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SCHOOL OF ARCHITECTURE, URBAN PLANNING AND CONSTRUCTION ENGINEERING

MASTER OF SCIENCE IN MANAGEMENT OF BUILT ENVIRONMENT

Environmental impact assessment within Asset and Property Management: Proposal of measurement and monitoring of energy consumption and efficiency indicators through an IWMS

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ABSTRACT (ENGLISH)

One of the main challenges that the organisations in the real estate sector are currently facing is achieving Net-Zero carbon and Net-Zero Energy Buildings goals by 2050. This means that, to achieve these objectives set at the national and international level, companies will need to have reliable information that allows them to take decisions more efficiently.

To find an adequate mechanism to face these challenges, this thesis focuses on developing a proposal for collecting, managing, and monitoring energy consumption and efficiency indicators during the operational phase of buildings using an IWMS as a technological support tool.

The content of this thesis is divided into three parts that structure the methodology defined to achieve the proposed objective. In the first part, a literature review is carried out to present the application of IWMS during the operation stage of the buildings and the indicators currently used by various world-renowned organizations.

As a result of the literature review, the second part consolidates all the indicators proposed by the different sources and identifies how, using the information within the database of an IWMS, these indicators can be measured and retrieved efficiently. Then, the third part implements a practical case within eFM Company that concludes with integrating the proposal of indicators within the module used for energy performance management and new user-friendly dashboards at asset and portfolio levels.

The interpretation of this thesis results shows that measuring and monitoring energy performance information within an IWMS can be considered a consistent mechanism for real estate companies to understand their consumption patterns, take necessary actions, measure the effectiveness of these actions, and report them to all interested parties.

Key words: *Environmental Impact, Information Management, IWMS, Digital Tools, Energy Management, Energy Performance Indicators, Monitoring Dashboards, Energy Efficiency in Buildings.*

ABSTRACT (ITALIANO)

Una delle principali sfide che le organizzazioni del settore immobiliare stanno attualmente affrontando è il raggiungimento degli obiettivi di Net-Zero carbon e Net-Zero Energy Buildings entro il 2050. Ciò significa che, per raggiungere questi obiettivi fissati a livello nazionale e internazionale, le aziende dovranno disporre di informazioni affidabili che consentano loro di prendere decisioni in modo più efficiente.

Al fine di trovare un meccanismo adeguato per affrontare tali sfide, questa tesi si concentra sullo sviluppo di una proposta per la raccolta, la gestione e il monitoraggio degli indicatori di consumo ed efficienza energetica durante la fase operativa degli edifici utilizzando un IWMS come strumento di supporto tecnologico.

Il contenuto di questa tesi è suddiviso in tre parti che strutturano la metodologia definita per raggiungere l'obiettivo proposto. Nella prima parte viene effettuata una revisione bibliografica per presentare l'applicazione dell'IWMS durante la fase operativa degli edifici e gli indicatori attualmente utilizzati da varie organizzazioni riconosciuti a livello internazionale.

A seguito della revisione bibliografica, la seconda parte consolida tutti gli indicatori proposti dalle diverse fonti e identifica come, utilizzando le informazioni all'interno del database di un IWMS, questi indicatori possono essere misurati e recuperati in modo efficiente. Dopodiché, la terza parte implementa un caso pratico all'interno di eFM Company, che si conclude con la proposta di integrazione degli indicatori all'interno del modulo utilizzato per la gestione energetiche e la creazione di nuove Dashboard user-friendly a livello di asset e portafoglio.

L'interpretazione dei risultati di questa tesi mostra che misurare e monitorare le informazioni di gestione energetica all'interno di un IWMS può essere considerato un meccanismo coerente per permettere alle organizzazioni del settore immobiliare comprendere i propri modelli di consumo, intraprendere le azioni necessarie, misurare l'efficacia di queste azioni e dichiararli a tutte le parti interessate.

Parole chiave: *Environmental Impact, Information Management, IWMS, Digital Tools, Energy Management, Energy Performance Indicators, Monitoring Dashboards, Energy Efficiency in Buildings.*

INTRODUCTION

Meeting the Paris Climate Accord goals requires the real estate industry to achieve net-zero carbon by 2050. To meet this goal, it is necessary to reduce as low as possible greenhouse gas new emissions, which means that all fossil fuels use must phase out and that energy consumption needs must be covered with renewable energy sources.

However, according to the European Commission: "*Buildings are responsible for approximately 40% of EU energy consumption and 36% of the greenhouse gas emissions. Buildings are therefore the single largest energy consumer in Europe*".

Real estate assets consume significant amounts of energy along their entire life cycle. During their operation stage, the energy consumption is primarily related to space heating, ventilating, air conditioning, water heating, lighting, and the use of equipment and appliances. This leads to a change of perspective, so instead of looking at buildings only as inanimate structures, they must be seen through both the physicality and the process by which they are created.

From this new perspective, many organisations focus on finding strategies to accelerate the process towards a more sustainable business aligned with the Net-Zero goals established at a national and international level.

One of the strategies that currently shows a strong trend in the Real Estate sector worldwide is the promotion and incentive of smart-ready systems and digital solutions in the built environment. This offers new opportunities to follow up the information generated inside the buildings in real-time.

In this context, the main objective of this thesis is to identify how the information gather in a Real Estate Integrated Workplace Management System (IWMS) can be used to measure and monitor energy consumption and efficiency indicators. In this manner, it can work as an opportunity tool for organisations to put strategies in place to mitigate a part of the negative impact their operations might have on the environment and work on their ability to demonstrate their contributions to consumption energy close to zero by 2050.

To fulfil the main objective and organise the structure of this thesis, the following specific goals are defined:

- Describe the application of IWMS during the building's operational phase and how it supports the environmental and energy performance assessment.
- Analyse the literature to identify the different sources of energy consumption and efficiency indicators.
- Propose a set of performance indicators with their units of measurement, method of calculation and data input.
- Identify the information gathered and managed inside the different modules of ARCHIBUS® (IWMS) that can be used to measure the set of indicators proposed.

- Develop an improvement proposal of integration between ARCHIBUS® modules and create new dashboards to monitor the progress of the set of indicators proposed.

Based on the main objective, the specific goals and expected results defined, the content of this thesis is divided into three parts: a first section including the theoretical framework, a second section including the proposal of energy consumption and efficiency indicators, and a third section concerning the analysis of the case study and the improvement proposal.

The first chapter defines the information system concept for real estate management, specifying the structure, requirements, main functions. Furthermore, it describes the IWMS software currently on the market and its application on the operation and management of a building, emphasising the support that can provide to organisations in assessing their environmental and energy management performance.

The second chapter describes the different most recognised entities that propose indicators framework to measure the environmental impact of buildings during the operation stage. Likewise, a list of indicators focused on energy consumption and efficiency is identified by each organisation described.

The third chapter, with which the second section begins, focuses on the in-use energy consumption and efficiency indicators identified in Chapter 2. A procedure of consolidation of indicators by similar field of interest is carried out. Then, for each indicator consolidated, the units of measurement, calculation method, and data input are defined.

The fourth chapter identifies the information managed within an IMWS database and how it can be used to measure and monitor the energy consumption and efficiency indicators. The outcome of this chapter is the definition of the best combination of the tables and fields managed through the IWMS modules to calculate the list of consolidated indicators proposed.

The fifth chapter, with which the last section begins, is dedicated to introducing the case study develop inside eFM company. In addition, the current scenario regarding the background data, integration between modules, processes workflow and reporting used for data analysis inside the Energy Management module of ARCHIBUS® is presented and described.

The sixth chapter is dedicated to the detailed description of the steps performed to create the new and improved scenario for the background data, the integration between modules, the workflow of processes and the measurement and monitoring dashboards inside ARCHIBUS®.

Finally, the seventh chapter describes the further improvements and the potential evolution of the proposal, explaining the scalability in the extension of the list of indicators and the potential integration of ARCHIBUS® platform with one of the key functions of IoT (sensors) to include updated real-time information inside the dashboards proposed.

Part 1: THEORETICAL BACKGROUND

CHAPTER 1: INFORMATION SYSTEMS FOR REAL ESTATE MANAGEMENT

1.1 The importance of the Real Estate information management

The Real Estate sector is going through a transformation of practices, processes, tools, and references due to the adoption of novel Information and Communication Technology (ICT) solutions which nowadays promise to improve the traditionally conceived processes, making new knowledge bases available to support data-driven decision-making processes and embracing a network approach to stakeholder management (Atta & Talamo, 2020).

Each real estate property includes different physical systems such as heating, lighting, air conditioning, plumbing and ventilation. In addition, the same property includes human systems, which reflects how occupants use the space and how the occupants inside the property use assets and equipment. Therefore, all these systems mentioned must interact in an integrated way within each other along the whole life cycle of the real estate properties (Maslesa & Jensen, 2019).

In this sense, Real Estate professionals have to deal with a large and increasing amount of information provided by various domains and stakeholders through the different phases of assets' lifecycle, as they are contemporarily engaged with other areas: facility and property management, financial management, energy management, change management, health and safety, contract management, procurement and supply chain management, building and engineering services maintenance and among others (Talamo & Bonanomi, 2015).

Assumed the variety of domains, data have to be combined, integrated, and managed to create more accurate and accessible knowledge and achieve greater re-use of existing knowledge and experience. Therefore, it is at this point when it is necessary to define the model of knowledge creation (Figure 1 Model of knowledge creation*Figure 1*), with the particular view with the Real Estate Management and Facility Management services, starting from the conceptual chain that links (Talamo & Bonanomi, 2015):

- **Data:** are words, facts, figures, texts that obtain meaning and value only in relation to a context and processing. Besides, according to the ISO 19650-1:2018, data is considered information stored but not yet interpreted or analysed (BSI, 2018).

- **Information:** is the data processed according to specific goals, referred to a context and managed to be used, shared, and combined. According to the ISO 19650-1:2018, information is considered the representation of the data in a formalised manner suitable for communication, interpretation, or processing by human or automatic means (BSI, 2018).

- **Knowledge:** is the result of applying, processing, relating, and combining information in a specific context. Leading information to enter in a system able to develop knowledge is the process that creates actual value and competitive advantage for the organisations. In fact, the value that knowledge can provide to an organisation is increased when it has a crucial purpose and focuses on mission, core values and strategic priorities (Smith, 2001).

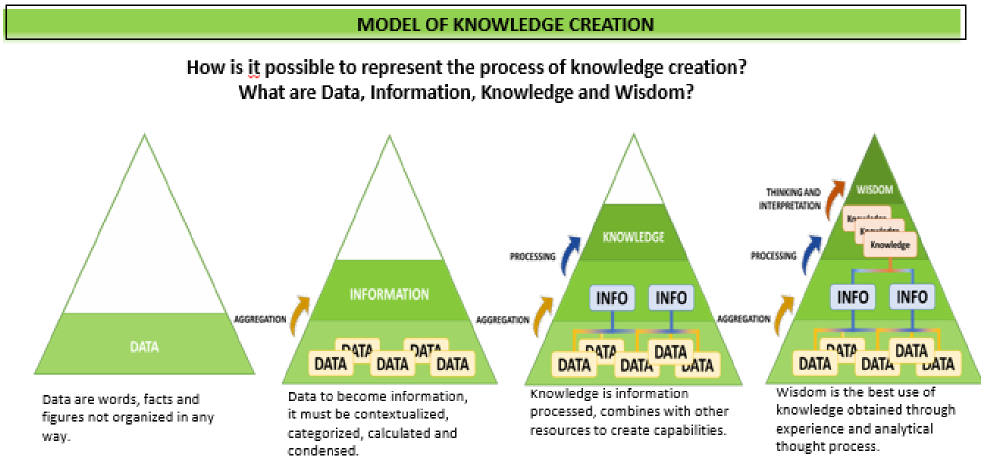

Figure 1 Model of knowledge creation
Retrieved from the slides of the course "INFORMATION SYSTEMS FOR THE MAINTENANCE AND MANAGEMENT" held by Professor Cinzia Talamo, a.y 2019/2020 in Politecnico di Milano, Master of Science Management of Built Environment.

Finally, it is important to highlight the impact of the volume of information generated throughout the life cycle of a real estate property. As shown in *Figure 2* Information over assets lifecycle, there is an inversely proportional relationship between the value and the cost of implementing an information strategy. This relationship indicates that the value of implementing an information management strategy from the early stages of an asset's life cycle, when the information volume is smaller, is far greater than deciding the operational or use phase. Also, the cost of the implementation during the asset operation stage is much higher than the initial design stages due to the significant amount of information that needs to be processed at that point.

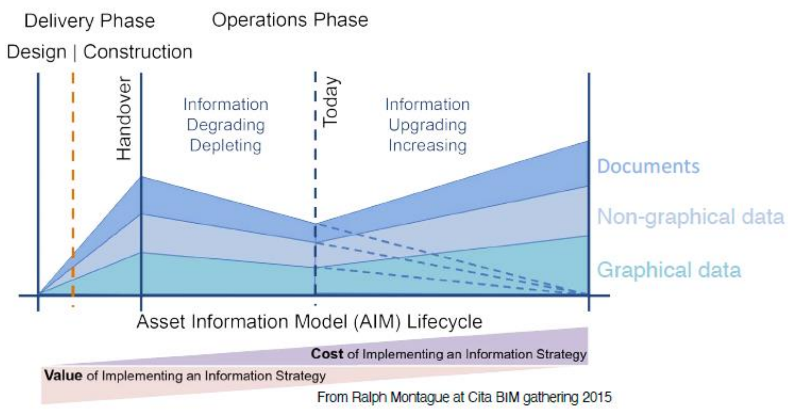

Figure 2 Information over assets lifecycle
Source: Presented by Ralph Montague at the CITA BIM gathering of 2015

In this scenario, information management and delivery have a fundamental role in increasing the efficiency of the real estate processes, such as:

- Effective decision-making process: Information is the core for decision-making during all the activities performed along the asset life cycle. For example, when there is an intention to develop a new asset, modify, enhance, or decommission an existing one, the action plans to execute these projects cannot be prepared without the asset's information.

- Creation of reliable information: Excessive information and communication flows are generated in an incremental way along the asset's lifecycle. Thus, it is necessary to periodically maintain information management systems to identify easily appropriate and accurate information. In fact, Knowledge Databases add value only when users have direct access and use them (Smith, 2001).

- People engagement: Consistent outputs create engagement of people and encouragement of appropriate behaviours. Besides, according to the ISO 19650-1:2018, there is a focus on continuous improvement by sharing knowledge and lessons learned (BSI, 2018).

1.2 Support Software for the Real Estate information management

According to the standard UNI 10951:2001 – Information systems for management of real estate assets:

*"An information system is a **decision-making and operational support system** consisting of a database, procedures and functions aimed at collecting, storing, processing, using, and updating the information necessary for the quality management of the processes (design, programming, organisational, technical and administrative, etc...) underlying the design, implementation and management of the maintenance service"* (UNI, 2001).

In general, an information system for management is considered a decisional and operational tool because it incorporates a set of information and instructions to support the two extremes of management activities: decisions and operations. In the real estate assets perimeter, it can be conceived as a set of rules, procedures, and tools to gather, elaborate, and distribute information needed to manage buildings. Therefore, the two main features of an information system are: firstly, to support decisions and activities regarding the building management; secondly, to represent the container in which information and instructions are collected and correlated, for later allow the integration and distribution of knowledge among the stakeholders (Pellegrini, 2018).

Regarding the database and functions, it is important to mention that according to the definition of the standard UNI 10951:2001, the core of an information system is the database (UNI, 2001). Therefore, within the information registered in the database and through the activation of different functions and procedures, an information system can provide two different categories of data due to different processing modes: aggregated and single data (Talamo & Bonanomi, 2015).

In summary, it can be said that an information system should allow to retrieve any stored data simply and rapidly. The methods of searching, extracting, and using data that can be mentioned for the real estate management practices are the following (Talamo & Bonanomi, 2015):

- **Obtain all or some specific available information about any object stored in the database:** For example, it can be mentioned a particular room inside a building as an object stored in the database, so from this object, the information that can be retrieved is the users, size and cost of maintenance operations performed for a given time frame.

- **Select objects according to various searching criteria:** For example, to obtain the list and the location of all the rooms within a building portfolio with the same category or function.

- **Connect alphanumerical and graphical information:** For instance, to obtain the floor plan from selecting an object and vice versa, which means to get the selection of an object, and the information related to it, from the floor plan containing it.

- **Extract graphical and alphanumerical information:** Directly through reports, work orders and operational instructions generated within the system.

Each element of the typical information system model for real estate management is presented in the following sub-items. According to the standard UNI 10951:2001, the model comprises a database, procedures, and functions.

a. <u>Database and structure</u>

Information systems for real estate management are platforms structured according to an architecture organized in a database and a set of specialized modules. Each module is generally related to the different application areas of the management of buildings during their whole lifecycle (Talamo & Bonanomi, 2015).

The information system database is made by a set of tables, integrated and connected, which allow to manage data relating to different areas of the buildings management services (Sun, 2013).

These tables organized the information in rows and columns. The columns are called fields and store the informative categories that characterize a building: name, code, gross internal area, space code, etc. The rows are called records and contain information about individual objects: specific buildings, rooms, equipment, furniture, etc.

The data that populates the tables can be alphanumerical or graphical information and is collected according to two different ways (Molinari et al., 2002):

- The asset's identification information collected permanently inside *registers* like the information regarding the location, the quantity consistency, the age, the functions, the technical description, the administrative data.

- The information coming from different sources and collected inside *files* like user manuals, technical sheets, certifications, service orders, standards, price lists, work procedures, operating instructions, etc.

A typical information system model for the management of real estate assets is composed of specialized modules integrated within the information system. This structure consists of a series of application modules, independent of each other, but refers to a single database, which is integrated among them, corresponding to different functions (*Figure 3*).

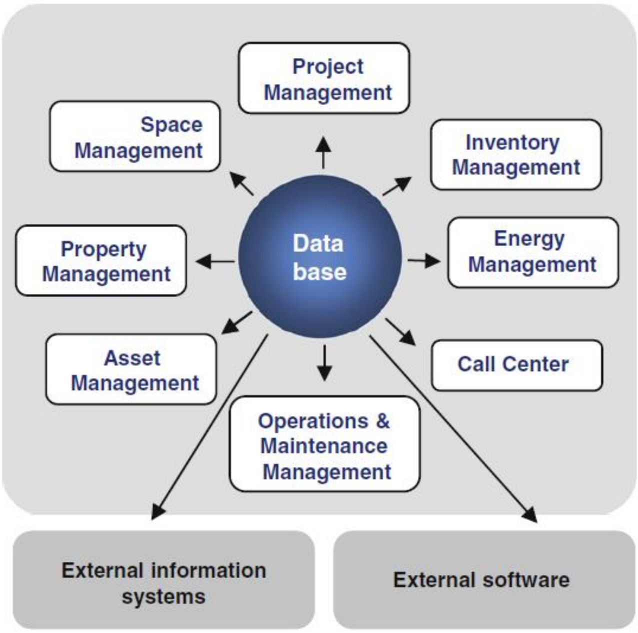

Figure 3 Some of the integrated modules that can constitute an information system
Source: Talamo, C., Bonanomi, M. Knowledge Management and Information Tools for Building Maintenance and Facility Management, 2015 pg. 129

According to specific procedures for data extraction and processing, the modules are all fed by the database. In addition, the modules can be activated in various ways and according to the specific needs related to the organizations. Also, information can be extracted and transferred for further processing to external processing environments like spreadsheets, specialized programs and other information systems (Talamo & Bonanomi, 2015).

b. Procedures

The procedures aim to guide the different uses of information inside an information system (*Figure 4*). Therefore, *it must provide guidelines for the inventory activities by defining, in a* *systematic and formalized way, subjects such as surveying methods, data collection parameters and measurement criteria, tools, necessary skills and responsibility* (Talamo & Bonanomi, 2015).

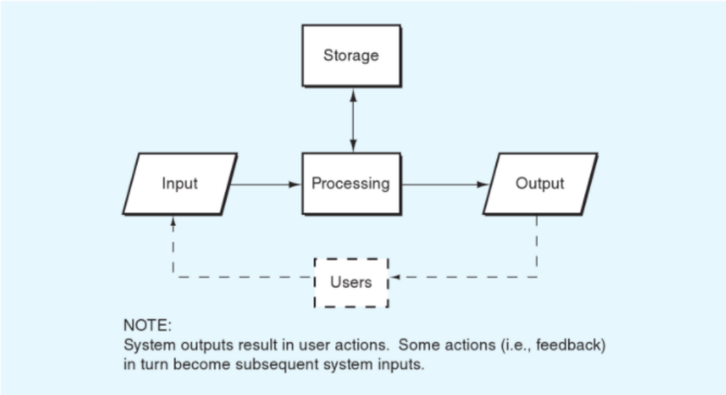

Figure 4 Functional Model of an Information System
Source: Gelinas, J., Dull, R., Wheeler, P. Accounting Information Systems, 2015 pg. 14

The system of procedures, together with the database structure definition, ensures the possibility to make the inventory standardized; consequently, the information acquired over time will be easily aggregated, controlled, and compared. The capabilities that a set of procedures must be able to describe are the following (Pellegrini, 2018):

- Hierarchies, roles, and responsibilities in the use of the information system.
- Rules and criteria for the management of the system, according to its structure and maintenance objectives.
- Levels and methods of access to the information.
- Levels and methods of data entry and updating information.
- Rules to guide survey activities prioritise the collection, organization, and storage of information over time.
- Rules to guide the activation of processes.
- Methods for collecting and normalizing data from external sources.
- Norms and protocols for reporting.
- Average time needed for the execution of the various activities within the information system.

c. **Functions**

The information system for real estate management must perform a complex system of functions in relation to building planning, management, and operation activities. The different parts characterizing an information system can be group into three categories:

- **Registry:** This system is a framework of criteria useful for classifying and coding spatial and technical elements. The registry system aims to collect, store, and immediately retrieve all the information necessary to describe the buildings' identity univocally (Talamo, 2011). Specifically, it contains and makes available both the quantitative, functional and localization aspects of the buildings and the basic information describing technical configurations of the different parts of the building (Talamo & Bonanomi, 2015). To sum up, this function responds to the need to have a clear and complete knowledge of the assets at any level of detail.

- **Monitoring:** This function provides a constantly updated vision of the different situations concerning the real estate progress toward reaching its objectives and guiding the assets' proper management decisions. Therefore, it is crucial that an information system can receive, store, process and return data coming from all the investigations, inspection and controls that aim at constantly checking conditions and compliance degree of the buildings with assumed quality levels (Talamo & Bonanomi, 2015).

- **Historicization:**This function can be defined as the collection of feedback information from the different activities performed along the asset's lifecycle with the aim of (Molinari et al., 2002):

  - ✓ Keep a history of the buildings and their parts.
  - ✓ Identify deterioration processes.
  - ✓ Progressively growth knowledge.
  - ✓ Increase the forecasting ability over time.
  - ✓ Define operational planning of the activities based on the gradually growing and consolidated knowledge base.
  - ✓ Track the performance of buildings, determine the optimal reference year, set operational goals, and monitor the objectives.

1.3 Application of Integrated Workplace Management Systems for environmental management during the operational phase

IWMS is the acronym of Integrated Workplace Management System. It is an information management system software often described as a combination of two data-driven management solutions: Computerized Maintenance Management System software (CMMS) and Computer-aided facility management (CAFM). While CAFM software traditionally operates from several technology platforms, an IWMS is based on a single database platform through which multiple business processes are interconnected (*Figure 5*). This ensures easier information management and increased interoperability as the core data comes from the shared database (Maslesa & Jensen, 2019).

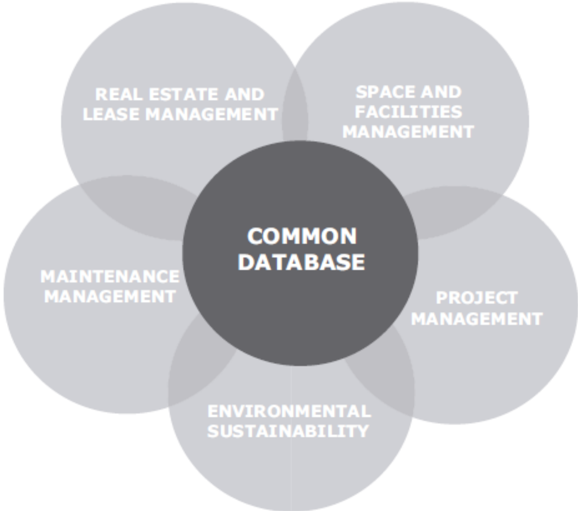

Figure 5 Generic model of IWMS
Source: Maslesa, E., Jensen, P. Drivers for IWMS implementation in real estate management, 2015 pg. 2

Another difference to highlight is that CAFM mainly focuses on Facility Management, space management and maintenance management, while IWMS includes additional features such as real estate and lease management, project management and environmental sustainability (Maslesa & Jensen, 2019).

In summary, an IWMS is designed to help companies in facilities management and corporate real estate management save money and be more efficient because it can produce reports that help them make smarter decisions, such as financial reports for capital projects or maintenance operations, space utilization reports or energy efficiency metrics.

One of the market-leading IWMS is ARCHIBUS®. With over 35 years of continuous innovation, ARCHIBUS® software is at the forefront of the world market for the application of technological solutions and complete services for the management of its real estate portfolio.
ARCHIBUS® enable companies worldwide to consolidate their systems into a single integrated platform for all data, planning and operations related to real estate, facilities, and infrastructure.

Through effective improvement processes and business transformation, ARCHIBUS® helps companies optimise properties, spaces, and procedures to facilitate the achievement of the following goals[1]:

- **Cost reduction:** With ARCHIBUS® platform modules and functionalities, the life cycle of the buildings is extended, their maintenance conditions are improved, and operations are optimised.

- **Productivity increase:** With ARCHIBUS® platform, organisations manage and maintain workspaces in optimal conditions, promoting employees' wellbeing and productivity.

[1] For further details about the Archibus see: http://www.efmnet.it/it/archibus

- **Sustainable approach:** ARCHIBUS® platform supports companies along the path towards economic, social, and environmental sustainability by reducing management costs, energy consumption and increasing the comfort of the people who live in the spaces.

ARCHIBUS® delivers unique information about real estate portfolio via Enterprise Information Modeling (EIM ™) and illustrates its value to the entire business via:

- A flexible and scalable platform that allows users to easily introduce rapid high-value / low-risk deployments of specific applications or the full range of applications for businesses of any size.

- A highly efficient collaborative platform that uses home pages to customise business analytics and data-driven results for various roles within the company.

- In-depth, ready-to-use information from a common operational results scheme to enable operational and strategic stakeholders to implement their long-term business strategy.

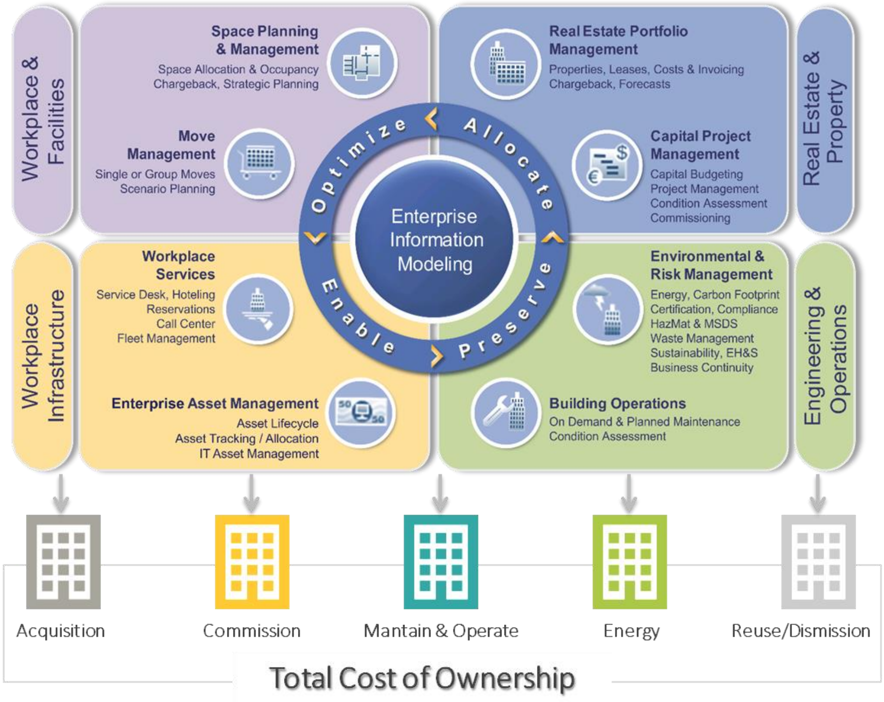

Figure 6 ARCHIBUS® Enterprise Information Modelling
Source: ARCHIBUS®

The core of this IWMS platform is ARCHIBUS® Web Central, which provides a common operating picture of all asset lifecycle data, processes, workflows, and analytics across the entire portfolio. Web Central includes web-based and mobile solutions for managing all aspects of the built environment, such as space, property and lease, equipment and maintenance, projects, moves adds and changes and many environmental and safety-related applications, as shown in *Figure 7*.

