



MSF SWEDEN INNOVATION UNIT
MSF OCB LOGISTICS BACK OFFICE

OCB ENERGY VISION

ENERGY MAPPING AND ROADMAP

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The OCB Energy Vision project team

ACRONYMS

AC:	Air conditioner
CO ₂ :	Carbon Dioxide
DHW:	Domestic Hot Water
DRC:	Democratic Republic of Congo
GHI:	Global Horizontal Insolation
GWP:	Global Warming Potential
HQ:	MSF's Head Quarters
HVAC:	Heating, Ventilation and Air-Conditioning
ICRC:	International Committee of the Red Cross
ITS:	Informal Tented Settlements
LCA:	Life Cycle Analysis
LOG:	Logistics
LogCo:	Logistics Coordinator
LRS:	Logistics Reporting System
KVA:	kilo Volt-Ampere (Power)
KW:	kilowatt (Power)
KWh:	kilowatt-hour (Energy)
MEI:	Moving Energy Initiative
MoH:	Ministry of Health
NFI:	Non-food items
OC:	Operational Center
OCB:	Operational Center Brussels
OCBA:	Operational Center Barcelona
OCHA:	UN Office for the Coordination of Humanitarian Affairs
OCP:	Operational Center Paris
O2:	Oxygen gas
PV:	Photovoltaic
RE:	Renewable Energy
RH:	Relative Humidity
SAFE:	Safe Access to Fuel and Energy
SGBV:	Sexual and Gender-Based Violence
SIU:	Sweden Innovation Unit
SPV:	Solar Photovoltaic
UPS:	Uninterrupted Power Supply

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EXECUTIVE SUMMARY

MSF OCB's activities are increasing in number and complexity. Energy production and use is key for MSF's operations, and ensuring quality energy production has become more important in recent years. Innovative long-term energy solutions adapted to MSF's different operational realities are needed; solutions focused on beneficiaries and staff health, and which are appropriate for particular contexts or environments.

From this need arises the following project, developed between June and December 2017, with the aim of aiding in the extension of the OCB energy vision: evaluating the potential of all energy alternatives (renewable and non-renewable), and helping to increase our impact on beneficiaries. As a means of achieving this general objective, the study proposes three questions:

1. **What is the current energy situation in OCB?**
2. **What is our desired energy situation?**
3. **How can we reach this envisioned energy situation?**

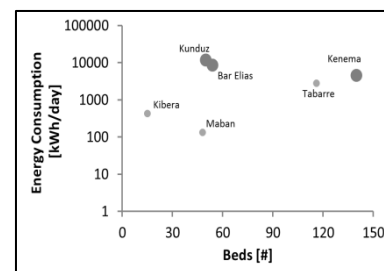
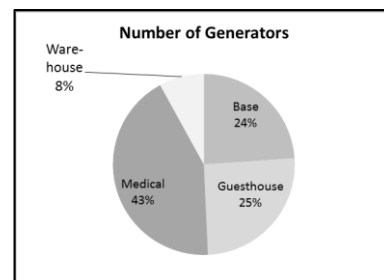
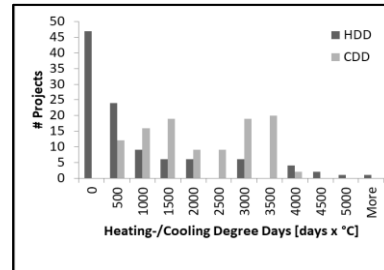
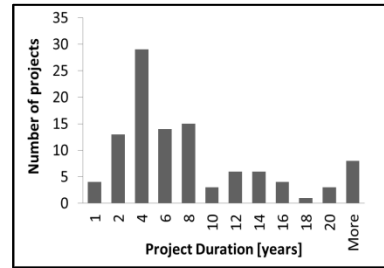
In order to answer these three main questions, we followed an ad hoc methodology based on quantitative and qualitative research techniques, using semi-structured and unstructured interviews, questionnaires, workshops, external literature review, and internal data analysis. In total we conducted 4 months of data collection, wherein qualitative methods were essential as they enabled a deep exploration of different stakeholders' aspirations and views on energy. The methods were also useful for understanding interactions between different actors and for identifying relevant issues in enacting the proposed solutions developed in this report.

Following that methodology and based on the different approaches that currently frame energy-based interventions in the humanitarian sector, we set our own approach to energy which will guide our analysis. This approach creates a **link between energy and health based on an energy system perspective**. Within this understanding, an energy system becomes a flexible and dynamic system which seeks to be reliable, cost-efficient, and sustainable, and where the introduction of innovative solutions appropriate for the unique and challenging contexts of our operations is actively encouraged — consequently resulting in an improvement of our impact on our beneficiaries.

Building on that approach, the study reveals and proposes the following key elements structured around the three main questions:

THE CURRENT SITUATION: WHERE ARE WE NOW?

- MSF sees its strength in its identity as a humanitarian emergency organization, but **a majority of its projects last for five years or longer** (sometimes even decades longer).
- There is a **need to establish planning processes that allow for long-term solutions to shape operations**, which are appropriate to local conditions and which may differ from those that are fast and effective in an emergency context.
- Growing attention has been given to HVAC systems due to their nature as an often high-energy consuming service for which the demand is increasing. In some settings as much as **60%-80% of the overall energy is used to ensure a suitable indoor climate and to prevent airborne infections**.
- Slightly less than 80% of OCB projects have grid access (pay electricity bills), but a majority use generators. We estimate around **350-400 stationary generators are currently deployed globally**, with an average size of about 60-65 kVA and a total generation capacity of more than 20,000 kVA.
- In 2016, OCB used around **5,000 m³ of fuel** (equivalent to about 5 M€ excl. costs related to transport of fuel).
- The carbon footprint related to the combustion of 5,000 m³ of fuel amount to around **13,500 tonnes of CO₂**, of which around 4,000 tonnes of CO₂ might be related to the diesel used in generators. The emissions related to electricity bought from the grid may add, as a rough estimate, another 2,000 tonnes CO₂ (5000 m³ of diesel would take a Toyota Land Cruiser almost 1000 times around the equator).
- One of the major challenges when trying to gain a wider overview of the OCB energy setup is the **lack of reliable and consistent data**. The reporting systems in place are not used consistently which undermines their potential informed decisions.



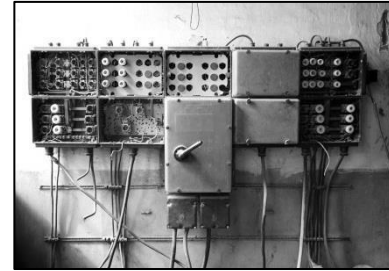
DESIRED FUTURE SITUATION: WHERE DO WE WANT TO GO?

- Desired improvements are largely reflected in the initiatives that are already in progress; the implementation of **passive energy solutions and energy saving measures** are discussed as parallel activities to **increase the use of renewable energies**. Interest in energy storage is raised in relation to intermittent renewable energies and non-electrical energy sources.
- The lack of reliable data from the field is recognized, and better continuity of information is desired partly to **improve the understanding of the actual energy use within our projects**, and to **enable a re-assessment of the needs behind that energy demand**.
- There is a wish to have **more time available for the planning process of projects** in order to allow appropriate solutions to develop from interdisciplinary cooperation.
- Limitations of internal HR capacities along with the growing complexity of projects incentivise the **use of more external partners and subcontractors to provide energy services**.
- Internally, the implementation of the new Log Vision strives to open for the **inclusion of competences and expertise held collectively by the OCB community**.
- Increase the diversity of the energy system to improve robustness and make some services less electricity grid dependent so as to improve both safety and continuity of services.



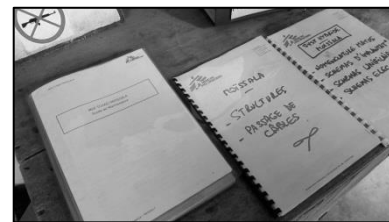
CONCEPTUAL SOLUTION PROPOSALS: HOW DO WE GET THERE?

Based on the current energy reality and on the desired energy vision, we propose several **actions** structured around 4 key elements: **mind-set change, capacity building, monitoring, and technology**. Those elements are concurrently the core pillars of the **road-map** developed in order to help the energy team to further build an action plan towards the implementation of the expanded OCB energy vision.



Change of Mind-Set

- Set up strategic communication in order to establish **support for a more long-term approach** to our operations.
- Create a vocabulary for **effective communication** of an expanded energy concept in which electricity is an important subset.
- Define **relevant performance indicators** that link between energy and the final services that that infrastructure supports, as well as between energy and health.
- **Communicate good initiatives taken in the field** or at other level of the organization, and support champions who lead the way.



Capacity Building

- Create internal validation of resources, **training material** and support documents on energy concepts **beyond the standard solutions for electricity systems used today**.
- Increase the number of technical managers and people with a **professional knowledge of electricity and energy**; explore new ways of recruiting from that category.
- Create space and time for **deeper collaborations across the technical families** to co-create appropriate solutions.
- Evaluate the **use of software tools to support design of energy systems** and potentially assess building energy properties.



Monitoring

- Well-chosen **energy-related data, made available remotely and well-visualized**, could provide support to improve the operation and management of technical systems in the field. It could also give valuable (and missing) input for planning interventions on the energy setup.
- Allow for **standardized automated monitoring systems** which could complement existing manual data collection routines.
- Assessing or re-assessing the actual service needs as they directly relate to the quality of care we offer to our patients and staff and the creation of suitable environments for our operations. Given the limited insight in the energy systems of individual projects, **energy audits** can be designed to map the situations in the field, regarding both infrastructure and its use.

Technology

- Hence, **hybrid electric or thermal systems combining** several generations of technologies are required, and in most cases together with energy storage: **new battery technologies and thermal energy storages**.
- The integration of for example **solar thermal** into the energy systems could offer a low-tech passive solution, appropriate to many contexts and readily availability in many places.
- As generators and incinerators will continue to serve MSF settings for a time to come, technology to **recuperate the waste heat** might be investigated further as a possibility to increase fuel efficiency.
- **Flexible operating loads** like ACs, perhaps along with a thermal storage, to match available solar resources via PV electricity production (potentially as a stand-alone unit) is of high interest given the increasing use of AC in the field.
- Create ways to **capture energy-related initiatives from the field** and **increase cooperation with external actors and service providers**.
- Integrate simple technical solutions such as automatic door closers, LED lighting, motion sensor lights, efficient water dispensers, and power consumption visualisation to reduce unnecessary energy waste.



*The above results give us the key elements of the current and desired energy picture. With these inputs, and together with the support of the relevant stakeholders, the energy team has formulated a **comprehensive and collective energy vision** to improve our operations.*

What are you waiting for? Join us on this journey!

1. INTRODUCTION

1.1. Justification and Background

MSF OCB's activities are increasing in number and complexity. While we are engaging in more complex medical activities, the contexts in which we are working are increasingly affected by power structures, social-political dynamics and, more and more, by environmental factors. This complexity, together with the introduction of innovative technologies and processes, is impacting and challenging the Logistics (LOG) Department.

In this context, energy production and use are key for MSF's operations. As the standard of care has increased in recent years, so too has the strain of ensuring quality energy production. There is a growing need to design long-term energy solutions adapted to MSF's various operational realities. Doing so requires both a systematic approach to planning for and management of energy provision, as well as innovative strategies. These should focus on beneficiary and staff health, and must consider which energy solutions are appropriate for a particular context or environment.

In order to do so, we have used a participatory and dynamic methodology which includes quantitative and qualitative research techniques. This methodology was designed with the continuous feedback provided by different actors as the report was in progress, which allowed us to include the learning process of several projects that were ongoing when developing the present report; thus connecting theory and practice, while also providing mutual reinforcement.

In light of the above, the following document presents the following issues: firstly, we analyse the approaches that have until now framed energy-based interventions in the humanitarian sector. Secondly, building upon these approaches, we define our own approach, which establishes the link between energy and health from an energy system perspective. We then present the methodology and sources employed during the research. Finally, we discuss the research results, and provide recommendations for building a further action plan for developing more appropriate energy solutions in MSF's operations that will finally lead to an expanded energy vision in MSF-OCB.

1.2. Objectives

The **general objective** of this research project is to assist in the creation of an OCB energy vision, which will consider the potential of all energy alternatives (renewable and non-renewable) and help OCB to increase MSF's impact on beneficiaries in terms of health services and patient safety.

Specific objectives took place between June and December 2017, as summarized in **Fel! Hittar inte referenskölla**. below. These include:

- Map the current situation of energy supply and energy needs within OCB projects.
- Discuss and establish the learning outcomes of this mapping with OCB by conducting several workshops.
- Write and establish a roadmap for an action plan towards the General Objective based on the mapping and the workshops.
- Develop dissemination material for the project (internal and external) by establishing collaboration with a publisher; gather raw material and guidance for the publisher to work with.

	Research	Workshops	Deliverables
jan-18		Final presentation	Project Film
dec-17	Analysis (Cross-correlation data, gap identification, etc.)	3rd Workshop (Preliminary Road-Map)	Report/Road-map
nov-17			
okt-17			
sep-17	Data collection (databases, internal reports, ext. literature, interviews, field survey)	2nd Workshop (Preliminary Findings)	
aug-17			
jul-17			
jun-17	Start-up	1st Workshop (Now/Wow/How)	

TABLE 1. OCB ENERGY VISION PROJECT TIMELINE

1.3. Questions to answer

Considering these objectives, we started by asking **three sets of questions** related to the **current MSF energy situation**, the **desired future situation**, and **how we bridge the divide between these two**. These questions were formulated by means of a participatory process (headquarters and field), helping us to canvass a wide range of views regarding OCB's current energy reality, with its challenges and potentials, visions for the future, and priorities to pave the road ahead.

Some of the questions used in approaching this project are as follows:

Explore the current situation: where are we now?

- What is the different stakeholders' perspectives of OCB's current energy situation?
- What is energy for MSF?
- What are the needs?
- What are the challenges?
- Who are the main stakeholders?

Explore the desired future situation: where do we want to go?

- Where do we want to go in terms of energy (medium and long-term)?
- What solutions do people envision? Maybe both technical and organizational.
- Why? What are the key performance indexes that would capture people's motivations to look for alternative energy systems?

Create conceptual solution proposals: how do we get there?

- How could the needs be approached, and the challenges tackled?
- Where do we begin? What actions, activities, and proposals are needed?
- What data needs to be collected? Why and how?

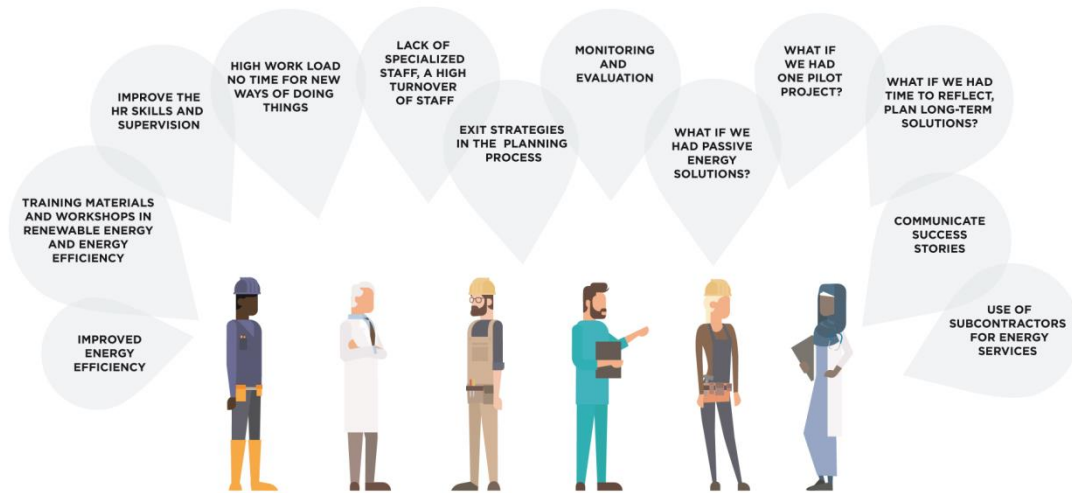


FIGURE 1. THE FIGURE HIGHLIGHTS VOICES FROM THE INITIAL “NOW, WOW, HOW” WORKSHOP THAT WAS HELD IN BRUSSELS IN JULY 2017 AND WHICH GATHERED PEOPLE FROM BOTH FRONT- AND BACK-OFFICE TO COLLECTIVELY DISCUSS THE CURRENT REALITIES AND FUTURE VISIONS OF THE ENERGY SYSTEMS.

2. KEY CONCEPTS: ENERGY AND HEALTH, ENERGY SYSTEMS AND APPROPRIATE TECHNOLOGIES

Energy has played a key role in humanitarian aid since at least 1995 (Bellanca, 2014). Healthcare facilities are some of the biggest energy consumers in the construction sector due to their high ventilation, cooling and heating loads, continuous operation, and high-consumption medical equipment (Balaras, Dascalaki, & Gaglia, 2007). However, despite the importance of energy issues for healthcare facilities in the humanitarian sector, surprisingly little attention is paid to how humanitarian organizations and professionals conduct energy-based interventions (Franco, Shaker, Kalubi, & Hostettler, 2017).

Most approaches have been driven by the development sector, energy being one of the main challenges of the New Development Agenda (UN, 2015). In this sector, decentralized systems based on solar PV have been widely used in electrification projects for isolated rural areas, promoted by the international cooperation system in a range of different countries and contexts (Barnes, 2011; Modi, McDade, Lallement, & Saghir, 2006; Shyu, 2014; Yadoo & Cruickshank, 2012). The humanitarian field on the other hand, in its relatively new approach to energy (Bellanca, 2014), has mainly focused on energy access for displaced people in humanitarian relief camps (Gunning, 2014).

But, **what about MSF?** MSF works in a variety of contexts, from refugee camps to large health facilities. Hence, as a humanitarian organization, the classic energy approaches considered in the development sector do not usually fit when designing energy-based interventions.

Considering the above, the ambition for extending OCB’s Energy Vision is to develop a more holistic approach to energy. That is, to support an understanding of a stronger link between final services and the energy system in order to improve our impact on our beneficiaries in terms of health services and patient safety.

But what do we understand by the term **energy system**? Traditionally, an ‘energy system’ refers to all processes comprising the energy chain: production, distribution and consumption. However, when referring to ‘energy system’ in this study, we consider the term to go beyond energy infrastructure (infrastructure needed to transform energy resources- either renewable resources such as solar, or non-renewables such as fossil fuels- in energy for users), and to include the political, economic, social, environmental, and technical dimensions of the energy chain (Alanne & Saari, 2006).

In light of this, to address the project objectives described in Section 0, we propose a dynamic approach, based on an energy system perspective, which considers the contributions from approaches that focus on the relationship between energy and health in the humanitarian field. Accordingly, we analyse MSF’s current energy situation while identifying actions for challenging the traditional logics of energy planning and for driving systemic changes in MSF’s energy interventions in order to improve our impact on our beneficiaries in terms of health services and patient safety.

In the following section, we present several key concepts that frame the research: a general overview of how energy relates to health in humanitarian aid and specifically within MSF; what an energy system involves and what do we understand by ‘appropriate energy solutions’; and what is our proposed approach.

2.1. Energy and Health

While the number and types of actors who promote **Safe Access to Fuel and Energy (SAFE)** practices in humanitarian settings have increased in the past decade, energy is currently not recognized as a formal part of humanitarian aid in the UN cluster system managed by the UN Office for the Coordination of Humanitarian Affairs (OCHA). According to the SAFE Working Group,¹ the latter not only has consequences on the resources provided to energy-based interventions in the humanitarian field, but also on coordination and planning mechanisms, including the lack of energy data resulting from its low prioritisation (SAFE, 2017).

The **Lancet Commission on Health and Climate Change**, referring to the impacts on public health of Climate Change (CC),² highlighted as early as 2015 that tackling CC could be “the greatest global health opportunity of the 21st century” (Watts et al., 2017, p. 1); the shift to more sustainable energy solutions being one of the key factors to fight CC and tackle related health concerns.

The **World Health Organization (WHO)** considers air pollution as one of its main concerns, as it is currently one of the largest single causes of premature mortality and morbidity worldwide (outdoor and indoor air pollution are responsible for more than 7 million premature deaths per year³) (WHO, 2016a, 2016b). Sexual and Gender-based violence (SGBV) has also been highlighted when talking

¹ After the Darfur crisis and as a response to the increase of SGBV towards women and children when collecting firewood, the SAFE Humanitarian Working Group was created with the mission to “facilitate a more coordinated, predictable, timely, and effective response to the fuel and energy needs of crisis-affected populations” (SAFE, 2017).

² The Lancet Commission pointed out that CC “threatens to undermine the past 50 years of gains in public health” (Watts et al., 2017).

³ Ambient air pollution, also known as outdoor air pollution, caused 3 million premature deaths worldwide in 2012 (WHO, 2016a). Indoor air pollution, or household air pollution, caused more than 4 million premature deaths in 2012 (WHO, 2016b).

about energy access and health, as street lighting can reduce the risks related to women's and girls' mobility before sunrise (Doleac & Sanders, 2012). At the request of the UN's Sustainable Energy for All (SE4All) initiative, the UN Foundation (UNF), WHO and UN Women are jointly leading an effort to increase energy access in health facilities, particularly in support of maternal and child health services. The effort, known as Energy for Women's and Children's Health, is one of SE4All's multi-stakeholder partnerships.

Among aid sector actors, energy has been related to health mainly in the **development field**. The role of energy in improving health conditions by decreasing women's and children's hard labour and ameliorating indoor house environments (eliminating 'kitchen smoke') was already pointed out in the Millennium Development Goals. In the post-2015 New Development Agenda, access to energy is considered to be one of the main challenges, with Sustainable Development Goal (SDG) number 7 aiming to: "ensure access to affordable, reliable, sustainable and modern energy for all" (UN, 2017). In this sense, modern energy provision is seen as a "critical enabler of universal health coverage" (AIE & BM, 2015, p. XIII) as it is needed for operating medical equipment or storing vaccines and drugs, helps retain qualified medical staff, and helps to reduce air pollution and risks arising from the use of traditional fuels and inefficient technologies.

Specifically in the humanitarian field, the link between energy and health has mainly focused on energy access for displaced populations. The **Moving Energy Initiative (MEI)**,⁴ an approach that is rethinking energy use in refugee camps, shows that out of the more than 8 million refugees and displaced people almost 90% lack access to reliable energy sources for lighting. The lack of adequate fuels for cooking and heating available to displaced populations is one of the main concerns in the SAFE agenda (SAFE, 2017). Over 20,000 displaced people die prematurely each year due to dependency on primitive fuels, and a growing number of people skip meals due to insufficient fuel for cooking (Gunning, 2014). The latter has also been pointed out by the **World Food Program (WFP)**, who warn of the health impact of insufficient energy access as shown by the growing number of people who often skip meals, eat undercooked meals, or avoid certain food groups to save fuel (SAFE, 2017).

The **UNF** is another key actor that has recently begun to address energy in the humanitarian field.⁵ They highlight that, in humanitarian crises, immediate needs often limit practitioners' ability to plan for the long term - but this approach is increasingly inefficient in a world where many refugees remain living in camps for several years. Short-term planning and budgeting cycles limit opportunities for energy solutions that require long-term planning and investments (e.g. solar PV systems compared to generators), especially where the financial break-even point may not manifest until a few years after installation. Another relevant concern is the critical scarcity of available data that could help facilitate long-term planning. According to UNF, steps towards bridging this gap could be made by studies investigating the willingness and ability of displaced people to pay for lighting or other energy services, and by impact evaluations or assessments of needs for social infrastructure such as health facilities and schools.

⁴ Initiative from Chatham House, UKAid, Energy4Impact, Practical Action, the Norwegian Refugee Council (NRC) and the United Nations High Commissioner for Refugees (UNHCR) (Chatham House, 2017).

⁵ The UNF, with the support of WHO and UN Women, created in 2017 the Working Group "Powering Healthcare" with the aim to advance the global agenda of health facility electrification.

On the other hand, actors who work in proximity with MSF in the energy field such as the **International Committee of the Red Cross (ICRC)** are taking the leap to include more sustainable policies in their organizations. For example, ICRC has developed a “Green Response” to minimize adverse impacts on the environment resulting from emergency response systems. Included within this scope, among the various measures promoted during the emergency response phase, is the selection of “greener” energy sources, such as solar power or energy-efficient cooking stoves (ICRC, 2016). One particular ongoing project aims to develop emergency kits for refugees for distribution upon arrival, including: providing a test of lighting and cooking technologies in the field to compile a catalogue of tested technologies; and developing a 'tool kit' for early use to explore beliefs and traditions involving lighting and cooking.

2.2. Energy Systems

The ambition with the extension of the OCB Energy Vision is to develop a more holistic approach to energy that is complementary to the priorities of the electrical installations. It will try to support an understanding and strengthen the link between final services and energy systems by exploring approaches that may be available to supply the needs. Since small off-grid electricity systems are often less robust than larger connected grids, it will be especially beneficial to explore both demand- and generation-side solutions. The sketch below depicts a project with a local electricity system, where service-driven needs necessitate a power distribution system fed by an on-site generator or by connection to an external grid. The electrical power distribution system is largely a matter limited to the expertise of electricians. However, at the consumption-side, the connected appliances which provide the necessary services can be well-designed and managed in accordance with the context of users and physical facilities to improve conditions at the distribution- and generation-side. Interplay across the entire system becomes increasingly important when exploring the possibilities of cleaner and more economic electricity production via intermittent renewable energy technologies.



FIGURE 2. LOCAL ELECTRICITY SYSTEM OF A PROJECT, WHERE THE NEEDS FOR SERVICE NECESSITATE A POWER DISTRIBUTION SYSTEM FED BY AN ON-SITE GENERATOR OR BY CONNECTION TO AN EXTERNAL GRID.

Consumption	-	Distribution	-	Generation
- Energy Efficiency				- Renewable energy
- Demand Side Management				- Non-electrical generation
				- Energy storage

The different elements of an energy system are tackled in Chapter **Fel! Hittar inte referenskälla..**

2.3. Energy planning and appropriate technologies

Despite the key role of energy in the humanitarian field, the way that energy-based solutions are planned (from design to evaluation) has not attracted much attention. In the development field, energy-based interventions have been criticized for using a managerial logic which results in them being approached from a merely technical standpoint. Consequently, these solutions have been criticised for being designed based on assumptions that bear more relation to the interests and visions of the development agencies themselves, rather than those of the people they are directed at (Li, 2007; Mosse, 2005).

Once more, how is MSF approaching this issue? How do we involve our beneficiaries in our energy solutions? Although discussion around this point is beyond the scope of this research, as within the frame of this project we are trying to challenge conventional logics of energy planning, we believe it is worth mentioning what we understand by ‘energy planning’ and ‘appropriate energy solutions’.

Traditional ‘project planning’ tries to capture processes of change and outputs within rigid timetables (Frediani, Boni, & Gaspar, 2014). Within this frame, conventional **energy planning** is usually based on a rational, pragmatic and neutral perspective focused on access to energy, but fails to address the underlying set of social, political and environmental relations that generate situations of injustice and inequality. However, based on the energy system approach described above, and considering the harsh and changing environments where MSF works, we understand energy planning as a flexible and ongoing learning process: an activity focused on long-term actions to satisfy our operational needs while striving to orientate mindsets towards more appropriate energy solutions. It is by doing so that scaling-up appropriate technological interventions becomes more plausible and sustainable as understanding, enacting, and transforming require emphasis on process, as opposed to just on products or outcomes.

But what are **appropriate technology** or **appropriate energy** solutions? Despite being diversified, the main features of the appropriate technology concept are simplicity, small-scale scope, low cost and

low participation. These features are designed to permit adaptation to the social and environmental conditions of beneficiary populations, and concurrently to reduce technological dependence. In that sense, and within the context of MSF, we understand an ‘appropriate energy solution’ to be a technological intervention that not only focuses on how energy infrastructure enables a health facility to run, but also the wider impact of the means of energy provision: that is, for example, what the energy solution directly enables people to do (i.e. increasing local capabilities). This requires planning strategies which consider under which scenarios and to what extent the various energy options are appropriate for different operations, the diverse social collectives, and the context and environment.

2.4. MSF’s approach: a general overview

In June 2017, MSF’s International General Assembly (IGA) announced the following motion applicable to all MSF Operational Centers:

“The IGA calls on the MSF movement to debate and promote actions to develop concrete capacities and expertise around the medical and humanitarian consequences of environmental degradation on health and of our own carbon footprint”.

Two factors arise from this motion:

1. The increase of health threats resulting from growing environmental degradation.
2. MSF’s environmental impact.

We shall now explore different initiatives taken by MSF responding to both factors, and their respective relations to energy.

GROWING HEALTH THREATS

During the last decade, the MSF movement has seen multiple raised voices expressing the importance of the link between energy and health. For example, as early as 2005, OCA was drawing attention to the fact that in Darfur, the majority (82%) of survivors of rape and sexual violence told MSF that the attacks occurred when women and girls left the villages and displacement camps to search for firewood or water. However, despite the growing number of concerned voices, only a few institutional initiatives have been undertaken to understand and act upon this issue (MSF, 2005).

The wider MSF movement has suffered from the same relative inactivity despite multiple voices demonstrating concern for the link between energy and health during the past decade, and only a few institutional initiatives have been taken. One of the most responsive partner sections to these issues has been **MSF Canada**. Based on the fact that MSF works with populations in coastal regions (such as Bangladesh) which are among the most affected by CC, with populations impacted by vector and water-borne diseases and health problems caused by air pollution (parts of India and sub-Saharan Africa), and with populations affected by the extractive industry where high rates of TB, HIV/AIDS or sexual violence is increasing (such as Sub-Saharan Africa), MSF Canada began an exploratory project in 2017 to “contribute to the movement’s understanding and positioning on this interface in further developing the work on the topics of climate, resource extraction and their respective impacts on health and their common interaction in the humanitarian sphere”. The preliminary results of this project are expected in early 2018.

MSF-OCP and MSF-OCBA also have several initiatives linking energy and health. Based on the growing number of indoor smoke-related diseases and SGBV due to lack of proper light, OCP has developed a strategy to explore the design and implementation of improved cooking stoves and solar standalone

lighting systems. Among the logistical implementation challenges, they highlighted considering the different local ways of cooking, identifying existing locally available stoves or lights, and matters concerning security, price, transport, distribution and proper training (López, 2016). OCBA's Nairobi Displacement Unit is also exploring alternatives to firewood collection in Nigeria due to the large number of women and children who suffer SGBV when venturing out in the dark to gather firewood.⁶ Both Operational Centres also have several renewable energy initiatives: OCBA's related to solar water pumping, and OCP's to solar-diesel systems (2 hybrid systems of 15 kWp and another one of 8 kWp; one additional system will be installed in South Sudan in 2018). It is worth mentioning that the OCP hybrid system projects pointed out the difficulties of estimating energy consumption, and highlighted the need for the field to take responsibility for not letting energy consumption escalate.

MSF'S ENVIRONMENTAL IMPACT

MSF's carbon footprint is the other issue that has been tackled when addressing energy within the MSF movement.

Several initiatives to reduce the ecological impact of MSF's field activities have been developed by some OCs,⁷ among which is OCB. In 2008 and 2009 the logistics department of OCB developed the **EcoLog Project** in order to create accountability for the environmental impact of OCB operations, and to recommend measures for the field and headquarters towards reducing MSF's carbon footprint (Crozier, Ledant, Mertens, Puttevils, & Brasseur, 2008; Deguaiquier, 2009). However, these initiatives have barely moved forward.

Another initiative is **OCB's Green Team**, in which several people have been pushing for the adoption and promotion of more sustainable practices within OCB's headquarters in order to lessen OCB's ecological footprint. The proposed measures range from reducing the number of plastic coffee cups to installing motion sensor lights in meeting rooms.

