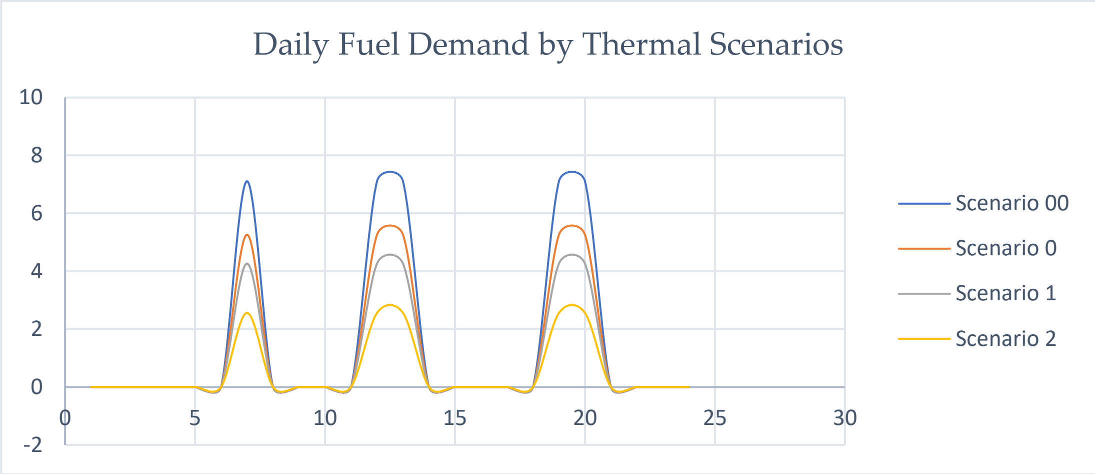


Chart 11 - Daily Fuel Demand by Cooking Scenarios

Focusing on the *Scenario 2*, where it is suggested to adopt solar cookers for all the households, even the high initial capital cost is high due to the investment for the cooking technologies, over the entire lifetime of the project, it can be seen the NPC is reduced by half with respect to the *Scenario 0*. In any case, even just looking at the *Scenario 1*, where the cooking practices had been shifted to the utilization of the more efficient improved cookstoves as unique cooking devices, the value of the NPC and the operating cost began to decrease.

In general for the cooking scenarios, the operation costs simply refers to the cost of consumed fuel. It is worth noting, in the *Scenario 1* and *Scenario 2,* the salvages related to the fuel savings are so considerable that, although the operation costs also includes the investment for the adopted stoves in the replacement years, it still remains substantially lower than in the previous cases. The Chart 9 above shows the daily fuel demand related to each of the proposed solutions. In terms of thermal energy, it makes no sense talking about LCOE, but in order to have an idea of the cost of energy, the monthly household energy bill has been calculated also for the cooking scenarios. Reminding the 30% of the total amount of consumed fuel is used to be donated by UNHCR or other humanitarian agency, for the purpose of calculating the cost of energy for household, it has been taking into account only the remaining 70%, obtaining as results:

Table 26 - Household Thermal Energy Bill

Cooking Scenarios Comparison			Monthly Household Cooking Energy Bill [$]
Scenario 0*	Three-Stone Fire	$	40,90
Scenario 0	Three-Stone Fire + ICS	$	30,33
Scenario 1	ICS	$	24,70
Scenario 2	ICS+Solar Cookers	$	15,72

With the aim of guaranteeing an adequate access to energy to the wholr population of Goudoubo refugee camp, it can be definitely demonstrated the most cost-effective solution among all the presented options, is given by the combination of the *Scenario 2* for the electric case with the *Scenario 2* of the thermal case. In this way, each household, paying a total energy bill of US$20,21 per month, could count on an affordable, reliable and, especially, clean and sustainable energy.

Conclusions

The development of this thesis allows to give way to a series of conclusive considerations.

For the purpose of the elaborate, intended to deliver a comprehensive guideline for energy planning in humanitarian settings, three different forms of activities have been performed. The initial part of the work has been dedicated to an accurate literature review aimed at getting an overall picture of the theoretical framework concerning the energy topic in humanitarian context. Reports, research papers, handbooks and manuals have been consulted and analysed in order to form a new conceptual framework.
It allowed, indeed, the author to design a novel energy response procedure, from energy needs evaluation to energy supply, enclosing both new proposed quantitative or qualitative tools, adjustments of the already existing ones or the simple inclusion of them as in the case of the well-structured softwares deemed to be appropriate.
Only in the latter part of the work, it has been possible to implement the proposed guideline to a real case study allowing to emphasize the significance and practicality of it and seeking to finally support humanitarian practitioners with a holistic approach, guaranteeing the affected people better living conditions, by acting in terms of energy.

The importance of considering energy as formal part of standard needs in the humanitarian settings has been highlighted more than once throughout the discussion. Unfortunately humanitarian actors are not always provided of the adequate preparedness to act promptly for the fulfilment of energy supply in their mandates. Since the existence of several but always incomplete tools and manuals, the need for a comprehensive procedure specifically designed for energy planning and intervention in humanitarian contexts has clearly emerged.

The adoption of targeted surveys directly addressed to the affected populations allows to act with a bottom-up approach in order to deliver an always tailored and adequate intervention, taking into account specific economic and socio-cultural factors and determined energy requirements. In this regard, it is possible to overcome the common practice of scaling-up project strategy.

According to the trends of forcibly displaced people’s movements recorded over the last decades, there is no reason to continue to consider refugee camps and informal settlements as temporary solutions. In this sense, there are no longer grounds for energy programmes depending on inefficient traditional fuelled systems: it is necessarily required to replace these energy sources or devices with sustainable energy solutions numerous advantages for refugees, host communities and, of course, for the environment.

In this respect, the studied case of Goudoubo refugee camp served to practically draw the attention to the transition from traditional to modern technologies in terms of electric and thermal energy. In general, LCOE, which the proposed scenarios' assessment and comparison have been based on, used to dramatically increase when adopting conventional fuels: this is because of the contribution given by the cost of fuel to the Operating Cost and consequently to the NPC value which the final cost of energy is function of. It can be said indeed the implementation of modern technologies implies a high investment, but nevertheless the expenditure is offset by the considerable savings in fuel consumption.

The work as a whole paves the way to further evolution of the discussed matter of energy solution planning in humanitarian contexts, maily taking into consideration the possibility of the development of a ready-to-use tool in order to improve even more the response capacity of the humanitarian actors to deliver adequate energy programmes in any study locations, from the earliest needs assessment to the final impact evaluation.

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Appendix A.1

Site planning standards for services and infrastructure (UNHCR)

Description	Standard	Further consideration
Communal latrine	1 per 20 persons - emergency phase	Separate latrine areas for men and women For long-term accommodation use one household latrine per family
Latrine distance	Not more than 50m from shelter and not closer than 6m	Latrines must be close enough to encourage their use but far enough to prevent problems with smells and pests
Shower	1 per 50 persons	Separate, well drained, shower areas for men and women
Water supply	20 litres per person per day	
Water tap stand	1 per 80 persons	1 per community
Water distance	Max. 200m from household	No dwelling should be further than a few minutes' walk from a water distribution point
Rubbish container of 100 litres	1 per 50 persons	1 per 10 families
Refuse pit – 2mx5mx2m	1 per 500 persons	1 per 100 families
Health centre	1 per 20,000 persons	1 per settlement Include water and sanitation facilities
Referral hospital	1 per 200,000 persons	1 per 10 settlements
School	1 per 5,000 persons	1 per sector 3 classrooms, 50 Sqm.
Distribution centre	1 per 5,000 persons	1 per sector
Market place	1 per 20,000 persons	1 per settlement
Feeding centre	1 per 20,000 persons	1 per settlement
Storage area	15 to 20 Sqm. per 100 persons	Refugee storage
Lighting	As appropriate	Consider priority locations such as latrine, wash areas, public service areas
Registration area	As appropriate	May include arrivals area, medical clearance, distribution, parking
Administration / office	As appropriate	
Security post	As appropriate	
Security fencing	Depending on the circumstances	

Appendix A.2

Total Energy Access Minimum Standards (Practical Action 2012)

Energy Service	Minimum Standard
Lighting	300 lumens at household level (per 4 hours during night time)
Cooking	1 kg woodfuel or 0.3 kg charcoal or 0.04 kg LPG or 0.2 litres of kerosene or ethanol per person per day, taking less than 30 minutes per household per day to obtain Minimum efficiency of improved wood and charcoal stoves to be 40% greater than a three-stone fire in terms of fuel use Annual mean concentrations of particulate matter (PM2.5) < 10 μg/m3 in households, with interim goals of 15 μg/m3, 25 μg/m3 and 35 μg/m3
Space Heating	Minimum daytime indoor air temperature of 12ºC
Cooling	Food processors, retailers and householders have facilities to extend life of perishable products by a minimum of 50% over that allowed by ambient storage All health facilities have refrigeration adequate for the blood, vaccine and medicinal needs of local populations Maximum indoor air temperature of 30ºC
Information and communications	People can communicate electronic information beyond the locality in which they live
Earning a living	Access to energy is sufficient for the start up of any enterprise The proportion of operating costs for energy consumption in energyefficient enterprises is financially sustainable.

