Chapter 6
Holistic Approach to Sufficient, Reliable, and Efficient Electricity Supply in Hospitals of Developing Countries - Cameroon Case Study

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Abstract While health technology has shown constant improvements in industrialized countries, developing countries have not been able to take full advantage of this evolution, partly because of unstable power supplies. According to a World Health Organization study, grid failures are responsible for one-third of medical device breakdowns. Therefore, the global slogan "Health for All in the Third Millennium" requires a reliable and sustainable electricity supply in hospitals.

This paper presents a power backup and electricity stabilization system that takes into account the technical constraints, as well as the socio-economic factors, impacting the electricity supply in Cameroonian hospitals. The implementation of technological solutions has to be adapted to the socio-institutional context of the hospital. Preliminary sociological studies highlight the impact of organizational culture, hierarchy, and professional education on the way that technical equipment is installed and maintained, as well as the way that supply failures are addressed. From an economic perspective, technical weaknesses imply higher energy costs and lower revenues. Preliminary studies suggest that the costs incurred in the installation and maintenance of a stable electric system can partly be compensated through energy saving and additional medical treatments resulting from the increased availability of medical devices.

The Problem Tree Analysis Method (PTAM) used in this paper allows the identification of interactions between technical and socio-economic factors leading to electricity breakdown and, hence, to the development of more holistic solutions for the supply of electricity to hospitals. Because of its multi-dimensional nature, this project actively involves scholars from the North and

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South who are specialized in engineering, social and political sciences, and management.

6.1 Introduction and Purpose

While health technologies have shown constant improvements in industrialized countries, developing countries are not yet able to benefit fully from this evolution. Among others, unstable power supplies, inappropriate technologies, and lack of maintenance cause many electric medical devices to malfunction (see e.g., Adair-Rohani et al. 2013). Regarding power supply in particular, regular blackouts cause frequent unavailability of medical devices and health services, while many devices are even damaged by electrical surges and transients. According to a vast study based on data collected from 33 hospitals in 10 developing countries (cf. Malkin 2007), on a total of 975 pieces of broken equipment, *"the most common single cause of failure was the power supply (29.9%)."* Therefore, the global slogan "Health for All in the Third Millennium" involves a reliable and sustainable electricity supply.

Despite this observation, most projects that aim to enhance hospital infrastructure in developing countries have focused either on medical equipment or on providing some electricity generating systems for those *not* connected to the national electricity network. In the same vein, most of the few studies concerning electricity supply in Sub-Saharan hospitals focus on the number of hours with access to energy and do not deal with electricity quality and reliability. This is problematic, as electricity supply failure impacts the sustainability and reliability of medical care and, hence, a population's health and well-being. This, in turn, indirectly impacts school attendance (and, hence, education level), as well as the national economy through the reduction of working population capacity.

In this paper, we consider the context in which electric medical equipment is used, that is, the technical and socio-economic characteristics of the electricity supply within hospitals. We contend that a thorough understanding of this multi-dimensional context is essential to develop the power backup and electricity stabilization system necessary for high-quality medical care.

From a technical perspective, we discuss a hospital-specific network design, as well as the device-specific electricity need, across time. From a socio-economic perspective, we discuss the impact of organizational culture, hierarchy, and professional education on the way that technical equipment is installed and maintained, as well as the way that supply failures are addressed. Furthermore, we present preliminary reflections about solutions that would secure electric power in hospitals without necessarily increasing costs.

From an empirical perspective, our study focuses on district hospitals in Cameroon, a country that is often considered as "little Africa", suggesting that solutions developed there might work, with some adaptations, in many other developing and emerging countries, especially sub-Saharan countries[1].

Section 6.2 presents the problem tree analysis method as a way to study complex issues and identify the core issue, its consequences, and its root causes. In Section 6.3, we discuss the technical and socio-economic factors impacting electric power in hospitals, and then integrate them into a problem tree that highlights their complex interconnections, pointing toward some specific root causes that need to be tackled. In Section 6.4, we sketch out potential solutions and discuss the limitations of the study, as well as further research.

6.2 Design and Methods

Because of the limited attention paid in the literature to the relationship between technical and engineering dimensions in electricity breakdowns on the one hand and socio-institutional, medical, and managerial ones on the other, a holistic approach of electricity failure requires (a) a thorough analysis of the existing technical situation in district hospitals, and (b) a participative approach involving local practitioners and scholars to better grasp the impact of the socio-institutional environment. Therefore, a multidisciplinary approach has been chosen to integrate insights from various disciplines in a single holistic framework, based on the problem tree analysis method (PTAM).