The **MSF Sweden Innovation Unit** together with the various OCs has managed a wide range of projects, some of which have had a strong energy and sustainability profile, for example the recent feasibility study on oxygen concentrators powered directly by solar PV.

2.5. Our approach: Rethinking Energy Services from an Energy System Perspective

But how do these two approaches fit with OCB's current energy reality? How do they relate to the ways in which OCB and the LOG department are managing energy-based interventions in our operations?

We need to formulate a more holistic approach to energy that not only improves the impact on our beneficiaries in terms of health services and patient safety, but equally an approach strongly linked to MSF's operational realities. In order to do so, it is essential that we consider the **LOG's purpose**:

"Beyond the fulfilment of essential needs of MSF's social mission, the LOG function is a solution-driven and innovative force that, within an operational framework, aims at giving the best

⁶ More info in: <https://displacementunit.msf.es/content/alternative-cooking-solution>

⁷ One of them is, for example OCG (Colrat, 2009).

environment of care to our beneficiaries and our medical team’s activities” (LOG-Department, 2017, p. 6).

We need therefore to focus on the design and implementation of energy-based interventions able to provide the “best environment of care” to our beneficiaries and our medical team. This involves defining the most appropriate energy solutions for a particular context or environment, and supporting an understanding of a stronger link between final services and the energy system. Resulting from this understanding, contrary to traditional energy approaches based solely on energy access, health, climate change, or on reducing the environmental footprint, **an energy system becomes a flexible and dynamic system which seeks to be reliable, cost-efficient and sustainable, and where the introduction of innovative solutions in our operations is actively encouraged.** This approach allows us to frame MSF’s energy reality and to design **energy solutions able to adapt to the different and challenging political and environmental contexts where we are currently working.** Moreover, it **encourages social and environmental change that will ultimately result in an improvement of our impact in our beneficiaries** in terms of health services and patient safety.

In Figure 3 we observe a simple diagram showing the different approaches previously described and the approach that we will follow during our entire analysis.

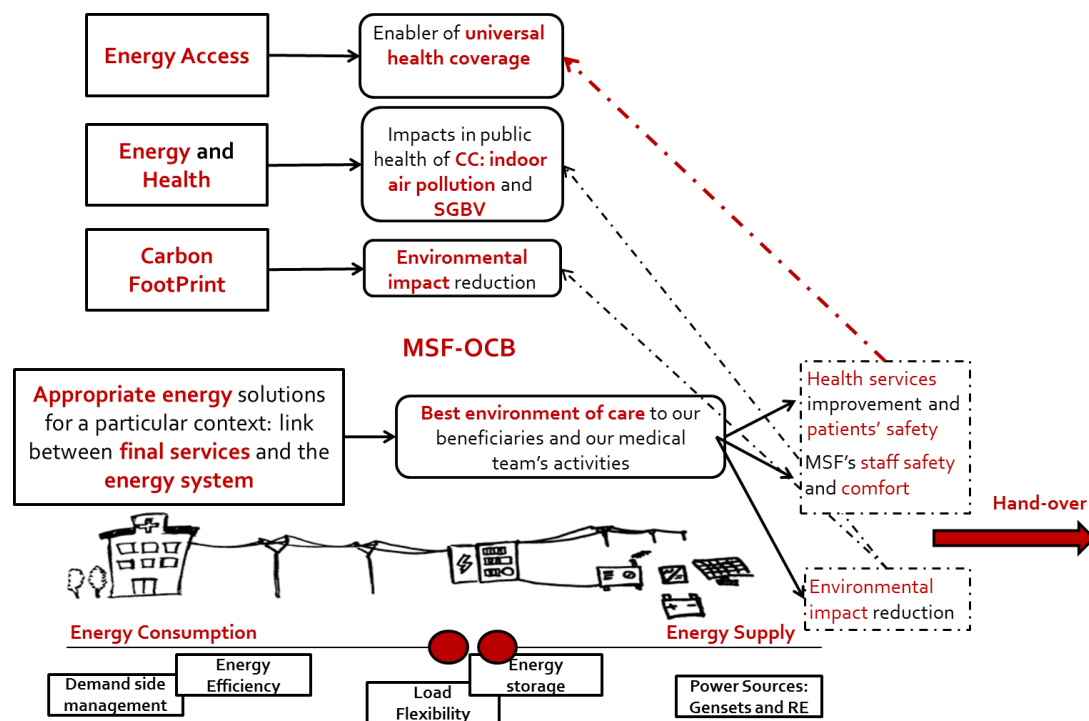


FIGURE 3. OUR APPROACH.

3. ENERGY SYSTEMS

Electricity is a “high quality” energy carrier, for which there are well-established conventions and an increasingly diversified market of components for building infrastructure. In many countries, there is a trend towards increased electrification and digitalization of energy systems, including electric vehicles, smart-home applications, heat-pumps and other building service systems, distributed RE

(primarily in terms of PV), grid-tied energy storage, etc. Electricity is versatile and can be converted to most other energy forms with rather low losses, which makes the entire setup very convenient. This transition, however, poses challenges also to large stable grids, which in some aspects are relevant to smaller mini-grids like many of those of concern to OCB.

The energy system introduced above links the needs for energy-based services to the technical installations, which allow for energy to be produced, distributed and consumed. Furthermore, the default solution in OCB today is often an electric grid either powered locally by diesel generators or connected to the city power. As long as we can have fuel transported to and stored at the project, a generator has practical benefits: relatively low investment cost; the fact of being a confined solution in one product; its sizing depends primarily on the scale of power demands; its energy can be dispatched when needed, etc. The challenges arise with the fact that many systems are remote; fuel transport and storage is an issue, local products might be substandard, and limited expertise in electrical systems make their maintenance difficult. In addition, the systems are small with a smaller load-diversity and need to deal with their own internal stability. Apart from being increasingly resource-demanding, diesel-based mini-grids rely on local combustion of fossil fuels, which have environmental and health implications.

The discussion that follows below addresses concepts to potentially improve the operation of the energy system and the environment in which it functions. Some of these concepts, like energy efficiency, energy storage, and some renewable energy technologies, were repeatedly raised by staff at OCB as elements of their vision for future energy systems during the workshops and interviews. Other concepts like load-flexibility and demand-side management are mentioned since they are tools with potential to facilitate improvements in energy efficiency and the use of intermittent renewable energies. As will be seen, several of these concepts are also part of current initiatives and challenges that reflect where OCB is at present regarding the development of energy services.

The concepts mentioned by no means exhaust all possibilities for rethinking an energy system, and several options and technologies are not addressed specifically, particularly those which involve context-specific technologies that could be of interest to OCB.

3.1. CONSUMPTION

Based on the energy system approach, the sections below discuss possibilities for assessing energy usage to provide required services, including potential options for improving the overall energy settings and the management of loads.

3.1.1. ENERGY EFFICIENCY

Regardless of the choice of electricity generation technology or the typology of the electrical system, energy efficiency is important as it can dramatically influence the energy and power consumption, and hence affect a system's financial viability (Alliance for Rural Electrification, 2011). Efficiency involves the optimization of energy services by minimizing energy losses, for example via policy-, strategy-, and technology-design measures.

The concept of energy efficiency is often inter-disciplinary, involving interplay between a holistic system design, the use of high quality products, and user behaviours. Focusing on health facilities, the ASHRAE-standard "Advanced Energy Design Guide for Small Hospitals and Healthcare Facilities"

emphasises the significance of energy consumption, rather than the actual energy source, and suggests a methodology for achieving a 30%⁸ energy reduction by addressing the major categories of large energy consumers. The process highlights the importance of close collaboration with the facility management team, multidisciplinary expertise, integral design approach, the use of tools for energy modelling, and follow-up to ensure that the installed systems are working as intended. (Bonnema, Pless, & Doebber, 2010)

“Reaching 30% energy savings is not difficult, but requires more than business as usual.” (Bonnema et al., 2010)

A study of the hospital sector in India addresses a developing issue wherein increasing numbers of privately funded and highly-specialized hospitals which occasionally report per-bed energy consumption rates 10-15 times higher than government hospitals (Gov. Urban Hospital: 2-4 kWh/bed/day, Gov. Rural Hospital: 0.4-0.8 kWh/bed/day, Private/NGO Hospital: 2.7-5.5 kWh/bed/day), a trend that could potentially cause problems for the national electricity infrastructure (Mathur, 2009); possible measures for reducing energy consumption by 20-30% are often overlooked due to a lack of awareness among hospital management and limited in-house expertise. The study highlights the benefits of monitoring energy use in order to establish a baseline, and therefore to enable both internal benchmarking where the energy consumption can be followed over time, as well as external benchmarking to allow for comparison to other facilities. Internationally established indicators for energy benchmarking include:

- Energy consumption per m²
- Energy consumption per bed

Different sources point out that the HVAC systems can amount to between 50% and 80% of health facilities' total energy consumption due to the need for high ventilation, cooling and heating, emphasizing HVAC-systems as one of the major energy consumers for buildings (ASHRAE, 2013; Bortolini, Gamberi, Graziani, & Pilati, 2015). The design of the building, its thermal properties, and its immediate surroundings will have a major impact on the energy consumed by the building's service systems, and may offer room for improvement. Furthermore, HVAC-components can be chosen to comply with existing standards for energy efficiency, such as the Ecodesign and Energy labelling directive which applies to the European market (“Ecodesign,” 2017), whereas also WHO refers to the use of energy efficient medical equipment (WHO, 2017). Changes in user behaviour to reduce unnecessary energy waste may be challenging and require building understanding of and respect for the use of limited resources, but could be facilitated by simple technical solutions such as automatic door closers, light switches, and power consumption visualisation.

“The team needs to make a particular effort to raise awareness of the importance of proper use of the air conditioners. This means keeping temperature within the comfort range, as well as basic behaviour like closing windows when the system is running. The LOG manager has even tried hiding the remote controls, but the staff bought new ones.” (Ten Palomares, 2017b)

⁸ With reference to facilities built according to the minimum requirements of ANSI/ASHRAE/IESNA Standard 90.1-1999.

The World Food Programme has implemented an energy efficiency strategy to systematically work on energy reductions and implementing renewable energy technologies. The strategy is motivated by the environmental and financial benefits of reducing energy consumption, and hence to redirect money from fuel spending to beneficiaries.

The strategy builds on energy audits in the field. Energy survey forms are prepared and complement physical measurements of both energy consumption and generation. The reported data forms a basis for recommendations on change-of-practices and upgrading electrical appliances or generation technologies. The recommendations are categorized as No cost, Low cost, and Capital investments, the implementation of which is supported by WFP Engineering team. As part of the strategy, a “Green box” has been developed containing everything needed to perform the energy audit, all of which can be managed by field workers themselves (WFP, 2017a, 2017b). USAID has also developed support material for energy audits of health facilities.

“Before focusing on installing a more cost effective energy supply, work must be done on reducing the energy consumption” (WFP, 2017a)

Other organizations have developed a size classification of health structures according to the number of beds, where four categories are defined as given in **Fel! Hittar inte referenskälla.** below (Franco et al., 2017; USAID, n.d.). These categories additionally represent different medical activities, and hence also energy and power needs. A few examples of projects operated by OCB are added to the table for comparison. Even if the estimates of energy use per bed given by USAID may be low, **the energy consumptions of the OCB projects are an order(s) of magnitude larger. The degree to which higher energy consumption reflects a higher quality of care is a key question when justifying our energy setups.** A recent benchmarking study of European hospitals (Morgenstern, Li, Raslan, Ruysssevelt, & Wright, 2016) separates energy use on different departments, and expresses it primarily as kWh/m²/year. The samples used show the highest electricity use in laboratories, with an average of almost 400 kWh/m²/year, while IPD wards is suggested to use about 235 kWh/m²/year. The study also addresses the impact of specific activities, where for example the re-heating of food in a ward in itself might use almost 1 kWh/bed/day.



Even if the high energy use within MSF projects is well justified by the work we do or the services we provide (i.e. laundry or kitchen), this could be an issue when handing over activities to the Ministry of Health or another less well-resourced organization.

USAID Classification				MSF-OCB examples
Facility	# of beds	Daily energy need	Installed power	
Hospital	>120	15-35 kWh	9 kW	Tabbarre, Haiti: 116 beds – 300 kVA - 2800 kWh/day ⁹
Health Centre	60-120	10-20 kWh	5 kW	Maban, South-Sudan: 48 beds – 13 kVA - 140 kWh/day ¹⁰
Health Clinic	<60	10 kWh	2.4 kW	Kibera, Kenya: 15 beds – 40 kVA - 430kWh/day ¹¹
Health Post	0	-	-	

TABLE 2. THE USAID CLASSIFICATION OF HEALTH STRUCTURES ACCORDING TO BED SIZE, WITH TYPICAL ENERGY AND POWER NEEDS SHOWING SIGNIFICANT DIFFERENCES COMPARED TO MANY PROJECTS WITHIN MSF-OCB, WHICH OFTEN USE MORE ENERGY AND POWER.

3.1.2. DEMAND-SIDE MANAGEMENT AND SHIFTING OF FLEXIBLE LOADS

Demand-side management refers to the process of modifying the energy or load-profile in order to e.g. avoid peak-power loads, or be able to shift loads according to when energy is available. It can help avoid capacity shortage and hence stabilize the electricity system, defer investments, and reduce fuel consumption (REEEP/UNIDO, 2006).

Observing load-profiles of an electricity system often shows significant variations in power demand over the course of a day as activities vary – simply a consequence of the needs for energy services not being constant. However, some loads can be made time-flexible, and could hence be shifted to operate at non-peak hours; ground source water pumps are a typical example of equipment that could be operated at more or less any time of day, provided the water storage volume is large enough to provide water over a sufficiently long period. Especially if relying on renewable and intermittent energy generation technologies, it would be beneficial to operate time-flexible loads during hours of power availability, even if the system uses batteries for energy storage. A study based on both medical and non-medical loads in a health centre in Yemen showed that load-shifting could significantly reduce the required battery size, with a relative decrease of 20% in the net value of the system (Al-kori, 2014)

As a water supply system was implemented in the villages of Masafer Yatta, Palestine, and connected to the solar-wind-battery-hybrid off-grid power systems that supplied the villages, a strategy was

⁹ Estimates based on data from the monitoring of the electricity system.

¹⁰ Assumes a diesel consumption of about 1300L/month at the hospital, and conversion efficiency of 0,3L/kWh electricity. Personal records from late 2015.

¹¹ Based on the measured load-profile at the generator. (Mujica, 2017a)

implemented to operate the many water pumps sequentially when the batteries were fully charged and there was access to the energy system. This way, the implementation of the water system minimized additional cycling of the batteries that would further reduce their lifespan. (J. Persson, 2016) In a similar manner, establishing a strategy for management of time-flexible loads can facilitate the employment of renewable energy technologies by making them meet the intermittent nature of e.g. solar PV.

Also, in electric systems powered by diesel generators, high-demand peaks will dictate the capacity scaling of the distribution system, as well as the power capacity of the generator, which during non-peak hours will then operate at non-optimal load-level where fuel efficiencies are lower. As will be mentioned later in this study, there are also approaches which involve using several generators of different sizes operating together in order to meet varying power demands.

3.1.3. HEAT PUMPS

Heat pumps play an increasingly important role in heating processes for the built environment, for space heating as well as for domestic hot water production. The heat pump offers an electrically-powered thermal cycle where heat is extracted from external sources (air, water and ground) and is then used to raise the temperature of the desired media – often water or air (heat pumps are in many ways similar to air-conditioners and refrigerators, although operated in reverse in order to produce heat). This way the thermal energy output might be 3-5 times as large as the electrical energy input, which denotes the COP-value. Partly due to the high COP-values, heat pumps are considered a low-CO₂ emission technology for heat generation, although the CO₂ emissions of course also depend on the electricity mix used. Secondly, heat pumps in combination with energy storages might offer flexibility on the demand side that can facilitate the integration of renewable energy sources. The degree of flexibility depends on the thermal demand, size of the heat pump, storage type, and size and dynamic properties of the system. Hence in order to succeed with the integration of heat pumps, a holistic view of the energy system is required (Fischer & Mandani, 2017).

3.2. GENERATION

The working assumption is that **the well-established standard solution for power generation in OCB projects is to connect to existing city power when possible, or operate diesel generators in off-grid settings**. Strategies for optimizing the operation of diesel generators as a primary power source or as back-up power are in place, and are also undergoing continuous development. For that reason, the following discussion will primarily refer to renewable energy technologies and lead into energy storage.

3.2.1. HYBRID ELECTRICITY SYSTEMS

There is a large range of studies which present **hybrid systems as the most cost-effective and reliable option for electricity generation in off-grid mini-grids in general**, but also specifically for hospital facilities in the Global South (Al-Akori, 2014; Franco et al., 2017). A hybrid system is an electricity system that combines at least two different sources of power generation (Blechinger, 2013), sometimes a combination of renewable energy technologies and often in parallel with generators and energy storages. They require significantly higher initial investments than diesel-only systems, but can be cost-effective solutions with a payback time of a few years (Blechinger, 2013; Breyer, 2012) that also allow for reduction in fuel dependencies, generator working hours, and green-house gas emissions (Alliance for Rural Electrification, 2011; Bortolini et al., 2015; Franco et al., 2017; UNEP, 2015; Yumoto, 2011).

Renewable energy sources are non-dispatchable and have the ability to produce power only when the resource (sun, wind, hydro...) is available. Hence the combination of complementary generation technologies helps to increase the penetration of renewables in an electricity system. However, due to the intermittency of renewable resources, energy storages and diesel generators are often needed in the systems in order to provide a stable electricity generation of high quality at all times.

For pure diesel- or solar PV-systems, the design process is rather straight forward. With a combination of several (site-dependent) technologies and possibilities for system configurations, the complexity and the need for detailed design increases. The design needs to take into account the choice of technology, renewable resources at the site, and power and energy demands. There are several tools available to support the design process for hybrid systems (Al-falahi, Jayasinghe, & Enshaei, 2017; USAID, n.d.).

The pattern of energy use (load-profile) is an important aspect when designing for renewable energies and can have substantial impact on the sizing of the system (Al-falahi et al., 2017). Hence, in order to make the best use of the system, energy efficiency (Alliance for Rural Electrification, 2011) and demand-side management (Franco et al., 2017; IED Innovation Energie Développement, 2013), as mentioned above, are important aspects that facilitate the use of renewables, minimize the need for energy storage, and can also avoid conditions where generators are put through extensive stress.

3.2.2. SOLAR PV MODULES

Solar photo-voltaic (PV) might be the first thing that comes to mind when discussing renewable energy. It is a mature technology with a long history of use in both off- and on-grid electricity systems, with installations all over the world. As **prices on modules are rapidly falling, from about 1.3 €/W_{peak} in 2000 to about 0.4 €/W_{peak} today** (Fraunhofer ISE, 2017), they are also becoming increasingly accessible in low-income countries. Current prices of PV make it a cost-effective technology, and competitive even in comparison to relatively low diesel prices (Breyer, 2010); as early as 2012, the payback period of PV in off-grid hybrid systems was estimated at 5-7 years.

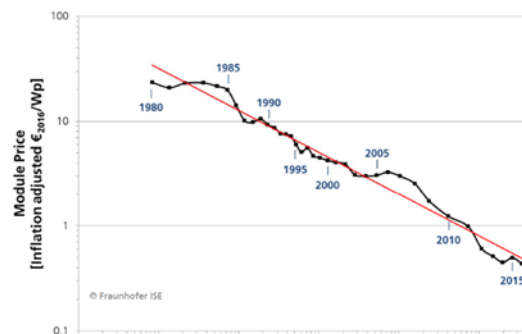


FIGURE 4. THE GRAPH DEPICTS THE RAPID DECREASE OF SOLAR PV MODULE PRICES. (FRAUNHOFER ISE, 2017)

The vast majority of PV-modules are produced in Asia, with price variations across the world mainly stemming from logistics, national regulations, and tolls. Modules constitute a significant part of the system costs, but as module prices decline a larger share of the system costs are attached to mounting the structures, inverters and electrical installations, without mentioning batteries if they are required.

The efficiency of solar to electricity conversion is also increasing, but generally a system installation requires modules of 6-7 m²/kWp for standard crystalline silicon modules. The potential power output from a PV system is non-dispatchable, and directly depends on the instantaneous amount of sunshine hitting the surface. The orientation of the installation will depend on geographical location and may also be optimized to match daily electricity consumption. In all circumstances, it is of paramount importance to make sure the modules are not in shade, as even a small amount of shade coverage

will significantly reduce power output. The PV modules must be handled with care, but require relatively low levels of maintenance. The **guaranteed service life of modules is often between 25-30 years**.

As the potential energy production from PV depends on the amount of available sunshine radiation, any system design must take site-specific solar resources into account. Solar resources naturally vary over the day and with the seasons. However, they can be accurately predicted, and generic datasets are usually sufficiently reliable, which are readily available as online resources.

The quality of system design, products, and installation work is of no less importance than for other electrical installations and comes down to three priorities: safety of people, protection of equipment, and continuity of service. PV modules produce a DC-current at a voltage that depends on the system configuration; sometimes a few 10s of volts, but could also be set to several hundred. Normally they cannot be turned off, and hence the modules are live as long as they receive sunshine.

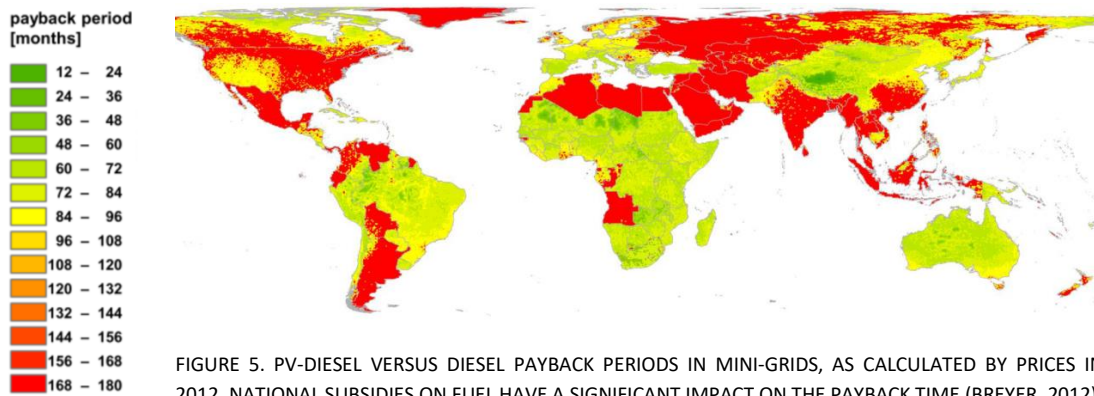


FIGURE 5. PV-DIESEL VERSUS DIESEL PAYBACK PERIODS IN MINI-GRIDS, AS CALCULATED BY PRICES IN 2012. NATIONAL SUBSIDIES ON FUEL HAVE A SIGNIFICANT IMPACT ON THE PAYBACK TIME (BREYER, 2012).

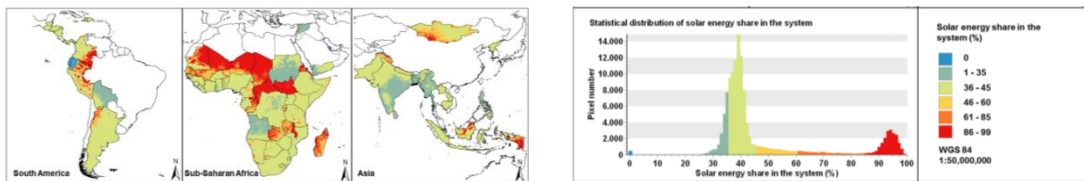


FIGURE 6. PV PENETRATION IN SOLAR DIESEL HYBRID SYSTEMS FOR SELECTED AREAS AS SUGGESTED WITH REGARDS TO MINIMUM LCOE. (CADER & BERTHEAU, 2016)

FIGURE 7. STATISTICAL DISTRIBUTION OF THE PV PENETRATION GIVEN IN FIGURE 6. (CADER & BERTHEAU, 2016)

The combination of solar PV working together with diesel generators in a hybrid configuration is rather common. The amount of PV electricity penetration depends on the site, user patterns, storage capacities, and of course the relative amount of PV installed. The illustrations in Figure 5, Figure 6 and Figure 7 are adopted from two statistical studies that use spatial GIS data to optimize hybrid configurations with respect to the levelized cost of electricity. As early as 2012, data suggested PV-diesel hybrid systems to have payback periods of less than 4 years in the most favourable settings, compared to diesel-only systems (Breyer, 2012). Furthermore, the studies also indicate a wide range of PV-penetration, from about 30% up to almost 100%, which also correlates well with the amount storage capacity needed (Figure 14).

3.2.3. SMALL-SCALE WIND

Small wind turbines are another option for renewable energy production. As wind resources are often complementary to solar, the inclusion of with turbines in a system might add reliability to the energy supply.

However, wind resources are intermittent and difficult to predict, both in time and space. They are extremely site-specific and even with guidance from good datasets available online [3], wind measurements at the site of installation are almost always necessary. The local geography, with different land use, topography, altitude, buildings, vegetation, etc. creates micro-climates that cannot be captured in generic simulated datasets. Wind measurements should preferably provide continuous data over a whole year to reveal seasonal variations, and as a rule of thumb the average monthly wind speed should not be below 4 m/s at hub height in order for wind turbines to be a viable option for energy production (Alliance for Rural Electrification, 2011).

Aside from wind resources, the local climate and weather will affect operational and maintenance needs. Turbines are complex mechanical devices with moving parts, which remain exposed to sunlight, rain, ice, salt, sand, etc. Turbines require servicing at regular intervals, which may involve lowering the tower in a safe manner. Sites that are exposed to (statistically rare, but) very strong winds, or sites with high frequency of lightning strikes, may be less suitable. By combining a set of environmental, technical, social and political parameters relevant to the use of small-wind in rural electrification, the organization WindEmpowerment (“WindEmpowerment,” 2017) recently published a brief global overview with countries rated according to their potential for small wind (Alsop, Eales, Leary, Persson, & Ruiz Almeyda, 2017).

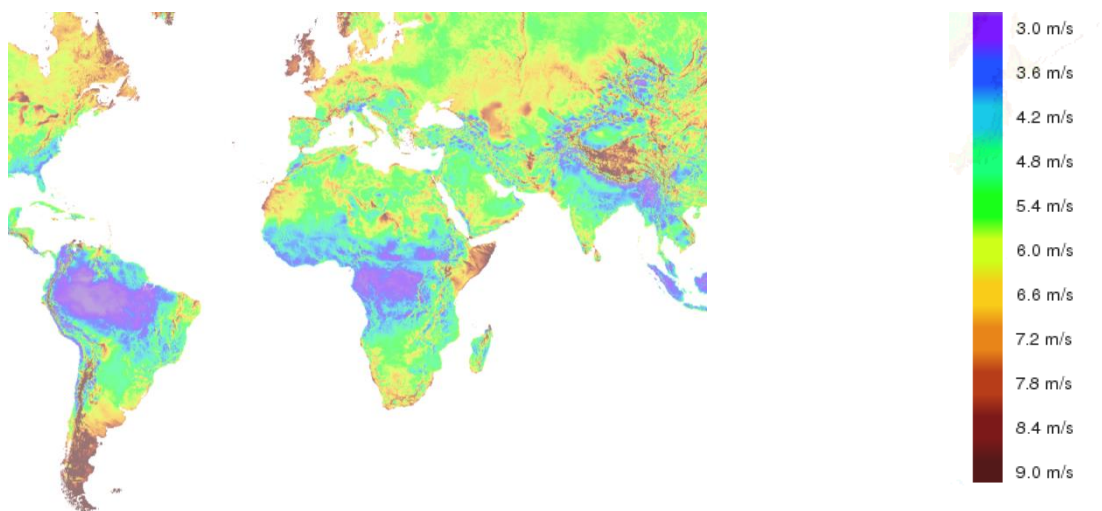


FIGURE 8. WIND MAP ADOPTED FROM IRENA GLOBAL ATLAS FOR RENEWABLE ENERGIES; VAISALA GLOBAL WIND AND SOLAR DATASETS, 80 M ABOVE GROUND (IRENA, 2017).

Small-scale wind turbines¹² have been commercially available for decades and producers can be found all over the world, although the market is much smaller than that for PV. There are also concepts for small wind turbines designed to make local production feasible, which will be manufacturable in relatively simple workshops by people with basic technical skills.

¹² Small-scale wind is normally referring to turbines less than 50kW.

3.2.4. MICRO-HYDRO

Micro-hydro systems are defined as hydro-electric power systems below 100kW capacity. They are even more site-dependent than wind, as they rely on a suitable stream of water which provides both enough flow and surface access over the seasons, in relatively close vicinity to the facilities. They often require significant infrastructural investments: dam, weir, penstock, and power house (the latter of which comes with high upfront costs of 2000-5000\$/kW). On the other hand, these structural investments might be managed with local capacity, and the well-designed micro-hydro plant could offer stable and cost-effective electricity. (IED Innovation Energie Développement, 2013; Sumanik-Leary et al., 2014)

3.2.5. SOLAR THERMAL

In contrast to solar PV, solar thermal systems produce thermal heat instead of electricity, and are often used to supply energy for domestic hot water and space heating. The types of systems relevant within this report can vary - from very simple low temperature systems which might be as simple as a black water hose exposed to the sun, to centralized hybrid systems that combine solar thermal collectors, thermal storage, and auxiliary heating sources to provide both Domestic Hot Water (DHW) and space heating for an entire building.

Thermal loads are often energy- and power-intense, and the motivation to consider solar thermal systems is to reduce the stress on the electric distribution and generation systems, as well as to utilize available solar resources. For example, **an electric water boiler of 120L might use more than 10kWh/day and require about 3kW of power** (NIBE, 2017). Electric water boilers are included in the European Eco-design directive, and the larger systems will need to be supported by solar or heat-pump heating sources in order to pass the energy efficiency criteria.

The sections below will address primarily the solar siphon systems, which are simple and complete outdoor systems for hot water production. A brief description will also be given of important design considerations for centralized systems, which relate closely to the use of thermal (hot water) storages. Thermal storages, in the same way as electrical energy storage, help to decouple energy production from power consumption, which often allows for a more efficient use of power sources.

SOLAR SIPHON

Solar siphon systems are commonly seen on the roofs of buildings all over the world. They are simple systems that combine a collector and storage tank in one product. The design details vary, but the common principle is a system that relies on self-circulation of water (in indirect systems, with anti-freeze additives for a separate collector circuit) that is heated in the solar collector and raises to the top of the tank, as cold water flows to the bottom of the tank and sinks down to the solar collector. The collector must always be placed below the storage tank to allow for the required self-circulation.

Solar siphon systems can replace standard electric water boilers (the most commonly used in MSF), although the solar siphon systems themselves are often equipped with a resistive heating element for auxiliary supply, in case the energy input from the solar collector is insufficient. The required size of the system depends on the hot water demand and the site where the system is to be used. The example below shows the performance of a specific solar siphon system installed in Greece. Here, **the energy input from the sun covers between 66%-78% of the energy needed for the hot water demand on an annual basis**. Referring to the same example, the system efficiency with regards to the ratio between heat delivery (Q_L) and annual radiation (G) is between ca. 32%-42%, which could offer guidance when sizing solar siphons. Instructions for sizing solar siphon systems are available, as for

example those provided in the UNDP material “User’s handbook on Solar Water Heater” (Kumar & Goswami, 2010).

There are standards available for testing the quality and performance of solar siphon systems, and this product group is also covered by the Solar Keymark labelling, which is the European market’s main quality labelling system (ESTIF, 2017). A Solar Keymark test certificate provides simulated performance data for different hot water demands and various sites (in Europe) that can provide support when choosing a suitable product. Other quality labelling systems are available for other world regions (Fernández, Fischer, Huggins, & Nielsen, 2012). A study on the growth of the solar thermal market in Thailand identified insufficient quality of products as one of the major barriers, with systems suffering corrosion and failure as a result. Lacking knowledge regarding sizing and installation of systems was raised as another reoccurring problem (SolTherm Thailand, 2007).