Appendix B

First-Step Sizing of solar PV technologies

1) *Rough estimation of the accumulation system*

The battery type recommended for using in solar PV system is deep cycle battery. Deep cycle battery is specifically designed for to be discharged to low energy level and rapid recharged or cycle charged and discharged day after day for years [33].

Once the total daily consumption referred to all the operating appliances has been estimated and therefore the daily average electricity load L_d obtained. The energy which has to be storage is given by:

$$L_{acc} = \frac{L_d * days\ of\ autonomy}{\eta_{batt}} \quad [kWh]$$

With η_{batt} is the charge/discharge cycle battery efficiency. The battery bank useful capacity is then computable as:

$$E_{batt} = \frac{L_{acc}}{V_{batt}} \quad [Ah]$$

Where V_{batt} is usually 12, 24 or 48 V but also other configurations are possible.

Now the battery bank overall capacity is given by:

$$Cap = \frac{E_{batt}}{D_{dis}} \quad [Ah]$$

With D_{dis} depth of discharge of the selected batteries.

In order to evaluate the number of batteries which have to be selected:

$$N_s = \frac{V_{syst}}{V_{batt}}$$

$$N_p = \frac{Cap}{C_{batt}}$$

$$N_{tot} = N_s * N_p$$

Where N_s is the number of batteries in series, N_p the number of batteries in parallel and N_{tot} the total number of batteries; while V_{syst} is the chosen system voltage which must be equal of higher of the PV module voltage; C_{batt} is the Amp-hour rating of selected batteries.

2) *Power Output Estimation*

The systems have to be designed considering the worst photovoltaic production and the highest possible load. Solar resource data referring to Global Horizontal daily Irradiation, expressed in [kWh/m^{2}day] provided in the previous *Diagnosis* need to be expressed the daily average solar irradiation hours:

$$h_s = \frac{GHI}{R_s} \qquad \left[\frac{kWh}{kW * day}\right]$$

Where R_s is the solar radiation energy flux equal to 1 kW/m^2.
Finally, the electric photovoltaic output can be calculated from:

$$P = \frac{L_d}{h_s * \rho} \quad [kW]$$

After evaluating the performance ratio parameter ρ that includes the location of the modules and their status of maintenance.

3) *PV Module Selection*

Trivially the number of the desired modules have to be calculated considering the nominal tension of the single module with respect of the total tension of the batteries V_{batt}.

4) *Inverter Sizing*

An inverter is used in the system where AC power output is needed. The input rating of the inverter should never be lower than the total wattage of appliances. The inverter must have the same nominal voltage as the battery (12,24 or 48 V).

For stand-alone systems, the inverter must be large enough to handle the total amount of Watts used at one time. The inverter size should be 25-30% bigger than the forecasted maximum peak power. In case of appliance type is motor or compressor then inverter size should be minimum 3 times the capacity of those appliances and must be added to the inverter capacity to handle surge current during starting.

For grid tie systems or grid connected systems, the input rating of the inverter should be same as PV array rating to allow for safe and efficient operation.

5) *Solar Charge Controller Sizing*

The solar charge controller should match the voltage of PV array and batteries and it must has enough capacity to handle the current from PV array.

For the series charge controller type, the sizing of controller depends on the total PV input current which is delivered to the controller and also depends on PV panel configuration (series or parallel configuration).

According to standard practice, the sizing of solar charge controller is to take the short circuit current of the PV array, and multiply it by the coefficient 1.3.

Appendix C.1

Daily Energy Demand for Scenario 0 and Scenario 1

User Class		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total Demand by Appliances [Wh/day]	
Community																				50	50	50				150	
		500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	12000	
							1000	1000	1000										1000	1000	1000					6000	
													120	120	120	120	120									600	
									100	100	100															300	
							320	320	320										320	320	320					1920	
		1000	1000	1000	1000																1000	1000	1000	1000	1000	9000	
		0	0	0	0	0																0	0	0	0	0	
	TOTAL HEALTH CENTER	1500	1500	1500	1500	500	1820	1820	1920	600	600	500	620	620	620	620	620	500	1820	1870	2870	1550	1500	1500	1500	29970	10939 kWh/year
Productive											10000	10000	10000	10000	10000	10000	10000									70000	
								12000	12000	12000								12000	12000	12000						72000	
	TOTAL WATER PUMP	0	0	0	0	0	0	12000	12000	12000	10000	10000	10000	10000	10000	10000	10000	12000	12000	12000	0	0	0	0	0	142000	51830 kWh/year
	TOTAL	1500	1500	1500	1500	500	1820	13820	13920	12600	10600	10500	10620	10620	10620	10620	10620	12500	13820	13870	2870	1550	1500	1500	1500	171970	62769 kWh/year

Appendix C.2

Daily Energy Demand for Scenario 2 and Scenario 3

User Class	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total Demand by Appliances [Wh]	
Household																			17500	17500	17500				52500	
							24500											24500	24500						73500	
							0													0	0				0	
						175000														175000	175000	175000	175000		875000	
	0	0	0	0	0																0	0	0	0	0	
	0	0	0	0	0	175000	24500	0	0	0	0	0	0	0	0	0	0	24500	42000	192500	192500	175000	175000	0	1001000	Total Daily Demand - Household Level [Wh
Community																			50	50	50				150	
	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	12000	
						1000	1000	1000										1000	1000	1000					6000	
												60	60	60	60	60									300	
								100	100	100															300	
						320	320	320										320	320	320					1920	
	1000	1000	1000	1000																1000	1000	1000	1000	1000	9000	
	100	100	100	100	100																100	100	100	100	900	
								40	40	40					40	40	40								240	
										100	100				100	100									400	
										3000	3000				3000	3000									12000	
																		100	100	100	100	100			500	
						100	100											100	100	100	100	100	100	100	900	
								40	40	40					40	40	40								240	
										200	200				200	200									800	
																		200	200	200	200	200			1000	
																		100	100	100	100	100	100	100	700	
							50	50	50	50								50	50	50					350	
									500	500							500	500							2000	
								750	750	750						750	750	750	750						5250	
								125	125	125						125	125	125	125						875	
																		500	500	500					500	
									500	500						500	500								2000	
	3500	3500	3500	3500	3500	3500														3500	3500	3500	3500	3500	38500	
	5100	5100	5100	5100	4100	5420	1970	2925	2605	5905	3800	560	560	560	3940	5315	2455	4245	3795	7420	5650	5600	5300	5300	97825	Total Daily Demand - Community Level [W
Productive										10000	10000	10000	10000	10000	10000	10000									70000	
							12000	12000	12000								12000	12000	12000						72000	
								45	45	45						45	45	45	45						315	
	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	18000	
						450												450	450	450	450	450	450		3150	
																									0	
								25	25	25						25	25	25	25						175	
	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	30000	
																		500	500	500	500				2000	
																		250	250	250	250	250			1250	
								5	5	5						5	5	5							30	
								100	100	100	100	100	100												600	
								50	50	50	50	50	50												300	
								70	70	70						70	70	70	70						490	
									700	700						700	700								2800	
										1050	1050	1050	1050												4200	
											175	175	175												525	
									700	700						700	700								2800	
																		700	700	700					2100	
	2000	2000	2000	2000	2000	2450	14000	14295	15695	14745	13375	13375	13375	12000	12000	13545	15545	16045	16040	3900	3200	2700	2450	2000	210735	Total Daily Demand - Productive Level [Wh