Figure 7 ARCHIBUS® Web Central Overview
Source: ARCHIBUS®

With increasing utility costs, mandates to reduce carbon emissions, and sustainability efforts gaining more visibility, effective environmental management has become even more critical for organizations. To respond to this situation and ensure that organizations understand the impact of their operations in the environment, ARCHIBUS® software solution provides the Environmental and Risk Management module, which main processes and their benefits are summarized in *Table 1*[2] (a more in-depth description of the modules for the Energy Management is carried out in Chapter 5):

Application Process	Description	Benefit
Environmental Sustainability Assessment	This process makes the concept of environmental sustainability a reality by tracking, ranking, and documenting details on the condition and use of physical assets so remedial action can be taken.	a. Identify which assets should be repaired, renovated, or replaced to achieve environmental efficiency goals or support an existing LEED™ or BREEAM® rating program b. Improve capital budgeting and planning capabilities by tracking costs and budgets associated with environmental deficiencies c. Increase efficiency of sustainability efforts by integrating assessment with work order management and by using a unified data repository
Energy Management	This process provides the means to easily aggregate, evaluate, and optimize energy and utility spending decisions to reduce unnecessary consumption and costs.	a. Lowers annual energy costs, typically by 5% (or approximately $0.10 – 0.20 USD per square foot of space/year) and reduces carbon footprint b. Provides audit capabilities to easily access, aggregate, and evaluate consumption patterns as the basis to renegotiate rates and consolidate energy providers c. Reduces business risk and exposure to changes in energy costs or carbon emissions regulation through "what-if" analyses

[2] For further details about the Archibus see: https://archibus.com/products/sustainability-risk/

Green Building	This process provides the information framework for reducing greenhouse gas emissions and managing the environmental sustainability certification and recertification process.	a. Facilitate compliance with internal or external reporting requirements b. Streamline the computation and comparison of greenhouse gas emissions for all buildings in a portfolio and tracks changes over time c. Track progress, evaluate payback and identify best practices to simplify sustainability certification and requalification initiatives
Waste Management	This process provides a streamlined and integrated approach to tracking, managing, and reducing hazardous and non-hazardous waste.	a. Facilitate the process of tracking and managing hazardous waste streams to sustain a safe working environment. b. Increase the visibility and improves accountability for waste reduction or recycling initiatives to help reduce carbon footprint.
Emergency Preparedness	This process provides rapid access to the critical facility, infrastructure, and occupant information to ensure life safety procedures are followed, the property is protected, and disruption to regular operations is minimized.	a. Enables quick access of accurate information to make critical life-safety decisions during a disaster b. Assists in expediting insurance claims and negotiating more favourable coverage terms c. Organizes information to implement disaster recovery plans and quickly resume normal operations
Compliance Management	This process provides a highly scalable solution to quickly and efficiently recordkeeping substantial data involved with regulatory compliance programs and permitting processes.	a. Maintain a comprehensive, defensible compliance program by reducing administrative time spent on data collection, notifications, and document management b. Implement a structured process to comply with regulations, codes, and/or best practices
Clean Building	This process provides a flexible and systematic approach to help ensure all hazardous materials are quickly and accurately located, tracked, and abated using searches that connect directly to graphical views of space and equipment inventories.	a. Reduce potential exposure of building occupants to hazardous materials b. Averts costly operating shutdowns, loss of facility uses, penalties, or fines resulting from hazardous material violations
Environmental Health & Safety	This process associate incidents with locations, equipment, and personnel and easily link employee training records and/or medical monitoring to these same incidents.	a. Provides a proactive process to identify, evaluate, and correct health and safety risks in the workplace. b. Delivers efficient tracking and follow-up of health and safety incidents to minimize risk and liability to the organization
Hazardous Materials	This process integrates materials inventories, space and occupancy data, equipment inventories, and organizational information with the site- and floor-plan graphics, providing the complete information to execute a plan of action to avert a crisis.	a. Maintain ad up-to-date Safety Data Sheets (SDS) library and satisfies inventory documentation reporting obligations b. Enables first responders to retrieve critical chemical safety information during an emergency quickly c. Facilitates maintaining and auditing detailed hazard inventory records by location and custodian

Table 1 Environmental & Risk Management application processes

Each process that belongs to the macro-module of Environmental and Risk Management has data tables, functionalities, dedicated reports, and specific indicators designed to serve as the primary support to organizations in assessing environmental performance during the operation of the buildings within their portfolio.

1.4 Building operation energy assessment supported by digital solutions

The real estate market is shifting its scope from the traditional meaning of the asset, conceived as tangible good, to the integration of physical assets into the set of services delivered to the client (Cecconi et al., 2020).

Within this change of paradigm, improving in-use building performance is critical. Digital transformation and solutions play a crucial role in achieving operational efficiency and hold the potential to support sustainable development goals, where the captured information is analysed by computational techniques to unveil trends and patterns and turned to be actionable dynamic information on human behaviours, environment, and experiences (ElMassah & Mohieldin, 2020).

Although the real estate industry can do a great deal to reduce the negative impact on the environment by improving building materials and processes during development, operating emissions account for nearly three-quarters of the 40% of carbon emissions contributed by buildings. Hence, reducing these in-use emissions can only be achieved by deploying technology to optimise operating regimes[3].

One of the most relevant aspects that is strongly connected to the in-use emissions during the operation stage of a building is the energy consumption and its drivers, which are often not visible or well-understood. So, digital tools for the operational phase mainly provide three functions that support building long-term relationships with energy users: (1) monitoring energy consumption, (2) giving recommendations to influence the behaviour of users and (3) reducing energy consumption through intelligent controls. To develop these functions, technological tools range from apps to measure and optimise energy use or guide occupants to reduce energy use to software for professional facility management (UN Environment Programme, 2020).

Although the significant and largely untapped potential to use digital tools to reach energy efficiency targets throughout the lifetime of a building is a current trend in the real estate sector, all the investment and the deployment of resources involved in the implementation of these solutions will not be able to achieve the desired impact if an appropriate set of indicators aligned with the strategic objectives of an organization is not defined.

[3]For further details about Wired Score Smart Buildings White Paper see: https://wiredscore.com/certify-a-building/smartscore/smart-buildings-white-paper-smartscore/smart-buildings-white-paper-why-do-we-need-smart-buildings/

According to the International Energy Agency, the lack of data for developing and build proper indicators to measure energy efficiency explain the gap between declarations and actions. Without data and indicators, it is also challenging to optimise energy efficiency policies and monitor progress and failures (International Energy Agency, 2011).

On that account, collecting data and developing indicators should not be seen as an end but more as a beginning for further use. In fact, data should be collected, and indicators created only if they can be used widely and efficiently (International Energy Agency, 2011).

According to the ISO 21929-1:2011: "*Establishing a system of energy performance indicators consists of choosing relevant indicators and developing or finding suitable methods and information to measure or assess the values of individual indicators*". Consequently, to be usable, an indicator shall be accompanied by an explanation that describes how to assign its value and should have a source of information that provides the basis on which the value of an indicator is calculated (ISO, 2011).

In synthesis, the efficiency level of the implementation of a system of energy performance indicators will be reflected in its capacity to ensure continuous improvement of energy efficiency, increase the energy performance awareness and transparency, increase the property value of buildings, be used as the basis for benchmarking and reduce costs across many end-uses (ISO, 2011).

CHAPTER 2: SOURCES OF ENVIRONMENTAL INDICATORS

The Real Estate sector needs to begin assessing a pathway to achieve net-zero. Therefore, sustainability targets, strategies and procedures for energy efficiency and renewable energy can be established based on the current conditions and the environmental performance of each asset of a real estate company portfolio.

According to the ISO 14031:2021, the starting point of the environmental performance evaluation of a building consists of selecting indicators that will subsequently assess, report, and periodically communicate the performance obtained to improve during the process (ISO, 2021). Therefore, the first term to define in the overall concept of energy consumption and efficiency indicators is "energy efficiency", which according to the Lawrence Berkeley National Laboratory, means "using less energy to provide the same service"[4]. On the other hand, the second term to clarify is "indicator", which can be defined as a specific, observable, and measurable characteristic used to show the changes and progress a program is making towards achieving a specific result.

Currently, for the real estate sector, it does not exist a single framework of indicators that is used as a unique worldwide standard to analyse and monitor the energy performance of buildings. Several independent, non-independent, profit, and non-profit organisations design, propose, and maintain different indicators selected by real estate companies based on their specific environmental purposes.

In this chapter, the different most recognised entities and organisations that propose indicators framework to measure buildings' energy consumption and efficiency during the operation stage are described. In addition, for each different international organisation, the indicators focused specifically on energy consumption and efficiency are identified and presented in a table with the corresponding units of measurement and frequency of measurement proposed.

2.1 International Reporting Frameworks for buildings performance

- **The Global Status Report (GSR) for Buildings and Construction**

  The Global Status Report (GSR) for Buildings and Construction is a reference document of the Global Alliance for Buildings and Construction (GABC) and the United Nations Environment Program (UNEP). The aim of this report, which is published annually, is to provide a snapshot of the progress of the buildings and construction sector globally towards the achievement of the goals of the Paris Agreement on Climate Change; particularly on the drivers of CO2 emissions and energy demand globally and the status

[4] For further details about the energy efficiency definition provided by the Berkeley Lab see: https://www2.lbl.gov/LBL-Programs/sp_energy.html

of policies, finance, technologies, and solutions that support a zero-emission, efficient, and resilient buildings, and construction sector[5].

As mentioned in the paragraph above, the two leading organisations in charge of the elaboration of this international report are the UNEP and the GABC. From one side, the UNEP is the leading global environmental authority that sets the global environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system, and serves as an authoritative advocate for the global environment[6]. On the other side, launched at COP21's Buildings Day in Paris in December 2015 by the French Government and the UNEP, the GABC is the leading global platform for governments, private sector, civil society, research, and intergovernmental organisations committed to a shared vision: A zero-emission, efficient and resilient buildings, and construction sector[7].

GABC members acknowledge that the buildings and construction sector can contribute significantly to achieving climate goals and the common objective of limiting global warming to well below 2 degrees Celsius. Accordingly, the Alliance aims to support and accelerate the implementation of countries' Nationally Determined Contributions (NDCs), and thus facilitate the implementation of the Paris Agreement for the buildings and construction sector regarding energy efficiency gains, growth of renewable energy and greenhouse gas emissions reduction[8].

The energy consumption and efficiency indicators identified within the GSR report are shown in *Table 2*:

The Global Status Report (GSR) for Buildings and Construction			
Report	**Indicator**	**Index (Unit of measurement)**	**Frequency of measurement**
2020 GLOBAL STATUS REPORT FOR BUILDINGS AND CONS TRUCTION	Total energy use/consumption	kWh/m2	annual
	Building energy consumption by fuel share	%	annual
	Energy intensity	kWh/m2	annual
	Incremental energy efficiency investment in buildings	euros	annual
	Building Energy codes and standards	Number of standards	-
	Green Building Energy certification	Number of certifications	-
	Renewable energy share in final energy in global building	%	-

Table 2 Indicators proposed in the GSR for Building and Construction

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[5] For further details about the Global status Report see: https://globalabc.org/news/launched-2020-global-status-report-buildings-and-construction

[6] For further details about the United Nations Environment Program see: https://www.unep.org/about-un-environment

[7] For further details about the Global Alliance for Buildings and Construction see: http://climateinitiativesplatform.org/index.php/Global_Alliance_for_Buildings_and_Construction

[8] For further details about the Global Alliance for Buildings and Construction see: https://www.iea.org/areas-of-work/promoting-energy-efficiency/global-alliance-for-building-and-construction

- **The Global Reporting Standards for Sustainability Reports**

The Global Reporting Standards are reference documents of the Global Reporting Institute (GRI), an independent international organisation aiming to create a common language for organisations – large or small, private, or public – to report on their sustainability impacts consistently and credible way. This enhances global comparability and enables organisations to be transparent and accountable[9].

With thousands of reporters in more than 100 countries, the GRI standards are advancing the practice of sustainability reporting and enabling organisations and their stakeholders to understand their impacts, act, and make better decisions that create economic, environmental, and social (ESG) benefits for everyone. In addition to reporting companies, the standards are highly relevant to many other groups, including investors, policymakers, capital markets, and civil society.

The standards are designed as an easy-to-use modular set that provides an inclusive picture of material topics, their related impacts, and how they are managed[10].

The energy consumption and efficiency indicators identified within the Global Reporting Standards for sustainability reports are shown in *Table 3:*

Global Reporting Institute (GRI)			
Standard	**Indicator**	**Index (Unit of measurement)**	**Frequency of measurement**
Standard 302-1	Total energy consumption within the organization	Joules or multiple	-
	Total fuel consumption from non-renewable sources	Joules or multiple	-
	Total fuel consumption from renewable sources	Joules or multiple	-
	Electricity consumption	Joules or multiple	-
	Heating consumption	Joules or multiple	-
	Cooling consumption	Joules or multiple	-
	Steam consumption	Joules or multiple	-
	Electricity sold	Joules or multiple	-
	Heating sold	Joules or multiple	-
	Cooling sold	Joules or multiple	-
	Steam sold	Joules or multiple	-
Standard 302-3	Energy intensity ratio	Joules or multiple	-
Standard 302-4	Amount of reductions in energy consumption achieved as a direct result of conservation and efficiency initiatives	Joules or multiple	-

Table 3 Indicators proposed in the Global Reporting Standards for sustainability reports

9 For further details about the Global Reporting Institute see: https://www.globalreporting.org/about-gri/mission-history/
10 For further details about the Global Reporting Standards see: https://www.globalreporting.org/standards/

- **The Business Reporting on Sustainable Development Goals (SDGs)**

  The Business Reporting on the SDGs is the first substantial resource produced as part of a collaborative effort from GRI and the UN Global Compact, the world's largest corporate sustainability initiative with a multi-year strategy to drive business awareness and action support of achieving the SDG by 2030. In addition, PwC provided technical and strategic support for the program, and the Principles for Responsible Investment (PRI) is a partner for the investor dimension of the program (UN Global Compact & Global Reporting Institute, 2020).

  This report aims to facilitate corporate reporting on the SDGs. So, following this main objective, the report provides:

  - A list of existing disclosures from established sources.
  - Gaps where disclosures do not exist or are not yet well-established.
  - For illustrative purposes, possible actions businesses can take.
  - A list of indicators developed by the UN-backed Inter-agency Expert Group on SDG Indicators (IAEG-SDG).

  This document is a first step towards creating a harmonised indicator set and methodology for companies to report on their contributions to the SDGs. It contains a list of existing and established disclosures that businesses can use to report, and identifies relevant gaps where disclosures are not available. It also lists illustrative actions that companies can take to make progress towards the SDG targets[11].

  Ultimately, this publication will contribute to a common language that will help direct innovation, strategic leadership, and capital towards the SDGs, thus accelerating progress towards the goals.

  The energy consumption and efficiency indicators identified within the Global Reporting Standards for sustainability reports are shown in *Table 4:*

[11] For further details about the Business Reporting on the SDGs see: https://www.unglobalcompact.org/library/5361

The Business Reporting on Sustainable Development Goals (SDGs)			
Target	Indicator	Index (Unit of measurement)	Frequency of measurement
Target 7.2	Total fuel consumption from non-renewable sources	Joules or multiple	-
	Total fuel consumption from renewable sources	Joules or multiple	-
	Electricity consumption	Joules or multiple	-
	Heating consumption	Joules or multiple	-
	Cooling consumption	Joules or multiple	-
	Steam consumption	Joules or multiple	-
	Electricity sold	Joules or multiple	-
	Heating sold	Joules or multiple	-
	Cooling sold	Joules or multiple	-
	Steam sold	Joules or multiple	-
	Energy consumption within the organization	Joules or multiple	-
	Amount of reduction in energy consumption achieved as a direct result of conservation and efficiency initiatives	Joules	-
	Renewable electricity output	% of total electricity output	-
	Renewable electricity consumption	% of total final energy consumption	-
	Renewable energy share in the total final energy consumption	% of energy consumption	-
Target 7.3	Electric power consumption	kWh	-
	Energy intensity level of primary energy	Joules	-
	Amount of reduction in energy consumption achieved as a direct result of conservation and efficiency initiatives	Joules or multiple	-
Target 13.1	Total electricity consumed	MWh	annual
	Total electricity produced	MWh	annual
	Total electricity purchased	MWh	annual
	Total renewable electricity produced	MWh	annual

Table 4 Indicators proposed in the SDG business reporting

- **Real Estate Scoring Document and Real Estate Assessment Reference Guide**

The Global Real Estate Sustainability Benchmark (GRESB) is an organisation driven by investors committed to evaluating real estate's ESG performance, which includes real estate. It uses consistent assessment methodologies, objective scoring, and standardised benchmarks to provide asset-level operational performance data[12].

[12] For further details about the GRESB Reporting see: https://energywatch-inc.com/gresb-reporting-who-what-why-and-how/

On one side, the GRESB Real Estate Assessment is the global standard for ESG benchmarking and reporting for listed property companies, private property funds, developers and investors that invest directly in real estate (GRESB, 2018). The Assessment evaluates performance against three ESG Components: Management, Performance, and Development. The methodology is consistent across different regions, investment vehicles and property types and aligns with international reporting frameworks, such as GRI and PRI[13]. On the other side, the GRESB Scoring Document provides a visual breakdown of each indicator score included in the annual GRESB Real Estate Assessment. Both documents are guided by what investors and the industry consider to be material issues in the sustainability performance of real asset investments. Furthermore, it is recommended to read the GRESB Scoring Document together with the Assessment Reference Guide because it includes the reporting requirements for each indicator[14].

The energy consumption and efficiency indicators identified within the GRESB Scoring Document and Reference Guide are shown in *Table 5:*

Real Estate Scoring Document and Real Estate Assessment Reference Guide (GRESB)			
ID	**Indicator**	**Index (Unit of measurement)**	**Frequency of measurement**
ESG Policies	PD1. Organization policies that address environmental issues (Energy consumption/management)	units	annual
Environmental and Social	R04. Has the entity performed in-house technical building assessments during the last four years to identify improvement opportunities within the portfolio? (Energy efficiency)	% portfolio by floor area covered	annual
	R04. Has the entity performed external technical building assessments during the last four years to identify improvement opportunities within the portfolio? (Energy efficiency)	% portfolio by floor area covered	annual
	R05. Has the entity implemented measures during the last four years to improve the energy efficiency of the portfolio?	% portfolio by floor area covered	annual
	ME2. Does the organization have a data management system with energy consumption indicators in place that applies to the entity level?	% portfolio by floor area covered	annual
	ME3. Does the entity monitor the energy consumption of the portfolio?	% portfolio by floor area covered	annual

[13]For further details about the GRESB Reference Guide see: https://documents.gresb.com/generated_files/real_estate/2020/real_estate/reference_guide/complete.html#overview_of_GRESB_assessments
[14]For further details about the GRESB Scoring Document see: https://documents.gresb.com/generated_files/real_estate/2020/real_estate/scoring_document/complete.html

Energy Consumption Data	PI1.0 Does the entity collect energy consumption data for the different property types of the portfolio?	m2	annual
	Total energy consumption of the managed assets	kWh	annual
	Total energy consumption of the indirectly managed assets	kWh	annual
	Like-for-like percentage change in energy consumption for the portfolio area with data coverage, by property subsector	% Variance from year to year	annual
	PI1.2 Energy use intensity rates	kWh/m2 + % of portfolio covered	annual
	PI1.3 On-site renewable energy generated	MWh	annual
	PI1.3 On-site renewable energy consumed	MWh	annual
	PI1.3 Off-site renewable energy generated	MWh	annual
	PI1.3 Off-site renewable energy consumed	MWh	annual
	PI1.3 Total renewable energy	MWh	annual
	PI1.3 Percentage of renewable energy	% of all the sources	annual
	PI1.4 Number of regulations and standards scheme used for the energy consumption data	number of regulations and standards per asset	annual
Building certifications	BC1.1 Does the entity's portfolio include standing investments that hold a valid operational green building certificate?	Number of certified assets or % of the portfolio covered	annual
	BC2. Does the entity's portfolio include standing investments that obtained an energy rating?	Number of certified assets or % of the portfolio covered	annual

Table 5 Indicators proposed in the GRESB Scoring Document and Assessment Reference Guide

- **ULI Green Print Performance Report**

The Greenprint Performance Report is a reference document of the Urban Land Institute (ULI) GreenPrint Center for Building Performance, a worldwide alliance of leading real estate owners, investors, and strategic partners committed to improving the environmental performance of the global real estate industry. Through measurement, benchmarking, knowledge sharing and implementation of best practices, Greenprint and its members strive to reduce greenhouse gas emissions by 50% by 2030 and an additional collective goal of net-zero carbon emissions by 2050.

On an ongoing basis, Greenprint also endeavours to demonstrate the correlation between environmental performance and enhanced property value (Urban Land Institute, 2020).

The Greenprint Performance Report is considered one of the largest global collections of transparent, verifiable, and comprehensive environmental data about buildings. The mission of this report is to lead the international real estate community toward value-enhancing carbon reduction strategies. Also, this report provides aggregate benchmarks for the real estate industry on carbon, energy, waste, and water, along with standout sustainability projects (Urban Land Institute, 2019).

The energy consumption and efficiency indicators identified within the ULI GreenPrint Performance Report are shown in Table 6Table 5*:*

Urban Land Institute (ULI)			
Report	**Indicator**	**Index (Unit of measurement)**	**Frequency of measurement**
ULI GreenPrint Performance Report	Energy use intensity	kWh/m2	annual
	GreenPrint Energy projects	units or euros	annual
	Green Building certifications	number of certifications per building	annual
	Energy use/consumption	kWh/m2	annual
	Building energy consumption by fuel share	%	annual
	Amount of reduction in energy consumption achieved as a direct result of conservation and efficiency initiatives	Joules	annual

Table 6 Indicators proposed in the ULI GreenPrint Performance Report

- **Real Estate Sustainability Accounting Standards Board Application Guidance**

The Sustainability Accounting Standards Board (SASB) is an independent non-profit organisation that sets standards to guide the disclosure of financially material sustainability information by companies to their investors. The SASB identify the subset of ESG issues most relevant to financial performance in more than 77 industries. In addition, it provides education and other resources that advance the use and understanding of its standards[15].

The SASB industry standards contain disclosure topics, associated accounting metrics and technical protocols, and activity metrics for each industry. Unless otherwise specified in the technical protocols, the guidance contained herein applies to the definitions, scope, implementation, compilation, and presentation of the accounting metrics. Also, it recognises that normalising performance data is important for the analysis of disclosures pursuant to the SASB standards. Therefore, the reporting standard contains activity metrics designed to assist in the accurate evaluation and comparability of reporting (SASB, 2018).

[15] For further details about the SASB Standard see: https://www.sasb.org/standards/download/

The structure of the SASB Standards is composed by:

- Disclosure topics: A minimum set of industry-specific disclosure topics with a brief description of how the management of each topic may affect value creation.
- Accounting metrics: A set of quantitative and qualitative accounting metrics intended to measure performance on each topic.
- Technical protocols: Each accounting metric is accompanied by a technical protocol that provides guidance on definitions, scope, implementation, compilation, and presentation, all of which are intended to constitute suitable criteria for third-party assurance.
- Activity metrics: A set of metrics that quantify a company's business scale and are intended for use in conjunction with accounting metrics to normalise data and facilitate comparison.

Among all the sustainability disclosure topics covered in the SASB Application Guidance, keeping the focus of the thesis objective, the Energy Management topic indicators with their respective units of measurement have been identified in *Table 7*:

Real Estate Sustainability Accounting Standards Board Application Guidance (SASB)			
Code	**Indicator**	**Index (Unit of measurement)**	**Frequency of measurement**
IF-RE-130a.1	Energy consumption data coverage as a percentage of total floor area by property subsector	% by floor area	annual
IF-RE-130a.2	Total energy consumed by portfolio area with data coverage	GJ	annual
	Percentage of renewable energy by property	%	annual
IF-RE-130a.3	Like-for-like percentage change in energy consumption for the portfolio area with data coverage, by property subsector	% variance from year to year	annual
IF-RE-130a.4	Percentage of the eligible portfolio that (1) has an energy rating and (2) is certified to ENERGY STAR by property subsector	%	annual

Table 7 Indicators proposed in the SASB Application Guidance

2.2 Regulations and Standards

- **International Organization for Standardization (ISO)**

The International Organization for Standardization (ISO) is an independent, non-governmental international organisation with a membership of 165 national standards bodies. Through its members, it brings together experts to share knowledge and develop voluntary, consensus-based, market-relevant International Standards that support innovation and provide solutions to global challenges[16].

The ISO plays an essential role in facilitating world trade by providing common standards among different countries. The standards are internationally agreed by people with expertise in their subject matter and who know the needs of the organisations they represent[17].

Among the different categories of the ISO Standards, two standards, from the Environmental and Energy management categories, have been identified that contain indicators highly related to the aim of this thesis:

- **ISO 14031:2021 (Environmental management - Environmental performance evaluation - Guidelines):** This document sets out a process called environmental performance evaluation (EPE) which enables organisations to measure, evaluate and communicate their environmental performance using key performance indicators (KPIs), based on reliable and verifiable information. In addition, it is applicable to all organisations, regardless of type, size, location, and complexity (ISO, 2021). This International Environmental Standard supports the requirements of ISO 14001 and the guidance given in ISO 14004 but can also be used independently (Medel-González et al., 2013).

- **ISO 5200:2017 (Energy performance of buildings – Overarching EPB assessment – Part 1- General framework and procedures):** This document establishes a systematic, comprehensive, and modular structure for assessing the energy performance of new and existing buildings (EPB) in a holistic way. It is applicable to the assessment of the overall energy use of a building by measurement or calculation, and the measure of energy performance in terms of primary energy or other energy-related metrics (ISO, 2017). In addition, it considers the specific possibilities and limitations for the different applications, such as building design, new buildings 'as built', and existing buildings in the use phase as well as renovation.

The energy consumption and efficiency indicators identified within each ISO Standard presented above are shown in *Table 8*:

[16] For further details about the International Standard Organisation see: https://www.iso.org/about-us.html

[17] For further details about the ISO Standards see: https://www.iso.org/standards.html

ISO 14031:2021 / ISO 5200:2017			
ISO	**Indicator**	**Index (Unit of measurement)**	**Frequency of measurement**
Environmental Management: Environmental performance evaluation **A.4.3.2.2 Energy**	Energy used per unit of product	kWh	annual
	Types of energy used	%	-
	Energy units saved due to energy conservation programs	kWh	-
Energy performance of buildings **3.5 Energy performance** **8. Measured energy performance** **9. Overall assessment of the energy performance of buildings**	3.5.8 Energy performance certificates	units per asset	-
	9.6 Total weighted energy performance (consumed - exported) by service	kWh	annual
	9.6 Total weighted renewable energy performance (consumed - exported) by service	kWh	annual
	9.6 Total weighted non-renewable energy performance (consumed - exported) by service	kWh	annual
	9.7 Share of renewable energy per service	% of the total energy sources	-

Table 8 Indicators proposed in the ISO Standards

- **European Standards (EN)**

European Standards (EN) are documents designed, created, and maintained by one of the 3 European Standards Organisations: European Committee for Standardization (CEN), European Committee for Electrotechnical Standardization (CENELEC) or European Telecommunications Standards Institute (ETSI) through a transparent, open, consensual process. Furthermore, they are a key component of the Single European Market because are crucial in facilitating trade and hence have high visibility among manufacturers inside and outside the European territory. A standard represents a model specification, a technical solution against which a market can trade. It codifies best practices and is usually state of the art[18].

Among all the European Standards (EN), two have been identified that contain indicators highly related to the area of energy management and efficiency:

- **EN 15221-7:2012 (Facility Management - Part 7: Guidelines for Performance Benchmarking):** This European Standard gives guidelines for performance benchmarking and contains clear terms and definitions as well as methods for benchmarking facility management products and services as well as facility management organisations and operations. In addition, it establishes a common basis for benchmarking facility management costs, floor areas and environmental impacts, and service quality, satisfaction, and productivity (BSI, 2012).

[18] For further details about the European Standards see: https://www.cenelec.eu/standardsdevelopment/ourproducts/europeanstandards.html#:~:text=European%20Standards%20(EN)%20are%20documents,%2C%20CEN%2C%20CENELEC%20or%20ETSI.&text=A%20standard%20represents%20a%20model,usually%20state%20of%20the%20art.

- **EN 15978:2011 (Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method):** This European Standard specifies the calculation method, based on Life Cycle Assessment (LCA) and other quantified environmental information, to assess the environmental performance of a building, and gives the means for the reporting and communication of the outcome of the assessment. The standard applies to new and existing buildings and refurbishment projects. It describes the object of assessment, the system boundary that applies at the building level, the procedure to be used for the inventory analysis, the list of indicators and procedures for the calculations of these indicators, the requirements for the presentation of the results in reporting and communication, and the requirements for the data necessary for the calculation (BSI, 2011).

The energy consumption and efficiency indicators identified within each European Standard presented above are shown in *Table 9:*

EN 15221-7:2012 / EN 15978:2011			
EN	**Indicator**	**Index (Unit of measurement)**	**Frequency of measurement**
"Facility Management—Part 7: Guidelines for Performance Benchmarking" **Energy Indicators**	Total Energy consumption	kWh	annual
	Energy consumption per fuel type	kWh	annual
	Energy consumption per sqm of net floor area	kWh	annual
Assessment of Environmental Performance **11.1.3 Indicators describing resource use**	Use of primary renewable energy	MJ	-
	Use of non-renewable primary energy	MJ	-
	Use of renewable secondary energy	MJ	-
	Use of non-renewable secondary energy	MJ	-

Table 9 Indicators proposed in the European Union Standards

- **EU Energy Policy Framework – Clean energy for all Europeans' package (CEP)**

The Clean Energy for all Europeans package (CEP) consists of eight legislative acts on the energy performance of buildings, renewable energy, energy efficiency, governance, and electricity market design.

The CEP is the fourth package of its kind. The new rules included in this package bring considerable benefits from a consumer perspective, from an environmental perspective, and from an economic perspective. Moreover, by coordinating these changes at the EU level, the legislation also underlines EU leadership in tackling global warming and provides an important contribution to the EU's long-term strategy of achieving carbon neutrality by 2050[19].

More specifically, the CEP updates the following EU targets for 2030:

- 40% cut in greenhouse gas (GHG) emissions compared to 1990 levels;
- 32% for renewable energy sources (RES) in the EU's energy mix;
- 32.5% energy efficiency target, relative to a baseline scenario established in 2007.