Example of solar siphon system

The data below is adopted from a test protocol for a solar thermosiphon product (Demokritos, 2015). Under the conditions specified, the system gives a solar fraction of between 66% and 78% depending on the daily hot water demands, while the remaining 22% - 34% of energy needs to be provided from an external source.

<i>Site</i>	Athens	<i>Collector</i>	1 piece, 1,78 m ²		
<i>G</i>	1748	<i>Tank</i>	1 piece, 140 L		
<i>T_a</i>	18,5	<i>Draw-off</i>	110	140	170
<i>T_c</i>	17,5	<i>Q_d</i>	1274	1622	1969
ΔT_c	7,5	<i>Q_L</i>	999	1165	1296
<i>T_h</i>	45	<i>f_{Sol}</i>	78	72	66

<i>G</i>	[kWh/m ² /year]	Annual radiation, South 45°
<i>T_a</i>	[°C]	Annual mean temperature
<i>T_c</i>	[°C]	Annual mean cold water temperature
<i>T_h</i>	[°C]	Desired hot-water temperature
ΔT_c	[°C]	Seasonal variations of T _c
<i>Q_d</i>	[kWh/year]	Heat demand
<i>Q_L</i>	[kWh/year]	Heat delivered by the solar heating system
<i>f_{Sol}</i>	[%]	Solar fraction
<i>Draw-off</i>	[L/day]	Daily draw-off from tank

OCB example: A recent initiative has been taken by the team in Bangui, DRC to use solar siphon systems to provide hot water, primarily for showers at the expat guesthouse. The team estimated an energy need of about 30-000 kWh/year for this purpose, which would correspond to an electricity cost of around 5000 €/year. They estimate a payback time of a couple of years.

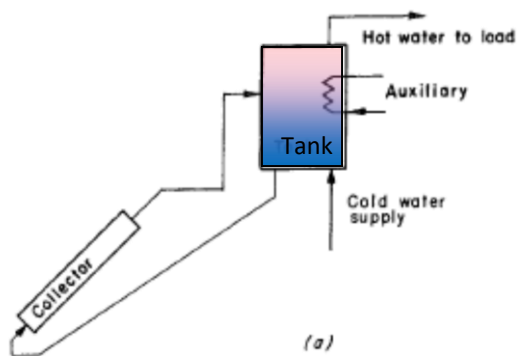


FIGURE 9. THE SKETCH ILLUSTRATES THE PRINCIPLES OF A SOLAR SIPHON SYSTEM, WHERE WATER SELF-CIRCULATES FROM THE BOTTOM OF THE TANK, VIA THE COLLECTOR TO THE TOP. NO CIRCULATION PUMPS ARE NEEDED. THE PICTURE IS ADOPTED FROM (DUFFIE & BECKMAN, 2013).



FIGURE 10. A TYPICAL SOLAR SIPHON SYSTEM COMBINING A COLLECTOR WITH A TANK, HERE INSTALLED ON A MSF BUILDING IN ZIMBABWE.

CENTRALIZED HYBRID SOLAR THERMAL SYSTEMS

There are several possibilities for system configurations that combine solar thermal and auxiliary energy sources (bio energy, direct electric heating, etc.), and local traditions on execution differ from country to country. Although there are rules of thumb for designing a system, it is generally hard to predict exactly how much auxiliary energy can be saved as it depends on the size of collectors, tank size and configuration, operating temperatures, solar resources, hot water demand and user behaviours. However, appropriate system design is crucial for reaching a good system performance with a high solar fraction, and the heart of the system is often the thermal hot water storage tank. Figure 11 below shows a typical system with a bio-fuel boiler and solar thermal collector connected to a storage tank. From the storage tank, domestic hot water as well as hot water for space heating is supplied. Hence, it is an altogether water-based system (sometimes with additives) that is being discussed. The text below may be perceived as detailed and technical, but highlights some crucial aspects regarding the design of a centralized solar thermal system.

It is generally highly desirable to have a good stratification in hot water storage tanks, which maintains a consistent temperature gradient with hot water on top and cold water at the bottom. All system components, connections, and internal heat exchangers should be installed in a way that helps to preserve this stratification. Good stratification will increase system efficiency and reduce the need for auxiliary power. The rule of thumb, which is used in cold European climates, suggests **50-100L of storage volume per m² of solar collector surface**. With a very small tank there is a risk of regularly filling the tank completely, hence letting the solar collectors reach stagnation. A much larger tank might be difficult for the collectors to charge to required temperatures. Normally, the system - both collector surface and tank - should be designed according to the domestic hot water demand (Kovacs, 2010).

“The heart of the system is often the hot water storage tank, and it is always desirable to strive for a good stratification with cold water at the bottom and hot water at the top”

There are a variety of solar collector types: unglazed collectors, flat-plate collectors, vacuum tubes, and various concentrating systems. Without any further details, a major difference between these

refers to the stagnation temperature, in case the system stops and the circulation of liquid ceases. A well-insulated flat-plate collector might reach 160-200°C, vacuum tubes and concentrating systems even higher. It is hence important to ensure that the system itself and all the materials in direct contact with the system can sustain these temperatures (and pressures) without taking damage.

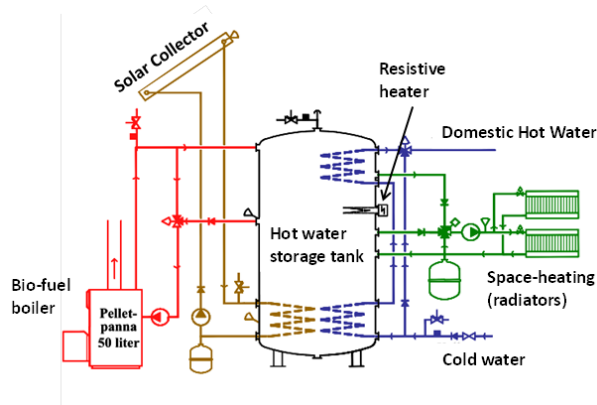


FIGURE 11. THE ILLUSTRATION SHOWS THE SCHEMATICS OF A HYBRID SOLAR THERMAL SYSTEM THAT PRIMARILY COMBINES A BIO FUEL BOILER AND SOLAR COLLECTOR TO CHARGE THE CENTRAL STORAGE TANK. FROM THE TANK, DHW AS WELL AS HOT WATER TO THE SPACE HEATING SYSTEM IS PROVIDED. AN AUXILIARY RESISTIVE HEATER IS INDICATED ON THE RIGHT OF THE TANK.

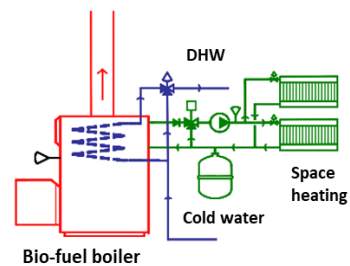


FIGURE 12. THE ILLUSTRATION SHOWS INSTEAD THE SCHEMATICS OF A BIO-FUEL BOILER THAT DIRECTLY PROVIDE DHW AND HOT WATER FOR SPACE HEATING.

3.3. ENERGY STORAGE

Energy storage can help integrate electricity and heat systems, and enable decoupling power and energy generation from power and energy demand. They can also play crucial role in the developments of energy systems by:

- Improving energy resource efficiency
- Introducing a higher level of intermittent renewable energy
- Improving grid stability, flexibility, reliability and resilience

There are a wide range of functions and values that energy storage can offer, both for energy and power management, and some of them will be addressed below (IEA, 2014; Rocky Mountain Institute, 2015).

3.3.1. ELECTRIC ENERGY STORAGE

This section below primarily treats batteries, and in particular lead-acid batteries, as they have until now often been the default choice in off-grid energy systems; lithium-ion batteries are a rapidly-developing technology which may be a viable alternative to lead-acid. There are many more available technologies which are not directly addressed here (Rydh & Sandén, 2005a).

The initial subsection considers the functionality of electric energy storage. The following subsections are deal with the perceived challenges of operating batteries. Batteries are sensitive components, which must be treated with great care so as not to reach a premature end of life. They might add very significantly to overall systems costs, especially when evaluated from a system life-time perspective.

Furthermore, battery consumption presents an environmental issue, especially if they cannot be recycled properly.

FUNCTIONALITY OF ELECTRIC ENERGY STORAGE IN MINI-GRIDS

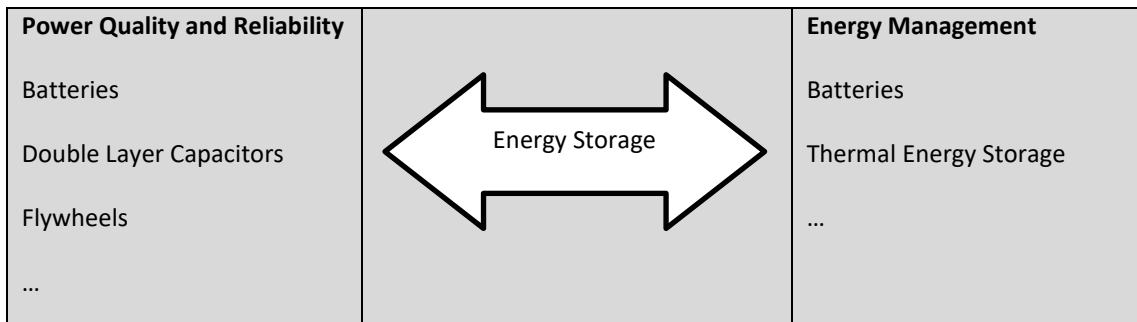
Small isolated grids, whether they are diesel-only or a hybrid system with several generation sources interacting, need to internally manage grid stability. They cannot rely on an external grid to ensure generation meets demand at every instance, that voltage level and frequency remain within limits, and that both real and reactive power can be provided for. The challenge is often further complicated by smaller load diversity and a potentially high penetration of intermittent renewable generation. Still, with the same kind of equipment and loads connected, the demand for grid stability and power quality characteristics are similar to those of centralized grids (Espinar & Mayer, 2011).

As the grid must be able to meet rapid changes in load-level or power input, there must be means for up-regulation of generation in case the load is suddenly increased, or if e.g. solar PV production is reduced by passing clouds; conversely, down-regulation is needed to balance the system if loads are suddenly disconnected. To some extent, this regulatory capacity can be provided by generators, which initially absorb or release kinetic energy of the rotating mass before the combustion process has adapted to the new conditions. This capacity requires the generators to operate at reduced efficiency below their normal capacity, and the transition from one point of operation to another might last for several seconds and result in significant frequency deviations.

Energy storage systems can be a means to improve grid stability, as they can absorb and provide power. Their functionality can serve either short-term grid stability (≤ 2 minutes), or long-term energy shifting from the time of production to a much later time of consumption. Each function adds different technical requirements to the energy storage system. For grid stabilization, the following characteristics need to be prioritized (Espinar & Mayer, 2011):

- Very fast response rate
- Flexible rate of changing power
- Discharge duration at rated power
- Symmetric charge/discharge capacity
- High efficiency
- Long cycle-life

Energy storages employed as uninterruptable power supplies (UPSs) ensure power supply and service in case the main generation source fails. Depending on the typology of the UPS, the system can also act to improve grid stability under normal running conditions.



TRENDS OF LITHIUM-ION BATTERIES

The price development for lithium-ion batteries is driven by the market for electric vehicles. Lithium-ion battery prices have plunged from about \$1000/kWh in 2010 to \$270/kWh in 2016. The scenarios for the rate of future falling prices vary, but most seem to agree that prices will reach less than \$100/kWh sometime between 2020-2030 (Berckmans et al., 2017; Curry, 2017). However, there is also a growing discussion regarding the environmental impact related to the mining and production industries of lithium and other metals used in the batteries.

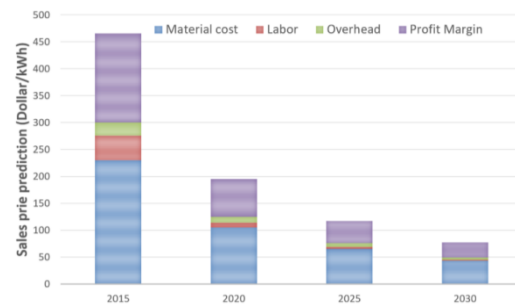


FIGURE 13. THE DIAGRAM IS ADOPTED FROM (BERCKMANS ET AL., 2017) AND SHOWS ONE SUGGESTED SCENARIO FOR THE PRICE DEVELOPMENT ON LITHIUM ION BATTERIES.

Also related to the above, even if it is a little-known debate, there is growing concern regarding human rights abuses linked to cobalt compounds used in the production of lithium-ion batteries (Amnesty International, 2017).

LCA-ANALYSIS

The environmental impact of battery production, transport, use, and disposal can be studied with a Life Cycle Analysis (LCA) from “cradle to grave”. The most frequently studied aspect is the impact on global warming or Global Warming Potential (GWP, measured in CO₂ emission equivalents) from the product life cycle. The least-studied impact in the references found is that of human toxicity. This will be elaborated somewhat at the end of this paragraph.

It should be noted that an LCA of a battery or a setup of batteries does not really provide the information required for an environmental assessment of the choice of energy and storage systems. The impact must be studied over a specified life cycle of a complete energy system, and should preferably be compared to the corresponding impact of a reference energy system. In this case, the solar energy system should include all components including the PV panels, batteries for a certain storage, chargers, inverters and connectors. These systems are usually studied over a full PV panel lifetime, 20-30 years, as this is normally the component with the longest lifespan in the system. The LCA will then include the periodical replacement of batteries (at least in the case of lead-acid batteries) and potentially other components as well. The comparison that is currently most interesting for MSF is with diesel generator-supplied electricity. For comparison, this should then be studied over the same timespan as the solar power system, including potential generator replacements.

Here we will concentrate on the GWP aspect, as this is currently considered to be of utmost importance globally, and since most of the other LCA parameters (abiotic resource depletion, acidification potential and eutrophication potential) seem to show approximately the same comparison results with the diesel generator system as does GWP.

References give a relatively wide GWP span for solar power system components. The variation is due to the manufacturing process and location of PV panels as well as batteries (energy mix for manufacturing) as well as the location of the installed PV system (less sunny locations have a higher PV production environmental impact). Two system comparisons that are almost directly applicable to typical MSF hospital operations in equatorial settings have been found (Bilich et al., 2017; Sandwell et

al., 2016). Both are recent comparisons of PV-based off-grid micro-grids in Kenya and India respectively, with energy supplies of approximately the same magnitude as a typical MSF field project. Both also compare the environmental performance of the PV-based systems with different combinations of hybrid PV-generator systems, as well with as pure diesel generator powered micro-grids. In both studies, the basic energy storage is in lithium-ion batteries, but some comparisons are also made with lead-acid batteries. Although they are not completely unanimous, the general conclusion of both is that the total life-cycle GWP of the PV-based systems (in general complemented by 5-7% diesel generator power) is significantly lower. The differences range from a factor of 3 to a factor of 17 in increased GWP for the diesel generator solutions compared to the PV hybrid solutions. Interestingly, the India study also compares the economies of the different systems, and indicates that PV-based systems and diesel generator systems have comparable production costs per kWh, even at a diesel cost of \$0.67/litre.

Another interesting system comparison has been found in the telecommunications sector for remote radio base stations (RBS). An MSc thesis (Bondesson, 2010), performed for Ericsson, shows that a PV solution with lead-acid battery storage would cut GHG emissions (GWP) to less than 10% of those of the diesel generator system without battery backup, and to approximately 15% of a diesel generator system with battery backup. The batteries account for slightly less than half the GWP of the total PV system.

Conclusions concerning different types of batteries again vary between studies, primarily due to different cycle life assumptions of different battery chemistries. But in general, the conclusion is that the GWP over a PV system lifetime is lower for lithium-based battery types than for lead-acid batteries. In the most thorough comparison found (Rydh & Sandén, 2005a, 2005b), the “energy return factors” of different battery technologies, i.e. the total cycle life energy throughout compared to the total manufacturing energy input, was compared. This shows that the energy return factor for the Li-ion batteries were roughly 8 (variation from 6 to 10) compared to 5 (variation 2.5-7.5) for the lead-acid batteries. Assuming the same power mix for the manufacturing processes of the two technologies, the GWP comparison would be approximately the same.

The impacts on human toxicity and related health effects from batteries, primarily at end-of-life, is not extensively covered in most of the studies found. However, in most of the studies, lead-acid batteries are identified as more harmful than lithium-based batteries, but very few direct comparisons are made. One recent study (Ericson et al., 2016) attempts to calculate the huge number of informal recyclers of lead-acid batteries and calculates the grievous health impact the process has on the population in proximity of these sites. Even though direct comparisons to health effects from other battery systems are not available, the overall conclusion is still that the negative effects of Li-ion batteries are smaller. Corresponding health impact estimates from diesel and generator-powered operations are not widely available, but according to (Bilich et al., 2017), the LCA estimator for human toxicity gives somewhat lower indications but in the same order of magnitude as for PV systems with Li-ion battery storage.

LEAD WASTE FROM BATTERIES

One of the main issues with lead-acid batteries is the often-lacking capacity for adequate recycling of lead in project locations. Hence, considerations need to be made on how to minimize the amount of lead that is consumed in relation to the total amount of energy passing through the batteries until they are at end-of-life. The example below is a rough “back-of-the-envelope calculation” intended to illustrate that batteries must be sized and treated carefully in order to minimize the amount of lead

waste. Input data is taken from two sources: the data sheet of battery cells intended for cyclic applications (BAE, 2017; Hoppecke, 2017), as well as from a publication on batteries in off-grid PV systems which refers to data on an older gel-type battery.

Capacity @ C10	Ah	729		As show in the tableFel! Hittar nte referenskälla., the cycle life of the battery cell strongly corresponds to the Depth-of-Discharge (DoD) allowed. The capacity is expressed in Watt-hours, by multiplying the number of Ampere-hours with the nominal voltage of the cell (2V) ¹³ . The lifetime energy throughout is the product of the cycles until end-of-life and the available energy capacity per cycle at the respective DoD.
	Wh	1458		
Gross weight	kg	51		
Cycle-nr [#]	DoD [%]	Life-Time throughput [kWh]	Lead-Waste [kg/kWh]	
2800	50	2000	0,018	
3750	40	2200	0,016	
5250	30	2300	0,016	
8250	20	2400	0,015	

At end-of-life, the battery is considered waste, which then leaves a quantity of lead in need of processing. As an estimate here, 70% of battery weight is lead. With the data from this specific battery cell, we see lead consumption in the range of 0.015-0.02 kg/kWh.

Cycle lives for lead-acid batteries can be tested according to standards like IEC 61427 or IEC60896-11/-21. The conditions behind the performance tests in the data sheets often differ from those seen in actual field applications. A publication that compared the battery performance at different charge current characteristics concluded that lead-acid batteries might degrade when charged with intermittent current (as is often the case for renewable off-grid systems) compared to when charged with a constant current. The reason was believed to be an incomplete recharge. (Krieger, Cannarella, & Arnold, 2013) If instead the cycle life given for a gel battery (data from 1997 in a publication on energy analysis of batteries for PV off-grid systems (Rydh & Sandén, 2005a)) is applied to calculate a lead consumption, the lead-consumption is in the range of 0.04 – 0.1 kg/kWh. The shift from 0.04 to 0.1 presented here is related to an increase in ambient temperature from 25°C to 40°C. **Hence, it is of paramount importance to keep lead-acid batteries fully charged and avoid elevated temperatures.**

SIZING AND OPERATION OF BATTERY SYSTEMS

The example above is not a complete representation of a real battery system and the conditions it might endure, but does illustrate the need to carefully setup a lead-acid battery bank according to existing standards and guidelines for the given application. Furthermore, it is extremely important to have the right type of battery for the required purpose. A more statistical approach to battery sizing for mini-grids, including a variety of generation technologies, suggested a linear proportionality of about 9 kWh battery storage per kW generation capacity (Breyer, 2012). However, the scattering of data is rather large, and the actual conditions for these systems are not specified. A more recent study, with a similar approach based on a GIS-mapping for minimizing LCoE in solar-diesel mini-grids,

¹³ The capacity is not an absolute number, but depends among other things on the size of the current relative to the battery capacity. Here the data for full discharge over 10h has been used (C10).

suggests a relation between the PV penetration (Figure 7) and the required battery capacity, as given in Figure 14 (Cader & Bertheau, 2016).

There is a range of degradation mechanisms that over time reduces the available capacity of a battery; corrosion of the positive electrode, physical loss of active material, sulphation of electrodes, porosity loss in negative electrodes, stratification of electrolytes, as well as growth of dendrites and damaged separators that could cause short-circuit. The major degradation mechanisms are the sulphation¹⁴ and corrosion of the positive electrode,¹⁵ which are often the main reasons for battery failures.

In order to ensure the longest possible lifetime of a lead-acid battery, it is important to (Jossen & Weydanz, 2006):

- Not discharge the battery more than necessary;
- Allow for battery recharge as soon as possible;
- Adjust the charge process to the battery use and the temperature;
- Fully recharge the batteries at least once a month;
- Avoid elevated temperatures;
- Recharge stored batteries regularly - never store batteries at temperatures >35°C.

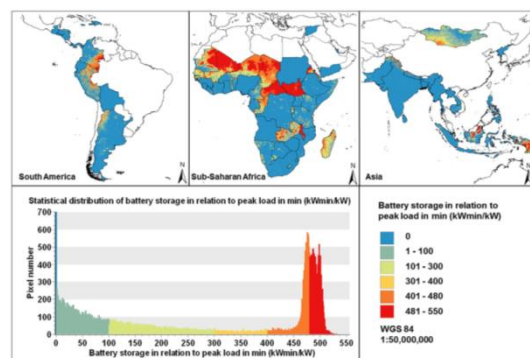


FIGURE 14. THE DIAGRAM SHOWS THE SPATIAL DISTRIBUTION OF BATTERY CAPACITY IN RELATION TO PEAK-LOAD FOR SOLAR-DIESEL MINI-GRIDS. (CADER & BERTHEAU, 2016).

The take-away of these recommendations is to allow the lead-acid batteries to stay at a high SoC and arrange for battery rooms to have as low a temperature as possible.¹⁶

Although lithium-ion batteries are less sensitive to low states-of-charge, they also suffer from degradation mechanisms, especially at elevated temperatures and high cell voltages. The range of chemistries within the 'lithium-ion' umbrella term is rather large and the technology is developing rapidly. However, remaining within a state-of-charge of 30%-70% enhances the life-time of the cells; frequent full-charge and deep-discharge should be avoided (Jossen & Weydanz, 2006).

TRANSPORTATION OF LITHIUM-ION BATTERIES

Lithium-Ion batteries are considered as dangerous goods and transportation is regulated in standards. Almost all lithium batteries need to pass the tests specified in UN DOT 38.3 (UN transportation testing), and transportation is regulated in UN3090 and UN3091, or UN3480 and UN3481.

¹⁴ During discharge of lead-acid batteries, small lead sulphate crystals are formed as a part of the reaction. If the battery remains in a discharged state, these crystals grow, the active surface decreases and it becomes very difficult to dissolve the crystals during the reverse charge reaction.

¹⁵ The oxidation of the positive electrode is complex, but is accelerated by high over-charge, high temperatures and discharge with very small currents and stratification of electrolytes.

¹⁶ Below -5°C, the batteries risk freezing.

For air freight the maximum quantity of lithium-based batteries integrated in equipment is limited to 5kg on passenger aircrafts, and 35kg on cargo aircrafts (IATA, 2017). Also transportation via sea or land must be carried out in accordance with existing regulations for dangerous goods.

COBALT SUPPLY CHAIN

Finally, at this point we consider that we cannot talk about Lithium-Ion batteries without mentioning the risk that it incurs regarding human rights abuses in the cobalt supply chain. As one of the elements used in the production of lithium-ion batteries, the growing demand for them has been contributing to an increase in cobalt prices since the beginning of 2017. Organizations such as Amnesty International report that the former is sustaining a market for minerals mined by hand “under extremely dangerous conditions”(Amnesty International, 2017, p. 4); especially in the Democratic Republic of Congo (DRC), one of the countries in which OCB is operational.

Different companies’ ways of approaching this issue vary massively from brand to brand, and, as an humanitarian organization, we believe MSF should take these differing approaches into account when selecting one brand over another. One of the latest comparisons on how different corporations producing lithium-ion batteries do or do not act against human right abuses can be found in (Amnesty International, 2017).

3.3.2. THERMAL ENERGY STORAGE

The use of thermal storages can be well-suited to allow for both supply-side and demand management. Although hot water storage might be the first that comes to mind, there is a range of technologies available for thermal energy storage, which differ in terms temperature range, specific energy capacity and power rating, as well as efficiency. The main types of technologies are sensible energy storages, latent heat storages and thermo-chemical storages. Sensible storage technologies, like hot and cold water storage tanks, are established and well-proven technologies. The commercial use of some technologies based on latent heat, like ice-storages, is also increasingly used to support cooling systems. The development of other phase-change materials (PCMs) and thermo-chemical energy storage continues to ensure cycle life and to reduce the costs. Although more advanced thermal storages might be of interest in certain projects, the brief introduction below is limited to sensible thermal storages as the cheapest and perhaps simplest alternative.

SENSIBLE THERMAL STORAGES

The hot water storage tank was addressed as an almost compulsory component for solar thermal systems, and the possibility for good stratification has been pointed out as a key aspect of a well-designed hot water storage (T. Persson, 2010). The way the tank and its interior are designed, how well it can preserve stratification, could have significant impact on the system performance. The objective when designing a tank is to minimize the need for auxiliary heating sources, while covering the hot water demand.

A fully-charged tank might well reach above 90°C, wherefore it is important to minimize heat loss from the tank. Such loss is often via convection, either through the insulation material or in the system’s pipes, which can be reduced by ensuring the insulation layer is airtight and installing pipe connections that bend downwards to avoid self-circulation. In a tank of about 700-900L, with an average temperature differential of 40°C to the ambient temperature, heat loss might amount to between 500 - >2000 kWh/year.

Domestic hot water storage tanks are used all over the world with multiple uses beyond just solar thermal systems, and permit timing the operation of e.g. electric boilers to avoid peak-hours - a measure employed on a large scale by utility companies in France, for example (IEA, 2014).

In a similar manner, cold water storage tanks present the possibility of supporting cooling systems. Compared to e.g. an ice storage unit, the energy density of cold water storage is several times smaller, but also a significantly cheaper as a technical system.

3.4. TOOLS FOR ENERGY SYSTEM DESIGN

Since accurate system design is one of the key factors for successful use of renewable energy technologies in off-grid systems, several tools have been made available to support the design process, offering different approaches with relative strengths and weaknesses. The list given below is not exhaustive, and only shows examples of existing tools. A more thorough compilation of resources for size optimization methodologies for standalone solar and wind hybrid energy systems has been put together by Monaaf D.A. Al-falahi et al. (Al-falahi et al., 2017). Although several of these tools are commercial, free but time-limited trial versions are often available.

HOMER ENERGY

Homer Micro Power Optimization Model was developed by National Renewable Energy Laboratories in order to facilitate comparison between different generation technologies. It uses time-series to perform simulations, optimization, and sensitivity analyses based on technical and economic inputs. Optimization is done to minimize life cycle costs (Lambert, Gilman, & Lilienthal, 2005).

A free and simplified online tool for designing energy systems for health clinics, powered by HOMER Energy, is available via USAID. It is, however, limited to a maximum energy use of 30 kWh/day. The tool can be found [here](#) (USAID, n.d.).

iHOGA

iHOGA is being developed by the Spanish university of Zaragoza and, similarly to Homer, provides modelling, optimization, and sensitivity analyses of hybrid electric stand-alone systems based on time-series. In addition to life-cycle costs, iHOGA offers multi-criteria optimization.

RETSCREEN

RETScreen is provided by the Canadian government and is designed to support feasibility studies for a wide range of both thermal and electrical energy generation technologies, and also addresses some passive solutions. The tool provides life cycle costs and green-house gas emissions relative to a defined base-case (*Clean Energy Project Analysis: RETscreen Engineering & Cases textbook*, 2005).

PVSYST

PVsyst is limited to the simulation of PV systems only, with a focus on grid-tied systems. However, DC off-grid and solar-water pumping systems can be modelled.

TRNSYS

TRNSYS offers a flexible simulation environment primarily developed for modelling transient thermal and electrical systems. However, it has vast libraries that allow for modelling of multi-zone, buildings, heat-pumps, HVAC equipment, etc. ("TRNSYS," 2017).

POLYSUN

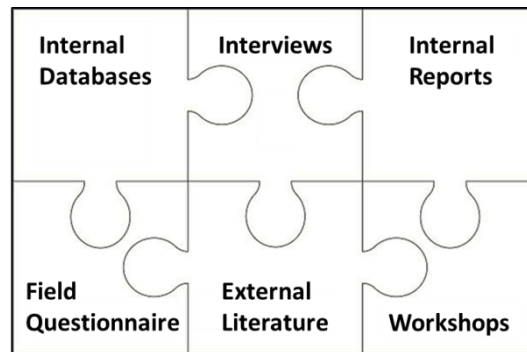
Polysun allows for the simulation and optimization of energy systems based on photovoltaic, solar thermal, heat-pumps, cooling systems, and cogeneration units, or a combination of these (Velasolaris, 2017).

BUILDING ENERGY PROPERTIES

A recent initiative within OCB has instigated the use of energy modelling tools to assess the building energy properties and HVAC performance of a prefab structure, the Gaptex modules (Ten Palomares, 2017a). There are several options for simulation software that address building systems and enable a deeper understanding of how energy properties could be improved. In those cases where HVAC represents a large share of overall energy use, it might be advisable to find support on how both active and passive solutions could reduce the energy demand related creating a desired indoor climate. Examples of relevant software include EnergyPlus, IDA ICE, IES VE, ESP-r and TRNSYS for which comparative studies are also available (Sousa, 2012).

4. METHODOLOGY AND SOURCES

Both **quantitative and qualitative research methods were used** to address the objectives of this study. Statistical data were collected from internal tools and departments, which are prepared by field projects and delivered to HQ. Documentary data were collected from project monitoring-, global planning and budgeting- and other internal reports. Primary qualitative data were obtained through consultative meetings and interviews with staff members from various departments.



The research methods included longitudinal and cross-sectional data analysis, with case studies and surveys. Structured questionnaires were distributed among staff in the field to collect information and opinions about the current energy situation in their projects. From July 2017 until September 2017, the authors conducted numerous formal and informal interviews with (1) staff working in Brussels HQ and (2) staff working in field projects. All interviews were conducted in English and analysed using content analysis.



4.1. DATASETS

The datasets used for the study were those available at HQ level, which constitute aggregated input from the field projects via centralized reporting systems. Data from three main reporting systems have been extracted: the Logistics Reporting System (LRS), the assets list of Buphagus, and the financial records.

In addition, complementary data has provided by the various logistics departments. These datasets are the product of individual initiatives taken to collect and locally manage data of relevance for the specific technical or tactical family. The sections below introduce these sources in more detail.

4.1.1. LOGISTICS REPORTING SYSTEM (LRS)

The Logistics Reporting System is an online reporting tool developed by OCA, but has used by OCB since June 2016. Once a project is registered on the LRS, logistics project staff can report on 11 different technical families, and a total of 99 indicators. Indicators consist of quantitative data (number values), and qualitative information (yes/no answers and narrative answers). An overview is provided in **Fel! Hittar inte referenskälla.** below. These results are then shared at the national coordination level and ultimately with OCB HQ in Brussels.

Technical Family	Number of LRS indicators	Technical Family	Number of LRS indicators
Biomedical equipment	9	Leadership and Management	8
Cold Chain	2	Mobility	14
Construction	9	Security and Safety	5
Energy	13	Telecom	5
Health Facility Management	16	WHS	9
ICT	9	Total	99

TABLE 3. EACH OF THE TECHNICAL FAMILIES ARE REPRESENTED WITH A NUMBER OF INDICATORS FOR WHICH THE FIELD PROJECTS PROVIDE MONTHLY INPUTS. IN TOTAL THERE ARE 99 INDICATORS.

