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1. Executive Summary

This deliverable describes an application for providing an energy management framework addressing reduction of energy usage and CO2 footprint over the Federal University of Pernambuco (UFPE). A field research was conducted in order to validate if IMPReSS framework's features were capable of mitigating the needs of the University. Such a research resulted in a summary of energy outages and a map of which centres have generator and which have not, and pointed a lack of efficient electrical management infrastructure as well. Provided with this overall knowledge, it was possible to confirm IMPReSS' applicability in some scenarios. The developed application employs then IMPReSS System Development Platform (SDP) modules in order to achieve the aforementioned objectives. For such, scenarios were made in order to clarify how the IMPReSS SDP is being used.

The deliverable is divided as follows. Chapter 1 is this executive summary. Chapter 2 presents an overview of the UFPE. Chapter 3 shows the energy infrastructure of Recife campus. Chapter 4 focuses on the current energy problems, which were discovered by interviewing people in different departments and buildings. Chapter 5 presents some scenarios in which the IMPReSS SDP can help solve those problems. Chapter 6 brings updates on analytics application, proposed in deliverable 8.1 [1]. Finally, the Chapter 7 contains a general discussion and conclusions.

2. The Federal University of Pernambuco (UFPE)

This chapter provides an overview of the Federal University of Pernambuco (UFPE), including information about its campuses, departments and the infrastructure on the Recife campus. Besides that, the historical context and relevance of the University are also elaborated.

2.1. A Bit of History

The Federal University of Pernambuco (UFPE) was founded in 1946, by the name of University of Recife (UR). After 19 years since its foundation, the former UR was promoted as a federal institution in the new system of education that was proposed at the time, bound to Brazil's Ministry of Education. Since then, due to the governmental programs for bringing higher education to the countryside and support for restructuration and expansion of Federal Universities, the UFPE expanded its reach to two more campi, located in towns Vitória de Santo Antão and Caruaru. More recently, between 2005 and 2013, twenty-eight new courses were implemented generating 2.482 new student positions in several different domains of knowledge. The UFPE has grown in a constant rate in the past decade, and is still expanding. As to this day, the UFPE gathers more than 40 thousand people, among professors, administrative staff and students, amounting to a total of 464 research groups.

2.2. Physical Structure

The UFPE, more specifically the Recife campus which is where the demo will take place, entails 40 buildings, including a Rectory, a Convention Centre, an Acoustic Shell, an University Club, an University Restaurant, an University Hospital, 3 Student Housing facilities and 12 academic centres in its in 149 hectares, located in the Várzea neighbourhood.

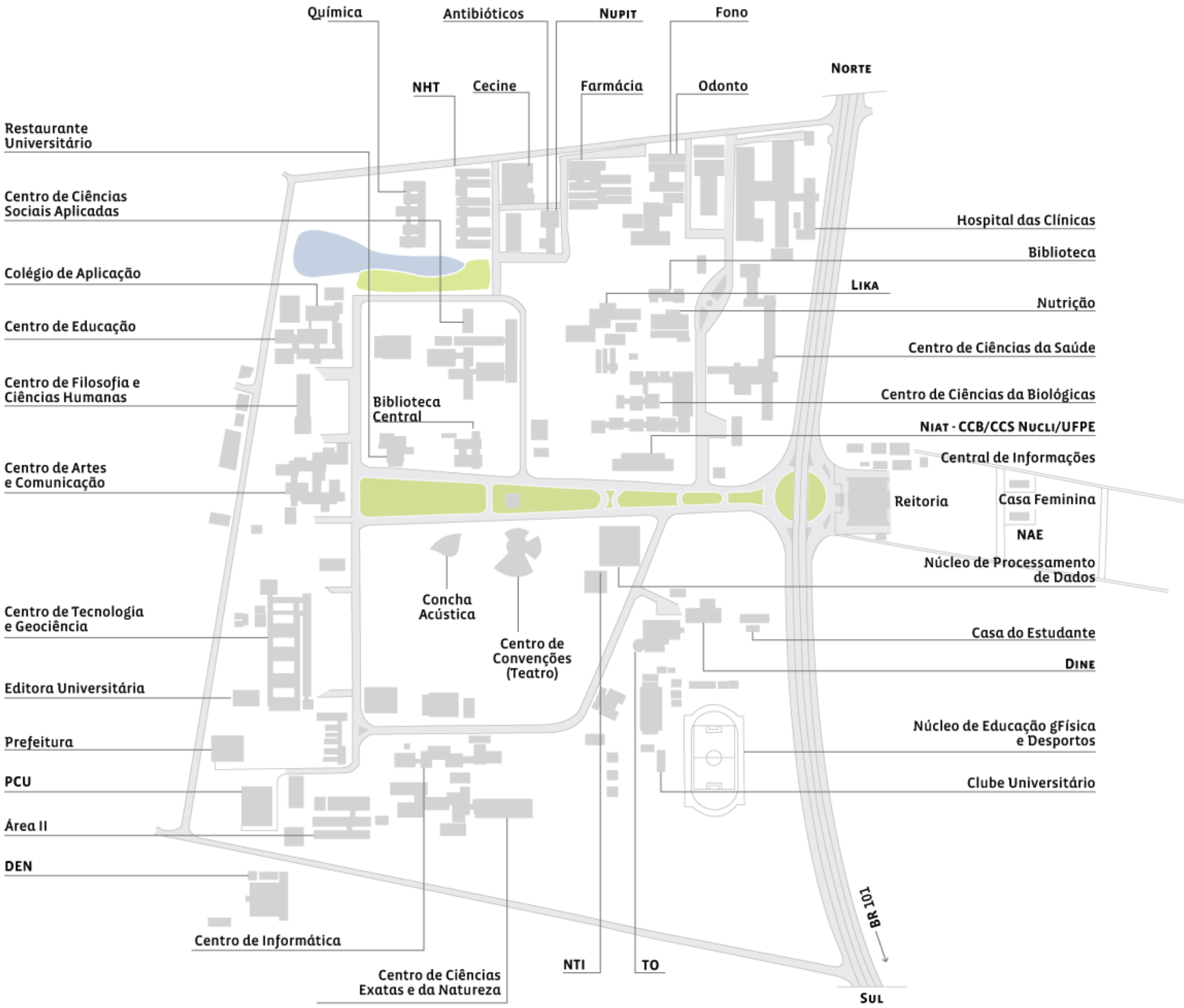

Figure 1. Recife campus of the Federal University of Pernambuco (UFPE).

Of the several buildings depicted in Figure 1, there are the *Restaurante Universitário* (University Restaurant), *Departmento de Engenharia Química* (Department of Chemical Engineering), *Centro de Ciências Sociais Aplicadas* (Centre of Applied Social Sciences), *Centro de Educação* (Centre of Education), *Centro de Filosofia e Ciências Humanas* (Centre of Philosophy and Human Sciences), *Biblioteca Central* (Central Library), *Centro de Artes e Comunicação* (Centre of Arts and Communications), *Centro de Tecnologia e Geociênci*a (Centre of Technology and Earth Sciences), *Editora Universitária* (University Publishing Office), *Prefeitura Universitária* (University Hall), *Centro de Energia Nuclear* (Centre of Nuclear Energy), *Centro de Ciências Exatas e da Natureza* (Centre of Exact and Natural Sciences), *Centro de Informática* (Centre of Informatics), *Núcleo de Educação Física e Desportos* (Nucleus of Physical Education and Sports), *Núcleo de Tecnologia da Informação* (Nucleus of Information Technology), *Reitoria* (Rectory), *Centro de Ciências Biológicas* (Centre of Biological Sciences), *Centro de Ciencias da Saúde* (Centre of Health Sciences), *Departamento de Nutrição* (Department of Nutrition), *Hospital das Clínicas* (University Hospital), *Departamento de Odontologia* (Department of Odontology), NTI (Nucleus of Information Technology) and *Departamento de Farmácia* (Department of Pharmaceutical Sciences). Despite that, differing from the aforementioned buildings, only the Law School is located downtown and therefore is not included in Figure 1.

3. The Energy Infrastructure

This chapter presents a macro view of the energy infrastructure in the Recife campus.

3.1 The Grid

The energy grid within the Recife campus is powered by two sub-stations, maintained by UFPE personnel, being one for each half of the Recife campus. The biggest sub-station amounts to 5 MW and powers buildings such as CIn, CTG and NTI. The other substation amounts to 3 MW and powers buildings such as CCS, CCB and the University Restaurant. One problem that amplifies the effect of power outages in the grid within the Recife campus is the fact that it has a ring topology, so when there is a problem in one of those substations, half of the Recife campus will experience an outage for as long as the problem remains. Also, the ring topology of the grid makes the grid less tolerant to damages in the infrastructure, since there is no redundant paths for the energy to keep flowing.

3.2 Distribution

Celpe, a subsidiary of the Grupo Neo Energia [2] , is the company that provides energy to most of the North-East region, which includes the whole state of Pernambuco and therefore the UFPE too. The distribution within the Recife campus, however, is made by specialised employees. Usually Celpe takes care of distributing energy up to buildings' electric panels, but the Recife campus opted to maintain its own internal energy infrastructure.

4. Problems of Energy Infrastructure

This chapter will focus on current energy problems within the Recife campus. Problems that were discovered by interviewing the university personnel in different departments/buildings.

4.1 Power outages

Power outages are a recurrent problem in the Recife campus as illustrated in [5] and [6]. When they occur, consequences are many. First, the activities of the affected building tend to be disrupted, which is at least an inconvenience. More serious consequences, like damaged equipment or lost research data have also been experienced [7] as will be shown in the next section.

For understanding the frequency and duration of power outages, the campus' mass meter data were analysed. Historical data from the period of 01/01/2015 to 03/11/2015 were extracted in order to identify power outages. The power outages are represented in Table 1.

Date	Start Time	End Time	Duration
24/01/2015	11:18	12:13	55 minutes
06/03/2015	03:31	05:07	1 hour and 36 minutes
09/03/2015	01:19	03:40	2 hours and 21 minutes
25/04/2015	07:31	08:05	34 minutes
25/04/2015	12:55	13:21	26 minutes
15/05/2015	22:37	23:15	38 minutes
06/06/2015	13:32	14:09	37 minutes
17/06/2015	09:42	11:44	2 hours and 2 minutes
17/06/2015	11:19	12:20	59 minutes
14/08/2015	10:14	10:27	13 minutes
02/09/2015	08:20	20:00	11 hours and 40 minutes
12/09/2015	09:28	12:05	3 hours and 37 minutes
26/10/2015	13:05	14:31	1 hours and 26 minutes

Table 1: Power Outages in the UFPE campus.