Among the four Directives and four Regulations that composed the CEP, three Directives focus on energy efficiency measurement of existing buildings in use were selected for the identification of the energy management indicators[20]:

- **Directive (EU) 2018/844 on Energy Performance of Buildings:** According to article 1, this Directive promotes the improvement of the energy performance of buildings within the EU, considering outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness. The Directive lays down the common general framework for national plans for increasing the number of nearly zero-energy buildings, energy certification of buildings, regular inspection of heating and air-conditioning systems in buildings, independent control systems for energy performance certificates and inspections reports (European Union, 2018c).

- **Directive (EU) 2018/2001 on Renewable Energy:** According to article 1, this Directive establishes a common framework for promoting energy from renewable sources. It sets a binding Union target for the overall share of energy from renewable sources in the Union's gross final consumption of energy in 2030. In addition, it lays down rules on financial support for electricity from renewable sources, on self-consumption of such electricity, on the use of energy from renewable sources in the heating and cooling sector and the transport sector, on regional cooperation between the Member States, and between Member States and third countries (European Union, 2018a).

- **Directive (EU) 2018/2002 on Energy Efficiency:** According to article 1, this Directive establishes a common framework of measures to promote energy efficiency within the European Union to ensure that the Union's 2020 headline targets on the energy efficiency of 20 % and its 2030 headline targets on the energy efficiency of at least 32,5 % are met. In addition, it provides for the establishment of indicative national energy efficiency targets and contributions

[19] For further details about the Clean energy for all Europeans' package see: https://ec.europa.eu/energy/topics/energy-strategy/clean-energy-all-europeans_en

[20] For further details about the Clean energy for all Europeans' package targets see: https://fsr.eui.eu/the-clean-energy-for-all-europeans-package/

for 2020 and 2030. It paves the way for further energy efficiency improvements beyond those dates(European Union, 2018b).

The energy consumption and efficiency indicators identified within each EU Directive included in the EU Energy Policy Framework are shown in *Table 10:*

Energy Policy Framework			
EU Directive	**Indicator**	**Index (Unit of measurement)**	**Frequency of measurement**
Amending Energy Performance in Buildings Directive (EU) 2018/844 (Replace the 2010/31/EU)	Annex 1.a. Actual energy use by system	kWh/m2	annual
	Annex 1.c. Total renewable primary energy use	kWh/m2	annual
	Annex 1.c. Total non-renewable primary energy use	kWh/m2	annual
	16. Financial mechanisms and incentives for energy efficiency	euros	-
	34. Energy performance corticates	units per building	-
	30. Smart readiness indicator: use of information, communication, and electronic technologies to improve energy efficiency	yes/no	-
	37. Building automation and electronic monitoring of building systems	yes/no	-
Renewable Energy Directive (EU) 2018/2001	Share of renewable energy consumed	%	-
	13. Investment in renewable energy projects	euros	-
	Gross final consumption of electricity from renewable sources	kWh	
	43. Energy generated on or in buildings from renewable energy	kWh	monthly/annual
Energy Efficiency Directive (EU) 2018/2002:	34. Implementation of technologies for measuring energy consumption	yes/no	-
	12. Adoption of new energy policy measures	yes/no	-
	12. Cost of implementation of energy efficiency measures	euros	-

Table 10 Indicators proposed in the EU Energy Policy Framework

2.3 Building Evaluation and Certifications

- **LEED Certification**

LEED stands for Leadership in Energy and Environmental Design and is a leading-edge system for certifying high-performance buildings and sustainable neighbourhoods. This certification was developed by USGC, created through volunteer committees, and aims to evaluate the building's performance throughout the building's life cycle. From 1994 to 2013, LEED grew from one standard of new construction to a comprehensive system of the interrelated standard covering all aspects of the development and constructions process (Christopherson, 2009).

LEED is a flexible system that applies to different building types and beyond the building's footprint. Due to this flexibility, there are different versions of rating systems depending on the project type. Based on the scope of the thesis regarding the building lifecycle stage selected: Operation, the rating system chosen is the LEED Operation and Maintenance for Existing Buildings (*Figure 8*).

Example: Operations & Maintenance

Category	Points
Location and Transportation	15
Sustainable Sites	10
Water Efficiency	12
Energy and Atmosphere	38
Materials and Resources	8
Indoor Environmental Quality	17
Total	**100**
Bonus Points	
Innovation & Design	6
Regional Credit	4
Total	**110**

Figure 8 Categories for LEED Rating System
Source: Green Living, LLC®

Finally, to measure if a building has met the definition of a high-performance green building as defined by LEED, every rating system has performance criteria in different major areas: Innovation and Design, Location and Linkages, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Awareness and Education, and Innovation and Design. Considering that this thesis aims to measure and monitor energy consumption and efficiency, the central area selected for the indicator's identification is the Energy and Atmosphere criteria. This sustainability category approaches the energy use in a building from a holistic perspective, addressing energy use reduction, energy-efficient design strategies, and renewable energy sources (Christopherson, 2009).

The energy consumption and efficiency indicators identified within the LEED Operation and Maintenance for Existing Building Certification are shown in *Table 11:*

LEED - Building Operation and Maintenance			
Credit	**Indicator**	**Index (Unit of measurement)**	**Frequency of measurement**
EA Credit: Energy performance	Annual Building's total energy consumption/Total energy consumption of comparable high-performance buildings	kWh/occupant/m2 GIA	annual
	Annual energy consumption by fuel type	kWh/m2 GIA	annual

Table 11 Indicators proposed in the LEED Operation and Maintenance Certification

- **United Kingdom's BREEAM**

BREEAM (Building Research Establishment Environmental Assessment Method) is a certification developed by BRE (Building Research Establishment), the most important English institution in the research for the field of buildings and construction works. This certification is an international scheme that provides independent third-party certification for assessing the sustainability performance of individual buildings, communities, and infrastructure projects. The assessment and certification can take place at several stages in the built environment life cycle, from design and construction through to operation and refurbishment[21].

BREEAM In-Use is the environmental assessment method that enables property investors, owners, managers, and occupiers to determine and drive sustainable improvements in the operational performance of their buildings. The BREEAM In-Use assessment process operates through an online platform that enables users to register assets and assess them based on the part(s) chosen. The secure online platform has dynamic scoring and flexible methodology, which produces instantaneous outputs and includes reporting functionality that allows the user to track and improve the performance for all building types[22].

The BREEAM In-Use process assesses environmental performance in three parts:

- Part 1 - Asset Performance: the inherent performance characteristics of the building based on its built form, construction, and services.
- Part 2- Management Performance: the management practices to optimise the building's performance during the operation.
- Part 3 - Occupier Management: the management of policies, staff engagement and performance against Corporate Social Responsibility (CSR) targets.

Each part is independently assessed and scored against performance benchmarks to produce a BREEAM rating and outline areas for potential improvement against best practice. Furthermore, BREEAM In-Use covers major environmental issues that affect

[21] For further details about the value of the BREEAM Certification see: https://www.breeam.com/discover/how-breeam-certification-works/

[22] For further details about the value of the BREEAM In-Use Assessment see: https://www.breeam.com/discover/technical-standards/breeam-in-use/

buildings throughout their operational life, capturing data across nine key sustainability categories: Energy, water, materials, pollution, Land Use and Ecology, Health and Wellbeing, Waste, Transport, and Management.

Considering the aim of this thesis, of the three parts of the process assessment, the second part is selected for the indicator's identification. On the other hand, from the nine key sustainability categories, the one chosen for the indicator's identification is the Energy category. The purpose of this category is to evaluate assets for the robustness of management practices relating to renewable electricity generation, energy-efficient technology infrastructure, energy usage awareness of occupiers, and other management policies, activities and technologies which reduce the consumption of energy of a property.

The energy consumption and efficiency indicators identified within the BREEAM In-Use Assessment Certification are shown in *Table 12:*

BREEAM - Building In Use Assessment			
Credit	**Indicator**	**Index (Unit of measurement)**	**Frequency of measurement**
KPI 6: Building Primary Energy	Building primary electricity consumption by source (renewable or not renewable)	kWh/m2 GIA	annual
	Building primary fuel consumption by type	kWh/m2 GIA	annual

Table 12 Indicators proposed in the BREEAM In-Use Assessment

- **Energy Star Certification**

The Energy Star certification is a voluntary labelling program managed by the US Environmental Protection Agency (EPA) that favours the adoption of energy-efficient products by residential and commercial consumers (Houde, 2012).

The Energy Star certification tools and resources help businesses identify cost-effective approaches to managing energy use in their buildings and plants, enabling the private sector to save energy, increase profits, and strengthen their competitiveness. In addition, real estate companies use the ENERGY STAR Portfolio Manager® score to demonstrate their sustainability to investors through reporting frameworks such as the GRESB and the SASB[23].

The ENERGY STAR Portfolio Manager® was used in 2020 to measure and track the energy, water, waste and materials of more than 270,000 commercial properties, comprising more than 25 billion square feet of floor space, across the nation. The tool

[23] For further details about the value of the Energy Star certification tools see: https://www.energystar.gov/about/origins_mission/energy_star_overview/about_energy_star_commercial_buildings

calculates a 1–100 ENERGY STAR score for eligible buildings, which has become the industry standard for rating a facility's energy performance[24].

The energy consumption and efficiency indicators identified within the Energy Star Portfolio Manager Rating are shown in *Table 13:*

Energy Star Rating - Portfolio Manager			
Credit	**Indicator**	**Index (Unit of measurement)**	**Frequency of measurement**
Glossary: Energy	Total Electricity Use	kWh	monthly/annual
	Energy Use by Fuel Source	kWh	monthly/annual
	Energy Cost	euros	monthly/annual
	Energy Rate	euros/kWh	monthly/annual
	Energy Use Intensity	Gigajoule/m2 GIA	monthly/annual
Glossary: Green Power	Onsite renewable energy	kWh + Number of Renewable Energy Certificates	monthly/annual
	Offsite renewable energy	kWh + Number of Renewable Energy Certificates	monthly/annual
Glossary: Investment in Energy Projects	Total cost/investment for an energy upgrade at your property	euros	-
Glossary: Onsite Renewable Systems (with Renewable Energy Certificate)	Electricity Use – Generated from Onsite Renewable Systems and Used Onsite (solar/wind)	kWh	monthly/annual
	Percentage of Total Electricity Generated from Onsite Renewable Systems	% of your total electricity use that is supplied by your onsite renewable system	monthly/annual
Glossary: Third-Party Certification	Third-party green building certification	units/asset	-

Table 13 Indicators proposed in the Energy Star Portfolio Manager Rating

- **EDGE Certification Protocol**

The Excellence in Design for Greater Efficiencies (EDGE) is a green building certification system focused on making buildings more resource-efficient. This protocol, designed by the International Finance Corporation (IFC), enables developers and builders to quickly identify the most cost-effective ways to reduce energy use, water use and embodied energy in materials.

This certification protocol is divided into three stages:

[24] For further details about the Energy star Portfolio Manager Score see: https://www.energystar.gov/about?s=footer

- Preliminary Certification (Design stage): During this stage, the EDGE Auditor shall verify through a Design Audit that the building project design meets the EDGE Standard at EDGE or EDGE Advanced level. This must be undertaken before the building project is complete. If a building is complete, the Client should proceed directly to the EDGE Certification.

- EDGE Certification (Post-construction stage): During this stage, the property owners should provide full access to the building project site and all supporting documentation to let the auditors verify that the EDGE measure claimed are physically present in the completed building project.

- EDGE Zero Carbon Certification: Finally, for this stage, the property owners must define a start and end date for a twelve-month period for which the project will provide operational data of the list of required efficiency measures of the Zero Carbon Certification. During these twelve months, the building should be occupied at 75 % of expected occupancy.

Considering that this thesis aims to measure and monitor energy consumption and efficiency during the operational phase of the assets, the stage selected for the indicator's identification is the EDGE Zero Carbon Certification.

The energy consumption and efficiency indicators identified within the EDGE Zero Carbon Certification are shown in *Table 14:*

EDGE - Zero Carbon Certification			
Credit	**Indicator**	**Index (Unit of measurement)**	**Frequency of measurement**
Item 5.15.5 Certification protocol: Energy bills	Quantity of energy consumed by type of fuel	kWh/m2 GIA	annual
	Quantity of electricity produced on-site by type	kWh/m2 GIA	annual
	Quantity of electricity purchased off-site by type	kWh/m2 GIA	annual

Table 14 Indicators proposed in the EDGE Zero Carbon Certification

Part 2: FRAMEWORK OF ENERGY CONSUMPTION AND EFFICIENCY INDICATORS

CHAPTER 3: IN-USE ENERGY CONSUMPTION AND EFFICIENCY INDICATORS

Building energy assessment, extended to its design, construction, and useful life allows for proper quantification of the building's energy implications and provides the basis for appropriate planning in the sector (Casals, 2006).

One of the key points for building energy management strategies, in terms of the fulfilment of their objectives, is the main indicators implemented. Therefore, quantifying building energy consumption and management through a set of key performance indicators (KPIs) is an essential step in achieving energy saving goals in both new and existing buildings (Li et al., 2020).

In this chapter, the set of energy consumption and efficiency indicators is selected and defined considering the following targeted objective for this thesis (*Figure 9*):

- Firstly, through the indicators selected, property owners and facility managers must be able to control and measure the energy consumption of their assets during the operational stage.
- Secondly, to complement the energy consumption monitoring, the indicators must provide information regarding the managerial actions taken to archive energy efficiency and limit the energy consumption during the operational stage.
- Finally, the set of indicators must help to declare non-financial disclosure to investors and stakeholders.

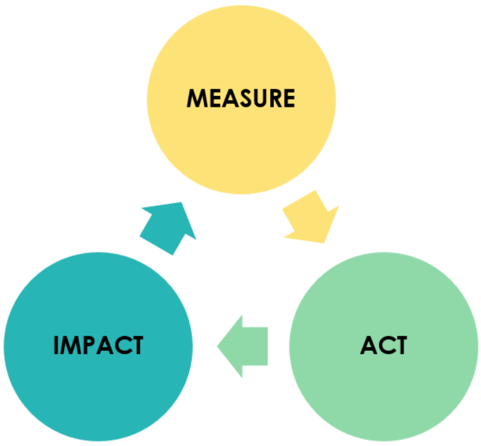


Figure 9 Measure-Act-Impact Model

3.1 Consolidation of indicators

Using as a database the total number of indicators presented by the sources analysed in the second chapter (117 indicators), the following procedure will be carried out to create a consolidated list of indicators to be used in the subsequent chapters of this thesis:

- Assignment of the "typology" to each indicator.
- Assignment of the "field of interest" to each indicator.
- Grouping of indicators by field of interest, analysis of similarity according to the description of each indicator by source.
- Presentation of the list of consolidated indicators.

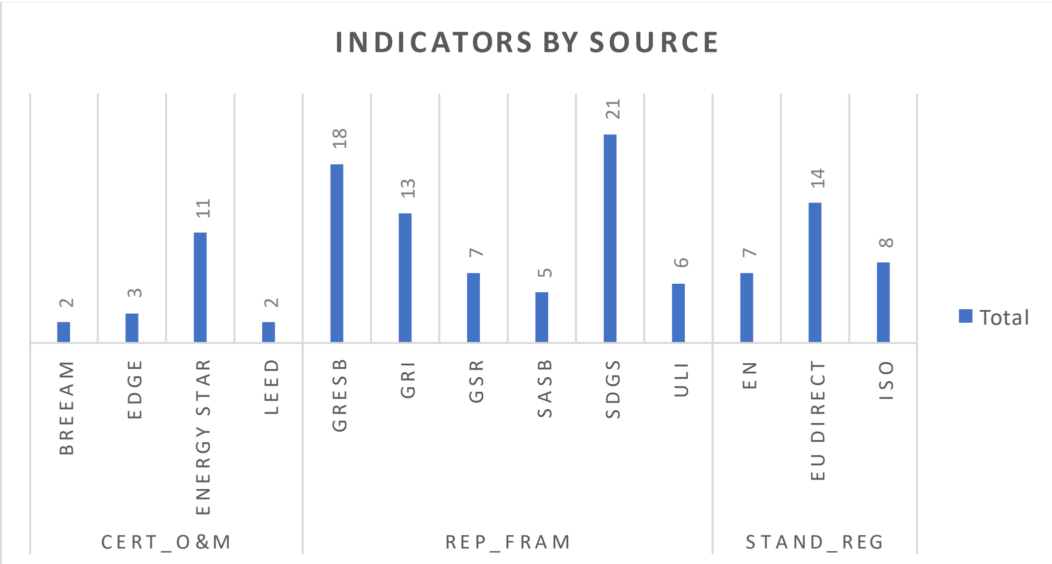


Figure 10 Indicators by source

Regarding the typology, using as reference and extending it within the perimeter of the energy aspect specified in the ISO 14001 and the GRESB framework[25] about the measurement of environmental performance, the indicators are separated in Management/Action and Performance/Impact type.

On the one hand, the Management/Action type comprises the indicators focusing on measuring the management efforts carried out to positively influence the energy performance, which can be relatively static information collected at the organizational or portfolio level such as management policies, processes, and investments aimed at the organisation energy efficiency projects. On the other hand, the Performance/Impact type comprises the indicators that measure the energy types, use and consumption during the operation of the daily services and processes performed within the assets. Therefore, the overall evaluation at an asset and portfolio level must consider a combination of both types of indicators (*Figure 10*).

[25]For further details about the GRESB Assessment see: https://gresb.com/2018-in-review-and-the-road-ahead/

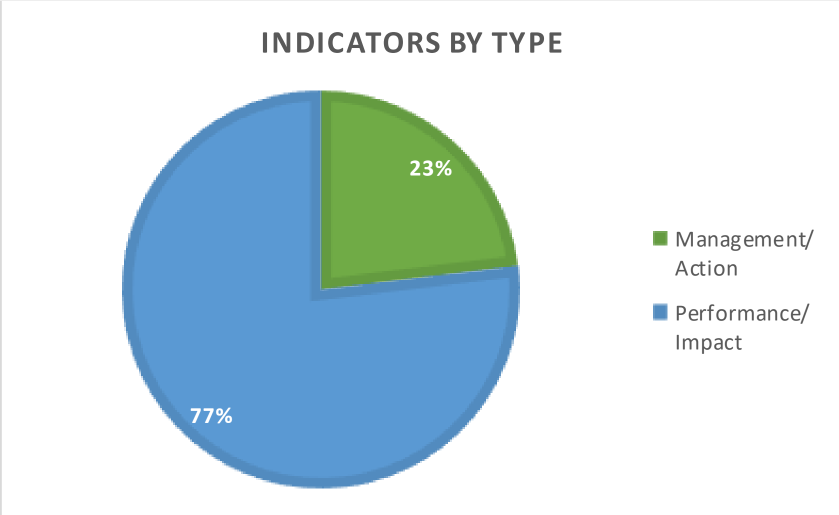


Figure 11 Indicators by type

Regarding the field of interest, the indicators are grouped in three macro-fields: Energy Monitoring, Building Certifications and Energy efficiency initiatives (*Figure 12*).

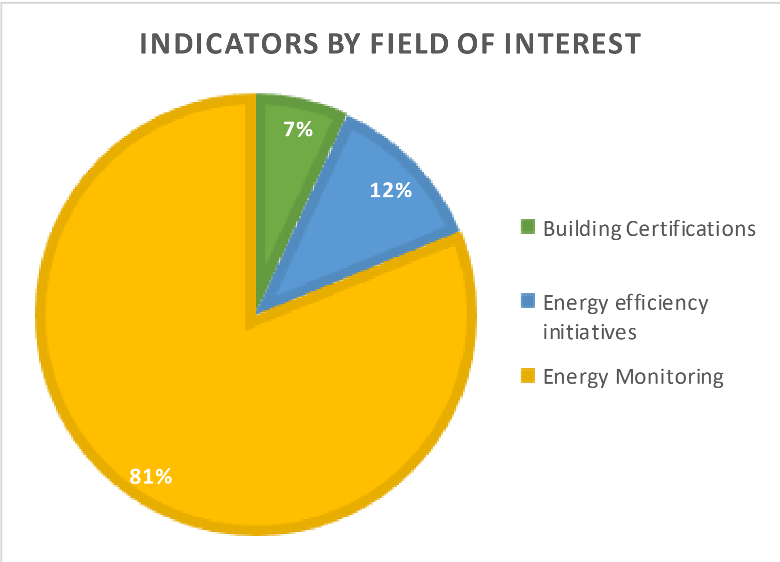


Figure 12 Indicators by field of interest

The 117 indicators were grouped within each major field of interest; subsequently, the indicators with description, objectives and similar units of measurement were unified. The list of 21 consolidated indicators proposed per field of interest is shown in *Table 15*, *Table 16* and *Table 17*.

	Asset level	Portfolio level		
Consolidated indicators	U.M	U.M	Type	Sources related
Amount of Green Building certificates at the operational stage	Number of green building O&M certifications per building	% of the portfolio covered	Management/ Action	Rep_Fram (GRESB, GSR, ULI) Cert_O&M (EnergyStar)
Amount of Energy performance rating certifications	Number of energy rating certifications per building	% of the portfolio covered	Management/ Action	Rep_Fram (GRESB, SASB) Stand_Reg (ISO, EU Direct)

Table 15 Building Certifications consolidated indicators

	Asset level	Portfolio level		
Consolidated indicators	U.M	U.M	Type	Sources related
Total investment for building energy upgrade	Euros invested per building	Total euros invested in all buildings	Management/ Action	Rep_Fram (GSR, ULI) Stand_Reg (EU Direct) Cert_O&M (EnergyStar)
Total investment in renewable energy projects	Euros invested per building	Total euros invested in all buildings	Management/ Action	Stand_Reg (EU Direct)
Amount of Building energy consumption policies	Number of policies per building	% of the portfolio covered	Management/ Action	Rep_Fram (GRESB) Stand_Reg (EU Direct)
Amount of Building energy consumption codes and standards	Number of energy consumption codes and standards per building	% of the portfolio covered	Management/ Action	Rep_Fram (GRESB, GSR)
Amount of Technical building energy efficiency assessments during the last four years	Number of technical energy efficiency assessments per building	% of the portfolio covered	Management/ Action	Rep_Fram (GRESB)
Amount of reduction in energy consumption achieved as a direct result energy efficiency initiatives	KWh or multiple by building	KWh or multiple in all buildings	Performance/ Impact	Rep_Fram (SDG, GRI, ULI) Stand_Reg (ISO)

Table 16 Energy efficiency initiatives consolidated indicators

	Asset level	Portfolio level		
Consolidated indicators	U.M	U.M	Type	Sources related
Building Automation and electronic monitoring of building systems coverage	sqm of floor area covered	% of the portfolio covered	Management/ Action	Stand_Reg (EU Direct)
Implementation of data management systems for data collection and measurement of energy consumption	sqm of floor area covered	% of the portfolio covered	Management/ Action	Rep_Fram (GRESB, SASB) Stand_Reg (EU Direct)
Building total energy consumption	KWh or multiple	KWh or multiple	Performance/ Impact	Stand_Reg (EU Direct, EN, ISO) Cert_O&M (LEED, BREEAM, EnergyStar) Rep_Fram (GRI, SDG, ULI, GRESB, GSR)
Total consumption from non-renewable sources	KWh or multiple	KWh or multiple	Performance/ Impact	Rep_Fram (GRI, SDG) Stand_Reg (ISO, EN, EU Direct)
Total energy consumption from renewable sources	KWh or multiple (off-site and on-site)	KWh or multiple (off-site and on-site)	Performance/ Impact	Cert_O&M (BREEAM, EnergyStar) Rep_Fram (GRESB, GRI, SDG) Stand_Reg (EU Direct, ISO, EN)
Building energy consumption by fuel share	% by fuel share	% by fuel share	Performance/ Impact	Rep_Fram (GSR, ULI)
Total electricity use	KWh or multiple/m2 GIA	KWh or multiple/m2 GIA	Performance/ Impact	Rep_Fram (GRI, SDG) Cert_O&M (EDGE, EnergyStar)
Energy Cost	euros	euros	Performance/ Impact	Cert_O&M (EnergyStar)
Energy intensity	KWh/m2 GIA	KWh/m2 GIA	Performance/ Impact	Rep_Fram (GSR, GRI, ULI, GRESB) Cert_O&M (EnergyStar)
Energy rate	euros/kWh	euros/kWh	Performance/ Impact	Cert_O&M (EnergyStar)

Like-for-like percentage change in energy consumption	KWh or multiple	KWh or multiple	Performance/ Impact	Rep_Fram (GRESB, SASB)
Energy generated from renewable sources	KWh or multiple (off-site and on-site)	KWh or multiple (off-site and on-site)	Performance/ Impact	Stand_Reg (EU Direct, ISO, EN) Cert_O&M (EnergyStar) Rep_Fram (GRESB, GRI, SDG)
% Total renewable energy	% share from all energy sources or fuels	% share from all energy sources or fuels	Performance/ Impact	Rep_Fram (GRESB, SASB, GSR, SDG) Stand_Reg (EU Direct, ISO)

Table 17 Energy monitoring consolidated indicators

3.2 Consolidated indicators: Description and calculation formula

Asset (whole building) and portfolio level indicators provide a snapshot of overall building energy performance through high-level benchmarking and tracking. Furthermore, the indicator's outputs can come in different forms based on the unit of measurement and the main goal and calculation description.

In this item, the description of the 22 consolidated indicators and the calculation procedure, based on the information defined in each related source, are presented to subsequently identify the necessary inputs to obtain the results of each indicator through time. The definition used the information that included and aligned the objective and units of measurement of the sources contained within the consolidated indicator.

As a general consideration for all the indicators explained in this section, the time range for the evaluation according to the information presented in each source is annual. Additionally, in some cases, two representation levels are proposed: Asset-level and portfolio-level. Finally, some sources propose to aggregate the results at portfolio-level according to the property type of the assets; in this case, as a possible additional way to represent the results, the total floor area in the denominator of the percentage fraction can be considered as follows:

"The percentage can also be calculated for each property type of the assets within the portfolio, in this case, the denominator in this indicator is the total floor area for a property type, not total floor area for the whole portfolio, and for the numerator, it considers the floor area of all assets for the property type (GRESB, 2018)".

- **<u>Amount of Green Building certificates at the operational stage</u>**

  Description: This indicator intends to assess the entity's voluntary use of green building certifications for building operation and maintenance (O&M) under leading schemes like LEED, BREEAM, WELL and among others, that evaluate the performance of a building and its energy service systems. As an additional consideration, this indicator must only include green building certificates that were awarded before or during the reporting period and specify the type and level of certification obtained for each asset (GRESB, 2018).

  Calculation method: At an asset level (1), the indicator is calculated as the amount of O&M green building certifications associated with each specific building. At a portfolio level (2), the percentage is calculated by dividing the sum of the floor area of the assets that have obtained at least one green building certification over the total floor area of the portfolio.

  Unit of measurement: (1) Number of green building O&M certifications per building and (2) % of the portfolio covered.

- **<u>Amount of Energy performance rating certifications</u>**

  Description: This indicator intends to assess the entity's use of building energy rating certifications, which may focus on rating operational energy use and certifications based on ongoing performance (SASB, 2018). As an additional consideration, this indicator must only include energy ratings that were awarded before or during the reporting period (pre-assessments or other unofficial rating schemes are not valid) because some energy ratings are valid for a limited period only, so is important that the rating should be officially in effect during the reporting period(GRESB, 2018).

  Calculation method: At an asset level (1), the indicator is calculated as the amount of O&M energy rating associated with each specific building. At a portfolio level (2), the percentage is calculated by dividing the sum of the floor area of the assets that have obtained at least one energy rating certification over the total floor area of the portfolio.

  Unit of measurement: (1) Number of energy rating certifications per building and (2) % of the portfolio covered.

- **<u>Total investment for building energy upgrade</u>**

  Description: This indicator intends to measure the investment carry out to increase the energy efficiency of assets within a portfolio. In specific, this indicator examines measures or projects undertaken to reduce the portfolio's energy consumption. Usually, the implementation of these measures results from technical building assessments, which are focused on investigating the energy use and requirements of the building based on its characteristics and installed equipment (GRESB, 2018).

Calculation method: At an asset level (1), the indicator is calculated as the sum of the amount of money invested per building energy upgrade project per building. At a portfolio level (2), the output is obtained by the sum of the amount of money invested in all the projects performed within the year of analysis.

Unit of measurement: (1) Amount of euros invested per building and (2) Total euros invested in all buildings.

- **Total investment in renewable energy projects**

  Description: This indicator intends to measure the investment put on essential infrastructure for an enhanced technically feasible and economically affordable uptake of renewable energy within a portfolio (European Union, 2018a). Examples of renewable energy technologies incorporated in building energy systems include Solar electric or photovoltaic (PV) systems, solar thermal and solar ventilation air preheating, geothermal heat pump, wind turbine and biomass systems (Hayter & Kandt, 2011).

  Calculation method: At an asset level (1), the indicator is calculated as the sum of the amount of money invested per renewable energy technology project per building. At a portfolio level (2), the output is obtained by the sum of the amount of money invested in all the projects performed within the year of analysis.

  Unit of measurement: (1) Amount of euros invested per building and (2) Total euros invested in all buildings.

- **Amount of Building energy consumption policies**

  Description: This indicator intends to measure the existence and scope of policies that address fuel consumption or management of energy from renewable and non-renewable sources. Policies on environmental issues assist organizations with incorporating sustainability criteria into their business practices (GRESB, 2018).

  Calculation method: At an asset level (1), the indicator is calculated as the energy consumption policies associated with each specific building. At a portfolio level (2), the percentage is calculated by dividing the sum of the floor area of the assets that have incorporated at least one energy consumption policy over the total floor area of the portfolio.

  Unit of measurement: (1) Number of energy consumption policies per building and (2) % of the portfolio covered.

- **Amount of Building energy consumption codes and standards**

  Description: This indicator intends to assess the performance of third-party verification and assurance of energy data reported across the whole portfolio and the used assurance code or standard (GRESB, 2018).