A complete export of all inputs across all reporting months was provided in July 2017 for use in this study. This export contained 13 months of data: from July 2016 to July 2017, inclusive. With this data, longitudinal results could be found.

Out of the 99 indicators, 17 were selected to obtain a limited yet initially comprehensive set of indicators that either individually or collectively could provide information on the energy supply, energy use and quality of the energy system. As detailed in **Fel! Hittar inte referenskälla.** below, these consisted of two indicators from construction (C&I), three from mobility (MOB), 11 from energy (NRG), and one from water, hygiene and sanitation (WHS).

4.1.2. BUPHAGUS

Buphagus is an asset management tool, used to record all field assets shipped via MSF Supply. The dataset provides information on the products supplied: dates, current status, costs, projects, etc. The dataset reaches back to 2002.

4.1.3. FINANCIAL RECORDS

Finance data lists all transactions related to the Fuel and Utilities categories. These lists covered the months of May 2016 to May 2017. Each export consisted of roughly 10,000 data values. The fuel dataset provided spending for energy and mobility purposes, primarily on diesel, petrol and oil. The utilities dataset provided spending on electricity, natural gas, firewood, and charcoal, as well as water purchases.

In some instances, finance data includes descriptive details about the amount spent within a given timeframe (usually one month), the quantity of fuel or electricity purchased, as well as if the fuel was intended for use in generators, vehicles or for space heating. The information also allowed us to determine unit rates of various energy sources.

Finance data was sorted by individual project and individual energy type, so that each project would have a breakdown of energy spending. Project spending is averaged over the entire set of data to give either monthly or yearly values.

Key	Title	Definition
C&I04	m ² of health structures	The total surface of all the (different) health structures managed by MSF in your project
C&I05	m ² of MSF warehouse	The total surface of warehouses (and storage areas)
MOB11	Price for one unit of fuel	The average cost for one (1) unit of fuel in your project
MOB13	Kilometres driven	This element tracks the distance (km) driven during the past month for all vehicles of your project.
MOB14	Quantity of fuel used	This element track the total liters or gallons of fuel consumed for transport over recent month
NRG03	Energy safety incidents	The number of energy related safety incidents over the current period
NRG04	Generator service schedule	The recommended service schedule for generators are done and documented in the generator follow-up sheet or logbook
NRG05	Critical power breakdowns	Reported critical unattended power breakdowns
NRG06	Generator running hours	The running hours (in hrs) of the generators (with the precise capacity of each generator) over a period
NRG07	Power back-up presence	The continuous power supply of critical devices is insured by backup system (UPS, charger-inverter, back generator...). The critical device will be determine by the logistician of the project and the Logistic Coordinator
NRG08	Generator fuel consumption	The fuel quantity (in liters) consumed per generator during the reporting month.
NRG09	Electrical equipment damaged	What is the number of the electrical equipment damaged?
NRG10	Equipment protection	All electrical critical/sensitive/important equipment is protected with the right means in every location
NRG11	Team comfort (in relation to electrical means provided)	Electric means are adapted to offer a minimum comfort for the teams. Anything related to operational efficiency and team life
NRG12	Reliability of city power	% of reliable city power available
NRG13	Medical structure power consumption	kw/h consumed (Inclus l'électricité de ville) for each medical structure. Consumption registered by a kw/h meter connected at the source of the facility.
WHS06	Number of beneficiaries	It's the number of beneficiaries that MSF treat/care directly over previous month

TABLE 4. THE LRS INDICATORS LISTED ARE SELECTED FOR INPUT TO THIS STUDY.

4.1.4. DEPARTMENTAL DATA

Through an initial assessment of the LRS, it became clear that additional sources would be needed to compile a more complete picture of energy use within OCB. To achieve this, apart from the Energy team, several departments were contacted in August 2017 for their respective project data.

FRONT OFFICE

The front office provided us with their budget forecast for 2017, which also contained project details including start/end dates. For some cells we also received data on six parameters: area of total facilities, area of medical facilities, logistical budget, number of logistical staff, fuel consumption over a 3-month period, and total number of computers. Together, these six parameters form what the Front Office refers to as a 'Project Volume'.

BACK OFFICE

In the back office, the different tactical and technical teams provided compilations of data relevant to their individual professions, broken down on project level. These compilations include:

- Generator details for the projects previously visited: the number of generators per project, their capacities, running times, and their exact locations within a project.
- Construction-relevant data where projects are represented by: project budget, medical activities, number of beds, areas of medical and total facilities, type of facility, etc.
- Data on size and location of medical and logistical warehouses.

- Tactical typology of the OCB projects, combining both medical and contextual indicators relevant for the operations. The tactical typology not only provides input on the different projects, but due to its tactical nature, also serves as a core resource onto which the energy mapping of this study is attached.

TACTICAL TYPOLOGY

Prior to this study, OCB's tactical team had reviewed operations and generated a typology of all ongoing OCB medical field projects. Within this typology, projects are categorized into one or more of the following three clusters, along with a set of indicators for the context in which they operate. The three clusters are:

- Emergency response
- Health facilities
- Specialized medical activities

The typology is developed as a tactical tool to give a global overview of OCB operations. It therefore serves as a suitable starting point for the work to understand the current OCB energy realities within the operations, and potentially find patterns that correlate with the clusters. Expanded with energy relevant indicators, the typology could further function as a first preliminary tool when planning future developments related to energy. As the typology gives a more-or-less contemporary snapshot of active projects, it has supported the definition of the list of projects considered within this study.

FACILITIES

In addition to field projects, the energy consumption of Brussels HQ was investigated as a reference object. The facilities department provided utility data on the use of electricity and gas. Data was provided for the period of March 2016 to February 2017, and included both cost (in Euros) and quantity (in kWh).

4.2. Stakeholder Meetings

A primary objective of this study has been to incite wide participation of people bringing different competencies and responsibilities within the entirety of OCB, including the back office and front office logistics department at HQ, but also the LOGs working in the field at coordination level or in individual projects. Attempts have also been made to reach outside the logistics department, although this has proven difficult. Representation from the medical side has primarily consisted of people working in the BioMed and WatSan departments.

The objective of wide participation serves two main purposes. The first is to collect a range of valuable input, not only from people whose activities require energy services, but also from those who provide the infrastructural settings within which energy systems are an integral part. This interdependency is also the main reason why any successful future implementation of new solutions or improvements will partly depend on a collective awareness of the challenges and possibilities regarding energy supply in the field. Hence, the second purpose behind stakeholder meetings was to create a buy-in from those who use energy systems, and those who influence the conditions in which energy systems operate. It is an imperative necessity that we engender a collective notion that energy is something that both serves and concerns us all.



4.2.1. GROUP WORKSHOPS

During the course of the study, three different workshops were conducted at OCB headquarters. Each workshop had its own objectives. The first one was set to gather people's initial ideas, inputs, and visions regarding energy services at operational level. The following two workshops allowed us to provide an update on the work being done and to receive feedback on how to move forward. The workshops were key in enhancing collective reflection, facilitating a deeper analysis, and getting the various actors on board.

Invitations were sent to back office technical specialists, including Energy, Biomed, Mobility, Construction, WatSan, and Supply. Back office logistics management was invited, as well as front office Cell LOGs.

FIRST WORKSHOP

As a part of the project orientation phase, a breadth of different stakeholder views are sought in order to uncover what the needs and challenges are regarding energy within MSF social missions, and to jointly collect input on what and how MSF could do differently in providing an energy service. For this reason, MSF Sweden Innovation Unit organized a half-day workshop with OCB headquarters representatives.

Preceding the workshop, participants were given the project background, an overview of the project timeline (June – December 2017), why energy means more than just electricity, and the current state of energy planning in the humanitarian sector. The main objectives of this workshop were:

1. *Explore the current situation. (Where are we now?)*

What are the different stakeholders' perspectives on OCB's current energy situation? What is energy for MSF? What are the strengths, needs, and challenges?

2. *Explore the desired future situation. (Where do we want to go?)*

Where do we want to go in terms of energy (medium and long-term)? What solutions do people envision? What are the key performance indexes that would capture people's motivations to look for alternative energy systems?

3. *Create conceptual solution proposals. (How do we get there?)*

How could the needs be approached, and the challenges tackled? Where do we begin? What actions, activities, and proposals are needed? What data needs to be collected to build a picture of what energy is to MSF today?

SECOND WORKSHOP

The second workshop was held after the initial data was collected, and when a preliminary data analysis had been conducted. The main objectives of this workshop were to:

- Discuss a proposal for an extension of the project tactical typology to include energy aspects, along with the methodology for the mapping of current energy realities used within the Energy Vision project.
- Discuss the initial findings on OCB's energy use globally and in certain projects.
- Together with the different stakeholders, build on the direction for the remainder of the project.

THIRD WORKSHOP

The third workshop was held at a stage when preliminary input for a road-map had begun to be formulated based on the learning outcomes from the study up until this point. The main objectives of this workshop were to:

- Provide an overview of the project scope along with some key learning outcomes.
- Introduce and discuss preliminary inputs for the road-map.

DISSEMINATION

The discussions and the findings from these individual workshops were summarized and distributed to all attendees and invitees following each workshop. These summaries are to be found in the annexes of this report.

4.2.2. INDIVIDUAL INTERVIEWS

A total of 18 interviews were held through July and September 2017 in the Brussels HQ office. The first group of interviews was held with individuals who could not attend the first workshop; this was to ensure opinions from all departments were collected and used in project planning. Interviews included staff from the back office—all technical families and the tactical team—and front office logistical cells. These individual meetings allowed for further in-depth discussions and provided possibilities for the collection of quantitative data managed by the respective people.

Additional interviews directly with selected LOGs in the field were held outside the Brussels HQ through phone calls. The main objective of these interviews was to gather their input on experiences related to individual initiatives on alternative energies taken in the field. These interviews partly addressed technical aspects, but mainly served to understand the conditions offered by OCB to pursue innovative solutions to specific or general energy-related challenges.

4.3. FIELD SURVEY (QUESTIONNAIRE)

After an initial review of the information available within OCB HQ, the research team developed an online survey to complete data with information from the field projects. The questions in this survey were organized into 4 categories:

- **Generation**, in terms of generators, back-up systems (UPS), city power, and alternative solutions
- **Supply** of fuel (transport, storage) as well as water (storage, pumping)
- **Consumption**, in terms of both heavy equipment and priority appliances. Examples include fridges, A/C units, O₂-concentrators, and washing machines.

- **Maintenance:** staff safety and skills, as well as other organizations with relevant knowledge in the project area.

The questionnaire was distributed via the LOGs at mission coordination level, who were asked to pass them on to their respective projects. It was sent on 7 August 2017 with reminders through the end of September.

4.4. Document Review

Two primary categories of documents have been reviewed to provide qualitative input on the work performed within the different technical families at the back office: field-visit reports and technical support documents. Assuming these documents reflect the main priorities of each family, the purpose was to understand to what extent energy-related aspects are practically addressed, and these maybe bridge the different disciplines. The documents also give an idea of where OCB is in terms of support and structures to assist its field workers in managing alternative energy systems. Given the vast number of documents of this kind, the review has neither been complete in terms of the number of documents reviewed nor in terms of depth. The documents have been reviewed with the above-mentioned aspects in mind, and contain far more information than was extracted for this study.

5. RESULTS AND ANALYSIS

The data analysis based on the methodological techniques described above was performed as the research was progressing in order to obtain permanent feedback to improve the methodology for data collection and analysis.

In order to contrast the information and maximally reduce possible biases, the information was triangulated in four different ways: 1. Between techniques; 2. Between stakeholders; 3. Between stakeholders in the same cluster (HQ and field), 4. Between stakeholders and techniques (see **Felittar inte referensskälla.**).

5.1 DEFINITION OF PROJECT LIST

It is not always straight-forward to define what a project is within OCB, and which that we should include within this study to have a comprehensive and manageable overview of the operations. Some projects open, others close; some project ID codes refer to specific activities within larger projects, like emergency preparations or constructions. Deciding which projects to include here was primarily influenced by a budget list provided by the front office with the 2017 annual budget for all OCB projects.

The budget list also contains information for each project, including: the budget forecast in Euros; the start date; the estimated end date; definition of the project; whether it is in a conflict zone; whether it was initiated by default or by choice. The final category is 'type of project' which has five options: (1) direct, (2) funding direct project, (3) association, (4) support coordination/base, (5) direct remote control.

*With this information we were able to identify **105 main projects** that were active in the 12 months prior to the start of data collection in July 2017. These projects delimited our research boundaries.*

5.2. PROJECT AND TACTICAL TYPOLOGY

After reviewing the existing tactical typology, it became apparent that coordination projects were not considered, as they do not normally run medical activities. They do however have a significant need for energy services to run offices, guesthouses, warehouses, pharmacies etc. For example, 90% of medical stock is held by coordinators according to the Cold-chain Referent. A **typology of projects capable of capturing all energy related-activities would need to include the tactical team’s three clusters plus “Coordination” as an additional fourth category.** In the present study, we integrate this fourth category in our data analysis. The four categories are given in the **Fel! Hittar inte referensskälla.** elow.

A Emergency Response	Distributions (NFI, Shelter, Vaccines & Water)
	Highly Contagious disease outbreaks
	Medical activities in emergency
	Surgical activities in emergency
B Health Facility	Multiple medical activity health structure
C Specialized Medical Activities	Mobile medical activities
	Vertical inpatient department (IPD) activities
	Outpatient department (OPD) activities
	Medical activities in restricted areas
D Coordination	Non-medical mission-wide and regional support
	Capital-based emergency-preparation stock

This expansion of the tactical typology to include coordination projects was suggested and discussed during the second workshop, together with people from both back and front office log department.

Valid questions were raised on how the typology can actually serve planning purposes, when the full scope of the context needs to be taken into account in the detailed implementation phase.

TABLE 5. CLUSTERS A, B AND C RELATE TO THE OCB MEDICAL PROJECTS, AND D IS ADDED HERE TO INCLUDE THE ENERGY SETTINGS OF THE CORDINATION PROJECTS.

5.2.1 ENERGY RELEVANT INDICATORS

Beyond these categorizations, the initial tactical typology also included a range of indicators defining the context of the projects. Indicators that reflect aspects more specific to various technical teams are also already used. For example, the energy technical team differentiates between new and rehabilitated electricity installations, which might relate to similar indicators set by the construction team on the type of buildings used within a project. We used the tactical typology for analysis purposes, but we are not proposing any energy typology. However, we see that there are several indicators that can be combined with the typology to have a clearer energy picture. Potentially, these indicators can offer practical relevance at an early planning phase. Some of the additional energy-relevant indicators are listed below, and are addressed in the following results section. These indicators partly overlap with the existing indicators used for Energy within the LRS, but are here pragmatically formulated to work along with the data that is available, primarily via finance data but also external datasets. As will be further described in section “5.3. Quality and Coverage of Datasets”, there is a general lack of good data on energy use and generation within OCB. The indicators are given per project, and are not necessarily refined in further details.

Indicator	Unit	Motivation
Project Coordinates	deg	The project coordinates allow for other geographical information to be collected.
Project Duration	years	The anticipated project duration is an essential parameter when evaluating the investment in different energy system solutions.
Total Fuel Consumption	L/month	Gives a very initial indication of the amount of energy services required by the project, including potential transportation and storage of fuel. Indirectly available from the financial records of

		fuel spending.
Grid Connection	Yes/no (spending)	The better the access to a stable grid, the less likely it is that OCB is involved with actual energy generation. Financial records provide data on utility spending.
Share of fuel for NRJ purposes	%	A separation of total fuel spending on energy and vehicles allows a refined estimation of the energy needs of the project. Partly available from financial records.
Annual Mean Solar Radiation	kWh/m ² /day	The annual average global horizontal radiation, along with a quantification of the seasonal variations, indicates the viability of solar energy technologies.
Annual Mean Wind Speed	m/s (@80m)	Less important, but might serve to rough indication for local wind conditions. Of interest to for example wind energy, natural ventilation.
Heating and Cooling Degree days	Days * °C with ref. to 18°C	Gives an indication of the potential need for a well-considered heating and/or cooling system, which is potentially very energy demanding.
Annual Relative Humidity	%RH	The annual average relative humidity may indicate challenging sites in terms of HVAC-needs.
Annual Mean Temperature	°C	Along with seasonal variations, the annual mean temperature gives an indication of the potential need for a well-considered heating and/or cooling system, which is potentially very energy-demanding.
Fuel prices	€ /L	The price of fuel influences the time until break-even for alternative energy setups compared to traditional diesel generators. Partly available from financial records and/or external datasets.

In addition to the indicators listed above, several of the indicators already established by the construction technical team are also of interest from an energy perspective, as given below. A systematic collection of these data would be valuable to improve the data coverage.

Indicator	Unit	Motivation
Total facility size	m ²	Large facilities in harsh climates may indicate rather demanding energy setups, partly in terms of HVAC, but also for the general installations and services like lighting. Energy consumption normalized on facility size is a well-established indicator for all kinds of facilities.
Medical facility size	m ²	
Warehouse and/or Pharmacy	Yes/no (m ²)	Pharmacies and medical warehouses might need a well-controlled temperature and humidity, to avoid destroying sensitive drugs.

Number of beds	#	The energy consumption normalized to the number of beds is an established indicator for hospital settings and can be used for both internal and external benchmarking.
Type of building	n/a	Distinguished between local buildings, prefab (semi-permanent) constructions and tents. The type of structure and its expected lifetime influence what kind of energy system installations might be anticipated.
Complexity	n/a	Indicates the existence of complicating activities, for example laundries, OTs and X-ray machines.

Furthermore, there are indicators of interest that until now have only been available randomly, as direct response from the field, as communication with people in office, or as input in field-visit reports. Access to these indicators would have value for future data collection. This list is not exhaustive, but may be complementary to the existing LRS indicators.

Indicator	Unit	Motivation
Energy Consumption and load-profiles.	kWh/day	Energy consumption separated between utilities, generators and non-electric energy systems. If sampled at high enough frequencies, this data could provide accurate load-profiles. For load-profiles, a time resolution of max 1h should be used, and data separated by the different phases and preferably also different lines.
Generator Run-time	h/day	When and how much is each generator running each day. Important to indicate if the generator is being used in the night.
Generator Capacity	kVA	The nameplate capacity and location of the generators in the project give an indication of the power demand of the projects facilities.
Centralized systems	Yes/no	If the project uses centralized heating or HVAC systems, there is an increased complexity and an increased need for dedicated competence at the project site.
Mode of fuel transport	Mode Difficulty	Is there a need for OCB to specifically transport fuel to the project? If so, what is the mode of transport and how long and difficult is the journey?
Fuel storage	m3	What is the maximum amount of fuel that the project keeps? This might relate to security concerns.
Main energy loads	n/a	A listing and count of main energy loads, including for example ACs, heat-pumps, space heating, water boilers, laundries, auto-claves, water pumps, sensitive biomed equipment, fridges, etc. This will provide info on what energy services are required, but also what competences are needed to operate the project.
Alternative energy	Type Capacity (kW)	What non-electric or renewable energy generation systems are

	and kWh/day)	deployed in the project, and what is their rated capacity?
Energy Storage	Type Capacity (kW and kWh/day)	What energy storages are deployed in the project, and what is their rated capacity?
UPS systems	Type Location Capacity (kW and kWh/day)	What UPSs are deployed in the project, and what is their rated capacity and location in the project?
Type of electric installation	New/rehabilitated/temporary	Which type of electrical installation works are present in the project: new installations made by OCB, local installations rehabilitated by OCB, temporary installations for emergency use.
Visit of electrician	Date (report)	When was the project's electricity system last inspected by an electrician?
Electric line diagram	Yes/no (Date)	Is there a line diagram of the electricity installations, and other energy systems? When were they last reviewed?

5.3. QUALITY AND COVERAGE OF DATASETS

The quantitative datasets were meant to serve as primary input for this study. However, there were a number of challenges in the data collection and verification processes, which limited the possibilities of using the data for analysis.

The Log Reporting System (LRS) was intended as a main centralized reporting tool for the logistics department and will be discussed below, but its limitations led us to also work with a range of other larger and smaller datasets. Some are centralized, and others are initiatives taken by individual technical teams to provide an overview of matters of direct relevance for their respective work. Generally, it has been challenging to obtain and compile data held in multiple, separate locations and by different people. A brief review of the quality and coverage of data in the main datasets will be given below.

5.3.1. LOGISTICS REPORTING SYSTEM (LRS)

The Logistics Reporting System (LRS) is available to all OCB projects and covers all the logistical families. There are currently **27 OCB missions and 114 projects with access to the LRS**.

Of the 114 OCB projects with access, **only 55 projects (40%) have reported data to the LRS**. The remained 60% of projects are not using the system.

All available LRS data was exported on 14 July 2017. This dataset covered 13 months of reporting, from June 2016 to June 2017, inclusive. The data export of all 99 LRS indicators produced 12,038 values; each one representing one input into the LRS. This was then reduced to 2,574 values by selecting the 17 indicators of primary relevance for this study. The completeness of the data for these indicators is given in **Fel! Hittar inte referensskälla..**

Key	Title	Completeness
C&I04	m ² of health structures	3%
C&I05	m ² of MSF warehouse	6%
MOB11	Price for one unit of fuel	6%
MOB13	Kilometres driven	26%
MOB14	Quantity of fuel used	26%
NRG03	Energy safety incidents	10%
NRG04	Generator service schedule	31%
NRG05	Critical power breakdowns	28%
NRG06	Generator running hours	5%
NRG07	Power back-up presence	11%
NRG08	Generator fuel consumption	5%
NRG09	Electrical equipment damaged	29%
NRG10	Equipment protection	11%
NRG11	Team comfort (in relation to electrical means provided)	11%
NRG12	Reliability of city power	31%
NRG13	Medical structure power consumption	2%
WHS06	Number of beneficiaries	3%

TABLE 6. THE COMPLETENESS REFERS TO THE DEGREE OF REPORTING PER INDICATOR, AGGREGATED OVER ALL THE PROJECTS WITH ACCESS TO THE SYSTEM.

Completeness was determined by the ratio of registered inputs to the total possible inputs. First, the total was calculated by multiplying the number of reporting months (=13) by the number of OCB projects using the LRS (=55) to determine the maximum number of values for each indicator (=715). The percent complete represents the number of actual response related to a given indicator across all projects on the LRS.

22 missions (81%) have reported information related to energy. Of the 114 projects present on the LRS, more than half (59 projects) did not report any energy data across 13 months. Another 10% (11 projects) reported information in 2016 but did not report in any months of 2017. Less than half (44) of the total 114 projects reported any energy data in 2017.

These results show that **there are very few projects consistently reporting energy data into the LRS.** Of the 55 projects that reported any energy data in 2016 or 2017, 23 of them (42%) were coordination projects. Therefore, a large number of field projects are not reporting energy information available to HQ.

5.3.2. FINANCIAL RECORDS

In contrast to the LRS data which had many gaps, data collected from the finance department contained a high level of detail and content. It is safe to estimate that **approximately 95% of projects are captured by the finance department’s data.**

Two datasets were exported by the finance department, each with roughly 10,000 data values. The first dataset was *fuel* (finance code 6061200), which includes diesel, petrol and oil. The second dataset was *utilities and other energy* (finance code 6065200), which includes electricity and non-liquid energy sources.

The financial records contain more project codes than the projects listed in the tactical typology and the main 105 projects identified from the front office dataset. In several cases these additional project codes can be attached to the “main” projects listed in the typology as subprojects. This has been done to account for the large quantity of fuel used within OCB. Matching subprojects, which might be shorter additional activities like a measles outbreak in the area of a project or an emergency preparation, is a subjective exercise, and in the extended typology the instances in which subprojects are included are indicated.

It is important to note that **costs related to the transport of fuel are not captured by the financial records**, even in those cases where it is of significant relevance. Nor is fuel used in auxiliary services

included, which included airplane travels or for subcontracted services where energy spending is included in the bulk price. These values were not captured as part of this research

Even if it is not always possible to say in detail what the purpose was for a specific fuel purchase, an input of the volume/quantity and type of fuel separate from the description would be useful.

An/ mois	Date doc.	Mis/ dép.	Proj/ cdf	Montant EUR	Description
42856	42853	MCF1	PCF112	26.37	ESSENCE 20L
42856	42855	MCF1	PCF112	259.16	GASOIL 200L
42856	42855	MCF1	PCF112	2,073.31	GASOIL 1600L
42856	42870	MCF1	PCF112	130.35	GASOIL 100L
42856	42886	MPK1	PPK127	98.78	MSF CAR PETROL 04/2017 143LITRES THQ
42856	42886	MPK1	PPK127	131.79	MSF CAR DIESEL 04/2017 172.19LITRES
42856	42886	MPK1	PPK127	1,805.09	GENERATOR DIESEL 04/2017 2358LITRES
42856	42886	MPK1	PPK127	249.55	RENTED AMBULANCE DIESEL 04/2017 326.

TABLE 7. SHOWS TYPICAL INFORMATION USED FROM THE FINANCE FUEL RECORD: PROJECT CODE, VALUE, AND THE DETAILS DESCRIBING THE TRANSACTION. WHEN POSSIBLE, INFORMATION ON THE VOLUME AND WHAT THE FUEL IS USED FOR GAVE VALUABLE INPUT TO UNIT PRICES OF FUEL.

An/ mois	Date doc.	Mis/ dép.	Proj/cdf	Montant EUR	Description
42856	42858	MAF1	PAF187	3,813.83	ELECTRICI BILL\$ 21/1>20/3/17\$ CHQ 00
42856	42862	MAF1	PAF187	4.80	CHARCOOL\$7KG\$ HOSP
42856	42864	MAF1	PAF187	106.83	LIQUID GAS\$108\$ HOSP & HSE
42856	42878	MAF1	PAF187	132.84	LIQUID GAS\$194KG\$ HSE
42856	42859	MLB1	PLB118	202.79	CHQ2 ELECTRICITY FEES 11-12/17 GH AK
42856	42859	MLB1	PLB118	169.29	CHQ2 ELECTRICITY FEES 09-10/17 GH AK
42856	42866	MLB1	PLB118	124.23	CHQ5 GENERATOR FEES\$311KW 04/17 GH A
42856	42866	MLB1	PLB118	152.24	CHQ5 GENERATOR FEES\$389KW 04/17 GH A

TABLE 8. ALSO, THE FINANCE UTILITY RECORD PROVIDES INFORMATION ON VARIOUS DETAILS OF SPENDING RELATED TO ELECTRICITY AND NON-LIQUID FUELS. THE QUANTITY IS OFTEN NOT GIVEN.

5.3.3. BUPHAGUS ASSET LIST

Buphagus lists assets shipped via MSF Supply. It does not cover items bought locally by the projects. The first records date from 2002, though Buphagus and MSF Supply first merged in 2010. The number of items registered every year is sharply increasing. The record is only used to see volumes of certain categories of products handled by MSF Supply, for example O₂-concentrators.

5.3.4. BACK OFFICE DATASETS

During this research project, we requested relevant information from the back office technical families. Below are three datasets that were used in our project:

- The **compilation of 145 generators** covers 10 missions and 31 projects. It includes information on capacity, daily run-time hours, total run-time hours, capacity, and calendar age.
- The **construction compilation** covers 82 projects in 28 missions. Values are given for size (m²) of built facilities, type of facilities, and number of beds, with coverage of around 50-60%. The

dataset further has a ‘complexity’ indicator, e.g. certain biomedical equipment, complex medical activities, and existence of laundry or multi-story buildings.

- The **compilation of warehouses** gives information on 47 warehouses in 27 missions, separated into logistical warehouses, medical stock and pharmacies. For slightly less than 50% of entries, warehouse size is given.

5.3.5. FRONT OFFICE DATASETS

The Project Volume is a rather new measure within the front office, which is currently in the process of being unified across all Cells. For that reason, not all Log Cells had data available for their respective projects. The measure use input on size of total facilities, size of medical facilities, LOG budget, number of LOG staff, monthly fuel consumption and number of computers.

5.4. OCB CURRENT PROJECTS AND SITES

The sections below summarize general observations regarding project durations, but also site-specific data regarding fuel prices and climate data. The statistical distributions are limited to the 105 projects that are currently active and were initially selected for this study.

5.4.1 PROJECT DURATION

In the discussion of appropriate infrastructural solutions and investment costs, the anticipated time that the operations will last is of course an important input. The diagram in Figure 15 below shows the distribution of durations for ongoing projects within OCB. The project duration is taken as the time from when the project was started until the anticipated future date of closure. **The average project lifetime is just below 8 years**, and the majority of the projects are anticipated to last longer than 4 years, before they are most likely handed over to another organization to continue the activities.

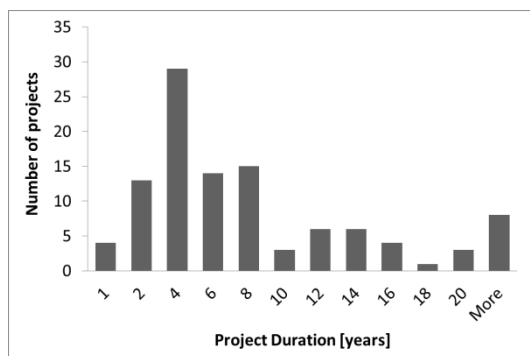


FIGURE 15. THE DISTRIBUTION OF TIME DURATIONS OF OCB PROJECTS IS GIVEN HERE WITH A 2-YEAR RESOLUTION. THE PROJECT DURATIONS ARE TAKEN AS UP UNTIL THE ANTICIPATED FUTURE DATE OF CLOSURE. ALMOST 60% OF THE PROJECTS LAST FOR MORE THAN 4 YEARS.

5.4.2. FUEL PRICES

The price of diesel at the tap station shows significant variations at a global level, and is often subject to national subsidy systems. The graphs below show the distribution of fuel prices at OCB projects. The prices do not include the transportation of fuel that the operations need to cover, and which could add significantly to the numbers. Furthermore, the dataset is based on the fuel costs as reported to finance (given in Euros) by the projects. In instances where no information could be extracted from the financial records, data from the World Bank global mapping (The World Bank,

2014) has been used as a complementary source. Prices are given in €/L, and a conversion of 1 € = 1.1\$ has been used for the World Bank data. With the combined datasets we get an OCB global average diesel price (over the given project sites) of about 1 €/L, excluding explicit costs for transporting the fuel to the projects.

As the data record from finance only covers 13 months, the World Bank data is only used show the trend of diesel prices over the last two decades. In the last ten years, the price has almost doubled across the world. The Middle Eastern countries are distinguished by generally lower diesel prices, although they have also seen significant price increases.

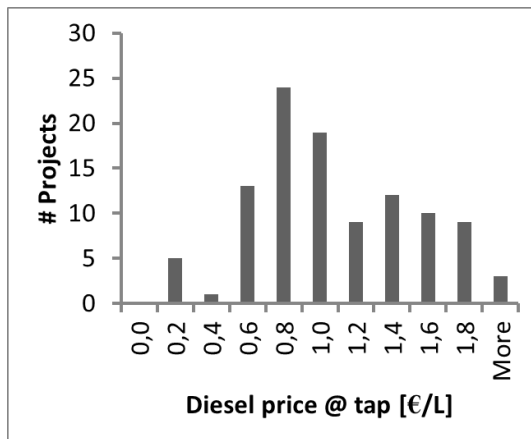


FIGURE 16. THE GRAPH SHOWS THE DISTRIBUTION OF DIESEL PRICES OVER THE OCB PROJECTS. THE MEAN GLOBAL VALUE IS ABOUT 1 €/L.

