

FACULDADE DE ENGENHARIA DA UNIVERSIDADE DO PORTO



# **Energy Efficiency Management Module**

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# Resumo

Atualmente, e cada vez mais, a gestão de recursos é essencial para a prosperidade das organizações a longo prazo, pertençam as mesmas à indústria, comércio ou serviços públicos. Paralelamente, no paradigma atual, existe uma crescente consciencialização para a questão energética, baseada nas premissas do esgotamento dos combustíveis fósseis, ainda a principal fonte de energia mundial, e na poluição que grande parte das fontes de energia produzem.

Neste contexto, a necessidade de minimização de custos por parte das empresas, associada à crescente legislação e pressão social, leva a que estas necessitem de rever os seus processos e ativos, na perspetiva de encontrar oportunidade de economia na utilização de energia. Adicionalmente, nas organizações em que a fatura energética tem maior expressão, qualquer poupança neste âmbito tem repercussões positivas e imediatas na situação financeira das mesmas. No mercado, existem múltiplos produtos e aplicações de software no âmbito da gestão de energia que permitem, principalmente, a monitorização automatizada dos consumos energéticos.

Em linha com as ideias mencionadas nos parágrafos anteriores, a *International Organization for Standardization* publicou a norma ISO 50001, no conjunto normativo da melhoria contínua e da redução do impacto ambiental, no sentido de proporcionar ferramentas e metodologias para avaliar a oportunidade de poupança no consumo de energia, melhorando a eficiência energética da organização, o que por sua vez se traduz em redução de custos e uma melhoria da reputação da empresa.

Fazendo uso deste documento normativo, e após uma análise extensiva dos requisitos que o mesmo propõe, foi possível a idealização de ferramentas e processos, que implementados num SGE, fornecessem às organizações uma solução integrada para a monitorização de consumos, a análise dos mesmos, a proposta de melhorias para a eficiência energética e a avaliação da implementação dessas melhorias.

Assim, foi proposto um módulo para implementação da norma ISO 50001, integrando-se no SGE buildONE, desenvolvido pela empresa Dreamo. A componente inicial deste módulo, numa fase preparatória, foca-se na gestão das instalações da organização, a gestão e manutenção da infraestrutura, nomeadamente equipamentos e contadores de energia, e na monitorização e comparação de consumos. Posteriormente, e sendo esta a base da implementação da norma, define-se os consumos principais, com maior oportunidade para melhoria, para os quais são concebidos os consumos de referência, através da relação entre consumos passados e a incidência de variáveis externas que influenciam os mesmos. Os consumos de referência funcionam como uma previsão do consumo, com base no valor das variáveis de influência, sobre o qual podem ser calculadas as eventuais poupanças energéticas de uma forma significativamente mais próxima da realidade. Posteriormente, foram implementadas várias das interfaces e funcionalidade propostas, para a aplicação web do SGE, fazendo uso dos softwares Visual Studio 2015 e SQL Server Management Studio 2016, respetivamente, para o desenvolvimento da aplicação web e para o armazenamento de dados.

Na fase final deste projeto de dissertação, a solução desenvolvida foi testada e implementada

no software buildONE, em colaboração com a equipa de desenvolvimento da Dreamo responsável pelo mesmo, o que permitiu a validação dos conceitos propostos, da usabilidade das interfaces concebidas e da importância deste tópico para uma eficaz abordagem à problemática energética.



# Abstract

Nowadays, resource management is being taken into consideration as an essential subject for the long-term prosperity of organizations, either in industry, commerce or public services. At the same time, in the current paradigm, there is an increased awareness towards the importance of seeing energy as a resource that has to be correctly managed, based in the premises of fossil fuels depletion, that are still the main global energy source, and in the inherent pollution that such sources entail.

In this context, the need for cost reduction by companies, associated with the ever-growing legislation and social pressure, leads to the necessity of the organizations' processes and assets revision, in the search for opportunities for energy consumption savings. Additionally, and as the energy bill is a major part of the companies' expenses, any cost reduction in this area has positive and immediate repercussions in their financial situation. Being so, there are currently available products in the market, with broad adoption, namely Energy Management Systems (EMSs), that mainly provide automated monitoring of energy consumptions.

In line with previously mentioned ideas, the International Organization for Standardization published the ISO 50001 standard, comprised in the normative set of continuous improvement and environmental impact reduction, in the effort to provide tools and methodologies for the assessment of savings opportunities in energy consumption, improving the energy efficiency of the organization, that hence translates in cost reduction and a better exterior perception of the company's reputation.

Making use of the normative document, and after the thorough analysis of the requirements it comprises, it was possible the conception of tools and process, that when implemented in an EMS, provide an integrated solution for consumption monitoring, its analysis, the assessment of opportunities for efficiency improvement and the evaluation of the implementation of such opportunities.

Therefore, a module for the implementation of ISO 50001 standard was proposed, to be integrated in the EMS solution buildONE, developed by Dreamo. The initial component of this module, in a planning phase, focuses in the facilities management of the organization, the infrastructure management, namely equipment and energy meters, and the monitoring and benchmark of energetic consumptions. Posteriorly, and translating the core of the ISO 50001 requirements, the main uses of energy are defined, as those higher potential for improvement, for which the baseline consumption are designed, through the relation of historical consumption and influence variables data. The baseline consumption allows an enhanced energy use prediction, based in the current values of the associated influence variables, by the difference between the baseline and actual consumption.

Followingly, several of the proposed interfaces and functionalities were implemented, for further integration in the buildONE web-based application, using two key software programs: Visual Studio 2015 and SQL Server Management Studio 2016, respectively, for the development of web-pages, and the data storage and handling.

In the final stage of this dissertation project, the developed resultant solution was tested and integrated in the buildONE software, in collaboration Dreamo's responsible team, which allowed the validation of the proposed concepts, the usability of the designed interfaces and the evidence of this topic's importance in an effective approach to the current problems of energy consumption and energy efficiency.

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João Almeida



*“Our greatest weakness lies in giving up.  
The most certain way to succeed is always to try just one more time.”*

Thomas A. Edison



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# Abbreviations and Acronyms

EMS	Energy Management System
EU	European Union
ISO	International Organization for Standardization
FEUP	Faculdade de Engenharia da Universidade do Porto
INESC TEC	Instituto de Engenharia de Sistemas e Computadores - Tecnologia e Ciência
KPI	Key Performance Indicator
MSc	Master of Science
EnPI	Energy Performance Indicator
HVAC	Heating, Ventilation and Air Conditioning
PDCA	Plan, Do, Check and Act





# Chapter 1

## Introduction

### 1.1 Context and Motivation

The industrial revolution marked the beginning of a period where the energy demand increased almost exponentially, and its exploitation transitioned from various sources. One could state that the population increase, present through times, and with a relevant acceleration from the mid eighteenth century [12, 13, 14], could be the main reason, and in fact it is a cause, but the energy demand per capita also felt a very pronounced rise [15]. People depend critically on energy, for transportation, businesses, industries, housing and so many other aspects of their lives, and consumption is expected to keep rising by 48%, between 2012 and 2040, with acceleration of natural gas and renewable sources and a steady pace rising of liquid, or fossil, fuels [16].

According to the European Commission, Industry, Commercial and Public Services account for almost 40% of the total energy consumption in the European Union (EU), from which 67% and 30% derive from electricity and fossil fuels respectively and, furthermore, still 48% of the EU electricity production comes from fossil fuels. [17]

As fossil fuels reserves are finite and rapidly exhausting [18] and their extraction and transformation negatively impacts the environment, increased legislation on its usage and on electricity obtained from those sources created the need to significantly reduce energy consumption [19], as alternative energy sources still cannot entirely provide for the current energetic needs. This regulation is not only applied to the production and the higher levels of distribution and consumption, but severely affects the final consumer. Furthermore, Robert Tromop, Head of Energy Efficiency at the International Energy Agency, in an interview to *Diário Económico* (July 18<sup>th</sup>, 2013), reinforced the value of energy efficiency as having the possibility to shift the global economy and allowing for billions of dollars in energy savings [2].

For these reasons, and limiting the scope of analysis to Industry, Commercial and Public Services sectors, for the purpose of this dissertation, these are investing in Energy Management Systems (EMS) [20], that provide information, through data collection and analysis, for decision making, planning and everyday control, in order to save money and make energy consumption more effective and efficient.

These systems are already substantially developed. Multiple solutions exist in the market, which is in constant development and shifting, as it is mainly based in software development, a rather rapid paced area of business. The tendency in the past years, with the introduction of ISO 50001 that defines the necessary processes to adequately identify cost saving opportunities, anomalies in energy consumption and mechanize maintenance procedures, is for the introduction of tools focusing on meeting the necessities of businesses on cost savings and environmental regulations. The main goal of the ISO 50001 is to enhance the significant importance and impact that mechanization of the monitoring process, assessment of improvement opportunities and implementation of action plans have on the continuous improvement of the business performance. The basis for its implementation is a constant and updated assessment of the organization's infrastructure, identifying opportunities through data analysis, definition of feasible goals and the implementation of measures, and its constant evaluation, that ultimately will lead to energy savings.

However, depending on the firm size, management of the different business components often relies on different software solutions that may or may not overlap in some functionalities or even run in different platforms. Besides, many companies still rely heavily on paper or spreadsheets, that are manually updated and handled, which in an era that offers so many possibilities for digital data management seems to be an under exploitation of such technological possibilities.

Thus, the challenge rests in creating a unified platform, capable of aggregating the prevailing EMS functionalities with the rest of the business components management, offering increased integration, value-added services, flexibility and customization, an all-in-one solution.

That is what Dreamo, a spin-off from Faculdade de Engenharia da Universidade do Porto (FEUP) is aiming to do with the joint project 3GEnergy, together with Sistavac, INESC TEC and Sustentepopeia – 2GO OUT Consulting. This project consists of an upgrade from its current software solution for energy management, buildONE [4]. This dissertation project was done in close cooperation with Dreamo, encompassed in the mentioned project.

## 1.2 Objectives

The goal with this MSc dissertation project, by analyzing the ISO 50001 standard, its requirements and procedures, is to idealize and implement these features in a new energy saving module, enclosed in the upgraded version of Dreamo's energy management software buildONE.

The aim is to provide a solution, completely embedded in the existing EMS, using already developed mechanisms for data collection and handling, creating the means for ISO 50001 certification as an alternative for the more complex and arduous procedures that many companies are employing, such as manual data collection, spreadsheets or paper data handling. At the same time, offering all the possibilities for work, communication, document and energy management tools available in the existing buildONE software.

Further specifying the main objective, this dissertation project aims to idealize the necessary features and tools, as infrastructure management of energy-using equipment and meters, calibration and maintenance management of that same equipment, system of categorization based in the equipment's location, main energy uses monitoring, baselines calculation and savings deduction. Being implemented in a larger and more complete solution, it should be prepared for easy integration and recurring updates, as these methodologies are relatively new and the market is in constant shift, as explained in section 1.1.

These tools provide the assessment of improvement opportunities and analysis, project creation and management of its implementation, constantly monitoring energy consumption and energy performance indicators (EnPI) control.

### 1.3 Methodology

The methodology for this project was based on a system engineering approach, in which the distinct phases are identified in the following list, and run almost subsequently:

- Problem definition;
- State of the art analysis;
- Requirements identification;
- Definition of the proposed solution;
- Idealization of interfaces;
- Implementation and integration;
- Testing and validation;
- Documenting and reporting the results.

The first three stages are composed of mainly research and analytical work, focusing in the definition of the objectives for this project, what should it deliver in the end. To do so, it was necessary to check current solutions available in the market, that provide similar tools for businesses. Comparing those with the initial buildONE, the idealized 3GEnergy solution and identifying opportunities for differentiation and complementation, the requirements for the proposed solution were deducted.

The definition of the proposed solution, contemplating those requirements, is defined afterwards, with the data model needed. Alongside, the actual system webpages, functionalities, data presentation and general layout is idealized, followed by an adaptation period to the concrete programming languages and frameworks, such as C#, TypeScript, JavaScript, jQuery and Telerik Kendo UI, either already used in the previous system or chosen for the upgraded buildONE solution.

Due to the limited time for this dissertation, work prioritization was necessarily done. Thus, having the solution designed, focus was shifted to actual implementation of key features for the ISO 50001 module, contemplating location-based labelling of equipment, infrastructure management, identification of the system's main loads with consumption visualization and baseline setting for posterior savings calculation.

Tests and validation, by the Dreamo team working in this same project, were performed alongside the implementation phase, creating a loop of programming, code revision and recognition of further improvements and corrections.

The final stage consisted in the writing of this dissertation, reporting the overall project lifecycle.

## 1.4 Document Structure

The present document comprises six chapters, in line with the methodology stages presented in section 1.3, as they are relatively iterative and this document aims to report them.

In the introductory chapter 1 for this MSc dissertation are presented the reasons for this project and what is expected to obtain with its conclusion. Chapter 2 regards the state of the art research, presenting and explaining the relevant subjects supporting this project and an exposure of similar competitor software.

Through chapters 3 to 5 it is presented the specification of the proposed solution, its main requirements and features, based on the findings from the literature analysis of chapter 2. Also, the actual implementation of parts of the proposed solution are exposed and detailed, followed by the explanation of the testing process and validation.

Lastly, chapter 6 refers to potential future work, that will certainly be developed after this MSc dissertation, in the context of the 3GEnergy project for a new generation of energy management solutions.

# Chapter 2

## State of the Art

### 2.1 Introduction

For the purpose of this MSc dissertation, it is important to introduce some relevant subjects to the field of energy management. The basis of the entire project is an energy management system, that will be introduced firstly, explaining in what it consists, how companies are using them and the evolution of these applications to the current day.

Following, ISO 50001 will be introduced, explaining the relation with EMS, how does it help businesses saving energy and avoiding costs, what are the requirements and how it can be applied through EMS, taking full advantage of these solutions.

Finally, as plenty of EMS solutions already exist on the market, and some offer energy efficiency improvement tools based on ISO 50001, an analysis of this market is presented, focusing on three commercial software: EnergyCAP, eSight Energy and Smarkia.

### 2.2 ISO 50001

#### 2.2.1 Introduction and Reasons for Application

The International Organization for Standardization introduced the ISO 50001 in 2011, as a contribute to a broader solution for the energy problematic, encompassed as the main standard on a series of normative documents about energy efficiency improvement in organizations. Altogether they intend to “help the organization [...] promote transparency [...] promote better energy management practices [...] assessment of the facilities [...] prioritizes the implementation of new technologies” and “introduce improvements on energy consumption that lead to a reduction on the emission of greenhouse gases” [2, p. 32, free translation].

One of the purposes of the standard, presented in the ISO website, is to specify “requirements applicable to energy use and consumption, including measurement, documentation and reporting, design and procurement practices for equipment, systems, processes and personnel that contribute to energy performance” [21]. These requirements, as the definition states, are applicable across

the entire organization, and its processes, whenever the flow, consumption, use or storage of energy occurs.

The ISO 50001 procedures and requirements rest on the Deming cycle methodology (or PDCA – Plan, Do, Check and Act), similarly to the ISO 9001 and ISO 14001, for continuous improvement and environmental focused policies, respectively, easing the integration with these previous standards [22] that many organizations are already complying with, focusing on the improvement of energetic management processes, within an organization and which can be controlled by that organization, consequence of a thorough analysis of the past and present energy consumption, using energy management systems.

According to the ISO [23], the standard's objectives are the following:

- Develop a policy for more efficient use of energy;
- Fix targets and objectives to meet the policy;
- Use data to better understand and make decisions about energy use;
- Measure the results;
- Review how well the policy works;
- Continually improve energy management.

Iolanda Soares [2] identifies the main benefits that arise from the implementation of the standard and that are consequence of meeting the previous goals, which will be listed concisely:

- Employees commitment and instruction throughout the organization;
- Benchmarking and further project prioritization;
- Consistence in the improvements implementation;
- Risk minimization;
- Identification of opportunities for continuous improvement.

Alongside, the same autor [2] infers other incentives, external to the organization, that have influence in the standard's adoption:

- Increase on energy costs;
- Inconsistencies on energy supply;
- Corporation transparency and reputation;
- Stricter legislation and taxation;
- Environmental aspects.

In its many forms, energy is present almost everywhere and used in an incalculable amount of ways, for so many purposes, and its consumption is predicted to keep rising [16]. Measures that directly affect the way it is used have an accumulated impact that one can imagine to be enormous. In fact, the US Energy Information Administration, cited by Iolanda Soares [2], estimates that the impact of this ISO standard in the worldwide energy consumption can be as high as 60%. Specific studies on the impact of the adoption of ISO 50001 have been performed, and McKane, Aimee *et al.* predicted “cumulative primary energy savings between 2011 and 2030 of approximately 105 EJ, delivered cost savings of nearly US \$700 billion (discounted to 2016 net present value), and an associated 6500 Mt of avoided CO2 emissions” [24] with an uptake of 50% in the commercial and industrial sectors. The potential is significant and organizations are realizing it.

### 2.2.2 Methodology

As ISO 9001 and ISO 140001, the methodology behind the construction of ISO 50001 is the Deming cycle, or PDCA cycle. This tool is very used in the field of quality, continuous improvement, lean manufacturing and business management.

The PDCA cycle is an iterative method, where each phase of the cycle is performed subsequently and cyclically. In this context of this project, the ‘Plan’ phase involves the necessary data collection, analysis and decision-making process, enabling the creation of a plan of action that can be implemented in the next stage, in the ‘Do’ phase. This second stage involves all the process of actually performing tasks that were considered to be worth implementing. ‘Monitoring’ the results of the implemented actions is crucial for quality control, and the detection of abnormalities, corrective and preventive actions must be performed in the final ‘Act’ step.

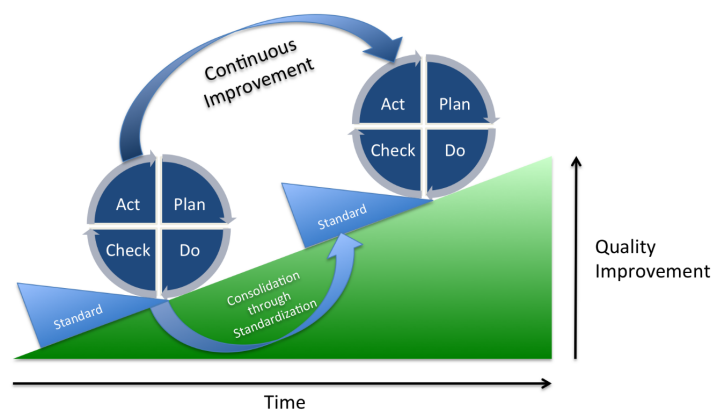


Figure 2.1: Relation between PDCA cycle, continuous improvement and quality improvement. [1]

Associated with this notion, and demonstrated in figure 2.1, standards as ISO 50001 play a vital component in the consolidation of continuous improvement measures, acting as a basis from where further developments can be made. In this context, the successful application of the ISO 50001 standard allows organizations to have a solid ground from where they can further progress

in the matter of energy efficiency, and its inherent consequences of cost saving and environmental protection.

Specific to the norm, the ‘Planning’ phase relates to the energetic assessment that needs to be made, before any action can be implemented. Also, the analysis of the collected data, the prioritization of improvement opportunities, the energy performance indicators and baselines definition, and the actual planning of those improvement projects fall in this planning phase. The ‘Do’ phase relates do the implementation of the action or improvement plans. Further, the EnPIs monitoring translates in the Check phase, whereas the Act phase englobes the continuous improvement that comes from the previous steps as well as the corrections and preventive measures that need to be implemented.

In subsection 2.2.1, the standard’s implementation goals are presented, according to the International Organization for Standardization, which can now be fitted into the PDCA methodology framework, as table 2.1 demonstrates.

Table 2.1: Relation between PDCA cycle and ISO 50001 objectives.

<b>Objectives</b>	
<b>Plan</b>	Energy policy development; Target and objectives definition; Data analysis and decision making.
<b>Do</b>	Energetic policy implementation.
<b>Check</b>	Results measurement and revision.
<b>Act</b>	Continuous improvement.

The implementation and certification conditions, that ultimately will lead to the previous enun-  
ciated objectives, can also be framed in PDCA methodology, as Iolanda Soares [2] aggregates in figure 2.2.

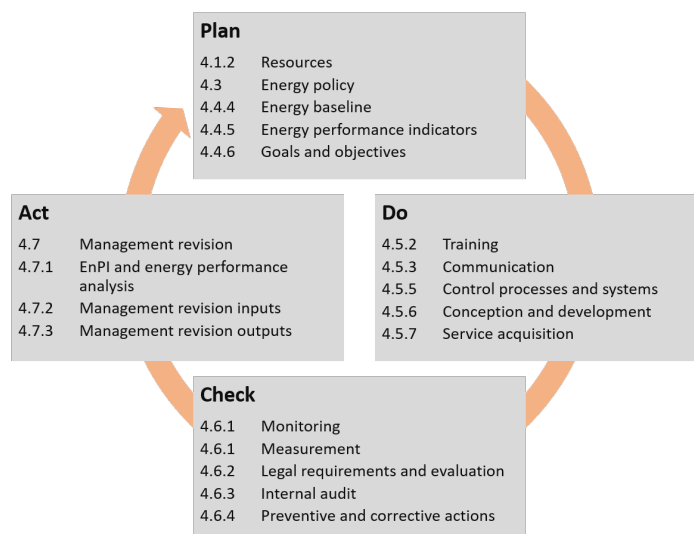


Figure 2.2: ISO 50001 requirements framed in the PDCA cycle. [2]



### 2.2.3 Requirements

The requirements of a standard are the foundation to its application and certification. These comprise the necessary things to implement or to achieve that will eventually lead to a successful application of the standard itself and the fully exploitation of the potential benefits [21].

In total, the number of requisites amounts to more than 40, that can be grouped, according to the standard documentation [3] in main categories presented in table 2.2, once again showing its association with the different iterations of the PDCA cycle. It is possible, by the same logic, to join the standard's official objectives to clearly obtain a picture of the main requirements, the goals and where they fit in the PDCA methodology.

Table 2.2: Relation between ISO 50001 requirements categories, PDCA cycle and the standard's goals.

Section	Requirement Category	PDCA	Objectives
4.1	Overall requirements	Plan	Energy policy development; Target and objectives definition; Data analysis and decision making.
4.2	Management responsibility		
4.3	Energy policy		
4.4	Planning		
4.5	Implementation and operation	Do	Energetic policy implementation.
4.6	Verification	Check	Results measurement and revision.
4.7	Management revision	Act	Continuous improvement.

Moreover, Miguel Lopes [25] in his master's dissertation, identified the main tools necessary to deliver those requirements:

- Ideas management;
- Reporting;
- Data analysis;
- Documentation management;
- Project management;
- Communication management;
- Management control;
- Simulation;
- Knowledge management;
- Consumption monitoring.

In ISO 50001 documentation [3], chapter 4 is dedicated to the thorough exposure of the requirements. Together with the Iolanda Soares' book [2] on energy efficiency, it is possible to

summarize the requirements' main section and additionally check what functionalities, identified previously, should be applied:

#### **Overall requirements (4.1)**

The standard presents the overall requirements, transversal to the rest of the document, stating the importance of the implementation of ISO 50001 documentation, beginning with the formalization of the application scope and what is the necessary methodology to the successful implementation of the requisites [3]. In this section, especially for auditing purposes, the previously mentioned documents should be available and updated.

#### **Management responsibility (4.2)**

Responsibilities and definition of the plan of action for the implementation of ISO 50001 and the EMS must be defined. Documentation should be provided, about the distribution of responsibilities and the accountability of the different actors. Besides, it is the of top management responsibility to create the conditions for the EMS and ISO 50001 employment. Also, major importance is given to raising awareness and training of the human resources.

#### **Energy policy (4.3)**

This requirement is, as 4.1 and 4.2, based on documentation. In the energy policy documentation should be included the context, justification, range of application and major guidelines and goals.

#### **Planning (4.4)**

The standard gives significant relevance to the preparation phase, structuring it in four main areas: energy assessment, reference energy consumption, energy performance indicators and energy efficiency improvement plans, with the flow structured as shown in figure 2.3 from the ISO 50001 documentation [3].

Energy assessment addresses the “identification of improvement opportunities” [3]. In this stage, energy sources are identified, the infrastructure and the energy measurement equipment is assessed to obtain consumptions used in benchmarking. Through the internal benchmark analysis, the main uses of energy can be recognized, as being the most significant consumption values with potential savings opportunity.

For a correct calculation of the energy efficiency improvement, cost avoidance or energy savings, it is acknowledged the importance of correct comparison between current consumption and historical data for a main use of energy. The standard requires the definition of baseline consumptions for main uses, according to the influence variables identified. This provides for a base reference consumption that takes in consideration deviations in external environment that directly affects energy use. For the calculation of the baseline consumption, historical consumption data is normalized by relevant influence variables (previously defined, as temperature, production or

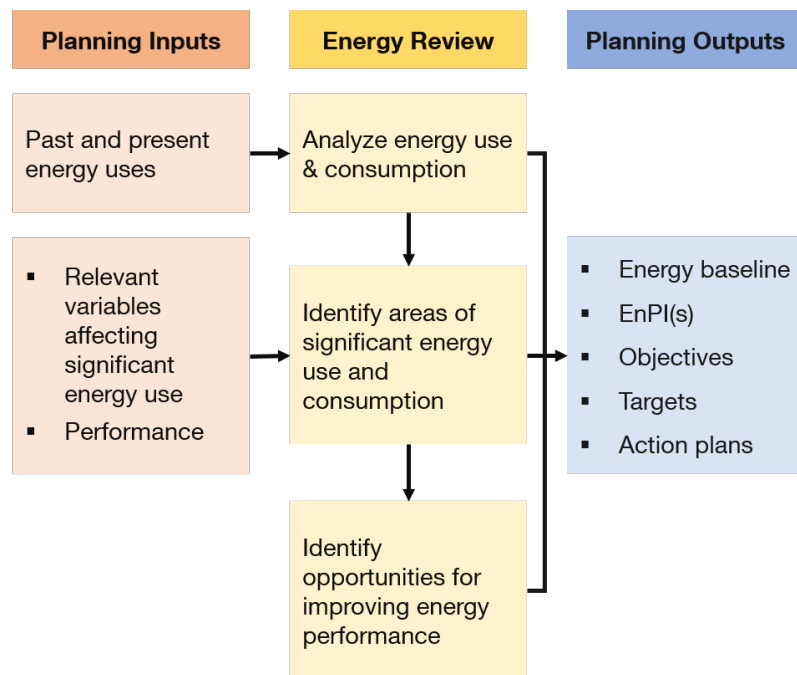


Figure 2.3: Conceptualization of the energy planning process. [3, p.23]

number of visitors, for instance), followed by a method, such as linear regression or manual best fit line, for retrieving the baseline mathematical expression.