  Calculation method: At an asset level (1), the indicator is calculated as the number of codes and standards used to review the energy consumption data per building. At a portfolio level (2), the percentage is calculated by dividing the sum of the floor area of the assets that have at least used one code/standard to review the energy consumption data over the total floor area of the portfolio.

  Unit of measurement: (1) Number of energy consumption codes and standards per building and (2) % of the portfolio covered.

- **Amount of Technical building energy efficiency assessments during the last four years**

  Description: This indicator intends to assess the use of technical building assessments to identify energy efficiency opportunities, including whether such assessments are in-house or external and the general portfolio coverage of such assessments during the last four years(SASB, 2018).

  Calculation method: At an asset level (1), the indicator is the number of the technical energy efficiency assessment performed associated with each building in the portfolio. At a portfolio level (2), the percentage is the fraction of the portfolio calculated by floor area for which energy efficiency assessments were performed during the last three years. Thus, the numerator is the floor area of the assets for which the applicable energy efficiency assessment was performed, and the denominator is the total floor area of the portfolio (GRESB, 2018).

  Unit of measurement: (1) Number of technical energy efficiency assessments per building and (2) % of the portfolio covered.

- **Amount of reduction in energy consumption achieved as a direct result of energy efficiency initiatives**

  Description: This indicator intends to measure the direct reduction in energy consumption achieved as a direct result of conservation and efficiency initiatives.

  Calculation method: The difference between the accumulated value of energy consumption in the month preceding the energy efficiency project implementation minus the energy consumption value in the following month after implementation.

According to the GRI Disclosure 302-4, the reduction can be reported by type of energy: fuel, electricity, heating, steam, cooling, or all.

Unit of measurement: (1) KWh or multiple by building

- **<u>Building Automation and electronic monitoring of building systems coverage</u>**

  Description: This indicator intends to assess the installation of building automation and electronic monitoring of technical building systems to secure energy savings over time.

  Calculation method: At an asset level (1), a building or floor area is considered to have complete energy consumption data coverage when energy consumption data (i.e., energy types and amounts consumed) is obtained for all types of energy consumed in the relevant floor area during the reporting period, regardless of when such data was obtained (SASB, 2018). At a portfolio level (2), the percentage shall be calculated as the portfolio floor area with complete energy consumption data coverage divided by the total portfolio floor area for which energy is used.

  Unit of measurement: (1) Square meters of floor area covered per building (2) % of the portfolio covered.

- **<u>Implementation of data management systems for data collection and measurement of energy consumption</u>**

  Description: This indicator intends to assess the use of a software system that enables an organization to collect, monitor and analyse energy performance data across individual buildings in the portfolio and benchmark building performance within or outside the portfolio or against industry standards. A data management system is primarily focused on quantitative information and works as a centralized data collection and analysis tool (GRESB, 2018).

  Calculation method: At an asset level (1), a building or floor area is considered to have complete energy consumption data coverage when energy consumption data (i.e., energy types and amounts consumed) is obtained for all types of energy consumed in the relevant floor area during the reporting period, regardless of when such data was obtained (Sustainability Accounting Standards Board, 2018). At a portfolio level (2), the indicator should reflect the proportion of the whole portfolio floor area covered by the data management system. Therefore, if the floor area covered changed during the reporting period, for example, because of a change in the number of assets, the floor area percentage applicable at the end of the reporting period must be used (GRESB, 2018).

Unit of measurement: (1) Square meters of floor area covered per building (2) % of the portfolio covered.

- **<u>Building total energy consumption</u>**

  Description: The indicator intends to assess the total energy consumption within the organization. The scope of energy consumption includes energy from all sources, including energy purchased and produced from sources external to the entity and its tenants (SASB, 2018).

  Calculation method: The indicator is calculated by the sum of the KWh or multiple energy consumed from all sources.

  Unit of measurement: (1) KWh or multiple

- **<u>Total consumption from non-renewable sources</u>**

  Description: The indicator must report the total energy consumption from non-renewable sources separately. According to the EIA, non-renewable energy sources can be divided into electricity, natural gas, district heat and fuel oil.

  Calculation method: The indicator is calculated by the sum of the KWh or multiple energy consumed from non-renewable sources.

  Unit of measurement: (1) KWh or multiple

- **<u>Total energy consumption from renewable sources</u>**

  Description: The indicator must report the total energy consumption separately from off-site and on-site renewable sources. Renewable sources can be divided into solar energy, wind energy, hydro energy, geothermal energy, and biomass energy.

  Calculation method: The indicator is calculated by the sum of the KWh or multiple energy consumed from renewable sources within the year of analysis. The indicator must be aggregated by renewable sources off-site (1) and renewable sources on-site (2).

  Unit of measurement: (1) KWh or multiple off-site (2) KWh or multiple on-site

- **<u>Building energy consumption by fuel share</u>**

  Description: This indicator calculates the total energy consumed in the organisation in the same way as the indicator *"Building total energy consumption"* but presents the result in a percentual format by fuel share.

  Calculation method: The indicator is calculated by dividing the amount of energy consumed by each fuel, renewable and non-renewable, by the total building energy consumed.

  Unit of measurement: (1) % by fuel share

- **<u>Electricity use</u>**

  Description: According to the EnergyStar Portfolio Manager Glossary, the indicator must report separately the total electricity use summed across all electricity meters. The information can be gathered using electronic devices or through the historicization of the KWh rate printed in the electric bills over time and includes electricity from renewable and non-renewable sources, whether imported or generated on-site.

  Calculation method: The indicator is calculated by the sum of the kilowatt-hour (kWh) of electricity consumed divided by the total gross floor area (GIA) of the asset within the year of analysis.

  Unit of measurement: (1) KWh or multiple/m2 GIA

- **<u>Energy Cost</u>**

  Description: According to the EnergyStar Portfolio Manager Glossary, this indicator measures the annual energy cost associated with the selected yearly period for a building. Energy cost is available for each energy type and as an aggregated value across all energy types.

  Calculation method: This indicator is calculated by the sum of the cost charged on each fuel type source bill within the reporting year.

  Unit of measurement: (1) euros

- **<u>Energy intensity</u>**

  Description: According to the EnergyStar Portfolio Manager Glossary, this indicator refers to the final energy used in buildings per unit of floor area. The final energy includes space heating and cooling, cooking, water heating, lighting, appliances and others.

Calculation method: The indicator is calculated by the sum of the KWh or multiple energy consumed from all sources divided by the total gross floor area (GIA) of the asset within the year of analysis.

Unit of measurement: (1) KWh or multiple/m2 GIA

- **<u>Energy rate</u>**

  Description: According to the EnergyStar Portfolio Manager Glossary, this indicator intends to calculate the price of energy per unit.

  Calculation method: This indicator is calculated by dividing the total energy cost over the total energy consumption by type of energy within the period of analysis. This indicator can be aggregated by asset-level (specific asset) and portfolio level (all the assets in the portfolio).

  Unit of measurement: (1) euros/kWh

- **<u>Like-for-like percentage change in energy consumption</u>**

  Description: This indicator intends to complement the absolute energy performance measures by showing the change in performance unrelated to fluctuation in portfolio size. In other words, the energy consumption that has been consistently in operation during the most recent reporting years.

  Calculation method: The indicator is calculated by the change in energy consumption for the part of the portfolio that has remained the same year-over-year or for which comparable consumption data has been available for both years (GRESB, 2018).

  Unit of measurement: (1) KWh or multiple

- **<u>Total energy generated from renewable sources</u>**

  Description: This indicator intends to measure the total energy generated and consumed on-site from renewable sources like solar electric or photovoltaic (PV) systems installed in the building (SASB, 2018).

  Calculation method: The indicator is calculated by the sum of the KWh or multiple energy generated and consumed on-site from renewable sources.

Unit of measurement: (1) KWh or multiple on-site

- **<u>% Total renewable energy</u>**

  Description: This indicator refers to the share of renewables in the final energy use of the buildings and the whole portfolio (SASB, 2018). The indicator is derived from the building final energy use by fuel type.

  Calculation method: The percentage shall be calculated as renewable energy consumed divided by total energy consumed.

  Unit of measurement: (1) % share from all energy sources or fuels

3.3 Consolidated indicators: Data input identification and description

Several data input elements are needed to build and calculate the energy consumption and efficiency indicators described in the previous section. Therefore, this section highlights and give a normalized definition of the key data input needed to build each indicator.

The most relevant data input, identified according to the methods of calculations presented in item 3.2, are grouped and divided by categories to organize them effectively. The categories selected are:

A. General Background data

- Baseline year: The initial year the participant uses as a starting point to set and measure improvement targets for any performance indicator (GRESB, 2018).

- Building code: Unique code that allows identifying a building within the portfolio of a company.

- Area of each building: According to the guidelines of the different sources, different types of areas can be used to calculate the energy ratios or percentages. The important thing is that they are used in a uniform way for all the input data. However, for this thesis, it is decided to normalize this data input as the Gross Internal Area (GIA) value in square meters.

B. Project Background data

- Project Code: an alphanumeric code for the recognition of an energy upgrade or renewable project.

- Project Type: is a project classification defined during the project definition that specifies essential project attributes and indicates the intended use of the funds. The two types of projects needed to be determined are energy upgrade and renewable energy.

- Project date start: the date that has been defined as the start of a project.

- Project date end: the date that has been defined as the start of a project.

- Project budget or cost: the total projected costs needed to complete a project over a defined period of time. It includes labour costs, material procurement costs and operating costs.

- Building energy upgrade project: projects with type value equal to Energy upgrade.

- Renewable energy project: projects with type value equal to Renewable energy.

C. Certifications Background data

- Baseline year: The initial year the participant uses as a starting point to set and measure improvement targets for any performance indicator (GRESB, 2018).

- Operational green building certificate: Green Building Certificate for operational buildings, obtained based on actual data of how the building is operated for a specific period. Typically, these Green Building Certificates certify that individual assets are managed in consistent and independently developed sustainability-related criteria.

- Energy rating certifications: Document which sets out the energy efficiency of a property on a traffic light system of A (most efficient) to G (less efficient). Typically, these rating certificates indicate the project's name and location, version of the rating system, certification date, and level of recognition.

- Level of certification: The level achieved with successful completion of the certificate or rating scheme.

- Year of certification: The year in which a rating or green building certification was awarded and is officially valid.

- Number of certified assets: The number of assets that were awarded with a green building certificate before or during the reporting period (excluding pre-assessments or other unofficial forms of pre-certification) (GRESB, 2018).

- Number of assets with a rating system associated: The number of assets with an energy performance rating before or during the reporting period (excluding pre-assessments) (GRESB, 2018).

D. Document Compliance Background data

- Energy Consumption policies associated to each building: Number of policies or programs which drive the implementation of projects that minimize or reduce energy use during the operation phase per building.

- Codes and standards associated to each building: Number of Energy codes and standards which set minimum efficiency requirements in energy use and emissions over the operation phase per building.

- Date created: Date on which a document was delivered or uploaded.

- Expiration date: End date on which a document is valid.

E. Condition Assessment Background data

- Technical building energy assessment: Formal documented assessment of a building undertaken by a person with technical expertise. As examples of types of assessment can include but are not limited to: Building envelope (insulation, fenestration), heating and cooling system, ventilation system, service water heating system, automatic controls, lighting system and energy-saving recommendations.

- Date created: Date on which the assessment was performed.

F. Energy Background data

- Fuel type: Includes primary non-renewable fuels such as natural gas, coal, and oil combusted onsite. Furthermore, it includes renewable fuels such as solar energy, wind energy, hydro energy, geothermal energy, and biomass energy.

- Energy consumption data by type of fuel: Consumption Data provided by a utility provider using official documentation (i.e. invoices) (GRESB, 2018). It includes all kinds of energy (electricity, natural gas, LPG, biomass, etc.).

- Date created: This is the date on which an invoice is uploaded or registered into the system.

- Buildings with associated energy services bills: Number of buildings that have associated invoices within the reporting period.

- Accumulated value of energy consumption per month: Sum of the consumption data per building specified in the invoices by fuel type received monthly.

- Energy cost: The costs to use each form of energy within all meters of a building. This value will be obtained from what is reported in the invoices for each type of fuel.

- Kilowatt-hour (kWh) or multiple of renewable energy: Sum of the consumption data per building coming from renewable energy sources or non-fossil fuels (i.e. wind, solar, geothermal, hydropower, biomass, biogases, etc.).

- Kilowatt-hour (kWh) or multiple of non-renewable energy: Sum of the consumption data per building coming from non-renewable energy sources or fossil fuels.

- Kilowatt-hour (kWh) of electricity consumed: Quantity of electricity consumed in kWh that can be gathered from the utility bills of a building.

- Energy generated in KWh or multiple from renewable sources on site: Sum of the energy production coming from renewable energy source inside the analysed building.

CHAPTER 4: CONFRONT BETWEEN LIST OF IN-USE INDICATORS AND ARCHIBUS

This chapter identifies the information managed within one of the most recognised IMWS software databases and how it can be used to measure and monitor the energy consumption and efficiency indicators described in the third chapter.

Using the definition and data input necessary to calculate the energy consumption and efficiency indicators, a comparison will be made between the information inside the IWMS database. This confrontation aims to present the best combination of the tables and fields managed through all the IWMS modules to measure all the identified indicators in the previous chapter.

4.1 ARCHIBUS® software modules

As explained in the first chapter, the IWMS is a useful software for companies in the management of services during the whole life cycle. This type of software covers several areas of real estate management, such as space management, workplace, maintenance management, efficient use of energy while respecting environmental sustainability, and the management of project capital (planning, management of tenders, documentation, and accounting). One of the most recognized and positioned software in the facility management market, and the analysis of this thesis is based, is the ARCHIBUS® platform.

ARCHIBUS® platform comprises six standard modules, i.e. Real Estate Portfolio Management, Capital Project Management, Space Planning & Move Management, Workplace & Asset Management, Building Operation and Environmental & Risk Management. In addition, it counts with a series of extensions that allow the integration with third technologies like AutoCAD and Revit.

Each module of ARCHIBUS® is subdivided into macro-environments or application processes that can be developed vertically, specialising on a single module, and horizontally, integrating processes that belong to different modules (*Figure 13*).

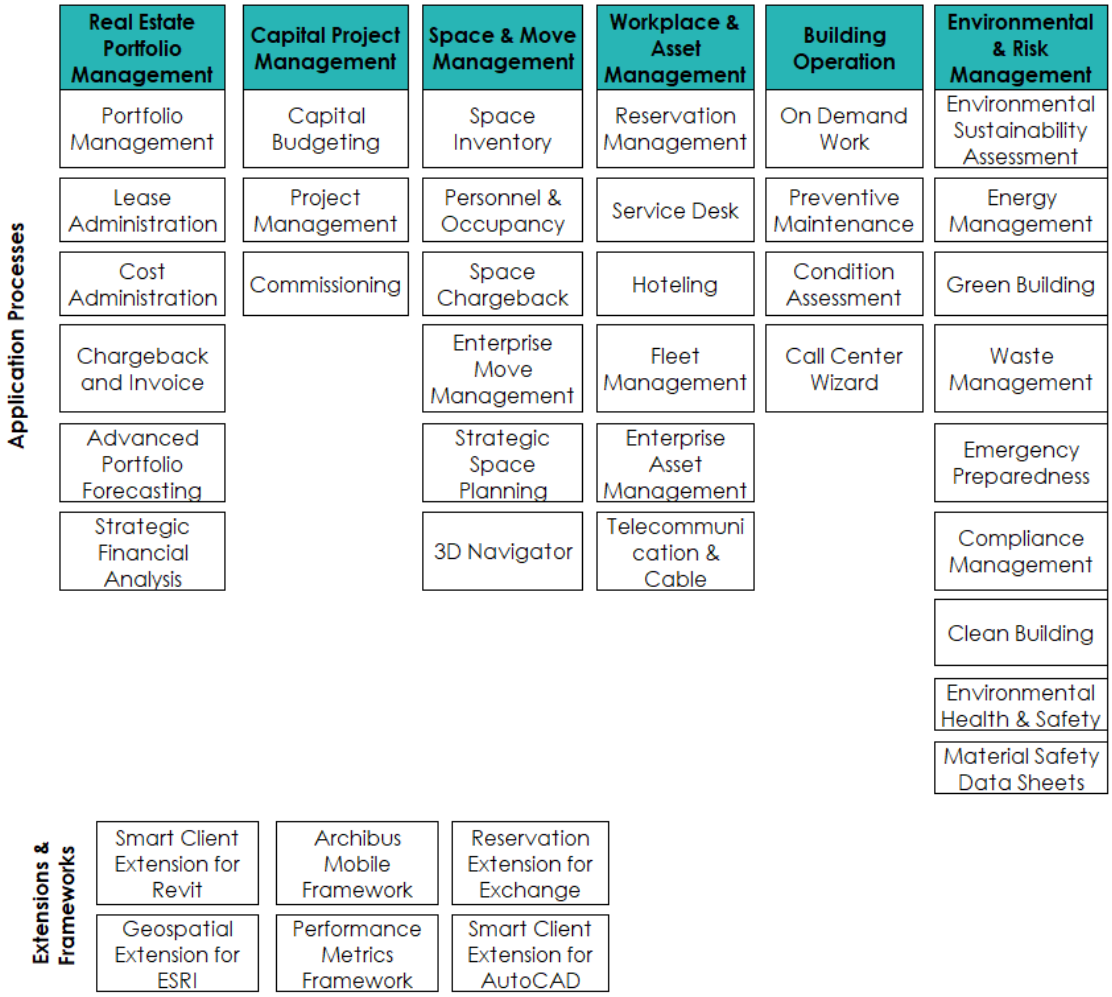


Figure 13 ARCHIBUS® graphical standard structure

Due to the modularity of the software, ARCHIBUS® offers an information system customizable by the users, able to meet specific needs. Therefore, the users have the possibility to:

- Carry out a single initial implementation which includes the installation and management of a single macro-environment or process.

- Carry out a gradual implementation of the platform within an organization, increasing the installation of environments over time and increasing the management perimeter inside the database.

4.2 Background information per module

The background information inside ARCHIBUS® is organized, within each module, by tables and fields. Being a centralized information database, from the various modules presented in the previous item, it is possible to access any table field. However, it must be considered that the registry and management of each table field are carried out from a specific main source. This concept allows us to understand that each of the application processes within ARCHIBUS® is in charge of managing specific tables and fields according to the aim and perimeter of each module.

To have an overview of the background data that belongs to the perimeter of each module, the main tables managed within ARCHIBUS® have been identified by macro-module in the following tables:

Real Estate Portfolio Management	
Entities	**Main data managed**
Sites	Site Code, Site Name, Country Code, Region Code, State Code and City Code
Properties	Property Code, Property Name, Property Use, Property Use, Property Status, Property Condition, Account Code, Property Occupancy, Zoning Type, Site code, Address, Number of Buildings, Land Acres, Rentable Area and Owned Percentage
Lease contracts	Lease Template Code, Lease Status, Tenant Name, Landlord Name, Building, Type of contract, Start date, End date, Date Move In and Account Code
Business Units	Business Unit Code, Business Unit Name, Employee Headcount and Chargeable Area
Divisions	Business Unit, Division Code, Division Name and Division Head
Departments	Division Code, Department Code, Department Name and Department Head

Table 18 Real Estate Portfolio Management data input perimeter

Capital Project Management	
Entities	**Main data managed**
Program	Program Type and Program description
Project Template	Project code, Project Name, Project Type, Project Summary, Project Description, Project Scope, Project Benefit, Budgeted Cost, Date requested, Date started, Date End, Estimated duration, Days per week, Criticality and Project Requestor
Project budget	Budgeted cost, Best Case cost, Estimated Baseline Cost, Committed Cost, Likely Cost, Estimated Cost of Design, Negotiated Cost, Cost paid and Cost worst case

Table 19 Capital Project Management data input perimeter

Space & Move Management	
Entities	**Main data managed**
Buildings	Building Code, Building Name, Building Type, Building Use, Building Status, Book Value, Market Value, Address, Postal Code, Construction Type and Facility Type
Floors	Floor Code, Floor Name, Gross Internal and External Area, Cost per square meter and Area occupied
Rooms	Room Name, Room Code, Room Type, Room Category, Room Standard, Room use, Room Area, Room photo and Employee Capacity
Employees	Employee code, Employee Name, Company Name, Email, Employee Title and phone work

Table 20 Space & Move Management data input perimeter

Workplace & Asset Management	
Entities	**Main data managed**
Assets and Furniture	Asset code, Asset Type, Asset Standard, Asset status, Condition
Systems	System Code, Building Code, Vendor Contact, Condition Index, System Type, Recovery Status, Classification Code and System Description
Equipment Systems	Equipment Code, Building System ID, System Name, Tree label, Mission Criticality, Function Criticality and Stakeholder Type
Custodians	Custodian Type and Custodian Description
Vendors	Vendor Code, Company Name, Vendor Description, Vendor Type, Address Line, City, State, Country, Postal Code, Phone Number, Email Address, Contact Name, Contact's Title, Website URL and Alternative Contact
Service Contracts	Service Contract Code, Service Contract Vendor, Service Contract Graphic, Service Contact, Date Service Contract Expires and Description

Table 21 Workplace & Asset Management data input perimeter

Building Operation	
Entities	**Main data managed**
Equipment Standards	Equipment Standard, Equipment Standard Description, Equipment Category, Classification Code, Manufacturer, Standard Price, Model Number, Standard Price, Standard Area, Amperage, Equipment BTU, Size/Capacity, Standard Cost to Move, Voltage, Power and Drawing Block
Warranties	Warranty Code, Warranty Vendor, Contact Info, Description, Expiration Date, Meter Units, Metered Expiration and Warranty document
Problem Type	Problem Type Code, Problem Type Description, Cost Category and Problem Class
Questionnaire Questions	Question Text, Sort Order, Question Name and Questionnaire Code
Craftsperson	Craftsperson Code, Craftsperson Name, Craftsperson's email, Work Team Codes, Primary Trade, Craftsperson Position, Special Skills, Contract Expiration, Status, Hourly Rate, Auto Insurance End Date, Overtime Rate and Liability Insurance End Date
Action Types	Action type, Action type description, Action type Instructions, Action type work request and Action Type Standard Cost

Table 22 Building Operation data input perimeter

Environmental & Risk Management	
Entities	**Main data managed**
Utilities	Bill Type, Cost Category, Bill type description, Bill type units and Conversion Factor to Common Unit
Meter/Data Point	Data Point Name, Data Point ID, Measurement type, Measurement Units, Equipment code, Interval, Data Type, Area Measured (Manual entry), Total Area Measured, Virtual Meter definition (Yes/No) and Data Point Description
Certification Standards	Certification Standard, Standard Type, Scoring Type, Standard Description, Certification Level, Minimum Score and Maximum Score
Document Compliance	Document Fulfilment ID, Document Fulfilment Description, Document Fulfilment Type, Document Fulfilment Category, Severity ID, Compliance Criteria, Repository Type, Expiration Period, Time to Notify, Interval to Notify, Date Start, Date End, Compliance Criteria ID, Compliance Level Code, Regulation Category Code, Regulation Category Description and Requirement Category Name
Waste Management	Waste Category, Waste Category Description, Container Categories, Container Category Description, Management Method Group, Management Method Code and Management Method
Waste Transporter	Transporter, Transporter Name, Status and Transporter Number

Table 23 Building Operation data input perimeter

4.3 Identification of the data input management within ARCHIBUS®

Considering the information presented in the third chapter, it has been carried out a comparison between the information inside the ARCHIBUS® database and the data input necessary to calculate all the consolidated indicators of energy consumption and efficiency.

Firstly, based on the basic information managed within each module or ARCHIBUS® application process, only the modules with the necessary information to calculate each indicator were identified in *Figure 14* ARCHIBUS® modules involved in the analysis. These modules are considered as the primary source of the data input required.

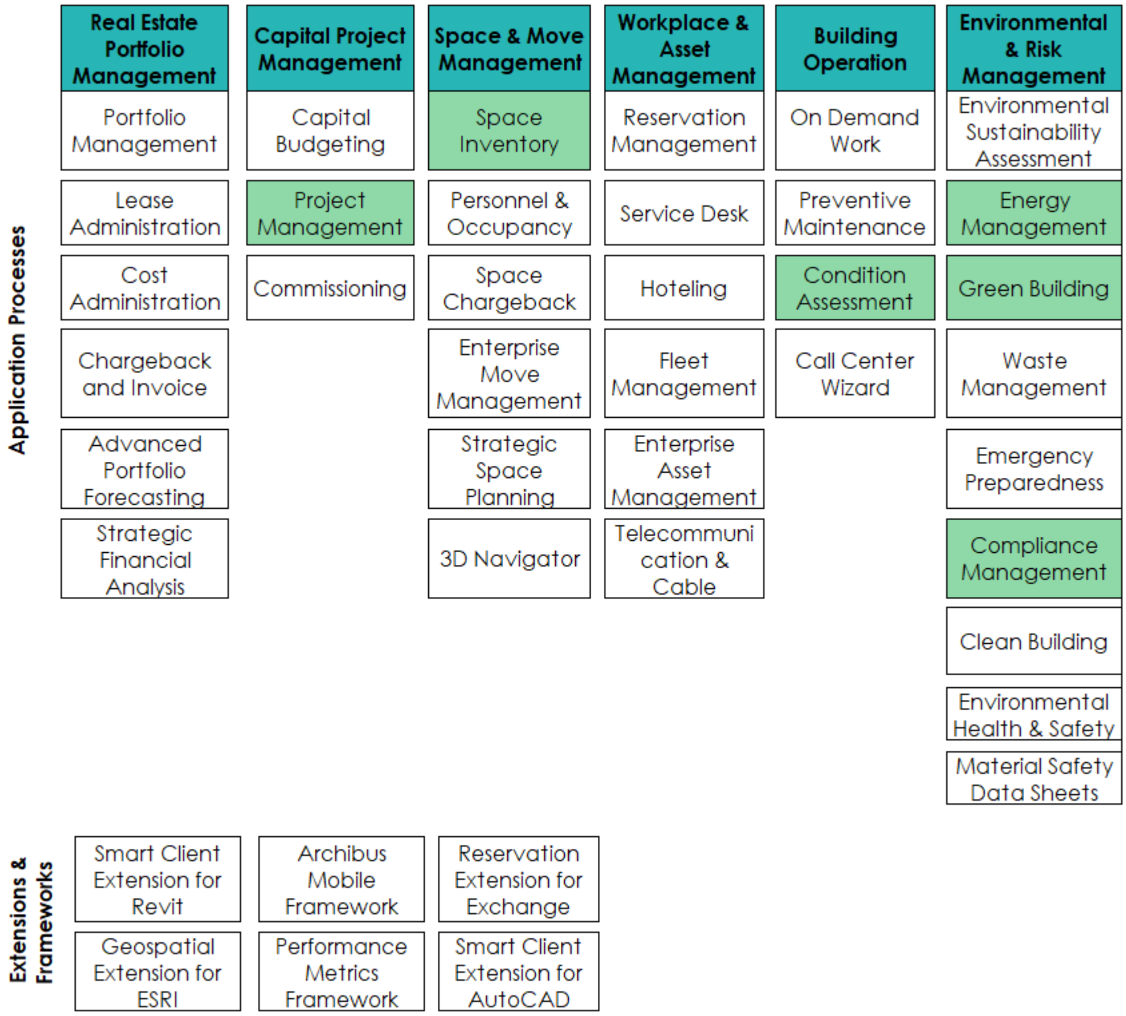


Figure 14 ARCHIBUS® modules involved in the analysis

Secondly, the comparison table was created for each field of interest of the consolidated indicators presented in the third chapter. In each table, as the main column, we have: Code and name of the indicator, data input required for the calculation. As the main row, we have the ARCHIBUS® modules involved in the analysis.