Appendix C.3

Daily Energy Demand for Scenario

	User Class	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total Demand by Appliances [Wh]	
Block 1	Household																			5000	5000	5000				15000	
								7000											7000	7000						21000	
								0													0	0				0	
							50000														50000	50000	50000	50000		250000	
		0	0	0	0	0																0	0	0	0	0	
		0	0	0	0	0	50000	7000	0	0	0	0	0	0	0	0	0	0	7000	12000	55000	55000	50000	50000	0	286000	Block1_Total Daily Demand - Household Level [Wh]
	Community																			50	50	50				150	
		500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	12000	
							1000	1000	1000										1000	1000	1000					6000	
													60	60	60	60	60									300	
									100	100	100															300	
							320	320	320										320	320	320					1920	
		1000	1000	1000	1000																1000	1000	1000	1000	1000	9000	
		100	100	100	100	100																100	100	100	100	900	
		1600	1600	1600	1600	600	1820	1820	1920	600	600	500	560	560	560	560	560	500	1820	1870	2870	1650	1600	1600	1600	30570	Block1_Total Daily Demand - Community Level [Wh]
Block 2	Household																			10000	10000	10000				30000	
								14000											14000	14000						42000	
								0													0	0				0	
							100000														100000	100000	100000	100000		500000	
		0	0	0	0	0																0	0	0	0	0	
		0	0	0	0	0	100000	14000	0	0	0	0	0	0	0	0	0	0	14000	24000	110000	110000	100000	100000	0	572000	Block2_Total Daily Demand - Household Level [Wh]
	Community								40	40	40					40	40	40								240	
											100	100				100	100									400	
											3000	3000				3000	3000									12000	
																			100	100	100	100	100			500	
							100	100											100	100	100	100	100	100	100	900	
									40	40	40					40	40	40								240	
											200	200				200	200									800	
																			200	200	200	200	200			1000	
																			100	100	100	100	100	100	100	700	
		0	0	0	0	0	100	100	80	80	3380	3300	0	0	0	3380	3380	80	500	500	500	500	500	200	200	16780	Block2_Total Daily Demand - Community Level [Wh]
Block 3	Household																			2500	2500	2500					
								3500											3500	3500							
								0													0	0					
							25000														25000	25000	25000	25000			
		0	0	0	0	0																0	0	0	0		
		0	0	0	0	0	25000	3500	0	0	0	0	0	0	0	0	0	0	3500	6000	27500	27500	25000	25000	0	143000	Block3_Total Daily Demand - Household Level [Wh]
	Community							50	50	50	50								50	50	50					350	
										500	500							500	500							2000	
									750	750	750						750	750	750	750						5250	
									125	125	125						125	125	125	125						875	
																			500	500	500					500	
										500	500						500	500								2000	
		3500	3500	3500	3500	3500	3500														3500	3500	3500	3500	3500	38500	
		3500	3500	3500	3500	3500	3500	50	925	1925	1925	0	0	0	0	0	1375	1875	1925	1425	4050	3500	3500	3500	3500	50475	Block3_Total Daily Demand - Community Level [Wh]
	Productive										10000	10000	10000	10000	10000	10000	10000									70000	
								12000	12000	12000								12000	12000	12000						72000	
									45	45	45						45	45	45	45						315	
		750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	750	18000	
							450												450	450	450	450	450	450		3150	
																										0	
									25	25	25						25	25	25	25						175	
		1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	1250	30000	
																			500	500	500	500				2000	
																			250	250	250	250	250			1250	
									5	5	5						5	5	5							30	
									100	100	100	100	100	100												600	
									50	50	50	50	50	50												300	
									70	70	70						70	70	70	70						490	
										700	700						700	700								2800	
											1050	1050	1050	1050												4200	
												175	175	175												525	
										700	700						700	700								2800	
																			700	700	700					2100	
		2000	2000	2000	2000	2000	2450	14000	14295	15695	14745	13375	13375	13375	12000	12000	13545	15545	16045	16040	3900	3200	2700	2450	2000	210735	Block3_Total Daily Demand - Productive Level [Wh]

Appendix D.1

Household Survey. Source: Author

Section 0HH - Context Assessment

Question ID	Question	Answer
1)	Name of the camp	
2)	GPS location	
3)	Type of settlement	□ Camp □ Informal settlement
4)	Type of main group living	□ IDPs □ Refugees □ Host community members □ Asylum seekers
5)	Type of shelter	□ No shelter (living in the open) □ Communal shelter (e.g. school) (Plastic sheet and wood with/ without grass but no mud or brick walling), that provides no privacy □ Emergency Shelter (Plastic sheet and wood with/without grass but no mud or brick walling) that provides privacy and protection □ UNHCR Tent □ Transitional Shelter (e.g. iron sheet roofing) that provides privacy and protection)
6)	Expected time of stay/how long have they been there	_____ Days/months
7)	Total population	
8)	Number of households	

Section 2HH - General Household Information

Question ID	Question	Answer
9)	Are you the head of the household?	□ Yes □ No
10)	If no, which role do you have in the household?	

11)	Can you answer on behalf of the head of the household?	□ Yes □ No
12)	Specify the gender of the head of household	□ Male □ Female
13)	How old are you?	
14)	How many people live in your HH? (specify age and gender of each component of the household)	
15)	Which is the main occupation of each component of the household?	□ Business owner/ manager/ self-employed □ Employee receiving wage/Incentive worker □ Farming/agriculture/fishing □ Casual/Day Laborer □ Volunteer with organisations □ Keeping house or raising children full-time □ Unemployed/ laid-off/ looking for work □ Retired □ Disabled / cannot work due to health issues □ Other
16)	What is the primary source of livelihood or income in your household?	□Farming / livestock NOT paid labour □ Farming / livestock paid labour □ Trade □ Retail □ Shop owner □ Paid employee □ Casual labourer □ Artisan □ Blacksmith □ Tailor □ Pottery □ Carpentry □ Mechanic □ Hairdresser □ Physician □ Transportation □ Maid □ Work with NGO □ Civil service □ Other □ Aid

17)	Do others in your household have any other jobs or role in the community?	□*Farming / livestock* □ *Farming / livestock paid labour* □ *Casual labourer* □ *Blacksmith* □ *Tailor* □ *Pottery* □ *Carpentry* □ *Mechanic* □ *Hairdresser* □ *Physician* □ *Transportation* □ *Maid* □ *Work with NGO* □ *Local government involvement* □ *Committee member* □ *Church leader* □ *Member of a coop* □ *Other* □ *None*

Section 3HH - Household Cooking

Question ID	Question	Answer
18)	Where do you normally do your cooking?	□ In house, in a room that is **NOT** a sleeping area □ In house, in a room that is also a sleeping area □ In a separate building □ In a veranda (roofed platform with at least two open sides) □ Outdoors □ Other, specify □ No food cooked by household members
19)	[if cooking is done indoors, on a veranda] Do you usually use a chimney, hood, or other exhaust system while cooking?	□ Yes □ No
20)	Do you share any of the following resources with other households?	□ Space □ Stoves □ Fuel □ Food □ Other (please specify) □ None
21)	What type of cookstove do you use for daily cooking in your household? (select multiple)	□ *Three stone fire* □ *Metal stove* □ *Fuel efficient stove* □ *LPG / Gas stove* □ *Kerosene stove* □ *Electric stove* □ *Solar cooker* □ *Other (please specify which one)* □ *None*