Energy performance indicators will serve as the reference for checking the evolution of the consumptions defined as main uses, as Iolanda Soares states: “As energy baseline consumption [...] is the base reference, EnPI should be chosen so that they translate the evolution of that consumption” [2, p. 53, free translation], further indicating examples of those indicators, as energy consumed by unity of production, area, generated energy, visitor or worker, distance travelled or time passed, again, according to the pertinent factors that influence energy efficiency.

Finally, and in the latest step of the energy planning process according to figure 2.3, objectives and action plans must be defined. The standard asserts the necessity of complete documentation of the action plans, comprising the goals to be achieved, deadlines and ways for achieving those goals, designation of the persons accountable and definition of the efficacy measurement of the plan.

#### **Implementation and operation (4.5)**

Fundamental to a successful execution of the action plans, regarding energy efficiency and ISO 50001 application, and clearly stated by the standard, is the focus on the human resources. Training of employees and awareness to the importance of these subjects are critical, not only with the purpose of cost reduction but also for environmental protection and energy saving. Communication of the action plans evolution is fundamental, as well as the documentation, and its availability, update, revision and approval. Regarding infrastructure management, a recurrent and thorough assessment, depending on the organization size, of the facilities, equipment and meters

is specially important for calibration and maintenance plans employment, the relation between energy consumption and the equipment responsible for that consumption and building optimization.

**Verification (4.6)**

Over the period of application of the action plan, there should be a constant monitoring of key variables [3]: energy main uses, influence variables, EnPIs, savings and cost avoidance.

This verification is useful for the detection of non-compliances, to the planned execution, and consequently application of preventive or corrective measures. Previously stated in the 4.5 requirement, of implementation and operation, the plan of maintenance and calibration of equipment and meters must also be monitored and documented regularly, considered as a verification process.

**Management revision (4.7)**

The organization management responsible must perform regular revision of the standard implementation and the EMS, from which, as in requirement 4.6, corrective and preventive actions should result from the finding of non-compliances, errors or deviations.

Miguel Lopes [25], as stated in chapter 2, listed tools needed for the correct employment of the standard’s requirements, and that are also used in other appliances present in a third generation EMS. Table 2.3 shows the relation of the requirement categories with the tools, that will be used in the proposed solution.

Table 2.3: ISO 50001 requirements and employed functionalities.

	Ideas management	Reporting	Data analysis	Documentation management	Project management	Communication management	Management control	Simulation	Knowledge management	Consumption monitoring
4.1 Overall requirements										
4.2 Management responsibility										
4.3 Energy policy										
4.4 Planning										
4.5 Implementation and operation										
4.6 Verification										

Some of these functionalities are already available in buildONE, used in other system modules.

## 2.3 Energy Management Systems

### 2.3.1 First Generation

As introduced in chapter 1, businesses are more conscious of the importance of achieving energy savings, creating a market demand for tools that ease this process and make it more effective. Although enterprises could already be using typical information technological systems, a “real-time energy view of the entire enterprise” was needed to “provide an ability to understand, change, and reinvent business processes to better support energy efficient practices” [26].

Software providers soon began creating what is now known as first-generation energy management systems, where the focus was almost entirely in energy monitoring, retrieving electricity use from different measurement points for basic data presentation and processing.

### 2.3.2 Second Generation

Evolution of these systems, driven by the development of computer-aided tools from information technologies and management solutions, introduced new tools for managers, also shifting focus to an economic perspective of energy management.

Jennifer Hermes states that EMS, in its second generation, are “analytics-based software systems that connect to the BMS [Building Management Systems] and mine the data to identify equipment problems and savings opportunities” or “software systems that capture utility billing data across all facilities in a portfolio and offer analysis aimed at finding billing problems as well as facility benchmarks” [20].

Figure 2.4 gives an illustrative demonstration of the components that first and second EMS generations comprise.

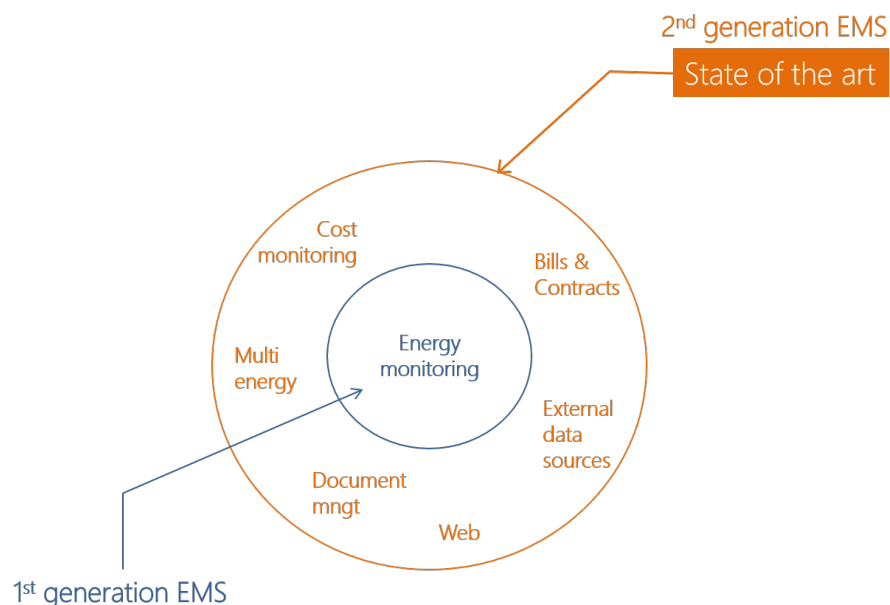


Figure 2.4: Components of first and second generation EMS. [4]

**Cost Monitoring:** the possibility of translation of energy units to currency units highlighted employees consciousness to the importance of energy management, making more evident the need to employ efficiency or cost reduction projects.

**Bill and Contracts:** with the introduction of energy contracts, including the prices of energy for the different time periods, made possible, together with the collected data, to review bills and simulate savings by contract changes on energy supply.

**Multi-energy:** contrary to first generation systems, the ability to manage various energy sources and forms, as gas, electricity or liquid fuels, significantly improved the potential benefits of EMS application.

**Documents Management:** some management software solutions already provided document management tools, as repository, file-sharing, version tracking and permissions. This integration on EMSs avoids the use of additional applications.

**Web-based:** the availability of EMS through web-based application (WBA), making installation and use simpler, gives more comfort and convenience using the solution, for all actors involved.

## 2.4 ISO 50001 Integration with EMS

The energy management system is the mean to employ the norm requirements, where the data is collected, presented, tools are available for analysis, decisions are made and control and monitoring is performed.

Current EMSs, in the defined second generation, do perform several of the tasks required, regarding energy data collection and availability, data presentation and several ways of monitoring consumptions. Further, in the same EMS or in complementary software, other tools are available and currently used, as document, communication and project management within organizations. However, this possible separation of systems isn't necessarily good. By the contrary, for business performance, focusing on the implementation of ISO 50001, it is problem. Whether it is for daily employment of energy saving projects, overall management of the energy policies or external audit, tools should be gathered in a unified solution, for simplicity and practicality.

Even the tools that regard some of the standard's requirements, as current energy monitoring systems, they may not be able to deal with particularities that the standard requires. Some sort of adaptation of the existing systems or complementarity must occur.

Tuning once more to the PDCA cycle, that is the implied framework for the standard, the software should reflect this methodology, clearly distinguishing the various stages for the sake of a successful implementation of the requisites.

A basic roadmap, from the standpoint of the business management, for the ultimate goal of energy saving translated in cost avoidance, is exemplified in this paragraph. EMS systems store and monitor energy consumption throughout the company, using the available measurement tools (as meters or manual input). The classification of the data, either by location, function or other category that suits the business, allows to benchmark consumption, further retrieving the main

energy uses, consequence of an analysis of the most significant consumption equipment and the ones where there is more room for improvement. For these later uses, historical data is essential for the prediction of the future consumption behaviour. Through this data, a baseline can be defined, either by regression analysis, best line fit or manual input, that will serve as the predicted consumptions for the next period. Savings are therefore deducted as the difference between the baseline and the actual consumption. Energy saving projects, resulting from the analysis of the previously mentioned benchmarks, as opportunities from improvement, will be assessed through the savings that they can deliver, as a success measure.

There are a considerable number of solutions currently available that provide modules or tools according to the ISO 50001. In the next section, a selection will be analyzed, not only by their overall EMS functionalities but for the application of the ISO 50001 requirements.

## 2.5 Commercial Solutions

Miguel Lopes [25] detects the main gap in the majority of commercial solutions analyzed in his master thesis as the lack of transversal involvement of the human resources in the actual identification of opportunities for improvement, leading to ideas, action plans and projects in energy savings. ISO 50001 [27] clearly highlights the importance of the commitment of the organization's employees to the concrete execution of the standard's procedures, particularly in the EMS where they are implemented.

In this section, three key commercial solutions, currently available in the market, are analyzed with the presentation of some of their main interfaces. The selection of EnergyCAP, eSight Energy and Smarkia was made taken into consideration the survey made of their functionalities, as they implement, to some degree, the requirements and tool of ISO 50001, and the perceived recognition of these software in the industry.

### 2.5.1 buildONE

The energy management solution from Dreamo, entitled buildONE, is currently undergoing its evolution from the second to the third generation, proposed by the 3GEnergy consortium. Figure 2.4 represents the current state of this application. In the context of this MSc dissertation, under the ISO 50001 subject, the buildONE solution misses the actual implementation of the ISO 50001 functionalities. These were developed thorough this dissertation, and exposed in the following chapters.

### 2.5.2 EnergyCAP

The software developed by EnergyCAP presents automated multi-energy monitoring features, developed primarily for public services, commercial and energy consultants. The product allows for the definition of alarms, dashboard customization, for energy and costs, and the production of automated reports. Great focus is given to the cost avoidance pursuit, using internal benchmarking

of consumption with normalized data, creation of baseline consumptions, mainly with the integration with weather services for the definition of influence variables, and the simulation of outcome scenarios and savings. [28, 29, 30]



Figure 2.5: EnergyCAP energy consumption dashboard. [5]



Figure 2.6: EnergyCAP costs dashboard. [5]





Figure 2.7: EnergyCAP benchmarking dashboard. [6]



Figure 2.8: EnergyCAP cost avoidance interface. [6]

### 2.5.3 eSight Energy

Another EMS that is currently available is eSight. The core of the system is multi-platform energy monitoring, with wide vertical integration (BMS, Scada, installed meters and even manual or excel import), alarm definition and reporting. The software enforces data consumption data monitoring and benchmarking with the features of energy policies creation in the form of projects, with the associated tracking and management tools. These energy policy projects are the ISO 50001 implementation of the solution. [31, 32, 7, 33]

Two main distinctions are the emphasis on personalized and interactive dashboards creation, with eSight Envy, and the geolocation of infrastructure, giving users another way of managing the system through images and maps of the organization.

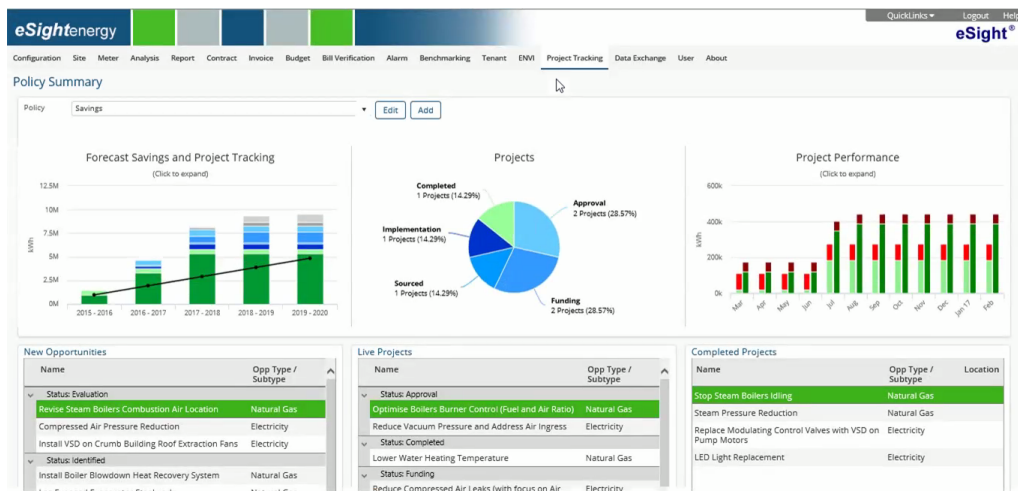


Figure 2.9: eSight Energy customizable dashboard. [7]

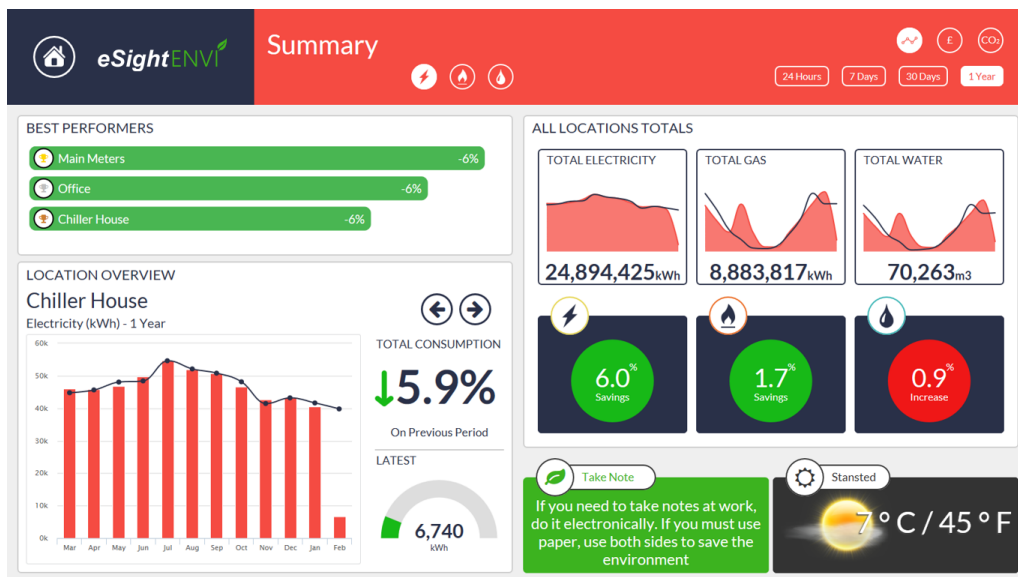


Figure 2.10: eSight Envy personalized dashboard. [7]

### 2.5.4 Smarkia

Smarkia software, as the other reviewed software for public services, commercial and industrial buildings, is multi-energy monitoring, featuring alarms, automated reporting, data export and bill simulation. In their website is stated multi-protocol and manufacturer integration both from standard technologies as “IEC-870, DLMS, MODBUS, M-Bus, PRIME;” and “proprietary: ION from Schneider; SCADA or BMS (building management system)” [9] which demonstrates the possible scalability.

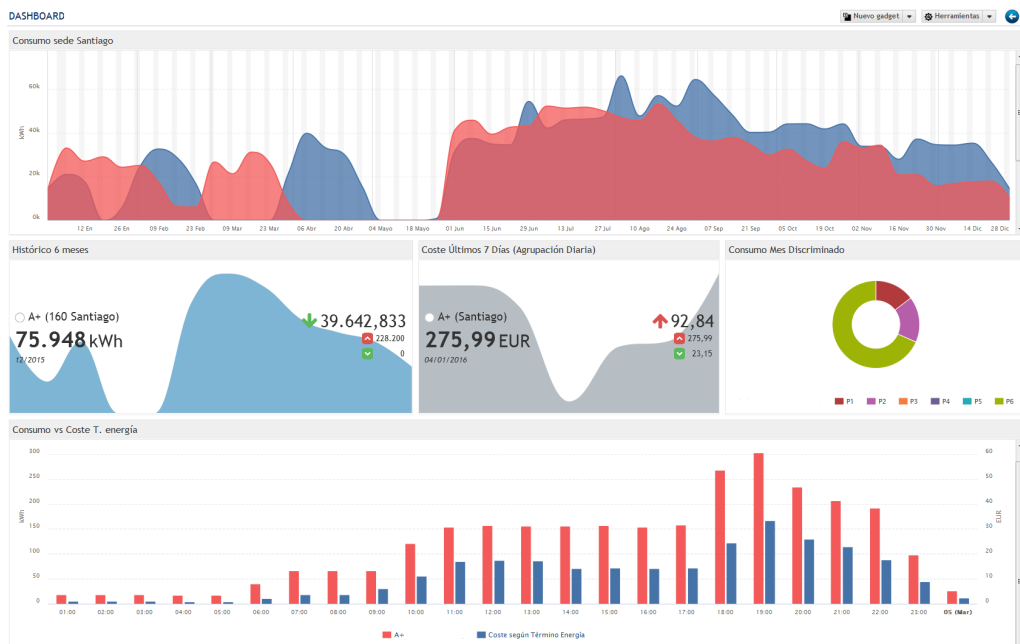


Figure 2.11: Smarkia dashboard interface. [8]

The solution accounts for multi-site organizations managements, with the personalization of dashboards, selecting the relevant data and presentation method, with geographic location management and tooltip glance data [9]. Also, it contemplates documentation management, as archiving mechanisms, versions management and “powerful search engine” [34], and energy flow analysis.

Implementation of the energy efficiency improvement and analysis tools, with ISO 50001 and IPMVP (International Performance Measurement and Verification Protocol), is done by consumption benchmarking, baselines calculation “through advanced calculation algorithms” [34], using influence variables, consumption prediction and later savings calculation and presentation.

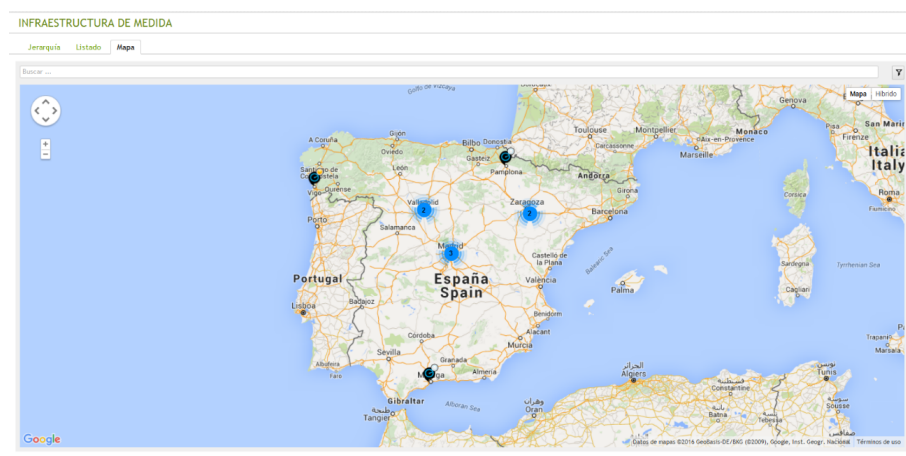


Figure 2.12: Smarkia geolocation. [8]

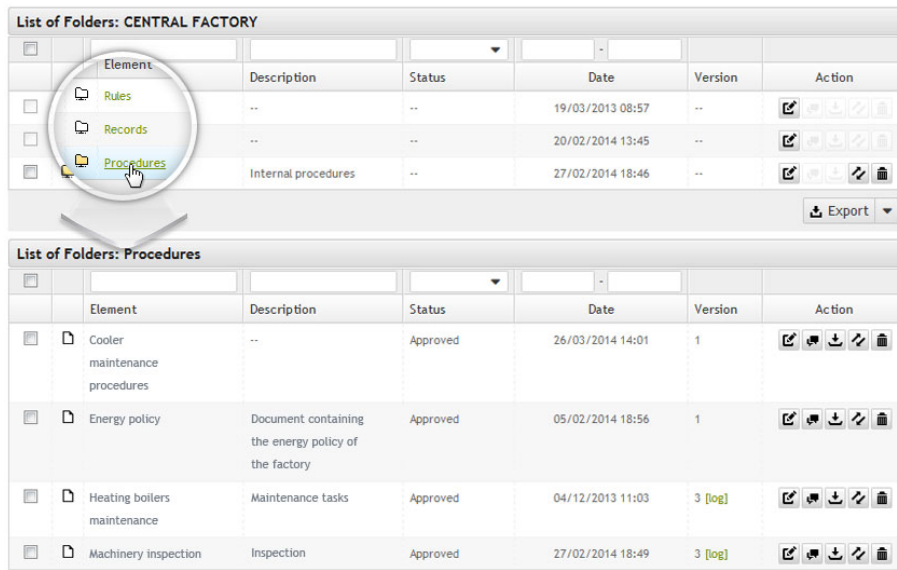


Figure 2.13: Smarkia document management interface. [9]

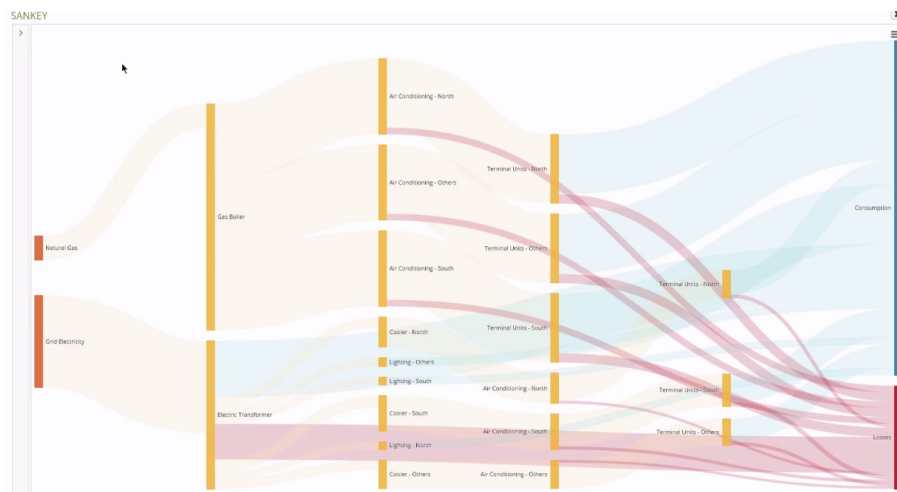


Figure 2.14: Smarkia energy flow analysis interface. [10]

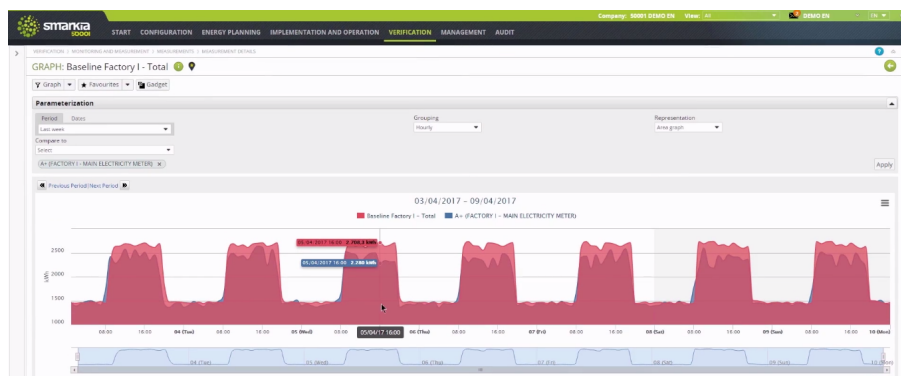


Figure 2.15: Smarkia prediction models interface. [10]

## Chapter 3

# ISO 50001 Module Analysis

Benefiting from the centralization of all energy management procedures in one single system, exploring the vantages of EMSs, ISO 50001 module should be just an additional feature of the EMS, a complement. The design of this system has to be made according to the standard's requirements, and tackling the identified problem, in section 2.5, of the lack of commitment from the organization's human resources, as the standard emphasizes the importance of the human resources interaction with the system, for a successful implementation of ISO 50001. The design of the interfaces and its *modus operandi* directly affects its adoption and use by people. Therefore, creating a solution that is simple to use and install, focusing in features that ease the tasks being performed and presenting interfaces with a clean and organized layout will directly impact the success of the ISO 50001 organization compliance.

The complementarity aspect of additional features that the EMS can provide, besides the required by the standard, is also important for a good adoption of the system and significantly increases the added-value of the solution. Not only supporting tools to the standard but also other features that companies consider positive, such the already mentioned system for categorization based in the infrastructure location and function, the management of infrastructure data in the application, the site manager component, for organizations that have to deal with multiple locations for its facilities, or the integrated baseline design tool, were all result of the real input made by major industrial clients, in the context of the 3GEnergy project, and hence of this MSc dissertation. Further, as this project aims to be implemented in an already existing solution and integrated in the mentioned 3GEnergy project, of innovation on energy management and efficiency tools, the implemented solution must be flexible and framed around the specifications from the team responsible for the "host" solution.

### 3.1 Requirements Analysis for ISO 50001 Module

The idealization of the ISO 50001 module was made in close cooperation with Dreamo's team responsible for the existing energy management solution, buildONE. This conception was done

taken into consideration the previous review of the standard, its requirements, the related functionalities desirable in an EMS, described in subsection 2.2.3, critical discussion with Dreamo team and collection of information provided by the organizations that Dreamo is working with.

### 3.1.1 Functional Requirements

Considering the deliberation of the system necessities, the EMS functional requirements can be organized in the identified system's main components: site manager, infrastructure management, energy monitoring, energy benchmarking, energy flow analysis, ISO 50001 standard presentation, identification of main uses of energy, definition of influence variables, baselines configuration, improvement projects management and energy savings calculation. The system should provide the following functionalities:

- **Site Manager:**

- Presentation of the organization's facilities based on its geographical location;
- Presentation of the facilities' information: address, person responsible, work schedule and contact;
- Link to the facilities' energy monitoring, energy flow and infrastructure.