				ARCHIBUS MODULES					
				Capital Project Management	**Space Planning**	**Building Operation**	**Environmental and Risks Management**		
Code	**Consolidated indicators**	**Data input needed**		**Project Management**	**Space Inventory**	**Condition Assessment**	**Energy Management**	**Green Building**	**Document Compliance**
I1	Amount of green Building certificates at the operational stage	O&M certifications associated to each building	rs_bld_cert_link					x	
		Year of certification	cert_year					x	
		Building code	bl_id		x				
		Area of each building	area_gross_int		x				
I2	Amount of Energy performance rating certifications	Energy rating certifications associated to each building	rs_bld_rating_link						x
		Year of certification	rating_year						x
		Building code	bl_id		x				
		Area of each building	area_gross_int		x				

Table 24 Building Certifications consolidated indicators

				ARCHIBUS MODULES					
				Capital Project Management	Space Planning	Building Operation	Environmental and Risks Management		
Code	**Consolidated indicators**	**Data input needed**		**Project Management**	**Space Inventory**	**Condition Assessment**	**Energy Management**	**Green Building**	**Document Compliance**
I3	Total investment for building energy upgrade	Building energy upgrade projects	project_type	x					
		Building energy upgrade project code	project_id	x					
		Project date start	date_start	x					
		Project date end	date_end	x					
		Building energy upgrade project cost	cost_budget	x					
		Building code	bl_id		x				
I4	Total investment in renewable energy projects	Renewable energy technology projects	project_type	x					
		Renewable energy technology project code	project_id	x					
		Project date start	date_start	x					
		Project date end	date_end	x					
		Renewable energy technology project cost	cost_budget	x					
		Building code	bl_id		x				

Code	Consolidated indicators	Data input needed		Project Management	Space Inventory	Condition Assessment	Energy Management	Green Building	Document Compliance
I5	Amount of Building energy consumption policies	Energy Consumption policies associated to each building	doc_fulfillment_type						x
		Date created	date_created						x
		Expiration date	expiration_date						x
		Building code	bl_id		x				
		Area of each building	area_gross_int		x				
I6	Amount of Building energy consumption codes and standards	Codes and standards associated to each building	doc_fulfillment_type						x
		Date created	date_created						x
		Expiration date	expiration_date						x
		Building code	bl_id		x				
		Area of each building	area_gross_int		x				
I7	Amount of Technical building energy efficiency assessments during the last four years	Technical energy efficiency assessments associated to each building	activity_log			x			
		Date created	date_created			x			
		Building code	bl_id		x				
		Area of each building	area_gross_int		x				
I8	Amount of reduction in energy consumption achieved as a direct result of conservation and efficiency initiatives	Accumulated value of energy consumption per month	qty_kwh				x		
		Building energy upgrade projects	project_type	x					
		Building energy upgrade project code	project_id	x					
		Project date start	date_start	x					
		Project date end	date_end	x					
		Building code	bl_id		x				

Table 25 Energy efficiency initiatives consolidated indicators

Code	Consolidated indicators	Data input needed		ARCHIBUS MODULES					
				Capital Project Management	Space Planning	Building Operation	Environmental and Risks Management		
				Project Management	Space Inventory	Condition Assessment	Energy Management	Green Building	Document Compliance
I9	Building Automation and electronic monitoring of building systems coverage	Building automation and electronic monitoring of technical building systems data point	meter_type				x		
		Building code	bl_id		x				
		Date entered in the system	date_bl		x				
		Area of each building	area_gross_int		x				
I10	Implementation of data management systems for data collection and measurement of energy consumption	Buildings with associated energy services bills	bill_id				x		
		Service bill date	date_issued				x		
		Building code	bl_id		x				
		Area of each building	area_gross_int		x				
I11	Building total energy consumption	Type of fuel	bill_type_id				x		
		Kilowatt-hour (kWh) or multiple of energy consumption per fuel type	qty_energy				x		
		Service bill date	date_issued				x		
		Building code	bl_id		x				
I12	Total consumption from non-renewable sources	Kilowatt-hour (kWh) or multiple of non-renewable sources consumption	bill_type_id qty_energy date_issued				x		
		Building code	bl_id		x				

Code	Consolidated indicators	Data input needed		Project Management	Space Inventory	Condition Assessment	Energy Management	Green Building	Document Compliance
I13	Total energy consumption from renewable sources	Kilowatt-hour (kWh) or multiple of renewable sources consumption	bill_type_id qty_energy date_issued				x		
		Building code	bl_id		x				
I14	Building energy consumption by fuel share	Kilowatt-hour (kWh) of energy consumption per fuel type	bill_type_id qty_energy date_issued				x		
I15	Electricity use	Kilowatt-hour (kWh) of electricity consumed	bill_type_id qty_energy date_issued				x		
		Building code	bl_id		x				
		Area of each building	area_gross_int		x				
I16	Energy cost	Cost charged on each fuel type source	amount_expense bill_type_id				x		
		Service bill date	date_issued				x		
		Building code	bl_id		x				
I17	Energy intensity	Kilowatt-hour (kWh) of energy consumption per fuel type	bill_type_id qty_energy date_issued				x		
		Building code	bl_id		x				
		Area of each building	area_gross_int		x				
I18	Energy rate	Kilowatt-hour (kWh) of energy consumption	qty_energy bill_type_id date_issued				x		
		Cost charged on each fuel type source	amount_expense				x		
		Building code	bl_id		x				

Code	Consolidated indicators	Data input needed		Project Management	Space Inventory	Condition Assessment	Energy Management	Green Building	Document Compliance
I19	Like-for-like percentage change in energy consumption for the portfolio area with data coverage, by property subsector	Buildings with associated energy services bills	bill_id				x		
		Kilowatt-hour (kWh) of energy consumption per fuel type	bill_type_id qty_energy date_issued				x		
		Building code	bl_id		x				
		Date registered in the system	date_bl		x				
		Area of each building	area_gross_int		x				
I20	Total energy generated from renewable sources	Energy generated in KWh or multiple from renewable sources on site	bill_type_id qty_energy date_issued				x		
		Building code	bl_id		x				
I21	% Total renewable energy	Kilowatt-hour (kWh) or multiple of renewable sources consumption	bill_type_id qty_energy date_issued				x		
		Energy generated in KWh or multiple from renewable sources on site	bill_type_id qty_energy date_issued				x		
		Kilowatt-hour (kWh) of energy consumption per fuel type	bill_type_id qty_energy date_issued				x		
		Building code	bl_id		x				

Table 26 Energy monitoring consolidated indicators

Analysing the result obtained in the comparison table, it can be observed in *Figure 15* that the ARCHIBUS® modules of Space Inventory and Energy Management have the most significant incidence in the management of data input as the main source. This can be explained considering these two facts:

- Firstly, since the highest proportion of consolidated indicators are those of the performance/impact typology. To calculate these indicators, it is necessary to resort to the energy consumption information collected mainly in the Energy Management module.

- Secondly, as explained in the third chapter, the indicators can be calculated at the asset or portfolio level; this is why the codification and registry of spaces managed by an organization are very important when it comes to identifying the calculation and control of the indicators.

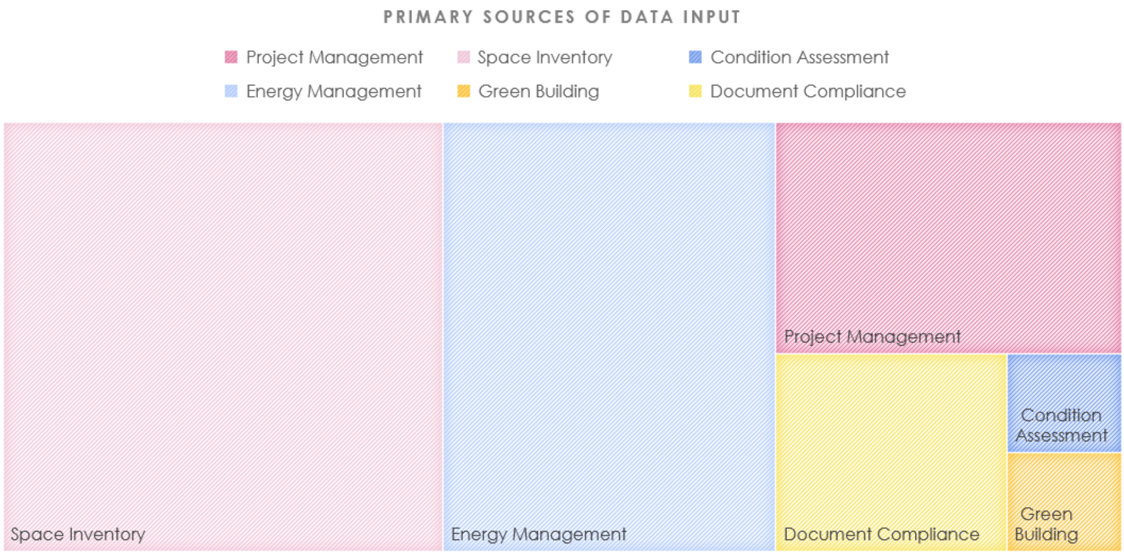


Figure 15 Proportion of data input management within ARCHIBUS modules

Finally, *Figure 16* is presented, which identifies the horizontal integration between ARCHIBUS® modules necessary to calculate the consolidated indicators described in the third chapter.

To calculate all the proposed indicators, it is necessary to integrate the Energy Management, Space Inventory, Condition Assessment, Green Building, Project Management and Compliance Management ARCHIBUS® modules. However, it is important to highlight that at least 60% of the proposed energy consumption and efficiency consolidated indicators can be calculated and managed by integrating only the Energy Management and Space Inventory module.

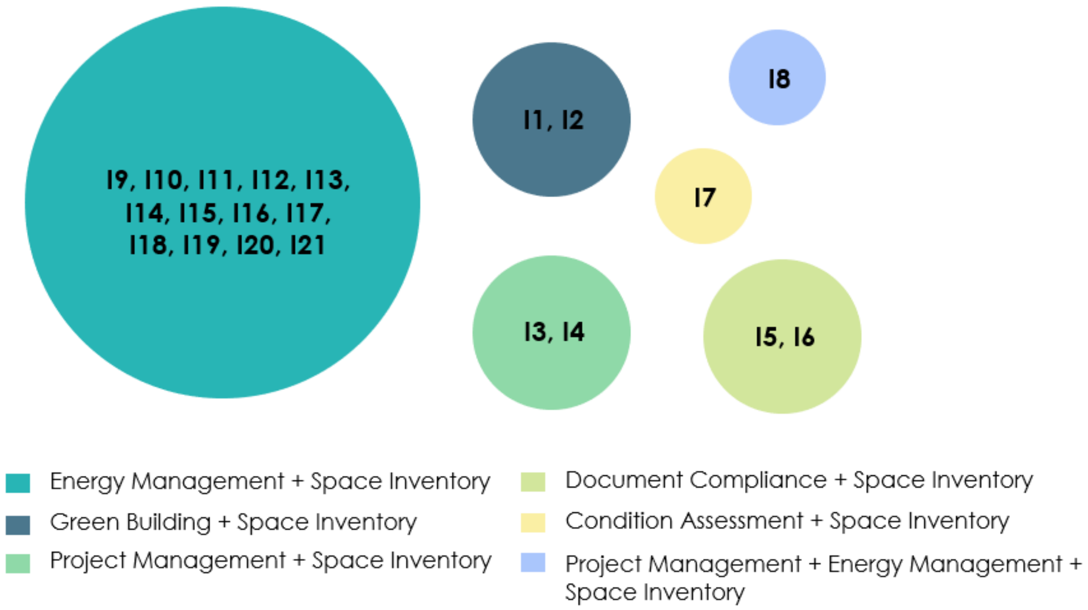


Figure 16 Indicators management identification within ARCHIBUS modules

Part 3: ANALYSIS OF A CASE STUDY AND PROPOSAL

CHAPTER 5: ANALYSIS OF THE CASE STUDY – eFM COMPANY

5.1 Company Description and Goals

Founded in 2000, eFM is a company specialised in management engineering, information technology and systems engineering for the management of the built environment in the field of Real Estate and Facility Management. It aims to innovate the Real Estate market through the integration between the physical and digital worlds. Through its platform and building digitisation, eFM designs places and processes, connecting business, people, and things, through a specific approach to improve wellness and sustainability.

In this direction, eFM has embarked on the path of digitising assets and properties to design, manage and monitor services, guarantee their quality through the integration, in a single platform, of all the different stakeholders (owner, provider, user, designer, developer). [26]
Today eFM provides innovative solutions, for both private and public clients, within the framework of consulting, engineering, and information systems, throughout the whole building life cycle (design, construction, management, and disposal).

"Sustain engaging places for a better life" is the mission of eFM company, which reflect their aim to support organisations in evolving working paradigms in the Real Estate Digital Transformation. Firstly, **Sustain** stands for the design, management and support of the buildings and its operation's services to make them sustainable from an economic, social, environmental, and technological perspective. Therefore, it considered the entire life cycle of the property, from design to its disposal, with an approach aimed at improving sustainability and focused on the concept of individual and collective wellbeing. Then, **Engaging Places** stands for transforming the living experience, through a harmonised connection between people and spaces, between the two converging worlds: the physical and virtual one. Finally, **For a better life** means the design of places and processes focused on putting the person at the centre and connecting activities, people and things[27].

To reach its mission, eFM provides innovative solutions developed by integrating its own skills within the Design, Engineering, Information systems and People Culture and Evolution framework. eFM leads Market Companies in the Real Estate Industry towards Stakeholders and integration of services for Total Cost of Ownership optimisation, Asset Lifecycle maximisation, Risks Monitoring and Mitigation Comfort, and lifestyle improvement, all through the integration of technologies such as BIM, BMS, IWMS, and IoT efficiently and smartly.

[26] For further details about the company see: https://www.bimportale.com/efm-innovare-mercato-del-real-estate-bim/ and http://www.efmnet.com/en/about-us
[27] For further details about the eFM company mission see: http://www.2bhappy.it/efm/

Finally, eFM is one of the ARCHIBUS® Business Partners, the founder of CREA (Corporate Real Estate Advisors), an international partnership providing real estate and facility management solutions to multinational companies, optimising centralised strategies while allowing for individualised local practices.

5.2 Introduction to the case: Scope selected

In general, based on each project and according to the characteristics and needs of each client, eFM provides the activation of a single information platform for Real Estate Management during the operation or governance stage that is based on the integration of the different macro-modules or components inside ARCHIBUS®.

However, for the case study of this thesis, a specific client has not been selected since the analysis and improvement proposal developed and described in the following items was carried out within the framework of a Research and Development project internal to the organization.

The specific request made within eFM was to analyse the feasibility of integrating new indicators within the Energy Management module so that it can be aligned with new demands from future customers and the new sustainability directives established at a global level.

Additionally, for the new indicators identified, that can be measured using the information inside the ARCHIBUS® database, as well as for the existing indicators within the Energy Management module, it is required to create dedicated reports / Dashboards that allow future users to efficiently control and manage their energy performance and the impact of the actions taken to reduce said consumption.

Considering the guidelines established for the project, the stages showed in *Figure 17* are defined for the process of analysis and development of improvement proposals:

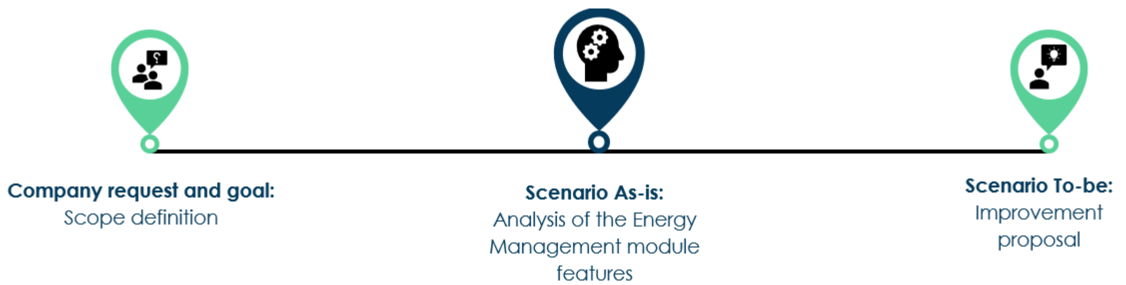


Figure 17 Case Study Stages

1) Company request and goal: This first phase is described in this section, in which the perimeter and requirements of the company for the project are identified.

2) Scenario As-is: This second stage is described in sections *5.3 Energy Management module: Background information*, *5.4 Workflows of integrations* and *5.5 Reporting used for data analysis: Scenario As-is*. In these three sections mentioned, the current features of the Energy Management module, the standard integration between other modules,

the main reports useful for monitoring the energy performance and the output data that can be derived from them are identified and described. The objective of this stage is to carry out an analysis of the management workflow and the functionalities within the module to structure later the most appropriate proposals to achieve the objectives defined for the project.

3) Scenario To-be: This last stage is developed in *CHAPTER 6: MEASUREMENT AND MONITORING IMPROVEMENT PROPOSAL* and consists of the analysis and definition of the improvement proposal based on the energy efficiency management indicators still absent within the ARCHIBUS® System and the integration between modules needed to include them. As the final output, an improved management workflow inside the Energy module and the graphic representation of the dynamic reports/business Dashboards for the efficient control and monitoring of the energy performance and the actions taken by organizations will be designed and described.

5.3 Energy Management module: Background information

The energy performance monitoring and assessment is handled through the functionalities of the ARCHIBUS® module of Energy Management. As it can be understood from the graphic representation of ARCHIBUS® structure (Figure 13 - *CHAPTER 4: CONFRONT BETWEEN LIST OF IN-USE INDICATORS AND ARCHIBUS)*, the Energy Management application is part of the macro-module of Environmental & Risk Management, used to understand the impact that and organization has on the environment. Therefore, the Energy Management module can be implemented singularly or in coordination with the other domains or application processes of the macro-modules, obtaining in this way a vertical integration or specialisation of one single module.

ARCHIBUS® Energy Management module provides the means to easily aggregate, evaluate, and optimize energy and utility spending decisions to reduce unnecessary consumption and costs. Furthermore, it helps users correlate and manage extensive cost and consumption data with real-time facility and infrastructure portfolio information to track energy expenditures against a business plan or objective benchmarks.

Among the main goals of the Energy Management module, it can be mentioned[28]:

- Reduce Costs and Carbon Footprint: The module maps current energy usage, model remediation scenarios, and measure the effectiveness of periodic changes, based on normative standards. In addition, it can organize and evaluate a large volume of current and historical consumption and costs, identify buildings with unusual consumption patterns or energy intensity to target remediation actions and reduce the incidence of

[28] For further details visit: https://archibus.com/products/environmental-and-risk-management/energy-management/

billing errors such as charges for overlapping dates, expired leases, and incorrect properties or tenants.

- Effectively aggregate and Evaluate Energy Usage: The module centralizes the management of energy initiatives based on actual operating data. It provides managers with the means to understand how and where energy is purchased and used to optimize efficiency and enforce best practices using real-time information.

- Mitigate risk with improved analyses and planning: The module Implement interactive dashboards to conduct "what-if" scenario planning and identify energy-inefficient buildings and cost centres that reduce profitability. In addition, run scenarios to determine the cost-effectiveness of various improvement measures and Conduct analyses to evaluate potential savings attributed to conservation, renovation, or demand-response agreements.

To use the functions within the module, it is necessary to include and set the background data, which can be grouped in: Facilities, Accounting and Utilities. The third category, for which the module is the primary source, set up information for any type of integration performed between other ARCHIBUS® modules.

To differentiate the background data within this module, Figure 18 is presented where the data inputs are grouped into "vertical integration" and "horizontal integration" (These two flows will be described in detail in item *5.4 Workflows of integrations*).

Vertical Integration	**Horizontal Integration**
a) Utility Bill Management Background Data	c) Location Background Data
b) Meter Analytics/IoT Background Data	d) Organizationl Background Data
	e) Equipment and Furniture Background Data
	f) Accounting Background Data
	g) Vendors Background Data

Figure 18 Background data for vertical and horizontal integration

G. Utility Bill Background Data (Utilities)

This data represents the bill types, bill unit types, and bill units tracked on utility invoices and meters for rolling up energy use. By default, the application provides the electrical, gas, Gas - Natural, Gas - Propane, fuel oil 1, fuel oil 2, and water and sewer bill types. However, it is possible to define additional bill types as needed. As an example, we can consider:

Bill Type = Electric
Billing Unit Type = Energy
Billing Units = kWh
Common Unit (measure consumption) = kWh

Conversion factor = 1

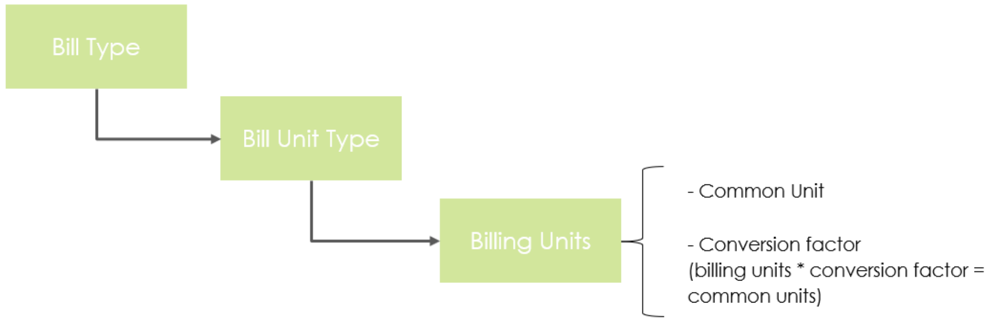


Figure 19 Levels hierarchy of the Utility Bill registry

H. <u>Meter Analytics Background Data (Utilities)</u>

Meters provide internal measurements for energy consumption and demand. By entering the meters data into the system and linking them to the vendor's meters, it is possible to compare measured values from your internal meters to the quantity the vendors are billing. In addition, the system differentiates the meter into two types: Virtual and physical meters. For example, meters could be installed on each floor of a building. A virtual meter could sum the values of all of these meters and present the result as a building total.

The main fields considered are Data Point Name, Data Point ID, Measurement type, Measurement Units, Equipment code, Interval, Data Type, Area Measured (Manual entry), Total Area Measured, Virtual Meter definition (Yes/No) and Data Point Description.

I. <u>Location Background Data (Facilities)</u>

This background data represents the information of the buildings for which the energy use has been tracking.

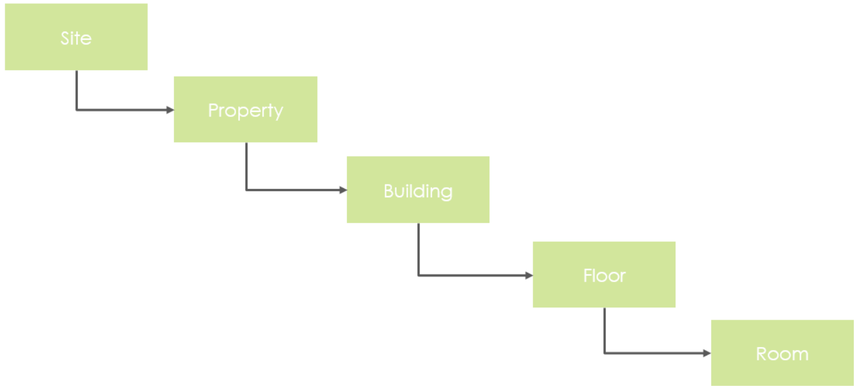


Figure 20 Levels hierarchy of the Real Estate registry

The main fields considered are: Site Code, Site Name, Country Code, Region Code, State Code, City Code, Property Code, Property Name, Property Use, Property Use, Property Status, Property Condition, Account Code, Property Occupancy, Zoning Type, Site code, Address, Number of Buildings, Land Acres, Rentable Area, Owned Percentage, Building Code, Building Name, Building Type, Building Use, Building Status, Book Value, Market Value, Address, Postal Code, Construction Type, Facility Type, Floor Code, Floor Name, Gross Internal and External Area, Cost per square meter, Area occupied, Room Name, Room Code, Room Type, Room Category, Room Standard, Room use, Room Area, Room photo and Employee Capacity.

J. Organisation Background Data (Facilities)

The organization consists of several Companies, to which several Budget Units are hierarchically associated, representing the business lines of the different Companies and necessary for the allocation of Facility costs (Franzoni, 2020).

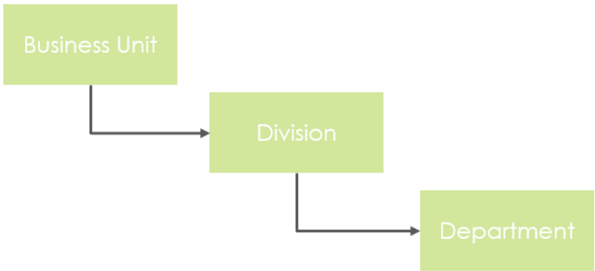


Figure 21 Level hierarchy of the Organisation Registry

The main fields considered are: Business Unit Code, Business Unit Name, Employee HeadCount, Chargeable Area, Business Unit, Division Code, Division Name, Division Head, Division Code, Department Code, Department Name and Department Head.

K. Equipment and Furniture Background Data (Facilities)

Equipment and Furniture Background Data include Equipment, Jack, Furniture, Software, Faceplate, Punch Block, Patch Panel, Cable and Telecom services. Each Asset is associated with specific attributes that help track, manage, and update equipment tagged furniture and furniture standards inventories.

The main fields considered are: Asset code, Asset Type, Asset Standard, Asset status, Condition, System Code, Building Code, Vendor Contact, Condition Index, System Type, Recovery Status, Classification Code, System Description, Equipment Code, Building System ID, System Name, Tree label, Mission Criticality, Function Criticality and Stakeholder Type.

L. Accounting Background Data (Accounting)

This data represents the cost categories and classes for rolling up energy costs and utility rate structures for entering utility bills.

The main fields considered are: Cost Class, Class Description, Cost Category, Cost Description, Cost Type, Account Code, COA Source Code, COA Cost Group Code, Account Description, Rate Description and Rate Type.

M. Vendors Background Data (Accounting)

This data represents the vendors and vendor that are involved in the facility management of a building. For example, the vendors can be service providers who should be assigned tasks based on a contract or can be specific service provider.

The main fields considered are Vendor Code, Company Name, Vendor Description, Vendor Type, Address Line, City, State, Country, Postal Code, Phone Number, Email Address, Contact Name, Contact's Title, Website URL, Alternative Contact, Service Contract Code, Service Contract Vendor, Service Contract Graphic, Service Contact, Date Service Contract Expires and Description.

5.4 Workflows of integrations

There are two types of integration between the different domains within ARCHIBUS®:

- Vertical Integration: Considered when an Organisation chooses to use only one ARCHIBUS® macro-module without requiring any kind of integration with the other modules.

- Horizontal Integration: Considered when an Organisation requires integrating two or more different macro-modules to fulfil their strategical goals.

In the case of the Energy Management module, to obtain the different reports and monitor the indicators configurated within the module, it is not enough to perform a vertical integration. In fact, a horizontal integration should be implemented to carry out efficient information management.

Figure 22 and *Figure 23* show the standard horizontal integration between the Energy Management module and the Portfolio Management, Strategic Financial Analysis, Space Inventory and Asset Inventory modules. The integration of background data between the mentioned modules is configured as standard when an organization decides to acquire or start working with the Energy Management module.

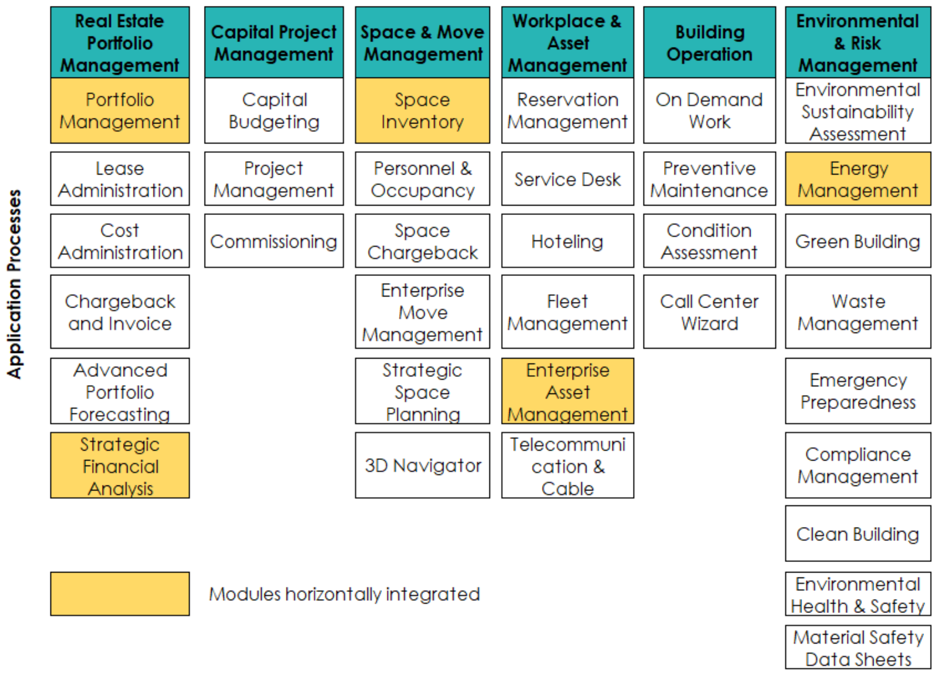


Figure 22 As-is horizontal integration

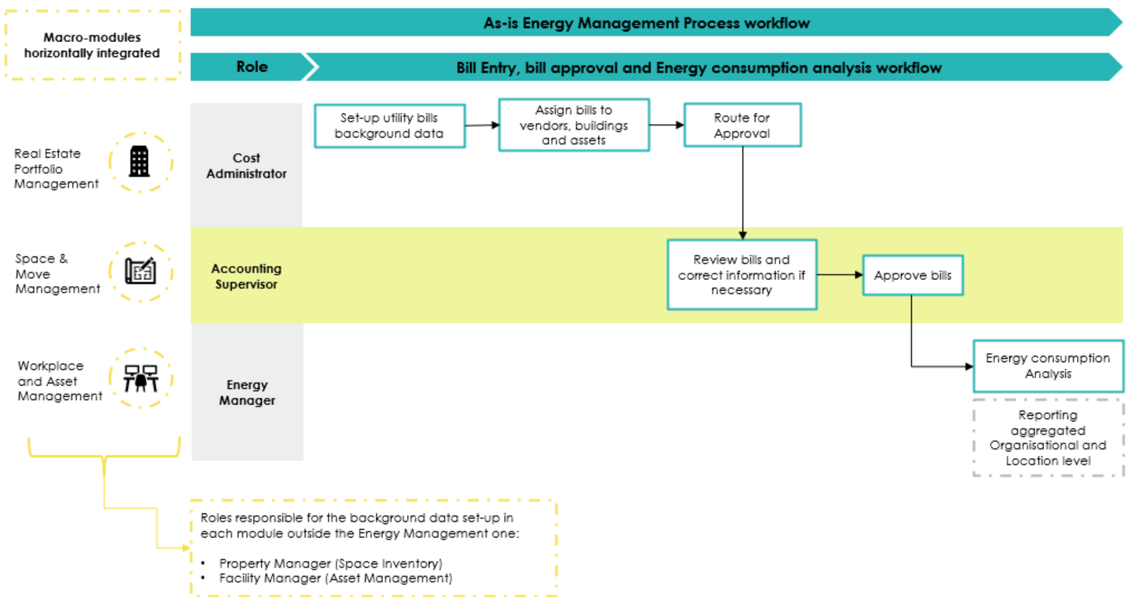


Figure 23 As-is workflow of the Energy Management process

5.5 Reporting used for data analysis: Scenario As-is

In this section, the main Reports and key performance indicators are introduced to highlight core existing features in the As-is Scenario to measure and monitor energy consumption and efficiency indicators.

During the operational phase of a building, it is possible to monitor all the main data regarding Energy Performance, such as:

- Consumption related to all the energy careers.
- Production, in the case of renewable plants for energy self-handling.
- Meter readings.
- Bills management and comparison with consumption data.