It is worth mentioning that the aforementioned outages are only the major ones. That is, those that affected the whole Recife campus. As for more local ones, within buildings, there were no way to get a historical of them, since the Recife campus does not have mass meters for individual buildings nor do they track separately local outages. Despite that, as can be seen in Table 1, during 10 months a total of 13 power outages happened, which usually took at least 30 minutes each (just two exceptions).

4.2 Impacts of outages

Interviews were conducted to understand the impacts of power outages over the Recife campus as well as the pain points in different areas. Among the interviewees there were professors, researchers and technicians of the following departments and laboratories: The Fungus Culture Lab, the Ornithology Lab and the Fungus Taxonomy lab of The Centre of Biological Sciences (CCB), the University Hospital (HC), the Drugs Technology Lab, the Pharmacognosy Lab, the Pharmaceutical Development Lab (NUDFAC), the Drugs Quality Control Lab (NCQMC) and the Antibiotics Lab of the Department of Pharmaceutical Sciences, the Department of Odontology, the Group of Electronic Power and Electrical Drives (GEPAE), that is one of the labs of the Electrical Engineering Department in the Centre of Technology and Earth Sciences (CTG). Besides that, technical support people of the Centre of Informatics (CIn) and the Nucleus of Information Technology (NTI) were also interviewed.

4.2.1 Centre of Biological Sciences (CCB)

The three labs that were interviewed in CCB did not have UPSs. As for generators, CCB has only one that is shared with several research groups. However, every research group has a limited number of sockets (i.e. 2 to 3 sockets).

Generally, these sockets are used for ultra-freezers (-80 ºC) and freezers (-20 ºC), since those equipment store biological samples that can be seriously damaged or even lost if exposed at room temperature. Despite that, all three labs have had previous damages due to power outages, especially in the past when there was no generator available in the centre. Also, power outages are both a source of financial losses, due to damages to internal components of expensive equipments, and working hours, due to long time experiments that have to be redone or samples that have to be collected again.

For instance, the mycology lab executes proceedings such as lyophilisation and usage of autoclaves, which cannot be interrupted otherwise those have to be redone. In terms of time, lyophilisation requires 12 hours of work while the use of autoclaves takes 2 hours.

The interviewed researchers on the aforementioned lab reported recurrent cases of weeks of work lost due to power outages. These delays affects the image of the lab in a bad manner, given that it provides services for both the industry and the scientific community, in a national and international level.

When questioned about the priority of equipment, all three research groups stated that ultra-freezers and freezers were the most critical, due to the fact that they serve as storages of samples that would otherwise be lost if not properly refrigerated. And, as a consequence, requiring uncountable hours of work in order to replicate past experiments.

4.2.2 University Hospital (HC)

The hospital uses two UPSs, one of 60 kVA and another of 360 kVA. The UPSs are utilized to power equipment that are necessary for medical procedures, such as ultrasounds, X-ray printers and other equipment of smaller profile.

As for generators, they have three, being them of 5000 kVA, 330 kVA and 150 kVA, respectively. The two more powerful are used to power rooms used for ICUs, neonatal ICUs, haemodialysis, obstetrics, nuclear medicine, sterilization, blood banks, milk banks, etc. While the other generator is used to power the hospital datacentre. Also, especially in cases where UPSs and generators were not available, the hospital had occurrences of broken clinical and general informatics equipment as damages due to power outages.

Finally, the interviewed staff did not know how to specify the priority of equipment, as it would probably change from unit to unit. Besides that, as a service provider, the hospital does not expect any medical domain to be more critical, except when life support equipment are at stake.

4.2.3 Department of Pharmaceutical Sciences (DCFAR)

Five different research groups were interviewed in *DCFAR*. In those, all of them had UPSs. Equipment such as high-performance liquid chromatographs (HPLC), ultraviolet-visible spectroscopy, thermogravimeters, differential scanning calorimeter, infrared spectrometers, ultraviolet-visible chamber, analytical weight scales, gas chromatograph, refrigerated centrifuges, dissolution machine, among others, are usually powered by UPSs.

However, only one of those laboratories have a generator (55 kVA), more specifically the *NUDFAC* group. There, their generator powers equipment that are connected to not only their whole lab, but also a few equipments of other labs.

All interviewed labs have lost equipment and raw materials. Purified substances, which are usually expensive, were also wasted due to the interruption of a continuous process, like centrifugation. Not to mention their own work, which could vary. In both the Pharmacognosy lab and the NCQMC lab, an energy outage stands for a loss of one to two days of work. In the Technology and Medicines lab, researchers reported that they use to lose one day of work in the event of power outages. More critical, however, is the Antibiotics lab's case. Up to now, they have lost lots of experiments due to the lack of refrigeration/interruption of experiments when power outages happen. Redoing experiments there tend to take from 1 week to 3 months. On the hand, the NUDFAC group, did not have a historic of loss work, since they have a generator to avoid major damages. Broken equipment, however, are more common. Recently, for instance, NUDFAC has to replace a broken tube agitator due to energy outages. The other groups also had problems with broken equipment. The Antibiotics lab reported broken refrigerators, weigh scales, surge protectors, and shaker tables. The NCQMC lab mentioned a broken UPS. The Pharmacognosy lab mentioned broken UPSs and a vacuum pump for lyophilizers. The Drugs Technology lab said they had broken equipment in the past, but could not assess if it was due to power outages in order to list them, besides raw material when experiments were interrupted.

Every responsible for those labs listed an order of priority for their equipment. Although some labs have similar equipment, the order of priority is different for each lab. Even though, refrigerators, freezers, ultra-freezers and high-performance liquid chromatographs (HPLC) tend to be the most important ones. For a complete list, separated by research group, check the questionnaires in the appendices.

As in the labs on CCB, research groups in DCFAR do many procedures which cannot be interrupted. Also, pharmaceutical sciences labs use many expensive equipment. A high-performance liquid chromatograph (HPLC), for instance, costs about R$ 200.000,00.

4.2.4 Department of Odontology (CCS)

The department of odontology does not have access to generators. Even though, it possesses ten UPSs, in which equipment such as tomography machines, x-ray machines and computers are connected, it was said that those do not suffice their current necessities.

As for this department, it is noteworthy that they provide services for low-income people, as a means to both help the local community as well as to mentor students with the intent of providing them practical experience.

In terms of losses due to power outages, there were many. From damaged equipment to interrupted odontological procedures, both during hypothetical learning situations as well as during real surgeries. In the last case, which is certainly a serious issue, patients had to be moved to other facilities while others waiting to be attended were sent home. Besides that, it is not rare for research material to be lost and/or classes to be cancelled. Finally, when asked about the priorities of their equipment, they told that when it comes to attending patients, all equipment are equally important, otherwise their capacity as dentists are drastically impaired.

4.2.5 Centre of Technology and Geosciences (CTG)

In CTG, researchers and associates of GEPAE (Group of Power Electronics and Electrical Drives), reported losses of common equipment such as conventional computers. As for lost work, it tend to be a less serious issue when in comparison with health sciences in general. Usual tasks related to measurements and calibration tend to be punctual and not long living processes as common in other areas. That said, priorities for equipments of any sort were not important in the interviewee`s opinion, since equipment are simply turned on, if required for a given task, and subsequently turned off, depending only on the ongoing research what is necessary on a given time.

Also, it is noteworthy that even though GEPAE has no generators or UPSs, they have their own substation, isolated from UFPE`s energy grid, so as to not affect it on an undesirable manner when larger experiments are being carried out.

4.2.6 Centre of Informatics (CIn)

CIn has many UPSs and two generators. Its UPSs power post-graduation labs, professor's room, research groups, partner labs (e.g. Motorola, Samsung), emergency lights and equipment from the auditorium. Also, the servers in the servers' room, are also powered by CIn's UPSs. As for the generators, they feed not only the aforementioned UPSs, but also the air conditioners in the servers' room, three elevators and six classrooms, being the last two in the new building that was inaugurated this year.

Due to the more robust infrastructure of UPSs and generators, when in comparison to other departments/buildings, and the nature of laboratories and experiments that require mainly just computers to work, power outages are not as damaging for CIn, as long as the generators have fuel. As for the priority of equipment, the infrastructure team said that they prioritise areas, not specific equipment. Therefore, research groups, partner labs and servers room, regardless of what they use inside it, are on top of their priority list.

4.2.7 Nucleus of Information Technology (NTI)

NTI has two UPSs and one generator, mainly as the backup energy of the university's data centre. Data centre which is composed of two clusters. One of them entails twenty-nine servers, which are used for hosting services such as an email server, a library management server and SIG@. The latter is a homemade software platform for managing academic information from both students and professors. SIG@ is largely used not only by UFPE, but also by UPE (University of Pernambuco) and UNIVASF (University of Vale do São Francisco) as well. The services for the two other campi of the UFPE are also hosted on the aforementioned cluster. Despite that, the second cluster hosts CENAPAD-PE (National Centre of High Performance Computing of Pernambuco), which is a nationwide initiative to provide high performance computing for Brazilian researchers. In terms of equipment's priority, there is not much to say. Their data centre, as a whole, is of paramount importance, since their provide services for a lot of users both for UFPE as well as other universities.

Finally, it was reported by the interviewees that although they had lost some equipment due to energy outages in the past, NTI possesses in general, likewise CIn, a reliable infrastructure of generators and UPSs that minimizes power outages' impacts on their critical infrastructure.

4.3 Summary

From an overall perspective, the findings obtained within the interviews and the mass meter's data can be summarised as follows:

- While UFPE not rarely suffers from energy outages, its energy infrastructure does not provide proper tools for monitoring and management, turning it difficult to react and prevent equipment damage due to outages
- Research data loss is also a common problem within University's centres, causing delays in local projects deliverables and even abroad services
- Besides machinery and data losses, health centres as the University Hospital and the Odontological Centre suffering from energy outages causes problems directly related to patients health
- University's needs are heterogeneous in matters of importance and priority, both at centre/lab purposes and specific equipment functionalities

Considering these observations, it was possible to identify requirements and use cases in terms of which information to monitor, e.g., energy consumption during generator-powered periods, and what kind of actuation to perform, e.g., orchestrate the powering of devices to avoid energy dips and swells. All these are better described in next chapter, about the UFPE's scenarios.