- **Infrastructure Management**

- List all equipment;
- Filter equipment by its code, location category, type of equipment or function;
- Group equipment by location category, location type, function or equipment type;
- Sort equipment by code, location category, function or equipment type;
- Delete equipment;
- See main information preview of the equipment in the list;
- Add new equipment or meter from scratch or copy data from an existing one;
- Filter listed equipment by location category while creating new equipment;
- See detailed equipment information: code, description, image, manufacturer and model, function and type, location categorization and coordinates;
- See equipment energy consumption, baseline and list of influence variables;
- Edit equipment information, including coordinates by clicking on facilities' plant.

- **Energy Monitoring**

- Select consumption point, associated to one or more equipment;
- Toggle between energy and currency units;
- Choose date range;

- See predicted consumption if exists;
- See disaggregated consumption;
- See comparison of consumption with previous year period.

- **Benchmarking**

- Choose benchmark by location, function or equipment type;
- See sorted equipment by decreasing consumption value;
- Define number results for benchmark;
- Toggle between absolute values comparison and relative to previous year period variation;
- Check equipment as main use of energy;
- Link benchmark items to equipment page.

- **Energy Flow:**

- Select facility for data visualization;
- Presentation of the relative and absolute consumption of energy by different uses of energy;
- Present recent consumption trend for individual uses of energy;
- Display recent events and alarms state for the uses of energy.

- **Dashboard**

- Provide three modes for interaction with the standard: operation, certification and audit;
- Operation mode: present a menu of the standard's documents and data;
- Certification mode: present the different processes that regard the standard's implementation lifecycle, its phases, milestones and outputs, with the possibility of defining the completion status for a task, its deadline and the person responsible;
- Audit mode: present the standard's requirements and the possibility of defining the completion statuses of individual requirements, visualization of the overall and the requirements categories implementation status.

- **Main Uses**

- List main uses of energy;
- See historical consumption, choosing date range;
- Attribute influence variables;
- See influence variables data;

- See baseline consumption;
- Add, edit and remove uses;
- See location of main uses of energy in the facilities' plant.

- **Influence Variables**

- List influence variables and present historical data;
- Associate variables to main uses;
- Add, edit and remove variables.

- **Baselines**

- See active baselines;
- Add, edit and deactivate baseline;
- Associate main use of energy or equipment consumption to baseline;
- Define validity period for the baseline application;
- Selection of main use or equipment for historical consumption data recovery;
- Plot of historical consumption data in relation to influence variable data;
- Choose baseline formula;
- Automatic calculation of best fit line for the presented historical consumption data;
- Manual input parameters feeding the baseline equation;
- Plot baseline according to automated calculation or manual input;
- Removal of outliers in consumption data with update of the baseline equation;
- Presentation of the correlation and coefficient of determination value.

- **Improvement Projects**

- Create new projects;
- Associate main uses to project, define energy or economic goal, choose deadline and person responsible for the project;
- Specify the project actions and the times;
- See project status and efficacy;
- Upload, review and validate documentation.

- **Savings**

- See savings for specific projects;
- See savings for overall consumption;
- See savings for specific main use of energy or equipment, with baseline attributed;
- Toggle between accumulated and instantaneous values.



### 3.1.2 Non-Functional Requirements

Besides the functional requirements, that will ensure the standard's application and the usability of the EMS solution, some non-functional requirements were identified as crucial to the creation of an improved quality solution, that not only strictly deliver tools but also ensure security, flexibility, scalability, environmental protection and integration features.

- **Security:** assure the safeguard of the collected data and its correct handling;
- **Scalability:** the module and its components should be able to handle with larger data quantities, depending on the size of the organization;
- **Flexibility:** the module should be customizable to fit the use of different kind of organizations, with diverse business and dimensions;
- **Environmental protection:** the solution, has it intends to implement ISO 50001 which is justified by the pressing need to protect the environment, must cover as many procedures and tools as possible from to avoid the need of using physical handling of documentation, therefore saving resources;
- **Integration:** the module is intended to be part of a larger EMS solution, so it should use and provide information, using the system's components and acting as its integral part.

## 3.2 Module Overview and Main Interfaces Analysis

The idea of the ISO 50001 integration in energy management systems, implies the evolution of these systems' concept. Nowadays, and as explored in chapter 2, EMS are found in a second generation, in which they provide tools that go beyond the "simple" automated monitoring of energy consumptions. The second generation of EMS allows for a more high-level control, of different energy sources, the simulation of the conditions for services acquisition, bills verification tools, alerts setting and automatic reporting.

However, the ISO 50001 module does not fit in the current paradigm, as a mere extension of the current EMS functionalities. If on the one hand this module makes use of key functionalities already existent and exploited in the second EMS generation, on the other it requires the development of other ones to comply with the standard's requirements.

In that sense, although it is not the goal for this dissertation to explore the possibilities and architect a third generation EMS, by idealizing the ISO 50001 module it is inherently constructing part of it. The 3GEnergy project [4] settled the concept of a third-generation energy management system, with the expected functionalities outlined in figure 3.1.

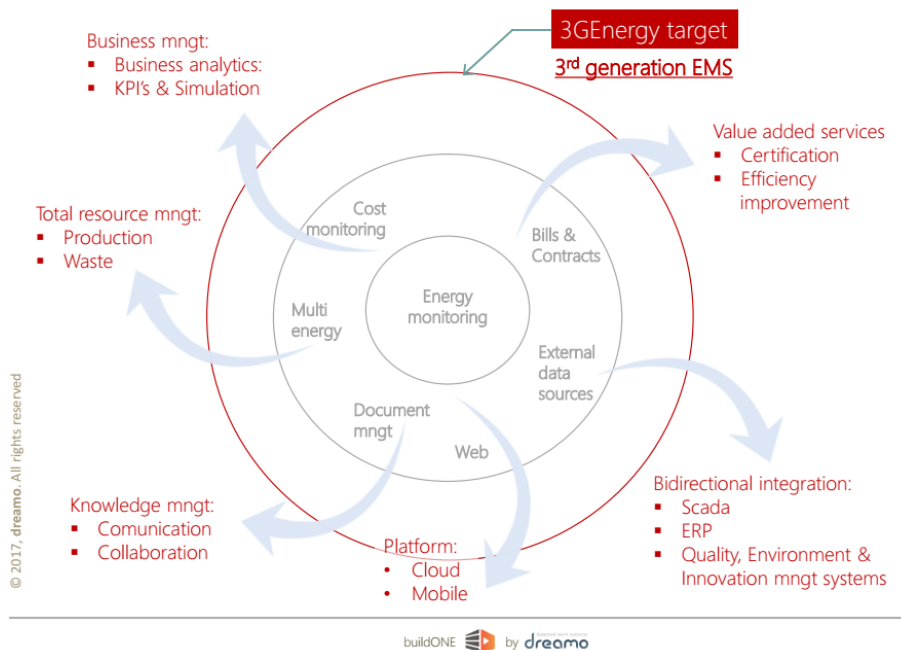


Figure 3.1: EMS evolution and idealized 3<sup>rd</sup> generation. [4]

It is possible to frame the proposal of this dissertation, in the scope of this more recent conception of energy management solution, as being the component supplying value-added services, a key differentiation from the previous generation. The possibility of certification by the standard ISO 50001 and the energy efficiency improvement are in fact purposes of this dissertation and the proposed module, but it also covers the area of knowledge management, with the need of collaboration mechanisms and document management, and the integration with quality, environment and innovation management systems.

The ISO 50001 focuses mainly on the estimation of baselines, having the historical consumption and influence variables data, to lately calculate savings and cost avoidance for a main use of energy. However, prior to this core aspect of the standard, it is necessary to have tools to assess the energy using infrastructure of the organization and means for automated energy monitoring, to present the energy uses and retrieve the main ones. Additionally, as emphasized in chapter 2 and is comprised in the standard requirements, in subsection 2.2.3, there is major importance to the human interaction with the system, the commitment of the organization's human resources towards the goal of full implementation of better energy efficiency practices through the ISO 50001 standard and the module that delivers it. So, there is the need for creation of interfaces that ease that connection, specially trough specific dashboards targeting different actors, that make the bridge for human interaction with the system.

To deliver the above-mentioned characteristics, the main components of the system were comprised within three main system areas: access to functionalities, the features themselves and the support components. In the following figure 3.2 the components are presented, as well as the key interactions between them.

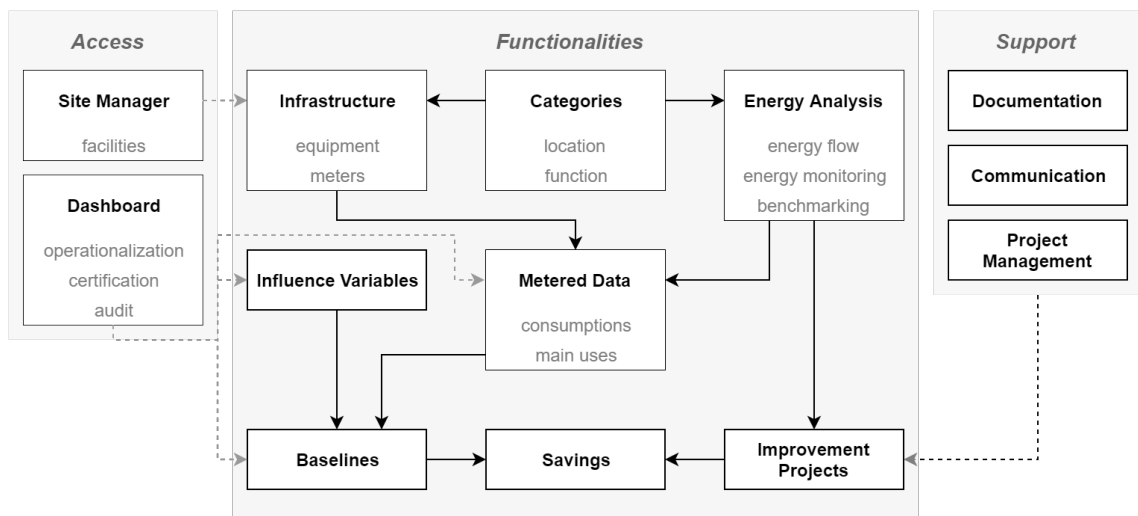


Figure 3.2: Functional organization of ISO 50001 module.

The access area englobes the components that will act almost as the main page of the ISO 50001 module, in two separated strands: the site manager component with the organization's facilities, linking to infrastructure management and further consumption and energy analysis, and the dashboard for the ISO 50001 features that, as mentioned in section 3.1.1, encompasses three modes of the ISO 50001 module presentation: operation, certification and audit mode. These access components, acting as starting points for the system, link to the rest of the ISO 50001 functionalities, in a way that the site manager connects to the infrastructure component and the ISO 50001 dashboard to the various components specific of the standard, as influence variables, main uses of energy and baseline consumptions.

The infrastructure component relates to the assessment and management of equipment and meters. The energy meters and the energy consumption measurements, represented in the diagram as 'consumptions' in the Metered Data component, are part of the already existent buildONE software. Meters represent a connection between the measured consumption values and the equipment, as one or more equipment energy consumption are measured by a meter.

The system elements, as infrastructure or consumptions, are categorized by two aspects, location or function. These act as labels for the elements in order to ease its accessibility, management and it are required in later energy analysis.

The already mentioned categories enables the classification of consumption and further analysis of the energy consumption. Three perspectives for energy analysis were considered to be fundamental for a good assessment of the overall and individual energy consumption. The first is energy monitoring, which is framed within the second-generation EMS, but essential for the next generation and for the application of the ISO 50001. This component must provide historical and current consumption data for a specific equipment, the forecasted consumption calculated from the equipment baseline, the disaggregated consumption of the submeters and a visual identification of the comparison status with the same period of the prior year, which allows for the analysis of the performance of the equipment and the possibility of alarm definition. The second component

regards benchmarking of equipment consumptions. Based in the defined categories, it is possible to compare the energy consumption of different locations and equipment by function or equipment type, either in absolute terms or relative comparison with the same period of the previous year. Lastly, the third analysis visualization is the energy flow, which regards the assessment of relative or absolute consumptions for different locations, disaggregated by energy use, as heating, ventilation and air conditioning (HVAC), transportation or lighting.

The main uses of energy are retrieved from the energy benchmark, where equipment is selected as main use of energy if their consumption, absolute or relative, is greater than a predetermined threshold, according to the ISO 50001 standard. For these ones, and with influence variable data entered into the system, the standard requires the definition of baseline consumption. The concept for this creation is based in the methodology further explained in subsection 3.2.2, which the system should support, allowing for the automatic or manual definition of the baseline equation, while visualizing its correspondent plot together with the historical consumption and influence variable data. Another important feature considered is the removal of outliers, points of consumption that by human analysis are found to be abnormal and therefore should not be considered, neither by visualization in the graph neither by the automatic calculation of the baseline equation.

The savings component of the system may be considered as the end page of the regular roadmap of an instance of the standard application. This component relates to the calculation of the deviation of consumption when compared to the defined baseline. So, the concept for this is to provide visualization tools to assess actual energy savings, global, per function or per equipment, and the evaluation of the possible cost avoidance.

After the classification of the main uses of energy and until the retrieval of savings and cost avoidance, these components are accompanied by the improvement projects entity, which in accordance to the standard, comprises the analysis of opportunities for improvement in energy efficiency, derived for the benchmarking analysis. The module, therefore, must provide tools for project management where the workflow of this part of the standard is monitored and managed. Supporting the energy efficiency improvement projects is the documentation and communication tools that comprise the area of supporting features in the conceptual model diagram. Additionally, documentation management, with document organization, versions control, author and editors identification, permits also the storage of all the documentation that the standard requires, and which is further detailed in subsection 3.2.1.

In agreement with the integrating software, buildONE, the proposal of this dissertation is a web-based application, that provides ease of use, ease integration in the organization, accessibility and flexibility, meeting the non-functional requirements, in section 3.1.2.

### **3.2.1 ISO 50001 Dashboards**

Identifying the users that will be dealing with the EMS, and particularly with the ISO 50001 module, three main profiles can be retrieved: management team, top-management and external auditors. The module, therefore in order to be as personalized as possible, contemplates three different dashboards for ISO 50001 features presentation.

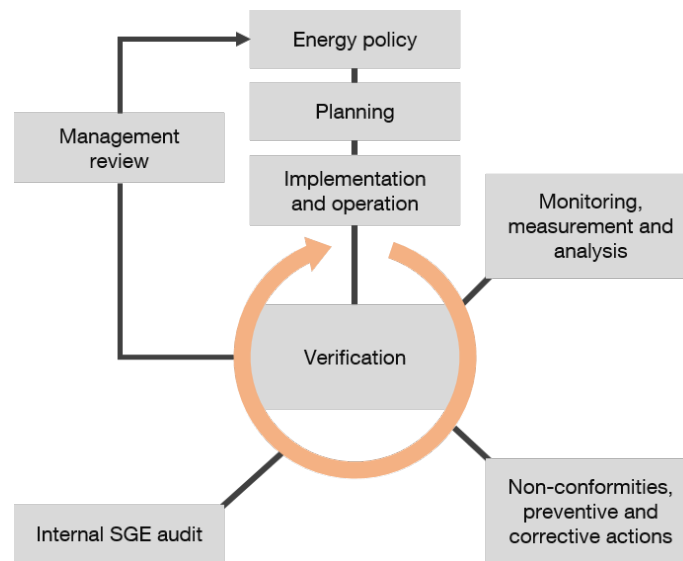


Figure 3.3: EMS model for ISO 50001 implementation. [3]

As verified in the state of the art analysis, the standard successful implementation revolves around its requirements which can be decomposed in tasks and outputs from those same tasks. Additionally, the standard's documentation provides a diagram, shown in figure 3.3 for a EMS that is articulated with the PDCA cycle and the ISO 50001 requirements.

For each requirement category, an exhaustive list of the requirements tasks and data or document outputs is presented in the appendix A, organized according to the categories of the EMS model for ISO 50001.

- **Operation dashboard**

For daily operation and management of the standard's tasks and documentation, the classification exemplified in the previous tables, and according to 3.3, gives an approach closer to the PDCA cycle, which allows for a more iterative workflow. Being so, the dashboard for daily operation and management focus on the graphical presentation of these categories, as a menu for displaying the required tasks and documents in a closer structure to the PDCA methodology, where the user can input the completion state for a task, manage documentation and handle alerts.

- **Certification dashboard**

The standard, mainly in the management responsibility requirements, acknowledges the importance of the organization's management department, with the definition of responsibilities and roles for top-management, management responsible and the management team in charge of accompanying the standard's procedures. For these actors, it matters to have a perception of the accomplishment status of the standard's requirements.

However, the standard application is not a single event or process and neither it is linear. Instead, it can be decomposed in many processes, that run simultaneously. Not being the purpose

of this dissertation to perform a complete and thorough analysis of the processes that compose the implementation and maintenance of the standard, an exemplification of such processes was conceived, and exhibited in appendix B, taken into consideration the analysis of the required tasks exhibited in this section.

The certification dashboard intends to present all the processes, as planning, infrastructure assessment, standard implementation, energy planning, certification, internal or external audit. For each one, the process model is presented, with phases, tasks and deliverables, as well as the person responsible for the individual tasks, its completion status, giving to the management department the complete and immediate assessment of the organization state.

- **Audit dashboard**

External audit of the system is another requirement of the standard. The audit dashboard aims to give another presentation of the systems state by list the overall requirements and their completion status, in the same classification as the standard's documentation.

### 3.2.2 Baseline Design and Cost Avoidance

The assessment of the energy efficiency improvement is made by calculating the difference between the actual consumption and the reference consumption for a main use of energy. However, energy use is significantly affected by factors, such as the outside temperature, which can be a problem for defining a reference. Consumptions for two different periods are very likely affected differently by these factors, which makes it difficult to calculate savings accurately.

Although it cannot be completely overcome, this problem is minimized using data normalization, based in the identified influence variables. In the literature, great focus is given to the impact of weather in energy, and much progress has been made in this area. Weather affects almost every organization, its buildings and facilities, and a significant percentage of energy is used counterbalancing weather variations. Data normalization can be applied to any influence variable, but given the importance placed by the literature to the weather [35, 29, 36], and for demonstration purposes, the external temperature will be used to exemplify how a baseline can be created.

A demonstration of the baseline creation process and its use to calculate energy savings is demonstrated below. In this example cost avoidance will be calculated for the HVAC, use of energy, where the consumption and influence variable values presented are mere examples for demonstration purpose:

1. **Historical consumption data:** For the actual definition of the baseline, data from a past period has to be available. To estimate consumption for a given period, usually it is considered historical data for the same time range of the previous year. This will be used as a basis for comparison for eventual savings calculation. In table 3.1 this historical consumption value is presented in column 'Outdoor Temperature' for June 2016.
2. **Historical and current influence variable data:** For the same period of the historical consumption data, and with the same time resolution, historical influence variable data also

has to be available. If we consider the outside temperature as the main influence factor on energy consumption, degree days can be determined as the difference between the average and the reference temperature, usually 65 °F (approximately 18 °C) as defined in the initial formulation of degree day calculation [37], and used as the influence variable. In table 3.1 it is presented the outdoor temperature for June 2016 and the correspondent degree days, with reference temperature of 18 °C.

3. **Plot:** Having both data sets explained before, it is possible to plot the relation between consumption and the degree days for the base period, as demonstrated in figure 3.4.
4. **Baseline equation:** From the plotted chart, either by manual trials or by regression techniques, it is possible to derive the equation of the best fit line from the relation between degree days and energy consumption for the base period. The baseline for the exemplified data in table 3.1, and using linear regression analysis, results the following equation dependent on the number of degree days, with correlation of 0,87 and a coefficient of determination of 74,86%, and plotted in figure 3.4:

$$y = 573.92x + 8623.48$$

5. **Cost avoidance:** Finally, having the baseline equation, retrieved for the base period defined, and the influence variable data for the savings calculation period, it is possible to determine a much more accurate consumption forecast. Cost avoidance, or savings, if they exist, are the difference between the forecasted consumption, fruit of the baseline application to the influence variable data, and the actual consumption times the cost of electricity per kWh.

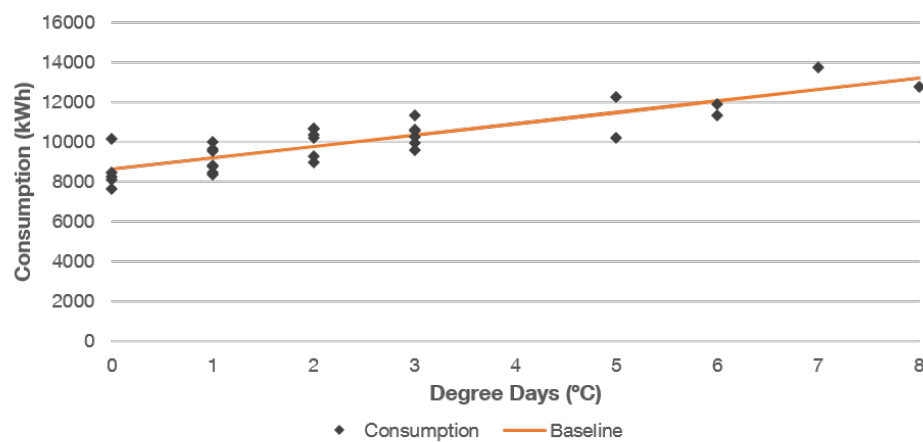


Figure 3.4: Consumption per degree day plot with correspondent baseline.

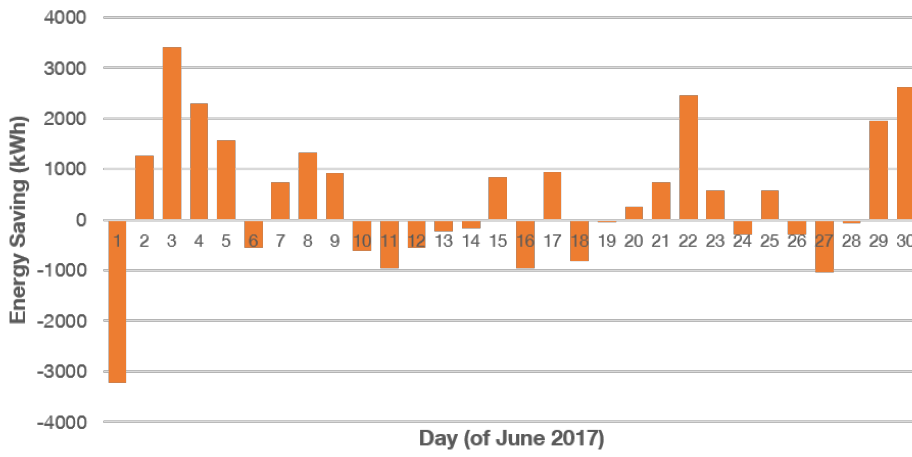


Figure 3.5: Plot of calculated savings, using the baseline consumption.

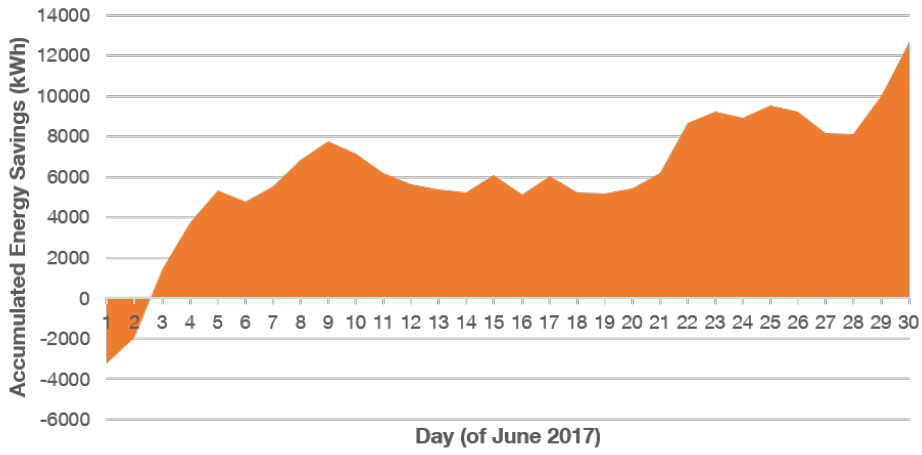


Figure 3.6: Plot of accumulated savings.



Table 3.1: Energy savings calculation from consumption forecast based in influence variables data.

Day	June 2016			June 2017			
	Outdoor Temperature (°C)	Degree Days (°C)	Real Consumption (kWh)	Degree Days (°C)	Predicted Consumption (kWh)	Real Consumption (kWh)	Energy Savings (kWh)
1	19	1	8490	1	9197	12422	-3225
2	18	0	8124	3	10345	9081	1264
3	18	0	7657	6	12067	8651	3416
4	19	1	8788	5	11493	9195	2298
5	20	2	8993	4	10919	9349	1570
6	17	1	8814	1	9197	9753	-556
7	18	0	10142	2	9771	9024	747
8	20	2	10364	3	10345	9026	1319
9	19	1	10001	2	9771	8845	926
10	21	3	9948	0	8623	9244	-621
11	16	2	10677	0	8623	9574	-951
12	15	3	10595	1	9197	9761	-564
13	20	2	9298	0	8623	8860	-237
14	18	0	8279	1	9197	9365	-168
15	17	1	8343	2	9771	8936	835
16	18	0	8459	0	8623	9581	-958
17	19	1	9556	3	10345	9399	946
18	15	3	9586	0	8623	9450	-827
19	16	2	10189	1	9197	9245	-48
20	24	6	11342	2	9771	9513	258
21	23	5	10210	3	10345	9602	743
22	21	3	10646	5	11493	9025	2468
23	20	2	10674	2	9771	9197	574
24	21	3	10270	1	9197	9492	-295
25	24	6	11930	3	10345	9761	584
26	26	8	12800	0	8623	8924	-301
27	25	7	13738	0	8623	9655	-1032
28	23	5	12268	1	9197	9277	-80
29	21	3	11346	4	10919	8973	1946
30	17	1	9647	5	11493	8882	2611
<b>Total Energy Savings:</b>							12652 kWh



## Chapter 4

# Proposed Solution and Implementation

In chapter 2, of this dissertation, a literature revision on the current practices and available commercial solutions was exposed. Followingly, in chapter 3, a conceptualization of the module and the requirements that it should comply with was proposed, with an explanation of key features, and an analysis of the system's interfaces, that will present the standard, was made. In this chapter, it is reported the concrete conception of the EMS, supporting the ISO 50001 standard. In an initial stage, the system's interfaces were idealized. Further, various of the interfaces were implemented in the current solution of Dreamo, the buildONE EMS.