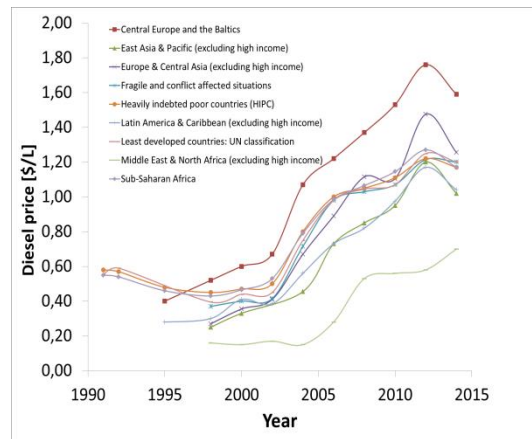


FIGURE 17. THE GLOBAL TREND, ESPECIALLY SINCE 2003, HAS BEEN SIGNIFICANTLY INCREASING DIESEL PRICES IN ALL REGIONS.

The graph in Figure 18 plots the projects with project duration versus the diesel prices at the project site. The sizes of the circles indicate the monthly expenses on diesel in the projects. The suggestion is that **long-lasting projects at sites with high diesel prices should have better conditions to handle infrastructural investments**, especially if a large monthly energy expense also represents a high potential for improving the services. There are projects with high monthly energy spending in all categories, although the few emergency projects are particularly energy intense. Projects furthest to the right on the horizontal axis include Italy, Greece, South Sudan, Malawi, Zimbabwe, DRC and CAR. Several of the later countries are further related to burdensome fuel transportation, like in Maban, South Sudan, where barrels of fuel need to be flown in from the capital.

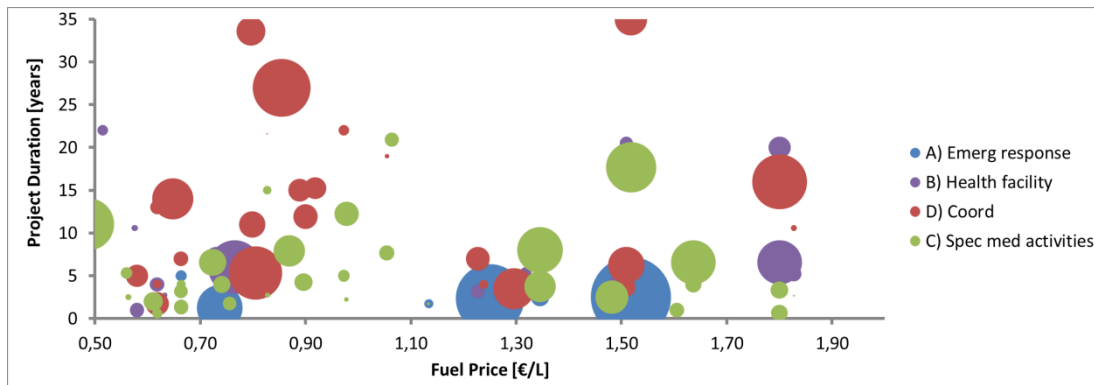


FIGURE 18. THE DIAGRAM PLOTS THE DURATION OF PROJECTS VERSUS THE DIESEL PRICES AT THE RESPECTIVE SITES. THE SIZE OF THE CIRCLES REPRESENTS THE RELATIVE FUEL CONSUMPTION OF EACH PROJECT. LONG-LASTING PROJECTS IN AREAS OF HIGH DIESEL PRICES SHOULD HAVE STRONGER ECONOMIC REASONS TO CONSIDER WAYS TO REDUCE DEPENDENCY ON DIESEL.

5.4.3. CLIMATE

As is mentioned several times throughout this document, there is an increasing demand for creating a suitable indoor climate within our hospitals and medical warehouses, but also for purely comfort reasons in guesthouses and offices. These processes are very energy consuming, and obviously depend on the difference between the outdoor and requested indoor climate.

The outdoor climate conditions at the sites of the projects have been extracted from the NASA resource database (NASA, 2017), which provide monthly and annual values with a special resolution of one degree. The datasets used here include:

Temperature	°C	Air temperature at 10m above the surface of the earth.
Heating-Degree-Days (HDD)	°C*days	Accumulation of degrees when the daily mean temperature is below 18°C.
Cooling-Degree-Days (CDD)	°C*days	Accumulation of degrees when the daily mean temperature is above 18°C.
Relative Humidity (RH)	%	Calculated from the air temperature and specific humidity at 10m above the surface of the earth.
Radiation	kWh/day/m ²	Refers to the global insolation on a horizontal surface. It includes both direct and diffuse radiation.
Wind speed	m/s	Wind speed at 50m above the surface of the earth.

TEMPERATURE AND HUMIDITY

The diagram in Figure 19 shows the relative humidity plotted against temperature for all the current sites of OCB projects. The values are annual mean values and both daily and seasonal variations will in some cases be considerable. The area indicated in grey represents the preferred indoor climate in a medical warehouse or pharmacy (Gaudesi, 2017). As expected, **many projects are in warm and humid areas, where buildings will potentially have a cooling need**. However, cooling the air might increase the challenge of maintaining a relative humidity of below 65% even further.

The distribution in Figure 20 shows the number of projects within a given range of cooling- and heating degree days, in both cases relative to a reference temperature of 18°C. Using this measure, all sites have a cooling need; in some cases it might not be very large, but for many project sites it is rather significant and is likely to place demands on the logistics for solutions to reduce the indoor temperature. **Around 75% of the projects have no or only small needs for heating.** However, a few sites are very cold and will need technical solutions for heating the indoor air; these are projects primarily in Afghanistan, Pakistan, Lebanon, Ukraine, South Africa, Egypt, Serbia, Turkey, Greece, and Italy. Several sites have both cooling and heating needs during various seasons.

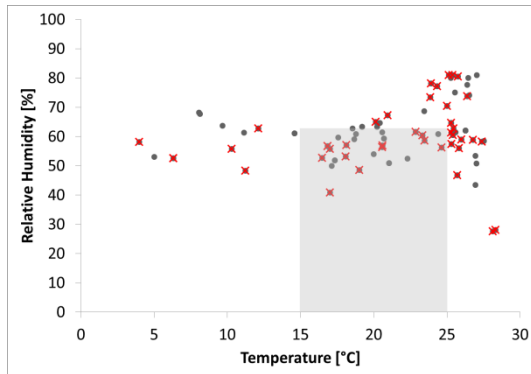


FIGURE 19. THE DOTS REPRESENT THE CURRENT ONGOING OCB PROJECT SITES WITH ANNUAL AVERAGE VALUES FOR RELATIVE HUMIDITY PLOTTED AGAINST TEMPERATURE. THE CROSSES ARE SITES WITH A MEDICAL STOCK OR PHARMACY.

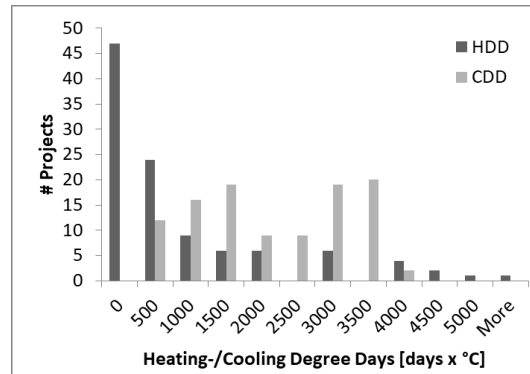


FIGURE 20. THE DISTRIBUTIONS OF HDD AND CDD SHOW THAT MOST PROJECTS HAVE A POTENTIAL NEED FOR COOLING (SMALL OR LARGE), WHEREAS A FEW PROJECTS HAVE RATHER LARGE HEATING NEEDS.

Apart from **the climate, the size and type of structures will influence the need for cooling and/or heating of indoor spaces, and will also influence what kind of technical solutions would be appropriate.** The diagram in Figure 21 shows the product of HDD/CDD and the available measures of facility sizes. Large facilities in very cold or warm places score higher, indicative of where special attention to the HVAC energy system might be required. In several cases, this pattern correlates well with the actual energy consumption reported by the projects.

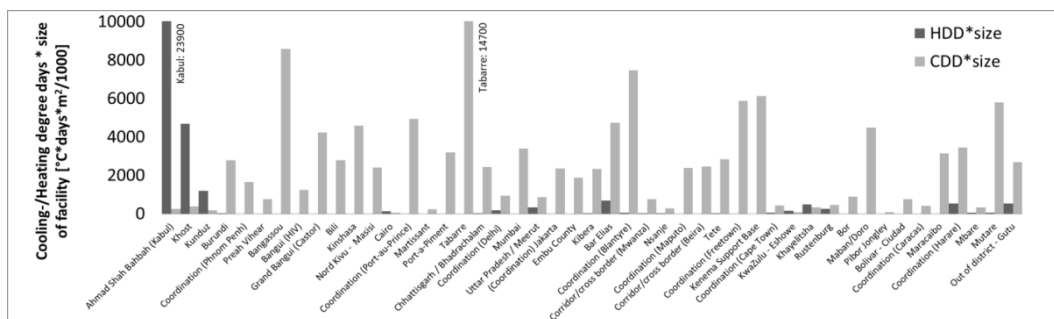


FIGURE 21. FOR EACH PROJECT WITH AVAILABLE DATA ON THE FACILITY SIZES, THE BARS GIVE THE PRODUCT OF THE SIZE AND THE HDD/CDD RESPECTIVELY. HENCE, LARGE FACILITIES IN VERY WARM OR VERY COLD PLACES SCORE HIGH, AS AN INDICATION ON WHERE CONSIDERATIONS ON WHERE HEATING- AND/OR COOLING SYSTEMS MIGHT BE NEEDED.

SOLAR AND WIND RESOURCES

Generally, solar resources are very good at OCB project sites. As the distribution in Figure 22 shows, **almost all projects show an annual average global horizontal radiation above 4,5 kWh/m²/day** (corresponding value for Brussels is 2.8 kWh/m²/day). The distribution along the vertical axis shows

the relative difference between the month with the lowest radiation compared to the annual average for each project. Many projects show both high annual mean radiation values and low seasonal variations. High and stable solar resources will make it easier to dimension a solar power system. It is primarily projects in the northern hemisphere - Ukraine, Serbia, Italy, Greece - that show high seasonal variations and relatively low radiation values.

The wind speeds (@ 50m) show a much larger distribution, with annual mean values between 2,5 m/s up to 6,5 m/s. The seasonal variations of the wind do not show the same high values as solar radiation, but it should be emphasised that for any project where the wind speed is of specific interest, the local micro-climate needs to be considered and preferably dedicated measurements performed. Datasets like this give only a rough indication of potential wind resources.

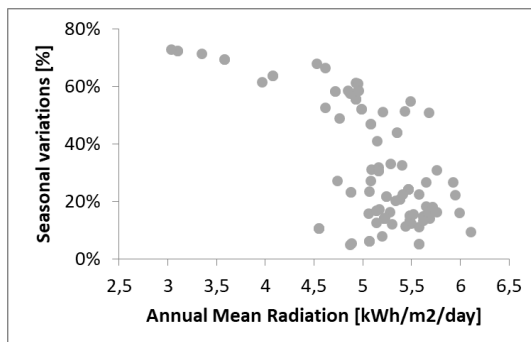


FIGURE 22. THE ANNUAL MEAN RADIATION IS GIVEN TOGETHER WITH THE SEASONAL VARIATION EXPRESSED AS THE RATIO BETWEEN THE MONTH OF LOWEST RADIATION AND THE ANNUAL MEAN.

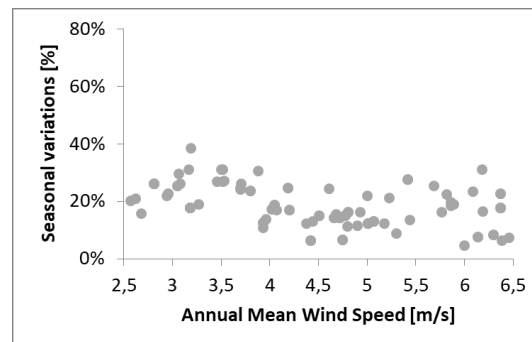


FIGURE 23. THE ANNUAL MEAN WIND SPEED IS GIVEN TOGETHER WITH THE SEASONAL VARIATION EXPRESSED AS THE RATIO BETWEEN THE MONTH OF LOWEST WIND SPEED AND THE ANNUAL MEAN.

5.5. ENERGY PRODUCTION

5.5.1. ENERGY SOURCES

A motive behind the OCB Energy Vision project is to extend the focus to a wider perspective of energy, including more than just electricity. The question is then whether this is solely a matter of shifting focus, or to what extent it would also imply developing new ideas about energy system setups. A compilation of how expenses for energy are distributed over different energy sources (Figure 27) indeed shows that fuel and electricity directly from the grid dominate the energy systems within OCB. Note must be taken that, at this stage, no separation is made between fuel for energy, which is primarily used for generators, and fuel for mobility.

The average monthly energy spending is given in Figure 24 to Figure 26 and shows a separation between the four different typology categories. The relation between the different categories differs slightly depending on how they are normalized, but coordination projects are relatively high in all three plots. The distribution of fuel and utility spending within the different typologies varies considerably and, especially for emergencies, the number of projects listed is small. Several projects have multiple classifications, wherefore these plots are rather ambiguous as one category has been chosen as the primary category.

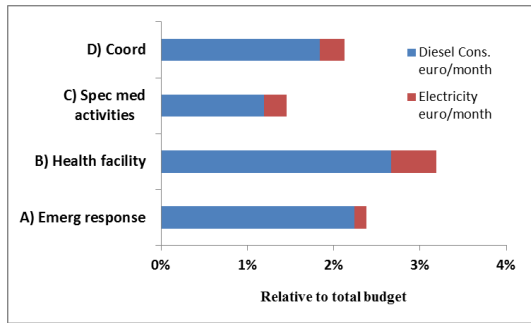


FIGURE 24. AVERAGE MONTHLY ENERGY SPENDING RELATIVE TOTAL PROJECT BUDGET, SEPARATED ON TYPOLOGY.

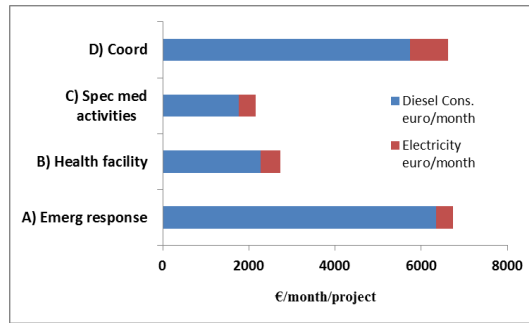


FIGURE 25. AVERAGE MONTHLY SPENDING PER PROJECT OVER THE DIFFERENT CATEGORIES.

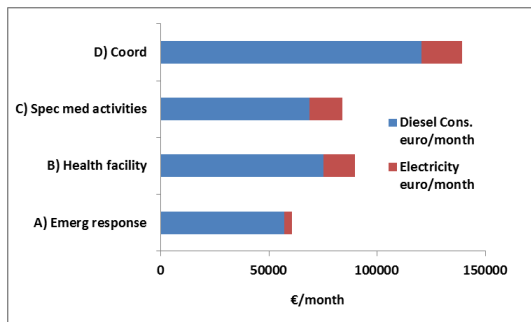


FIGURE 26. AVERAGE MONTHLY ENERGY SPENDING TOTAL OVER THE DIFFERENT CATEGORIES.

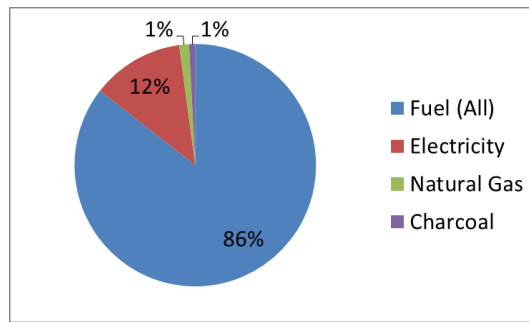


FIGURE 27. THE DIAGRAM GIVES THE DISTRIBUTION OF SPENDING ON VARIOUS ENERGY FORMS FOR ALL OF OCB. FUEL SPENDING INCLUDES BOTH ENERGY AND MOBILITY.

The total utility spending from June 2016 to May 2017 was almost 1.1 M €. This includes spending on electricity, water and non-liquid fuel sources, such as natural gas, charcoal and firewood.

The global monthly spending on fuel and utilities is given in Figure 28, with an average just above 400 000 € for fuel, and around 100 000 € for utilities. One of the main reasons for the peaks seen in monthly fuel consumption is the activity of the search and rescues operations, for which fuel was bought in large batches. To add a reference, the utility spending (electricity and gas) in the headquarters (Figure 29) constitutes about 170 000 €/year, or slightly over 10% of the utility costs of the field.

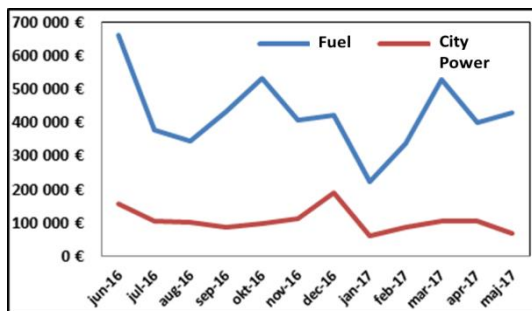


FIGURE 28. THE GRAPH SHOWS THE GLOBAL MONTHLY SPENDING ON FUEL AND UTILITIES, AS GIVEN AT THE TIME OF PURCHASE.

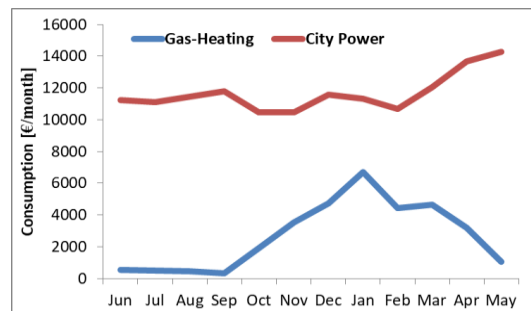


FIGURE 29. THE ELECTRICITY USE AT HQ IS RATHER STABLE, WHEREAS THE COLD SEASON DICTATES THE USE OF GAS.

CO₂-EMISSIONS FOR MSF-OCB: SOUTH-AFRICA CASE STUDY

In terms of global warming potentials, the mission in South-Africa has compiled data on CO₂ emissions from their operations, categorized by consumption of water and paper, number of flights, as well as the use of electricity and fuel for vehicles. A summary of their mapping study is presented in Figure 30 below, and the **three categories that dominate CO₂ emissions are electricity use, flights and fuel used in vehicles** (the projects in South Africa are served by relatively stable electricity grids and only have generators for back-up use (Ait Yahia, 2016)). This example illustrates the relevance of discussion of our energy systems also from the perspective of climate impact, even when relying on electricity from the grid.¹⁷

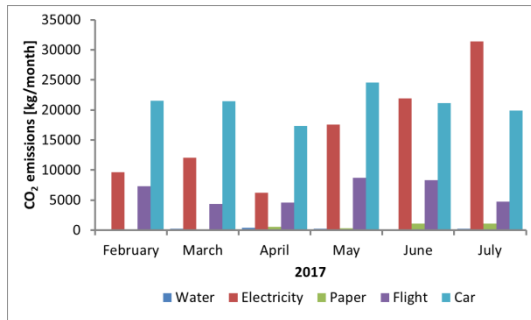


FIGURE 30. THE GRAPH SHOWS THE CALCULATED CO₂-EMISSIONS FOR THE SOUTH-AFRICA OCB MISSION, BROKEN DOWN INTO THE FIVE CATEGORIES. ELECTRICITY FROM THE GRID, DIESEL FUEL AND FLIGHTS ARE THE DOMINATING THE CO₂-EMISSIONS.

Electricity: The conversion factor used in the example of South-Africa is 0.99 kgCO₂/kWh electricity (McKenzie, 2015). On a global level, this conversion factor will vary with electricity mix in the grid.

Car: The CO₂-emissions are estimated based on the total amount of fuel used by the vehicles. The conversion factor is taken as 2.7 kgCO₂/L for diesel (NTC Australia, 2017).

Flights: Emission from flights are here estimated based on assumed average distance of 1600km/flight with a conversion factor of 0.13 kgCO₂/km (DEFRA, 2012).

5.5.2. GENERATOR POWER CAPACITIES AND LOCATION IN PROJECTS

Within this study, we have managed to collect data on the capacity and location of 138 generators, distributed over 12 missions¹⁸ and 31 projects. The dataset does not include all the generators in the 12 missions, as not all the projects within these missions are represented. It is also uncertain even to what degree it covers all the generators within the given 31 projects – it may well be that there are still generators in these projects that have not been reported. However, given the data that we have, the diagram in Figure 32 shows the distribution of generator capacities, which in total represents 10800 kVA. These generators are all assumed to be stationary generators, installed to serve one or another facility. There is likely to be more than one mobile generator dedicated for use in outreach operations within 31 projects, which is further supported by Buphagus records shown in Figure 33, which covers the generators shipped by MSF Supply from 2004 until 2017; a total of more than 500 generators. Almost 70% of these are smaller than 10 kVA, and most likely used in mobile or temporary settings.

¹⁷ The electricity mix will vary in different regions and influence the CO₂ emissions per kWh.

¹⁸ Afghanistan, Burundi, Cambodia, CAR, Haiti, Kenya, Malawi, Mozambique, Pakistan, Sierra Leone, South Africa, South Sudan.

A large number of the generators in the Buphagus records are indicated as “In stock”. 218 are reported as “in use”, but only 33 of them have had their records updated within the last 3 years. Furthermore, the Buphagus data does not include generators bought locally, but only those shipped from Brussels. For that reason, this data is not used to complete the set of 138 generators that we collected from other sources. However, the Buphagus records include prices of the generators, and the diagram in Figure 31 shows an indicative relation between price and generator capacity.

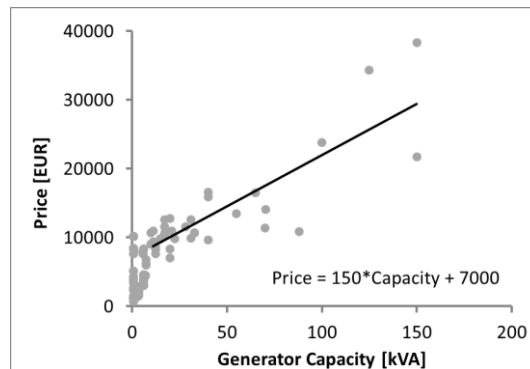


FIGURE 31. THE GRAPH SHOWS THE PRICE OF GENERATORS SHIPPED BY MSF SUPPLY. THE TREND LINE IS GIVEN ONLY FOR GENERATORS LARGER THAN 10 KVA.

Smaller projects which are often located out in the bush usually bring small generators that are cumbersome to manage and which are not always suited to the tasks (Sardo Infirri, 2017). These small generators are not specifically addressed in the following general discussion on fuel consumption and energy, even if they might serve equally important functions as do larger generators.

In order to reach an estimate of the total generation capacity within OCB globally, 120 generators distributed over 28 projects are used, along with the assumptions that these projects are representative of OCB and that there are not too many large generators that remain unreported within them. Within this study, 105 active OCB projects are considered globally. A simple linear extrapolation in terms of numbers would give a global count of 450 generators with a total nameplate capacity of 28500 kVA. However, some of the reported projects are rather large, like for example Tabarre, Timagara, Maban and Bangassou, and in total 31 projects represent about 35% of the total budget of entire 105 projects. Scaling the generator capacity on budgets, rather the number of projects, gives a slightly **lower estimate of 350 generators with a total nameplate capacity of 22000 kVA**. The quality of this estimation will be further discussed below.

A global estimate of 350 generators, with a total nameplate capacity of 20000-25000 kVA in use.

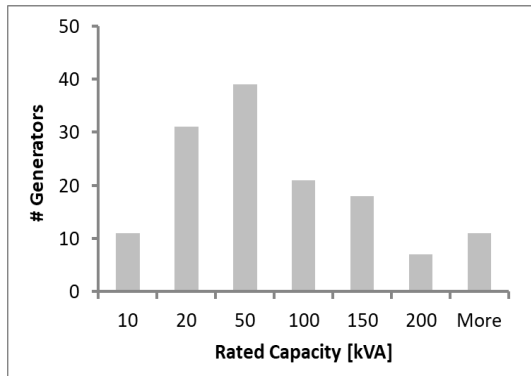


FIGURE 32. THE DISTRIBUTION OF GENERATOR CAPACITIES SHOWS THAT THE MAJORITY ARE 50KVA OR SMALLER. DATASET OF 138 GENERATORS, EXCLUDING BUPHAGUS DATA.

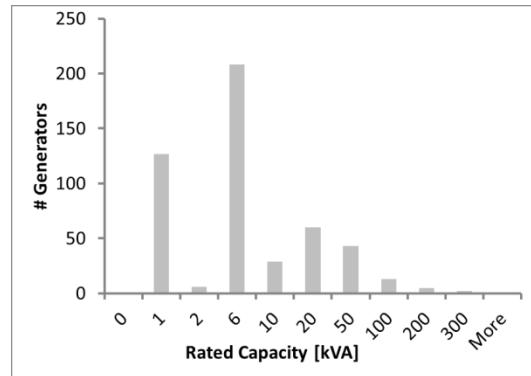


FIGURE 33. THE DISTRIBUTION OF GENERATOR CAPACITIES, SHIPPED BY MSF SUPPLY FROM 2004-2017. MORE THAN 70% OF THE GENERATORS ARE SMALLER THAN 10 KVA.

The **location of generators** within a project is, in terms of numbers, fairly evenly distributed among the different facilities, with **about 40% employed in medical settings and 25% each at bases and guesthouses**, leaving a few operating in warehouses. The categories are not perfectly clear-cut, and in several instances one generator serves more than one type of facility. The distribution of generators is shown in Figure 34 below.

If we then look at the size of these generators, it is clear that most of the accumulated generation capacity is located in medical settings, as is shown in Figure 35. This suggests that the generators in medical settings are generally larger than those used for bases and guesthouses. The distribution diagram in Figure 36 shows that all of the largest generators are in medical settings, whereas most of the generators used for bases and guesthouses are smaller than 50 kVA.

These distributions do not include information on whether the generators are actively used, or if they are primarily kept for back-up generation. It would be reasonable to assume that there are more generators kept for back-up in medical settings to safeguard medical activities.

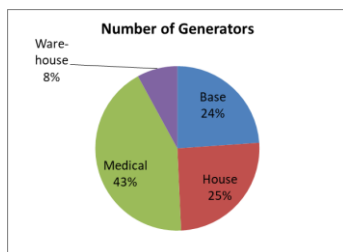


FIGURE 34. THE DIAGRAM SHOWS THE DISTRIBUTION OF GENERATORS IN TERMS OF NUMBERS.

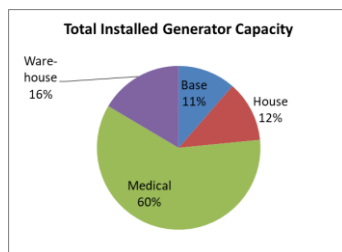


FIGURE 35. THE DISTRIBUTION OF GENERATOR CAPACITIES RELATED TO THE FOUR DIFFERENT CATEGORIES OF FACILITIES.

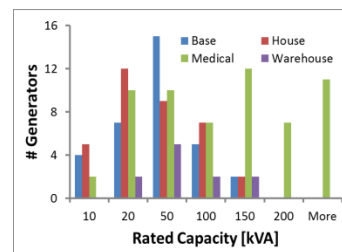


FIGURE 36. THE DISTRIBUTION DEMONSTRATES GENERALLY LARGER GENERATORS IN MEDICAL AND WAREHOUSE SETTINGS, AND SMALLER ONES AT BASES OR GUESTHOUSES.

5.5.3. GENERATOR DIESEL CONSUMPTION

As the LRS system has not yet had time to be fully established, and is adopted only in a few projects, data for estimating fuel consumption has instead been collected primarily from financial records and the responses given in field questionnaires.

DIESEL CONSUMPTION AND GENERATOR RUN-TIME HOURS FROM LIMITED DATASETS

Among the 132 generators, staff in the field have provided us with direct information on the monthly fuel consumption of 49 units, distributed over 13 projects and 7 missions. The monthly fuel consumption is plotted versus the nameplate capacity of the respective generator in Figure 37 below. The generators all serve different loads and are used to different extents, but in total these generators are reported to consume 64.8 m³/month and constitute a total nameplate capacity of 2400 kVA. Hence, the data gives an average fuel consumption of about 27L/month/kVA, which according to the following estimations seems to be significantly more than for OCB generators in general. Furthermore, the data from the questionnaires contains neither information on the load-level nor how many hours a day the generators are used.

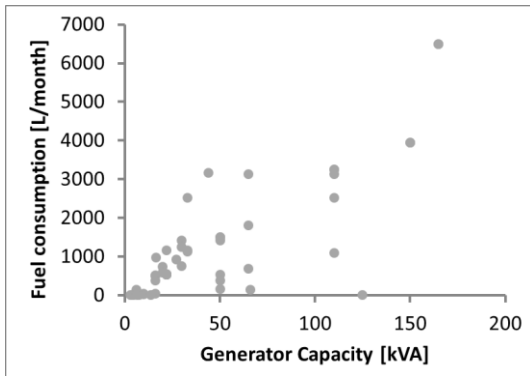


FIGURE 37. THE DIAGRAM SHOW THE FUEL CONSUMPTION PLOTTED AGAINST NAMEPLATE CAPACITY FOR THE 49 GENERATORS FOR WHICH DATA HAS BEEN REPORTED VIA QUESTIONNAIRES.

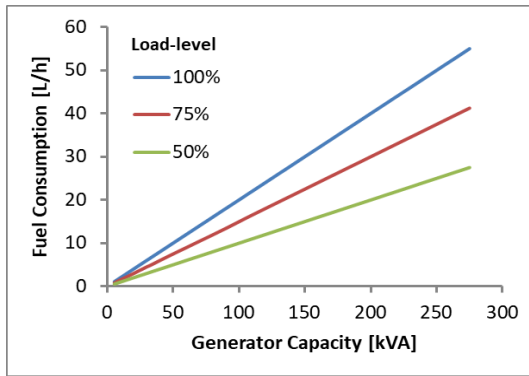


FIGURE 38. THE GRAPHS SHOW THE FUEL CONSUMPTION OF GENERATORS OF VARIOUS SIZES AND FOR VARIOUS LOAD-LEVELS, AS COMMUNICATED BY THE AFGHANISTAN MISSION.

The Afghanistan mission provided an updated list of their 41 generators in October 2017, with daily run-time hours given in fairly narrow spans. The distribution of generators over their run-time hours is presented in Figure 39. On average, these generators run 6.7 hours/day.

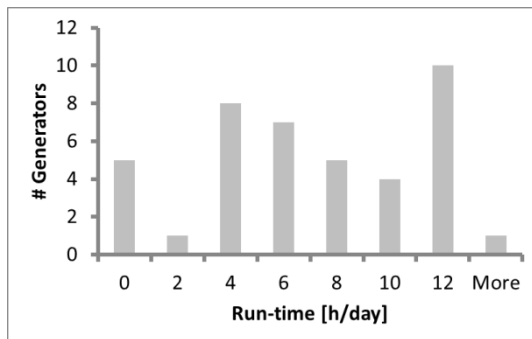


FIGURE 39. THE GRAPH GIVES DISTRIBUTION OF RUN-TIME HOURS (MEAN VALUE OF EACH INTERVAL) FOR THE GENERATORS REPORTED BY THE AFGHANISTAN MISSION. THE AVERAGE RUN-TIME IS 6.7 H/DAY.