4. UFPE's Scenarios for IMPReSS SDP

As showed in the previous sections, power outages are a problem in the Recife campus. The power outage statistics, presented in section 4.1, demonstrate that campus-wide outages are not rare. Also, the interviews presented in the Chapter 4 show that many labs do have problems, which amount to much more than just inconvenience. Especially when it came to health sciences in general, which are subjected to long-running experiments and storage constraints, usually in the form of constant refrigeration. Situation that reveals the existence of different criticality levels and therefore deserves special attention. For such, IMPReSS SDP provides built-in support for dealing with mixed-criticality, which can greatly help in the task of assuring the most critical infrastructure are prioritized so as to avoid damages like lost work, raw material and broken equipment.

For such, four scenarios were elaborated in order to exhibit Recife campus use cases for IMPReSS platform. Those scenarios explore IMPReSS capabilities of dealing with power outages from four standpoints: energy efficiency, damage avoidance, data analytics and orchestrated shutdowns.

4.1 Scenario 1

As described in Chapter 4, the impacts of power outages vary per department and/or lab. The departments have also different priorities in terms of equipment' importance in a given context, even when the departments share the same research area. The ones with the highest priority are expected to have energy backup sources. Sometimes less important equipment are also powered by a generator/UPS due to the current layout of the grid. Situation in which heavier loads may increase the amount of fuel usage, since a generator would burn more fuel. In other cases, the criticality of a given equipment could make a good use of a dynamic behaviour. For instance, a user may reconsider criticality levels according to the amount of remaining fuel/energy, which greatly correlates with the available runtime, therefore making a more intelligent use of the generator/UPS capacity. Besides that, fuel consumption can become a major concern. The depletion of oil reserves and rising fuel cost may oblige you to monitor and regulate your fuel usage to at least save you a significant amount of money and perhaps help in the preservation of an eco-friendly environment, therefore allowing the reduction of CO^2 footprint, which is also one of the objectives of Recife campus demonstration.

For achieving this vision, this scenario proposes the use of an orchestrated shutdown mechanism, according to a predefined order. Therefore, reducing the load that the generators/UPSs have to copy with, by shutting down less important electronics over time, and maximising the more important ones' runtime. Likewise, when the energy is back to normal, those electronics that were shutdown should also be turned on in an orderly fashion.

Finally, this scenario is part of the energy management use cases described in D2.1.1. For a better understanding of the scenario, have a look at Figure 5.1. It is composed of four equipment (i.e. a server, an elevator, a coffee machine and a projector) connected to an IMPReSS controller, which is an actuator type IoT Resources that provides means to control (i.e., turn on/off) the equipment. When a power outage happens, the generator would start to work. IMPReSS SDP would then react to this new grid configuration, so as to, for instance, minimise their load by using the aforementioned IMPReSS controllers. The reduction of the load is not however an arbitrary decision, since it depends on what a user finds to be less harmful if unavailable. In Figure 5.2, for instance, both the projector and the coffee maker were turned off, since they are less critical in the given context. The configuration of equipment criticalities and the execution of device-level mixed criticality management during power outages are presented in more detail in the D4.3 - Resource management and access scheduler.

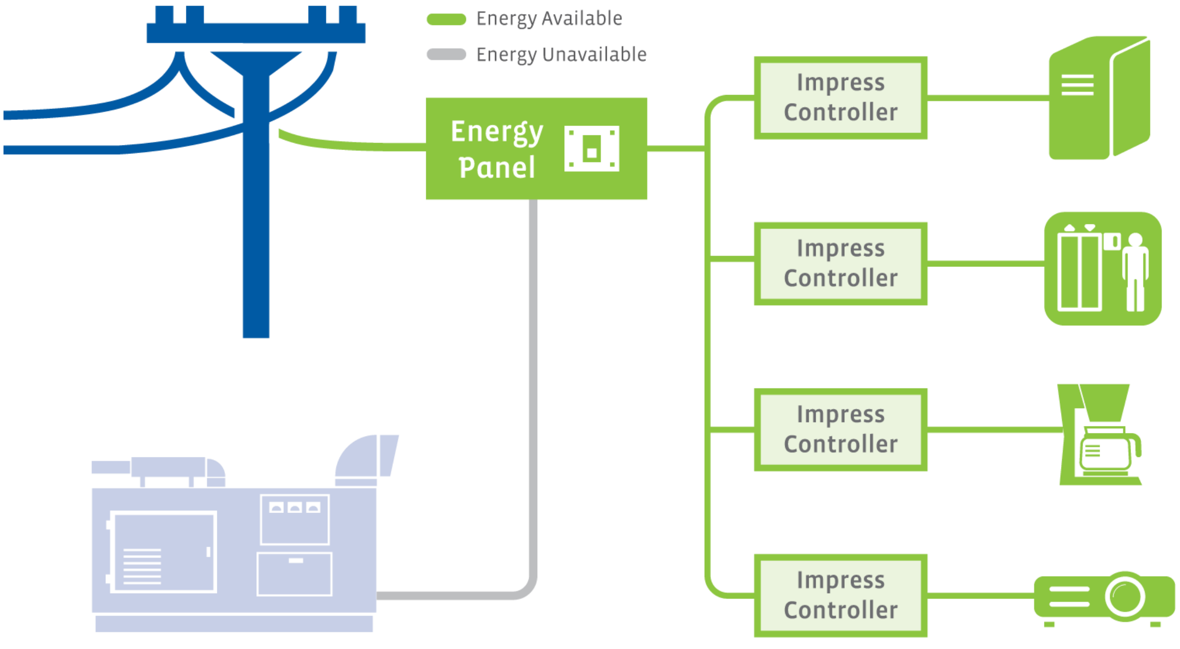

Figure 5.1: The normal operation of the energy grid.

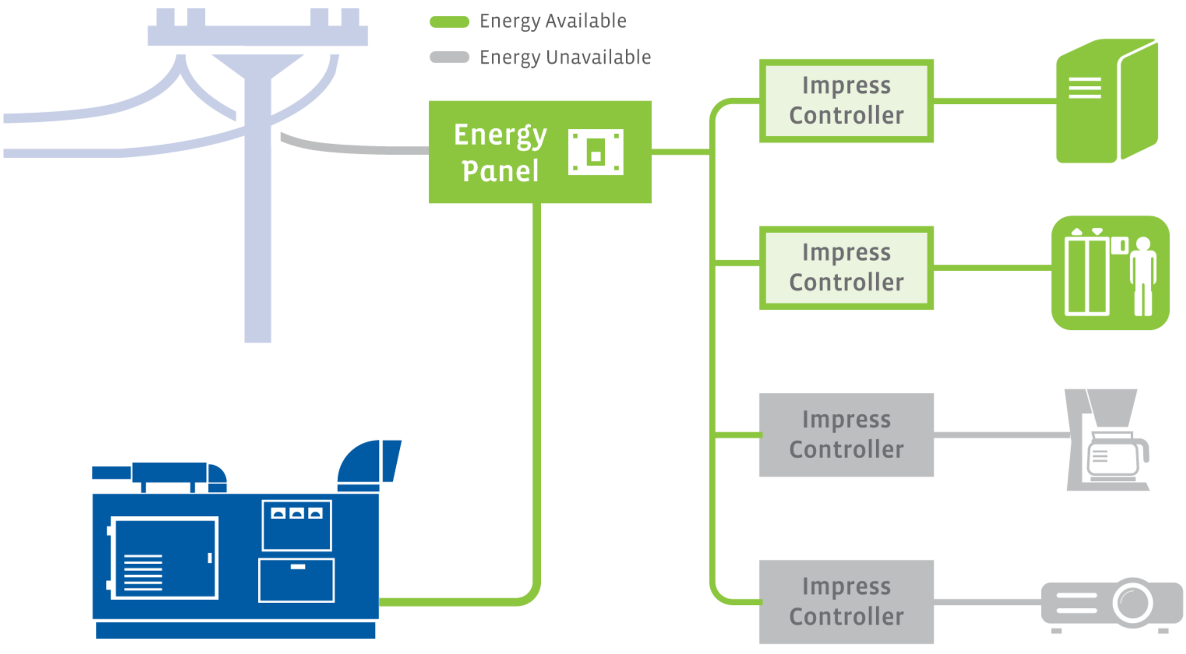

Figure 5.2: IMPReSS SDP shutting down less prioritary devices during a power outage in order to minimise generators/UPSs load.

4.2 Scenario 2

In section 4.2, a discussion on the different energy use cases within the Recife campus and the consequences of power outages was made. Analysing those, it is clear that most laboratories and departments have had some sort of broken equipments due to power outages. Traditionally, UPSs and surge protectors are used in order to protect the most important equipments. In order to minimise possible long-term damages, this scenario plans to mimic part of the behaviour present in UPSs. More specifically, UPSs tend to monitor voltage signals, in real-time, so as to provide its battery energy instead if the grid is experiencing voltage dips and swells that could be harmful. Even though there are no energy storages in this scenario, the ability to wait for the grid to stabilise (e.g. voltage in a safe range) after a power outage is one more layer of protection for equipments in general.

Figures 5.3 to 5.5 should provide a better understanding of this scenario. Figure 5.3 depicts a grid during a power outage with no generator available. When the grid recovers from an outage, it can suffer voltage dips and swells. If the electronics powered by the grid receive these voltage variations directly, they can get seriously damaged. In order to avoid such harm, IMPReSS controllers block the current, as in Figure 5.4, until the grid stabilises again. Figure 5.5 represents the scenario final state.

Finally, this scenario is supposed to work in collaboration with Scenario 1.