Schematically, this chapter begins with an approach to the technologies used in the development of the module, including programming and the supporting technologies, as the database. Posteriorly will be presented the mock-ups for the interfaces and the actual implemented web pages, with its key functionalities and components. As the explanation of the interfaces is being made, and always that a new and relevant component is introduced, mainly from the Kendo UI framework, it will be exposed and its configuration explained. The same applies for key coding functions.

### 4.1 Development Technologies and Methodology

The development and implementation of the solution was made taken into consideration that the goal is the integration in the web-based application buildONE. So, the programming languages and environment are mainly the same as used by the Dreamo's team, which, not being part of the curricular program where this dissertation is enclosed, required a familiarization and learning period before any implementation could be done.

Two main software programs were used in the development: Visual Studio Community 2015 and SQL Server Management Studio (SSMS) 2016, both from Microsoft. The first software, Visual Studio [38], is an Integrated Development Environment (IDE) that meets the necessary tools for the development of an WBA, supporting .Net Framework, with the possibility of installation of programming languages plugins besides the ones already built-in. The later program, SQL Server [39], provides storage and a base for data management that will feed the system. The joint

use of these software allows the creation of web pages, with user interaction and dynamic data supply.

The programming tools used in the implementation phase are: Transact-SQL (T-SQL) [40], C# [41], JavaScript (JS) [42], TypeScript (TS) [43], Hypertext Markup Language (HTML) [44] and Cascading Style Sheets (CSS) [45]. Their purpose and use is explained in table 4.1.

Table 4.1: Definition of the programming tools used in the implementation phase.

<b>HTML   CSS</b>	Used in the creation of standard web pages and applications, and its stylization.
<b>JS   TS</b>	JS allows for the creation of dynamic web pages, complementing the use of HTML and CSS. TS is used as a superset of the JS language, specifically adding variable handling options, which compiles into JS code.
<b>C#</b>	Used in the programming of web services, for communication between the solution and the database.
<b>T-SQL</b>	Employed in the stored procedures, in SQL Server, for relational data handling.

Complementing the use of JavaScript language, and in line with the current practices from the Dreamo's team, two libraries were used. jQuery [46] is a JS library that adds the possibility of more complex animations in the webpage and a much intuitive handling of events. Also, it allows for AJAX calls, to communicate with the server asynchronously, for the presentation of dynamic content whenever required. The other used library is Kendo UI [47], that provides user interface components, as grids, drop downs, combo boxes, menus, charts and maps, as well as themes and many other tools to improve the quality of the user interface. These components from the Kendo UI are identified in the webpage by HTML elements that then, in JavaScript, are initialize and configured. The code structure of these different components is very similar. First there is an initialization, using the HTML element id and afterwards the component is configured as follows:

- In case the component needs data a data source is defined, whether static or using an AJAX call to retrieve remote data;
- Having the data source, there is a configuration of the retrieved data use, as where, when and how it will be displayed and used;
- There is the possibility of configuring the appearance and available options of the component, and;
- Configuration of actions and behavior of the component, when the user or other components interact with it.

## 4.2 Application Architecture

The logic behind the buildONE solution, and a general web application, is a three-tier architecture, which is comprised of the presentation, business and data layer.

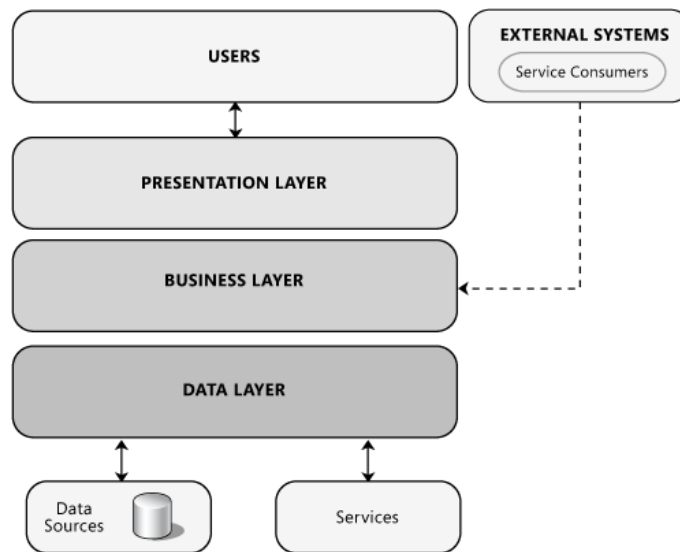


Figure 4.1: “The logical architecture view of a layered system” [11]

In this kind of application architecture, the presentation layer is responsible for decoupling the user interface, where the interaction with the system occurs, from the rest of the underneath application logic and complexity. In this case it contemplates the web browser presenting the HTML from the server.

The business tier makes the connection between the user interface and the data layer, containing the logic behind the application. It can use input from the client side and gives output, in the form of rendered HTML to the user interface after processing information and retrieving data from the data layer.

Finally, the data layer is responsible for the handling of the information stored in the database, asked via queries from the business logic and the response with the data, that will be presented to the user.

Presentation and business logic layers are explained in section 4.4, when presenting the ISO 50001 module, its interfaces, tools and properties. As for the data layer, it is presented in the following section 4.3.

### 4.3 Database Design

The system database management is done using a relational model. Data is grouped in tables of the same entity, with the columns corresponding to the properties and the lines to the different elements of that entity. Entities can have constraints and relations to other tables.

The buildONE solution has already established a database for the EMS system and, some of the necessary functionalities for the 50001 module are already developed and currently used. This means that some of the entities present in the current buildONE database may and should be used by the new module, and doing so the connection with the other solution modules will be made.

Currently, it is employed a relational database that in the context of the developments made in this dissertation will be expanded, with the creation of the new necessary entities, the relations between them and with the other entities, particularly with the ones relating to the energy consumption values.

After the analysis performed in the previous chapters, especially in the definition of the requirements and the construction of the functional model for this implementation proposal, it is possible to create the data model, represented through figure 4.2 to 4.4. In order to present the relational model of the database in this dissertation, the same had to be divided in three figures, only for presentation purposes. In fact, there is a relationship between the Equipment and Nodes entities that is represented in both correspondent figures.

The above figure 4.2 relates to site manager component of the system. In this, the Facilities entity is the main one, where together with the Brands entity, stores the data from the different organization’s facilities. The FacilityLocations entity comprises the information that regards the location of the facility, namely its address, geographical coordinates and the Google Maps iframe component, in order to present an embed visualization of the man in the webpage.

Figure 4.3 contains the entities for the infrastructure management part of the system. This is a key feature of the planning phase of the standard, for assessing the organization’s energy-using equipment. Equipment is the main entity containing a description, internal code and the geographical coordinates. In the left-hand of the Equipment entity is presented one categorization possibility of the equipment, using Types, type of equipment, and Functions. On the right-hand side are presented the entities responsible for the location categorization. FirstLevels, SecondLevels, ThirdLevels and FourthLevels enable the organization of the infrastructure on four different and hierarchical levels, enforced by a relation of parent-child between the different levels. The coordinates column in the levels also represents the geographical coordinates of that location, for further presentation in map.

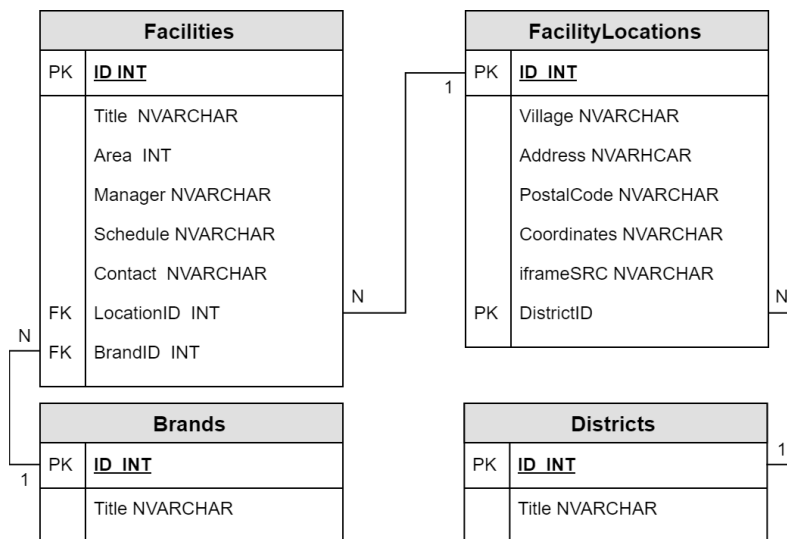


Figure 4.2: Site manager relational model.

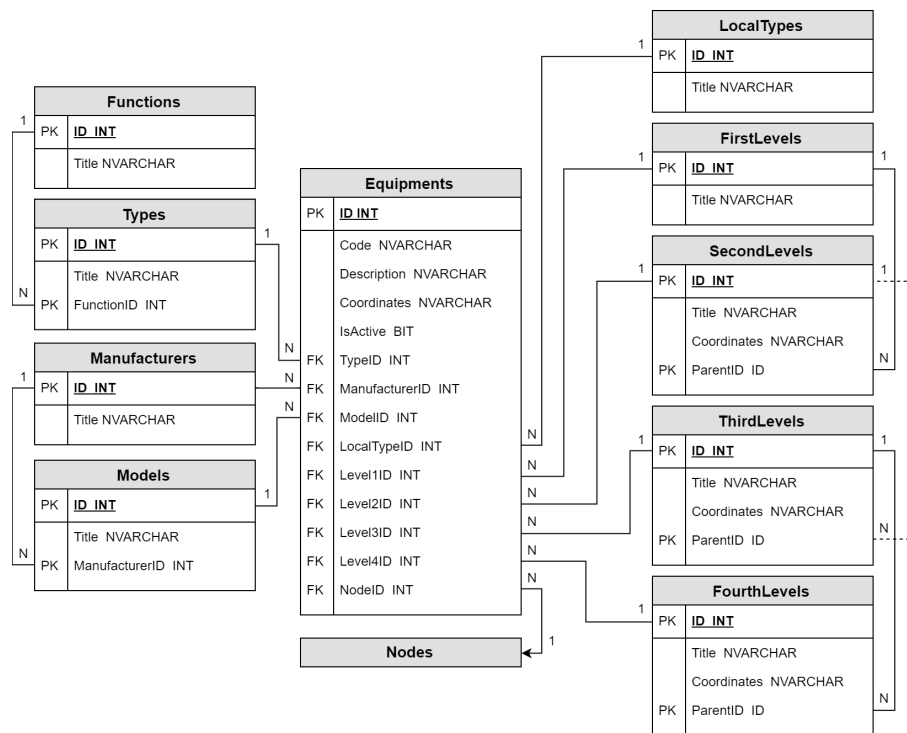


Figure 4.3: Infrastructure management relational model.

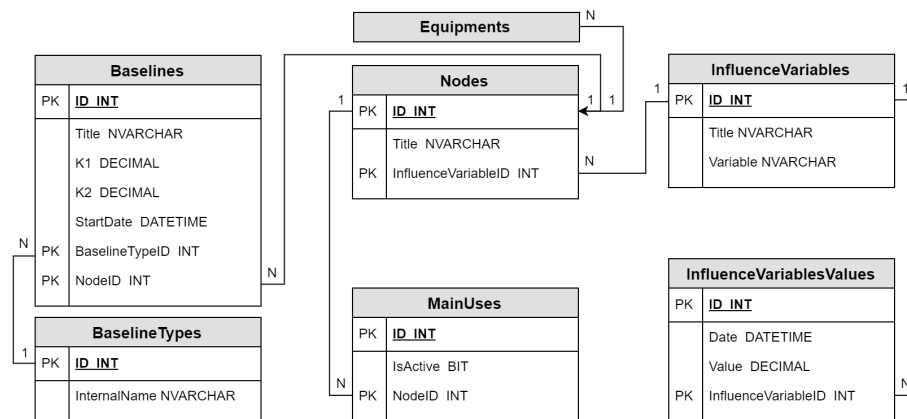


Figure 4.4: ISO 50001 functionalities relational model.

Lastly, in the above figure 4.4 are displayed the entities responsible for the energy analysis and energy efficiency components of the developed system. In the current buildONE solution, the consumption values by the energy meters are stored in the database under many entities corresponding to different time resolutions for those measures. Each measure has a correspondent Node attributed and so this latter entity is used for accessing the energy consumption data. Mainly, as exhibited in the figure, each Equipment consumption is represented by a Node wich can be set as a main use of energy. Further, the InfluenceVariables entity comprises the defined variables that affect energy consumption and its data is stored in the InfluenceVariablesValues, with the related timestamp. On the left-hand side are the entities that enable the baseline definition and that relate

to a specific Node, and therefore to an Equipment. K1 and K2 columns are the parameters values attributed to the baseline equation, which type is defined in the BaselineTypes table. The Baseline has a starting date of application (StartDate) defining the initial day of application of the baseline.

The supporting components of the standard, such as communication, document or project management are not part of the presented database, as they are already developed and implemented in the buildONE solution.

## 4.4 User Interfaces

In this section, the proposed interfaces for the ISO 50001 module are presented, complementing the current Dreamo's buildONE solution, adding the component of site management, infrastructure management, energy analysis and energy efficiency to the existing EMS.

With the development of the new 3GEnergy third generation EMS, Dreamo is currently working in the integration of this software in two main clients, Sonae MC and Lipor. Each client is interested in distinctive features of the new solution at this point: Sonae MC wants to implement the site manager component, enabling the management of its many facilities energy consumption; and Lipor intends to fully apply the ISO 50001 standard. So, the proposed interfaces were created and implemented in the context of these clients' actual needs, and the data presented, in the implemented webpages figures, relates to those clients.

The following figure 4.5 presents the designed, marked with a '\*', or implemented interfaces, grouped in the component's categories of the proposed module.

Site Manager	Infrastructure Management	Energy Analysis	Energy Efficiency
Facilities Map	Equipment Dashboard Equipment Map Equipment Page	Energy Monitoring Benchmarking Energy Flow*	ISO 50001 Dashboard* Main Uses Overview Baseline Configurator

Figure 4.5: Proposed interfaces for the ISO 50001 module.

### 4.4.1 Site Manager

The site management component focuses on the presentation of information of the organization's facilities. So, a survey was made to assess the different Sonae MC stores that would be englobed in its site manager. Having that information, and using the entities in the site management part of the database, explained in section 4.3, an interface was designed having three main areas, as demonstrated in figure 4.6.





Figure 4.6: Site Manager interface with facilities' map.

The presentation of the facilities is made by markers in a KendoMap element with the default view of Portugal, using the coordinates information of the FacilityLocations table, in the database. Tooltips are used presenting the facility name when the marker is clicked. Also in this event, an AJAX call to the database is made followed by the presentation of the retrieved information. In central section of figure 4.6, an image of the facility is shown, its name, address and location, contact, work hours and the name of the facility manager. Additionally, an embed Google Map is presented, again using the facilities coordinates to center the map, which gives more tools to the user, as the possibility to see route indication to the specific local.

```

if (_cbSelectMapArea.select() != -1) {
  $.each(_mapDS, function (index) {
    if (this.DistrictID != _cbSelectMapArea.value()) {
      _array.push(index);
    }
    else {
      this.Coordinates = JSON.parse(this.Coordinates);
      this.MarkerTooltip = this.FacilityTitle;
    }
  });
  _array.reverse();
  $.each(_array, function (index) {
    _mapDS.splice(_array[index], 1);
  });
  $.each(_mapDS, function () {
    _lat += this.Coordinates[0];
    _long += this.Coordinates[1];
  });
  _mapProperties = { center: [_lat/_mapDS.length, _long/_mapDS.length], zoom: 10 };
}
else {
  $.each(_mapDS, function () {
    this.Coordinates = JSON.parse(this.Coordinates);
    this.MarkerTooltip = this.FacilityTitle;
  });
}

```

Figure 4.7: Function for filtering markers according to the selected options.

In most of the presented interfaces for the ISO 50001 module, a right panel is displayed, dedicated to the options that will affect the other elements of the interface. In this particular webpage, and using the Districts data, a KendoComboBox provides the districts title which allows

the user to search and select one of the districts, while seeing, in the same element, the number of facilities that are under that district. This selection, refreshes the map data source sorting the facilities that correspond to the selected district and centering the map in the geographical center. This latter function is exhibited in figure 4.7.

## 4.4.2 Infrastructure Management

The infrastructure management component is integrated in the standard's planning phase, and, as explained in the module analysis chapter, it translates in the incorporation of all equipment that uses and measures energy in the management system. This component is made of three different webpages: dashboard, map and detail interfaces, implemented for the equipment infrastructure.

### 4.4.2.1 Equipment Dashboard

The first interface, according to the requirements defined in section 3.1.1, entails the visualization of all the equipment and energy meters, for its further management. In the context of this dissertation project, only the equipment component of the infrastructure was regarded, mainly due to time constrains as the energy meters management is quite similar to the equipment entity handling, and the data presentation is the same.

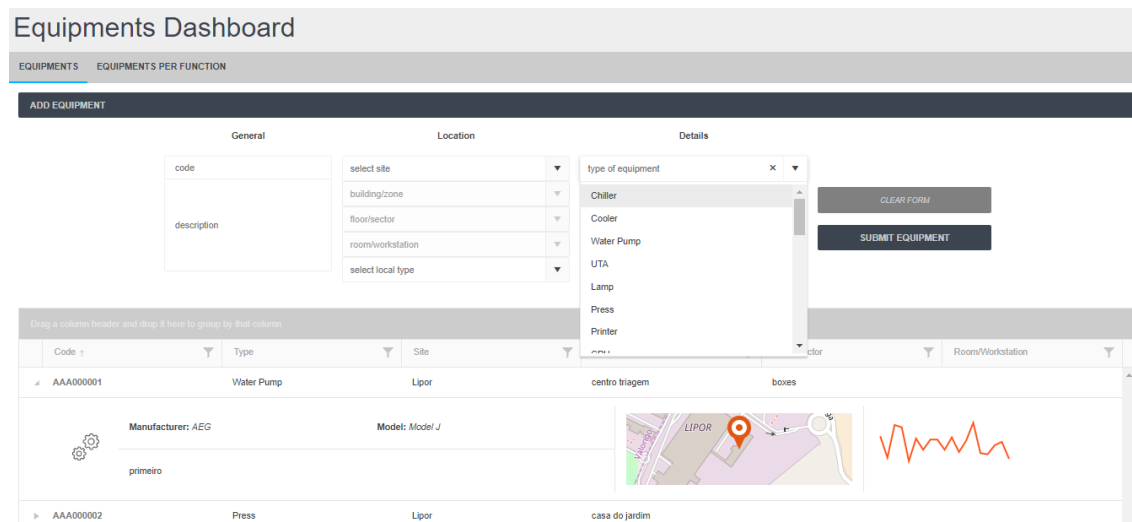


Figure 4.8: Equipment dashboard with expanded form section and equipment type option.

In the figure 4.8 the interface is presented, with KendoGrid element occupying most of the interface. This webpage main component, a table like element, displays the list of equipment. This type of visualization allows for condensed presentation of information while maintaining the organization, search and usability required. The KendoGrid data is fed by a webservice that retrieves all the equipment information, such as its details, location data and function.

The screenshot shows the 'Equipments Dashboard' with a navigation bar containing 'EQUIPMENTS' and 'EQUIPMENTS PER FUNCTION'. Below this is a dark 'ADD EQUIPMENT' button. The main area is divided into three sections: 'General', 'Location', and 'Details'. The 'General' section has a 'code' field and a 'description' field. The 'Location' section has a dropdown menu currently open, showing a list of locations: 'Lipor', 'centro triagem' (4 equip(s)), 'aterro' (8 equip(s)), 'casa do jardim' (5 equip(s)), 'ecocentro' (5 equip(s)), and 'ed. apoio administrativo' (2 equip(s)). The 'Details' section has a 'type of equipment' dropdown and a 'function' field. To the right of the form are 'CLEAR FORM' and 'SUBMIT EQUIPMENT' buttons. Below the form is a table with the following data:

Code	Type	Location	Building/Zone	Floor/Sector	Room/Workstation
AAA000001	Water Pump	Lipor	centro triagem	boxes	
AAA000015		Lipor	centro triagem	compactador	
AAA000021	Cooler	Lipor	centro triagem	compactador	
AAA000027	Ventilator	Lipor	centro triagem	nave	
tes	Water Pump	Lipor	centro triagem	compactador	

Figure 4.9: Equipment dashboard with expanded form section and data filtered by location.

The second component of this page is the form that permits the addition of new equipment to the system, and hence to the database. This form is initially occulted and can be presented with the click of the 'Add Equipment' button on top of the KendoGrid. The new equipment information is inputted via a series of elements from the Kendo UI framework, such as masked text box, combo box and drop down list, the first for text input and the latter ones for option selection, which are retrieved from the infrastructure management entities of the database. Selection of the new equipment location will automatically sort the equipment's grid according that same selection, as shown in figure 4.9.

The list of equipment can be customized to facilitate the user interaction. Users can sort, group or filter, cumulatively, the various columns of the grid, in order to view specific equipment or group of equipment. Specifically for the filter functionality, more complex solutions than the provided by Kendo UI had to be created. This comprises the definition of an array that stores the active filters for the KendoGrid, that are updated when the column filters change or the KendoComboBoxes are modified in the add equipment form, unifying the parameters of the filter applied to the KendoGrid. Also, the possibility for searching while typing was implemented, exposed in figure 4.10.

```
filterable: {
  cell: {
    showOperators: false,
    operator: "contains",
    template: function (args) {
      args.element.css("width", "90%").addClass("k-textbox").keydown(function (e) {
        setTimeout(function () {
          $(e.target).trigger("change");
        });
      });
    },
  },
}
```

Figure 4.10: Example of filtering function implemented for equipment grid.

Further easing the use of the infrastructure management, was made use of another Kendo UI component that permits the addition of context menus to various elements of the webpage. In this

specific interface, this is employed to individual rows, exemplified in figure 4.11, where it offers the option to delete or edit the related equipment or copy the equipment information to the add equipment form. This later functionality is useful for companies that have significant quantities of similar equipment, easing this same process.

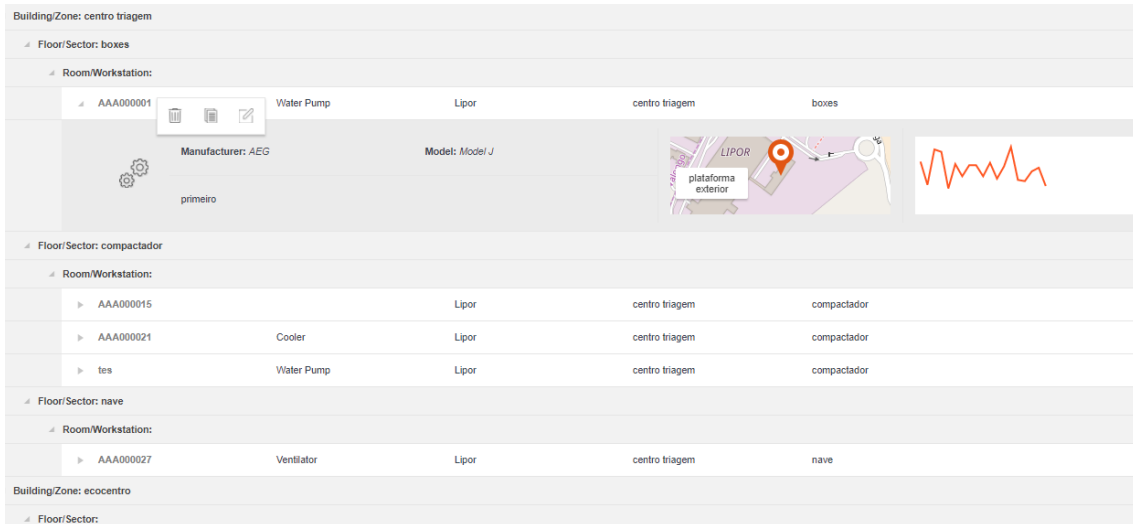


Figure 4.11: Equipment grid with expanded row and context menu.

The grid, when listing the equipment, immediately presents several information: id, code, location levels, and function. However, the entity has more information related that cannot be displayed in the grid due to lack of space or overcrowding of information. To solve this problem, the remaining information is displayed in an expandable section, that is occult by default. The user can expand a certain row of the grid, that relates to a specific equipment, and the more detailed information is presented: the manufacturer and the equipment model, a brief description, an image of the equipment, the geographic location in a map, using KendoMap, and simple chart with the consumption outline for the previous thirty days, with the KendoSparkLine element. In figures 4.8 and 4.11 it is exemplified the expansion of a row, made possible with the addition of an HTML template that is rendered in each 'expandRow' event.

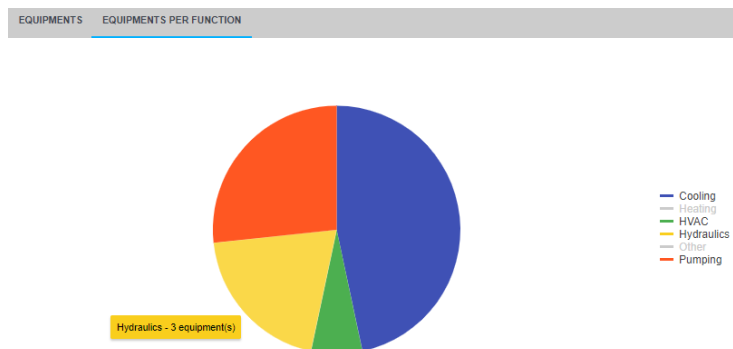


Figure 4.12: Equipment functions chart.

A second tab implemented in this webpage contains a chart, using the KendoChart element, to provide a visualization assessment of the different equipment functions and the correspondent quantity of equipment they comprise. In figure 4.12 such interface can be visualized, demonstrating the possibility of selection the data series to be presented.