Among the main characteristics, functionality and reports within the energy management module, the following can be mentioned:

a. DATA COLLECTION

The platform enables to define and collect data from different sources, as presented in the Table 27 Data Collection Framework *Table 27*:

DATA COLLECTION FRAMEWORK		DATA TYPE		
		Technical data and heritage	Energy data	Extra-financial data
DATA COLLECTION METHOD	A. Integration with EMS		B	
	B. Integration with Meters/Counters/BMS		OD	
	C. App mobile for data collecting from Vendor Counters		OD	
	D. Integration with existing software	OD	OD	OD
	E. Import from .XLS files from Users	OD		
	F. .XLS forwarded to eFM	OD	OD	OD
	G. Questionnaires			B
	H. Management Processes Framework	B	B	OD
	I. Automatic data collecting from Utilities Vendors		OD	

B = Basic Solution; OD = On demand Solution

Table 27 Data Collection Framework

b. BILL ENTRY

- Define type of utility bill:

This functionality allows the user to add a specific type of utility bill, such as Gas - Natural, Gas - Propane, Electric, Geothermal, Solar, among others. In addition, it allows defining the unit of measurement of each type of bill and the conversion factor for the calculation of the consumption in a common unit value if necessary.

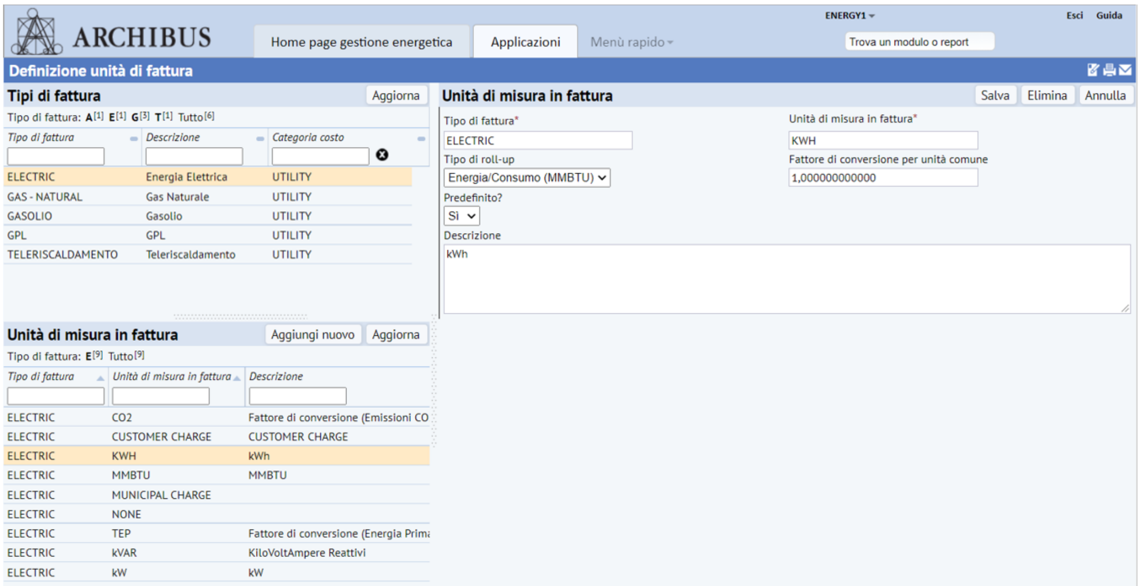


Figure 24 "Define type of utility bill" functionality
Source: ARCHIBUS®

- <u>Define of energy supplies functionality:</u>

This feature allows the correct management of all types of energy supplies of interest. The users can insert and create a new supply, change a supply already registered in the system and view the historical changes made on all energy supplies.

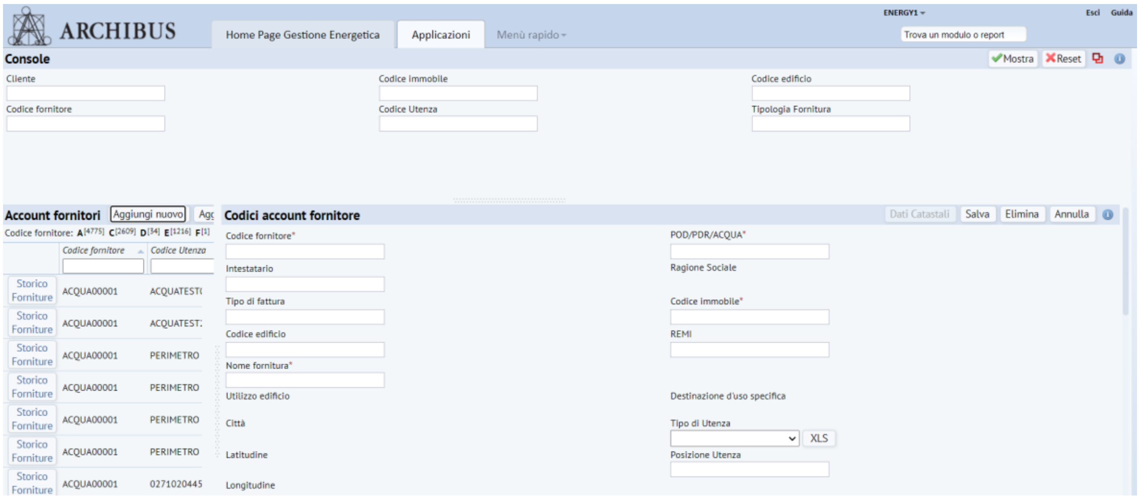


Figure 25 "Define energy supplies" functionality
Source: ARCHIBUS®

In addition, once the operation has been saved, it is possible to reselect the energy supply of interest and correctly associate it to a specific cadastral unit.

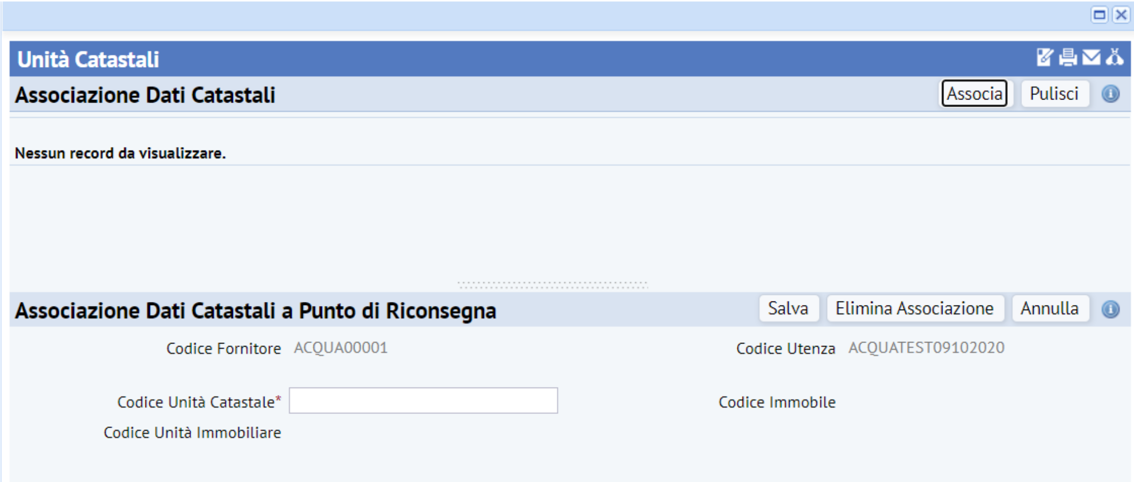


Figure 26 Association to cadastral data feature
Source: ARCHIBUS®

- <u>Enter utility bills functionality:</u>

The "Enter Utility bills" functionality allows the users to manually enter/modify the data of the bills for all the type of energy sources previously defined in the system. Furthermore, it allows the users to assign each bill to the correspondence building (location background data), as previously defined within the system.

The functionality has four sections: Supplier, supplier account, bills, bill lines.

In the "Bills" section, as shown in the figure below, it is possible to enter/modify the main information present in the header of the bill itself.

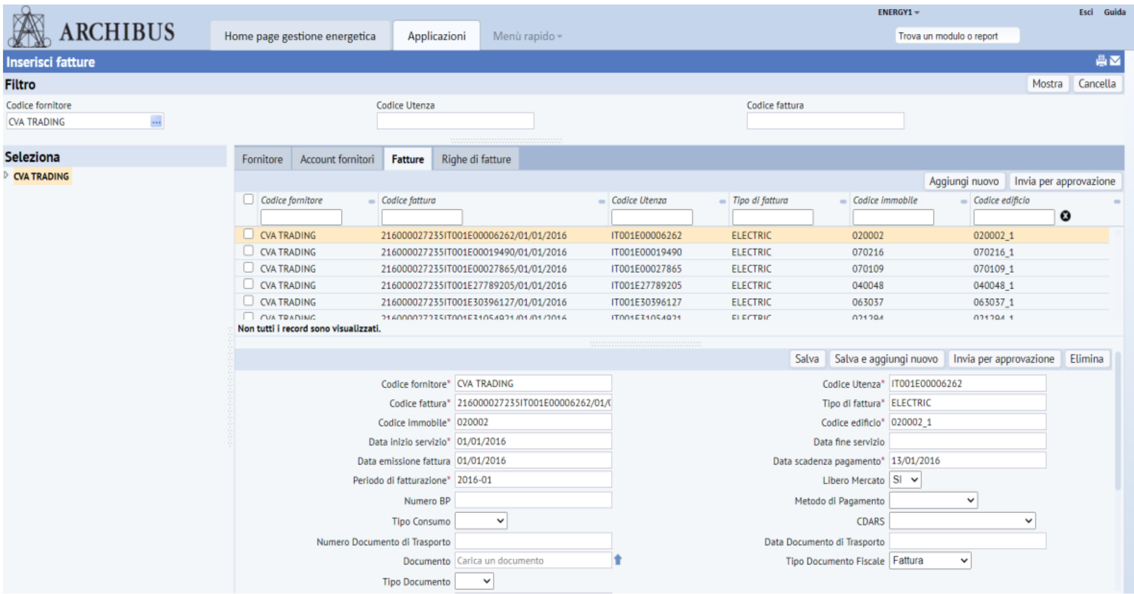


Figure 27 "Enter utility bills" functionality
Source: ARCHIBUS®

After clicking on the bill of interest, the user can move to the "Bill Lines" section, as shown in the figure below, and can enter/edit the main information in the bill line selected.

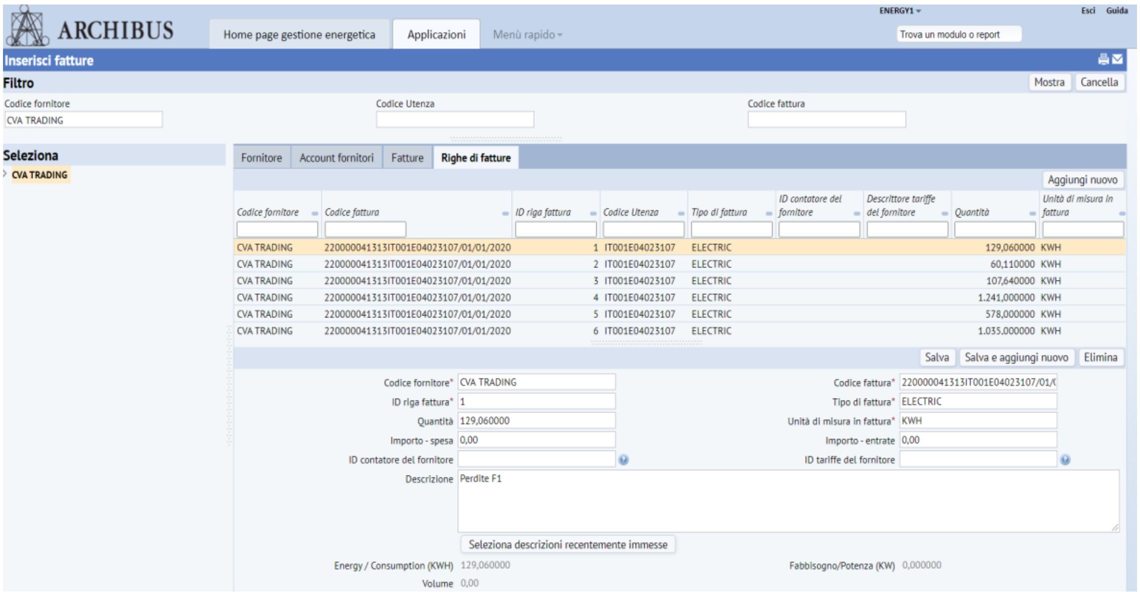


Figure 28 "Bill lines" section
Source: ARCHIBUS®

c. <u>VERIFICATION OF THE ADEQUACY OF ACCOUNTING DOCUMENTS</u>

- <u>Allocation of costs on Cost Center functionality:</u>

This functionality allows the correct display of cost data for each type of supply. This means that the users can divide the costs with aggregation into three levels: Building, Floor and Room, through the distribution of costs according to the square meter driver.

In addition, it is also possible to check how the costs are divided among the Cost Centers defined and associated with the individual rooms present within a plan of the building of interest. For a more in-depth and detailed analysis, this functionality allows downloading the data in Excel format.

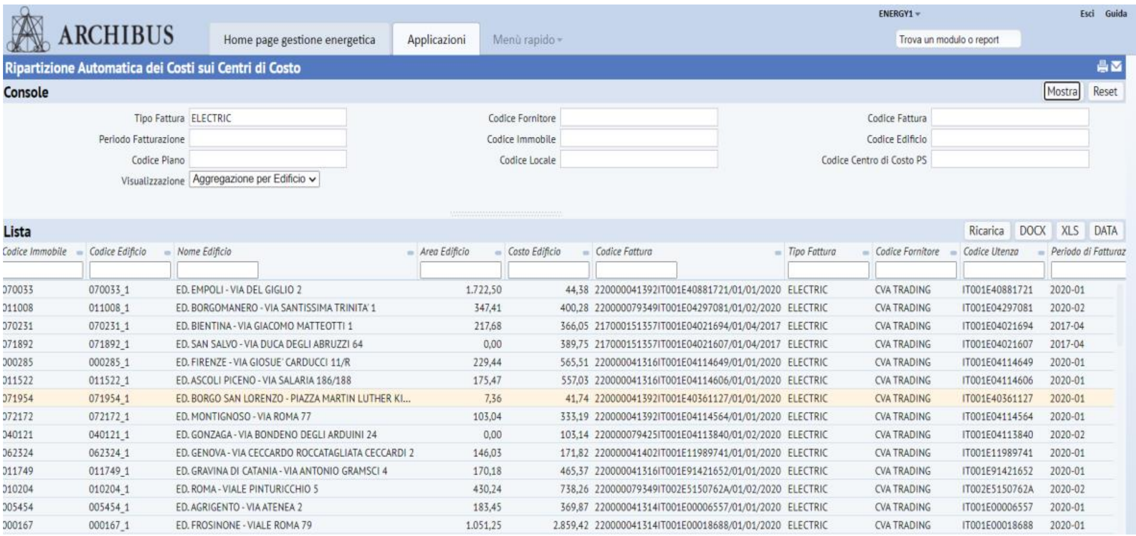


Figure 29 "Allocation of costs on Cost Center" functionality
Source: ARCHIBUS®

d. ENERGY CONSUMPTION MONITORING

- Allocation of energy consumption on Cost Center functionality:

This functionality allows the correct display of consumption data for each type of supply. This means that the functionality, through the distribution of consumptions according to the square meter driver, allows dividing the consumptions with aggregation on three levels: Building, Floor and Room.

For a more in-depth and detailed analysis, this functionality allows downloading the data in Excel format.

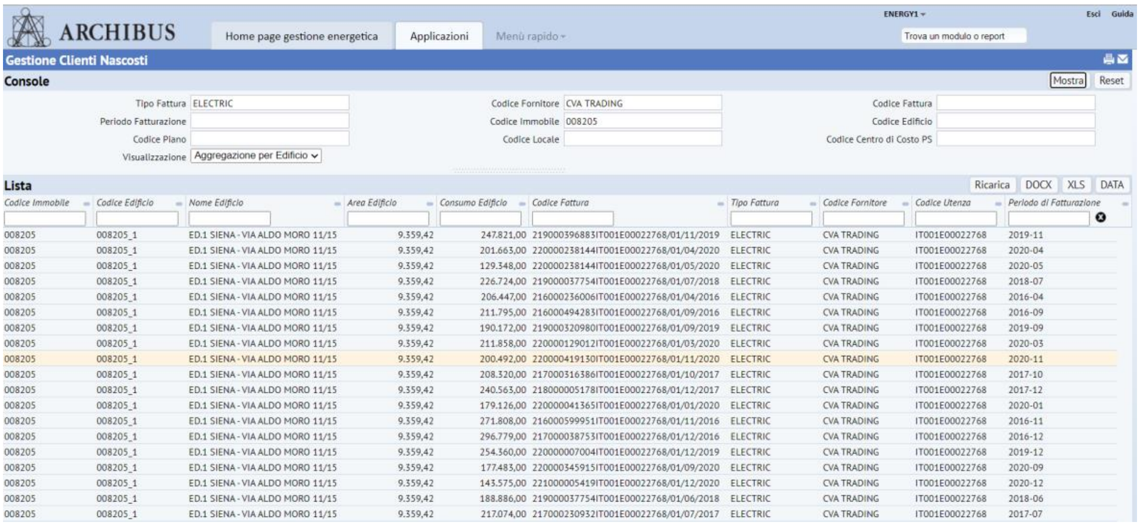


Figure 30 "Allocation of energy consumption on Cost Center" functionality
Source: ARCHIBUS®

- <u>Energy consumption data management report:</u>

This functionality allows the users to view the details of each bill loaded into the system. In addition, this feature can carry out a detailed analysis of all items regarding the single bill or invoice.

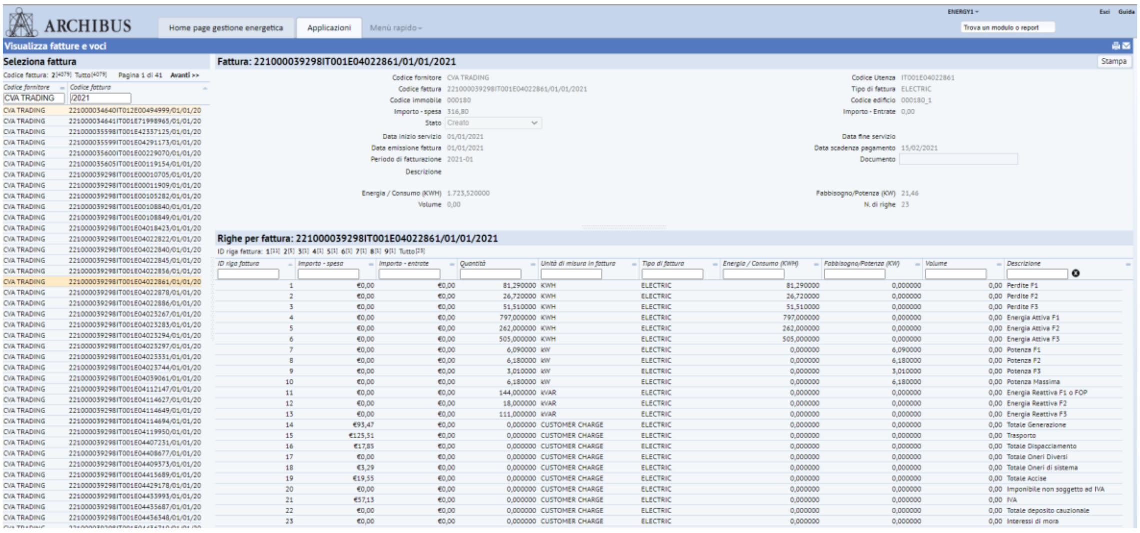


Figure 31 Energy consumption data management report
Source: ARCHIBUS®

- <u>Energy consumption report:</u>

This functionality allows the correct display of consumption data for each type of supply/source, regarding the display in Standard mode, in kWh, in tonnes oil equivalent (TOE) and the report of CO2 emissions.

In addition, it allows to compare consumption according to the different display modes chosen by the user and offers the possibility of multi-selection within the filter console.

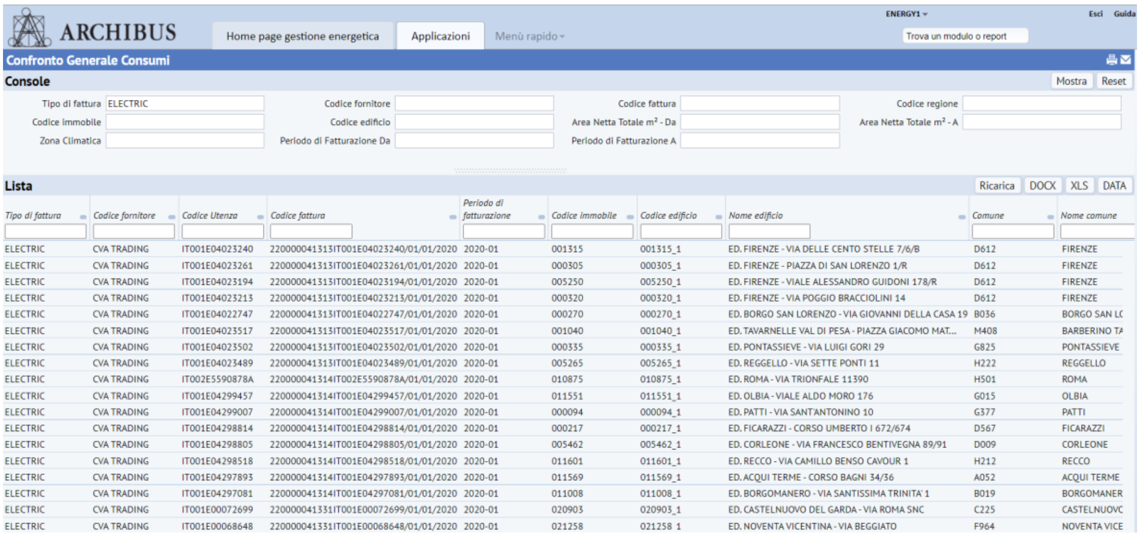
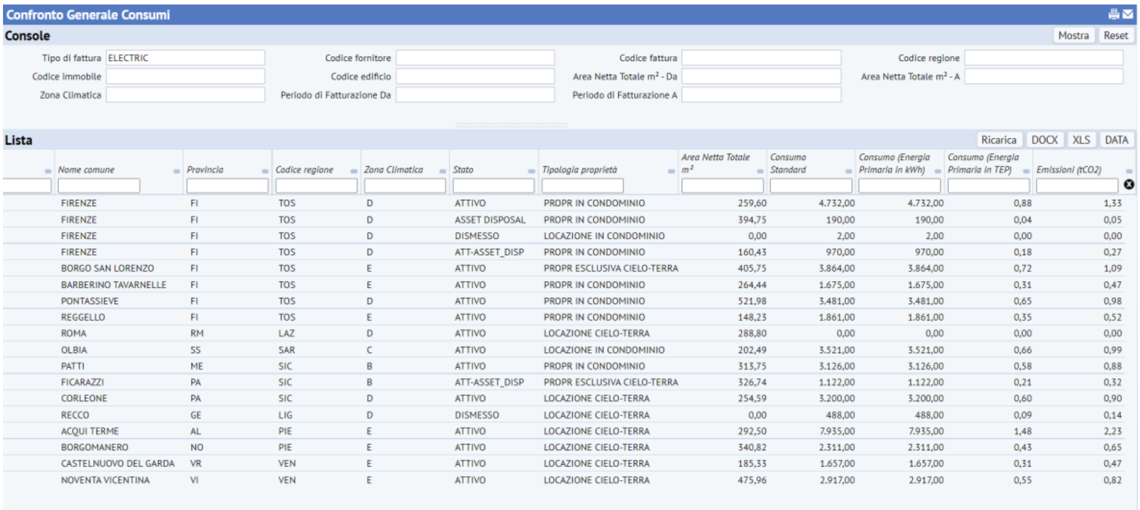


Figure 32 Energy Consumption Report - View 1
Source: ARCHIBUS®



Confronto Generale Consumi

Console

Mostra | Reset

Tipo di fattura	ELECTRIC	Codice fornitore		Codice fattura		Codice regione	
Codice immobile		Codice edificio		Area Netta Totale m² - Da		Area Netta Totale m² - A	
Zona Climatica		Periodo di Fatturazione Da		Periodo di Fatturazione A			

Lista

Ricarica | DOCX | XLS | DATA

Nome comune	Provincia	Codice regione	Zona Climatica	Stato	Tipologia proprietà	Area Netta Totale m²	Consumo Standard	Consumo (Energia Primaria in kWh)	Consumo (Energia Primaria in TEP)	Emissioni (tCO2)
FIRENZE	FI	TOS	D	ATTIVO	PROPR IN CONDOMINIO	259,60	4.732,00	4.732,00	0,88	1,33
FIRENZE	FI	TOS	D	ASSET DISPOSAL	PROPR IN CONDOMINIO	394,75	190,00	190,00	0,04	0,05
FIRENZE	FI	TOS	D	DISMESSO	LOCAZIONE IN CONDOMINIO	0,00	2,00	2,00	0,00	0,00
FIRENZE	FI	TOS	D	ATT-ASSET_DISP	PROPR IN CONDOMINIO	160,43	970,00	970,00	0,18	0,27
BORGO SAN LORENZO	FI	TOS	E	ATTIVO	PROPR ESCLUSIVA CIELO-TERRA	405,75	3.864,00	3.864,00	0,72	1,09
BARBERINO TAVARNELLE	FI	TOS	E	ATTIVO	PROPR IN CONDOMINIO	264,44	1.675,00	1.675,00	0,31	0,47
PONTASSIEVE	FI	TOS	D	ATTIVO	PROPR IN CONDOMINIO	521,98	3.481,00	3.481,00	0,65	0,98
REGGELLO	FI	TOS	E	ATTIVO	PROPR IN CONDOMINIO	148,23	1.861,00	1.861,00	0,35	0,52
ROMA	RM	LAZ	D	ATTIVO	LOCAZIONE CIELO-TERRA	288,80	0,00	0,00	0,00	0,00
OLBIA	SS	SAR	C	ATTIVO	LOCAZIONE IN CONDOMINIO	202,49	3.521,00	3.521,00	0,66	0,99
PATTI	ME	SIC	B	ATTIVO	PROPR IN CONDOMINIO	313,75	3.126,00	3.126,00	0,58	0,88
FICARAZZI	PA	SIC	B	ATT-ASSET_DISP	PROPR ESCLUSIVA CIELO-TERRA	326,74	1.122,00	1.122,00	0,21	0,32
CORLEONE	PA	SIC	D	ATTIVO	LOCAZIONE CIELO-TERRA	254,59	3.200,00	3.200,00	0,60	0,90
RECCO	GE	LIG	D	DISMESSO	LOCAZIONE CIELO-TERRA	0,00	488,00	488,00	0,09	0,14
ACQUI TERME	AL	PIE	E	ATTIVO	LOCAZIONE CIELO-TERRA	292,50	7.935,00	7.935,00	1,48	2,23
BORGOMANERO	NO	PIE	E	ATTIVO	LOCAZIONE CIELO-TERRA	340,82	2.311,00	2.311,00	0,43	0,65
CASTELNUOVO DEL GARDA	VR	VEN	E	ATTIVO	LOCAZIONE CIELO-TERRA	185,33	1.657,00	1.657,00	0,31	0,47
NOVENTA VICENTINA	VI	VEN	E	ATTIVO	LOCAZIONE CIELO-TERRA	475,96	2.917,00	2.917,00	0,55	0,82

Figure 33 Energy Consumption Report - View 2
Source: ARCHIBUS®

CHAPTER 6: MEASUREMENT AND MONITORING IMPROVEMENT PROPOSAL

Starting from the analysis of the processes described above, this chapter aims to develop some proposals that can be implemented within the Energy Module of ARCHIBUS® to effectively monitor the progress of organizations (existing clients and potential future clients) in reducing their energy consumption and in the effectiveness of the measures that have been decided to adopt to achieve or improve the energy efficiency of a building during the operation stage.

6.1 Structure of the proposal: Scenario To-be

The design of the structure of the Scenario To-be described in this section uses as its main basis the information presented in the following chapters:

- **Chapter 3:** Presents the consolidated indicators that include the main indicators related to measuring energy consumption and efficiency proposed by different international institutions (described in detail in Chapter 2).

- **Chapter 4:** Presents the analysis and identification of the necessary information integration within ARCHIBUS® modules to calculate the proposal list consolidated indicators.

In the first place, Table 28 Indicators to be integrated for the case study*Table 28* shows the complete list of consolidated energy consumption and efficiency indicators (described in chapter 3) and the integration between the modules within ARCHIBUS® necessary to calculate each one of them.

Field of interest	Code	Indicator Title	Module Integration needed
Building Certifications	I1	Amount of Green Building certificates at the operational stage	Green building + Space Inventory
	I2	Amount of Energy performance rating certifications	Green building + Space Inventory
Energy efficiency initiatives	I3	Total investment for building energy upgrade	Project Management + Space Inventory
	I4	Total investment in renewable energy projects	Project Management + Space Inventory
	I5	Amount of Building energy consumption policies	Document Compliance + Space Inventory
	I6	Amount of Building energy consumption codes and standards	Document Compliance + Space Inventory
	I7	Amount of Technical building energy efficiency assessments during the last four years	Condition Assessment + Space Inventory
	I8	Amount of reduction in energy consumption achieved as a direct result of conservation and efficiency initiatives	Project Management + Energy Management + Space Inventory
Energy Monitoring	I9	Building Automation and electronic monitoring of building systems coverage	Energy Management + Space Inventory
	I10	Implementation of data management systems for data collection and measurement of energy consumption	Energy Management + Space Inventory

	I11	Building total energy consumption	Energy Management + Space Inventory
	I12	Total consumption from non-renewable sources	Energy Management + Space Inventory
	I13	Total energy consumption from renewable sources	Energy Management + Space Inventory
	I14	Building energy consumption by fuel share	Energy Management + Space Inventory
	I15	Electricity Use	Energy Management + Space Inventory
	I16	Energy Cost	Energy Management + Space Inventory
	I17	Energy intensity	Energy Management + Space Inventory
	I18	Energy rate	Energy Management + Space Inventory
	I19	Like-for-like percentage change in energy consumption for the portfolio area with data coverage	Energy Management + Space Inventory
	I20	Total energy generated from renewable sources	Energy Management + Space Inventory
	I21	% Total renewable energy	Energy Management + Space Inventory

Table 28 Indicators to be integrated for the case study

As can be seen, considering the standard configuration of the Energy module, the necessary data input for the calculation of the "Energy Monitoring" (field of interest) indicators is currently managed within the module. That is, no additional integration is necessary. However, not all the identified indicators are calculated or have a dedicated report within the As-is scenario. For this reason, a general interactive Dashboard can be designed to immediately calculate, include, and organize the 13 indicators of this field of interest inside the system (To-be proposal).