22)	Which is the most frequently used for cooking? (select one of the previous)	□ *Three stone fire* □ *Metal stove* □ *Fuel efficient stove* □ *LPG / Gas stove* □ *Kerosene stove* □ *Electric stove* □ *Solar cooker* □ *Other (please specify which one)* □ *None*
23)	Do you use a secondary cookstove? If yes what type?	□ *Three stone fire* □ *Metal stove* □ *Fuel efficient stove* □ *LPG / Gas stove* □ *Kerosene stove* □ *Electric stove* □ *Solar cooker* □ *Other (please specify which one)* □ *None*
24)	How long has you or your household been using this cooking source?	#___ (months)
25)	How did your household get this cooking stove? PRIMARY	□ Purchased in full □ Purchased in instalments □ Donated □ Received voucher in lottery □ Self-Built □ Other (please specify)
26)	How did your household get this cooking stove? SECONDARY	□ Purchased in full □ Purchased in instalments □ Donated □ Received voucher in lottery □ Self-Built □ Other (please specify)
27)	[if purchased] Where did you purchase it? PRIMARY/SECONDARY	□ Inside the camp □ Outside the camp
28)	Who is responsible for cooking meals in your household?	
29)	How many hours do you or someone in your household spend cooking on a typical day?	#
30)	How many hours per day (in a typical month) the stove is lit?	#
31)	What types of cooking fuel do you use? (multiple options possible)	□ *Firewood* □ *Charcoal* □ *Bisomass (straw, shrubs, agriculture waste)* □ *Biomass charcoal briquettes* □ *Kerosene* □ *Ethanol* □ *LPG / gas* □ *Briquettes/pellets* □ *Animal Waste* □ *Electric* □ *Solar* □ *Other* □ *None*

<table>
<tr><td>32)</td><td>What is your primary cooking fuel or which fuel does your household use most often? (please choose one of the previous)</td><td></td></tr>
<tr><td>33)</td><td>How much does your household consume and spend in a typical month on the following fuels for the cookstoves?</td><td>
<table>
<tr><td>Supply</td><td>Unit</td><td>Quantity</td><td>Amount spent</td></tr>
<tr><td>Firewood (purchased)</td><td>Kg</td><td></td><td></td></tr>
<tr><td>Firewood (received for free)</td><td>Kg</td><td></td><td>-</td></tr>
<tr><td>Firewood (collected)</td><td>Kg</td><td></td><td>-</td></tr>
<tr><td>Charcoal (purchased)</td><td>Kg</td><td></td><td></td></tr>
<tr><td>Charcoal)received for free(</td><td>Kg</td><td></td><td>-</td></tr>
<tr><td>Kerosene</td><td>litre</td><td></td><td></td></tr>
<tr><td>Ethanol</td><td></td><td></td><td></td></tr>
<tr><td>LPG</td><td></td><td></td><td></td></tr>
<tr><td>Briquettes</td><td>Kg</td><td></td><td></td></tr>
<tr><td>Other (please specify)</td><td></td><td></td><td></td></tr>
</table>
</td></tr>
<tr><td>34)</td><td>How many hours a week does someone from your household spend to collect/gather/purchase this fuel?</td><td>#</td></tr>
<tr><td>35)</td><td>In the last 12 months, has your household had difficulty with access to cooking fuel for your primary cooking source?</td><td>□ Yes
□ No</td></tr>
<tr><td>36)</td><td>[if yes] What months of the year did you have difficulty with access to cooking fuel?</td><td>_____</td></tr>
<tr><td>37)</td><td>What was the reason that you had difficulty accessing this cooking fuel?</td><td>□ Scarcity
□ High cost
□ Distance
□ Other</td></tr>
<tr><td>38)</td><td>Has any member of your household experienced any incident of violence during fuel collection in the last month?</td><td>□ Yes
□ No</td></tr>
<tr><td>39)</td><td>Is there anything that you would like to change about your cooking situation? If so, what?</td><td>□ None
□ Kitchen is hot
□ Less smoke
□ Improved Ventilation
□ Hard to start the fire
□ More access to fuel
□ More efficient cook stoves
□ Less expensive
□ Better area for cooking, less dust
□ Other</td></tr>
</table>

Section 4HH - Household Lighting

Question ID	Question	Answer
40)	What types of lighting source do you use in your household? (multiple answer)	□ *Indirect lighting (e.g. street lights)* □ *Candles* □ *Kerosene lantern* □ *Gas lantern* □ *Battery Powered Torch* □ *Phone flashlights* □ *Solar lantern* □ *Solar home system* □ *Generator* □ *Electricity Light* □ *Other* □ *None*
41)	What is your household's primary source of lighting? (please select one of the previous)	
42)	What does your household use these lighting sources for?	□ *General lighting* □ *Cooking* □ *Studying* □ *Social Activity* □ *Walking Outside* □ *Checking on animals* □ *Gardening* □ *Other* *None*
43)	How much does your household spend on lighting per month?	____$ (local)
44)	How many hours can you light your home on average after it has become dark outside?	□ Less than 1 hour □ 1-2 hours □ 2-3 hours □ 3-4 hours □ >4 hours □ Other (please specify)
45)	On average, how many hours a day of lighting do you need?	____ hrs IN THE MORNING BEFORE SUNRISE ____hrs IN THE EVENING AFTER SUNSET ____hrs DURING DAYLIGHT HOURS
46)	Would you prefer another type of lighting technology if you had the choice? What would you prefer?	
47)	If your household had more light, what activities would you use it for?	

Section 4.1HH – Solar Lanterns [if the answer of Q40 is Solar Lantern]

Question ID	Question	Answer
48)	How many solar lantern do you use?	#
49)	What is the manufacturer and model of this solar lantern?	Manufacturer: ________ Model: ______________ Don't Know
50)	How would you describe your ownership of solar lantern equipment?	□ Own outright (Paid all the cost upfront or finished repaying) □ On hire purchase / paying in instalments □ Renting the equipment □ Pay As You Go arrangement (electricity credits) □ Sharing (for free) with someone who owns one □ Received as donation and can keep it if I leave the camp □ Received as donation but have to give it back if I leave the camp □ Other (specify)
51)	Have you had any of these problems with the SOLAR LANTERNS?	□ Broken (would not charge or light) □ Stolen □ Traded/sold □ Lent and not got it back □ Other (please specify)

Section 4.2HH – Solar Home Systems [if the answer to Q40 is Solar Home System]

Question ID	Question	Answer
52)	What is the manufacturer and model of this solar home system?	Manufacturer: ________ Model: ______________ Unbranded

53)	How did you obtain it?	□ Shop outside the camp □ Shop inside the camp □ Donors/Camp personnel/NGOs □ Brought it with me from previous residence □ Traded/received from another camp resident □ Traded/received from somebody outside the camp □ Other (specify)
54)	How many light bulbs do you use with the Solar Home System?	#
55)	Have you had any of these problems with the SOLAR HOME SYSTEM?	□ Broken (would not charge or light) □ Stolen □ Traded/sold □ Lent and not got it back □ Other (please specify)

Section 5HH - WASH (water treatment, supply and sanitation)

Question ID	Question	Answer
56)	How many minutes does it take to collect drinking water, including walking to, time spent at the water point and walking back from the water point	□ Under 30 minutes □ *30 minutes to less than 1 hour* □ *1 hour to less than half a day* □ *Half a day* □ *More than half a day* □ *I don't know* □ *I don't want to answer*
57)	How many water containers (bucket and/or jerry can) does your HH have?	#
58)	What type of water container does the HH have? (To be observed and filled by the enumerator)	□ *Bucket 10 to 20 Lt* □ *Jerry can 10 to 20 Lt* □ *Drum 250 Lt* □ *None* □ *Other*
59)	Where do you and your family usually go to the toilet?	□ *Latrine built by NGO* □ *Family-owned and constructed latrine* □ *Bush* □ *River/stream* □ *Latrine built by community* □ *Other*
60)	When do you wash your hands? (Multiple selection)	□ *Before Breastfeeding* □ *Before Cooking* □ *After cleaning child's feces* □ *After Defecating*