#### 4.4.2.2 Equipment Map

As location is a core part of the infrastructure categorization, an interface was developed using this information, to present the equipment's location in a map of the facility, as demonstrated in figure 4.13. This gives an alternative and more visual view to the regular equipment list.

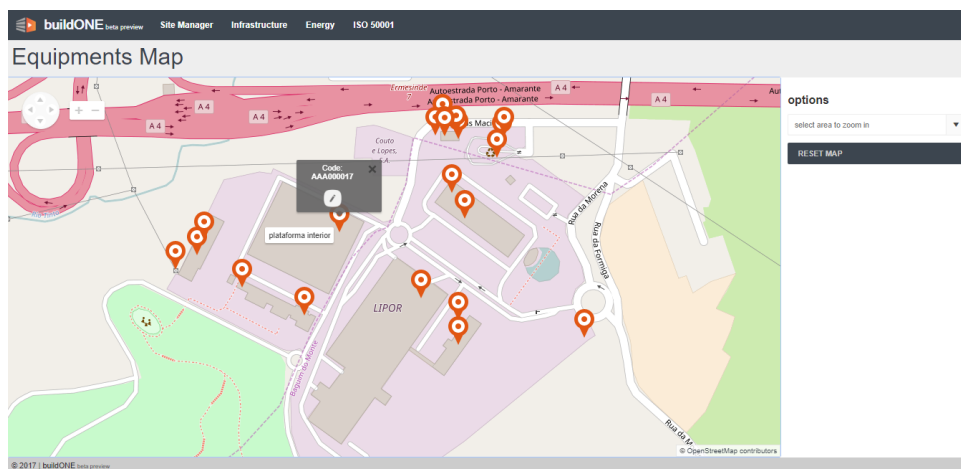


Figure 4.13: Equipment Map interface, with marker selected.

```

_mapEquipments = $("#_mapEquipments").kendoMap({
  center: _mapProperties.center,
  zoom: _mapProperties.zoom,
  layers: [
    {
      type: "tile",
      urlTemplate: "http://#=# subdomain #.tile.openstreetmap.org/#=# zoom #/#=# x #/#=# y #.png",
      subdomains: ["a", "b", "c"],
      attribution: "@ <a href='http://osm.org/copyright'>OpenStreetMap contributors</a>"
    },{
      type: "marker",
      shape: "pinTarget",
      dataSource: _mapDS,
      locationField: "Coordinates",
      titleField: "MarkerTooltip",
      tooltip:[...]
    },{
      type: "shape",
      style:[...],
      dataSource: {
        type: "geojson",
        transport: {
          read: "scripts/Lipor.geo.json"
        }
      }
    }
  ],
  shapeCreated: onShapeCreated,
  shapeFeatureCreated: onShapeFeatureCreated,
  shapeMouseEnter: onShapeMouseEnter,
  shapeMouseLeave: onShapeMouseLeave,
}).data("kendoMap");

```

Figure 4.14: Configuration of KendoMap element of Equipment Map interface.

The KendoMap element uses layers to display the information contained in the map, in this specific case three layers are used, explained followingly and with its implementation shown in figure 4.14.

- The base layer makes use the Open Street Map tools. This free community offers an open source map that the KendoMap layer can retrieve and display as image tiles;
- The second layer regards the different building or zones that composes the organization's site. In this case, where the organization considered is Lipor, a survey of the organization's buildings and zones was made, and are stored in the 'SecondLevels' table of the database. A GeoJSON [48] file was created with Lipor's plant and the respective building or zone information. KendoMap uses this information, and presents these shapes in the map, in this case transparently, and the information is only accessed when moving the cursor over the map;
- The third and last layer comprises the equipment's markers with presentation of the respective internal code and linking to the equipment page on tooltip, figure 4.13.

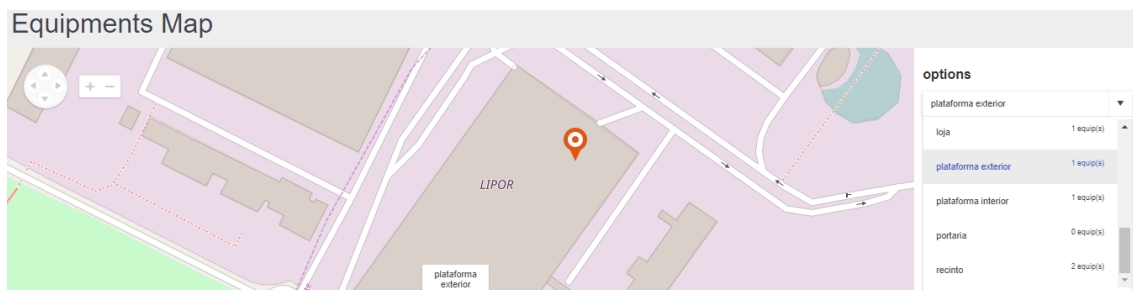


Figure 4.15: Equipment map with markers filtered from the options selection.

In the same way as the site manager interface, a right-hand side zone of the webpage is dedicated to the options menu. Here the user can select the 'SecondLevel', referring to the building or zone in the Lipor case, and filter the markers in the map according that selection. To center the map in the correct position while filtering equipment, the information of the 'Coordinates' column in the 'SecondLevel' table of the database is used.

#### 4.4.2.3 Equipment Page

Detailed information of the equipment is presented in the Equipment Page interface, in figure 4.16. Users can get to this page via the Equipment Dashboard or Equipment Map.

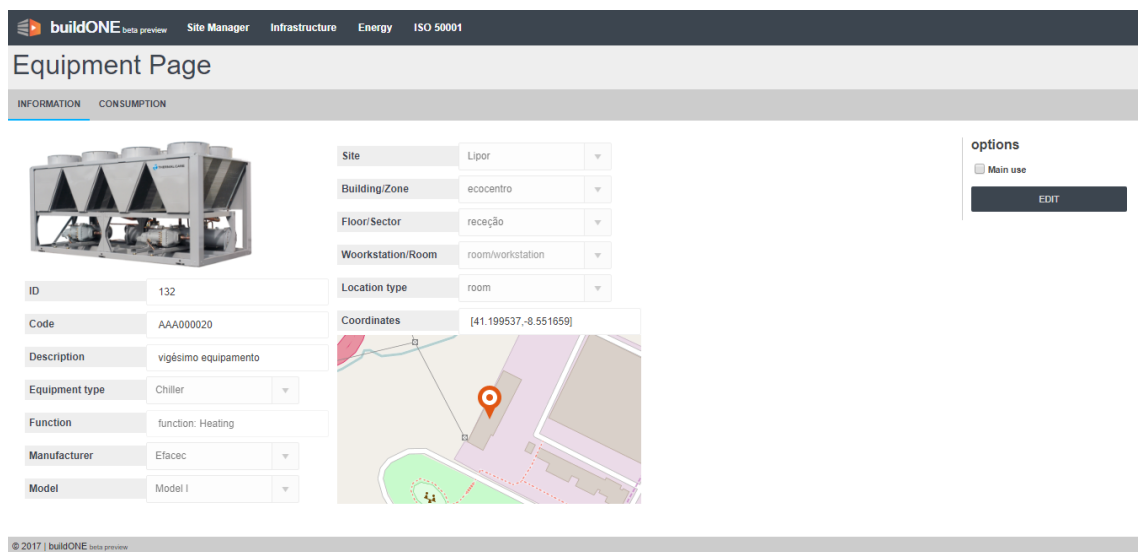


Figure 4.16: Equipment Page interface.

According to the defined functional requirements, in section 3.1.1, all the detailed information of the equipment has to be presented. The layout of this interface, as shown in the above figure displays the equipment information on left and the options on the right. By default, the data fields are disabled for editing. The user can then enable them in the options menu, where the menu changes to 'Save' and 'Discard' the modifications made, as shown in figure 4.17.

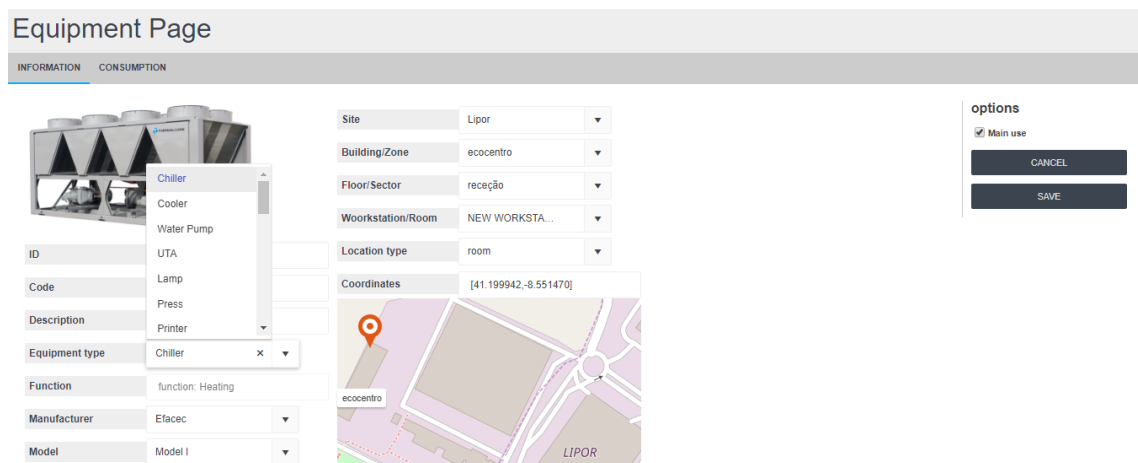


Figure 4.17: Editable equipment data, with changed marker position and equipment type options.

Particularly to the page, the edition of the equipment's coordinates can be made via two different ways. The system recognizes the input of coordinates in the form of "[latitude, longitude]", automatically refreshing the marker position in the map when changed, or by clicking in the desired position on the map. This functionality was implemented using the 'click' option of the KendoMap element, retrieving the coordinates from the event and updating the respective marker position. Both possibilities code is shown in figure 4.18.

```

function onEquipmentMapClick(e) {
  if (_flagEditEquipment) {
    _equipmentEdited.Coordinates = _mapEquipment.eventToLocation(e);
    _mapEquipment.markers.clear();
    _mapEquipment.markers.add({ location: _equipmentEdited.Coordinates });
    $("#_tbCoordinates").val([' + _equipmentEdited.Coordinates + ']);
    if (_mapEquipment.zoom() < 17) {
      _mapEquipment.zoom(_mapEquipment.zoom() + 1);
      _mapEquipment.center(_equipmentEdited.Coordinates);
    };
    _equipmentEdited.Coordinates = '[' + _equipmentEdited.Coordinates + '];
  }
  else {
    return false
  }
};

function UpdateMarkerCoordinates() {
  var _newCoordinates = [JSON.parse($("#_tbCoordinates").val())[0], JSON.parse($("#_tbCoordinates").val())[1]];
  $("#_mapEquipment").data("kendoMap").items[0].location(_newCoordinates);
  _equipmentEdited.Coordinates = JSON.parse($("#_tbCoordinates").val());
  _mapEquipment.center(_equipmentEdited.Coordinates);
  _mapEquipment.zoom(17);
};

```

Figure 4.18: Equipment location update functions.

Still in the same page, is used the KendoTabstrip element, that enables the definition of different tabs in a single page, configured in figure 4.19. The above-mentioned information is presented in the first and default tab, whereas in the second tab the user can view the consumption detailed chart for the same equipment, exemplified in figure 4.20.

```

function SetEquipmentTabStrip() {
  var _tsEquipmentPage = $("#_tsEquipmentPage").kendoTabStrip({
    animation: false,
    select: function (e) {
      if (e.item.id == "_tsInformation") {
        SetEquipmentInformation();
        SetEquipmentOptions();
      }
      else if (e.item.id == "_tsConsumption") {
        SetEquipmentConsumption();
      }
    }
  }).data("kendoTabStrip").select("#_tsInformation");
};

```

Figure 4.19: Implementation of tab elements for Equipment Page interface.

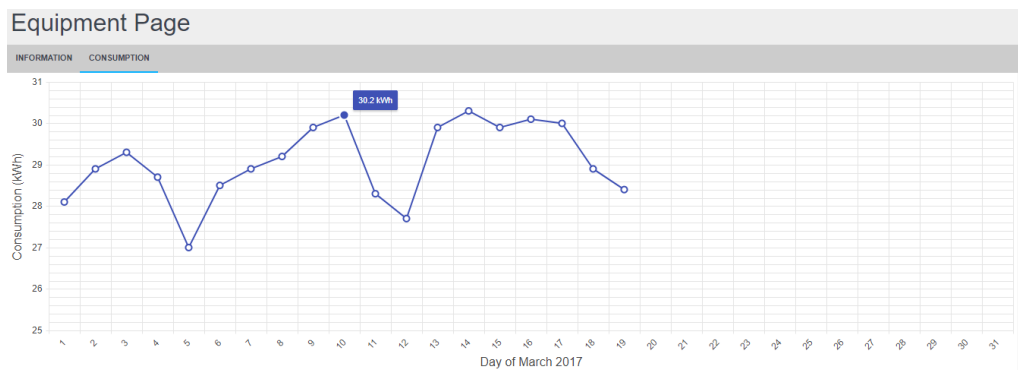


Figure 4.20: Consumption monitoring tab in Equipment Page.



### 4.4.3 Energy Analysis

According chapter 3, in the analysis of the system, the energy analysis part comprises the visualization of energy consumptions. These, as previously mentioned, can be shown in two separate ways: through the energy monitoring and the benchmarking interfaces. The first relates to the presentation of a single consumption point or equipment consumption data, while the latter regards the comparison of consumption values.

#### 4.4.3.1 Energy Monitoring

Energy monitoring features are not exclusive of the ISO 50001 standard requirements. Instead they are a key component of the typical EMS, and hence of the buildONE software. For this MSc dissertation project, was idealized an interface for the monitoring of energy, taken in consideration the ISO 50001 requirements and principles. Important to an effective monitoring of energy is the visualization of consumption through time, or historical consumption data. Additionally, to improve the assessment of the energy use, two more features can be used for displaying the disaggregated consumption of a node and the comparison to homologous period of the previous year.

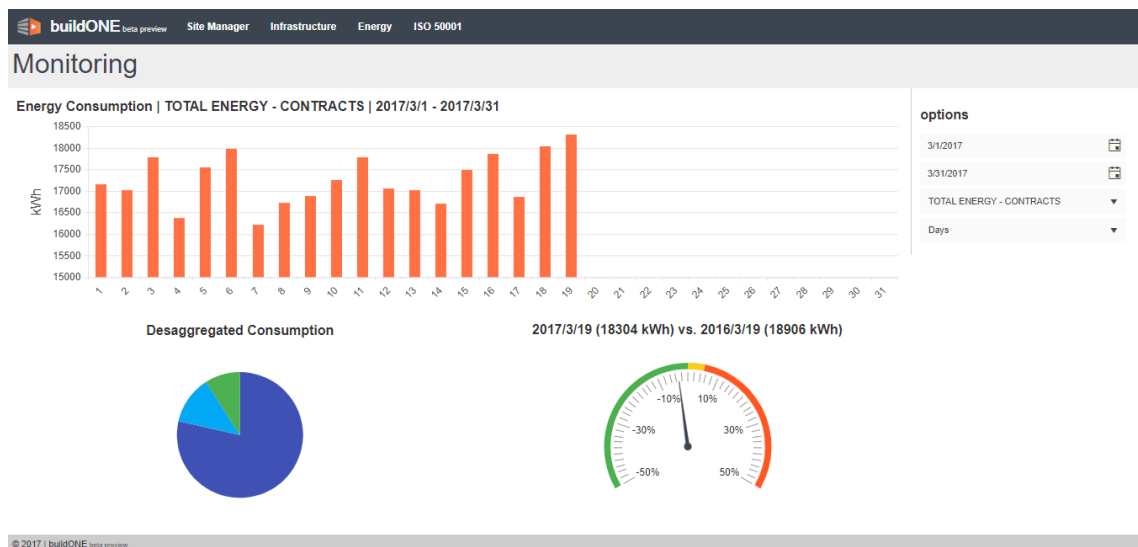


Figure 4.21: Energy Monitoring interface.

In this way, besides the typical two areas of the already explained webpages, this interface main content, viewed in figure 4.21, is divided in three main chart components of Kendo UI:

- Column chart: in order to visualize the consumption of an equipment or meter through time, the best approach is the visualization in a line, using KendoChart with the data series configuration for 'column' chart. By default, the period shown corresponds to the current month, with daily time resolution.

- Pie chart: when visualizing the consumption of a node, it matters to have an assessment of the relative consumption of the child nodes. This is made possible using the KendoChart and configuring the series type to 'pie'. The absolute value for the child node is presented in tooltip, together with the node title, when hovering the chart with the mouse. For example, for the HVAC use of energy it would be presented the heating, ventilation and air conditioning components of this energy consumption.
- Gauge chart: the system retrieves the consumption value for the selected node, for both current day and the same day from the previous period, and compares the measures energy values. The user can then immediately perceive if the node is consuming more or less energy.

Concerning the options menu for this interface, it configures the data presented in the aforementioned charts, updating its data source when the fields are changed, namely the node or equipment selected, the time range, using KendoDatePicker, and the time resolution for the data presentation, by default configured to 'days'.



Figure 4.22: Options area for monitoring page configuration, with consumption point selection.

#### 4.4.3.2 Benchmarking

The selection of the main uses of energy, as explained in chapter 2 and stated in the ISO 50001 standard, should correspond to the most energy consuming equipment. However, this selection must allow human judgment for a more correct choice of main uses, or more aligned with the organization's energy policy.

Allowing the user to decide the main uses requires the presentation of consumption in a way that is easy perceivable the comparison between the different equipment. This interface translates this idea, using 'bar' series on KendoChart, shown in figure 4.23, retrieving from the database the top number of results chosen by the user from the 'Equipment' table, sorted in descendent order by consumption value. As the individual bars relate to a specific equipment, the user can reach the equipment page by clicking on the correspondent bar, or the axis label, where once in the equipment page, and analyzing the rest of the information, the configuration as main use of energy can be made toggling a check box in the options area.

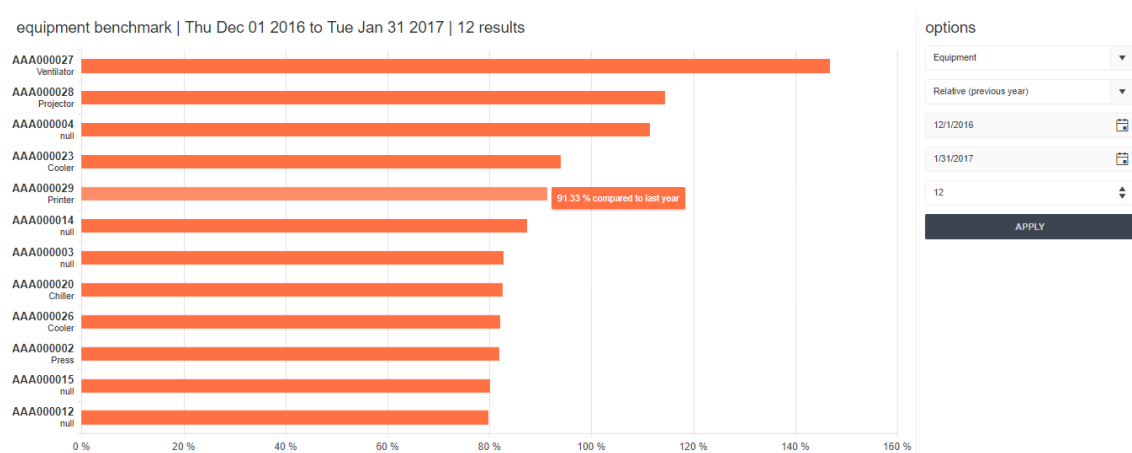


Figure 4.23: Benchmark interface.

In this interface, an additional form of benchmarking was implemented, where the comparison values are relative to the same period of the previous year, instead of the previous mentioned absolute values. Although, not implemented, benchmarking by equipment's function and location can also be performed, and the system easily supports those options.

In figure 4.24 is presented an example of a stored procedure, implemented in SQL Server Management Studio, that is used in the application of queries to the database.

```

SELECT
  Nodes.ID as NodeID,
  Nodes.Title as NodeTitle,
  InfluenceVariables.ID as InfluenceVariableID,
  InfluenceVariables.Title as InfluenceVariableTitle,
  InfluenceVariables.Variable as InfluenceVariable,
  InfluenceVariablesValues.ID as ValueID,
  InfluenceVariablesValues.Date as ValueDate,
  InfluenceVariablesValues.Value as Value,
  ConsumptionValues.Consumption as Consumption,
  CASE
    WHEN ISNULL(@K1,@K1) IS NOT NULL AND ISNULL(@K2,@K2) IS NOT NULL THEN InfluenceVariablesValues.Value*CAST(@K1 as FLOAT)+CAST(@K2 as FLOAT)
  END AS Baseline
FROM Nodes
LEFT JOIN InfluenceVariables ON InfluenceVariables.ID = Nodes.InfluenceVariableID
LEFT JOIN InfluenceVariablesValues ON InfluenceVariablesValues.InfluenceVariableID = InfluenceVariables.ID
OUTER APPLY fn_getValuesDay(@VariableTypeID, Nodes.ID, InfluenceVariablesValues.Date, DATEADD(day,1,InfluenceVariablesValues.Date)) AS ConsumptionValues
WHERE Nodes.ID = @NodeID AND InfluenceVariablesValues.Date >= @InitDate AND InfluenceVariablesValues.Date <= @EndDate

```

Figure 4.24: Example of stored procedure employed, for benchmarking data retrieval.

### 4.4.3.3 Energy Flow

This interface aims to present the disaggregated consumption of a facility, in its main energy uses. Using the same webservice that feeds in the Energy Monitoring webpage presentation charts, in this interface this the consumption information is retrieved for the facility, as a all, and its main uses of energy.

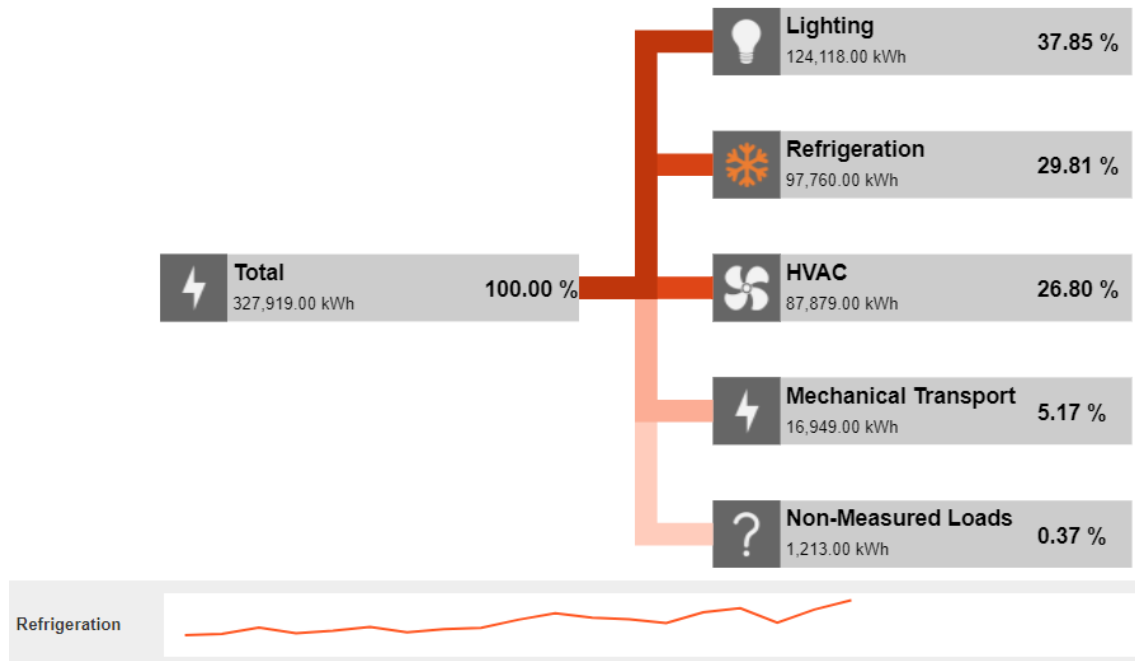


Figure 4.25: Interface design for Energy Flow visualization.

In this interface is used the KendoDiagram element. This component mainly provides graphic elements for the creation of shapes, either programatically or with the user input, that can be linked via connections. After the initialization of the diagram, the visual template is designed in a specific function that appends shapes and connections, and ultimately fills the predesignated fields with the information retrieved from a webservice.

Each main use shape links to the Energy Monitoring interface, showing its consumption history. Further, in order to create a visual, and more immediate, assessment of the weight of the different main uses related to the facility consumption, a function was implemented, that retrieves the several consumption values for the main uses, calculates the average and retrieves the minimum and maximum value, which are associated to three different hexadecimal color codes. Followingly, while appending the the different connections between the facility block and the main uses one, the color for those connections is calculated according to the predetermined color range. The result can be seen in figure 4.25 and the implemented function for the connections coloration in figure 4.26. Furthermore, in those pictures is also presented the quick visualization chart of the consumption trend from the past month for a specific main use, using 'sparkline'.

```

var numConnections = diagram.connections.length;
var _items = [];
for (var i = 0; i < numConnections; i++) {
  _items.push(diagram.connections[i].to.dataItem.absValue / _parentConsumption);
  _med += (diagram.connections[i].to.dataItem.absValue / _parentConsumption);
}
_max = Math.max.apply(null, _items);
_min = Math.min.apply(null, _items);
_med = _med / _items.length;

for (var i = 0; i < numConnections; i++) {
  var shape1 = diagram.connections[i].from;
  var shape2 = diagram.connections[i].to;

  var posShape1 = shape1.getPosition("bottom");
  var posShape2 = shape2.getPosition("top");

  var point1 = {
    x: posShape1['x'],
    y: posShape1['y'] + ((posShape2['y'] - posShape1['y']) / 2)
  };

  var point2 = {
    x: posShape2['x'],
    y: point1['y']
  };
  diagram.connect(shape1.connectors[3], shape2.connectors[2], {
    stroke: {
      width: 15,
      color: getColorForPercentage(diagram.connections[i].to.dataItem.absValue / _parentConsumption),
    },
    points: [point1, point2]
  });
}

```

Figure 4.26: Function for color association to KendoDiagram connections.