On the other hand, regarding the indicators of the fields of interest, "Building Certifications" and "Energy efficiency initiatives", it is impossible to calculate any of these indicators with the As-is integration of the Energy Management module. Therefore, to counteract the lack of the necessary data input, the following actions must be carried out:

- Horizontal integration between the Energy Module and the Project Management and Condition Assessment modules.

- Vertical integration between the Energy Module and the Green Building and Compliance Management modules.

Therefore, the To-be configuration/integration structure is presented in *Figure 34*, which is composed of the necessary applications for the improvement solution implementation:

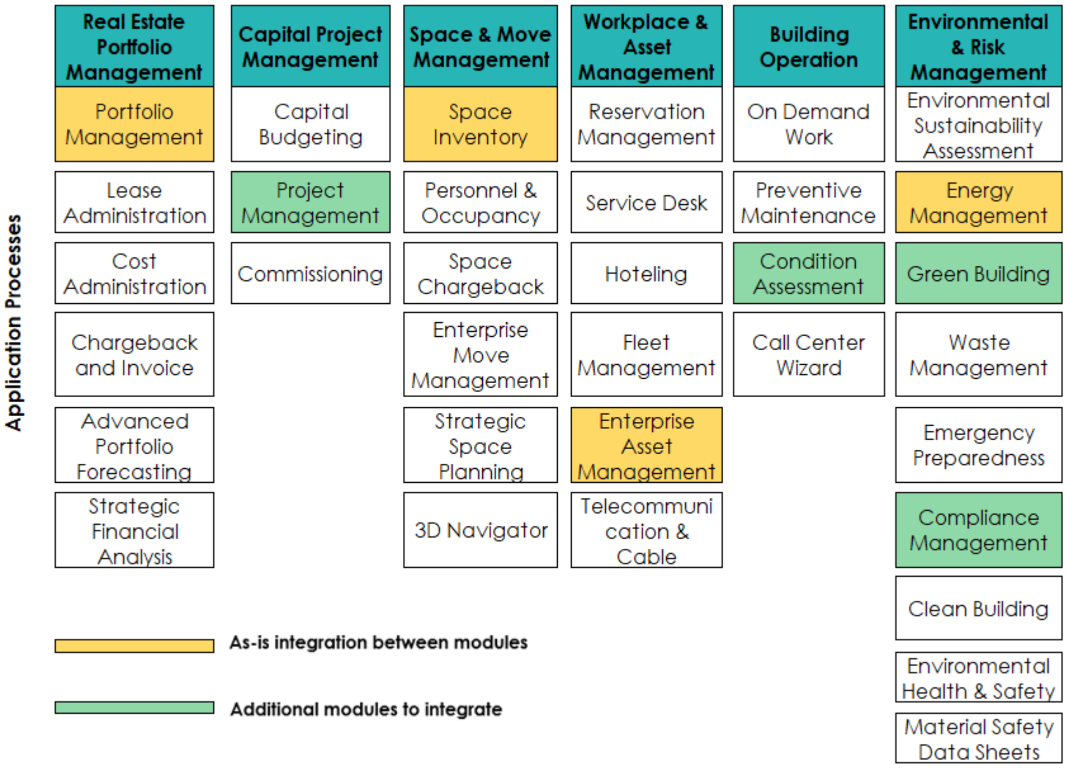


Figure 34 To-be Integration between ARCHIBUS® modules

In the second place, considering the To-be Integration showed in *Figure 34*, the following improved Energy Management workflow inside ARCHIBUS® is proposed with the additional responsibilities assigned to the Energy Manager role for the integrated background data configuration process and the improved output for the energy performance monitoring (*Figure 35*):

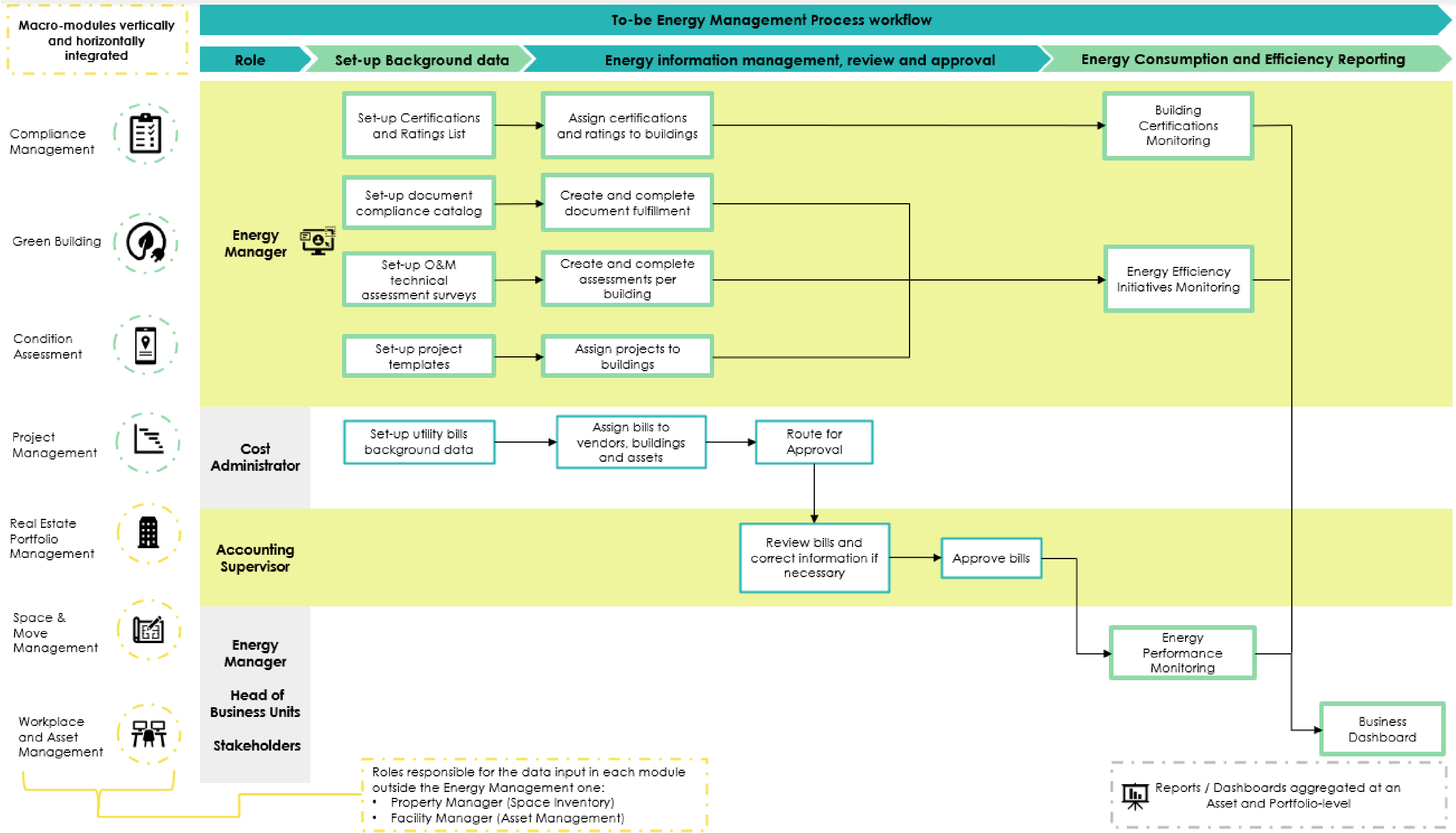


Figure 35 To-be Energy Management workflow

Finally, considering all the actions necessary to achieve the improvement proposal objectives set for this project, it is decided to use a structure that follows the grouping logic of the fields of interest of the consolidated indicators, as presented below:

I. **Building Certifications:** The perimeter for the proposal in this field of interest is to identify the functionalities that must be vertically integrated within the Energy Management module. In addition, to establish the guidelines on the correct data input necessary to calculate the proposed indicators in this field of interest. Finally, to design a Dashboard where the results of the proposed consolidated indicators will be represented at a building-level and portfolio-level.

II. **Energy Efficiency Initiatives:** The perimeter for the proposal in this field of interest will be to identify the functionalities that must be vertically and horizontally integrated within the Energy Management module. In addition, to establish the guidelines on the correct data input necessary to calculate the proposed indicators in this field of interest. Finally, to design a Dashboard where the results of the proposed consolidated indicators will be represented at an asset and portfolio level.

III. **Energy Performance Monitoring:** The perimeter for the proposal in this field of interest is to create a Dashboard that allows users to have the complete panorama of energy performance at an asset and portfolio level. Therefore, the Dashboard will be designed to be used by users with the Energy Manager role and by the Heads of the various business units of an organization. In addition, the Dashboard must serve as an automatic report to declare non-financial indicators to investors inside and outside an organization.

All the proposals described in the following items went through a collaborative design and implementation process in collaboration with the developers/IT within the company. Overall, the process starts with identifying the indicators, the calculation formulas, the input data, and the functionalities to integrate. Then, the next and final step is the configuration within ARCHIBUS® for the automation and visualization of the graphs and tables that will constitute the proposed Dashboards.

6.2 Building Certifications: Proposal of strategic integration between modules

To develop the "Building Certifications" Dashboard, it is necessary to integrate the information currently managed within the Energy Management module vertically with the Green Building module. So, the background data needed to calculate the two consolidated indicators presented in Chapter 3 needs to be previously set using some functionalities from the Green Building module.

The two functionalities selected to be integrated inside the menu of the Energy Manager role are: *Building Certifications Management* and *Building Certification Association*.

The database of the Operation and Maintenance certificates and ratings will be found in the same functionality. This is proposed to allow the Energy Manager to define and associate them with each building inside the portfolio efficiently from the same functionality.

Using the "Building Certifications Management" functionality (*Figure 36*), users will be able to enter the schemes and levels that will later be associated with the buildings and year of certification using the "Building Certification Association" functionality (*Figure 37*).

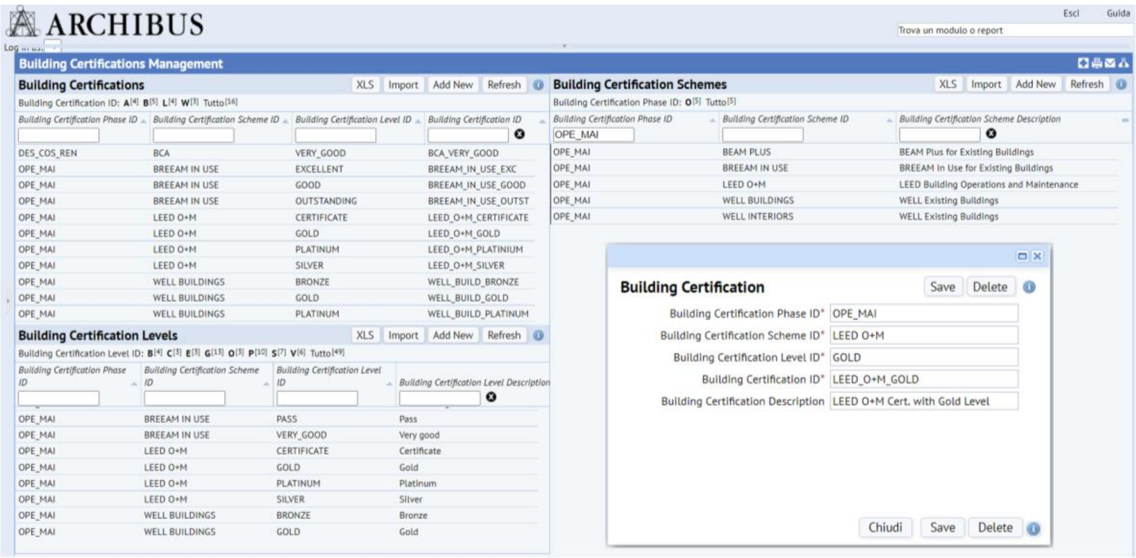


Figure 36 "Building Certification Management" functionality
Source: ARCHIBUS®

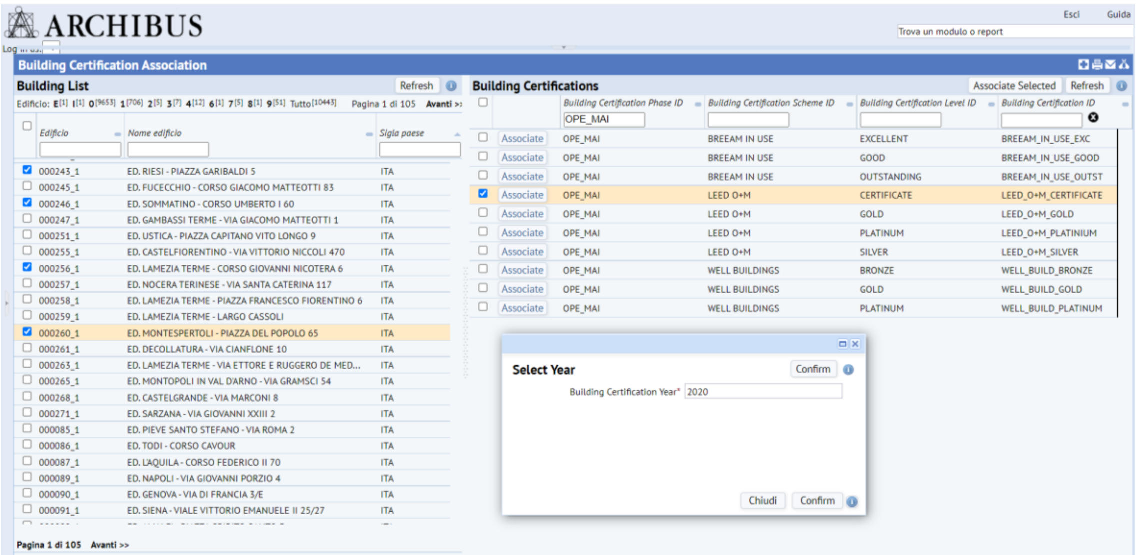


Figure 37 "Building Certification Association" functionality
Source: ARCHIBUS®

After the Energy Manager enters and associates the information in the two previously explained functionalities, the indicators *I1-Amount of Green Building certificates at the operational stage* and *I2-Amount of Energy Performance rating certificates* can be calculated and represented visually through different types of graphs within the Dashboard proposed for this field of interest (*Figure 38*).

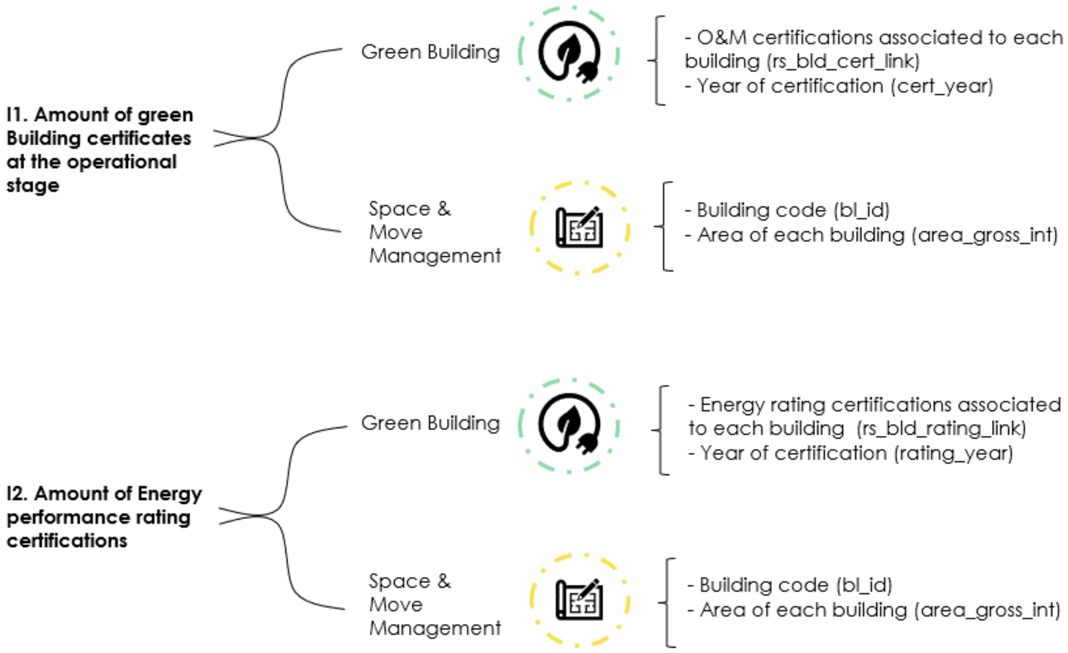


Figure 38 Scheme of data integration for the "Building Certifications" indicators

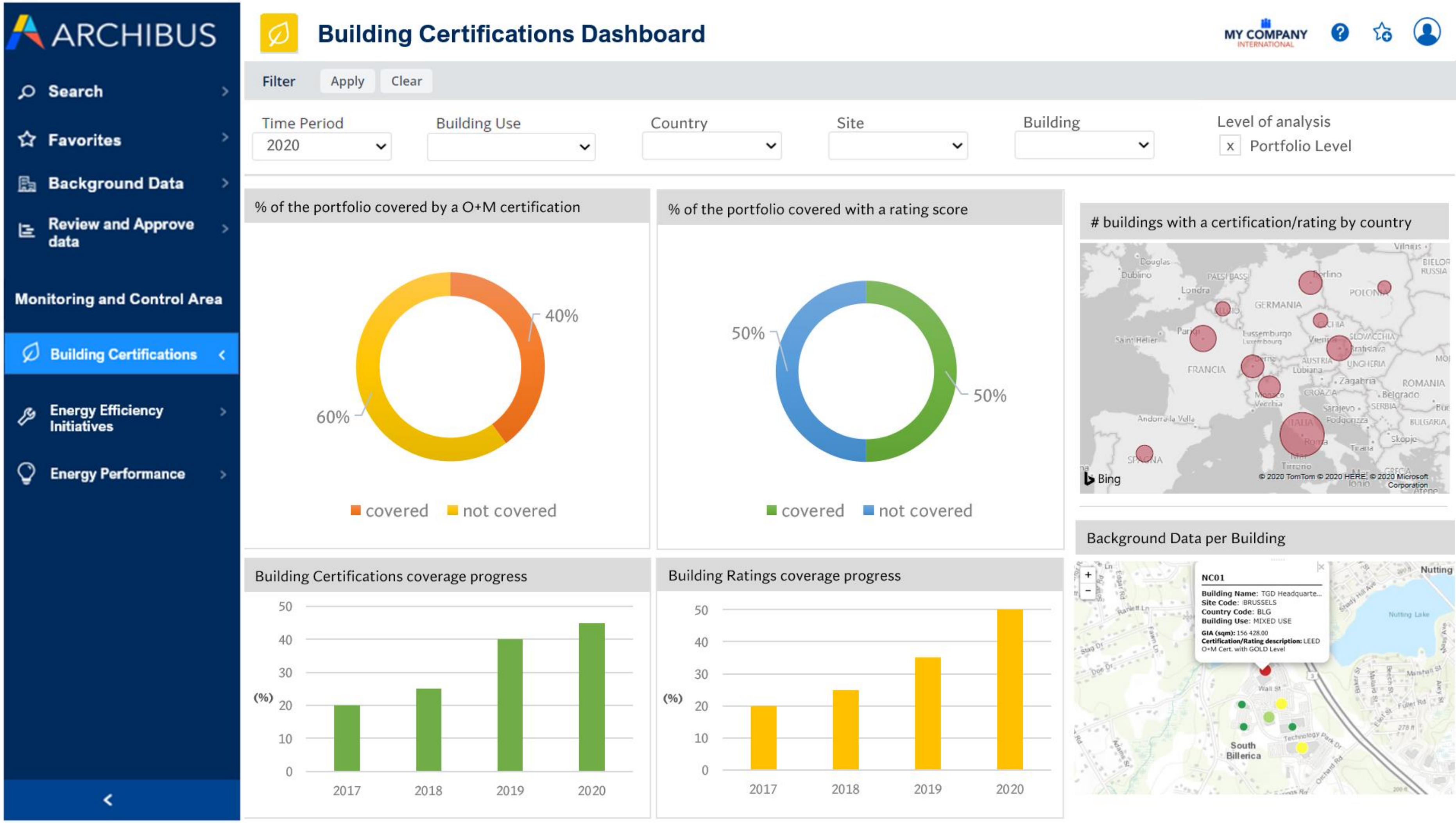
One consideration to highlight is that the "Building Certifications" Dashboard has two display formats based on the type of analysis selected: Asset or Portfolio Level. This is because, as was shown in Chapter 3, the measurement units of the indicators are different according to the level of analysis.

Finally, the main characteristics that were selected and configurated in the Dashboard of this field of interest are:

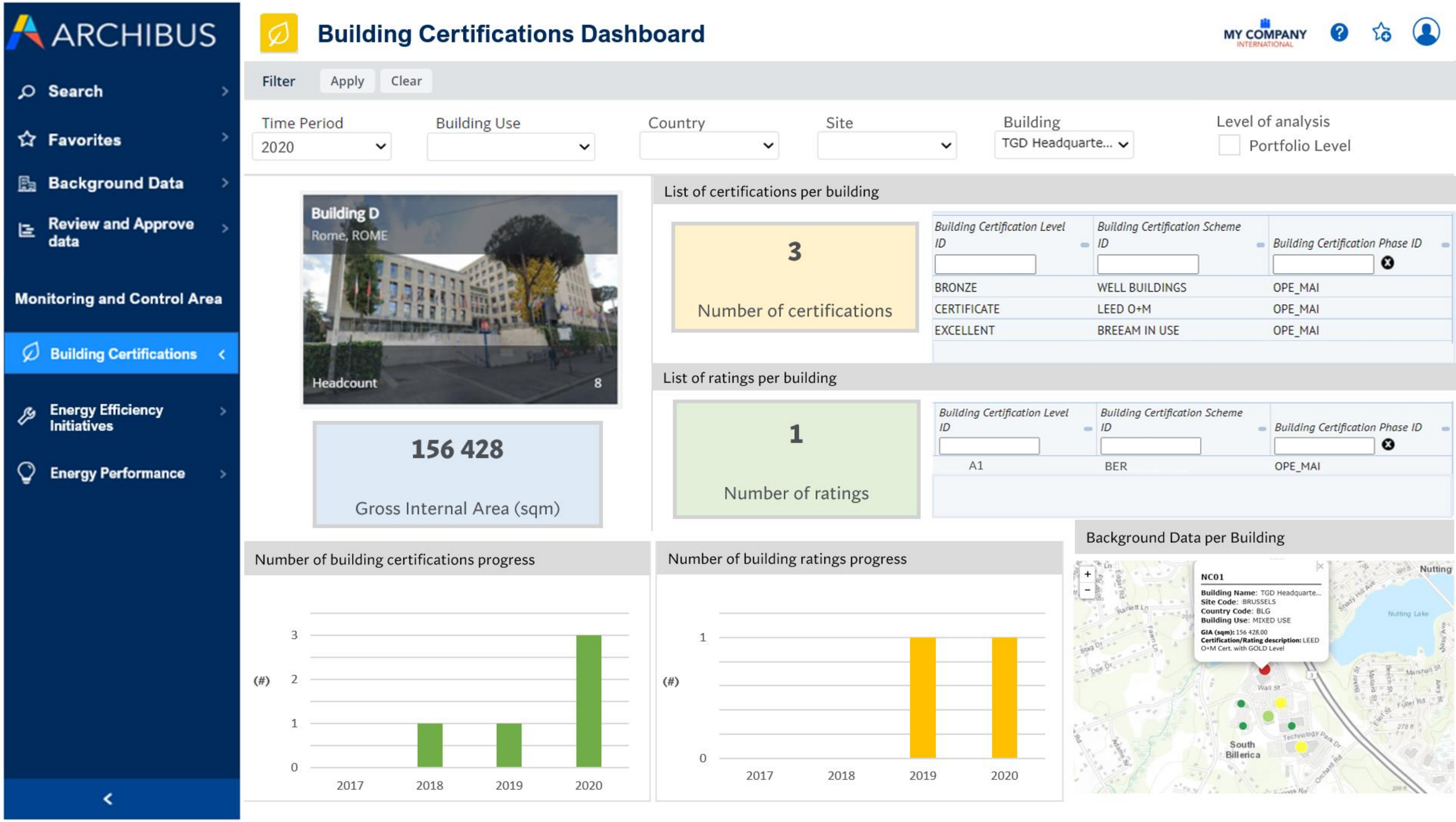
- A filter console that facilitates the search or analysis of the results either by year, type of analysis (by single building and portfolio level), buildings with the same type of use, buildings located in the same country, or buildings located in the same site: Dashboard 1 (display at Portfolio Level) and Dashboard 2 (display at Asset Level).

- Interactive graphs that retrieve from ARCHIBUS® database the data input necessary to show or calculate the performance metrics based on the filters selected by the users. In addition, with the mouse cursor, the users can view the values in any graph or chart by clicking on the point of interest: Dashboard 1 (display at Portfolio Level) and Dashboard 2 (display at Asset Level).

- Geolocation and thematic maps that allow to visualize the geographical location of the asset selected in the filter console and to open, with one click, a pop-up window which shows basic information about the building along with the certifications or ratings associated : Dashboard 1 (display at Portfolio Level) and Dashboard 2 (display at Asset Level).



Dashboard 1 Building Certifications (Portfolio Level)



Dashboard 2 Building Certifications (Asset Level)

6.3 Energy Efficiency Initiatives: Proposal of strategic integration between modules

To develop the "Energy Efficiency Initiatives" Dashboard, it is necessary to integrate the information currently managed within the Energy Management module vertically with the Compliance Management module and horizontally with the Project Management and Condition Assessment modules. So, the background data needed to calculate the six consolidated indicators presented in Chapter 3 must be previously set using some functionalities from the modules mentioned in this paragraph.

The two functionalities of the Project Management module selected to be integrated inside the menu of the Energy Manager role are: *Define Project Types* and *Define and Edit Projects*.

Through the "Define Project Types" functionality, the Energy Manager will define the project typologies: Energy upgrade and renewable energy (*Figure 39*). Later, using the " Define and Edit Projects" functionality (*Figure 40*), these two project types can be assigned or specified when a new project related to any of these types of initiatives is approved and planned inside a company.

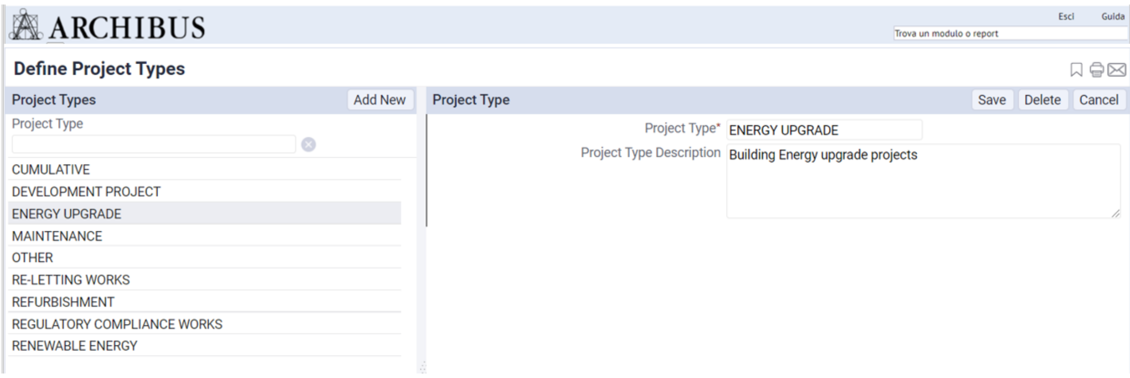


Figure 39 "Define Project Types" functionality
Source: ARCHIBUS®

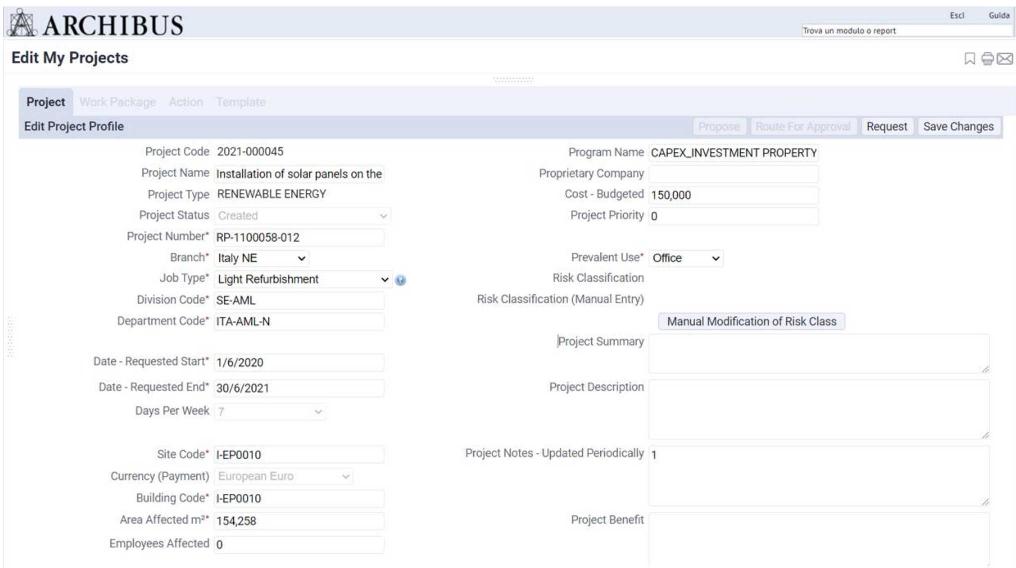


Figure 40 "Define and Edit Projects" functionality
Source: ARCHIBUS®

In this way it is possible to identify and retrieve the data necessary to calculate the indicators *I3-Total investment for building energy upgrade, I4-Total investment in renewable energy projects* and *I8- Amount of reduction in energy consumption achieved as a direct result of conservation and efficiency initiatives* (*Figure 41*).