6.2.1 The Problem Tree Analysis Method

The PTAM is widely used by international development actors, and it represents an effective participatory tool to identify and structure problems faced by a community or an institution (e.g., Anyaegbunam et al. 2004; GTZ 1988, 1991). A main assumption underlying the PTAM is that the main issue is always interconnected with others issues. Through the PTAM, the causal links between these various issues are identified to (1) highlight the core problem, (2) define the root causes of this problem, and (3) understand the multiple consequences of the problem. The causes are identified by asking the simple question "Why does this problem occur?", while the effects stem from the question "What does the problem lead to?" As a result of this analysis, a kind of mind map, which looks like a tree, can be drawn. The main problem represents the trunk, the causes and their multiple ramifications are illustrated through the roots, and the consequences, with numerous multiple ramifications, are found in the branches. This presentation highlights the root causes that need to be addressed to obtain a more profound

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1 See e.g., http://www.rfi.fr/contenu/20091231-cameroun-une-afrique-miniature.

impact. To take into account as many related issues as possible, the PTAM ideally requires a participative approach. Brainstorming and a focus group often allow for the identification of “hidden” issues and links.

6.2.2 Research Method

Following the PTAM, we conducted a three-step study of the quality and reliability of the electricity supply in district hospitals in Cameroon. In the first step, information was gathered in regard to the technological and socio-institutional issues related to the electricity supply in district hospitals. A Cameroonian engineer visited various district hospitals to analyze the situation in regard to electric components, wiring, and management. The audit was conducted in four representative hospitals (public and confessional) located in different regions of Cameroon: a district hospital based in an urban area, two district hospitals based in a rural area, and a district hospital developing its activities with the help of international actors. These hospitals were selected because they all have sufficient electric equipment and electro-medical devices. They have between 70 and 120 beds, employ 40 to 90 people, and receive patients from all social classes.

The study used an audit protocol inspired from tools developed by the PoweringHealth initiative of the United States Agency for International Development (USAID) (2009). We interviewed key actors, such as mayors, directors, heads of service, doctors, nurses, and technicians. The questions asked referred to the exploitation and the management of the electric infrastructures, the equipment, the processes, the perceived quality of the electricity supply, and the impact of this quality. As no electrical diagrams were available, we also produced comprehensive electrical schemas for all hospitals. In addition, two Cameroonian experts—an engineer from an energy-efficiency service company and a sociology professor—provided important background information through their analysis of the socio-institutional and managerial factors impacting the electricity supply in district hospitals.

In the second step, meetings were organized with the research team and with external partners. In particular, a focus group in Yaoundé involved various persons representing the medical staff, the Ministry of Public Health, foreign companies that install and ensure the maintenance of medical equipment, and the hospital staff in charge of electric installation (Fig. 6.1). As a result, a problem tree that defined the main problem and proposed multiple root causes of the problem was drawn.

Fig. 6.1 Focus group meeting in Yaoundé. These meetings included entrepreneurs, engineers, doctors, and social scientists

In the final stage, a tentative solution tree was developed that pointed to potential solutions for the main root causes of the problem. These solutions do not necessarily directly address the main problem (the trunk of the tree), but rather target root problems that will, in turn, impact the main issue.

6.3 Results

6.3.1 Characterization of Technical Problems

6.3.1.1 Quality of the Electrical Installation

The first important observation is that nobody seems interested in the electricity flow from the delivery point in the hospital to the use point. If a lamp can be lit, electricity is considered to be present—regardless of its quality. When an electric extension has to be made, no consideration is given to the maximum load capacity of existing cables. Consequently, 12 inappropriate extensions resulted in fires in the audited hospitals. Nineteen out of 41 buildings do not have earth connectors, 30% of plugs are not sealed to the wall, and 17 cables lack insulation. In addition, the main electrical panel and the different departures of three audited hospitals contain intermingled cables, making it very difficult to look for the causes of an electrical problem. Ninety percent of the medical devices in the audited hospitals are connected to plugs by an intermediary of small ups or small voltage regulators, yet these devices are overloaded. They regularly break down and are not replaced until the financial service grants the necessary funds. Furthermore, the absence of an overall electric diagram of the installation does not allow for suitably balancing the loads between the phases in the case of an electric extension—sparks were observed on the principal departure of a phase in one of the audited hospitals because of an overload, while the other two phases were almost unused. Seventy percent of the circuit breakers are exposed and can be switched off by anyone (Fig. 6.2). Finally, no protection against overvoltage was observed in these hospitals.