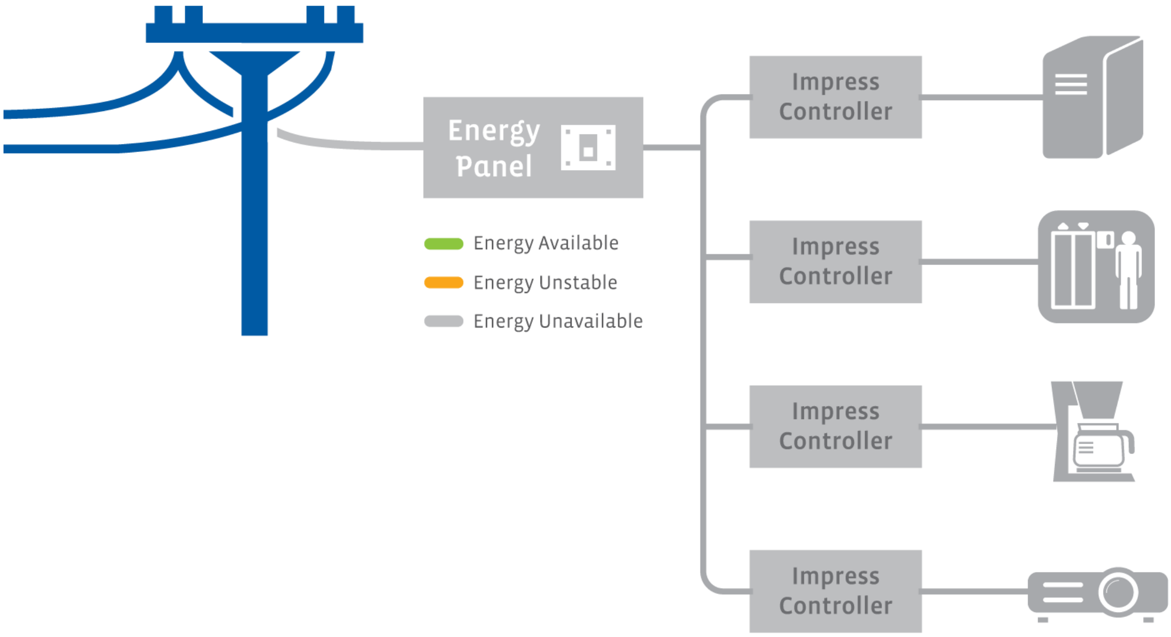

Figure 5.3: Unavailability of energy due to a power outage.

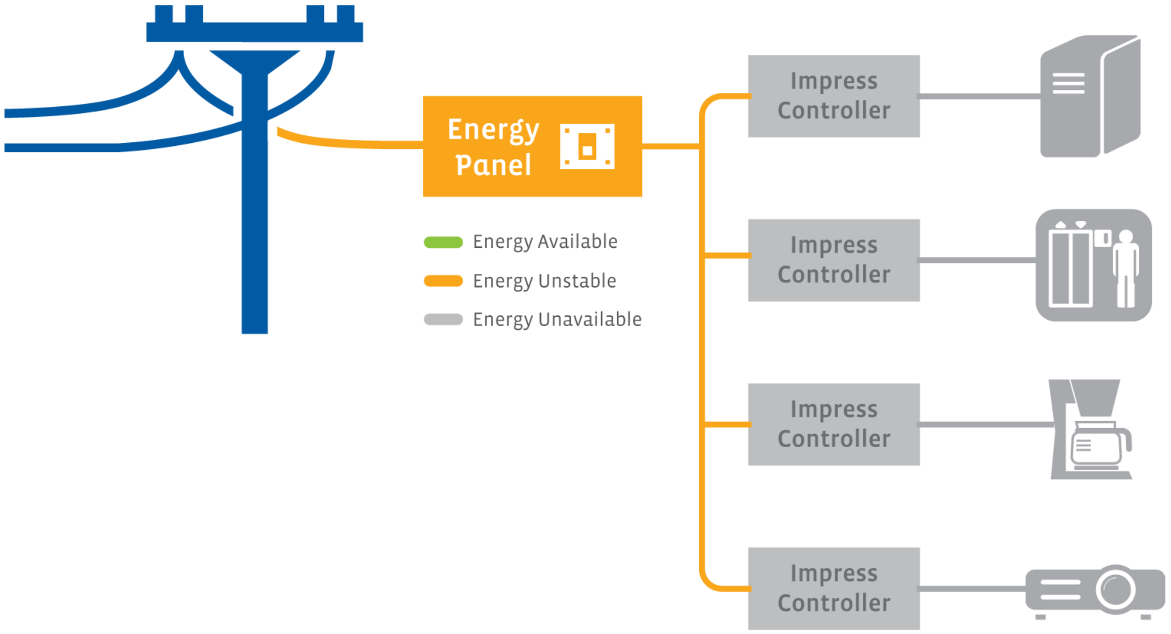

Figure 5.4: IMPReSS Controllers blocking the current flow when energy is available, but unstable (i.e. not in a safe voltage range).

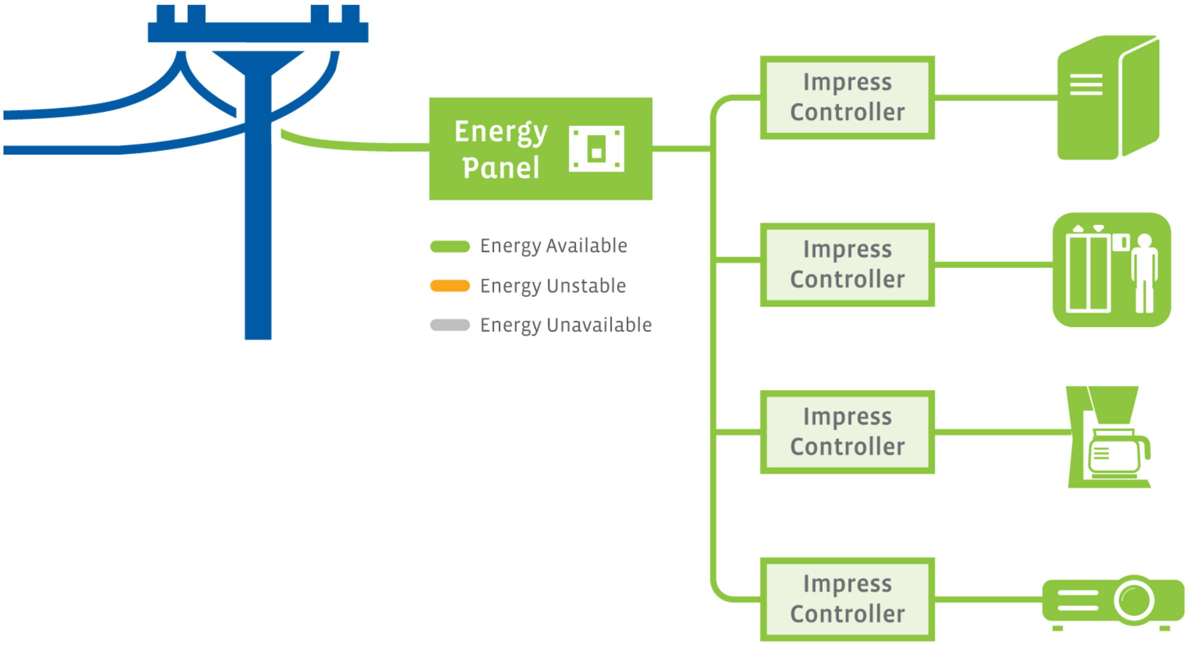

Figure 5.5: IMPReSS Controllers permitting the current flow when energy is stable (i.e. in a safe voltage range).

4.3 Scenario 3

Monitoring a myriad of electronics can be a really difficult problem, especially if those are being measured in a granular fashion (i.e. socket by socket). Excess of data makes it hard for a user to make sense of the bigger picture. On the other hand, even though monitoring less granularly can be a solution, this approach may hide patterns that can be signals of a more serious issue, like current inefficiencies in the energy usage.

For tackling that problem, business analytics tools [3][4] have been employing slicing-and-dicing capabilities, which is the process of breaking information down into smaller parts to examine and understand it, possibly to assemble a new whole that is a function of the many variables available.

One limitation, however, lies in the general purpose focus of business analytics tools. Despite they have the capabilities to allow complex slicing-and-dicing, energy use cases do not require all that flexibility. Also, the domain knowledge of energy use cases cannot be directly mapped into equivalent concepts in those tools. Therefore, requiring users to manage part of it as an out-of-bound knowledge, since equipment' aggregations such as areas and groups are not handled transparently for instance.

Inspired by business analytics tools and on their limitations for energy use cases, an application was proposed in deliverable 8.1 [1] during the very beginning of the project. Since then, many changes were made in order to enhance overall user experience, updates that are covered in chapter 6.

4.4 Scenario 4

Usually, those portraying the Internet of Things (IoT) understand it as a plethora of network-enabled devices that offers interfaces for monitoring and/or actuating purposes. In a sum, any service that is willing to use those devices capabilities will compete for such. In general, monitoring is not much affected by that concurrent access, as the only thing that could happen are race conditions. For actuation, however, a certain degree of orchestration is needed, since different services could require the same device to do contrary actions (e.g. turn on versus turn off). For such, IMPReSS SDP implements novel mechanisms in the IoT panorama, in order to bring mixed-criticality concepts as a solution for concurrent control. This mechanism, called application-level mixed criticality management, is described in more detail in the D4.3.

In scenario four, mixed-criticality capabilities are used to allow three different applications to monitor/actuate available light resources. Those applications are an **energy saver application**, a **GUI for controlling lights** and an **alarm system**. Those are in order of criticality, being the alarm system the most critical application among them. In a situation in which more than one application tries to control the lights at the same time, just the one with the highest criticality level will succeed. So, in a normal operation, the energy saver application will be tackling efficiency concerns, such as turning off lights after work hours. However, if an employee needs to work during the night, he/she can just use the aforementioned GUI application to give a contrary order to what the energy saver app have been enforcing. And since it has a higher criticality level, the lights would be turned on accordingly. Imagine, however, that afterwards the building`s alarm system application detects a fire outbreak. In this case, all the lights, no matter if they were off, would be turned on and start to change colours, as commanded by the alarm system application, in a pattern that warned those inside the building that they should leave as soon as possible.

5. UFPE's Analytics Application

As aforementioned in section 5.3, this chapter presents updates on the UFPE's analytics application, which was proposed in deliverable 8.1 [1]. As a quick reminder, this application aims to provide end users with the ability to make sense of energy consumption trends in a given monitored environment, meeting requirements of the scenario 3, described in the previous chapter.