#### 4.4.4 Energy Efficiency

The conceptualization of the dashboards for the standard was made in chapter 2. In this section the idealized interfaces, although not implemented, are presented in the form of mockups.

##### 4.4.4.1 Operational Dashboard

The operational dashboard, as is intended for the responsible actors on the standard implementation and maintenance, seen in figure 4.27, presents a visual menu of the ISO 50001 components of the EMS. According to the analysis done, were the standard's requirements were classified under the EMS model for ISO 50001, the links under those same classifiers are redirect to pages were tasks are performed or pages were information produced is present.

Important to the daily management of the standards tasks, alerts and occurrences produced for the system are shown. A preview of the documentation regarding the selected menu is displayed in the bottom area of the interface, with the possibility of document management without leaving the dashboard.

##### 4.4.4.2 Certification Dashboard

This interface, exemplified in the mockup of figure 4.28, as it intends to present the various processes that are part of the standard implementation and maintenance, provides a workflow visualization of the tasks involved in each process. In the example of that same figure, and according to

the survey made in chapter 3, the energy planning process, its phases and tasks, are organized in the interface, where an occulted menu can be accessed on the left, showing the complete processes list.

The darker phases in the process diagram indicate the input and output elements of the process, and the green phase relates to the selection made by the user.

#### 4.4.4.3 Audit Dashboard

In this last dashboard for the ISO 50001 module, the requirements of the standard are presented under the original documentation classification. A status for each category is presented as a color on the right side of the category row. For each individual requirement, information about the responsible actor and the completion status is presented. The user can attribute a status clicking on the respective check box, updating the left-hand side of the interface.

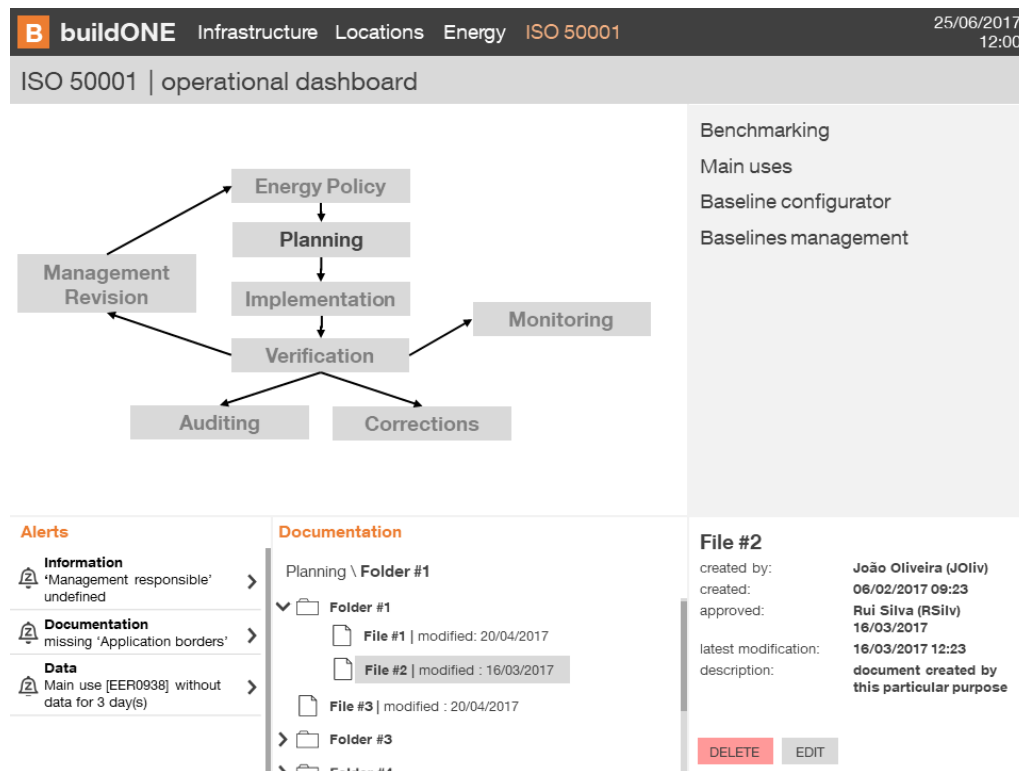


Figure 4.27: Mockup for ISO 50001 Operational Dashboard.

In this latter area, the completion status is presented for the all system in the form of a bar chart and the disaggregated statues of the standard's requirement categories are displayed using a radar chart. This type of data presentation is useful when dealing with multiple data categories.

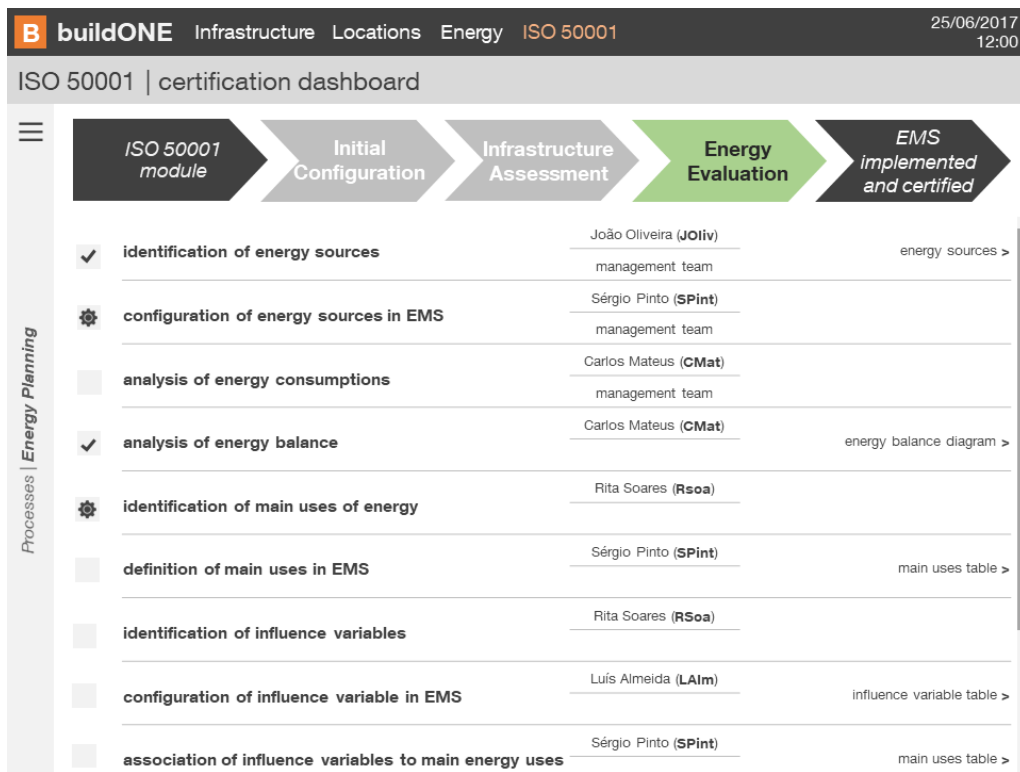


Figure 4.28: Mockup for ISO 50001 Certification Dashboard.

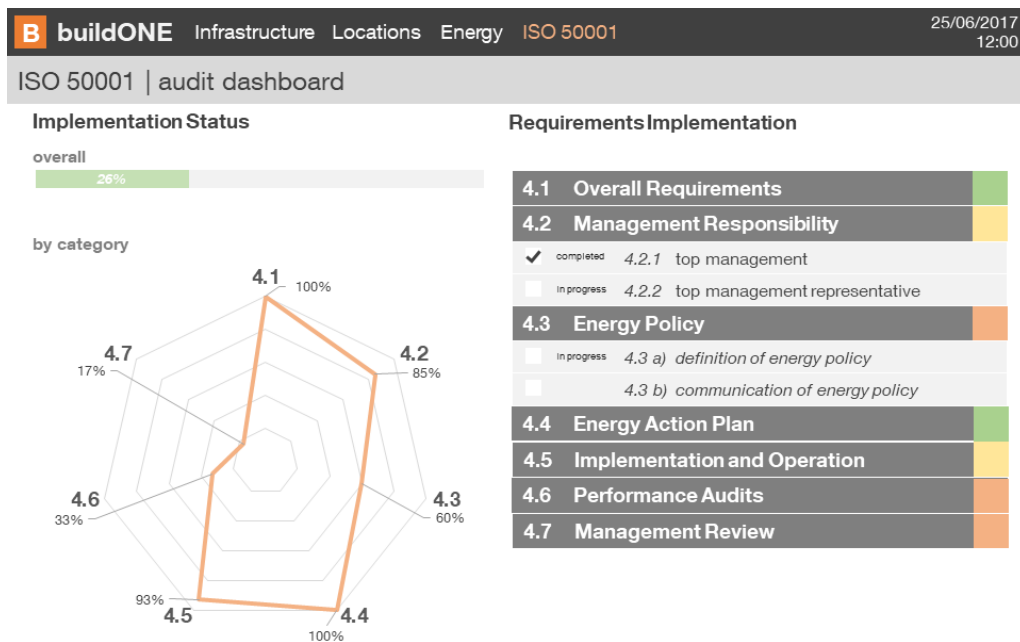


Figure 4.29: Mockup for ISO 50001 Audit Dashboard.

#### 4.4.4.4 Main Uses Overview

Presenting the equipment defined as main energy users, for uniformization purposes across the system, utilizes the same interface construction as the Equipment Dashboard, figures 4.30 and 4.31, together with the employment of the KendoMap feature to display the location of the main uses.

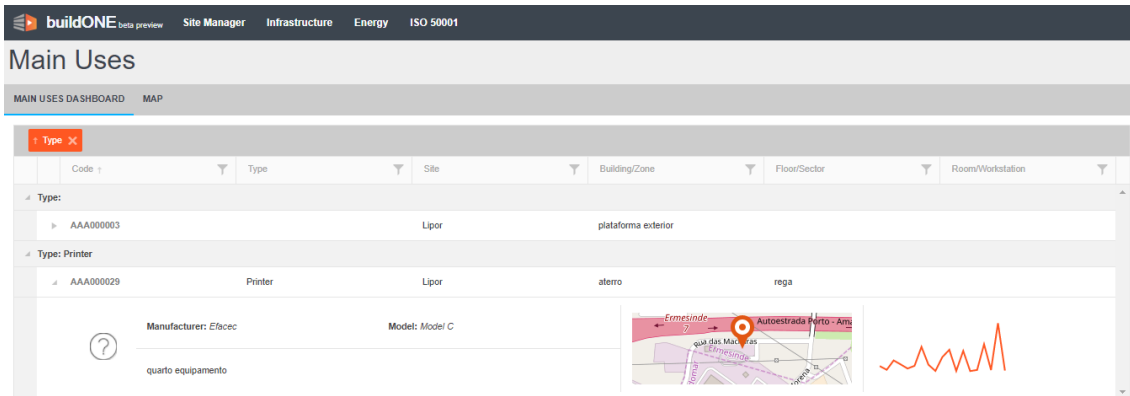


Figure 4.30: Main Uses presentation interface.

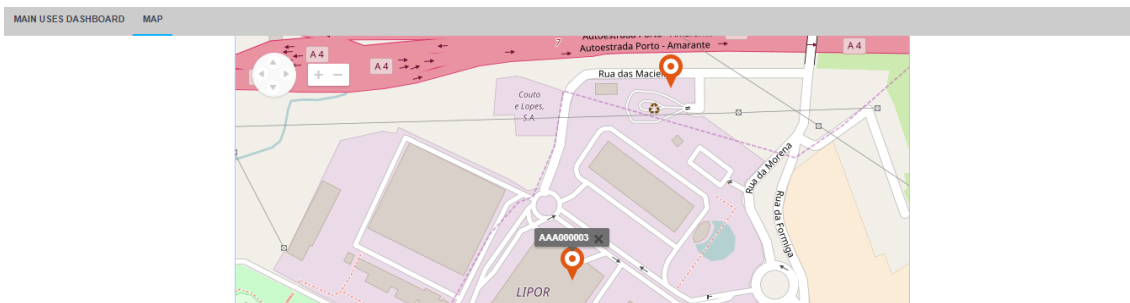


Figure 4.31: Location of main uses tab, in Main Uses interface.

#### 4.4.4.5 Baseline Configuration

In the core features of the ISO 50001, and as major value-added function of a third generation EMS, is the possibility of defining the baseline for an equipment, node or main use of energy. In subsection 3.2.2 an example of this configuration is made for set of consumption points retrieved from the current buildONE solution. In the example, and as demonstrated in the plot of figure 4.32, the baseline uses a linear equation in its definition, either by manual input of trial and error parameters to the equation or by linear regression analysis.



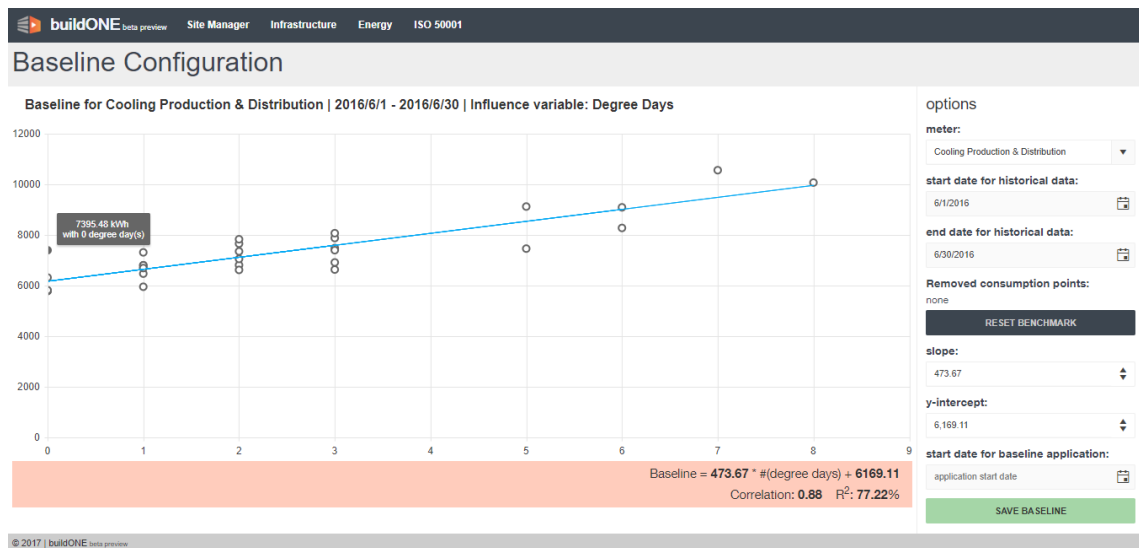


Figure 4.32: Baseline Configuration interface.

In the development of an interface that translated these functionalities, three primary areas were designed, and exhibited in figure 4.32: graphical visualization, baseline configuration and baseline equation data.

- **Graphical visualization:**

From the ISO 50001 requirements, subsection 2.2.3, the essential data for the definition of the baseline is the historical data, for both consumption and influence variable. This visualization was implemented using another Kendo UI chart component, configured to ‘scatter’ chart, 4.33.

```

_chartBaseline = $("#_chartBaseline").kendoChart({
  theme: "material",
  dataSource: {
    transport: {...},
    change: function (data) {
      $.each(_toRemoveIndexChart, function (index) {
        data.items.splice(_toRemoveIndexChart[index], 1);
      });
    },
    sort: {...}
  },
  legend: {...},
  series: {...},
  tooltip: {...},
  seriesClick: function (e) {
    _toRemoveNodeID.push(e.dataItem.ValueID);
    _toRemoveIndexChart.push(e['point'].pointIx);
    $("#_divRemovedPoints").text(_toRemoveNodeID.toString());
    linearRegression();
    setBaselineChart();
  },
}).data("kendoChart");

```

Figure 4.33: Function for baseline chart presentation and outliers removal on consumption point click.

The stored procedure, in SQL Server and demonstrated in fig 4.34, connects the selected consumption node with correspondent consumption values for the desired time range, which is retrieved by the KendoChart using a specific webservice, displayed in fig 4.35.

```

DECLARE @InitDatePrevYear as DATETIME = DATEADD(year,-1,@InitDate)
DECLARE @EndPrevYearDate as DATETIME = DATEADD(year,-1,@EndDate)
SELECT TOP(@ResultsNumber)
    Equipments.ID, Equipments.Code,
    Equipments.Level1ID, Equipments.Level2ID, Equipments.Level3ID, Equipments.Level4ID,
    Functions.Title AS FunctionTitle, Types.Title AS TypeTitle,
    SecondLevels.Title as SecondLevelTitle,
    SUM(fnCurrYear.Consumption) as TotalConsumptionCurrYear,
    SUM(fnPrevYear.Consumption) as TotalConsumptionPrevYear,
    CASE
        WHEN SUM(fnPrevYear.Consumption) <> 0 THEN SUM(fnCurrYear.Consumption)/SUM(fnPrevYear.Consumption)
        WHEN SUM(fnPrevYear.Consumption) = 0 THEN '0'
    END AS Ratio
from Equipments
CROSS APPLY dbo.fn_getValuesDay(@VariableTypeID,Equipments.ID,@InitDate,@EndDate) as fnCurrYear
CROSS APPLY dbo.fn_getValuesDay(@VariableTypeID,Equipments.ID,@InitDatePrevYear,@EndPrevYearDate) as fnPrevYear
LEFT JOIN Types ON Types.ID = Equipments.TypeID
LEFT JOIN Functions ON Functions.ID = Types.FunctionID
LEFT JOIN SecondLevels ON SecondLevels.ID = Equipments.Level2ID
WHERE Equipments.IsActive = 1
GROUP BY Equipments.ID, Equipments.Code,
    Equipments.Level1ID, Equipments.Level2ID, Equipments.Level3ID, Equipments.Level4ID,
    Functions.Title, Types.Title,
    SecondLevels.Title
ORDER BY Ratio DESC

```

Figure 4.34: Stored procedure implemented for baseline chart supply and forecasted consumption calculation.

```

[WebMethod]
[ScriptMethod(ResponseFormat = ResponseFormat.Json)]
-references | 0 exceptions
public void GetEquipmentsRelativePrevYearEffectiveConsumption(
    string initDate, string endDate, string variableTypeID, string resultsNumber
)
{
    try
    {
        using (AppData.ModuleDataContext _db = new ModuleDataContext())
        {
            Context.Response.Clear();
            Context.Response.ContentType = "application/json";

            DateTime _initDate = Convert.ToDateTime(initDate);
            DateTime _endDate = Convert.ToDateTime(endDate);
            int? _variableTypeID = string.IsNullOrEmpty(variableTypeID) ? (int?)null : Convert.ToInt32(variableTypeID);
            int? _resultsNumber = string.IsNullOrEmpty(resultsNumber) ? (int?)null : Convert.ToInt32(resultsNumber);

            List<GetEquipmentsRelativePrevYearEffectiveConsumptionResult> _lEquipmentsRelativePrevYearEffectiveConsumption
                = _db.GetEquipmentsRelativePrevYearEffectiveConsumption(
                    _initDate, _endDate, _variableTypeID, _resultsNumber
                ).ToList();

            JavaScriptSerializer js = new JavaScriptSerializer();
            js.MaxJsonLength = int.MaxValue;
            Context.Response.Write(js.Serialize(_lEquipmentsRelativePrevYearEffectiveConsumption));
        }
    }
    catch (Exception exception) { throw new Exception("WebService error (GetEquipmentsRelativePrevYearEffectiveConsumption

```

Figure 4.35: Web service used to supply the baseline chart and calculate the forecasted consumption.

- **Baseline configuration:**

In the right section of the interface, in line with the rest of the interfaces developed, the options for the baseline configuration are presented, where the user will input the desired data to retrieve the consumption, influence variables and baseline values.

This is accomplished using KendoComboBox, KendoDatePicker and KendoNumericTextBox, that create the necessary input fields in the webpage. The user can select the node or equipment that the baseline will be attributed to, and the base period for the historical data. The linear baseline parameters, currently the only form of baseline implemented, are automatically calculated when the user defines the previous information. Simultaneously, the baseline equation is plotted in the joined chart of the historical data, as seen in figure 4.32.

The options menu also contemplates two KendoNumericTextBox's that correspond to both K1 and K2 parameters of the linear equation. Their value is automatically updated when the baseline equation is calculated. However, these also serve as input for custom changes in the equation, as when the 'change' event is triggered the baseline equation and its plot are updated, through the function displayed in figure 4.36. The user can, therefore, visualize the baseline equation and perform trial and error experiments on the equation, and see the result immediately.

```
$.ajax({
  url: "/Services/Webservices.asmx/GetInfluenceVariablesConsumptions",
  data: ...,
  type: "POST",
  async: false,
  success: function (e) {
    var _data = e;
    $.each(_data, function (index) {
      if ($.inArray(_data[index].ValueID, _toRemoveNodeID) != (-1)) {
        _toRemoveIndex.push(index);
      }
    });
    _toRemoveIndex.sort(function (a, b) { return b - a });
    $.each(_toRemoveIndex, function (index) {
      _data.splice(_toRemoveIndex[index], 1);
    });
    _n = _data.length;
    $.each(_data, function (index) {
      _avgY += _data[index].Consumption;
    });
    _avgY = _avgY / _n;
    $.each(_data, function (index) {
      _ssTot += Math.pow(_data[index].Consumption - _avgY, 2);
      _ssRes += Math.pow(_data[index].Consumption - _data[index].Baseline, 2);
    });
    _rSquared = (1 - (_ssRes / _ssTot))*100;
    _correl = Math.sqrt(_rSquared/100);
    _toRemoveIndex = [];
    $("#_valueCorrelation").text(_correl.toFixed(2));
    $("#_valueRSquared").text(_rSquared.toFixed(2));
  },
  error: function (xhr, textStatus, errorThrown) ...,
});
```

Figure 4.36: Developed function for correlation and coefficient of determination calculation, using manual inputted baseline parameters.

- **Baseline equation data:**

The third area of the webpage is located below the baseline chart and presents the information that is the intended output of this process. The baseline equation, in case of figure 4.32 being a linear equation, is presented alongside the relevant parameters that translate the baseline fit with the historical data: namely the correlation factor and the coefficient of determination. This field of the interface is automatically updated when any changes are made in the graphical visualization or in the baseline options.

Increasing the functionality and usefulness of this page, a complementary feature was implemented in the graphical visualization. Many times, the historical consumption values can be affected by other factors rather than the determined influence variable, causing the presence of outlier points in the baseline chart. These consumption points are not relevant to the baseline calculation. Using the 'seriesClick' event of the KendoChart component it was possible to implement the outliers' removal feature by selection of the consumption point, directly in the baseline chart. This function is exhibited in figure 4.33.

```

success: function (e) {
    var _data = e;
    $.each(_data, function (index) {
        if ($.inArray(_data[index].ValueID, _toRemoveNodeID) != (-1)) {
            _toRemoveIndex.push(index);
        }
    });
    _toRemoveIndex.sort(function (a, b) { return b - a });
    $.each(_toRemoveIndex, function (index) {
        _data.splice(_toRemoveIndex[index], 1);
    });
    _influenceVariableTitle = _data[0].InfluenceVariableTitle;
    _n = _data.length;
    $.each(_data, function (index) {
        _avgX += _data[index].Value;
        _avgY += _data[index].Consumption;
    });
    _avgX = _avgX / _n;
    _avgY = _avgY / _n;
    $.each(_data, function (index) {
        _a = _data[index].Value - _avgX;
        _b = _data[index].Consumption - _avgY;
        _ab += (_a * _b);
        _a2 += Math.pow(_a, 2);
        _b2 += Math.pow(_b, 2);
    });
    _correl = _ab / (Math.sqrt(_a2 * _b2));
    _rSquared = Math.pow(_correl, 2)*100;
    $.each(_data, function (index) {
        _sX += Math.pow(_data[index].Value - _avgX, 2);
        _sY += Math.pow(_data[index].Consumption - _avgY, 2);
    });
    _sX = Math.sqrt(_sX / (_n - 1));
    _sY = Math.sqrt(_sY / (_n - 1));
    _slope = _correl * _sY / _sX;
    _yIntercept = _avgY - _slope * _avgX;
    _tbK1.value(_slope);
    _k1 = _slope;
    _tbK2.value(_yIntercept);
    _k2 = _yIntercept;
},

```

Figure 4.37: Linear regression function implemented.

Two main actions derived from this outlier selection: its removal from the chart data source, even when it is reloaded, and its elimination from the parameters calculation data. Consequently, the linear regression function, implemented as figure 4.37 shows, recalculates the baseline equation, the chart is updated and so is the baseline equation data area of the interface, inclusively the correlation and determination coefficient.

#### **4.4.4.6 Savings**

Finally, in the ISO 50001 model features is the savings interface, which aims to display graphically the savings and cost avoidance, positive or negative. The interface, although not implemented in the system, should present the results of the data presented in figures 3.5 and 3.6, demonstrates:

It is mainly comprised of a main area, using KendoChart element, with the difference between the baseline and the actual consumption, with a secondary area of options that allow the user to select the main use and the savings type, instantaneous or accumulated, through the use of KendoCombobox's, and choice of the period from which the calculations will be made, similarly to the other presented interfaces using KendoDatePicker elements to store the initial and end date.



# Chapter 5

## Testing and Validation

Following the implementation reported in chapter 4, the usability of the developed interfaces and its features are demonstrated in this chapter, through sections 5.1 to 5.4. In the various interfaces is shown information of Lipor and Sonae MC, which, as explained previously, are the current solicitors of this module. The demonstration of interfaces is divided in four sections, in line with the organization made on the other chapters of this MSc dissertation, when explaining the conceptualization behind the interfaces or its actual realization.

Afterwards, completed the development of the proposed interfaces, a integration in the new version of Dreamo's EMS was performed by the buildONE team that is explored in section 5.5.

### 5.1 Site Manager Test

The systems current home page is set to be the site manager component, with the Facilities Map interface, exposed in section 4.4.1, that can also be accessed through the 'Site Manager' entry on the EMS top menu.