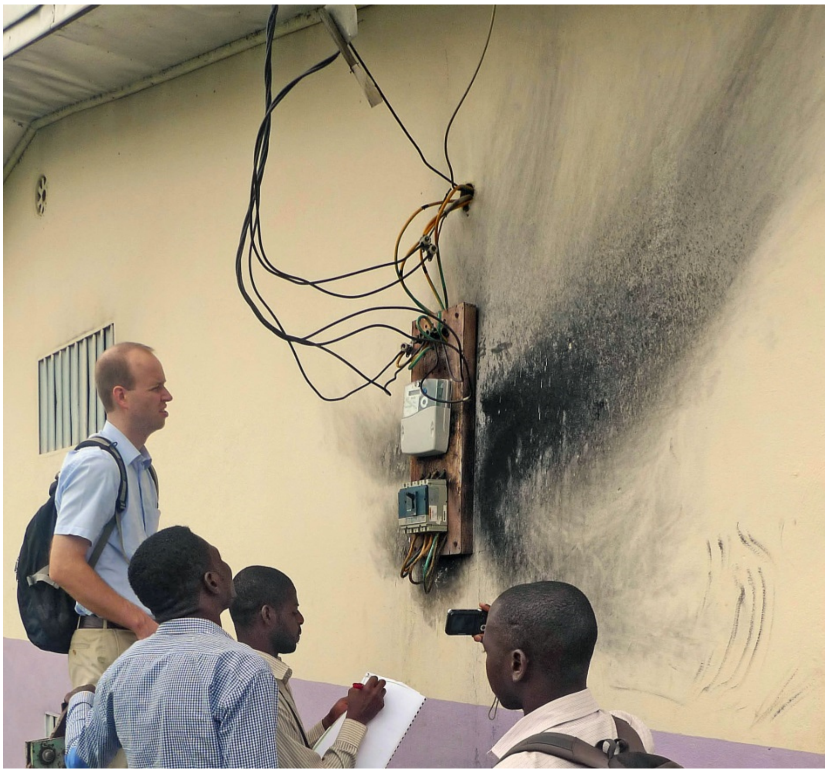

Fig. 6.2 Marks of fire on an electric panel exposed to weathering

In addition to technical misconceptions, the technical staff seems to lack knowledge about the earthing system used. Safety devices, such as circuit breakers, are placed randomly, and the lack of spare parts regularly forces the staff to short-circuit damaged circuit breakers—seven such cases of short-circuiting circuit breakers were observed, two of which involved general circuit breakers. As a consequence of these technical misconceptions and maintenance problems, medical devices, as well as patients and staff, are insufficiently protected against overloads, short circuits, and insulation defects.

6.3.1.2 Power Quality Issues and Consequences

The national Cameroonian electrical energy supply is insufficient and unreliable, with recurring power cuts ranging from one hour to three days[2]. In all services audited, people complained about the frequent destruction of medical instruments because of bad electricity quality. Sixty percent of the interviewees affirmed that there is one power cut lasting from 10 minutes to three hours every day. Furthermore, each recovery of the supply network is followed by an overvoltage that is responsible for 70% of device breakdowns. Medical equipment is protected against these surges through small uninterruptible power supplies (UPS) that ultimately break down after one year (Fig. 6.3).

Fig. 6.3 Small uninterruptible power supplies are frequently used to provide emergency power to a load when the main electricity fails. Many of them are damaged by electrical surges.

An anecdotal, but dramatic, illustration of this recurring problem is the destruction of 50% of the electric equipment of one hospital due to overvoltage coming from the grid in 2011. This is a problem commonly observed in sub-Saharan Africa, for example, in the Albert Schweitzer Hospital in Gabon (a country bordering Cameroon), where frequent breakdowns of radiology equipment are caused by the voltage drops and overvoltage of the public

[2] http://isnblog.ethz.ch/development/cameroon-electric-dreams-for-development-by-2035.

electricity network (Journal de l'association suisse Albert Schweitzer, Nouvelles de Lambaréné N°112, Janvier 2014). At peak hours, the equipment, such as sterilizers, remains unavailable due to the lack of energy, especially in rural areas, forcing the medical staff to use fire to sterilize the equipment. Two hospitals that have mortuary refrigerators also complained about the putrefaction of bodies resulting from longer power cuts—a situation that disappoints many bereaved families.

6.3.1.3 Analysis of Energy Needs

Not only is the electrical energy supply insufficient and unreliable, it is also used without planning in the hospitals. The audit allowed for the establishment of a power budget for all devices, taking into account the coefficient of utilization and simultaneity. Among others, it is to be noted that in case of power cuts, only generators ensure electricity production, covering on average 69% of daily energy needs of the four hospitals.

Furthermore, the consumption load of radiology devices is largely above the capacity of the generator (Fig. 6.4). This overload causes additional voltage drops in the hospital and subjects the generators to hard working conditions that eventually lead to damage. This is the case in three out of the four audited hospitals. Furthermore, generators can function no more than an average of 10 hours per day due to the lack of fuel.

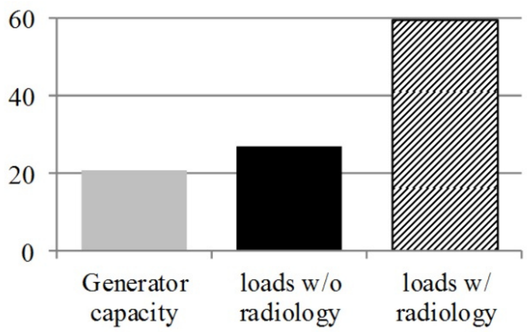

Fig. 6.4 Average generator power and loads during power cut [KW]

6.3.2 Socio-Institutional and Economic Factors Related to Hospital Electric Instability

The shortcomings mentioned in Sect. 6.3.1, however, cannot be explained merely from a technical perspective. They also result from a lack of interest by the hospital directors for the management and maintenance of the electric infrastructure and equipment. There is no exploitation and/or maintenance plan and often one single (unqualified) person, without any formal authority, is in charge of all the maintenance within the hospital. Furthermore, there is a lack of financial resources and spare parts. For instance, in one of the audited hospitals, the two motors of a Caterpillar generator donated by the Swiss army were destroyed because the oil was not replaced.