As part of the application's features, users are able to organize electronics, already integrated with the IMPReSS SDP, in different representations, such as areas, which would then imbue those with a spatial meaning, or groups. Those different representations could then be used to plot past consumption trends or to simulate future consumption. Both capabilities are keys as means to empower users, especially those in charge of maintaining electrical infrastructure, with the real-time data that helps facilitating decision-making and understanding the impact of those decisions in the long run.

In next subsections, some user workflows are described as functions of the domain knowledge (e.g., areas, electronics, and groups) provided by the application. Those subsections are organized as follows: first, the **dashboard**, with an overall view, then **areas**, **electronics**, **groups** and finally **simulations**.

5.1 Dashboard

Figure 6.1: Home dashboard.

Recalling the deliverable 8.1 [1], there were some changes in the application's dashboard. Feedback from users pointed out that it was not that relevant to have a Total Consumption box, thus, it is not present the application anymore. Its removal also provided the electronics box with more space, which is useful since the electronics list is always expected to be the longest. Another minor change is that the configuration button is gone, as well as there was nothing to actually configure in the application so far.

Without further ado, the functionalities found in the dashboard are pretty much the same as described in the deliverable 8.1 [1]: users can see and interact with its areas, groups, electronics, simulations and notifications. In that screen, users are able to interact by ordering, creating, editing and removing domain items (e.g., areas, electronics, groups etc.).

5.2 Areas

User workflows such as creating, editing and removing areas can be performed in the dashboard and in the areas' tab. For creating, editing and removing areas presents dialogs to users, as illustrated in Figure 6.2.

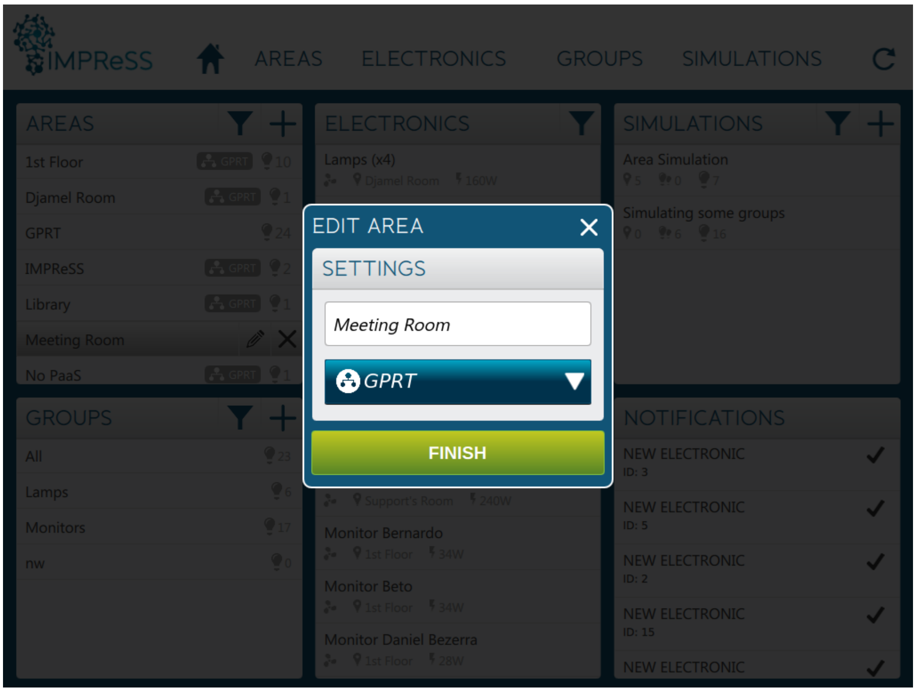

Figure 6.2: Dialog for editing an area

Besides the well-known create, edit and remove actions, in the area tab the user can also filter, in the left box, the list of areas using a text search field, which works based on names of list's items.

It is in the areas tab as well that the user can see which electronics belong to each area, as they are listed in the electronics box. This box has a text search field, like the area box on the left. Below the electronics box it is located a power consumption graph of a selected area. Also, in the areas tab it is possible to select more than one area at the same time, overlapping different graphs. The graph of a selected area is depicted in figure 6.3.

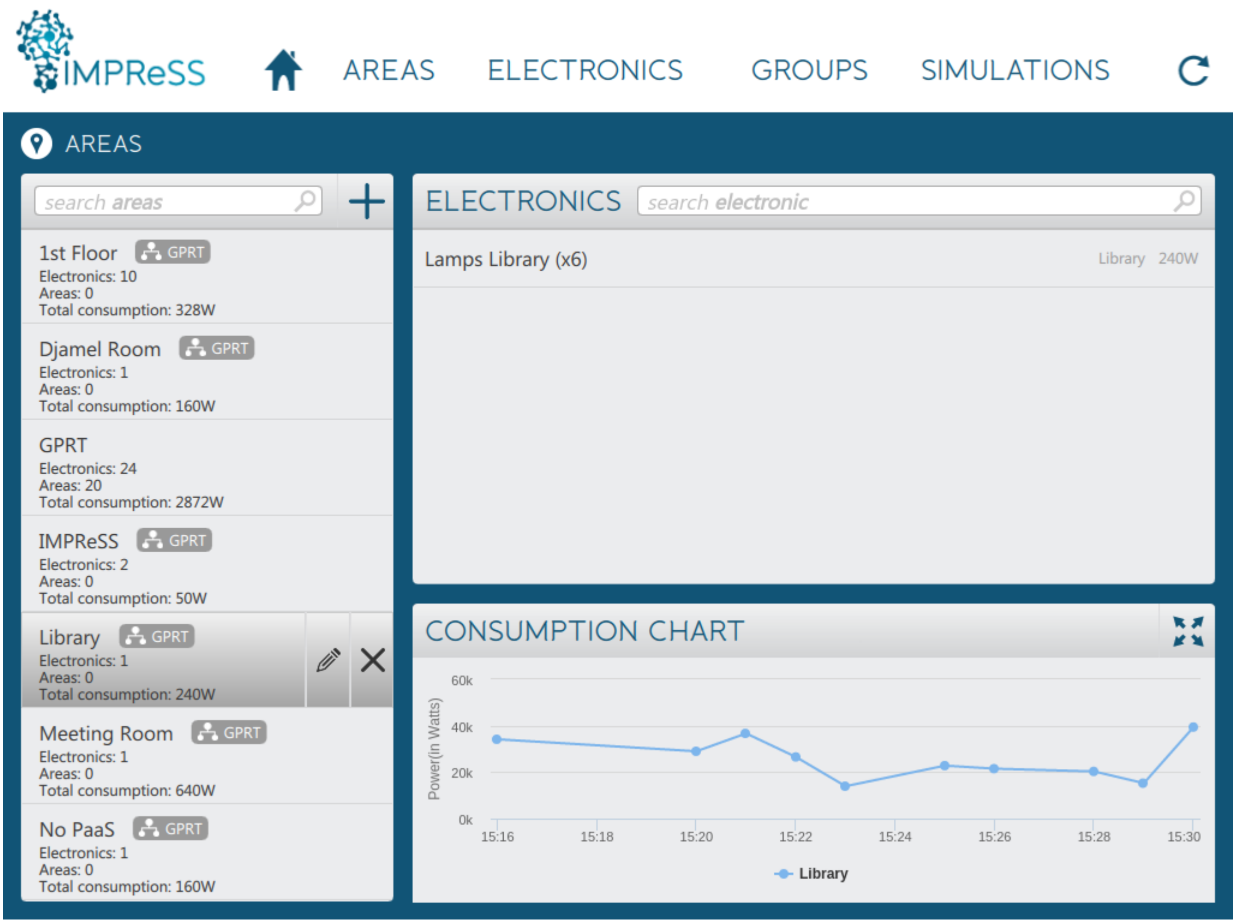

Figure 6.3: A selected area in the Areas Tab.

Still in the graphs topic, there is a feature of every graph shown in the application tabs (areas, electronics, groups and simulations): the expand button provides the user with a bigger graph window, as depicted in Figure 6.4, allowing a better observation of the data and to turn the soft real-time graphic into a static graphic of a moment in the past, by using the calendar button.

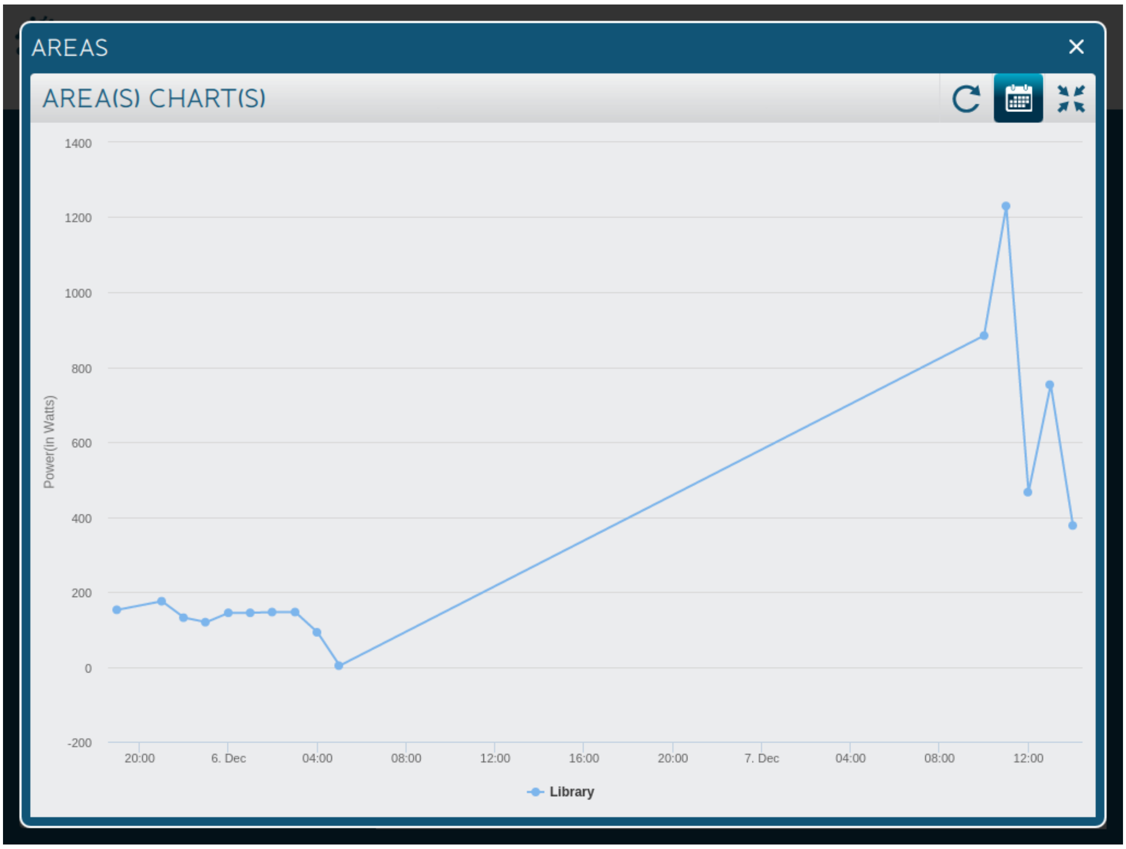

Figure 6.4: Expanded consumption graph of an area, with an active date filter.