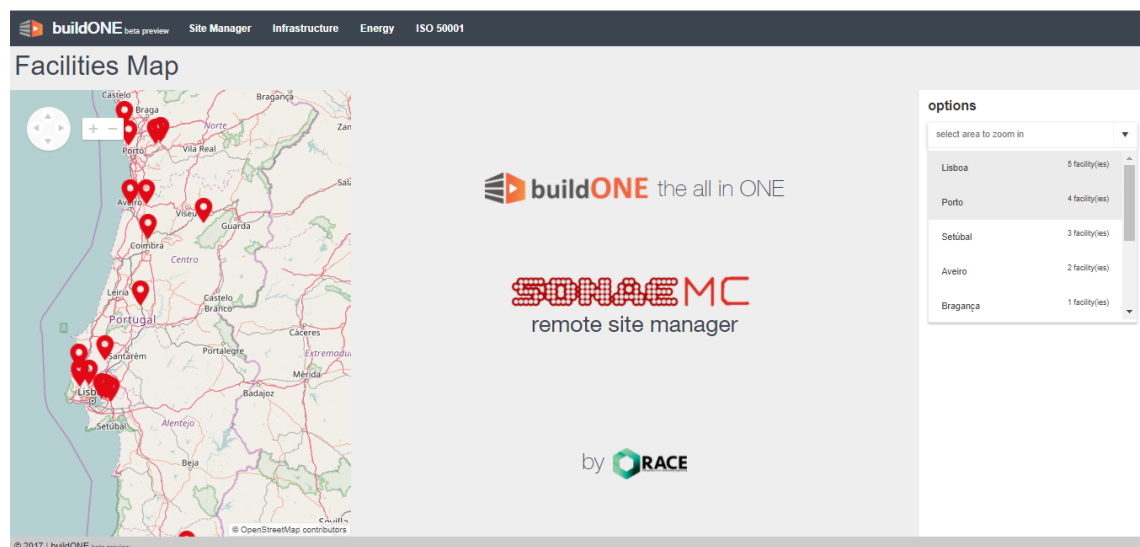


Figure 5.1: Initial page of Site Manager.

This interface, in figure 5.1, is currently dedicated to the facilities of SonaeMC that adopt the buildONE solution. The user can visualize the facilities location on the map, zooming in or out and moving it freely. Using the options menu, the user in this case selects the ‘Porto’ option, immediately perceiving that in this district four facilities will be presented.



Figure 5.2: Presentation of the selected facility’s information.

The map will then focus in the geographical center of Porto’s facilities, and present only these four facilities, even if the user further moves the map to other area. When a marker is clicked, the name of the facility is displayed next to its location and the central interface are fades out and in, this time with the information on the facility selected, exemplified in figure 5.2. By clicking in the ‘Reset Map’ button, in the options menu, the map is restored to its initial visualization mode.

## 5.2 Infrastructure Management Test

Moving to the next menu entry, the principal interface is the ‘Equipment Dashboard’, with the related implementation in section 4.4.2.1. The totality of the equipment is presented initially in this page. Typically, the user can in this webpage see information, open the equipment detailed page, delete and add new equipment.

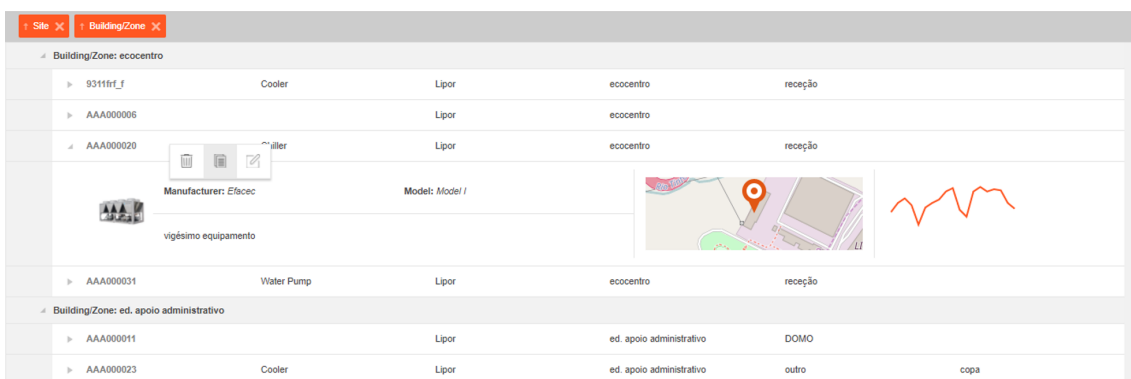


Figure 5.3: Equipment Dashboard interface with expanded row and context menu.



The user can configure the information presentation on the grid of equipment, by sorting, filtering or grouping by the columns presented. In figure 5.3, the equipment are grouped by Site and then by Building or Zone. Each row displays an arrow that allow its expansion. In the same figure, the user expanded the row corresponding to equipment with the code “AAA000020”. In this section more information is detailed, as its location the ‘Eccentro’ building.

The context menu is accessed with a right mouse click on the equipment row, appearing the three mentioned options in section 4.4.2.1. Clicking in the ‘Copy equipment data option’, the middle one in the context menu, the hidden form for addition of a new equipment is opened, as demonstrated in figure 5.4, with the selected equipment data.

Figure 5.4: Form for adding new equipment.

The user can then further change the several fields information, seeing the list of equipment bellow the form updating its content based in the new equipment location. In figure 5.5 is displayed the result from saving the form data, that will automatically close and present the newly added equipment in the grid. Filters, as the exemplified in figure 5.6 refines the list, and in this case shows the previously added equipment with code “NEW000000”.

Building/Zone: eccentro				
▶	AAA000006		Lipor	eccentro
▶	AAA000020	Chiller	Lipor	eccentro
▶	AAA000031	Water Pump	Lipor	eccentro
▶	NEW000020	Chiller	Lipor	eccentro

Figure 5.5: Added equipment presented in the Equipment Dashboard.

Figure 5.6: Organization of equipment per function interface.

The information of figure 5.7 is accessed through the ‘Equipment’s per Function’ tab.

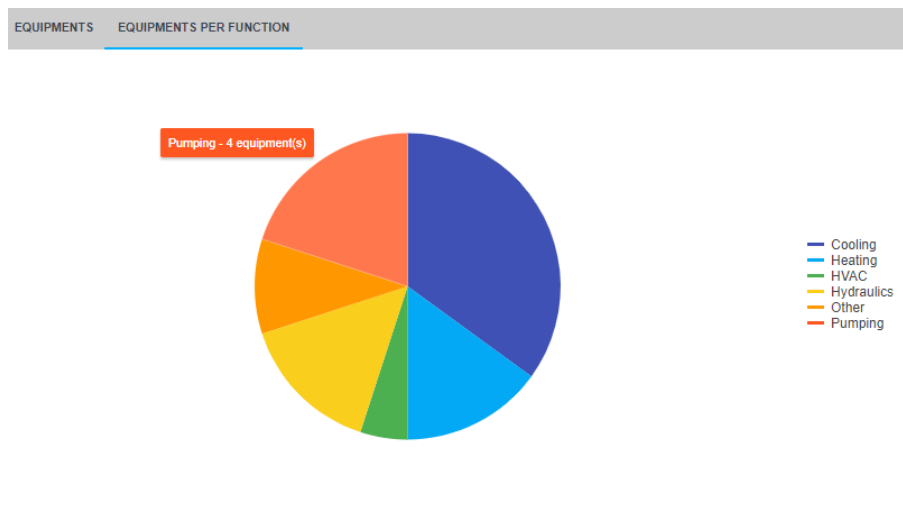


Figure 5.7: Organization of equipment per function interface.

In order to edit the rest of the information for the newly added equipment, “NEW000000”, the related Equipment Page is accessed clicking in the code area of its row, or in the context menu of figure 5.3, displaying the interface exposed in figure 5.8.

Field	Value
Site	Lipor
Building/Zone	ecocentro
Floor/Sector	recepção
Workstation/Room	room/workstation
Location type	room
Coordinates	[41 199537,-8.551659]
ID	132
Code	AAA000020
Description	vigésimo equipamento
Equipment type	Chiller
Function	function: Heating
Manufacturer	Efacec
Model	Model I

Figure 5.8: Equipment detail page for newly added equipment “NEW000000”.

Accessing the page through the context menu inherently enables the edition of the different fields. The user can then choose the manufacturer and model, and edit the location fields. Further the user selects the geographical location of the equipment in the ‘Ecocentro’ building in the map. The coordinates are updated in the correspondent field, and after saving, the edition ability of the fields is disabled, changing its appearance to a more faded visualization, as viewed in figure 5.9.

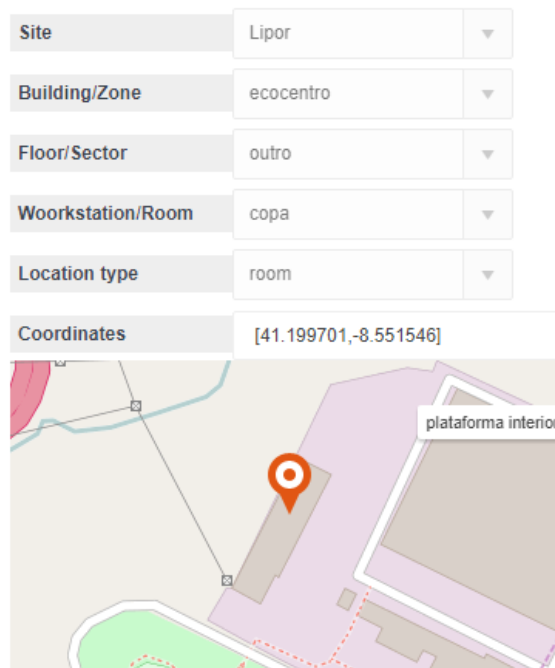


Figure 5.9: Equipment information fields disabled.

A quick view of the equipment energy consumption can be accessed by ‘Consumption’ tab, which displays the current month data:

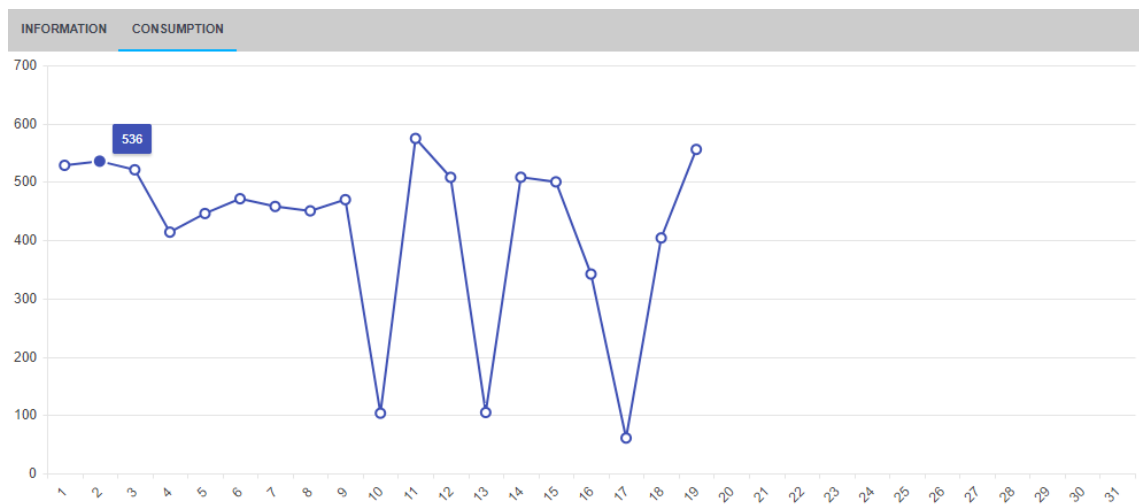


Figure 5.10: Energy consumption chart in the Equipment Page.

The map visualization of the organization’s equipment is present within the ‘Infrastructure’ menu, showing the equipment that have the coordinates information defined. The user can view, in the interface presented by figure 5.11, the organization site plant, exemplified with the Lipor plant in Baguim do Monte.

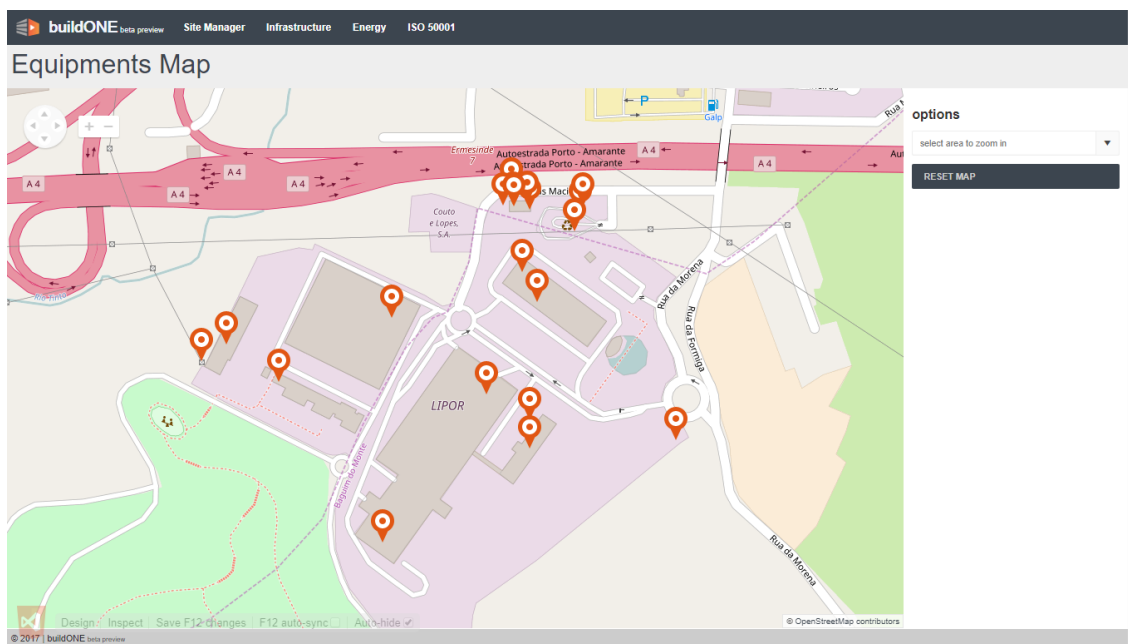


Figure 5.11: Equipment Map interface.

The user can treat this map as an alternative equipment dashboard. An option is provided (figure 5.12) to filter the shown equipment, that presents the Buildings and Zones of the Lipor site. By selecting one of the selection entries, the map is focused on that location, only showing the correspondent equipment.

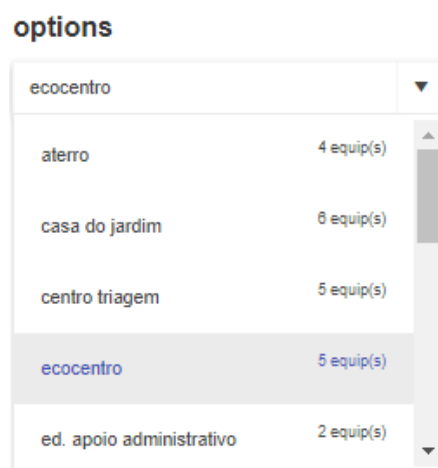


Figure 5.12: Equipment Map filter option.

Figure 5.13, demonstrates the selection of an individual equipment, through its marker on the map, presenting a small menu with the possibility of redirection to the equipment page, for information edition.

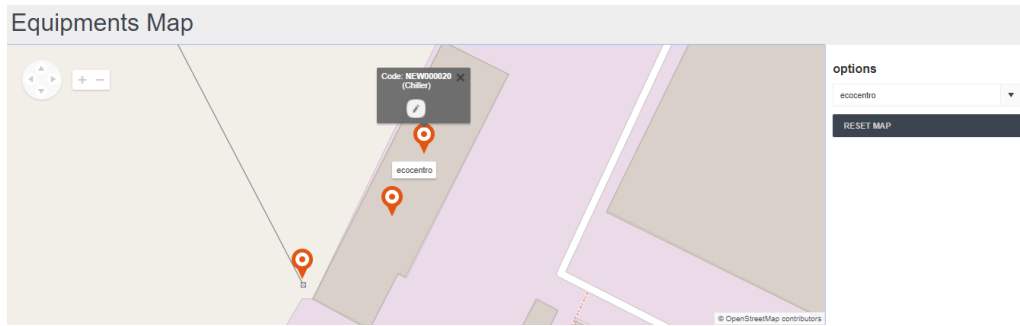


Figure 5.13: Selection of individual equipment in the Equipment Map interface.

### 5.3 Energy Analysis Test

Having configured the company’s infrastructure, the user can then assess the energy consumption data, in the Energy Analysis menu. This comprises two options, ‘Energy Monitoring’, ‘Benchmarking’ and ‘Energy Flow’.

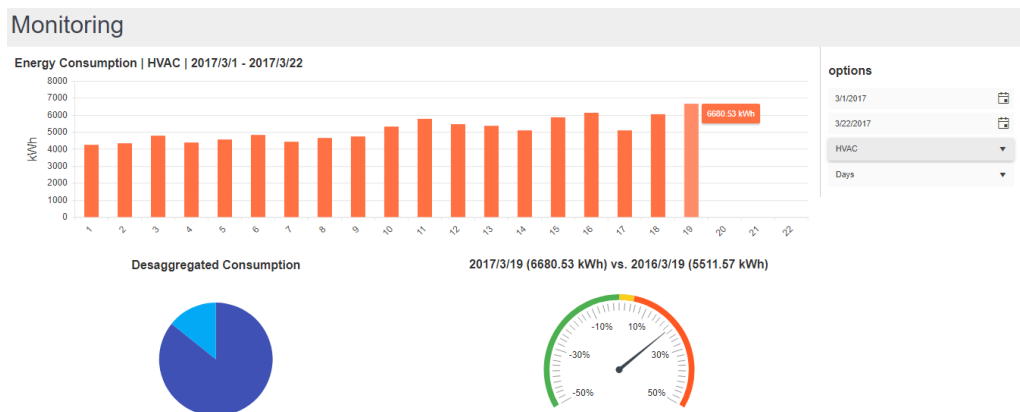


Figure 5.14: Energy Monitoring interface, for HVAC node with daily resolution.

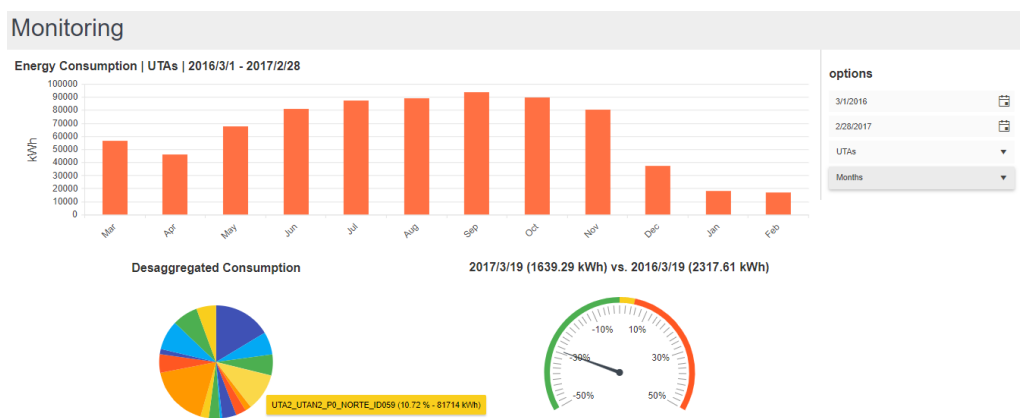


Figure 5.15: Energy Monitoring interface, for ATU’s (Air Treatment Unit) node with monthly resolution.

This page is configured by the options area, where selection of the period, the measurement node and the time resolution can be selected. The charts presented are automatically refreshed as the options are changed. Figures 5.14 and 5.15 present two examples of configuration of the webpage. Both differ in the selected consumption node, the period selected and the data resolution. In the same line, two examples are presented in figures 5.16 and 5.17 that demonstrate the usability of the Benchmarking interface.

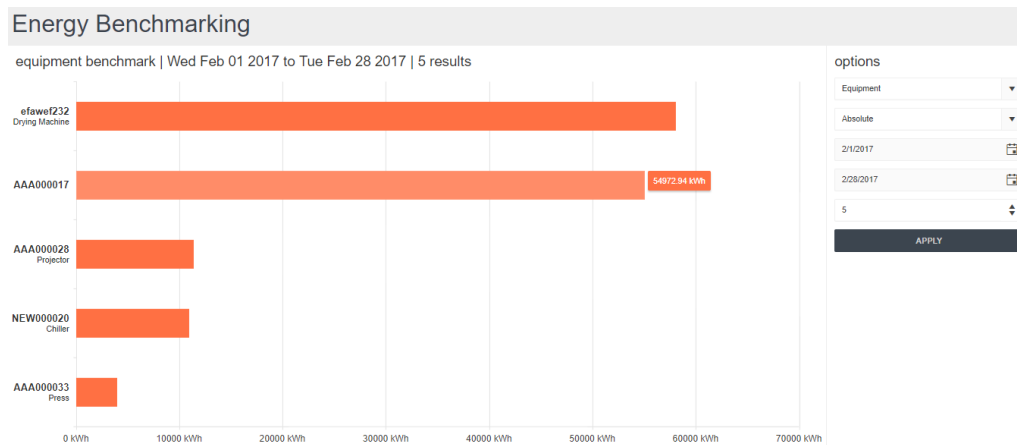


Figure 5.16: Benchmarking interface example, for equipment absolute consumption.

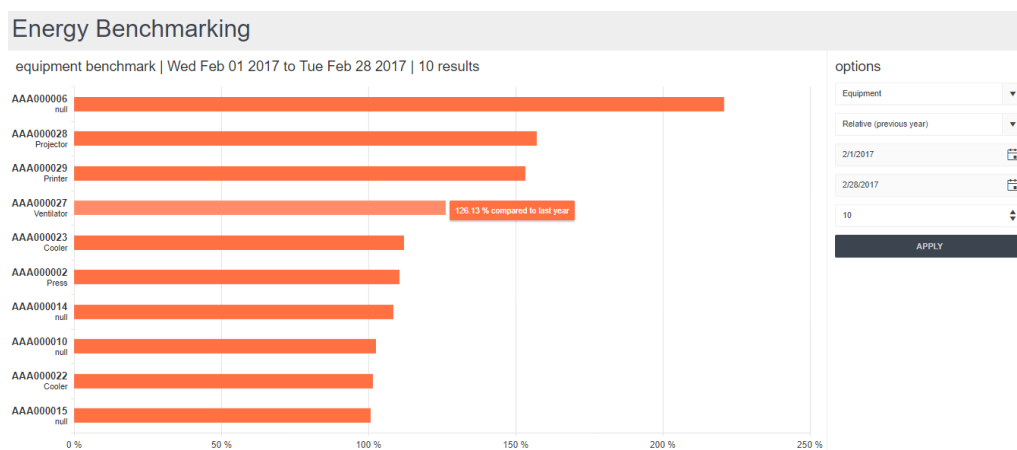


Figure 5.17: Energy Monitoring interface, for equipment relative consumption.

The user can select the type of benchmarking, the period of time for consumption data and the number of results to be presented. Contrary to the previous interface, in this one the validation of the configured options, and consequent display of the benchmark data, is made with the user clicking the 'Apply' button. In tooltip, the specific to each element of the chart, is presented the consumption value, absolute or relative and the user can access the Equipment Page interface both via a click on the axis label or in the actual bar of the chart.

## 5.4 Energy Efficiency Test

Similarly to the infrastructure related interfaces, the functionalities on the main uses dashboard and map are quite the same. The definition of an equipment as a main use of energy is made in the equipment page, in the options menu. Hence, the presentation of all the identified main uses of energy is made in the interface of figure 5.18.

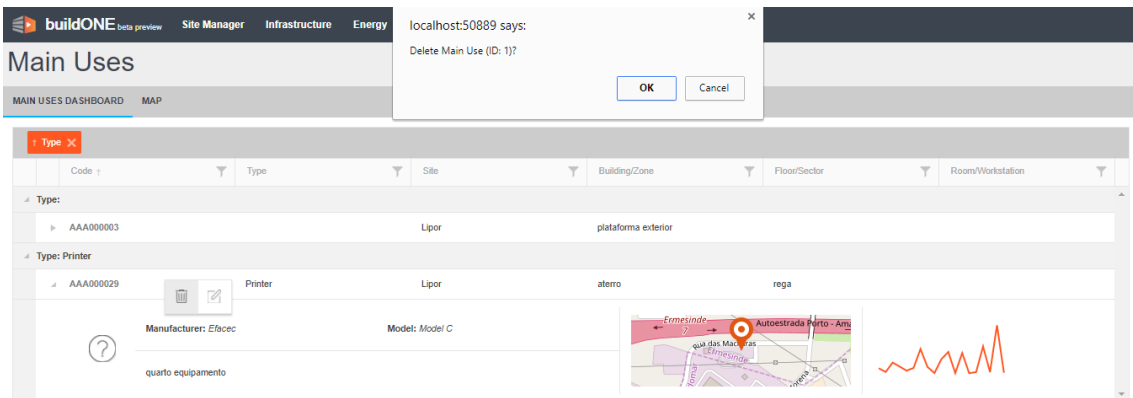


Figure 5.18: Presentation of the list of energy main uses.

The interface is close to the Equipment Dashboard, and the user can view a list of the main uses, expand the related row to view additional detail on that element. A context menu serves to delete the equipment as a main use, demonstrated in figure 5.18, and to redirect to the equipment edition page. As for the map display, figure 5.19 exemplifies such interface accessed by the ‘Map’ tab in the Main Uses Dashboard.

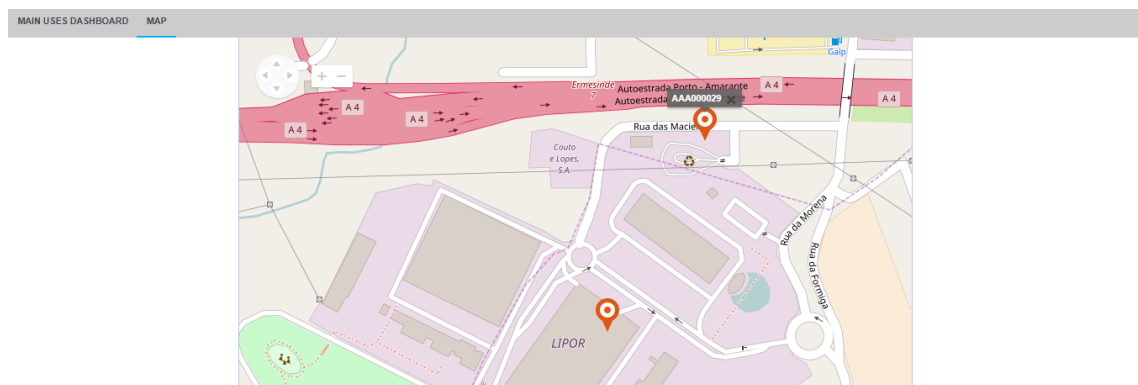


Figure 5.19: Map display of the main uses of energy in the organization’s plant.