In the same vein, the absence of incentives regarding energy use can lead to an inefficient use of that energy. For instance, as the national grid electricity bill is paid directly by the Ministry of Public Health, there is no incentive to switch lights off during the day. As a result, external lights are systematically lit during the day in all the audited hospitals. However, in the eventuality of power cuts, the hospitals have to buy fuel for the generator using funds from their own budget. Unfortunately, the only functional generator in one audited hospital automatically starts during peak hours due to the voltage drops of the grid. This situation requires the hospital to use their revenues to buy more fuel for the generator even though energy from the grid is available. The consequence of this additional expenditure is a reduction in the production bonuses for the medical staff, a situation that frustrates doctors. The data collected during the audit allowed us to sketch the distribution of the annual energy budget, with the biggest part being paid directly by the Ministry (Fig. 6.5).

A conclusion of a study made by the “Institut de l’énergie et de l’environnement de la Francophonie” (2006) on health facilities in developing countries is that the issue of energy savings is more important in health institutions in developing countries than in industrialized countries. This study shows that the energy consumption of major national and regional hospitals (fuel and electricity) in developing countries is estimated to constitute about 5% of the overall budget, although it can reach 10%.

By implementing adequate measures to monitor energy use, coupled with some changes in equipment and process management, not only could medical equipment availability be improved but energy use could also be drastically reduced, leading to major savings for the hospitals. In regard to the socio-institutional factors, multiple causes have been identified that contribute to the current deficiencies, but they also show potential for developing novel solutions.

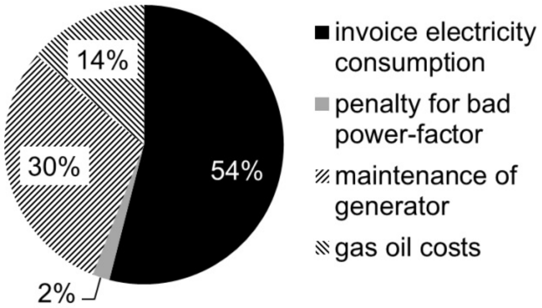

Fig. 6.5 Distribution of the annual energy budget (27,000 Swiss francs (CHF))

However, such changes are often difficult to implement because they go against the established organizational structure and culture. As mentioned, technical issues are often considered to be secondary by the top management, and (unqualified) technical staff is minimized. Furthermore, the technicians often seem disconnected from the rest of the hospital team, including the administrative staff. Therefore, their sphere of influence is highly limited and they lack the capacity to make appropriate decisions and to implement new routines and processes regarding the use of a hospital's electric installation. Furthermore, the absence of an incentive scheme and of clear responsibility regarding energy use and installation maintenance is also valid for the entire administrative and medical staff. This leads to situations in which no organizational member feels responsible for the problem and, if one does, this person often lacks the capacity and authority to tackle the issue effectively. More broadly, the regional culture encourages people to avoid intervening in issues that they are not fully sure how to solve to avoid being held responsible for the problem. Finally, fatalism prevents pro-active "insurrection" against specific dramatic problems, a rage that sometimes provides motivation to find new and innovative solutions.

In the broader context of a hospital, preliminary studies suggest that the government is willing to support small and medium-sized enterprises (SMEs) and new initiatives—a factor that might be relevant to the potential solutions that will be discussed in Sect. 6.4.1.2. It is also noteworthy that patients often pay for additional services in hospitals—a point that might open an avenue for additional revenues in relation to additional comfort-related electricity consumption (e.g., the use of light for comfort or the use of televisions in the patient rooms).

6.3.3 The Complex Problem Tree of Electricity Supply Instability within Hospitals

6.3.3.1 Causes

Figure 6.6 presents the problem tree resulting from the studies, brainstorming, and focus group. It shows that the core problem is the non-satisfactory coverage of electric power needs. While the different boxes of the figure have been addressed in the previous sections, a few important points regarding their interconnections deserve attention at this stage. First, there are some specific technological problems that need to be addressed regarding the conception and installation of electric equipment to ensure that the electricity supply is sufficient in terms of quantity and quality.

However, the second observation is that there are various socio-institutional and managerial factors that lead to an unsatisfactory energy supply and that interact with the technical dimensions. Among others, the absence of strategic planning regarding the importance of the various devices and the possibility to connect them simultaneously to the network compared to the wire and generator capacity seem to play an important role. In the same vein, the absence of clear delegation of responsibility (and the corresponding capacity and authority to act) leads to an inefficient use of energy and to the absence of maintenance planning. In most structures, no plan, routine, or roadmap exists that would guide the medical and administrative staff in the proper manner to use, connect, and switch on/off specific electric devices, especially in times of shortage.