		□ *Before eating* □ *I don't wash my hands* □ *Other*
61)	What do you usually wash your hands with?	□ *Soap* □ *Ash* □ *Water* □ *Nothing* □ *Other*
62)	Which type of hand-washing facility is present in the household? (To be observed and filled by the enumerator)	□ *Bucket with water and soap* □ *Bucket with water and ash* □ *Bucket with no water and no soap/ash* □ *Tipi tap (5L jerry can)* □ *Plastic Cattles (1L)* □ *Nothing* □ *Other*

Section 6HH - Access to Electricity

Question ID	Question	Answer
63)	What are the sources of electricity in your household? (multiple options possible)	□ *Electric grid* □ *Local mini grid* □ *Generator* □ *Solar home system* □ *Solar powered lantern* □ *Disposable batteries* □ *Other* □ *No electricity available*
64)	What is the primary source of electricity in your household? (please choose one)	□ *Electric grid* □ *Local mini grid* □ *Generator* □ *Solar home system* □ *Solar powered lantern* □ *Disposable batteries* □ *Other* □ *No electricity available*

65)	What does your household use these electricity sources for?	□ *Lighting* □ *Phone Charging* □ *Fan* □ *Radio* □ *TV* □ *Air Conditioner* □ *Refrigeration* □ *Internet modem* □ *Computers* □ *Water Pump* □ *Agricultural Processing* □ *Electric Cooking Equipment* □ *Clothes Washing Machine* □ *Other* □ *None*
66)	How long have you been using your primary source of electricity in your household?	____ (months)
67)	In a typical month, how many hours per day does your source of electricity provide your household with electricity (per 24 hours)?	____hrs
68)	In a typical month, how many hours per day does your source of electricity provide your household with electricity (from 6PM to 10 PM)?	____hrs
69)	Where do/did your household purchase your primary source of electricity in your household?	□ *Electric company* □ *Pre-paid meter* □ *Community group* □ *Relative* □ *Neighbour* □ *Landlord* □ *Purchased from store* □ *Other* □ *No one*
70)	How much does your household spend on your primary source of electricity (per month)?	____$ (local)

Section 6.1HH - Mobile Phone and Internet Access

Question ID	Question	Answer
71)	How many mobile phones does your household own?	#
72)	How many of these mobile phones have Internet access?	#

73)	Where does your household charge these mobile phones?	□ *At home* □ *Neighbour* □ *Store or Business* □ *Community center* □ *School* □ *Work* □ *Religious insitution* □ *Government building* □ *Nearby community* □ *Other* □ *None*
74)	How many times per week does your household charge mobile phone outside your home?	#
75)	How far from the home is the place where you charge your phone located?	□ *At home* □ *Less than 100m* □ *100m to 500m* □ *500m to 1km* □ *Greater than 1km*
76)	How much does your household spend per charge?	___ $ (local)
77)	How much does your household spend per week on phone airtime (minutes/data)?	___$ (local)
78)	Do you have access to the internet via a computer? If yes, where do you access the Internet?	□ *At home* □ *Neighbour* □ *Store or Business* □ *Community center* □ *School* □ *Work* □ *Religious insitution* □ *Government building* □ *Nearby community* □ *Other* □ *None*
79)	If yes how much do you spend per week on Internet access?	___$ (local)

Appendix D.2

Community Survey. Source: Author

Section 1CF - Community services

Question ID	Question	Answer
1)	Where the facility is located in the camp? (zona, block, area)	
2)	Which kind of facility is the survey about?	□ Camp operations □ Camp security □ Food storage and distribution □ Education □ Community centre (e.g. women's or youth centres) □ Government/NGO □ Religious □ Health □ Water and sanitation □ Other (specify)
3)	How many weekly users do you have?	#
4)	Which groups does your facility serve?	□ People living in the camp □ People living in the host community □ UNHCR or NGO staff □ Others
5)	What best describes the type of building you operate in?	□ UNHCR tent □ UNHCR housing (non-tent) □ Tent (not provided by UNHCR) □ Pre-constructed-structure □ Structure built of natural materials □ Plastic tarp □ Other (please specify) □ Do not operate in a building
6)	How many rooms does your facility occupy?	#
7)	On average, for how many months per year does your facility operate?	_____ months
8)	During those months in which your facility operates, on average for how many days per week does it operate?	_____ days
9)	During those days in which your facility operates, on average for how many hours per day does it operate?	_____ hours
10)	Which of the following applications do you regularly use in your facility activities?	□ Lighting □ ICT & Entertainment (including charging batteries) □ Motive Power (including moving machinery and pumping) □ Heating (including cooking and heat for processing) □ Cooling (including freezing and refrigeration) □ None of the above

Section 2CF - LIGHTING

Question ID	Question	Answer
11)	Which type of the primary energy source you use for lighting in your facility?	□ Electricity □ A non-electric source
12)	Are your lighting needs constant over the year, or do they vary depending on the season?	□ Constant over the year □ Higher in the rainy season □ Higher in the dry season □ Variable, but don't depend on the season

Section 2.1CF - Electricity

Section 2.1.1CF Electricity Needs

Question ID	Question	Answer
13)	Typically, for how many hours per day is the electricity supply needed for lighting?	____ hours
14)	For what proportion of the time that lighting is needed is the electricity supply available?	□ Almost all of the time (95% - 100%) □ Most of the time (75%-95%) □ At least half the time (50% - 75%) □ Less than half the time (less than 50%)
15)	Does inadequate electricity for lighting in terms of quantity or duration constrain your facility's operations?	□ Yes □ No

Section 2.1.2CF – Electricity Supply

Question ID	Question	Answer
16)	What is the primary source of electricity for the supply that is used for lighting? (select multiple if hybrid system)	□ Solar lantern □ Solar stand-alone system □ Rechargeable battery □ Generator (hydro) □ Generator (wind) □ Generator (biomass) □ Generator (biofuel) □ Generator (biogas) □ Generator (diesel) □ Generator (gasoline) □ Mini grid □ Grid □ *(Don't know)*

17)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watts) of the primary electricity supply that is used for lighting?	____ Watt □ *(No name plate or documentation)*
18)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watt hours per day) of the primary electricity supply that is used for lighting?	____ Watt-hours/day □ *(No name plate or documentation)*
19)	How many times per week on average do you face unscheduled interruptions of electricity supply or breakdowns of electricity supply equipment?	_____ times
20)	On average, what is the cumulative length (in hours) of the unscheduled interruptions you face in a week?	_____ hours
21)	What is the current unit price you pay for electricity in $ (local)?	*Per kilowatt-hour (kWh)* ____ / kWh *Per charged battery* ____ / charge *Per litre of liquid fuel* ____ / litre *Per m3 of gaseous fuel* ____ / m3 *Per kg of solid fuel* ____ / kg *Other* ____

Non-Electrical

Question ID	Question	Answer
22)	In the last month, has your facility used any kerosene lamps for lighting?	□Yes □ No
23)	If yes, how many?	#
24)	Thinking about the last 12 months, how much do you estimate that your facility used and spent on average per month on kerosene for lighting?	*Quantity* ___*litres* *Spend* ___*$ (local)*
25)	In the last 1 month, has your facility used any candles for lighting?	□Yes □ No
26)	In the last 1 month, has your facility used any candles for lighting?	□ Yes □ No
27)	Thinking about the last 12 months, how much do you estimate that your facility spent on average per month on candles for lighting?	___ $ (local)
28)	In the last 1 month, has your facility used any dry-cell battery torches for lighting?	□Yes □No
29)	Thinking about the last 12 months, how much do you estimate that your facility spent on average per month on dry-cell batteries for lighting?	___ $ (local)
30)	In the last 1 month, has the facility used any of the following other lighting sources?	□ Diesel/Gasoline Lamp □ LPG Lamp □ Biogas Lamp

		□ Other (specify) □ No other lighting sources

Section 3CF - ICT & ENTERTEINMENT

Question ID	Question	Answer
31)	Which type of primary energy source you use for ICT & Enterteinment?	□ Electricity □ A non-electric source
32)	For which activities do you use ICT & entertainment?	
33)	Is energy for ICT & Entertainment provided from the same primary electricity source as lighting?	□ Yes □ No