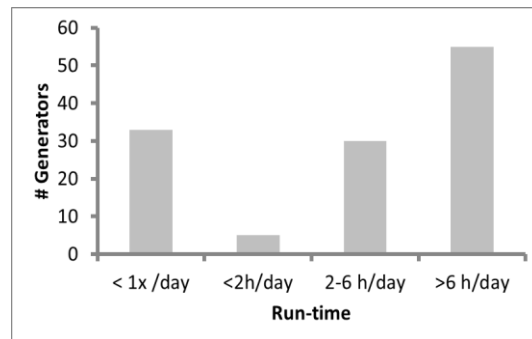


FIGURE 40. THE DISTRIBUTION SHOW THE RUN-TIME HOURS FOR GENERATORS IN THE COMPILATION OF GENERATOR DATA KEPT BY THE OCB ENERGY TEAM.

The OCB energy team has a compilation of generators, where 123 units are presented along with an indication of daily run-time hours (generators kept in stock are excluded). Some of these overlap with the dataset from Afghanistan. The run-time categories used are given on the horizontal axis of Figure 40, which also shows the distribution of generators over these different categories. In order to

calculate an average daily run-time for this set of generators, the last category “> 6 h/day” needs to be refined; in the Afghanistan dataset, the average run-time for those generators operating more than 6 h/day is 10.5 h/day. Further assuming that the remaining categories in Figure 40 correspond to 0 h/day, 1 h/day, 4 h/day respectively, the **average daily run-time is calculated to be 5.7 h/day**. It must be pointed out that the average daily run-time over a full year is probably less than what is shown by these distributions and averages. For example, a generator that is said to be operating 2-6h/day might only be used during winter months, wherefore the overall deployment is less than reported.

CASE-STUDY: AFGHANISTAN

The Afghan mission has taken the exemplary initiative to closely follow the use of vehicles, generators, heating systems and incinerators. Apart from providing information that helps track the use of equipment and routine services, it also provides monthly values on fuel use across the mission. The consumption of fuel distributed among different categories is given for the Ahmad Shah Baba (ABS) project in Figure 41 and for the Khost project in Figure 42, along with the temperature profile for the sites. In both projects, fuel use is predominantly taken up by generators and heating systems, with the periods of higher consumption corresponding fairly strongly with heating needs in winter and some cooling needs in summer. Both ABS and Khost have centralized heating systems, supported by local heating units.

It is worth noting that the fuel use in ABS is smaller than in Khost, which seems to have a much higher base load. However, ABS is grid-connected, and uses on average about 7000 kWh/month of electricity from the grid on top of the energy provided by the generators, which corresponds to between 25000 kWh/month (January) and 3000 kWh/month (June). Khost does not have a grid connection, and hence all energy is provided by the generators.

In both ABS and Khost, **the incinerators are used to burn around 3000 kg of solid waste each month, which, provided with the necessary setup, could offer a potential energy source for heating a hot water storage tank, for example.**

The carbon footprint of Khost related to the fuel consumption would be **670 tonnes of CO₂ per year, with 88% from generators and 9% from heating.**

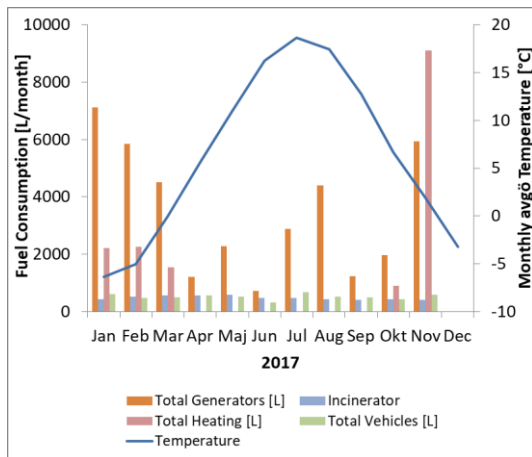


FIGURE 41. THE DATA SHOWS THE FUEL USE IN THE AHMAD SHAH BABA PROJECT, SPLIT ACROSS DIFFERENT CATEGORIES. MOST OF THE FUEL IS USED FOR GENERATORS AND HEATING. OVERLAID IS THE TEMPERATURE PROFILE OF THE SITE.

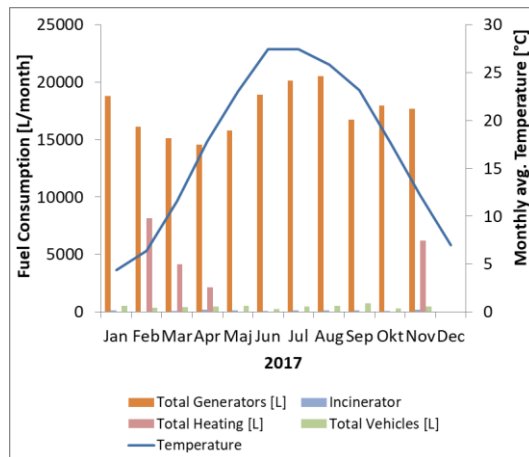


FIGURE 42. THE DATA SHOWS THE FUEL USE IN THE KHOST PROJECT, SPLIT ACROSS DIFFERENT CATEGORIES. MOST OF THE FUEL IS USED FOR GENERATORS AND HEATING. OVERLAID IS THE TEMPERATURE PROFILE OF THE SITE.

5.5.4. GENERATOR LOAD-LEVELS AND DEMAND PROFILES

Since very few measurements have been done on actual real-time electricity use, and also considering the wide range of different activities within OCB operations, it is hard to come to a conclusion about load-levels and demand profiles. Two examples from Tabarre (Prager, 2017a) and Kibera (Mujica, 2017a) are shown respectively in Figure 43 and Figure 44 below. In Tabarre, five different generators and the grid are managed to supply the hospital and laundry with the most suitable source depending on load-level. If needed, the total load can be supplied by a 300 kVA generator. The clinic in Kibera has a 45 kVA generator which, based on the measurement campaign in March 2017 just before the clinic was handed over, was recommended for upgrade to a 60kVA.

Assuming a 300kVA generator in Tabarre, the average load-level over these two days is about 50%; and with a 45kVA generator in Kibera, the load-level is also about 50-55%.

The OCB Energy team suggests **an average load-level over the entire fleet of generators of about 40%**, however missions like Afghanistan claim that all their gensets are used at a load-level above 50%. The optimal load-level should be around 60% according to most of the gensets technical specifications. Hence, with strong daily variations in load-profile, it is hard to even reach optimal load-level on average, before the generator needs to be up-sized due to power peaks. If these peaks could be avoided by load management whereby equipment performing time-insensitive tasks is switched off during peak hours, a more optimal use of generators can be achieved, increasing both fuel efficiency and reducing machine wear.

The supply-side management of shifting between differently-sized generators depending on load-level is employed not only in Tabarre, but also in other settings, where for example day- and night generators of different power ratings are used to accommodate different power needs between day and night. In the new setting in Kunduz, synchronization of generators will enable several generators to work in parallel and hence allow them to be turned on or off depending on power demand; it will hence be easier to stay within the optimal operation range of the generators.

Supply- and demand-side management are complementary. If introducing a share of intermittent, non-dispatchable renewable energy, demand-side management might be a strategy to increase the direct use of generated energy without having to store it in batteries or other storage forms.

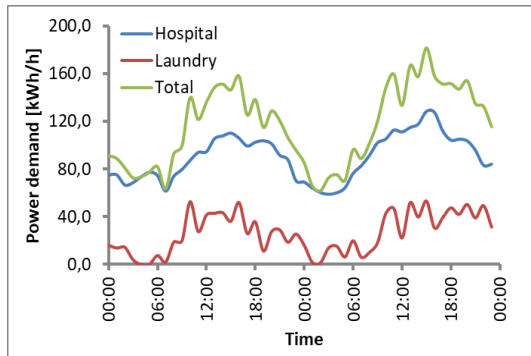


FIGURE 43. THE GRAPHS SHOW THE POWER DEMAND IN TABARRE OVER TWO DAYS IN EARLY JANUARY 2017 (PRAGER, 2017A). THE DATA HAS BEEN AVERAGED FROM 25 TO 1H. AS CAN BE SEEN, LAUNDRY CONSTITUTES A SIGNIFICANT PART OF THE TOTAL LOAD.

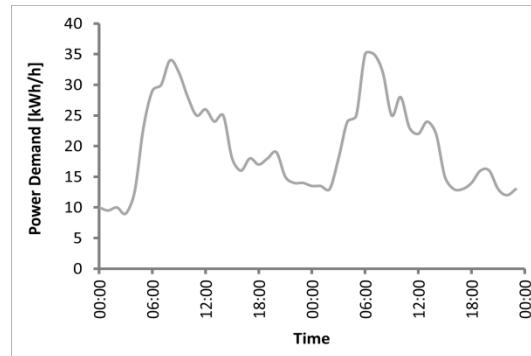


FIGURE 44. THE GRAPH SHOWS THE POWER DEMAND FOR THE CLINIC IN KIBERA, KENYA, IN END OF MARCH 2017 (MUJICA, 2017A). PEAK-LOAD HOURS ARE IN THE MORNING.

Returning to the fuel consumption data on the 49 generators reported directly by the field: average fuel consumption was calculated to 27 L/month/kVA. Assuming a 40% load-level and using the data in Figure 37 allows us to estimate an average run-time among these generators of about 11 h/day. This would then be more than the rough global estimate of 6 h/day for generators.

It also worth pointing out that the efficiency of diesel generators might be less than 40% at low load-levels, and the remaining power is given off as waste heat, hence good ventilation is required for generator rooms. However, if well planned, this waste heat could be collected for productive use where low temperature thermal energy might be requested, as for example in the case of hot water and hot air supply to a laundry. An added benefit of such a solution would also be a reduced electric load, as less electricity is needed to heat the same water or air.

5.5.5. BREAKDOWN OF FUEL SPENDING.

For a few projects, financial records allowed us to estimate where the fuel was used. It has been categorized into fuel for Mobility, Generators and Heating. The figures below show the distribution over these categories for a number of projects. It can be noted that a significant part of the fuel is used to run our cars, but the variations are large; in some settings almost 100% is used in vehicles, whereas in other settings over 90% is used for generators. The financial records of the most remote projects, which also seem to be the ones with the largest spending on fuel, for example projects in countries like CAR, DRC, South Sudan, Afghanistan, Haiti, and Sierra Leone, do not permit the compilation of a breakdown of where fuel is used, but instead estimations are based on a few inputs of fuel used in mobility, taken from the LRS system. The share that each project represents in relation to total OCB fuel spending is provided alongside the figures. The spending on energy per mission is given in **Fel! Hittar inte referenskölla.** below.

It should also be noted that in several projects fuel is used directly for space heating. The amount of fuel used for heating purposes can potentially be rather large, as is illustrated in the case for north Belgrade. Belgrade is one of OCB's highest fuel-consuming projects, partly because of the fuel needed for heating. Timegara, which has almost twice as many heating-degree-days as Belgrade, most likely

has the corresponding energy consumption figures for space heating hidden in the fuel for generators. Direct input from the field suggests that at least some of the projects in Pakistan use electrically powered air-to-air heat pumps, while others use direct electric heaters (Khan, 2017).

Almost 20% of the total fuel spending (ca. 1 M €) was used for Search-and-Rescue in the Mediterranean Sea.

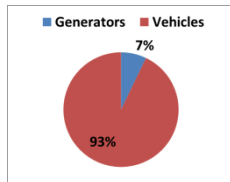


FIGURE 45. KIBERA, KENYA; KE141. PROJECT REPRESENTS 0,16% OF OCB TOTAL FUEL SPENDING.

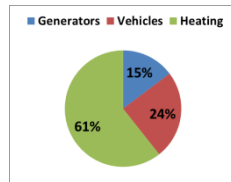


FIGURE 46. NORTH BELGRADE, SERBIA; EU214. PROJECT REPRESENTS 1,8% OF OCB TOTAL FUEL SPENDING.

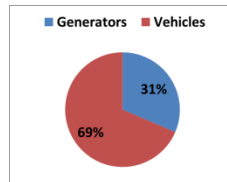


FIGURE 47. PREAH VIHEAR, CAMBODIA; KH161. PROJECT REPRESENTS 0,13% OF OCB TOTAL FUEL SPENDING.

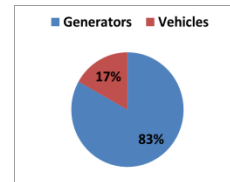


FIGURE 48. BILI, DRC; CD124. PROJECT REPRESENTS 6% OF OCB TOTAL FUEL SPENDING.

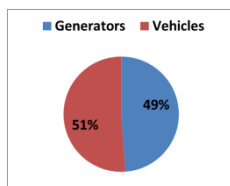


FIGURE 49. MBERA, MAURITANIA; MR106. PROJECT REPRESENTS 2,7% OF OCB TOTAL FUEL SPENDING.

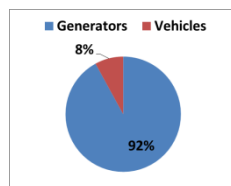


FIGURE 50. LOWER DIR / TIMEGARA, PAKISTAN; PK117. PROJECT REPRESENTS 2,7% OF OCB TOTAL FUEL SPENDING.

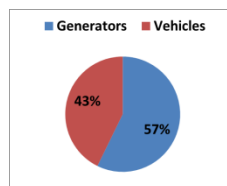


FIGURE 51. KARACHI, PAKISTAN, PK124; PROJECT REPRESENTS 0,45% OF OCB TOTAL FUEL SPENDING.

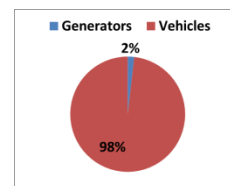


FIGURE 52. KHAYELITSHA, SOUTH AFRICA; ZA140. PROJECT REPRESENTS 0,19% OF OCB TOTAL FUEL SPENDING.

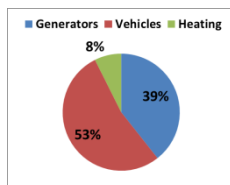


FIGURE 53. COORDINATION (HATAY), TURKEY; TR101. PROJECT REPRESENTS 0,51% OF OCB TOTAL FUEL SPENDING.

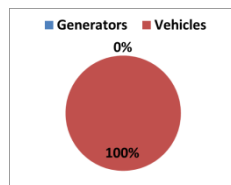


FIGURE 54. DNEPRO/DONESK, UKRAINE; UA103. PROJECT REPRESENTS 0,22% OF OCB TOTAL FUEL SPENDING.

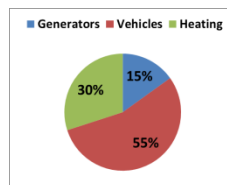


FIGURE 55. BAR ELIAS, LEBANON; LB120+114. PROJECT REPRESENTS 0,17% OF OCB TOTAL FUEL SPENDING.

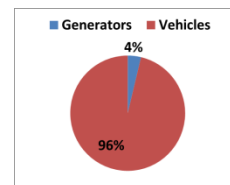


FIGURE 56. COORDINATION (HARARE), ZIMBABWE; ZW101. PROJECT REPRESENTS 0,48% OF OCB TOTAL FUEL SPENDING.

The financial records further suggest that almost 80% of projects do pay electricity fees, and hence have grid connections. However, dependency upon generators for electricity supply is still rather high. The percentage of fuel costs relative to the total costs for electricity service (grid fees + fuel to generators) indicates that the generator share is often very high, even in projects where only a small part of the total fuel supply is allocated to the generators. In terms of kWh, the distribution might look slightly different, as it is most likely that electricity from the grid is cheaper than electricity from a local generator, regardless of global location.

Using all the projects which have an estimation for the amount of fuel used for mobility versus generators, an average value can be calculated, weighted by the percentage of OCB total fuel spending that each of these projects represent. The calculation suggests that on average around 35% of fuel is used for generators.

STORAGE OF FUEL

The questionnaire also addressed energy storage in terms fuel volumes kept at a project. The variations are obviously very large, ranging from nothing up to 30 m³, and given the numbers reported the projects that keep the largest volumes are also those with the highest share of fuel used for generators. That distinction is often difficult, since the projects that keep large fuel storages also buy fuel in bulk to power both vehicles and generators. As indicated by the financial records, these projects are often the more remote ones for which transportation of fuel might also be an issue (Perrochet, 2017), and storage itself might present security issues (López, 2017).

Mission	Energy [Euro/month]	Fuel [Euro/month]	Electricity [Euro/month]	Fuel [% of OCB total]	Energy [% of OCB total]
Afghanistan	28900	22800	4100	6%	6%
Burundi	5100	3300	1200	1%	1%
DRC	54400	52000	700	13%	11%
CAR	50200	48200	1100	12%	11%
Egypt	900	200	700	0%	0%
Serbia	10171	8845	1326	2%	2%
Greece	25956	20340	5616	5%	5%
Guinea	12100	10600	1100	3%	3%
Haiti	38600	27700	9900	7%	8%
Nauru	700	300	400	0%	0%
India	5300	2600	2600	1%	1%
Italy	81100	79900	1000	20%	17%
Kenya	4100	1600	2300	0%	1%
Cambodia	1500	600	900	0%	0%
Lebanon	8300	3600	4600	1%	2%
Mauritania	19000	13100	5600	3%	4%
Malawi	12600	11200	900	3%	3%
Mozambique	8200	6500	1500	2%	2%
Nigeria North	9500	9200	100	2%	2%
Pakistan	24700	17600	6000	4%	5%
Sierra Leone	14100	13400	600	3%	3%
South Sudan	30700	30100	0	7%	6%
Tunisia	1200	700	500	0%	0%
Turkey	2800	2300	500	1%	1%
Ukraine	3300	1600	1600	0%	1%
Venezuela	100	100	0	0%	0%
South Africa	8300	5900	2300	1%	2%
Zimbabwe	17800	16300	1400	4%	4%
Total	479627	410585	58542	100%	100%

TABLE 9. SPENDING ON ENERGY (INCLUDING FUEL, ELECTRICITY, GAS AND CHARCOAL), FUEL AND ELECTRICITY SEPARATELY ARE GIVEN AS TOTALS FOR EACH MISSION. NO BREAKDOWN OF FUEL USE IS POSSIBLE FROM THE FINANCIAL RECORDS FOR THE LARGEST MISSIONS.

5.5.6. ESTIMATION OF GLOBAL DIESEL CONSUMPTION

Based on the financial records, the total fuel spending for OCB adds up to around **4.9 M €/year**. With an average fuel price of around 1 €/litre, that gives us slightly less than **5000 m³/year in total**.

If we combine the estimations given above; assuming there are 350 generators globally with an average capacity of 65kVA, nominally running 6h/day on a load-level of 40%, we would reach a **global diesel consumption to be around 10500 L/day or 3800 m³/year for generators only**. An estimate of the fuel used only in vehicles, done by the mobility referent, suggests yearly fuel spending of about 10 M€/year. The details are not presented within this report, but together with the 3800 m³/year, estimated above, the ratio of about 35% total fuel being used in generators would still hold true.

It might be reasonable to believe that we primarily have data on the subsection of OCB generators that belongs to missions where generators are of high importance for the electricity supply. That subset probably represents both more generators/project than on average, as well as longer run-time

hours. The breakdown of fuel spending shows that for at least some projects, only a small share of fuel is burned in generators, which suggests that the generators kept by these projects are mainly for extraordinary use.

If we instead start with the total of 5000 m³/year, subtracting the 1000 m³/year (20%) that is used for the search-and-rescue operations, and assuming that 35% of the fuel is used for generators, we are left with around **1400 m³/year for local electricity production using generators**. How this translates into details for the size and use of the OCB generators is hard to tell.

Although the good coverage of the financial data has allowed it to serve as the primary data set used to evaluate energy used within OCB, the variations and inconsistencies in actual numbers when comparing data sources suggest that there is still a significant uncertainty regarding the volume of fuel being used within OCB.

5.6. ENERGY USE

The sections below address aspects of how OCB currently uses energy, which is largely in the form of electricity. The input is a combination of data from the Buphagus asset list which covers larger items shipped via MSF Supply, and input provided by the field on what major energy loads they use.

5.6.1. NEW LARGE AND LONG-TERM PROJECTS

The hospital in Tabarre, Haiti was started 2012, and until now has perhaps been the largest and most complex project run by OCB. The hospital is operated by over 500 full-time staff, supporting 116 beds and providing specialized medical activities including an out-patient department, in-patient department, emergency room, operation theatre, X-ray, etc.

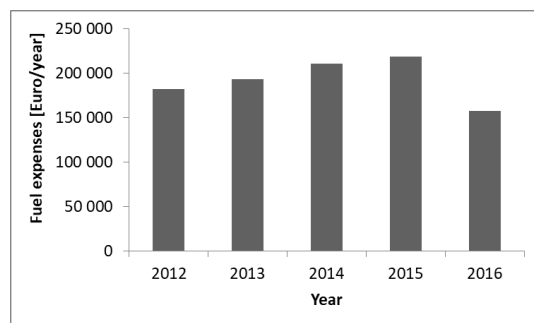


FIGURE 57. THE ENERGY USE IN TABARRE INCREASED OVER THE FIRST YEARS FROM 180 000 €/YEAR IN 2012 UP TO 219000 €/YEAR IN 2015.

Furthermore, the number of patients visiting the hospital has at least doubled compared to the first operational years, which partly also reflected in the energy use of the project. The graph in Figure 57 shows the fuel expenses, excluding electricity from the grid, in Tabarre and indicates a trend of increasing energy use (with exception for 2016).

To meet the energy needs of these activities, the energy system in Tabarre is large and technically advanced. Its function employs frequency converters, motorized switching systems, monitoring- and signal systems, and automated power management. Both the size and configuration are adequate for this project, although it has proven to be fragile and challenging to manage. Several technical problems have occurred since the project opening, which can be partially explained by the mismatch between the system's complexity and the technical expertise available at the site, but also by the failure to conduct basic preventive maintenance (Prager, 2017c).

As OCB is currently planning new large and complex hospital projects in Kunduz (Afghanistan), Kenema (Sierra Leone), and Bar-Elias (Lebanon), the energy technical team is trying to capitalize on the experiences of Tabarre in order to avoid similar difficulties and improve the setups. These large projects are summarised in

Long-term projects NRG Comparison

	Kenema	Kenema Hybrid	Kunduz	Tabarre	Bar Elias	Kibera	Comments
Number of beds	140	140	51	116	54	15	Source: Construction
Surface (m ²)	10 300.0	10 300.0	9 507	4 086.0	4 960.0	1 575.0	Source: Construction (Review if are constructed or total land). Kunduz: does not consider Zeppelning
Medical Activities	Pediatric Hospital. Medical activities: OPD / ER / OT / ICU / IPD. Services: Lab, Ster/Pharma, etc.	Pediatric Hospital. Medical activities: OPD / ER / OT / ICU / IPD. Services: Lab, Ster/Pharma, etc.	Trauma Center. Medical Activities: OPD / ER / OT / IPD / ICU. Services: X-ray/lab/Pharma/Ster	Surgical Hospital. Medical Activities: ER/OT/ICU. Services: X-ray/lab/Pharma/Ster	OPD + general hospital. Medical Activities: OPD + ER + OT Services: Xray/lab/Pharma/Ster	Activities: OPD / IPD / OT / Obst Services: Ste / Lab / Pharm	Source: Construction, Tactical team
Shelter	Modul(h)o, Bricks, Containers, Shelters	Modul(h)o, Bricks, Containers, Shelters	Zeppelin, Modul(h)o, Bricks, Containers, Tents, Local Prefab	Prefab containers: off containers,	Concrete: Rehabilitation	Local	- Tabarre: Prefab containers: "Containex" brand. Not well insulated that is explaining the load in HVAC in that type of climate.
Opening date	October 2018	October 2018	June 2018	2 012	March 2018	July 1997	
Total project budget (log)	€ 9 500 000.00	€ 9 500 000.00	€ 9 466 000.00	€ 2 500 000.00	€ 4 300 000.00	€ 138 000.00	No equipment included. Sources: Tabarre (only includes construction 2016), BE (LogCell), Kunduz (2018, 2017 is 8.400.000, total 11,3 Million) and Kenema (2018) (Task Force)
Installed Power (kW)	460	460	1 583	800	875	36	- Bar Elias: Energy Consumption Spectrum (June 2017) - Kenema, Kunduz, Tabarre (2012): NRG Team - Kunduz: ZMS: 410 kW (26%). NRG efficient measures to be applied in the other 74% of the setting.
Average used Power (kW)	184	184	475	240	350	17	- 40% of the total power.
Peak (kW)	1 260.8	1 261	5 214	720	1 050	40	
kW/bed	3.3	3.3	31.0	6.9	16.3	2.4	
Generators (KVA)	704	528	1 408	930	600	80	
PV (MWp)	-	1.50	-	0	0	0	
Batteries (kWh)	-	4 000.00	0	0	0	0	
Fuel consumption (includes city power) (eur/ly)	€ 419 000.00	€ 119 000.00	€ 711 950.99	€ 379 316.00	€ 297 000.00	€ 35 280.00	- Bar Elias: 2000 LP = 1 Eur. Energy Consumption Report Spectrum (June 2017). - Tabarre (June 2016 - May 2017, NRG Vision Project): Monthly Electricity spending = EUR 4,812 Monthly Diesel spending = EUR 10,131 (approx. 24,000 L diesel used per month) = 14,943 eur/m = 279,316 eur/ly. Log Cell data (march) = 15,100 eur/month. City powers = 30% - Tabarre: LogCell Info (includes consultancy visits, etc.) - Kenema and Kunduz: NRG Team (0,5 Eur/h)
O&M Generator (eur/ly)	€ 6 570.00	€ 1 200.00	€ 8 760.00	€ 40 000.00	-	€ 4 380.00	- Includes monthly check-up and remote monitoring
O&M RE	0	€ 9 000.00	0	0	0	0	
HVAC Load (%)	18%	18%	44%	60%	27,4%		- Bar Elias: Energy Consumption Report Spectrum (June 2017). Electrical heating and cooling load included. Hot water heating not included. - Kenema, Kunduz, Tabarre (2012): NRG Team.
HVAC energy costs	€ 77 423.91	€ 77 423.91	€ 310 806.87	€ 107 589.60	€ 81 696.00		- Bar Elias: Energy Consumption Report Spectrum (June 2017). - Kenema Hybrid: to be reduced
HVAC system	-	-	-	Heating load = 822 kW (fuel oil); Cooling load = 827 kW; Electrical load chillers: 300 KVA	Solar Thermal		Bar Elias Source: Energy Consumption Report Spectrum (June 2017)
Distribution (eur)	415 600.00	415 600	473 378.00	-	-		Kunduz: Principal Distribution Cabling: 273,378 Eur, Secondary Distribution Cabling: 100.000 Eur, Distribution Cabling (inside buildings): 50.000 Eur, Power Distribution Panels: 100.000 Eur
Biomed Equipment (kW)	75.75						

below, along with "Kibera" as a more normally-sized project in Nairobi, Kenya, which OCB operated since 1997, a was subsequently handed over to MoH at the end of 2017.

The possibilities for energy-saving measures have been addressed in interviews (Chauvel, 2017; Ordenes, 2017) and workshops since the start of this study. In particular, the high estimates for energy use in new hospital settings strongly motivate considerable efforts to administer energy-saving measures and implement the most energy-efficient setups possible to supply the hospitals. For example, the Gaptex modules that are to be used in Kunduz are upgraded with canvas coverings to better cope with the cold climate; in Kenema solar heaters are will be used to heat the water for the laundry; and in Bar Elias solar heaters are used to preheat the water used for heating purposes in the air handling units.

There are also high ambitions regarding the use of renewable energy sources: Kenema is planned to be served by a solar-diesel hybrid system including 1,4 MWp of PV (PV modules with a total area larger than a soccer field).

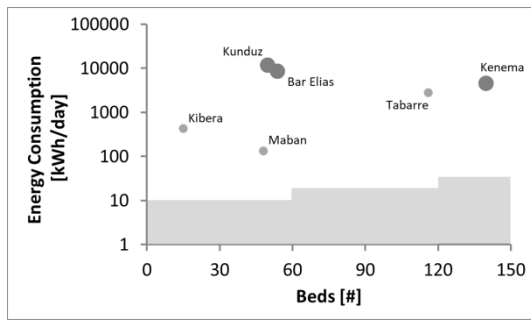


FIGURE 58. THE DIAGRAM SHOWS MEASURED AND ESTIMATED ENERGY USE VERSUS NUMBER OF BEDS FOR A FEW SELECTED EXISTING- AND FORTHCOMING OCB PROJECTS. THE SHADED AREA SHOWS THE ENERGY USE ACCORDING TO A CATEGORIZATION OF BASIC HOSPITALS DONE BY USAID.

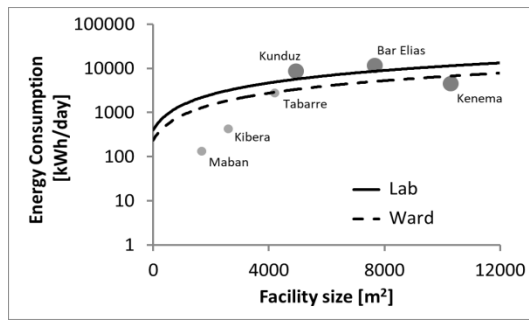


FIGURE 59. THE DIAGRAM SHOWS MEASURED AND ESTIMATED ENERGY USE VERSUS FACILITY SIZE. THE TWO LINES SHOW ENERGY CONSUMPTION FOR EUROPEAN HOSPITAL SETTINGS, WITH 400 KWH/M²/YEAR FOR LAB FACILITIES AND 235 KWH/M²/YEAR FOR WARDS.

As is depicted in Figure 58, which plots the energy use against number the of beds at these projects, **energy use could be estimated as order(s) of magnitudes larger for these new large projects** than for other OCB projects like Kibera and Maban (South-Sudan). The grey shaded area in the figure illustrates the energy use of basic hospitals in the global south as categorized by USAID.

Obviously this plot does not include information on what medical activities each project provides, in some cases the relation between energy use and number of beds might not be perfectly adequate. Such observations underpin the indicators that are relevant to tie energy use to the medical services of the project. However, the comparison in Figure 59 shows that the estimations for the specific energy use in the larger OCB projects are comparable or even higher than energy use in European hospital settings. Laboratory facilities are suggested to have the highest energy consumption with around 400 kWh/m²/year, whereas wards are reported to use on average 235 kWh/m²/year (Morgenstern et al., 2016).