5.3 Electronics

Adding a new electronic has a slightly different workflow, and it can only be made at the dashboard. To add a new electronic, the user needs to go through a 'NEW ELECTRONIC' **notification**, in the notifications' box. Once there is this an occurrence of this kind of notification, a user can select it to then configure the new electronic as depicted in Figure 6.5. Editing and removing electronics workflows are similar to the other domains (i.e. areas, groups and simulations).

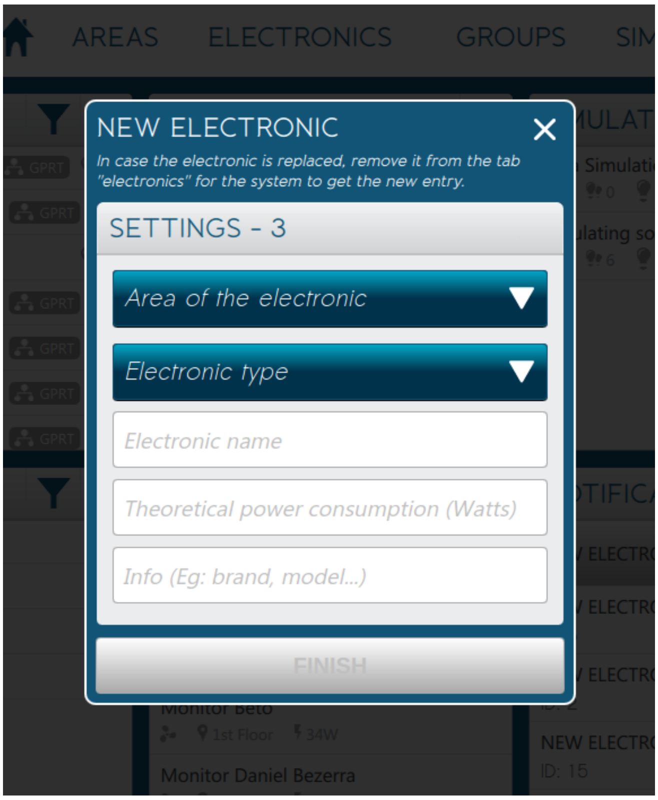

Figure 6.5: New electronic dialog window.

In the Electronics Tab, a user can view its additional information in the technical info box, as illustrated in Figure 6.6. Similarly to other tabs, it has a consumption chart as well.

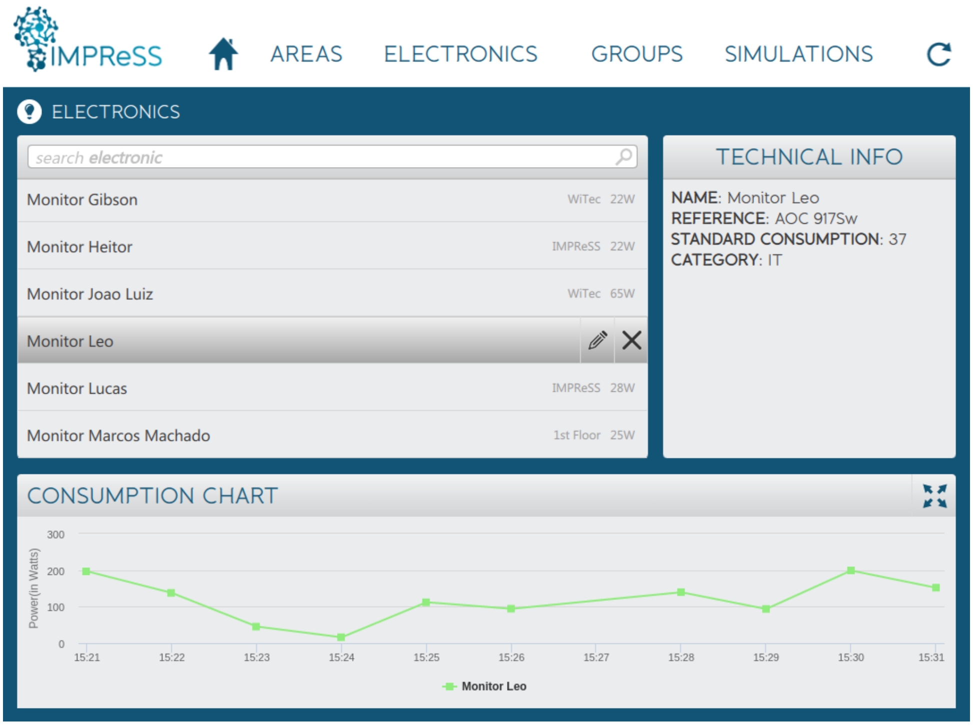

Figure 6.6: Electronics with a selected electronic.

5.4 Groups

Groups and areas have similar workflows. Although, creating or editing a group demands choosing which electronics will compose the group. In the dialog window, the user will see two electronics' lists, depicted in Figure 6.7. The list on the left contains all the electronics existent in the application that are not included in the group yet. The list on the right contains the electronics belonging to the group which is being created or edited. Users can switch electronics from one list to another using add and remove buttons. Also, the check box at the top selects a whole list.

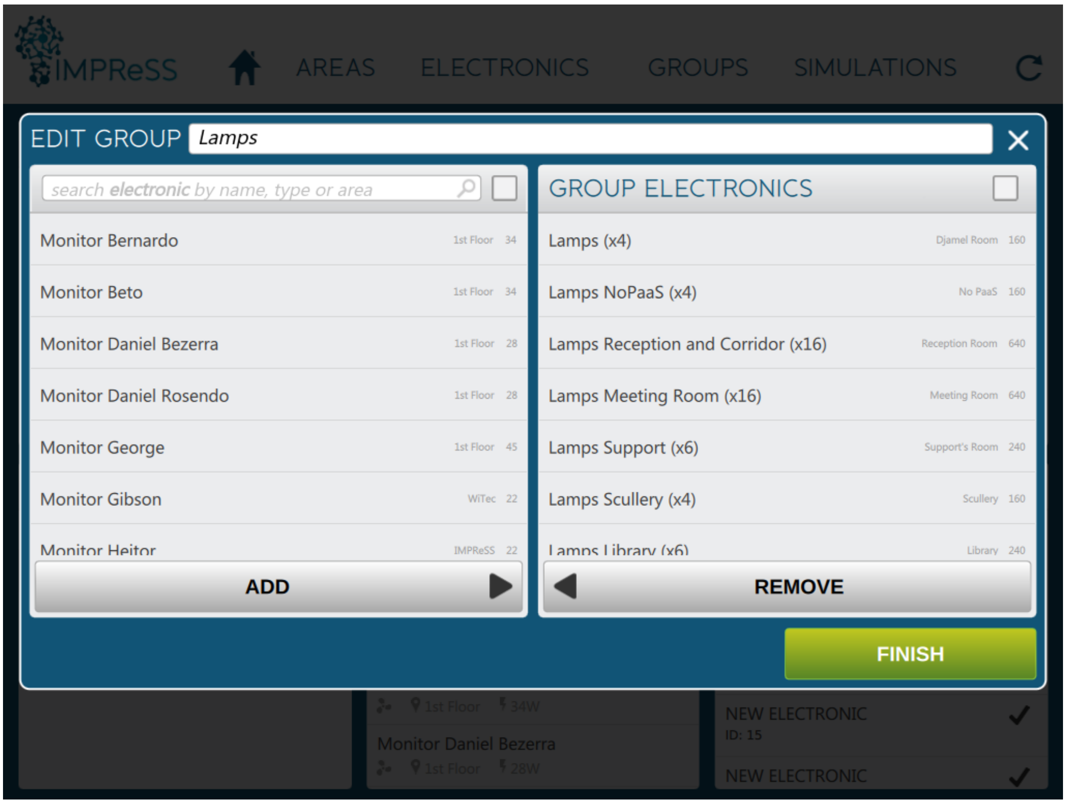

Figure 6.7: Edit group dialog window.

Groups tab has the same features and workflows as the areas tab, and looks equal as well.

5.5 Simulations

There are two types of simulation: areas' simulation and groups' simulation. Before creating a simulation, the user will be prompted by a dialog window to choose one of those types. Independently of the choice, creating and editing both simulation types have the same workflow, and it resembles group creation workflow. Both lists in simulation dialogs are tree views with electronics as leaf nodes, but users can only switch area or group nodes from one list to another. Once an area/group is on the right list, its electronics can be checked or unchecked to be part of the current simulation. Figure 6.8 depicts the dialog for creating an area simulation.