_Needs

Question ID	Question	Answer
36)	Typically, for how many hours per day is the electricity supply needed for ICT & Entertainment?	_____ hours
37)	For what proportion of the time that ICT & Entertainment is needed is the electricity supply available?	Almost all of the time (95% - 100%) Most of the time (75%-95%) At least half the time (50% - 75%) Less than half the time (less than 50%)

_Supply

Question ID	Question	Answer
38)	What is the primary source of electricity for the supply that is used for ICT & Entertainment? (select multiple if hybrid system)	□ Solar lantern □ Solar stand-alone system □ Rechargeable battery □ Generator (hydro) □ Generator (wind) □ Generator (biomass) □ Generator (biofuel) □ Generator (biogas) □ Generator (diesel) □ Generator (gasoline) □ Mini grid □ Grid □ *(Don't know)*
39)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watts) of the primary electricity supply that is used for ICT & Entertainment?	_____ Watt *(No name plate or documentation)*

40)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watt hours per day) of the primary electricity supply that is used for ICT & Entertainment?	___ Wh/day *(No name plate or documentation)*

Section 4CF - MOTIVE POWER

Question ID	Question	Answer
41)	Which type of primary energy source you use for motive power?	□ Electricity □ A non-electric source
42)	For which processes/activities do you need motive power?	
43)	Is energy for Motive Power provided from the same primary electricity source as ICT & Enterteinment?	□ Yes □ No

Electricity

_Needs

Question ID	Question	Answer
44)	Typically, for how many hours per day is the electricity supply needed for motive power?	__ __ hours
45)	For what proportion of the time that motive power is needed is the electricity supply available?	Almost all of the time (95% - 100%) Most of the time (75%-95%) At least half the time (50% - 75%) Less than half the time (less than 50%)
46)	Does inadequate electricity for motive power in terms of quantity or duration constrain your facility's operations?	□ Yes □ No

_Supply

Question ID	Question	Answer
47)	What is the primary source of electricity for the supply that is used for motive power? (select multiple if hybrid system)	□ Solar lantern □ Solar stand-alone system □ Rechargeable battery □ Generator (hydro) □ Generator (wind) □ Generator (biomass) □ Generator (biofuel) □ Generator (biogas) □ Generator (diesel) □ Generator (gasoline) □ Mini grid □ Grid

		□ *Don't know*
48)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watts) of the primary electricity supply that is used for Motive Power?	____Watt *(No name plate or documentation)*
49)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watt hours per day) of the primary electricity supply that is used for Motive Power?	____ Wh/day *(No name plate or documentation)*

Non-Electrical

Question ID	Question	Answer
50)	What type of non-electrical energy source is used for motive power?	□ Fuel □ Direct mechanical power (e.g. wind or water turbine) □ Human/animal □ Other (specify)
51)	How many hours per day do you need energy for motive power in your facility?	___ hours/day
52)	Does inadequate electricity for motive power in terms of quantity or duration constrain your facility's operations?	□ Yes □ No
53)	Which is the main fuel that is used?	□ Coal □ Briquettes □ Wood □ Other biomass □ Biofuels □ Biogas □ Natural gas □ Kerosene □ LPG, propane or butane □ Diesel □ Gasoline □ Other petroleum products □ Other (specify)
54)	Thinking about the last 12 months, how much do you estimate that your facility spent on average per month on energy for motive power?	____$ (local)
55)	What is the current unit price you pay for Motive Power in $ (local)?	*Per kilowatt-hour (kWh)* ____ / kWh *Per charged battery* ____ / charge *Per litre of liquid fuel* ____ / litre *Per m3 of gaseous fuel* ____ / m3 *Per kg of solid fuel* ____ / kg *Other* ____

Section 5CF - HEATING

Question ID	Question	Answer
56)	Which type of primary energy source you use for Heating?	□ Electricity □ A non-electric source
57)	Which types of heating are provided from this energy source?	□ Cooking □ Space heating □ Water heating □ Other (specify what is heated)
58)	Are your heating needs constant over the year, or do they vary depending on the season?	□ Constant over the year □ Higher in the rainy season □ Higher in the dry season □ Variable, but don't depend on the season

Electricity

_Needs

Question ID	Question	Answer
59)	Typically, for how many hours per day is the electricity supply needed for heating?	___ hours
60)	For what proportion of the time that heating is needed is the electricity supply available?	Almost all of the time (95% - 100%) Most of the time (75%-95%) At least half the time (50% - 75%) Less than half the time (less than 50%)
61)	Does inadequate electricity for heating in terms of quantity or duration constrain your facility's operations?	□ Yes □ No

_Supply

Question ID	Question	Answer
62)	What is the primary source of electricity for the supply that is used for heating? (select multiple if hybrid system)	□ Solar lantern □ Solar stand-alone system □ Rechargeable battery □ Generator (hydro) □ Generator (wind) □ Generator (biomass) □ Generator (biofuel) □ Generator (biogas) □ Generator (diesel) □ Generator (gasoline) □ Mini grid □ Grid □ *Don't know*

63)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watts) of the primary electricity supply that is used for heating?	____Watt *(No name plate or documentation)*
64)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watt hours per day) of the primary electricity supply that is used for Heating?	____ Wh/day *(No name plate or documentation)*

Non-Electrical

Question ID	Question	Answer
65)	What type of non-electrical energy source is used for heating?	□ Fuel □ Solar □ Other (specify)
66)	How many hours per day do you need energy for heating in your facility?	___ hours/day
67)	Does inadequate electricity for heating in terms of quantity or duration constrain your facility's operations?	□ Yes □ No
68)	Which is the main fuel that is used?	□ Coal □ Briquettes □ Wood □ Other biomass □ Biofuels □ Biogas □ Natural gas □ Kerosene □ LPG, propane or butane □ Diesel □ Gasoline □ Other petroleum products □ Other (specify)
69)	Thinking about the last 12 months, how much do you estimate that your facility spent on average per month on energy for heating?	____$ (local)
70)	What is the current unit price you pay for heating in $ (local)?	*Per kilowatt-hour (kWh)* ____ / kWh *Per charged battery* ____ / charge *Per litre of liquid fuel* ____ / litre *Per m3 of gaseous fuel* ____ / m3 *Per kg of solid fuel* ____ / kg *Other* ____

Section 6CF - COOLING

Question ID	Question	Answer
71)	Which type of primary energy source you use for Cooling?	□ Electricity □ A non-electric source
72)	Are your heating needs constant over the year, or do they vary depending on the season?	□ Constant over the year □ Higher in the rainy season □ Higher in the dry season □ Variable, but don't depend on the season

Section 6.1CF – Electricity for Cooling

Section 6.1.1CF – Electricity Needs for Cooling

Question ID	Question	Answer
73)	Typically, for how many hours per day is the electricity supply needed for cooling?	___ hours
74)	For what proportion of the time that cooling is needed is the electricity supply available?	Almost all of the time (95% - 100%) Most of the time (75%-95%) At least half the time (50% - 75%) Less than half the time (less than 50%)
75)	Does inadequate electricity for cooling in terms of quantity or duration constrain your facility's operations?	□ Yes □ No

Section 6.1.2 – Electricity Supply for Cooling

Question ID	Question	Answer
76)	What is the primary source of electricity for the supply that is used for cooling? (select multiple if hybrid system)	□ Solar lantern □ Solar stand-alone system □ Rechargeable battery □ Generator (hydro) □ Generator (wind) □ Generator (biomass) □ Generator (biofuel) □ Generator (biogas) □ Generator (diesel) □ Generator (gasoline) □ Mini grid □ Grid □ *Don't know*
77)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watts) of the primary electricity supply that is used for cooling?	____Watt *(No name plate or documentation)*
78)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watt	____ Wh/day

	hours per day) of the primary electricity supply that is used for cooling?	*(No name plate or documentation)*