Long-term projects NRG Comparison

	Kenema	Kenema Hybrid	Kunduz	Tabarre	Bar Elias	Kibera	Comments
Number of beds	140	140	51	116	54	15	Source: Construction
Surface (m ²)	10 300.0	10 300.0	9 507	4 086.0	4 960.0	1 575.0	Source: Construction (Review if are constructed or total land). Kunduz: does not consider Zeppeling
Medical Activities	Pediatric Hospital. Medical activities: OPD / ER / OT / ICU / IPD. Services: Lab, Ster/Pharma, etc.	Pediatric Hospital. Medical activities: OPD / ER / OT / ICU / IPD. Services: Lab, Ster/Pharma, etc.	Trauma Center. Medical Activities: OPD / ER / OT / IPD / ICU. Services: X-ray/lab/Pharma/Ster	Surgical Hospital. Medical Activities: ER/OT/ICU. Services: X-ray/lab/Pharma/Ster	OPD + general hospital. Medical Activities: OPD + ER + OT Services: X-ray/lab/pharma/Ster	Activities: OPD / IPD / OT / Obst Services: Ste / Lab / Pharm	Source: Construction, Tactical team
Shelter	Modul(h)o, Bricks, Containers, Shelters	Modul(h)o, Bricks, Containers, Shelters	Zeppelin, Modul(h)o, Bricks, Containers, Tents, Local Prefab	Prefab containers: off containers,	Concrete: Rehabilitation	Local	- Tabarre: Prefab containers: "Containex" brand. Not well insulated that is explaining the load in HVAC in that type of climate.
Opening date	October 2018	October 2018	June 2018	2 012	March 2018	July 1997	
Total project budget (log)	€ 9 500 000.00	€ 9 500 000.00	€ 9 466 000.00	€ 2 500 000.00	€ 4 300 000.00	€ 138 000.00	No equipment included. Sources: Tabarre (only includes construction 2016), BE (LogCell), Kunduz (2018, 2017 is 8.400.000, total 11,3 Million) and Kenema (2018) (Task Force)
Installed Power (kW)	460	460	1 583	800	875	35	- Bar Elias: Energy Consumption Spectrum (June 2017) - Kenema, Kunduz, Tabarre (2012): NRG Team. - Kunduz: ZMS: 410 kW (26%). NRG efficient measures to be applied in the other 74% of the setting.
Average used Power (kW)	184	184	475	240	350	17	- 40% of the total power.
Peak (kW)	1 260.8	1 261	5 214	720	1 050	40	
kW/bed	3.3	3.3	31.0	6.9	16.2	2.4	
Generators (KVA)	704	728	2 408	930	600	80	
PV (MWp)	-	1.50	0	0	0	0	
Batteries (kWh)	-	4 000.00	0	0	0	0	
Fuel consumption (includes city power) (eur/ly)	€ 419 000.00	€ 119 000.00	€ 711 950.99	€ 179 316.00	€ 297 000.00	€ 35 280.00	- Bar Elias: 2000 LP = 1 Eur. Energy Consumption Report Spectrum (June 2017). - Tabarre (June 2016 - May 2017, NRG Vision Project): Monthly Electricity spending = EUR 4,812 Monthly Diesel spending = EUR 10,131 (approx. 14,000 L diesel used per month) = 14,043 eur/m = 279,316 eur/ly. Log Cell data (march) = 15,100 eur/month. City powers= 30%
O&M Generator (eur/ly)	€ 6 570.00	€ 1 200.00	€ 8 760.00	€ 40 000.00	-	€ 4 380.00	- Tabarre: LogCell Info (includes consultancy visits, etc.) - Kenema and Kunduz: NRG Team (0,5 Eur/h) - Includes monthly check-up and remote monitoring
O&M RE	0	€ 9 000.00	0	0	0	0	
HVAC Load (%)	18%	18%	44%	60%	27,4%		- Bar Elias: Energy Consumption Report Spectrum (June 2017). Electrical heating and cooling load included. Hot water heating not included. - Kenema, Kunduz, Tabarre (2012): NRG Team.
HVAC energy costs	€ 77 423.91	€ 77 423.91	€ 310 806.87	€ 107 589.60	€ 81 696.00		- Bar Elias: Energy Consumption Report Spectrum (June 2017). - Kenema Hybrid: to be reduced.
HVAC system	-	-		Heating load = 822 kW (fuel oil); Cooling load = 827 kW; Electrical load chillers: 300 KVA	Solar Thermal		Bar Elias Source: Energy Consumption Report Spectrum (June 2017)
Distribution (eur)	415 600.00	415 600	473 378.00	-	-	-	Kunduz: Principal Distribution Cabling: 273,378 Eur, Secondary Distribution Cabling: 100.000 Eur, Distribution Cabling (inside buildings): 50.000 Eur, Power Distribution Panels: 100.000 Eur
Biomed Equipment (kW)	75.75						

TABLE 10. THE INFORMATION SUMMARIZES THE LARGE AND LONG-TERM PROJECTS OF OCB. TABARRE AND KIBERA ARE EXISTING PROJECTS INCLUDED HERE AS REFERENCES FOR THE NEW PROJECTS IN KENEMA, KUNDUZ AND BAR-ELIAS.

5.6.2. HEAVY LOADS

It is of primary interest to **understand not only the amount of electricity consumed in different facilities, but also which services use the vast majority of energy.** As suggested earlier, a large share of energy is predicted to be used for HVAC systems and hot water preparation, lighting etc. Much of this rather standard equipment is purchased locally, and hence is not fully represented on asset lists like Buphagus, which only covers items coming from MSF Supply. A potential challenge presented by the local purchase of so many of these units is the limitation of possibilities for quality control and assurance of energy efficiency standards. In many places, there may be no regulations preventing the worst-performing products from entering the market, and necessary information for making informed product purchasing decisions might also be lacking.

To complete the limited information in the central records, the field questionnaire also addressed the existence of a set of anticipated important loads in the projects. The projects responded only with the number of units for each class of equipment that they use, neither giving any details on the size nor type of equipment, nor indeed how frequently they are used. The loads addressed are highlighted in the table below.

16 projects responded, and the numbers are summarized in the table below. An extrapolation of these numbers to the total of 105 projects regarded in this study is done by scaling on total project budgets.

Units	Count (sample, 16 projects) 18% of total budget	Count (global, 105 projects) 100 % of total budget
A/C units	418	2300
Water Boilers	76	420
Washing machines	43	240
Drying machines	60	330
Water pumps	33	180
Autoclaves	7	40
Fridges	95	530
Freezers	60	330
O2-concentrators	60	330

It is noteworthy that **OCB might be operating almost 2500 air-conditioning units globally**. However, it correlates well with the frequent cooling need presented in Figure 20 above. The international energy working group estimates that **ACs only represent 35% of energy consumption globally, which for OCB would equal almost 500 m³/year of fuel**.

If ACs are operated primarily in daytime, as might be the case for offices, the demand could correspond well with available solar resources, and would allow for high direct consumption of electricity from a solar PV system.

Washing (laundry) machines are also demanding units that can require high water temperatures above 90°C, especially when used for thermal sterilization. Often in standard laundry machines, water is heated directly by resistive heaters, which require both high power and a lot of energy. As can be seen in Figure 43 above, **laundry consumes almost 25% of total energy**. It has been suggested that several smaller laundry machines should be used to avoid large power peaks, and instead spread the operation of the laundry machines over longer time (Motard, 2016). Furthermore, substantial energy savings could be achieved if water can be pre-heated, for example using solar thermal systems or available waste heat from generators. Waste heat or alternative heating sources may also present a possible means of reducing the energy use of drying machines. In some setting the use of heat-pumps might be a possibility to reduce energy use for heating water.

5.6.3. PRIORITY LOADS

The largest and most demanding loads in terms of power and energy also share the same electric mini-grids as other high priority loads for direct medical activities and cold-chains. These loads are often supported by UPS, many of them with a battery backup, to bridge unexpected power losses. As can be seen in Figure 60 and Figure 61 below, there are around a hundred new UPS units registered in the Buphagus system each year, which have three different prominent power ratings.

The multitude of UPS systems also indicates a large number of batteries related to these installations. Batteries are challenging but could, as stated above, also work to stabilize the electricity system.

Properly set up, they may allow better working conditions for the generators, as has been tried in several projects already, or absorb intermittent solar PV power and extended electricity service hours, as has been recently tested in a hybrid UPS-configuration in Pakistan.

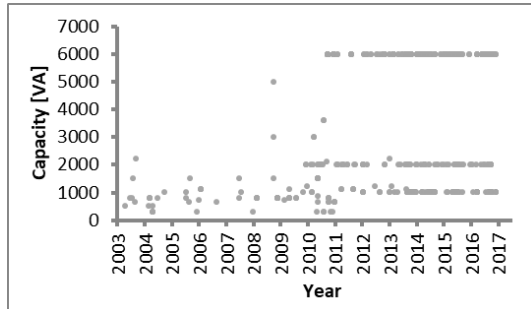


FIGURE 60. THE GRAPH SHOWS THE DISTRIBUTION OF 650 UPS UNITS IDENTIFIED FROM THE BUPHAGUS SENT BY MSF SUPPLY SINCE 2004. CAPACITY HAS BEEN INCREASING, AND UNITS SEEM TO BECOME STANDARDIZED IN CAPACITY.

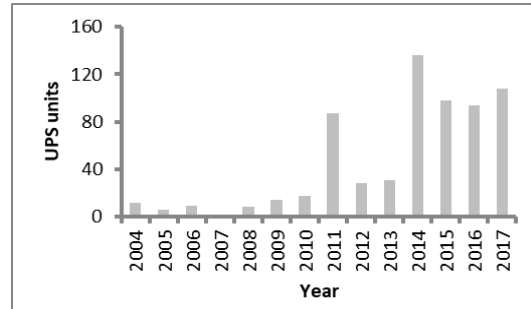


FIGURE 61. THE GRAPH SHOWS AN INCREASING NUMBER OF NEW UPS UNITS REGISTERED TO BUPHAGHUS IN RECENT YEARS.

Biomed equipment is naturally an important category within OCB. A recent study on biomed equipment shows that around 25% of equipment is ordered throughout OCB. Some equipment might take damage due to poor electricity quality, specifically when switching from city grid power to generators. Often, logistics departments lack in-depth knowledge on biomed equipment, which partly explains the high fail-rate. In addition, it has been pointed out that it is often very challenging to establish good communication between medical, tactical, and technical teams to support the operation of biomed equipment (Rodríguez, 2017).

O2 CONCENTRATORS

Oxygen concentrators are an example of vital, basic biomed equipment used in most MSF operations, as they enable life-saving interventions and serve in a wide range of medical activities. They are often connected to priority electricity lines supported by UPS units, and often remain as essential equipment after MSF has withdrawn from a project. The data in Figure 62 shows the number of new oxygen concentrators managed by MSF Supply each year for OCB. The graph also gives an estimate of the accumulated number of units assuming a 5-year equipment lifetime.

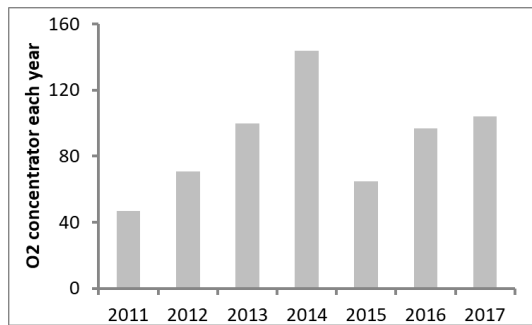


FIGURE 62. THE GRAPH SHOWS THE NUMBER OF NEW O₂ CONCENTRATORS LISTED IN BUPHAGUS EACH YEAR. THE LINE SHOWS THE ACCUMULATED NUMBER, ASSUMING A UNIT LASTS FOR 5 YEARS. (NO DATA BEFORE 2011)

Using Buphagus data, the accumulated value for OCB is here estimated to be slightly less than 500, which is slightly higher than the 330 estimated for the 105 projects regarded in this study. There are a growing number of oxygen concentrators within the operations, primarily used in hospital settings that require stable electricity supply both day and night.

5.7. ENERGY ID CARDS

With a substantial portion of this study having been the collection and organization of information on the various projects, scattered throughout different databases and locally-managed Excel sheets, an overview of project data and indicators was setup as a one-page, comprehensive summary – an “Energy ID-card”. The initiative to create comprehensible data was communicated during the second workshop. Our simple example is shown in Figure 63 below.

Having a comprehensive overview of a project in terms of prioritized indicators and measured data would be very valuable for tactical planning purposes of all kinds. Today, that overview is rather cumbersome to acquire, because there is no centralized and working database that gathers all input. However, “Track my Stuff” is currently being developed as a new and more flexible system to replace the LRS and perhaps even more of the existing reporting systems (Lemaire, 2017).

5.8. FIELD-VISITING REPORTS

The field-visits conducted by the energy technical family over recent years are naturally motivated by the three priorities of ensuring safety of people, protection of equipment, and continuity of electricity service. The evaluations of field electricity systems and measures taken for improvements generally aim at identifying substandard and dangerous installations and making them meet the minimum MSF requirements.

In many cases, MSF uses existing facilities with electricity installations done according to local practises and using components found in the local market. The quality of these distribution systems varies substantially on both global and local levels, and the systems often require rehabilitation in order to offer adequate services to MSF. Similarly, new installations originally designed and implemented by MSF electricians and according to MSF standards often degrade over time as operational needs change and require the electricity distribution to expand, often in a less organized way, to always meet the needs for electricity services. Likewise, electrical components take damage from hard use by people and exposure to the environment, and the resulting problems are normally solved by the log teams in the projects to maintain the continuity of service in the short-term, but often using quick-fixes that pose safety and long-term reliability issues.

“But at the coordination level no one is able to technically supervise them, to make them grow, building enough skills so that we are able to make a correct job not only by fixing problems, but installing long-term solutions that will be satisfying our need to have safe and sustainable electrical installations.” (Prager, 2012)

The field-visits also address the proper sizing, installation, operation and maintenance of the generators supplying electricity to the different health facilities, offices and staff houses. Again, as operational needs grow and demands on the distribution systems change, power capacities of the generators might become insufficient and the balance between different electricity distribution lines are skewed. Short-term electricity measurement campaigns are often conducted to provide further insight into the situation and the quality of electricity at the generator. In particular, when connected to the city power, potential stability issues are reported to originate further upstream and demand measures to be taken by MSF to ensure protection of equipment inside MSF facilities (Prager, 2012) (Ait Yahia, 2015a)

To a large extent, the field reports reflect and directly highlight the need for qualified electricians in the field. The local LOGs in the projects are dedicated and excellent at finding solutions to keep things running, but often have neither the correct training nor sufficient technical support and guidance from their supervisors to adequately manage the work required on electricity systems. Linked to this, there is often a lack of proper electrical tools and access to high quality electrical components in the local market.

Although the field-visits focus on the quality of the installations for electricity generation and distribution and are conducted from the perspective of an electrician, there are of course also considerations related to the final services that these systems support. The access to multiple generators and back-up energy sources is ensured and high-priority electrical loads are put on separate lines with UPS systems. Further, load-shedding devices are used to focus the limited capacity of off-grid electricity systems to be used by high priority loads like e.g. cold-chain, biomedical

equipment and IT systems. (Ait Yahia, 2015b). In a similar manner, OCB applies supply-side management, where differently sized generators are used during different parts of the day to better match variations on the load side. In Tabarre, Haiti, switching between generators is automated, whereas in for example Juba, South-Sudan, the night and day generators are of different sizes (Ait Yahia, 2015b). The electricity systems currently under development for Kunduz, Afghanistan and Kenema, Sierra Leone will deploy synchronized generators to increase the possibility of following the load variations and thus improve the life-time of the generators.

Furthermore, there are also valuable suggestions on how to improve the conditions for providing the final energy services required by the operations, based on considerations beyond the electricity system itself. In most cases, these relate to improvements in the thermal energy performance of buildings that are subject to heating, ventilation, and air-conditioning (HVAC) needs. Poor building energy performance and improper use of HVAC systems are responsible for substantial energy waste that stresses the limited capacity of the electricity system and threatens continuity of service.

“Since it is not possible to increase the power available without over-loading the cable (which cannot be changed), it is necessary to diminish the demand as much as possible.” (Mujica, 2017b)

The recent extension of the energy technical team to address these issues in more depth is clearly illustrated by recent field-visits to for example Lebanon, where operations are using substantial and partly centralized installations to provide appropriate indoor conditions. The field-visit was conducted with close collaboration between the construction-, biomed-, watsan-, and energy technical teams in order to grasp the interplay between these services. The concept of energy is thus broadened from electricity generation and distribution to aspects related to the HVAC systems that can easily consume more than half the electricity in a project. The field-visit formulates the need for protocols and standards regarding operation and maintenance of HVAC systems, audits of projects’ energy needs and consumption, and training of the staff to better understand the effect that user behaviours have on the energy system (Ten Palomares, 2017b).

“The team needs to make a particular effort to raise awareness of the importance of proper use of the air conditioners. This means keeping temperature within the comfort range, as well as basic behavior like closing windows when the system is running.”(Ten Palomares, 2017b)

To further support capacity building on these aspects also at coordination and HQ level, it was suggested that a third-line project¹⁹ be pursued to develop and pilot a remote monitoring solution for the operation of the energy system and energy consumption (Prager, 2017b). It is concluded that the lack of good data and expertise on energy system performance hampers the implementation of renewable energy, as well as solutions that could improve the final services to the operations (Ten Palomares, 2017b).

“The use of solar heating systems is increasing in MSF’s operations; however, there is a shortage of data that sometimes hinders effective interventions. Reliable data collected from the system could be useful for other projects and missions when evaluating the different energy options for heating health

¹⁹ Third-line project: research and development project.

facilities.” (Ten Palomares, 2017b)

The need for robust installations, technical competence, and adequate supervision of staff, as well as established maintenance protocols is further emphasized with the growing complexity of systems in large projects. The reports from the field-visits to Tabarre seem to depict a limit of complexity of what the field-team under the current organizational structure can manage. As is mentioned in the field-visit reports and in the testimonies arising from several interviews, the system has had issues with both the generation and distribution side since the beginning. Growing energy and power needs (with thermal loads like air-conditioners, electric boilers for hot water, laundry, etc.) are stressing the generators to their limit and could premature breakdowns. Faulty installations are the suspected reason behind burnt cables and resulting system failure, where the proceeding troubleshooting failed to identify the actual fault and unfortunately instead caused new difficulties. The same issues that were reported from the other projects are also raised as the main reasons for failures and challenges in Tabarre, which stresses the need for technical competence, especially among supervisors in the field (Prager, 2017c).

Energy is also indirectly addressed in the field-visit reports of other technical families. The health facility manager of Bar-Elias, project pointed out as being one of the most technically challenging projects that OCB is running, anticipated the need for specific competences and an adequate organizational setup and implementation of operation and maintenance protocols for the hospital, but also addressed the need for the physical space with tools and resources required for the technical systems that are in place. Also here the need for a monitoring strategy with defined quality indicators and analysis possibilities on system performance was identified (Motard, 2017).

During the assessment of the biomedical resources in Kibera, Kenya, the importance of keeping the laboratory at a maximum temperature of 28°C was emphasised, with doors and windows closed to reduce dust accumulating. Additional air-conditioning units were recommended, along with an upgrade of the UPS system. Double-conversion UPS units are currently favoured (Mujica, 2017b), as these require no switching time in case of power failure, and also provide grid stabilization during normal operation. As the project was to be handed over to Ministry of Health, a set of requirements were specified to ensure a good functional status of the equipment. Scenarios for how a hand-over could be arranged that ensures that the receiver is able to use and maintain the equipment for at least another two years (spares, service contracts, accessories, etc) were also considered. (Rodríguez Ortiz, 2017)

The assessment of the facilities built in Kenema has a strong focus on structural integrity, as well as the quality of the surface layers. The functionality of the building in terms of natural light, and natural- and mechanical ventilation is addressed, along with the appropriateness of the space and layout for the activities inside the facility and patient flow. Data on the individual facilities (size (m²), bed numbers, building type, orientation, drawings) is gathered, along with a general statement of the climate at the site – all of which is also relevant from an energy perspective, although not specifically expressed in energy terms.

Finally, it is worth mentioning that a rather unique field-visit to Tabarre was conducted in spring 2016, when eight referents from different disciplines (both technical and medical) visited the site together. The expansion in activities since the project opened in 2011 has put a lot of stress on the structures, and it was recognized that a long-term strategy is needed to ensure the continuous operation of the hospital. The diversity of competences present had an added value in the unique solutions that were recommended and documented in the field-visit report, which contains a format for an action-plan on

how the project can operate until 2022 (Motard et al., 2016). The field-visit was further raised as a fruitful example of cross-disciplinary collaboration by participants at the third OCB Energy Vision workshop in Brussels.

“This work was carried out by a multidisciplinary team composed of medical and logistical technical referents. Having this cross-cutting approach to finding integrated solutions and doing this work on an MSF project in operation was a unique opportunity.” (Motard et al., 2016)

5.9. MSF TRAINING MATERIAL AND RESOURCES ON THE OOPS-PLATFORM

The competences and knowledge bases of field staff and supervisors have been highlighted as a challenge when it comes to managing facilities and equipment in the field. They have implications on the reliability of equipment, the safety of personnel and staff, and in the quality of medical services possible. With a high turn-over of people, increasing project complexity, and new technologies, there is a need for adequate training material, protocols, and available resources to support the operations, as is also highlighted by the “innovative” energy initiatives presented below. This section reviews material available on the Ooops platform regarding energy directly, but also attempts to capture energy-relevant aspects from training material that are not managed by the energy technical team.

ENERGY TECHNICAL TEAM

The module ‘The process in electrical project management’ (Prager, 2017d) is given as a part of the tactical training (TT), and is further included as a chapter in the recently published MSF and ICRC technical reference book on electricity systems, ‘Electrical Installations and Equipment in the Field – Rules and Tools’ (Prager, 2016). The module offers generic support on the management of electrical projects by addressing the prerequisites, required competences, tools, responsibilities, deliverables and validation processes of the various phases of the project, from the initial vision to the evaluation of a finished installation. The suggested procedures aim at helping team members in the field feel comfortable with their respective tasks and responsibilities, at supporting clear communication, and at ensuring quality at each step of the process. Close communication between the different stakeholders at the various phases is emphasized, and the module particularly addresses the involvement of all end-users when needs are being defined at an early stage of the planning process.

“Electrical projects are not stand-alone projects: they are an integral part of a general building process or they are applied to already existing permanent or non-permanent constructions or buildings. In that way, their relevance is related to the relevance of more general questions and answers.” (Prager, 2017d)

The close connection between the electricity installations, the building and the activities does of course apply irrespectively of whether the installations concerns the rehabilitation of existing installations, extensions, replacements, or the design of a completely new system. As the process described covers all steps from an initial vision to a working installation, room should be found also for considerations related to wider aspects of energy use (beyond electricity), either within or parallel to the described process.

INDOOR CLIMATE - CONSTRUCTION AND COLD-CHAIN TECHNICAL TEAMS

The guideline “Planning and Design of Health Care Facilities” (Coelho, 2013) addresses the construction considerations required to meet the general operational needs in different parts of a healthcare facility. There is strong emphasis on designing a building with clear consideration for the medical- and supportive activities that it should accommodate, which also has implications for the technical aspects of construction. For example, specifications in terms of the indoor climate state that natural ventilation needs to be balanced with infection control, and in hot and humid climates air-conditioning is suggested wherever possible so as to improve working conditions. Coordination between the construction project and the design and installation of the electricity system is outlined in terms of the three primary priorities for electricity: safety of people, protection of equipment, and continuity of service.

There are general recommendations for energy efficiency in the choice of lighting equipment and for some other appliances, like dryers and washing machines, where energy- and power consumption are mentioned as important criteria for choosing product. Smaller washing machines are recommended to distribute energy consumption throughout the day and to reduce power peaks, thus saving the generators from unnecessary stress. Suggestions are also given on how to reduce energy consumption when drying laundry by careful choice of drying technique. (Motard, 2016)

The slightly older reference material on air-conditioning in OTs suggests taking a few simple measures to improve thermal insulation of a room before installing an AC unit, and also on to install and operate the machines in order to provide the best possible service (Lermusiaux, 2005). In a similar manner, the guidelines for planning pharmacies and medical warehouses (which require controlled indoor climates) recommend carefully-considered building construction and solutions for natural ventilation in order to reduce artificial cooling needs (*Cold Chain Guideline*, 2002). The same guideline further suggests seeking advice from the energy referent before installing AC-units in a pharmacy.

These last examples from MSF’s online resources also show examples of how well-installed systems can improve the efficiency of the required service, which consequently reduces the load on energy systems.

APPROPRIATE ENERGY SYSTEMS AND INTERDISCIPLINARY COLLABORATIONS

There are very few examples of resources on the Oops platform that address the use of alternative energy. In fact, the only support material found gives a brief instruction to how solar PV can be employed in stand-alone mode for powering communication equipment (Simon, 2003).

The guidelines for planning healthcare facilities highlight the need for a long-term and holistic approach, in which the most appropriate technical solution is defined and due consideration is given to:

- Ensuring reasonable sustainability of the project;
- The cost implications of the project;
- Technology adapted to the operational context and objectives;
- The human resources and technical competences needed;
- Maintenance of facilities;
- Exit strategy and hand-over considered from project inception.

These recommendations are general and broad, but provide basic conditions for good practice, which are also applicable beyond construction projects. They emphasise the value of collaboration between

technical families and other complementary expertise. This is further addressed by the newly-introduced HVAC family, who actively seek interdisciplinary collaborations.

“HVAC is a sector of applied engineering which combines construction, electrical, mechanical, watsan, and architecture. In MSF HVAC design and implementation will also involve other stakeholders as log managers, warehouse managers, pharmacists, infection prevention and control, lab technicians, hospital staff, etc.” (Ten Palomares & Roreng, 2017a)

Although the need for HVAC in medical settings is partly motivated by control of infection from airborne diseases, and the control of indoor climates for patients, drugs and biomed equipment, the HVAC training material further address these services in relation to the climate at the project site and the quality of the building. The links between satisfactory service, improvements of building standards, choice of HVAC equipment, and energy use are clearly outlined (Ten Palomares & Roreng, 2017b).

As mentioned above, there seems to be a lack of concrete training material and internal resources (tools and guidelines) that address possible ways of making energy-based services more efficient by considering the interplay between, for example, the building design and physics, building service systems, climate, local and non-electric energy resources, specific loads, and of course social aspects that influence the ways in which people use the services. This interplay is difficult and varies greatly dependent on context, but its importance will probably increase as OCB social missions grow larger and more technically complex (Coelho, 2013).

PROCUREMENT

The OOps platform provides support on the procurement process of items and services, but seems to offer very limited details on the technical aspects of energy-related products that are often purchased at local markets, or indeed advice how to ensure they are of sufficient quality.

MSF Supply and MSF Logistique have been working with Ecovadis Platform²⁰ since 2015, which is a Corporate Social Responsibility (CRS) tool used to improve their sustainable procurement strategy. Although products related to energy are not yet included, an evaluation is being conducted in order to establish whether MSF would benefit from extending the use of the platform to other products.

5.10. ENERGY INITIATIVES IN OCB

As part of the initial mapping of energy realities with operations, several examples of interesting initiatives taken directly in the field have been communicated to us. They reveal the creativity behind some non-standard energy solutions employed throughout MSF to meet the challenging needs LOGs encounter in their operations. To some extent, these initiatives concern the employment or development of specific technology solutions, whereas in other cases it comes down to supporting improvements in standard practices. The examples below try to depict the scale of both smaller and larger initiatives taken at different levels at the organization, and the listing by no means claims to be exhaustive. The large projects of Kenema and Kunduz for example are excluded, as they are presented in the results section (p.70) of this document.

²⁰ More info in: <http://www.ecovadis.com/>

The growing number of individual initiatives like those below show the need to share experiences within the community and further build on organizational knowledge. We quickly take note of the emails that pass from one log to another regarding specific system setups and tips for good practises. At the same time, there are explicit requests for centralized support, as has been the case in Afghanistan where the Log Cell has asked the HQ HVAC focal point for a one-day training on energy efficiency measures for the Construction-, Energy- and WatSan managers, along with creating a mission-specific action-plan on the topic.

1. *Biodigester, Lebanon*

Based on the needs of Syrian refugees living in Informal Tented Settlements (ITS) scattered within the region in the north of Lebanon, a sanitation solution was required. In the discussions between the watsan and energy manager of the project, the idea of a developing a biodigester took shape. A prototype was gradually developed in close cooperation with the local community, which included community training and specific training for women, who were also interested in using the biogas produced by the digester for cooking to reduce the substantial expenses of buying gas. The initiative was given small financial support by the coordination team, and was further recognized by other missions as well as at HQ. Despite still being an early prototype and located in an area with limited facilities for technical product development, the team behind the initiative hope for an opportunity to continue exploring the potential of the concept for OCB in more controlled circumstances and in warmer countries.

“From our experience the bio-digester might have a larger potential as a sanitation solution for treating feces than for actually producing biogas fuel” – Diana Benato, Mission Energy Manager

2. *Solar Hybrid UPS, Pakistan*

In order to extend electricity service hours and reduce the noise pollution from the generators at the guesthouses in the Nawagai/Bajaur projects, the Energy Manager in Islamabad took the initiative to install solar PV systems to support the UPS systems. The projects are inaccessible for expats, but the local communities in the north have experience using solar PV as an alternative to generators, and a local contractor was employed to set up the systems. Efforts were also made to manage the loads and switch to more energy efficient alternatives. As the initial systems have been working satisfactorily, additional installations will follow.

“It would have been good with some support on sizing and designing” – Asadullah Khan, Country Logistics Specialist, Energy

3. *Solar PV, Kenya*

The Silanga health centre has been using solar PV to support the electricity supply since 2015. A recent visit inspection by the MIO Energy in March 2017 showed that the panels and

batteries are still in good shape. The system was handed over to MoH in June 2017, and is still working properly.

4. *Solar PV, Afghanistan*

Recently a solar PV system was installed at the Khost CHC, and a local contractor supplied and installed the system. A large part of the load is supplied by DC-electricity, and a generator operates as backup supply. The mission has emphasized that small access to energy via e.g. a solar system can also made a difference at rural sites where access to the grid, fuel, and qualified technicians is difficult. Furthermore, the energy and cold-chain referent in Kabul has expressed thoughts on how solar PV can be used to off-load generators during warm summer days.

5. *Energy Efficiency Trainings, Afghanistan*

The mission in Afghanistan has requested training on energy efficiency practices and protocols specifically relevant to their operational realities. As a result, a unique training within OCB was conducted at the end of 2017 to cover both short- and long-term arrangements.

6. *Solar thermal, DRC*

In Bangui, the LOGs proposed the idea of installing solar siphon water heaters to improve access to hot water. The systems are simple and would offer increased services without adding too much stress to the generators, which are already at their limit. The team in Bangui estimates a payback time of a few years. There is also discussion of using a hybrid system (genset and PV panels) together with a centralized HVAC system for the pharmacy to reduce energy consumption.

7. *Energy Efficiency and Carbon Footprint, South Africa*

The LogCo in Cape-Town has, together with one of the field LOGs, set up a routine to monitor the consumption of fuel, electricity, flights, water and stationary generators, and convert this data into CO₂ equivalents. In parallel with the monitoring proposal, they are promoting suggestions for energy efficiency measures based on a range of locally available products. It was mentioned that a main challenge has been to collect the basic consumption data. An analysis of the data from this initiative is provided in the results and discussion section of this document (p. 60).

8. *Energy Policy, Malawi*

The coordination in Malawi has written an energy policy document that addresses the priorities of safety of people, protection of equipment, and continuity of service, as well as the optimization of the energy system in terms of cost control and limitations of environmental impacts.

9. *HVAC system, Ukraine*

The climate in Zythomyr is challenging with respect to the large temperature variations between summer and winter. A mechanical HVAC system is designed to meet standardized requirements, and to provide additional heating on top of the existing biofuel-powered

heating system for winter and air-conditioning in the summer. Great care has been taken to minimize the energy demand of the new HVAC system by using energy efficient components, heat-recuperation, a well-considered control system, and a consistent monitoring procedure. The added value of defining a sustainable solution within a working group in which all people concerned were represented was highlighted.

The initiatives listed above can be further supported with the responses given in the questionnaire which was sent to all field projects via the coordination. The questionnaire specifically addressed what alternative energy solutions could be used in the projects, and how energy use could be made more efficient. The vast majority mentioned solar energy as a technology of interest, for example to serve security lighting, to operate in hybrid configuration with generators, or to be used for heating water. Replacing old equipment with new equipment or more energy-efficient units was mentioned as a means to improve efficient energy usage. In addition, improvements of insulation in warehouses, better sizing of air-conditioning systems, monitoring of energy consumption, load management, as well as the need to train people with regards to how energy is being used were all brought up.

6. CONCLUSIONS AND DISCUSSION

Once the results of the research have been exposed, in this section we summarize the outcomes of the study and present a discussion around them by answering our initial research questions: where are we now in terms of energy; where we would like to go; and how can we get there?

6.1. THE CURRENT SITUATION: WHERE ARE WE NOW?

MSF-OCB considers its strength to come from its identity as a humanitarian emergency organization; however, the traditional emergency context is changing, and the majority of MSF projects currently last for five years or longer (sometime even decades longer). Within this framework, there is a need to establish planning processes that allow for long-term solutions to shape operations, which are appropriate to local conditions and which may differ from those that are fast and effective in a classical emergency context. MSF continues to develop new large-scale projects to host increasingly complex medical activities that demand very high-standard infrastructure — with which the energy needs grow by order(s) of magnitude. Both this **long-term nature** and the **increasing complexity** are factors that call for an extension of the vision of what energy means to MSF, and how we meet the needs of our patients and staff. Concepts — largely based on existing technology — are needed that offer both cost-effective and more sustainable energy solutions.