For the defined main uses, and explained in the previous paragraphs, the user can therefore, via the ‘Baselines’ menu, configure the different consumption baselines.

options

**meter:**  
HVAC

**start date for historical data:**  
6/1/2016

**end date for historical data:**  
6/30/2016

**Removed consumption points:**  
none

RESET BENCHMARK

**slope:**  
573.92

**y-intercept:**  
8,623.48

**start date for baseline application:**  
application start date

SAVE BASELINE

Figure 5.20: Options menu for the baseline configuration.

In the Baseline Configurator interface, the user has available a series of menu, under the ‘Options’ label, that are used to configure the data presented in the rest of the webpage and, also, the actual baseline equation. Figure 5.20 demonstrates this menu. To begin the data presentation in the chart, and show the relation between consumption and the influence variable that affects it, the user has to configure the three first fields, namely: ‘meter’ – where the selection of the main use is made, and the ‘start’ and end ‘date for historical data’ – that will define the period from which the baseline will be established. Figure 5.21 shows the correspondent data that can be selected, for both the ‘node’ selection and the ‘start’ and ‘end’ date.

**meter:**

HVAC

BROWSE BY

SYSTEMS

TOTAL ENERGY - CONTRACTS

CORPORATE INDICATORS

OTHER INDICATORS

HVAC

LIGHTING

MECHANICAL TRANSPORT

**start date for historical data:**

6/1/2016

JUNE 2016

Su	Mo	Tu	We	Th	Fr	Sa
29	30	31	1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	1	2
3	4	5	6	7	8	9

FRIDAY, JUNE 23, 2017

Figure 5.21: Type of options in the baseline configurator period and node.



After selecting the aforementioned configurations, the user can hence view the display of the consumptions values per influence variable. In the presented case of figure 5.22, and selected the HVAC use of energy, from June 1<sup>st</sup> and June 30<sup>th</sup>, 2016, the plot of the consumption values is presented in the form of gray circles. The user has then the possibility of seeing the detailed consumption, hovering the points with the mouse.

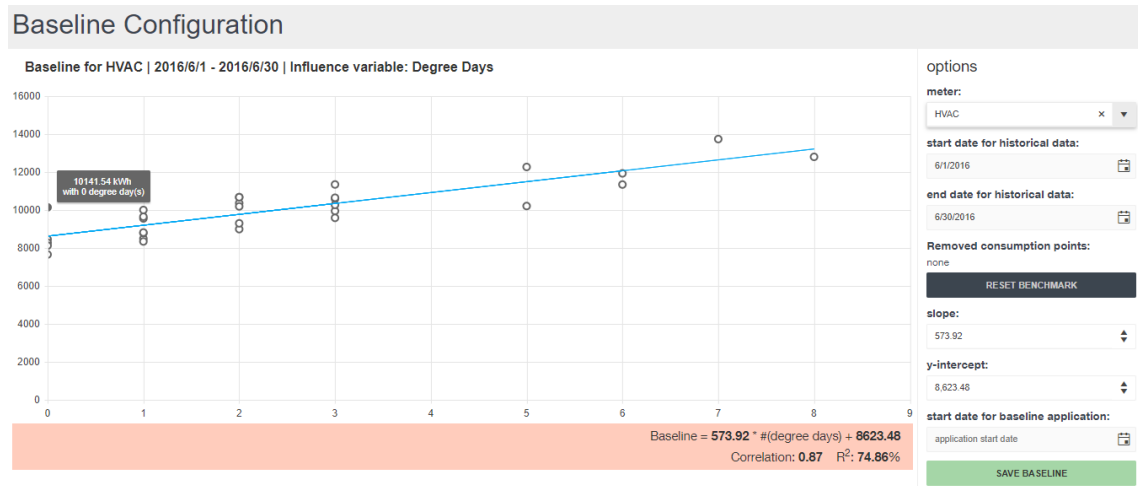


Figure 5.22: Baseline Configurator interface, after initial input from user.

Still, in the same moment, the system automatically calculates the baseline expression that best fits the consumption values retrieved. This information is presented in three areas, below the chart in the form of equation and the correlation and determination coefficient, in the options menu as parameters ‘slope’ and ‘y-intercept’, and finally in the actual chart with the plotting of the previous mentioned equation.

As explained in chapter 4, of the system implementation, a significant valued feature for correct baseline calculation is the removal of outlier points of consumption. In figure 5.22, the user can perform such task by directly clicking in the points which are intended to be removed. In the same figure, is identified one of the points to be removed, as an example of this functionality.

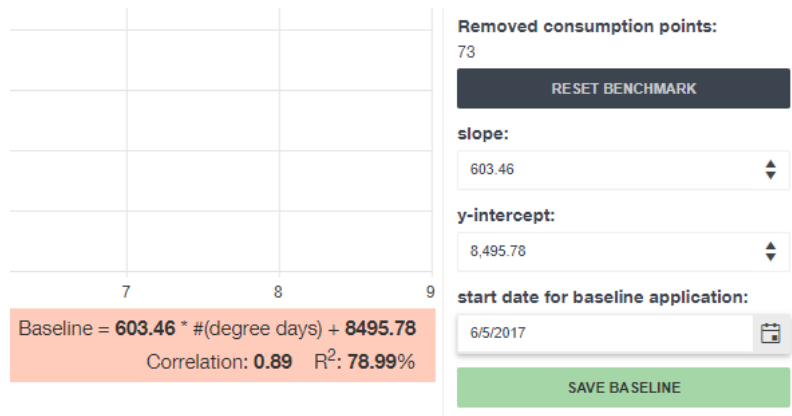


Figure 5.23: Baseline data after elimination of one outlier.

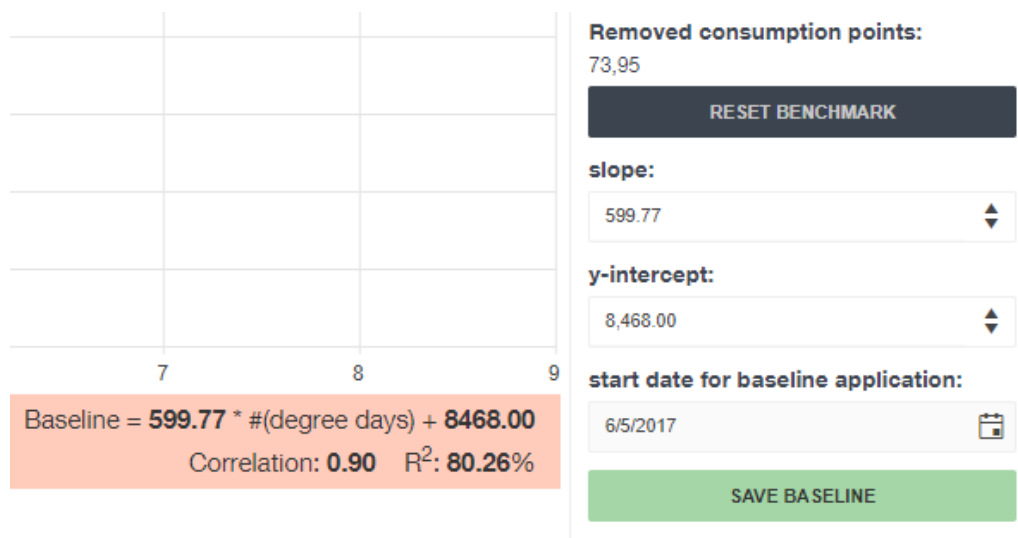


Figure 5.24: Baseline data after the elimination of two outliers.

It is proven to the user, that after the selection of the outlier consumption point number '73', and following point number '95', that the baseline equation changes and the correlation and coefficient of determination factors significantly improve in this scenario.

Afterwards, the user can then save the baseline equation after the definition of the date by which the baseline will be active.

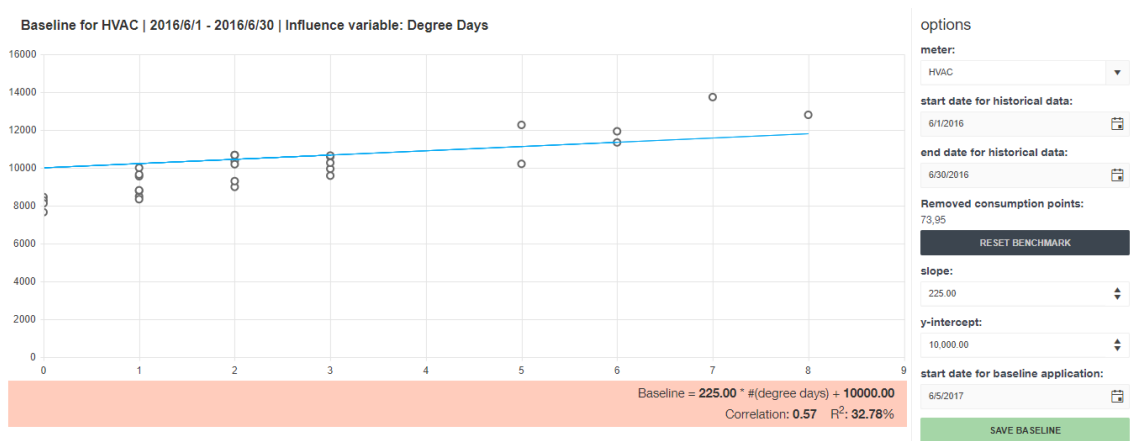


Figure 5.25: Baseline Configurator with manual definition of equation parameters.

Yet, there is also the possibility of manual definition of the 'slope and 'y-intercept' values. The user does so by inputting these values in the options menu correspondent fields. The system automatically refreshes the chart, under the new baseline equation, and recalculates the baseline data. For the shown example of figure 5.25, it is perceived that a deterioration of the baseline equation factors occurs.

## 5.5 Technical Validation and System Integration

The developed solution, of the ISO 50001 module and associated functionalities, was made in a separated environment from the solution being simultaneously developed by the buildONE team. The database was copied from the currently used by Dreamo's EMS, and only the structure for solution code development in line with the used by Dreamo team was used. As the development made by Dreamo's team and performed in the context of this dissertation projects were based in the same coding and database structure, and further evolved from that core, its integration was eased and the required changes were minimal.

Integrating the outputs of this dissertation project required the upload of the database structure to the final one and the importing of the files produced in the coding of the solution.

During the development phase, a PDCA methodology for the collaboration with the host solution developers and the supervisor was employed. Preceding any concrete development, an analysis of the interfaces to be produced and the requirements they should comply with was made, proceeded by the actual development. The team performed an analysis on the code produced, approving and integrating it or suggesting corrections, which were taken into consideration and implemented. This cycle was made recurrently until the final integration of the results reported on this document.

Not only the concrete features were evaluated, but also the design and stylization of the interfaces, as well as the usability of the overall system and its suitability within the larger EMS, made in close collaboration with the project supervisor.



## Chapter 6

# Conclusions and Future Work

This project aimed to address the clients' needs regarding energy management solutions and tools, that not only perform monitoring of energy consumption, but also produced value-added information that managers may use in the decision-making process, specially those regarding with the improvement of everyday energy efficiency practices.

Approaching this problem, two key results were at stake: the analysis and design of a set of tools and functions that enable such improvement in energy efficiency and the development of a solution that implemented those features. The importance of this topic is widely recognized, in such a way the International Organization for Standardization produced a standard, ISO 50001, providing guidelines and requirements that result in the incorporation of better energy practices in industry, commerce or public services organizations.

Through the analysis of the standard, and focusing in its extensive requirements, combined with the current available solutions for energy management systems, four groups of tools were identified as key to integrate ISO 50001 standard principles in an EMS: site management, infrastructure management, energy analysis and energy efficiency. Briefly, these system components regard: (1) the management of the organization various facilities, through a dashboard that englobes all data in a single interface and acts as home page to the ISO 50001 module of the EMS; (2) interfaces that comprise the management of energy-using infrastructure of the organization, namely its equipment and energy meters, with emphasis in the categorization system used; (3) energy analysis interfaces that present relevant consumption data for energy monitoring or equipment consumption benchmark, in order to assess possibilities of improvement; and (4) the core aspect of the ISO 50001, by providing interfaces and tools for the definition of mains uses of energy, the calculation and configuration of their baseline consumption and measurement of energy savings and cost avoidance of the actions plans employed.

Several interfaces were implemented for the purposes aforementioned, demonstrated in chapter 4 and 5, being the final solution a web-based application, comprised of a database and web-pages, which allows the delivery of complex and extensive tools via a simple web browser. This type of application provides a bridge between the user interaction and the complex underneath business logic of the system, easing the installation of such system in a corporation and the sub-

sequently use by its employees. The final product was intended to be a part of a broader EMS solution, buildONE, developed by Dreamo and encompassed in the 3GEnergy project for the development of a generation of energy management solutions.

This project had many strands during its lifecycle, inclusively the thorough analysis of the standard, the development of the interfaces in previously unknown languages and frameworks, the teamwork with the company that develops the host solution, buildONE, and the collaboration with other entities and persons, namely in the definition of the system functionalities and requirements, for the integration of the buildONE solution, and hence the proposed ISO 50001 module, in two major industrial facilities.

An adaptation phase to the mentioned conditions of this project had to occur initially, and many obstacles were overridden during this project. However, the implementation of many features, after the complete analysis of the ISO 50001 and the tools needed to implement such practices, with the validation of the results and the integration on a broader EMS, prove this approach to be successful and hopefully to be implemented and used by many companies in the future.

## 6.1 Future Work

This MSc dissertation, as explained in the project methodology, comprised two essential phases that occurred recurrently and simultaneously: analysis and design of features and interfaces, and its final implementation. Also in both perspectives, several items can be identified as potential future developments.

The implementation of the other interfaces and tools proposed in the initial chapters is the next logical step. Being so, the following interfaces were identified as priority: the webpage for management of influence variables, the meters inclusion in the infrastructure management component, the baselines, savings and alarms dashboards. Additionally, giving complementarity to the buildONE EMS, an important step is the use of the already developed project management functionalities for the definition of efficiency improvement plans.

In the aspect of the baselines configuration, the implementation of other, non-linear, types of baselines and the possibility of multiple influence variables association with on main use of energy, and hence in the baseline calculation, are tools that significantly impact the added value of the ISO 50001 module, and provide an even more precise calculation of savings and cost avoidance.

Regarding an improved effectiveness assessment of the action plans, besides the savings and cost avoidance output, one possible development is the association with other defined EnPIs, or key performance indicators (KPIs), with the implementation of the associated definition and monitoring interfaces.

In line with the work developed in cooperation with other entities, that supplied inputs to the definition of the application requirements and tools, a continuous approach to the industry and the potential clients will certainly provide future improvements and additions to the solution.

## Appendix A

# ISO 50001 tasks and outputs classified under the EMS model

category	tasks	documents and data	
		type	description
energy policy	definition of scope and boundaries	doc	decision on scope and boundaries
	definition of scope and boundaries	doc	communication of scope and boundaries
	define of energy policy	doc	energy policy (integrated management policy)
	designate management representative	data	management representative
	designate management representative	doc	minute of the management's representative choice
	designate energy management team	data	management team
	designate energy management team	doc	minute of energy management team approval
	definition of scope and boundaries	doc	decision on scope and boundaries
	definition of scope and boundaries	doc	communication of scope and boundaries
	communicate energy management importance	doc	internal communication of the importance of energy management
	identification of energy management team	data	management team
	definition of responsibilities and authorities of the representative and the team	doc	communication of responsibilities and authorities of the management representative and the team
	definition of implementation and operation criteria	doc	implementation and operation criteria
	promote consciencialization of energy policy and objectives	doc	internal communication of energy policy and objetcives
	definition of energy policy	doc	energy policy (integrated management policy)
communication of energy policy	doc	internal communication of energy policy	

Figure A.1: Tasks and outputs from energy policy requirements.

category	tasks	documents and data	
		type	description
implementation and operation	analysis of the planning process	doc	document of implementation and operation guidelines
	identification of personnel skills and training requirements	doc	document of personnel training and skills guidelines
	identification of personnel related to main uses of energy	data	list of personnel involved with main uses of energy
	identification of personnel training and education necessities	data	table of personnel training needs
	calendarization of the training process	data	table of personnel training needs
	definition of the internal and external communication plan and procedures	doc	minute of the decision on internal and external plan and procedures
	definition of the internal and external communication plan and procedures	data	table of internal and external communication plan
	definition of documentation requirements for control and management	doc	minute of the decision on documentation requirements for control and management
	definition of mandatory and non-mandatory EMS documentation	doc	minute of the establishment of documentation obligatoriness
	definition of document control requirements	data	table of documents to be controlled
	definition of guidelines for operational control	doc	document of operational control guidelines
	registration of operation control activities	data	table of operation control activities
	definition of guidelines for conception of new projects, maintenance and requalification	doc	document of new projects, maintenance and requalification guidelines
	analysis of improvement opportunities conception, maintenance and requalification	data	table of potential improvement projects
	registration of activities on conception, maintenance and requalification	data	table of regist of activities
	definition of requirements for acquirement of energy, services, products and equipment	doc	minute of the decision of the requirements for energy, services, products and equipment supply
registration of acquisition of energy, services, products and equipment	doc	regist of acquisition of energy, services, products and equipment	

Figure A.2: Tasks and outputs from implementation and operation requirements.

category	tasks	documents and data	
		type	description
internal EMS auditing	review ISO 50001 implementation	doc	report of management revision
	reporting of EMS performance	doc	report of the EMS performance
	definition of guidelines for EMS internal audit	doc	document of EMS internal audit guidelines
	calendarization of the auditing process	doc	calendar of audits
	assessment of compliance with the requirements	data	charts of requirements implementation progress
	reporting of audit result and conclusions	doc	regist of audit results and conclusions
	reporting of audit result and conclusions	doc	internal divulgation of the audit result

Figure A.3: Tasks and outputs from internal EMS audit requirements.



category	tasks	documents and data	
		type	description
management review	revision of energy policy	doc	report on state and necessary modification to energy policy
	registration of EMS actions	data	table EMS actions regist
	revision of the EMS	doc	minute of the top management revision
	revision of energy policy	doc	energy policy
	revision of EnPI performance	data	table of EnPI
	revision of the compliance with legal and other requirements	doc	evaluation of compliance with legal and other requirements
	review of compliance with objectives and goals	data	table of action plans
	revision of audits result	doc	audits report
	revision of the corrective and preventive measures	data	table of corrective and prevention actions
	revision of energy performance for next year	doc	energy performance forecast
	revision of improvement recommendations	doc	improvement recommendations
	definition of changes to the energy performance	doc	recommended changes to the EMS and the organization
	definition of changes to the energy policy	doc	recommended changes to the EMS and the organization
	definition of changes to EnPI	doc	recommended changes to the EMS and the organization
definition of changes to objectives and goals	doc	recommended changes to the EMS and the organization	
definition of change to resource allocations	doc	recommended changes to the EMS and the organization	

Figure A.4: Tasks and outputs from management review requirements.

category	tasks	documents and data	
		type	description
corrective and preventive actions	identification of non-conformities	data	table of non-conformities
	determination of the non-conformities causes	data	table of non-conformities
	identification of future prevention measures	data	table of corrective and prevention actions
	identification of corrective measures	data	table of corrective and prevention actions

Figure A.5: Tasks and outputs from corrective and preventive actions requirements.

category	tasks	documents and data	
		type	description
planning	identification of energy management team	doc	minute of energy management team approval
	definition of goals and objectives	doc	minute of goals and objectives decision
	definition of EnPI	doc	minute of EnPI decision
	create energy planning diagram	data	energy planning diagram
	identification of legal and other requirements	doc	table of requirements
	definition of methodology and criteria for energy evaluation	doc	document of methodology and criteria for energy evaluation
	identification of energy sources	data	list of energy sources
	monitoring of energy sources	data	chart of energy sources (absolute and relative values)
	identification of energy-consuming equipment	data	list of energy-consuming equipment
	monitoring of energy-consuming equipment	data	char of equipment consumption evolution
	assessment of energy balance	data	chart of energy balance from energy sources
	definition of methodology and criteria for identification of main uses of energy	doc	document of methodology and criteria for main uses identification
	analysis of the main uses of energy	data	list of main uses of energy (main use, relative weight and improvement opportunity classification)
	analysis of the main uses of energy	data	chart of distribution of the main uses
	monitoring of main uses of energy	data	chart of historical consumption data of main uses (according to energy measurement plan)
	identification of consumption influence variables	data	list of influence variables
	analysis of relation between influence variables and main energy uses	data	table of main uses and influence variables
	monitoring of influence variables	data	chart of influence variables evolution
	identification of improvement opportunities	data	table improvement opportunities
	identification of evaluation criteria for improvement opportunities	doc	document with criteria for evaluation of improvement opportunities
	prioritization of improvement opportunities	data	table of improvement opportunities prioritization matrix
	calculation of consumption baseline	data	table of consumption baselines
	calculation of consumption baseline	data	chart of consumption baselines
	definition of EnPI	doc	minute of EnPI definition
	definition of EnPI	data	table of EnPI
	monitoring of EnPI	data	chart of EnPI evolution over time
	identification of objectives and goals	data	table of objectives and goals
	creation of action plans	data	table of action plans
definition of responsibilities	data	table of action plans	
definition of means and deadlines	data	table of action plans	
definition of implementation and verification method	data	table of action plans	

Figure A.6: Tasks and outputs from planning requirements.

category	tasks	documents and data	
		type	description
verification	reporting of measured results	doc	report of the measured results (energy measurement plan)
	reporting of measured results	data	report of the energy measurement plan
	reporting of measured results	doc	communication of the results to top management
	reporting of energy performance	data	energy consumption and EnPI
	reporting of energy performance	doc	report of energy performance
	definition of the guidelines for measurement equipment calibration and verification	doc	document of measurement equipment calibration and verification guidelines
	definition of the energy measurement plan	data	table of measurement plan
	registration of the evolution of main uses of energy consumption relative to the baseline	data	chart of main uses consumption and baseline evolution
	registration of influence variables evolution	data	chart of influence variables evolution
	registration of EnPI evolution	data	chart of EnPI evolution
	assessment of the effectiveness of action plans	doc	report of the assessment of the action plans effectiveness
	calibration and verification of measurement equipment	data	table of calibration and verification actions on measurement equipment
	registration of calibration and verification actions of measurement equipment	data	table of calibration and verification actions on measurement equipment
	assessment of the installed meters	data	diagram of the general and partial meters
verification of legal and other requirements compliance	doc	report of compliance situation of legal and other requirements	

Figure A.7: Tasks and outputs from verification requirements.



## Appendix B

# Example for ISO 50001 Energy Planning Process

Energy Planning			
phase	task	actor	data and documents
<b>infrastructure assessment</b>	infrastructure survey (equipment, meters and consumption points)	energy management team	
	configuration of infrastructure in EMS	energy management team	table of infrastructure elements (equipment, meters and consumption points)
	creation of meters and consumptions measurement diagram	energy management team	meters diagram
<b>energy evaluation</b>	identification of energy sources	energy management team	
	configuration of energy sources in EMS	energy management team	list of energy sources
	analysis of energy consumptions	energy management team	diagram of energy balance
	analysis of energy balance	energy management team	
	identification of main uses of energy	energy management team	
	definition of main uses in EMS	energy management team	table of energy main uses
	identification of influence variables	energy management team	
	configuration of influence variable in EMS	energy management team	table of influence variables
	association of influence variables to main energy uses	energy management team	table of energy main uses
	calculation of consumption baselines	energy management team	table of baselines
	analysis of consumption improvement opportunities	energy management team	document with opportunities for improvement analysis
	definition of EnPI for main uses	energy management team	
	configuration of EnPI in EMS	energy management team	table of EnPI
	definition of goals, means and methods	energy management team	action plans table
	attribution of responsibility	energy management team	action plans table
creation of action plan in EMS	energy management team	action plans table	

Figure B.1: Infrastructure assessment and energy evaluation phases for energy planning process.

<b>Energy Planning</b>			
<b>phase</b>	<b>task</b>	<b>actor</b>	<b>data and documents</b>
<b>initial setting</b>	definition of scope and boundaries	energy management team	minute of scope and boundaries decision
	communication of energy management importance	energy management team	communication of consciencialization for energy management
	upload scope and boundaries document into EMS	energy management team	document with scope and boundaries
	definition of energy policy	energy management team	minute of energy policy decision
	upload energy policy to EMS	energy management team	energy police document
	communication of energy policy	energy management team	energy police divulgation document
	definition of objectives for the standard implementation	energy management team	minute of objectives decision
	upload objectives to EMS	energy management team	objectives for EMS document
	communication of implementation's objectives	energy management team	objectives divulgation document
	designation of top management representative	top management	minute of top management approval
	designation of energy management team	top management	minute of management team approval
	definiton of top management representative and energy management team reponsabilities	top management	minute of responsibilities definition
	insert top management representative and energy management team into EMS	top management	
	survey of legal requirements	energy management team	list of legal and other requirements
	analysis of constraints and consequences related to ISO 50001	energy management team	
	upload requirements to EMS	energy management team	legal and other requirements list
	identification of personnel skill and training requirements	energy management team	
	upload personnel skills and training requirements to EMS	energy management team	skills and taining profile required document
	definition of communication procedures	energy management team	communication procedures document
	upload communication procedures to EMS	energy management team	
	definition of requirements for documentation management	energy management team	documentation management requirements document
	upload documentation management requirements	energy management team	
definition of guidelines for energy, services, products and equipment supply	energy management team	guidelines for supply document	
upload guidelines for energy, services, products and equipment supply	energy management team		

Figure B.2: Initial setting phase for energy planning process.

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