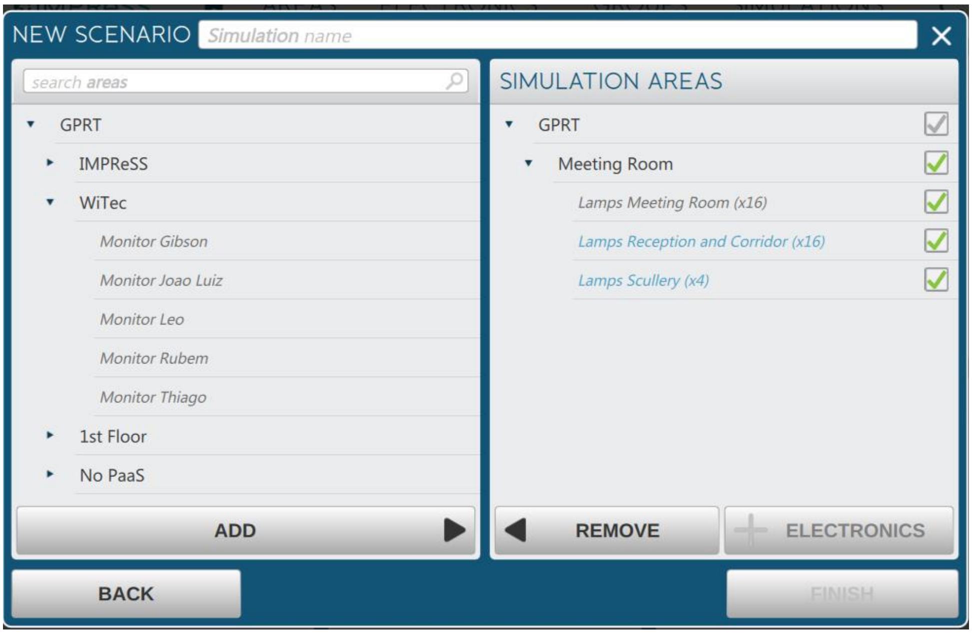

Figure 6.8: Dialog for creating an Area Simulation.

Another particular feature in simulation dialogs is the possibility of adding "fake" electronics, which will exist only in the simulation and allow users to pre-plan for modifications such as electronics arrangement, removal or addition. In other words, it's an useful feature for a scenario in which a user want to know what kind of changes would happen to some area or group's consumption if a set of electronics were added, removed or replaced by another. These "fake" electronics can actually be electronics already registered in the system but that are part of other area/group, or can be freshly created at the moment. To do so, users need to first select the desired area or group, then click on the (now enabled) "+ ELECTRONICS" button and a new dialog will be presented, as depicted in Figure 6.9.

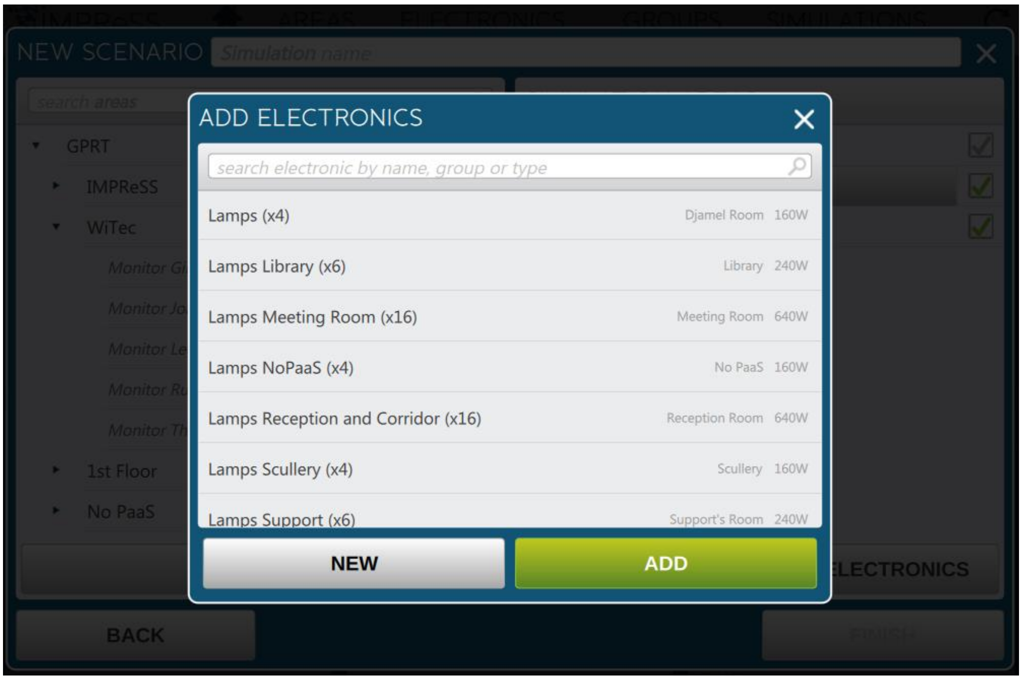

Figure 6.9: Add electronic to simulation dialog window.

In the add electronics dialog there's a list of all electronics. Multiple electronics can be selected at once to create fake copies of them in the simulation. To create a fresh new "fake" electronic, the "NEW" button can be used.

Simulations' tab workflow is similar to electronics' tab workflow, but with a different box arrangement. A list of all simulations is displayed on the left box, selecting a simulation will show detailed information in the technical info box besides a chart similar to the aforementioned ones, as depicted in Figure 6.10.

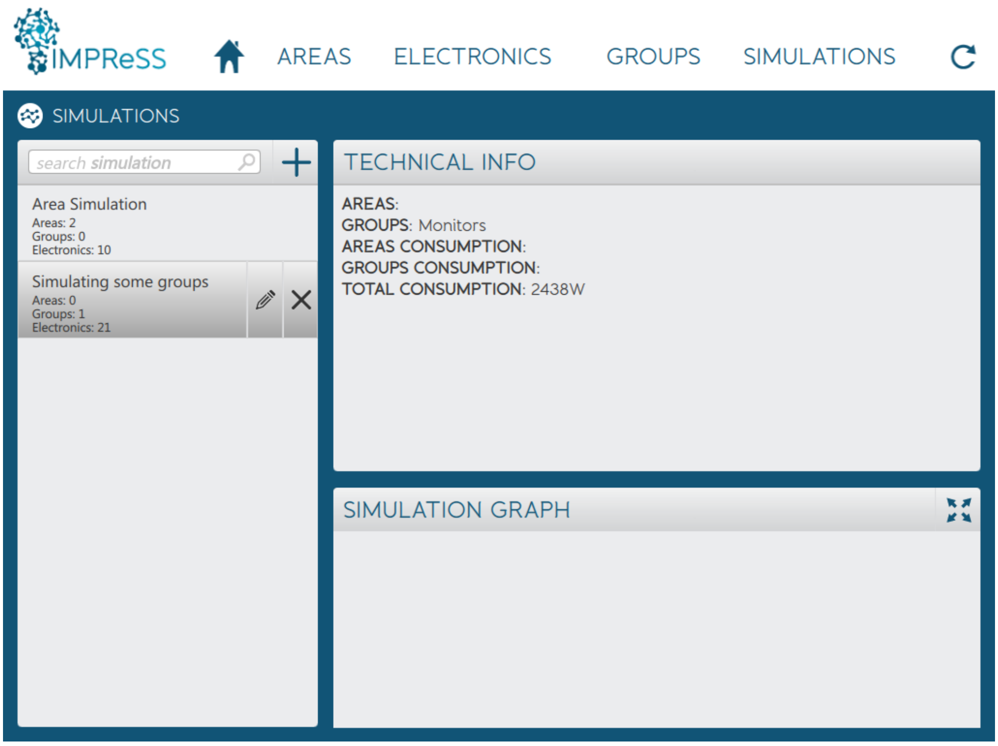

Figure 6.10: Simulations tab with technical info of a highlighted simulation.

7. Conclusion

This document has portrayed the Federal University of Pernambuco (UFPE) from a different perspective, at least when compared to its recent publicity efforts. By collecting data via interviews with staff of different laboratories, a fragile electric infrastructure got in evidence, exposing occurrences of power outages that caused damage and harm to several research labs in different research centres within the Recife campus.

Despite the grid itself being a problem, reasoning on the collected data leads to the conclusion that physical damages and months of lost work could be avoided by employing simple methods for mitigating them, such as waiting for a stable current flow in order to turn electronics on after a power outage or using backup power sources like generators and UPSs. Furthermore, the University lacks a monitoring system which could help the infrastructure staff to make informed decisions and act accordingly. To a certain extent, those are all features that could be provided by the IMPReSS framework, as described by the aforementioned scenarios in section 5. Additionally, given a proper electrical infrastructure based on smart grids, the IMPReSS framework could even allow more powerful use cases, such as routing energy from one building to another.

Finally, by empowering the UFPE and, by extension, other universities with means to analyse consumption data, deal with power outages, instabilities and concurrent criticality conditions, the IMPReSS framework reveals itself as a good fit for addressing the reduction of energy usage and CO_2 footprint, reducing the use of generators. Furthermore, it provides tools for avoiding machinery damage and research losses.

8. References

[1] IMPReSS 8.1 deliverable "Specification of Proof of Concept Applications", 16 March 2014.

[2] http://www.neoenergia.com/Pages/Default.aspx (accessed in 10 December 2015)

[3] http://www.qlik.com/ (accessed in 10 December 2015)

[4] http://www.tableau.com/ (accessed in 10 December 2015)

[5] https://www.ufpe.br/agencia/index.php?option=com_content&view=article&id=47609:reitoria-da-ufpe-suspende-aulas-devido-ao-blecaute&catid=207&Itemid=72 (accessed in 9 December 2015)

[6] http://jconline.ne10.uol.com.br/canal/cidades/geral/noticia/2014/01/16/blecaute-interrompe-aulas-na-ufpe-113661.php (accessed in 12 December 2015)

[7] http://jconline.ne10.uol.com.br/canal/cidades/geral/noticia/2013/06/06/anos-de-pesquisa-na-ufpe-vao-parar-no-lixo-85625.php (accessed in 10 December 2015)

6. Appendix

Questionnaire about energy problems in UFPE

1) Do you have UPSs? How many?

1.1) If so, which equipments are powered by UPSs?

2) Do you have generators? How many?

2.1) If so, which equipments are powered by generators?

3) Did you ever lost any equipment and/or work due to an energy outage in the University?

3.1) If so, can you mention some examples?

3.2) What were the consequences in such cases? Could you estimate the cost (e.g. economic, time) of those?

4) Can you list your equipments by how prioritary to your daily tasks they are?

5) Any additional information related to your energy infrastructure that you would like to share?