At a more general level, education and vocational training programs for the staff to acquire the required competencies might be lacking. In addition, the prevailing donation logic within many public or private international organizations tends to prevent a systematic reflection about the total electric capacity of the hospital, as well as about the development of incentives regarding the careful and parsimonious use of the devices. This contributes to the overexploitation of the electric capacity, as well as to poor operational management, which regularly leads to the breakdown of the sponsored devices.

6.3.3.2 Consequences

The main problem regarding the electricity supply in Cameroonian district hospitals, identified as non-satisfactory coverage of electric power needs, not only has multiple causes, but it also impacts, in various ways, the processes and performance of the hospitals. For instance, many medical devices (e.g., radiography equipment) can be damaged by electrical instability. Moreover, the lack of light in surgical theatres and patients' rooms makes night work impossible and increases the number of mosquitoes and, hence, the risk of malaria. All these problems, in turn, decrease the quality and reliability of the services provided by hospitals. They might also discourage people from seeking medical help before their injury or illness becomes too severe to be treated (Fig. 6.7).

In addition, the non-satisfactory coverage of electric power needs might lead to tensions among the staff or between staff and patients, resulting in reduced motivation and, hence, lower quality of the services provided. Finally, the inefficient use of energy leads to additional and unnecessary energy expenses—a situation especially problematic in a context in which financial resources are often lacking even for very basic medical care. Combined, these consequences can lead to irremediable medical outcomes for patients and even to the loss of human lives, particularly in operating rooms and neonatal services, as well as the destruction of reagents, vaccines, and blood banks if they cannot be refrigerated properly.

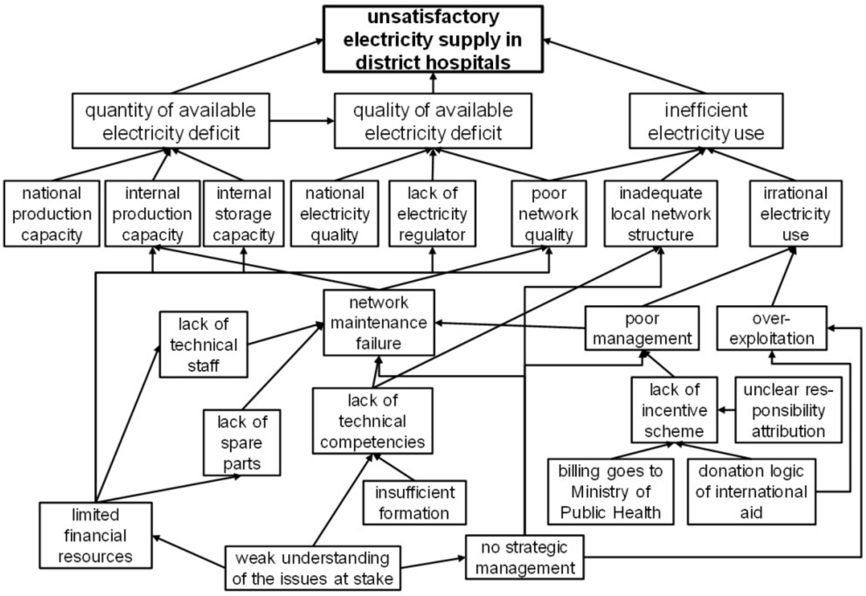

Fig. 6.6 Problem tree of the energy supply in Cameroonian district hospitals: lower part (causes)

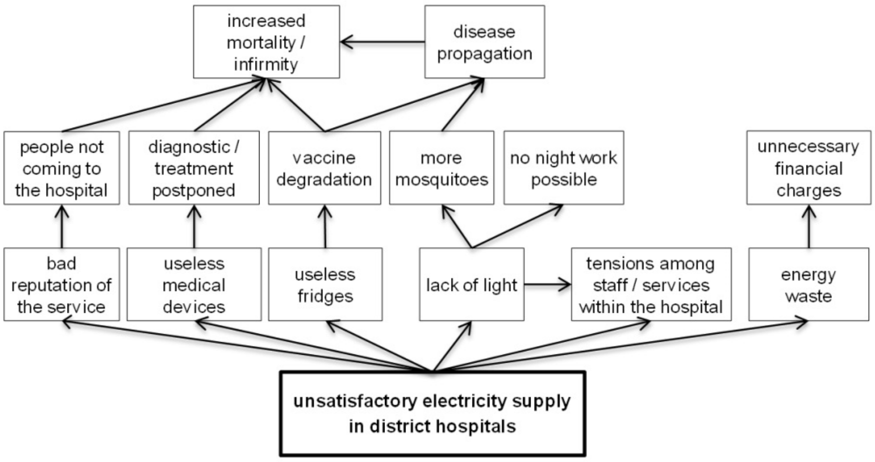

Fig. 6.7 Problem tree of the energy supply in Cameroonian district hospitals: upper part (consequences)

6.4. Analysis and Solutions Perspectives

6.4.1 Core Issues and Potential Solutions

By combining the technical and socio-institutional factors that lead to an unsatisfactory electricity supply in Cameroonian district hospitals, the problem tree developed in Sect. 6.3 offers new insights that point toward new potential solutions. Among others, it highlights that most of the roots also contain factors that relate to managerial and socio-institutional dimensions. Consequently, the solution tree must include both technical and socio-institutional dimensions (see Fig. 6.8).