One of the major challenges when trying to gain a wider overview of OCB's energy setup is the **lack of reliable and consistent data**. The reporting systems in place are not used systematically, which undermines their potential to inform decisions. Consequently, different departments only collect and combine data of relevance to their own work, and a detailed overview is practically non-existent — surviving instead in more general terms with experienced personnel within the organisation. The reporting systems depend upon the engagement of field staff, but have limitations in the value of support they offer to improve the management of the systems that are used on a daily basis.

From that starting point, we used both quantitative and qualitative research methods to gather enough data to frame OCB's current energy situation, triangulating the information in order to contrast it and reduce possible biases. With this methodology, we have found out that slightly **less than 80% of OCB's projects have access to city power** (and thus pay electricity bills), but a majority use generators. We estimate **around 350-400 stationary generators are currently deployed globally**,

with an average size of about 60-65 kVA and a **total generation capacity of more than 20,000 kVA**. The generators primarily serve hospitals, offices, guesthouses and warehouses. Larger generator sets are normally required for warehouses and hospitals, and around 60% of the total capacity is installed in hospitals. In 2016, OCB used around **5,000 m³ of fuel (according to the financial records)**. 20% of this was used in search-and-rescue operations in response to the crisis of people drowning in the Mediterranean Sea. Within projects, the split between fuel for energy (electricity via generators) and other purposes — primarily transportation — range from almost 0% energy in several projects with good grid access, to more than 90% in some remote settings. It is estimated that on average **around 35% of the fuel is used in generators**, which means about **1500 m³/year globally**. The share of the total project budget spent on energy (all fuel and city power) ranges from close to nothing to more than 10%, with an average of around 2-3%. **However, there is still a possibility the actual fuel use within OCB is significantly larger than what is given by the financial data, as has been suggested by other data sets that unfortunately are less complete**²¹. That does not take into account any auxiliary costs for the logistics of fuel supply, which in remote areas can be cumbersome, and can implicate security issues where fuel storages are particularly large .

The carbon footprint related to the combustion of 5,000 m³ of fuel amounts to around **13,500 tonnes of CO₂**, of which around 4,000 tonnes might be related to the diesel used in generators. The emissions related to electricity bought from the grid may add another 2,000 tonnes²² CO₂, as a rough estimation. 5000 m³ of diesel would take a Toyota Land Cruiser around the equator almost 1000 times.

On the other hand, growing attention has been given to HVAC systems due to their nature as an often high energy-consuming service, for which demand is increasing. In some setting, as much as **60%-80% of the overall energy is used to provide a suitable indoor climate**. The requirements for these services are based on: the medical and infection control needs inside our health structures; the storage requirements of pharmaceutical products; and the comfort of our staff and patients. Climate data shows that almost all OCB project sites have a potential need for cooling, and several sites in Europe and central Asia have very significant heating demands during winter. Especially in relation to the larger and more demanding projects, increased measures focusing on energy efficiency — primarily through the use of solar thermal systems — have been considered in order to reduce the load on the electrical system. In some projects, a combination of generators is used to better match the load variations throughout the day, which are partly due to the use of ACs and, for example, laundries. Within OCB we also see an increasing number of electrical appliances in the field — among them, sensitive biomedical equipment that risks being damaged by insufficient electricity on relatively unstable grids.

Although the quality of MSF's work in the energy field has improved in recent years, the operation of electricity systems in the field remains challenging as **there is often a lack of adequate technical knowledge to manage the systems; a short-fall of quality products on local markets; and installations that do not meet MSF's standards**. These shortcomings might cause safety issues for

²¹ Data collected from the logcells suggests that fuel expenditure is 12 million euros per year (mobility and energy). Estimations from the mobility referent suggest that 10 million euros per year are used just in fuel for cars

²² Assuming an average electricity price of 0,18 euro cent, and an average of 0,6 kgCO₂/kWh.

people, reduce protection of equipment, and have implications on the continuity of service. The need for qualified technical managers is likely to increase further as projects need larger and more complex energy configurations. On the other hand, increasing the diversity of the energy system could increase robustness and make some services less electricity grid dependent — which could improve both safety and continuity of services.

Globally, there is a strong and growing interest in renewable energy technologies — often motivated by the possibility of reducing our carbon footprint — and this also exists within the MSF movement, usually driven by the field. As a humanitarian organization, our environmental impact reaches far beyond the energy systems we set up to enable our core activities, and may for example include transportation, procurement, and handling of materiel and drugs. Energy is an area where technological solutions are available to reduce MSF’s carbon footprint, at the same time as improving service delivery. Furthermore, although often related to higher upfront investments, many renewable energy technologies may show payback times shorter than the duration of most of our projects. Relying on freely-available resources, the use of renewable technologies can also improve the possibilities for less well-resourced organizations to continue providing services when MSF leaves a project. Even for MSF, several remote projects might benefit from a reduced dependency on elaborate and costly fuel supply chains, further motivated by the fact that **most project sites benefit from excellent solar resources**.

Taking all the above into account, we can now say that the research has helped us construct a general picture of the current energy situation in MSF-OCB. Although the dearth of data available made some estimates difficult, the triangulation between different sources and stakeholders has helped to bridge this gap. The study clearly reveals the importance of having reliable and consistent data; not only to understand the current energy reality, but also to facilitate long-term planning and to assess the impact of energy in our operations. There is still, however, a long way to go. The data collection process that we have started is just the first step towards drawing the complex and diverse energy picture, a dynamic process that must continue under the leadership of the energy team and with the collaboration of the other technical and tactical families.

6.2. THE DESIRED FUTURE SCENARIO: WHERE DO WE WANT TO GO?

The ideas for the direction of the future strategy regarding energy within OCB have primarily been gathered from dialogues with LOGs working at OCB HQ and in the field. When picturing the desirable energy situation in the mid and long-term, the **main actors envision the desired scenario in terms of specific energy solutions**, usually pointing out **structural bottlenecks that explain why the desired energy situation has not yet been accomplished**. On the other hand, there are also strategic initiatives taken at HQ that have impacts on how OCB envisions the energy systems in the future.

Many of the desired improvements that have been expressed are already reflected in the initiatives and work currently in progress to improve the robustness of energy services. The implementation of **passive energy solutions** and **energy saving measures** are discussed as parallel activities to **increase the use of renewable energies**. Interest in **energy storage** is raised in relation to intermittent renewable energies and non-electric energy sources, like the recuperation of waste heat from generators.

The lack of reliable data from the field is widely recognized, and **better continuity of information** is addressed along with a wish to understand the actual energy use within our projects, and to re-assess the needs behind that energy demand. A necessary change of mentality within the organization must

acknowledge the added value of **better monitoring and information management** from field projects: both in terms of strategic planning and for support in the daily management of projects.

The default emergency mode in which OCB is operates — with a tendency towards a ‘throw-away’ mentality — is highlighted, demonstrating the need to have **more time available for project planning**. Several actors pointed out that that the former would allow the development of more appropriate solutions based on **interdisciplinary cooperation**, and could help to **establish an exit strategy early on**, in which **end-users and beneficiaries are included in the planning of the energy setup**. At the same time, there is a growing interest in **convenient and robust technical solutions specifically for emergency responses**, such as small/portable energy sources for quick installation.

Another challenge that several actors see as a major constraint are the **limitations of internal HR capacities** along with the **growing complexity of projects**, therefore highlighting the possible benefits of using more external partners and subcontractors to provide energy services. Internally, this is aligned with already existing initiatives that are trying to face these challenges from a broader perspective. That is for example, the implementation of the new Log Vision, which strives for a more flat organizational structure where the inclusion of competences and expertise held collectively by the OCB community is managed via up-coming tools like Sherlog.

Finally, we do not want to conclude this point without highlighting that the process of building on an energy vision entails **bringing about fundamental changes in the way in which energy is currently approached** in OCB. It is therefore necessary to have a clear and consensual desired future scenario - the goal that we want to reach in terms of energy - to give us a long-term perspective that will help us avoid falling into traditional patterns and existing structures. This aspirational exercise entails looking beyond the possible future to also see a desirable future (predictable future doesn't mean desirable), but then balancing between desirability and feasibility (a desirable future isn't necessarily a feasible one). This study has therefore provided the first steps needed not only to envision this new desirable and (to a certain extent) feasible energy scenario, but also to picture how we can face the main constraints that could hinder our goal of considering the potential of all energy alternatives (renewable and non-renewable). Based on this, we think that **the energy team**, together with the support of the other relevant stakeholders, now has **enough tools to formulate a specific, comprehensive, and collective energy vision that is able to fill in the gaps between the desired future and the present energy situation**.

6.3. POSSIBLE SOLUTIONS: HOW DO WE GET THERE?

Finally, we collectively identified a prospective path to achieve the desired energy scenario. This includes the identification of possible activities and actions needed to face the different challenges, while considering their feasibility and implications. Those actions are structured around 4 pillars: mind-set change, capacity building, monitoring, and technology, which are the core pillars of the road-map presented in the last section.

CHANGE OF MIND-SET

This study has revealed that there is a need for a strategic communication drive (addressed not only to LOGs, but also medical staff and management at all levels of the organization) in order to establish support for a more long-term approach to our operations. This strategy should make use of already existing communication resources in the field — at both local and regional level — to which both expats and national staff have access.

This new long-term view should also be reflected in the energy setups. In that sense, developing and using a ‘mantra’ — a kind of speech that is repeated in several ways using different communication tools — might be an effective way to establish the core components of **expanding from an emergency mindset into the creation of new energy solutions** that are also **identified with long-term operations and responsibilities**.

In that sense, there is a need to develop specific terminology that allows **effective communication** of an expanded energy concept in which electricity is an important subset, and which acknowledges energy as a limited resource. These aspects could be supported by defining relevant **performance indicators** that link between **energy and the final services** that that infrastructure supports, as well as between **energy and health**. These could be included in extended energy briefings and debriefings with field staff. It would also be beneficial to spread news of good initiatives taken in the field or at other levels of the organization, and provide support to champions who lead the way.

As further outlined below, the communication strategy needs to be conducted in phases with the development of appropriately reliable tools and technical resources that can challenge the default options of today.

CAPACITY BUILDING

There is a need for internally validated resources, **training material**, and support documents on **energy concepts beyond the standard solutions for electricity systems** used today. Some are already being developed as direct requests from the field are increasing.

Technical managers and people with a professional knowledge of energy are needed, and it might be worthwhile exploring new ways of recruiting from that category. Identifying energy-based services that can be supplied by means other than electricity may reduce the stress on electrical systems but, per definition, also require competences that go beyond those of an electrician or electrical engineer — especially regarding thermal processes and related technology. The need to create space and time for **deeper collaborations across the technical families** was highlighted in the workshops as a key aspect to co-create appropriate solutions. This corresponds with ongoing ambitions to further involve HQ in third-line development projects, which involve transversal collaboration within technical families, and might be framed within that process.

At field level, similar collaboration might be possible within the Sherlog platform if an area is developed and actively managed to foster a wide and open discussion on energy solutions with people of various backgrounds. The recent collaboration in HVAC that bridges construction, energy, watsan, biomed, and cold-chain exemplifies an initiative that puts the final service in focus. The resources of this collaboration might be extended to allow it to continue and take the lead in the implementation of cross-disciplinary collaborations.

When navigating relatively new areas of expertise, where different systems might interact and add complexity, there could be benefits in using existing software tools to support planning processes. Examples might include designing hybrid electricity systems, simulating building energy performance, solar thermal- or HVAC-systems, as well as smaller things like solar-water pumping, battery sizing for peak-shaving, etc. However, as always, the better the input data and understanding of the actual system, the more reliable the output, which hence relates to the need for increased efforts in monitoring and auditing.

MONITORING

Well-chosen **energy-related data**, available remotely and well visualized, could provide the support necessary to improve the operation and management of technical systems in the field. It could also give input for planning interventions on energy setups. To permit continuous monitoring and reduce the influence of limited human resources, automated monitoring systems might complement existing manual data collection routines. It is important to implement data tools that provide value to the LOGs at all levels of the operations in order to **improve the consistency of collection**.

Improvements to the energy systems may include **assessing or re-assessing the actual service needs**, as these directly relate to the quality of care we offer our patients and staff. Given the limited insight into the energy systems of individual projects, **energy audits** can be designed as tools to map situations in the field, regarding both infrastructure and its use. Audits should provide input on how energy use can be better directed to provide for the services required (energy efficiency) and how the operation of energy-dependent appliances can be arranged to avoid strong demand peaks. Energy audits are complementary to, or combined with, automatic monitoring.

If at all possible, it may be worth looking at **synchronizing the new database with the financial records**, as these have good coverage over all projects and also potentially contain details on everything involving financial transactions, which in terms of energy could be: volume of fuel, type of fuel, number of kWh, etc. It also seems that the Annual Review of Operations is a well-established process covering all projects, and which might contain the possibility of integrating the collection of more long-term or static indicators: coordinates, area of built facilities, etc.

Equipped with the coordinates for all projects, a graphical interface may also be able to link to GIS information: maps, climate data, renewable energy resources, ground covers and other already ongoing MSF-internal mapping projects, as is currently done with the tactical typology

TECHNOLOGY

Energy systems built on renewable sources are limited not only in terms of power but also energy, and are generated only when the source is available - a solar PV system would for example only produce electric power when the sun is shining, and give a potential amount of energy that is limited by the amount of sunshine that day. Hence, hybrid electric or thermal systems combining several generation technologies that complement each other are required, and in most cases together with energy storage.

Batteries are — and will most likely continue to be — a difficult technology to manage, but the developments in **lithium-ion battery technologies** might offer systems better-suited for field conditions than traditional lead-acid batteries, both in terms of functionality and the waste left behind.

Furthermore, as many of the most demanding loads are thermal loads that serve to heat or cool water and/or air, there is potential to **explore thermal energy systems** that 1) may reduce the stress on the electricity system and 2) could use renewable energy or waste heat together with thermal storages. Integrating, for example, solar thermal into the energy systems could offer a low-tech passive solution, appropriate to many contexts and readily availability in many places. As generators will continue to serve MSF settings for a long time to come, technology for recuperating the waste heat might be investigated further as a possibility for increasing fuel efficiency. Flexible operation of ACs, perhaps along with thermal storage to match available solar resources via PV electricity production (potentially as a stand-alone unit) to the AC energy needs, have been addressed in MSF before, and is of high interest given the increasing use of AC in the field.

Energy-related needs and challenges are seen by our field staff, who also often improvise creative ideas to meet them, occasionally developing technical concepts that are either new to the world or new to MSF. However, the field is a difficult place to refine those initiatives and a structure that **acknowledges and helps evaluate relevant ideas to find further development support** has been requested. To some degree this is already happening, as examples of innovations from the field are recognized and shared within the organization during the Innovation Days, for example hybrid UPS systems, bio digesters, etc.. On the other hand, as the global push that is being given to third-line projects where HQ and the field can collaborate together. **Presenting ideas that resolve real needs within MSF to external actors** may result in an increasing amount of relevant products available on the market. From the long-term perspective, this might help OCB improve its energy setup and increase cooperation with external actors and service providers.

Although many ongoing initiatives already reflect the visions for energy system developments, a dedicated plan for developing, implementing, and following-up on activities that can offer incremental improvements to a project could present a direct means of learning and evaluating strategies in real contexts. Indicators can be defined and used to **quantify changes from before to after interventions**, and to **capture long-term effects**.

To conclude this point, we want to highlight that when proposing solutions, the nature of our operations and our emergency-orientated view often make us focus on the technology itself, usually forgetting the wider relationship between technology and society and how our operations are affected by this relationship. Even if the scope of this research does not allow us to dig deeper into this matter, as our approach considers the concept of appropriate technology, we think that this is worth mentioning. To take steps towards mindset change, we should aim to pay more attention to **the process of change** when implementing any kind of energy-based intervention. That is, **under what circumstances do energy-oriented operations optimally contribute to increasing the capabilities and agency of our missions?** If, given the nature of our operations, our beneficiaries' involvement in choosing an energy solution to fit their needs produces an infeasible result, should responsibility for the decision lie solely with the field staff? And what about their role in the generation and dissemination of knowledge? Considering the frame of the new LOG vision, these questions must be further discussed and tackled.

7. ROAD-MAP

The global energy mapping has given us the qualitative and quantitative framework around which we have been able to formulate a road-map. As a result, from the entire participatory research process, and based on the themes outlined in the final section of the conclusions, a set of recommended work packages are listed below. The work packages are described in brief along with a short motivation. Although some are more specific than others, they will need to be broken down into well-framed and manageable actions, which can realistically be implemented by the energy team and OCB-LOG as a whole, and integrated with other ongoing activities into a concrete timeframe.

An initial prioritization of the activities, given by the OCB-LOG energy team, is summarized in the right column below, where a “1” is a high priority and “3” is a lower priority.

7.1. CAPACITY BUILDING

Capacity building is here used as an umbrella term for all activities that would help OCB as organization have ready access to knowledge, resources, and tools regarding alternative energy and its interplay with other technical and tactical families.

Topic	Description	Motivation	Priority
Training solutions	Develop MSF internal trainings and training materials for project development and operation of alternative energies, energy efficiency measures, HVAC-systems, hybrid systems, priority loads, load management, and interdisciplinary aspects on energy services. The material should bridge the gaps between technical families.	There is little support to be found regarding alternative energy among internal and validated MSF internal material. With a growing number of initiatives in the field for these systems, a need for more centralized support in terms of trainings and reference material is needed. Furthermore, it would be beneficial to provide support emphasizing the relationship between energy and the other technical families, covering for example the interplay between energy and building properties or energy and biomed equipment.	1
Procurement	Develop support documents for the procurement of energy-related products and services. These could include e.g. requests for energy performance certifications, guidelines for technical considerations, or companies’ due diligence certificates regarding energy supply chain (i.e. supply chain due diligence for cobalt or other minerals).	The importance of high-quality products and qualified service providers is emphasized in both internal and external documents. MSF Supply gives general support and is currently working on improving the procurement socio-environmental criteria (i.e. working with Ecovadis platform) but more technical guidance and minimum performance requirements are needed.	2
Internal standards	Develop internal MSF standards related to energy systems, to complement existing electrical guidelines. This may well be a range of separate documents, dedicated to each specific aspect. E.g. guidelines for load-side management, design guidelines for hybrid system setups, stand-alone PV-systems, solar-water pumping, solar siphon, etc. Further integrating energy considerations into the document ‘Planning & design of healthcare facilities’ might a possibility, and would work towards energy considerations at an early planning stage by a wide range of stakeholders.	The growing interest in alternative energy solutions, particularly solar PV and Solar thermal, also shown in growing amount of initiatives in the field requests for minimum quality standards to be defined for products and systems setups. Initiatives in the field request centralized support. Energy-related guidelines for e.g. HVAC are already under development.	2
Capitalize on Kenema and Kunduz	Develop a strategic plan to follow and document the implementation and operation of the energy settings in Kenema and Kunduz. It should address both the processes and the technical aspects.	The ongoing developments in Kenema and Kunduz offer opportunities to build experience on a for OCB unique and new initiative: - Kenema: hybrid system PV-gensets, thermal solar panels, energy efficiency measures, etc. - Kunduz: synchronized gensets, HVAC innovative solution (including heat recuperation), energy efficiency	2

		measures.	
	Implement a strategy to operate the system on principles that will ensure the three priorities for electrical systems. Explore what this would take in terms of responsibilities at different levels, needs for monitoring, recruitment of qualified staff, hand-over procedures, out-sourcing, preventive involvement of HQ, etc.	Given the experiences from e.g. Tabarre, where the rather advanced setup of the energy system has proven to be a challenge for the operations, it would be valuable to explore new approaches to ensure the operation of the new large projects.	2
Baselining and evaluation	Identify suitable project(s) to perform an initial energy audit and implementation of a monitoring system, with the purpose to document a baseline for energy use.	The field-project is meant to serve as a case-study for addressing all aspects of an energy system. The activity could also serve as case for energy audits and give feedback on the auditing methodology. Likewise, it could be used to evaluate the functionality of an online monitoring system.	2
	Implement both technical improvements on the consumption side and trainings with aiming to improve energy efficiency. Evaluate to what degree energy efficiency and energy management measures and improvements of services can be made in symbiosis.	It is necessary to further explore and demonstrate procedures and potential benefits of adopting energy efficiency measures. Practical examples and documented initiatives may serve as support to build upon.	
	From the baseline data from the energy audit and monitoring, design an alternative energy system solution with appropriate energy generation and storage.	With accurate data and understanding of the needs for energy services, an appropriate energy system solution can be designed for the specific context.	
	Evaluate the impact (technological, social and environmental) of the different energy solutions on our beneficiaries and our field staff. Pilot site-specific integrated energy strategies in several missions, with monitoring and evaluation over several years.	Based on the appropriate energy solution approach that we propose in this study, a long-term evaluation can help us to identify to what extend the different energy solutions not only enable our health facilities to run but also enable people to do excel.	
Log Vision and Sherlog	Develop an area so the Sherlog platform can work as a capacity node regarding alternative energy, energy systems setups, and energy efficiency measures to gain input from a wide range of potential expertise.	The new log vision addresses the interplay between technicians and tacticians in a wide network of capacities, which with guidance can support development in the energy field. Sherlog is the platform that will allow LOGs to share and manage knowledge, good practices and discover new experts through the network.	2
Simulation tools	Explore the potentials of using software simulation tools to better understand complex systems, and to facilitate the development of improved solutions that remain simple in the field. This could include e.g. building energy and indoor climate simulation tools, or support for preliminary design of hybrid energy systems. Examples could be IDA, Energyplus, Homer, iHOGA, RETScreen, etc.	With increasing complexity and larger projects, also the added value of software tools in the design process is growing. They can help to better understand how energy is used within other technical families. Internal initiatives have already been taken to test a simulation tool for building physics and indoor climate of the Gaptex modules.	2
Handover	Develop routines and support material to integrate a strategy for project handover as early as the initial phases of a project setup. The strategy should help to address energy solutions appropriate to the local context.	As we've seen, many projects are relatively energy intense compared to classification of similarly-sized local hospital facilities done by USAID. Defining a handover strategy in which energy solutions are directly addressed might help to secure basic energy supply also after that OCB has left.	2

7.2. CHANGE OF MIND-SET

The phrasing “mind-set change” here refers to the scope of activities whose purpose is to raise the awareness of the need for a more holistic view on energy or the creation of arenas where interdisciplinary, appropriate, and long-term solutions can take shape.

Topic	Description	Motivation	Priority
Communication strategy	Define a long-term communication strategy regarding the progress of the OCB Energy Vision to keep both LOGs and medical staff aware and engaged, at all levels of the organization, via established communication channels and with different communication materials (videos, leaflets, presentations, etc.).	Changing the mind-set of an organization will require dedicated efforts over many years, and the support and engagement of people at all levels of the organization.	1
NRG Briefings	Improve the energy briefings and debriefings of field staff to include general concepts about energy efficiency and raise awareness of energy use in operations. A template for these communications might be required.	The deployment of alternative energy and work on energy efficiency will need the vocabulary to include energy as a finite resource and energy as more than electricity. The debriefings might be a possibility to address needs and potential improvements.	1
Field initiatives	Establish a format for reporting creative and positive energy initiatives from the field. Sherlog might serve as a platform to evaluate and store the initiatives.	There is a growing portfolio of inspiring initiatives taken in the field to meet specific challenges faced, or to improve on daily practices. Capitalizing on these initiatives can provide valuable input on the solutions to reoccurring needs in the field, as well as input to develop the centralized support structures: training material, guidelines, etc. It will also help to build a library of communication material.	1
	Establish a procedure to capture potentially promising initiatives to help them find both internal and external support to continue developing into mature solutions or products.	A part of the long-term strategy might be to work closer together with organizations outside OCB or MSF to develop mature commercial solutions that meet clear needs in the field.	
Interdisciplinary working group on energy	Setup an interdisciplinary working group with the mandate and resources to jointly define and develop methodologies and tools to bridge the energy concept between technical families. The HVAC could be a relevant starting point to address a final service in which energy is an integral part. It could also integrate the definition of transversal rules on standards for design.	All technical families support infrastructure that interdepend upon each other. However, the training material and field-visit reports show rather clear-cut divisions of responsibilities which hamper a holistic approach that could benefit the end service of everyone.	2
International Energy Working Group	Actively work together with the energy technical and tactical teams of the other OCs to share experiences, solutions and material that can be of mutual use. Support collaboration across OCs to develop solutions or innovations of common interest.	The needs, challenges and possibilities to improve are most likely similar over all OCs. Working together to share efforts and solutions will make us progress faster and have a bigger impact.	2

7.3. MONITORING

The theme of monitoring might partly overlap both with that of “Capacity Building” and of “Mind-Set Change”. However, in this section, we consider it as specifically directed at activities to improve data collection from the missions that would facilitate long-term energy planning, and how this data can be made accessible in a constructive way.

Topic	Description	Motivation	Priority
Online monitoring system	Implement robust online monitoring based on the energy system approach: generation capacities, major energy consumers, and indoor climate. The effort should also include a strategy for data evaluation. An integration of the monitoring system and other reporting systems would be beneficial.	A monitoring device can help OCB with data to both follow the daily operation of the system, as well as to have data for improved accuracy in future planning. A 3rd line project has already been defined.	1
Project indicators	Create indicators to capture 1) the quality and type of energy service given to the operations and 2) the quality of service in relation to energy use and system design. Involve both BO technical and tactical families, as well as FO in the process.	There is a need to clearly link energy use to the quality delivered by the operations. The definition of indicators should indicate which data is needed from the operations and how it is collected, compiled, and communicated.	2
Project Dashboards	Develop a dashboard that presents project indicators and ties data from various reporting and monitoring systems together to give a project overview for long/medium term developments. A project ID card might be an initial step.	Both tactical, technical and HR related decisions could be supported by having an overview of the project and its development over time, which today is only partly available by manual and tedious gathering of the data.	2
Visualization	Implement a simple visualization of online monitoring data in the field to assist correct operation and fault indications. Could include e.g. alarms, systems on/off, power at individual phases, power on priority/secondary lines, battery voltage, daily energy consumption, activity schedules, and reminders.	There is a need to assist the field teams to in their day-to-day operation and maintenance of technical systems. A well-designed visualization of monitored data can be a suitable tool. A joint venture between Log BO, FO and Medical to create a valuable tool could also increase the incentives for reporting data.	2
GIS-mapping	Integrate energy aspects with the Log Typology layer. At a first stage this could involve layers of natural resources (temperature, humidity, insolation, wind, ground cover, road network, etc.) but also the initiatives on alternative energy initiated in the field.	Climate and natural resources have strong impact on energy demands and potentials for energy systems. The Log typology is being visualized by the GIS-team, which opens the possibility of further merging the concepts.	3

7.4. TECHNOLOGY

The technology “activities” highlight technical solutions and products that have been brought up during the process of this work as potentially relevant and interesting to OCB operations. Some of them are rather specific, while others are more thematic.

Topic	Description	Motivation	Priority
Solar Water Pumping	Pilot existing commercial products. Set up a project to try implementation procedures, dimensioning tools, need for resources and capacities, integration with automatic chlorination systems.	With the possibility of storing pumped water, the operation of the pump can meet the intermittent direct supply from solar (or wind). It further allows the pump to be disconnected from external the electricity supply.	1
	Capitalize on and document experiences from pilot installations to create MSF guiding documents, support for dimensioning systems, and KIT solutions.	With abandoned solar resources and a large number of water pumps at a majority of OCB projects, the facilitation of correct deployment, and communicating possibilities and limitations of systems is needed.	
Simple solar thermal	Develop guidelines for designing, quality assuring, and purchasing relatively simple solar thermal systems. These might be solar siphon systems or unglazed pool-heaters, which can both be found locally in many places.	Electric water boilers powered directly by electricity are major energy and power consumers. The hot water demand could be provided directly by solar thermal systems, or these systems can be used to preheat water for the boilers. Initiatives using these systems are taking place in Kunduz and Kenema projects.	1
Solar AC	Support the development of an AC-system with direct power from solar PV along with the possibility for thermal storage. (Also other relevant loads that can use direct solar power is of potential interest)	There is a growing demand for air-conditioning, which adds significant stress and costs to the electricity system. ACs are estimated to consume on average 35% of the overall energy in MSF’s projects. A project application is being formulated by the MSF SIU to take on the development project lead by OCP.	1
Batteries and electrical storages	Design a project around conducting a detailed review of electric energy storage technologies and their control strategies. Based on a mapping of the range of possibilities regarding e.g. reliability, durability, functionality, environmental and social aspects as well as operational and logistical conditions, the output should be suggestions for piloting them.	For backup of priority lines and for grid-stabilization, there is already a need and use of batteries in the field. These are considered a major issue, and with a growing use of intermittent renewable energy supply, there is a growing need for energy storage. There are fast advances in the technology, which have created alternatives to traditional lead-acid batteries.	1
Building energy improvements	Develop concrete guidelines for simple energy efficiency measures regarding buildings. These could include e.g. external solar shading structures, porch constructions, automatic door closings, various insulation possibilities for walls, windows and roofs, natural ventilation, ground ducts for ventilation, and other passive solutions.	Creating a comfortable and suitable for medical purposes indoor climate is a major burden on the energy bill. Improvements on buildings’ climate shells might both reduce energy needs and improve the indoor comfort stability of indoor environments.	1
Technology watch	Allocate time and resources to keep informed on new responsible technology solutions that might be relevant to field projects.	New and interesting technology that might be appropriate to serve in field applications is continuously being developed. There is a need to keep informed on solutions that can help improving energy setups.	1
Heat recuperation	Define a project around existing technologies and the possibilities of recuperating waste heat from generators.	OCB has almost 400 generators installed globally, where the waste heat in some contexts could offer a cheap source of energy to serve adjacent facilities.	1
	Define a project around the existing technologies and the possibilities of recuperating waste heat from laundries	Laundries constitute a significant part of the total load in most MSF health facilities. Recuperation of waste heat in some contexts could offer an efficient source of energy, for example for heating purposes.	

	Define a project around the existing technologies and the possibilities of recuperating waste heat from incinerators.	Incinerators are present in lots of MSF projects. Recuperation of waste heat in some contexts could offer an efficient source of energy, for example for heating purposes.	
Centralized thermal systems	Further investigate to what degree centralized systems could be appropriate solutions to supply hot water and space heating demands in cold climates, but maybe also in facilities in the south that consume large amounts of hot water.	Centralized heating systems might be possible, especially for permanent structures where thermal storages can offer the possibility to couple solar collectors, heat-pump or biofuel sources to support the demand of both tap water and space heating. In missions such as Afghanistan, centralized heating systems are being used; it could be a good opportunity to capitalize the lessons learned.	2
Thermal storages	Conduct a review of thermal energy storage technologies, including the conditions for interfacing heat or cold sources used within OCB. Output should be a suggestion for application that can be piloted.	The energy needs in projects are to a large extent thermal, either for space cooling, space heating or for hot water. Having adequate thermal storages could add flexibility to the generation side, which could strengthen existing electricity systems and also allow for integration of intermittent energy sources.	2
Small Energy KITS	Make a market survey to identify high-quality energy products that could be added to the KIT-catalogue. It is valuable to specify procurement requirements, with reference to quality insurance.	Might include a range of small products for fast deployment in emergencies and in potential energy "distributions". Can be bought locally - fast growing market; emergency lights, solar pico systems, portable power, improved cookstoves, etc.	3
Biodigesters	Support further development of biodigesters to provide biogas for cooking purposes (at household level or for kitchens in bigger health facilities).	Based on the Lebanon experience, capitalize on the lessons learned and best practices in order to replicate the solution in other settings and other scales.	3

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