Department / Laboratory: Ornithology Lab (CCB)

1. No, we do not have UPSs.
2. There is one generator that is shared with several research groups in CCB. However, every research group have a limited number of sockets (~2-3 sockets).
   - 2.1. As for the equipments which use those sockets that are connected to the generator, they are: a freezer for biological samples (min -20 ºC), an air-conditioner, a dehumidifier.
3. Yes, we had previous damages due to power outages.
   - 3.1. When CCB did not have a generator, any outage in weekends would cause the loss of samples. However, I do not know how to estimate/quantify the damages.
4. Freezers for biological samples, air-conditioners, dehumidifiers, respectively.
5. No, we do not have any extra information to add.

Department / Laboratory: Fungus Culture Lab (CCB)

1. No, we do not have UPSs.
2. There is one generator that is shared with several research groups in CCB. However, every research group have a limited number of sockets (~2-3 sockets).
   - 2.1. As for the equipments which use those sockets that are connected to the generator, there is only an ultrafreezer (- 80 ºC).
3. Yes, we already had previous damages due to power outages.
   - 3.1. In our lab, we do several tasks that cannot be interrupted. For instance, Lyophilized samples, obtained from a process called lyophilization that takes about 12 hours of work. Or even materials, obtained from an autoclaving process that takes about 2 hours of work. Despite that, on average power outages tend to destroy about 5 days of work.
4. Ultrafreezers, lyophilizers, freezers, autoclaves, thermal cyclers, ultracentrifuges, refrigerators, weigh scales, microscopes, air conditioners, respectively.
5. Our lab provide services to the scientific community and to the industry, both locally and in an international level, therefore not losing work is of paramount importance for us to meet our deadlines.

Department / Laboratory: Fungus Taxonomy (CCB)

1. No, we do not have UPSs.
2. There is one generator that is shared with several research groups in CCB. However, every research group have a limited number of sockets (~2-3 sockets).
   2.1. As for the equipments which use those sockets that are connected to the generator, they are: a freezer (-20 ºC) and a ultrafreezer (-80 ºC).
3. Yes, we already had previous damages due to power outages.
   3.1. For instance, we had air conditioners and ultrafreezers that broke due to power outages. Besides that, we also experienced the loss of reagents, when our freezers stopped working.
   3.2. The last time our ultrafreezer broke due to outages, we had to change its compressor (i.e. ~R$ 10.000). As for the loss of reagents, that takes about 2 hours of work.
4. Ultrafreezers, freezers, autoclaves, thermal cyclers, centrifuges, respectively.
5. Our circuit breakers are not able to handle all equipments on at the same time.

Universitary Hospital (HC)

1. Yes, we have 2 three-phased UPSs, being one of 60 KVa and the other 360 KVa.
   1.1. Medical equipments, like ultrasound machines, x-ray machines, etc.
2. Yes, we have 3 generators, which provides 500 KVa, 330 KVa and 150 KVa respectively. The two first generators provides backup mainly to emergency rooms (e.g. illumination, energy sockets). Besides that, they are also used by intensive care units, hemodialysis units, midwifery units, nuclear medicine units, sterilization units, blood banks, breast milk banks, vaccine banks and pharmaceutical units. Besides that, refrigerators are in general powered by those generators too. As for the 150 KVa generator, it is used to power the datacenter of the University Hospital.
3. Yes, we already had previous damages due to power outages.
   3.1. PCs and medical equipments.
   3.2. Cost for replacing/fixing broken equipments.
4. I do not know how to specify priorities, for such you would probably have to ask each unit individually.
5. No, we do not have any extra information to add.

Department / Laboratory: Drugs Technology Lab (DCFAR)

1. Yes, we have UPSs, but I do not know how many.
   1.1. High-performance liquid chromatograph (HLPC), ultraviolet–visible spectroscope, thermogravimeter, differential scanning calorimeter, infrared spectrometer.
2. No, we do not have generators.
3. Yes, we already had previous damages due to power outages.
   3.1. The loss of raw material and unfinished samples, which usually entail 1 day of work. Cost for replacing/fixing broken equipments.
4. High-performance liquid chromatographs (HLPC), thermogravimeters, Differential scanning calorimeters, spray driers, respectively.
5. No, we do not have any extra information to add.

Department / Laboratory: Pharmacognosy Lab (DCFAR)

1. Yes, we have 6 UPSs.
   1.1. 2 Ultraviolet–visible spectroscope, ultraviolet–visible chamber, analytical weigh scales, UV scales, gas chromatograph, high-performance liquid chromatograph (HLPC), PCs, high-performance thin-layer chromatograph.
2. No, we do not have generators.
3. Yes, we already had previous damages due to power outages.
   3.1. In the past we have lost raw material, unfinished samples, purified substances which are expensive. Redoing experiments usually take 1 to 2 days of work. Besides the cost for replacing/fixing broken UPSs and a vacuum pump for lyophilizers.
4. High-performance liquid chromatographs (HLPC) (R$ 200,000.00), Gas chromatographs, spray driers, lyophilizers, respectively.
5. No, we do not have any extra information to add.

Department / Laboratory: Pharmaceutical Development Lab (DCFAR)

1. Yes, we have 1 7.5 KVa UPS.
   1.1. 3 High-performance liquid chromatograph (HLPC), 2 mass spectrometer, ultrafreezer (- 80ºC), refrigerated centrifuge.
2. Yes, we have one 55 KVa generator.
   2.1. The same equipments connected to the UPS plus an air-conditioner.
3. Yes, we already had previous damages due to power outages.
   3.1. Cost for replacing/fixing broken a tube agitator and loss of samples.
4. Mass spectrometers, ultrafreezers, high-performance liquid chromatographs (HLPC), refrigerated centrifuges, respectively.
5. No, we do not have any extra information to add.

Department / Laboratory: Drugs Quality Control Lab (DCFAR)

1. Yes, we have 1 UPS.
   1.1. Spectrophotometer, dissolutor.
2. No, we do not have generators.
3. Yes, we already had previous damages due to power outages.
   3.1. A UP and loss of samples. Usually, we lose 1 to 2 days of work.
4. Spectrophotometer, dissolutor, water distiller, weigh scales, pH meters, respectively.
5. No, we do not have any extra information to add.

Department / Laboratory: Antibiotics Lab (DCFAR)

1. Yes, we have several UPSs.
   1.1. High-performance liquid chromatograph (HLPC), gas chromatograph with mass spectrometer.
2. No, we do not have generators.
3. Yes, we already had several previous damages due to power outages.
   3.1. In the past we had to replace/fix broken refrigerators, weigh scales, surge protectors, shaker table, besides losing lots of experiments due to the lack of refrigeration/interruption of experiments when power outages happen. Redoing experiments tend to take from 1 week to 3 months.
4. Refrigerators, freezers, shaker tables, high-performance liquid chromatographs (HLPC), spectrophotometers, stoves, autoclaves, vacuum pump, thermostatic baths, respectively.
5. No, we do not have any extra information to add.

Department / Laboratory: Odontology (CCS)

1. Yes, we have about 10 UPSs.
   1.1. PCs, tomographs, x-ray machines and other odontological equipments.
2. No, we do not have generators.
3. Yes, we already had several previous damages due to power outages.
   3.1. In the past we already lost research material and had to send patients to other clinics in the middle of a surgery, due to power outages. In terms of work, we tend to have to reschedule patients if a long outage happens.
4. There is no priority for equipments. Or all equipments are working or we cannot attend patients and/or carry on dental surgeries.
5. Our department provides odontology treatments to low-income patients.

Department / Laboratory: Group of Electronic Power and Electrical Drives (CTG)

1. No, we do not have UPSs.
2. No, we do not have generators.
3. Yes, we already had previous damages due to power outages.
   3.1. Cost for replacing/fixing broken PCs and/or surge protectors.
4. There is no priority for equipments. Usually power outages means that our capacity to carry on our research is limited.
5. Some research labs in CTG have their own sub-station, being isolated from the UFPE energy grid.

Department / Laboratory: Centre of Informatics (CIn)

1. Yes, we have several UPSs.
    1.1. Post-graduation labs, professors' rooms, research groups' rooms, partnerships' rooms (e.g. Samsung, Motorola), emergency lights, CIN's auditorium. As for the servers' room, its air conditioners and servers are being powered by our UPSs too.
2. Yes, we have two generators.
    2.1. Post-graduation labs, professors' rooms, research groups' rooms, partnerships' rooms (e.g. Samsung, Motorola), emergency lights, CIN's auditorium. As for the servers' room, its air conditioners and servers. As for the new building, its generator powers 3 elevators and 6 classrooms, excluding air conditioners.
3. Probably, but that is not a frequent issue in terms of lost work, since we already cover all research groups' rooms and partnerships' rooms with our generators.
    3.1. As for broken equipments due to outages, I cannot say for sure. Usually, power outages are more of an inconvenience to the sectors that do not have a backup energy. For our generator-powered infrastructure, usually it is just a matter of buying more diesel.
4. Our priority are research groups' rooms, partnerships' rooms (e.g. Samsung, Motorola) and our servers' room, in general. As for more granular priorities, in a partnership and/or research group, you would probably have to ask each individually.

Department / Laboratory: Nucleus of Information Technology (NTI)

1. Yes, we have two redundant UPSs.
    1.1. Currently, those are used solely to backup up the University's Processing Center. Center which is composed of two clusters. The first one have 29 servers and, among many things, it host the University's webmail, library management system and SIG@, which is our home-made software for managing academic related data (e.g. test scores, students, professors). Besides that, this cluster also provides instances of SIG@ for two other universities: UPE and UNIVASF. UFRPE's SIG@ was once hosted there too, but they preferred to move it to their premises. Also, it is noteworthy that UFPE currently have three campi, being our (i.e. Recife) the bigger one, so services for the others are also hosted in NTI. Despite that, there is also another cluster for CENAPAD-PE (National Center of High Performance Computing of Pernambuco), which offers high performance computing for Brazilian researchers.
2. Yes, we have a generator.
    2.1. The same equipments that were described in the question above plus the air conditioners of the Processing Center's room.
3. Probably, but for broken equipments, I cannot say for sure. Besides that, since other sectors of our building does not have any backup energy, our daily work tend to be limited, but usually that is not a serious issue. For our generator-powered infrastructure, usually it is just a matter of buying more diesel.
4. Our priority are the CENAPAD-PE cluster and the IT services (e.g. SIG@) that we host, since their unavailability affect a lot of users.
5. No, we do not have any extra information to add.