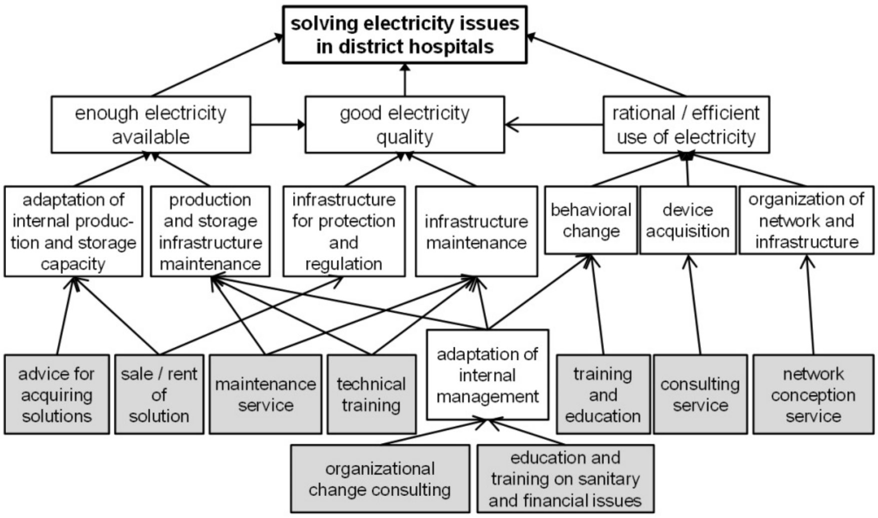

Fig. 6.8 Preliminary solution tree

6.4.1.1 Technical Solution for Adequate Power Backup and Electricity Stabilization

The audit enabled us first to note that the energy supplied at off-peak hours could be stored in accumulator batteries and re-used at peak hours when the energy provided by the grid becomes insufficient. Second, in the case of a power cut, all the hospital loads are supplied by a generator that cover an average of 69% of daily energy needs for the hospital while being overloaded and at the risk of failure. The analysis also revealed that the energy available could be sufficient to ensure the provision of vital services during an entire day if needed—with no overload and risk of failure—in the case of wise energy use. An analysis of the various electricity needs, worked out from a medical perspective developed in collaboration with all heads of services (26 Cameroonian doctors) and Dr. Beat Stoll[3] enabled the identification of three different types of loads:

- *Vital load*. The load in which any interruption can endanger a patient's life (e.g., a respirator);
- *Essential load*. The load in which interruptions make a diagnosis extremely difficult (e.g., in the radiology unit);
- *Useful load.* The non-necessary load in the case of insufficient power (e.g., room ventilation during a hot period).

[3] Dr. Beat Stoll worked for many years in Cameroonian hospitals and is, among others, the Chief Medical Officer of the EssentialMed Foundation (http://www.essentialmed.org).

It is noteworthy that the prioritization of loads must take into account many local socio-cultural aspects. For example, a lamp in a room is perceived differently in an urban zone than in certain rural zones. In one of the rural hospitals audited, some nurses and doctors do not administer care in rooms that have no light. The reason lies in stories of sorcery and malefic spirits that operate in the darkness and which would have been at the origin of certain patient deaths.

After having hierarchically arranged the hospital loads, we computed the daily average distribution of energy needs (Table 6.1, *column 1*) according to each type of load *(column 3*) and the corresponding required power at peak hours (*column 2*). Based on this, we propose to segment loads by linking the various medical needs to specific medical device technologies (*column 4*). We first distinguish between the useful loads, which do not need secured power, and the vital and essential loads that need secured power. Secured power is further subdivided into two subgroups: secured power without interruption (vital and essential loads supplied without interruptions) and secured power that tolerates short interruptions while waiting for the generator to be started (vital and essential loads that tolerate short interruptions). The latter category includes, for instance, medication fridges that are vital, yet have a thermic inertia and can, hence, withstand short power cuts.

Table 6.1 Load segmentation according to the types of medical needs and the types of technologies

Segmentation Based on Type of Medical needs			**Segmentation Based on Type of Medical Device Technologies**	
Column 1	*Column 2*	*Column 3*	*Column 4*	*Column 5*
Average Daily Needs	Peak Power	Type of Load	Peak Power	Group of Segmentation
35%	7.5 KW	Vital	4 KW	**Secured**, *no interruption*
			3.5 KW	**Secured**, small interruption tolerable
47%	12 KW	Essential	1 KW	**Secured**, *no interruption*
			11 KW	**Secured**, small interruption tolerable
18%	6 KW	Useful	6 KW	**Non-secured** power

Considering the daily average need and the average peak power need for each type of load, the power of the generator is sufficient to supply a vital and essential load during an entire day at no overload and risk of failure. However, this excludes the X-ray machine that must have its own power source to avoid overloading the generator. From a technical perspective, we obtained a refined segmentation by conciliating the medical needs according to the load types (*columns 4 and 5*).