Section 6.2CF - Non-Electrical Source for Cooling

Question ID	Question	Answer
79)	What type of non-electrical energy source is used for cooling?	□ Fuel □ Solar or waste heat □ Other (specify)
80)	How many hours per day do you need energy for cooling in your facility?	___ hours/day
81)	Does inadequate electricity for cooling in terms of quantity or duration constrain your facility's operations?	□ Yes □ No
82)	Which is the main fuel that is used?	□ Coal □ Briquettes □ Wood □ Other biomass □ Biofuels □ Biogas □ Natural gas □ Kerosene □ LPG, propane or butane □ Diesel □ Gasoline □ Other petroleum products □ Other (specify)
83)	Thinking about the last 12 months, how much do you estimate that your facility spent on average per month on energy for cooling?	____$ (local)
84)	What is the current unit price you pay for cooling in $ (local)?	*Per kilowatt-hour (kWh)* ____ / kWh *Per charged battery* ____ / charge *Per litre of liquid fuel* ____ / litre *Per m3 of gaseous fuel* ____ / m3 *Per kg of solid fuel* ____ / kg *Other* ____

Appendix D.3

Productive Survey. Source: Author

Section 1ES - General Enterprises Services

Question ID	Question	Answer
1)	Where the enterprise is located in the camp? (zona, block, area)	
2)	In what context is this interview being carried out?	□ Respondent owns a business □ Respondent manages a business □ Respondent has a productive activity in the house
3)	Which of these categories would you say the business best fits into?	□ Farming: crop culture □ Farming: livestock/poultry □ Farming: fishery □ Farming: other □ Transport/driving □ Construction □ House repair/carpentry □ Mechanic □ Domestic help/maid □ Tailoring/sewing □ Pottery □ Blacksmith/metalworking □ Agro-processing □ Food preparation/sale □ Hospitality (hotel/restaurant/bar) □ Trade/retail shop - including phone charging □ Physician/healing □ Hairdresser/barber □ Teaching □ Generation or supply of energy □ None of the above □ Other
4)	How long did you start this activity?	_____ months
5)	What best describes the type of building you operate in?	□ UNHCR tent □ UNHCR housing (non-tent) □ Tent (not provided by UNHCR) □ Pre-constructed-structure □ Structure built of natural materials □ Plastic tarp □ Other (please specify) □ Do not operate in a building
6)	How many rooms does your productive activity occupy?	#
7)	On average, for how many months per year does your enterprise or productive activity operate?	_____ months
8)	During those months in which your enterprise or productive activity operates, on average for how many days per week does it operate?	_____ days

9)	During those days in which your enterprise or productive activity operates, on average for how many hours per day does it operate?	____ hours
10)	Has your productive activity ever accessed any of the following financial services?	□ Loans from banks or dedicated moneylenders □ Loans from other camp residents □ Microfinance □ Paying suppliers in instalments □ Grants from UNHCR or other donors
11)	Which of the following applications do you regularly use in your enterprise or productive activity activities?	□ Lighting □ ICT & Entertainment (including charging batteries) □ Motive Power (including moving machinery and pumping) □ Heating (including cooking and heat for processing) □ Cooling (including freezing and refrigeration) □ None of the above

Section 2ES - LIGHTING

Question ID	Question	Answer
12)	Which type of the primary energy source you use for lighting in your enterprise or productive activity?	□ Electricity □ A non-electric source
13)	Are your lighting needs constant over the year, or do they vary depending on the season?	□ Constant over the year □ Higher in the rainy season □ Higher in the dry season □ Variable, but don't depend on the season

Section 2.1ES – Electricity for Lighting

Section 2.1.1ES – Electricity Needs for Lighting

Question ID	Question	Answer
14)	Typically, for how many hours per day is the electricity supply needed for lighting?	____ hours
15)	For what proportion of the time that lighting is needed is the electricity supply available?	□ Almost all of the time (95% - 100%) □ Most of the time (75%-95%) □ At least half the time (50% - 75%) □ Less than half the time (less than 50%)

16)	Does inadequate electricity for lighting in terms of quantity or duration constrain your facility's operations?	□ Yes □ No

Section 2.1.2ES – Electricity Supply for Lighting

Question ID	Question	Answer
17)	What is the primary source of electricity for the supply that is used for lighting? (select multiple if hybrid system)	□ Solar lantern □ Solar stand-alone system □ Rechargeable battery □ Generator (hydro) □ Generator (wind) □ Generator (biomass) □ Generator (biofuel) □ Generator (biogas) □ Generator (diesel) □ Generator (gasoline) □ Mini grid □ Grid □ *(Don't know)*
18)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watts) of the primary electricity supply that is used for lighting?	____ Watt □ *(No name plate or documentation)*
19)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watt hours per day) of the primary electricity supply that is used for lighting?	____ Watt-hours/day □ *(No name plate or documentation)*
20)	How many times per week on average do you face unscheduled interruptions of electricity supply or breakdowns of electricity supply equipment?	_____ times
21)	On average, what is the cumulative length (in hours) of the unscheduled interruptions you face in a week?	_____ hours
22)	What is the current unit price you pay for electricity in $ (local)?	*Per kilowatt-hour (kWh)* ____ / kWh *Per charged battery* ____ / charge *Per litre of liquid fuel* ____ / litre *Per m3 of gaseous fuel* ____ / m3 *Per kg of solid fuel* ____ / kg *Other* ____

Section 2.2ES - Non-Electrical Source for Lighting

Question ID	Question	Answer
23)	In the last month, has your enterprise or productive activity used any kerosene lamps for lighting?	□Yes □ No
24)	If yes, how many?	#
25)	Thinking about the last 12 months, how much do you estimate that your facility used and spent on average per month on kerosene for lighting?	*Quantity ___litres* *Spend ___$ (local)*
26)	In the last 1 month, has your facility used any candles for lighting?	□Yes □ No
27)	In the last 1 month, has your facility used any candles for lighting?	□ Yes □ No
28)	Thinking about the last 12 months, how much do you estimate that your facility spent on average per month on candles for lighting?	___ $ (local)
29)	In the last 1 month, has your facility used any dry-cell battery torches for lighting?	□Yes □No
30)	Thinking about the last 12 months, how much do you estimate that your facility spent on average per month on dry-cell batteries for lighting?	___ $ (local)
31)	In the last 1 month, has the facility used any of the following other lighting sources?	□ Diesel/Gasoline Lamp □ LPG Lamp □ Biogas Lamp □ Other (specify) □ No other lighting sources

Section 3ES - ICT & ENTERTEINMENT

Question ID	Question	Answer
32)	Which type of primary energy source you use for ICT & Enterteinment?	□ Electricity □ A non-electric source
33)	For which activities do you use ICT & entertainment?	
34)	Is energy for ICT & Entertainment provided from the same primary electricity source as lighting?	□ Yes □ No

Section 3.1ES – Energy Needs for ICT&Enterteinment

Question ID	Question	Answer
35)	Typically, for how many hours per day is the electricity supply needed for ICT & Entertainment?	____ hours
36)	For what proportion of the time that ICT & Entertainment is needed is the electricity supply available?	Almost all of the time (95% - 100%) Most of the time (75%-95%) At least half the time (50% - 75%) Less than half the time (less than 50%)

Section 3.2ES – Energy Supply for ICT&Enterteinment

Question ID	Question	Answer
37)	What is the primary source of electricity for the supply that is used for ICT & Entertainment? (select multiple if hybrid system)	□ Solar lantern □ Solar stand-alone system □ Rechargeable battery □ Generator (hydro) □ Generator (wind) □ Generator (biomass) □ Generator (biofuel) □ Generator (biogas) □ Generator (diesel) □ Generator (gasoline) □ Mini grid □ Grid □ *(Don't know)*
38)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watts) of the primary electricity supply that is used for ICT & Entertainment?	____ Watt *(No name plate or documentation)*
39)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watt hours per day) of the primary electricity supply that is used for ICT & Entertainment?	___ Wh/day *(No name plate or documentation)*

Section 4ES - MOTIVE POWER

Section 4.1ES – Electricity for Motive Power

Section 4.1.1ES – Electricity Needs for Motive Power

Question ID	Question	Answer
43)	Typically, for how many hours per day is the electricity supply needed for motive power?	__ __ hours

44)	For what proportion of the time that motive power is needed is the electricity supply available?	Almost all of the time (95% - 100%) Most of the time (75%-95%) At least half the time (50% - 75%) Less than half the time (less than 50%)
45)	Does inadequate electricity for motive power in terms of quantity or duration constrain your facility's operations?	□ Yes □ No

Question ID	Question	Answer
40)	Which type of primary energy source you use for motive power?	□ Electricity □ A non-electric source
41)	For which processes/activities do you need motive power?	
42)	Is energy for Motive Power provided from the same primary electricity source as ICT & Enterteinment?	□ Yes □ No

Section 4.1.2ES – Electricity Supply for Motive Power

Question ID	Question	Answer
46)	What is the primary source of electricity for the supply that is used for motive power? (select multiple if hybrid system)	□ Solar lantern □ Solar stand-alone system □ Rechargeable battery □ Generator (hydro) □ Generator (wind) □ Generator (biomass) □ Generator (biofuel) □ Generator (biogas) □ Generator (diesel) □ Generator (gasoline) □ Mini grid □ Grid □ *Don't know*
47)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watts) of the primary electricity supply that is used for Motive Power?	____Watt *(No name plate or documentation)*
48)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watt hours per day) of the primary electricity supply that is used for Motive Power?	____ Wh/day *(No name plate or documentation)*

Section 4.2ES - Non-Electrical Source for Motive Power

Question ID	Question	Answer
49)	What type of non-electrical energy source is used for motive power?	□ Fuel □ Direct mechanical power (e.g. wind or water turbine) □ Human/animal □ Other (specify)
50)	How many hours per day do you need energy for motive power in your enterprise or productive activity?	___ hours/day
51)	Does inadequate electricity for motive power in terms of quantity or duration constrain your enterprise or productive activity's operations?	□ Yes □ No
52)	Which is the main fuel that is used?	□ Coal □ Briquettes □ Wood □ Other biomass □ Biofuels □ Biogas □ Natural gas □ Kerosene □ LPG, propane or butane □ Diesel □ Gasoline □ Other petroleum products □ Other (specify)
53)	Thinking about the last 12 months, how much do you estimate that your enterprise or productive activity spent on average per month on energy for motive power?	____$ (local)
54)	What is the current unit price you pay for Motive Power in $ (local)?	*Per kilowatt-hour (kWh)* ____ / kWh *Per charged battery* ____ / charge *Per litre of liquid fuel* ____ / litre *Per m3 of gaseous fuel* ____ / m3 *Per kg of solid fuel* ____ / kg *Other* ____

Section 5ES - HEATING

Section 5.1ES – Electricity for Heating

Question ID	Question	Answer
55)	Which type of primary energy source you use for Heating?	□ Electricity □ A non-electric source
56)	Which types of heating are provided from this energy source?	□ Cooking □ Space heating □ Water heating □ Other (specify what is heated)

57)	Are your heating needs constant over the year, or do they vary depending on the season?	□ Constant over the year □ Higher in the rainy season □ Higher in the dry season □ Variable, but don't depend on the season

Section 5.1.1ES – Electricity Needs for Heating

Question ID	Question	Answer
58)	Typically, for how many hours per day is the electricity supply needed for heating?	___ hours
59)	For what proportion of the time that heating is needed is the electricity supply available?	Almost all of the time (95% - 100%) Most of the time (75%-95%) At least half the time (50% - 75%) Less than half the time (less than 50%)
60)	Does inadequate electricity for heating in terms of quantity or duration constrain your enterprise or productive activity's operations?	□ Yes □ No

Section 5.1.2ES – Electricity Supply for Heating

Question ID	Question	Answer
61)	What is the primary source of electricity for the supply that is used for heating? (select multiple if hybrid system)	□ Solar lantern □ Solar stand-alone system □ Rechargeable battery □ Generator (hydro) □ Generator (wind) □ Generator (biomass) □ Generator (biofuel) □ Generator (biogas) □ Generator (diesel) □ Generator (gasoline) □ Mini grid □ Grid □ *Don't know*
62)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watts) of the primary electricity supply that is used for heating?	____Watt *(No name plate or documentation)*
63)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watt hours per day) of the primary electricity supply that is used for Heating?	____ Wh/day *(No name plate or documentation)*

Section 5.2ES - Non-Electrical Source for Heating

Question ID	Question	Answer
64)	What type of non-electrical energy source is used for heating?	□ Fuel □ Solar □ Other (specify)
65)	How many hours per day do you need energy for heating in your enterprise or productive activity ?	___ hours/day
66)	Does inadequate electricity for heating in terms of quantity or duration constrain your enterprise or productive activity's operations?	□ Yes □ No
67)	Which is the main fuel that is used?	□ Coal □ Briquettes □ Wood □ Other biomass □ Biofuels □ Biogas □ Natural gas □ Kerosene □ LPG, propane or butane □ Diesel □ Gasoline □ Other petroleum products □ Other (specify)
68)	Thinking about the last 12 months, how much do you estimate that your enterprise or productive activity spent on average per month on energy for heating?	____$ (local)
69)	What is the current unit price you pay for heating in $ (local)?	*Per kilowatt-hour (kWh)* ____ / kWh *Per charged battery* ____ / charge *Per litre of liquid fuel* ____ / litre *Per m3 of gaseous fuel* ____ / m3 *Per kg of solid fuel* ____ / kg *Other* ____

Section 6ES - COOLING

Section 6.1ES – Electricity for Cooling

Question ID	Question	Answer
70)	Which type of primary energy source you use for cooling?	□ Electricity □ A non-electric source

71)	Are your cooling needs constant over the year, or do they vary depending on the season?	□ Constant over the year □ Higher in the rainy season □ Higher in the dry season □ Variable, but don't depend on the season

Section 6.1.1ES – Electricity Needs for Cooling

Question ID	Question	Answer
72)	Typically, for how many hours per day is the electricity supply needed for cooling?	___ hours
73)	For what proportion of the time that cooling is needed is the electricity supply available?	Almost all of the time (95% - 100%) Most of the time (75%-95%) At least half the time (50% - 75%) Less than half the time (less than 50%)
74)	Does inadequate electricity for cooling in terms of quantity or duration constrain your enterprise or productive activity's operations?	□ Yes □ No

Section 6.1.2ES – Electricity Supply for Cooling

Question ID	Question	Answer
75)	What is the primary source of electricity for the supply that is used for cooling? (select multiple if hybrid system)	□ Solar lantern □ Solar stand-alone system □ Rechargeable battery □ Generator (hydro) □ Generator (wind) □ Generator (biomass) □ Generator (biofuel) □ Generator (biogas) □ Generator (diesel) □ Generator (gasoline) □ Mini grid □ Grid □ *Don't know*
76)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watts) of the primary electricity supply that is used for cooling?	____Watt *(No name plate or documentation)*
77)	DO NOT ASK INTERVIEWEE (enumerator reads from supply): What is the capacity (in watt hours per day) of the primary electricity supply that is used for cooling?	____ Wh/day *(No name plate or documentation)*

Section 6.2ES - Non-Electrical Source for Cooling

Question ID	Question	Answer
78)	What type of non-electrical energy source is used for cooling?	□ Fuel □ Solar or waste heat □ Other (specify)
79)	How many hours per day do you need energy for cooling in your enterprise or productive activity?	___ hours/day
80)	Does inadequate electricity for cooling in terms of quantity or duration constrain your enterprise or productive activity 's operations?	□ Yes □ No
81)	Which is the main fuel that is used?	□ Coal □ Briquettes □ Wood □ Other biomass □ Biofuels □ Biogas □ Natural gas □ Kerosene □ LPG, propane or butane □ Diesel □ Gasoline □ Other petroleum products □ Other (specify)
82)	Thinking about the last 12 months, how much do you estimate that your enterprise or productive activity spent on average per month on energy for cooling?	____$ (local)
83)	What is the current unit price you pay for cooling in $ (local)?	*Per kilowatt-hour (kWh)* ____ / kWh *Per charged battery* ____ / charge *Per litre of liquid fuel* ____ / litre *Per m3 of gaseous fuel* ____ / m3 *Per kg of solid fuel* ____ / kg *Other* ____

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