The advantage of this solution is that, in the case of a crucial deficit of energy, for example, a lack of fuel, the useful and/or the essential loads can be temporarily switched off. Likewise, since the size of accumulator batteries can be reduced if they supply only the devices that do not tolerate interruptions, our solution foresees to separate the load supply with interruptions from loads that tolerate short interruptions. Furthermore, the solution is designed to protect the secured loads from grid disturbances (overvoltage, voltage drops, and harmonics), to compensate for the short interruption on secured loads without interruptions until the generator is started, and to contribute to reducing fuel consumption of the generator by controlling the automatic starting. The solution (Fig. 6.9) is based on the static technology of uninterruptible power supplies and more precisely on the online topology[4], which has the advantages of being ideal for equipment that is very sensitive to power fluctuations, and as well as being redundant.

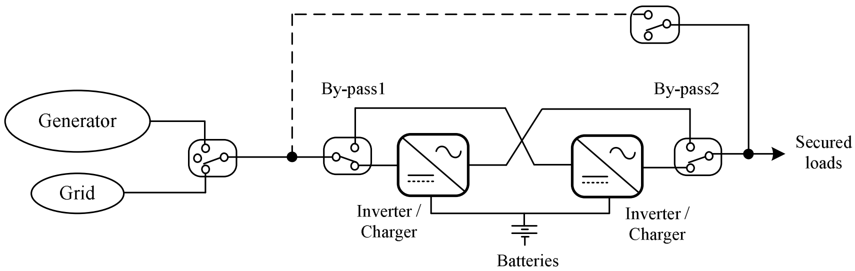

Fig. 6.9 Diagram of the proposed power backup and electricity stabilization

A frequent limitation of the durability of traditional power backup systems is the use of lead acid batteries that have a reduced lifespan in hot environments and/or when used with deep cycles. Therefore, we have chosen the particular technology of nickel–metal hydride batteries (NiMH)[5], which offer a longer lifespan than lead batteries in situations of high discharge, are resistant to temperatures up to 60°C, and do not produce explosive gas.

The suggested solution includes protection against voltage surges and has an estimated lifespan of at least 10 years. The capital costs for all the system components are based on public price quotations obtained from manufacturers, including the typical discount of integrators. These costs are likely to change for the actual system quotes due to many markets factors. Therefore, the costs used in the analysis are indicative. The estimated cost of installation is based on the number of hours of work and hourly cost of a technician in Cameroon. The preventive maintenance of the system can be ensured by a technician in the hospital (after training) with a monthly maintenance budget. The corrective maintenance cost over 10 years should cover the damaged units. Indeed, the two main elements of the system are: the power converters and the batteries. The NiMH batteries that we have selected to realize this system require no maintenance, are more resistant to overload (ARE 2013), and have an estimated

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[4] See e.g., http://en.wikipedia.org/wiki/Uninterruptible_power_supply for an introduction

[5] The specific solution was developed based on work by the "Distributed Electrical System Laboratory" (see http://desl-pwrs.epfl.ch).

lifespan of more than 10 years. Only one of the two power converters is exposed to the disturbances of the network. If we assume that we must replace a damaged power converter during its lifespan, then the replacement cost is estimated as the price of the device and the commission cost is calculated according to the number of intervention hours.

The number and characteristics of the system components are sized according to the total power of the essential equipment that has to be protected. The total power of equipment to be protected depends on each audited hospital and is given in Table 6.2. Table 6.3 details the total cost estimate for 5 KW and ten years exploitation.

Table 6.2 Total power of the equipment to be protected in each hospital

Hospital	Total power equipment to be protected	Total cost over 10 years (investment + exploitation)
District hospital in an urban area	3 KW	CHF 27,500.-
District hospital in an urban area with the help of international actors	4 KW	CHF 37,000.-
Confessional hospital	5 KW	CHF 44,700.-
District hospital in an urban area	5 KW	CHF 44,700.-

Table 6.3 Indicative budget for a typical installation of 5 KW and exploitation over 10 years

Parameters	Hours	Labor Cost (CHF/hour)	Monthly Cost (CHF)	Total Cost Over 10 years (CHF)
Capital costs	///	///	///	32,000
Installation costs	70[a]	8	///	560
Preventive maintenance costs	///	///	50	6,000
Corrective maintenance costs				
Estimated replacement costs	///	///	///	6,000
Costs of commissions	14	10	///	140
Total				**44,700**

[a] 10 days x 7 hours

Compared with the average annual energy bills of the audited hospitals, the suggested solution represents 14% of these costs, including operation and maintenance costs. Indeed, the average annual electricity bill of the hospitals is about 15,000 CHF, and the average annual costs for fuel and maintenance for the generators are about 12,000 CHF. The expenses of installing the suggested solution could be covered by cost savings from energy efficiency and savings measures.

However, while drastically increasing the quality and reliability of the power supply, the proposed technical solution also implies changes regarding the socio-institutional aspects of power management, as discussed in the following section .

6.4.1.2 Elements of Socio-managerial Solutions for Adequate Power Backup and Electricity Stabilization

From a socio-economic perspective, the study points to the importance of adapting specific patterns, job descriptions, management strategies, as well as education and vocational training, to ensure that all the roots of the problem are addressed in concerted ways and to prevent the failure of the implementation of the technical solution due to the non-adaptation of the organizational structures. For instance, the repartition of the devices into three categories, useful, essential, and vital, requires a strategic analysis of the needs and functions of the services, an experienced engineer to design the corresponding electric network, and a skillful deployment of the wires. This, in turn, might require important investments in the education and training of technical as well as managerial and medical staff to evaluate correctly the various needs in the case of an energy breakdown.

Managerial skills are also needed to plan maintenance, fuel stocks, and device replacement. More generally, changes in incentive schemes can contribute to ensuring that all actors contribute to the quality, safety, and reliability of the electric network, both under normal and grid failure conditions. Finally, awareness training might help actors understand the importance of reliable energy and, consequently, of its parsimonious and well-planned use to reduce costs and increase stability. This, in turn, will impact the quality and reliability of the health care services provided.

These changes in institutional and organizational culture are important in regard to the financial feasibility of the deployment of the solution. The proposed solution, as well as its maintenance, costs many tens of thousands of Swiss francs. However, by implementing the structural and cultural changes, much of this money can be recuperated through energy cost savings of up to 20%, as well as through increased “productivity” within the hospitals. In addition, as the solution prevents medical devices from being damaged, the cost of replacement of the medical devices can be drastically reduced. Finally, the solution ensures the continuity of medical care even during grid failure, thereby allowing for additional patients to be treated and for increased staff motivation. These factors, in turn, might lead to increased reputation and additional patients.

From an entrepreneurial perspective, the additional income, combined with adapted training, leads to new opportunities to create service and consulting firms. These might offer services such as the conception, installation, and maintenance of the electrical network, as well as power management and organization change.

From a broader perspective, reflections are needed on the conditions set by international organizations that donate medical devices to hospitals. A more thorough verification of hospital electricity capacity, but also of security devices to protect medical equipment from bad electricity quality—and, if needed, the donation of adapted devices to protect medical equipment—might contribute to increasing the lifespan of these devices, thereby drastically increasing their impact on the quality of hospital medical care.

6.4.2 Limitations and Further Studies

This study represents a preliminary work focused on four district hospitals and involving a limited number of stakeholders. Additional hospital audits and the inclusion of other stakeholders in the discussion of the problem tree and the solution tree might increase the reliability of the results and of the links identified. Measurement campaigns are also needed to gather data on the power supply (power availability and power quality) and electricity need (power consumption dynamic profiles).

Furthermore, while the technical solution sketched out in this article is undergoing preliminary tests, the managerial and socio-institutional aspects need further study regarding the ways the proposed changes can be implemented so that they impact the quality and reliability of the health care services in the long run.

Despite the need for additional confirmatory studies, this article contributes to clarifying the relationship between technical development and managerial challenges in the deployment of solutions for the stabilization of the energy supply in hospitals. As such, it points to innovative solutions to tackle unsatisfactory energy issues in district hospitals connected to the national grid by relating technical issues to specific socio-institutional and managerial aspects of hospital and energy management. It also challenges international aid agencies and non-governmental organizations (NGOs) to ensure that the hospitals receiving medical devices through their agencies have the technical and managerial capacities to ensure the provision of proper electric resources and the maintenance of the devices.

6.5 Conclusion

In Cameroon, the technical specifications of equipment in district hospitals take into account the evolution of technology in the field of hospital equipment and undergo periodic updates (Ministère de la santé public du Cameroun 2004). Taking into account the vulnerability of these medical devices faced to grid disturbances and the unavailability of vital medical devices due to repetitive blackouts and the automatically starting of generators in case of grid voltage drops, the investment in an efficient electricity supply in district hospitals in Cameroon will reduce the unavailability of medical devices by at least 30%. It will compensate for the short interruption in protected equipment until the generator is started, and it will also contribute to reducing the maintenance costs and fuel consumption of generators. All this will lead to increases in production bonuses for the medical staff, and it will improve the quality of care. In contrast to traditional power backup systems that use lead acid batteries, the developed solution uses NiMH batteries, which have the advantage of a longer lifespan in hot and wet climates for applications such as the supply of emergency power in hospitals, which requires many deep cycles. The solution has been tested in the laboratory and is being tested in the field. Considering the results obtained, the solution could significantly improve the quality of the power supply in hospitals. This would improve the quality of care and confidence of patients who often renounce treatment in hospitals because of a lack of functioning equipment.

Compared with the average annual energy bills of the audited hospitals, the suggested solution represents 14% of the electricity, fuel, and maintenance costs. The suggested solution could be financed through costs savings thanks to adequate energy efficiency and savings measures. However, it should be noted that after installing such a system in a district hospital, some changes in institutional and organizational culture are important for proper operation of such an electrical system.

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