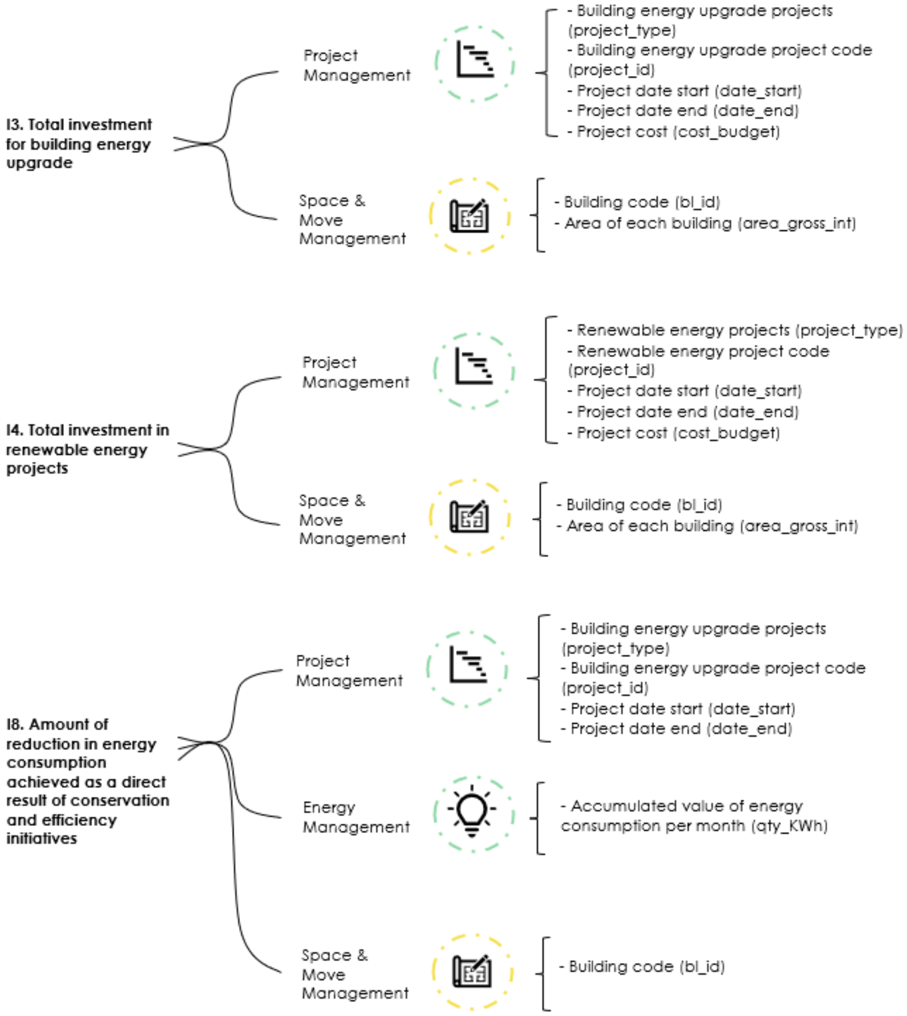


Figure 41 Scheme of data integration for the "Energy Efficiency Initiatives" indicators-Part 1

In second place, the two functionalities of the Compliance Management module selected to be integrated inside the menu of the Energy Manager role are: *Define and configure new document fulfilment* and *Manage document fulfilment per project*.

Through the "Define and configure new document fulfilment" functionality, the Energy Manager will be able to define the list of energy consumption policies, codes and standards that must be requested, kept updated and fulfilled at along the whole operational stage of each building within the portfolio of a company *(Figure 42*). Later, using the " Manage document fulfilment per project" functionality (Figure 43), the documents defined in the document fulfilment list can be delivered, reviewed, validated, and archived in the database throughout the operational/governance stage of each building that belongs to the portfolio of a company.

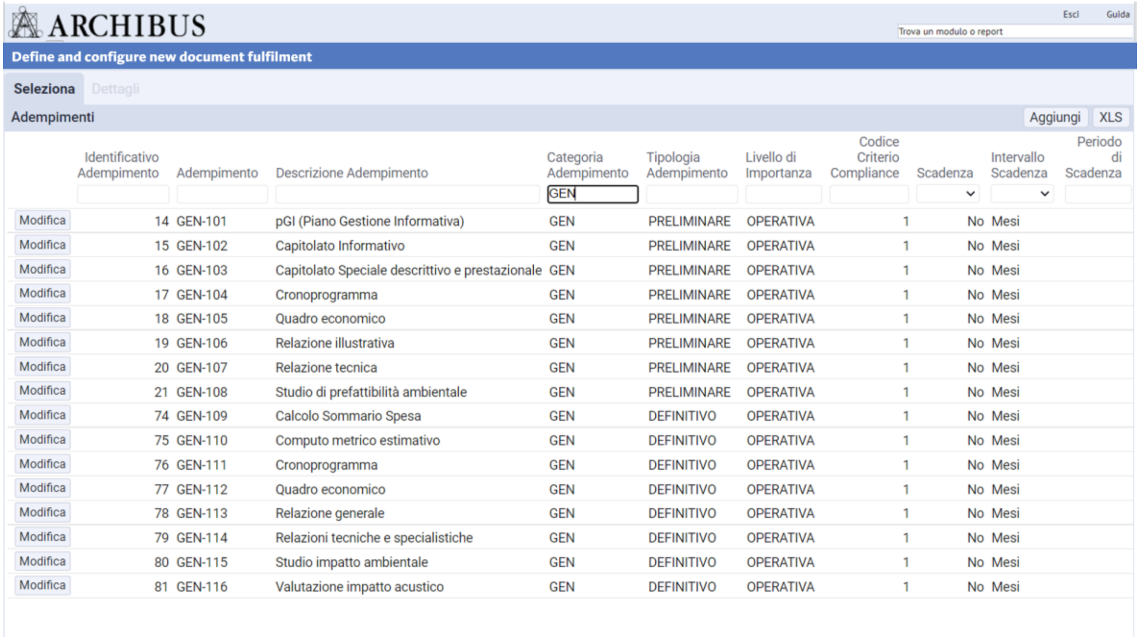


Figure 42 "Define and configure new document fulfilment" functionality
Source: ARCHIBUS®

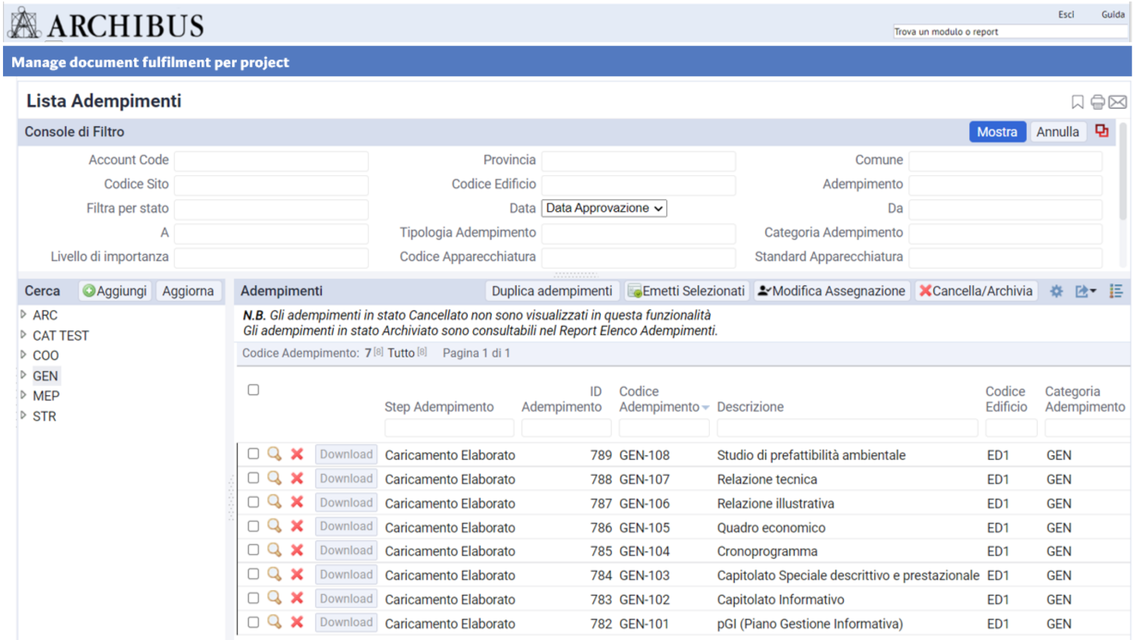


Figure 43 "Manage document fulfilment per project" functionality
Source: ARCHIBUS®

In this way, it is possible to identify and retrieve the data necessary to calculate the indicators *I5-Amount of Building energy consumption policies* and *I6-Amount of Building energy consumption codes and standards* (*Figure 44*).

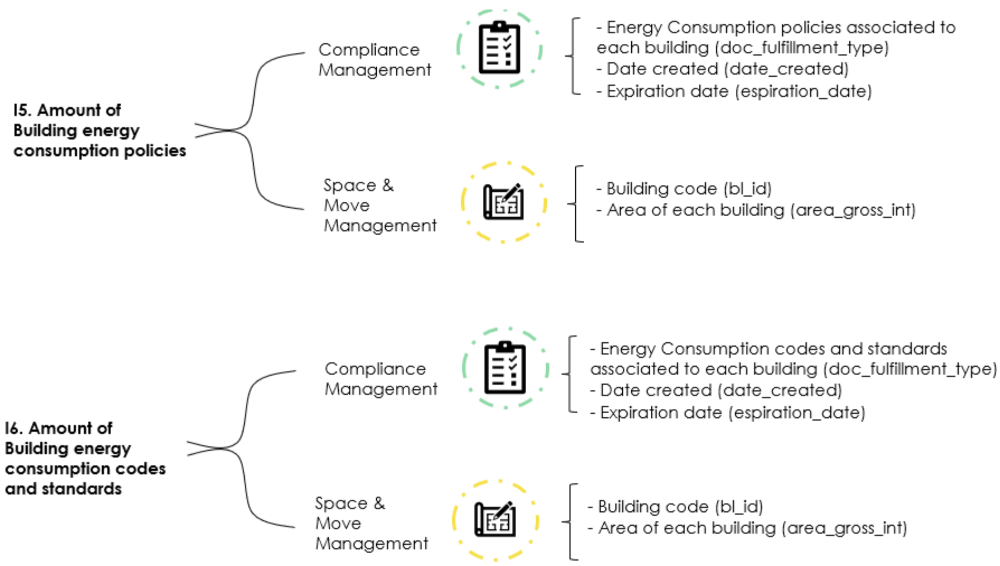


Figure 44 Scheme of data integration for the "Energy Efficiency Initiatives" indicators-Part 2

In third place, the two functionalities of the Condition Assessment module selected to be integrated inside the menu of the Energy Manager role are: *Create and manage technical assessments* and *View questionnaires.*

Using the functionalities mentioned, the Energy Manager can use one of the building energy efficiency assessment templates configured in ARCHIBUS® and automatically save the information in the database after carrying out an inspection in a specific building.

Figure 45 "Create and manage technical assessments" functionality
Source: ARCHIBUS®

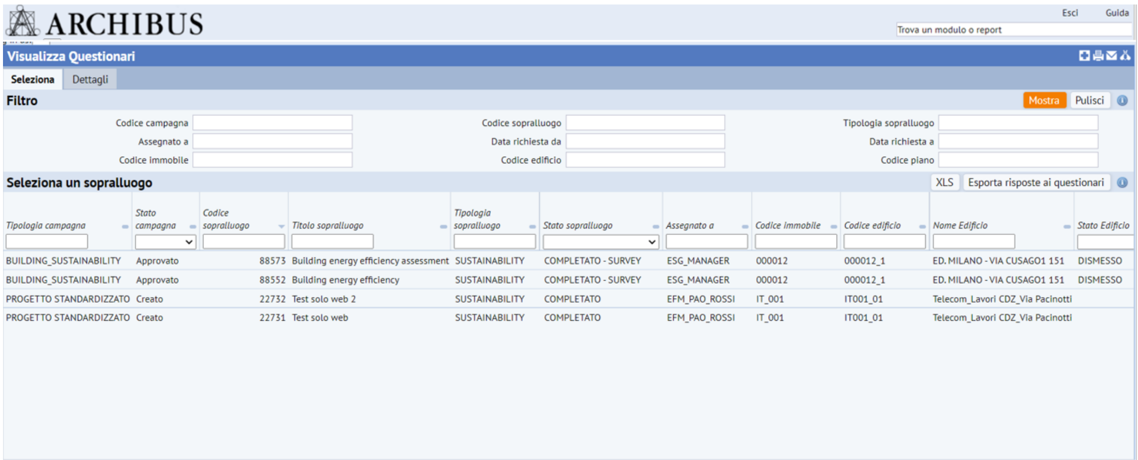


Figure 46 "View questionnaires" – Tab Select functionality
Source: ARCHIBUS®

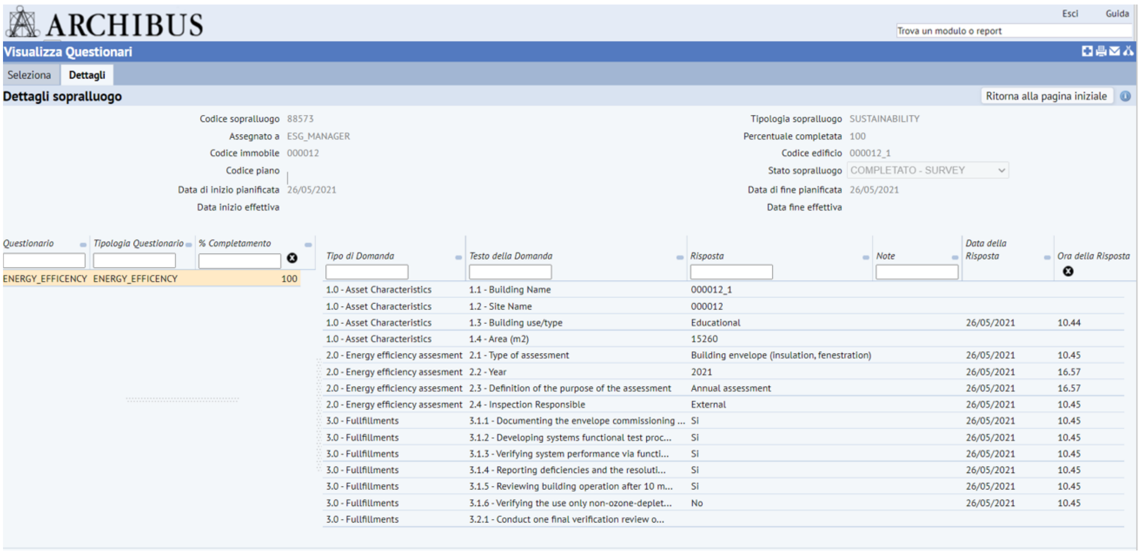


Figure 47 "View questionnaires" – Tab Details functionality
Source: ARCHIBUS®

In this way, it is possible to identify and retrieve the data necessary to calculate the indicator *I7-Amount of Technical building energy efficiency assessments during the last four years* (*Figure 48*).

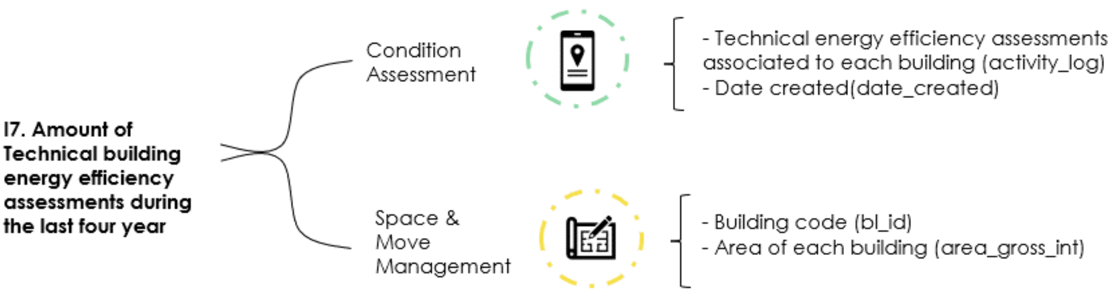


Figure 48 Scheme of data integration for the "Energy Efficiency Initiatives" indicators-Part 3

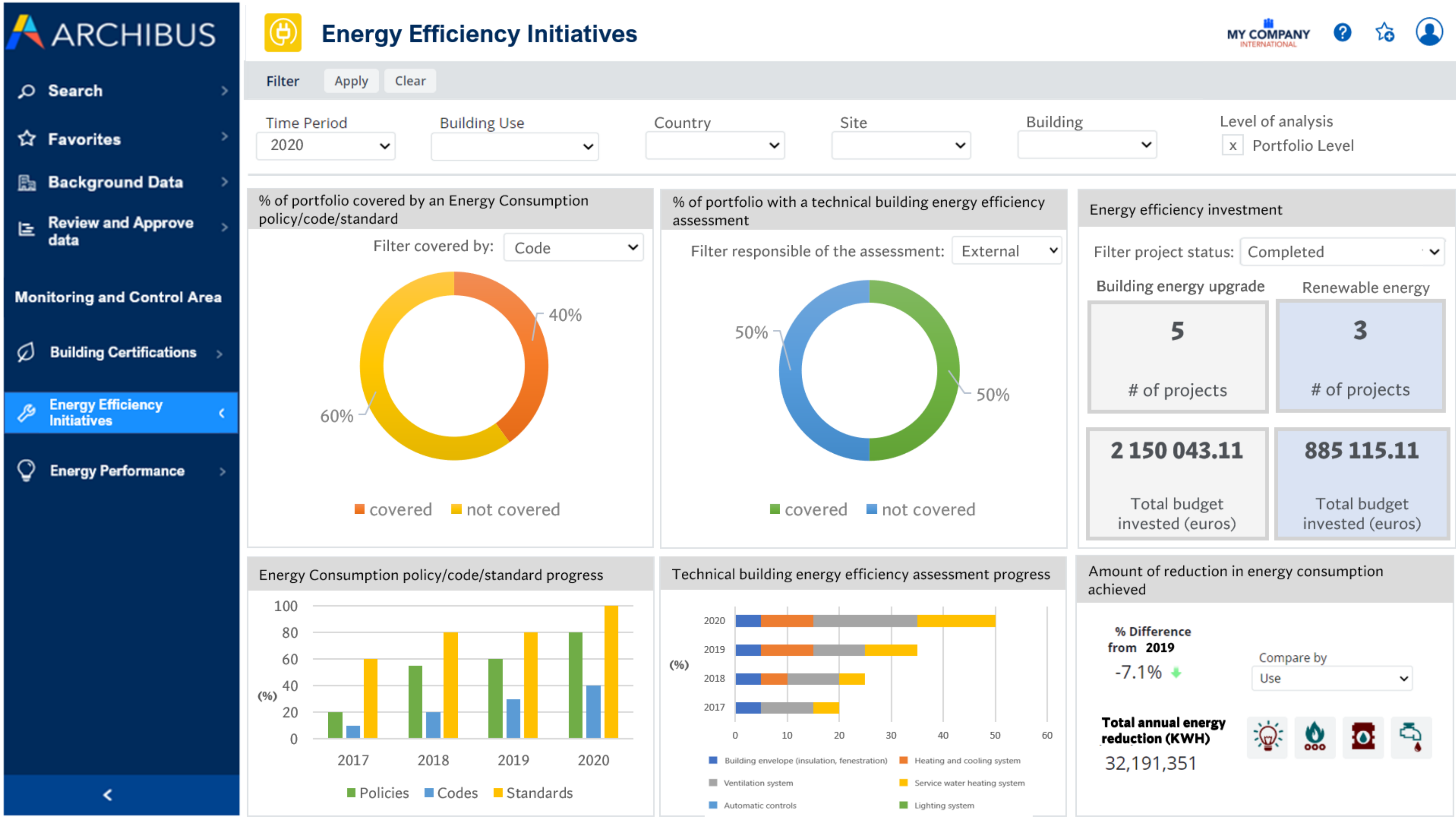
After the Energy Manager enters and associates the information in the previously explained functionalities, the indicators of this field of interest can be calculated and represented visually through different types of graphs within the Dashboard proposed for this field of interest.

One consideration to highlight is that the "Energy Efficiency Initiatives" Dashboard has two display formats based on the type of analysis selected: Asset or Portfolio Level. This is because, as was shown in Chapter 3, the measurement units of the indicators are different according to the level of analysis.

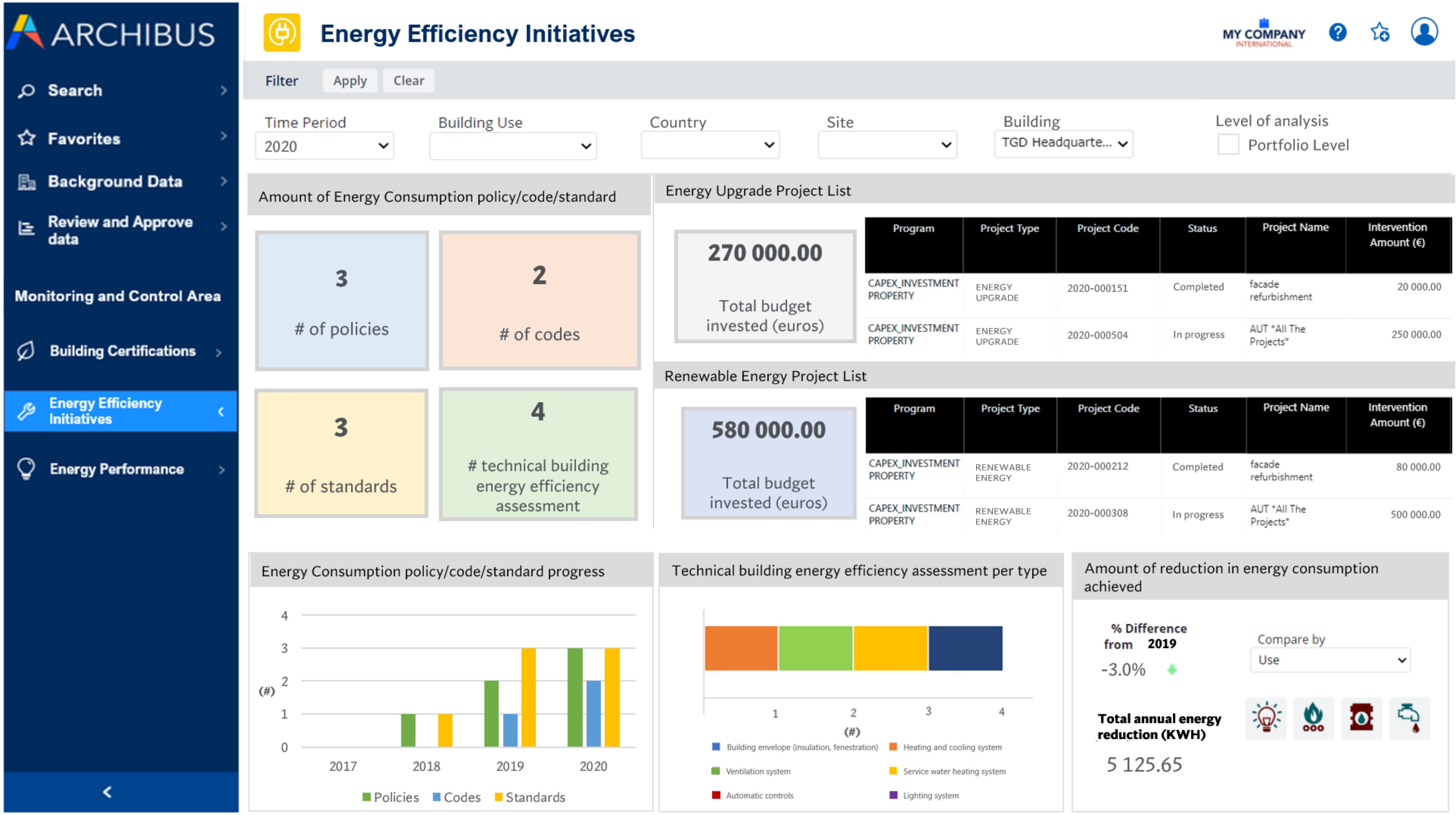
Finally, the main characteristics that were selected and configurated in the Dashboard of this field of interest are:

- A filter console that facilitates the search or analysis of the results either by year, type of analysis (by single building and portfolio level), buildings with the same type of use, buildings located in the same country, or buildings located in a same site: Dashboard 3 (display at Portfolio Level) and Dashboard 4 (display at Asset Level).

- Interactive graphs and tables that retrieve from ARCHIBUS® database the data input necessary to show or calculate the performance metrics based on the filters selected by the users. In addition, with the mouse cursor, the users can view the values in any graph or chart by clicking on the point of interest: Dashboard 3 (display at Portfolio Level) and Dashboard 4 (display at Asset Level).



Dashboard 3 Energy Efficiency Initiatives (Portfolio Level)



Dashboard 4 Energy Efficiency Initiatives (Asset Level)

6.4 Energy Monitoring: Overview Dashboard

For the development of the "Energy Performance" Dashboard, it is not necessary to integrate the information currently managed within the Energy Management module horizontally or vertically with other additional modules Therefore, the 11 consolidated indicators presented in Chapter 3 can be immediately configurated within the Dashboard (*Figure 49* and *Figure 50*).

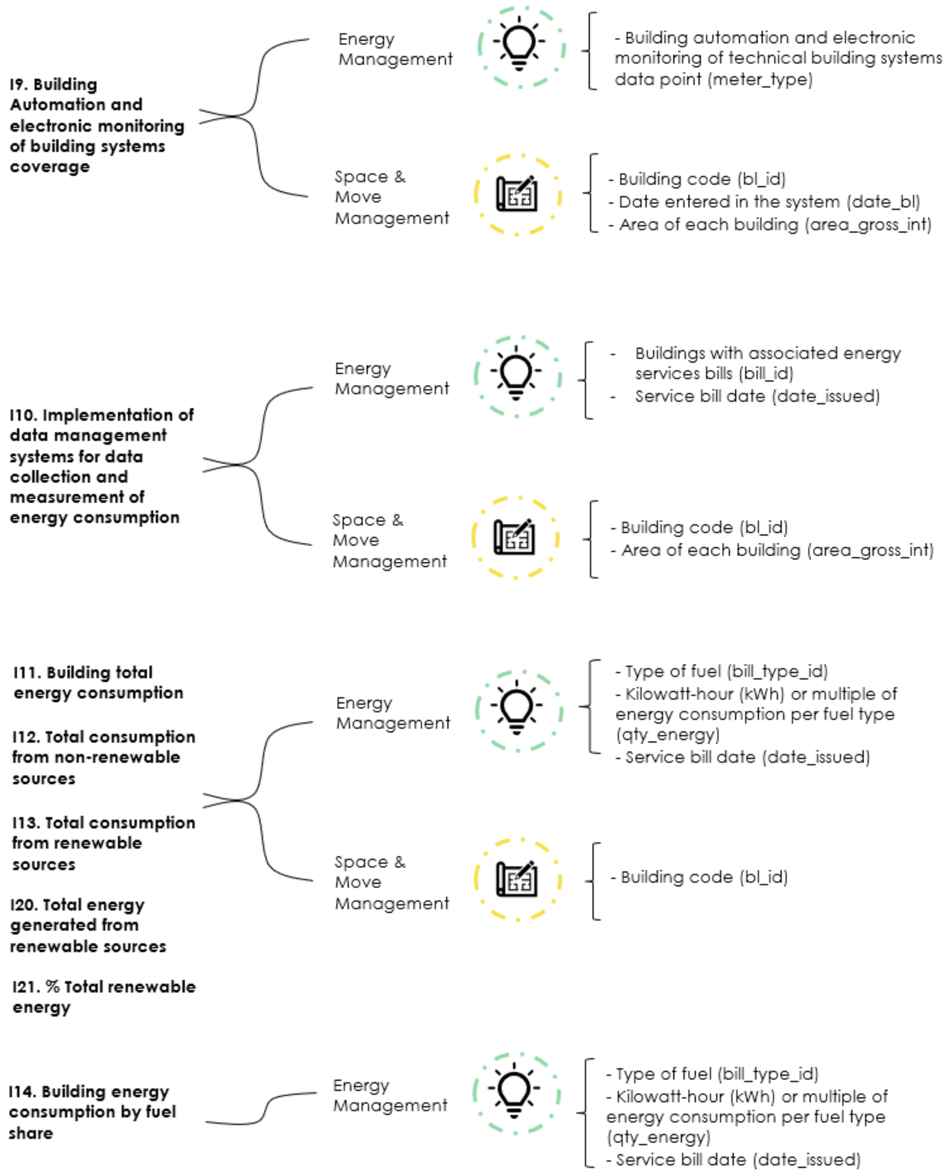


Figure 49 Scheme of data integration for the "Energy Monitoring" indicators – Part 1

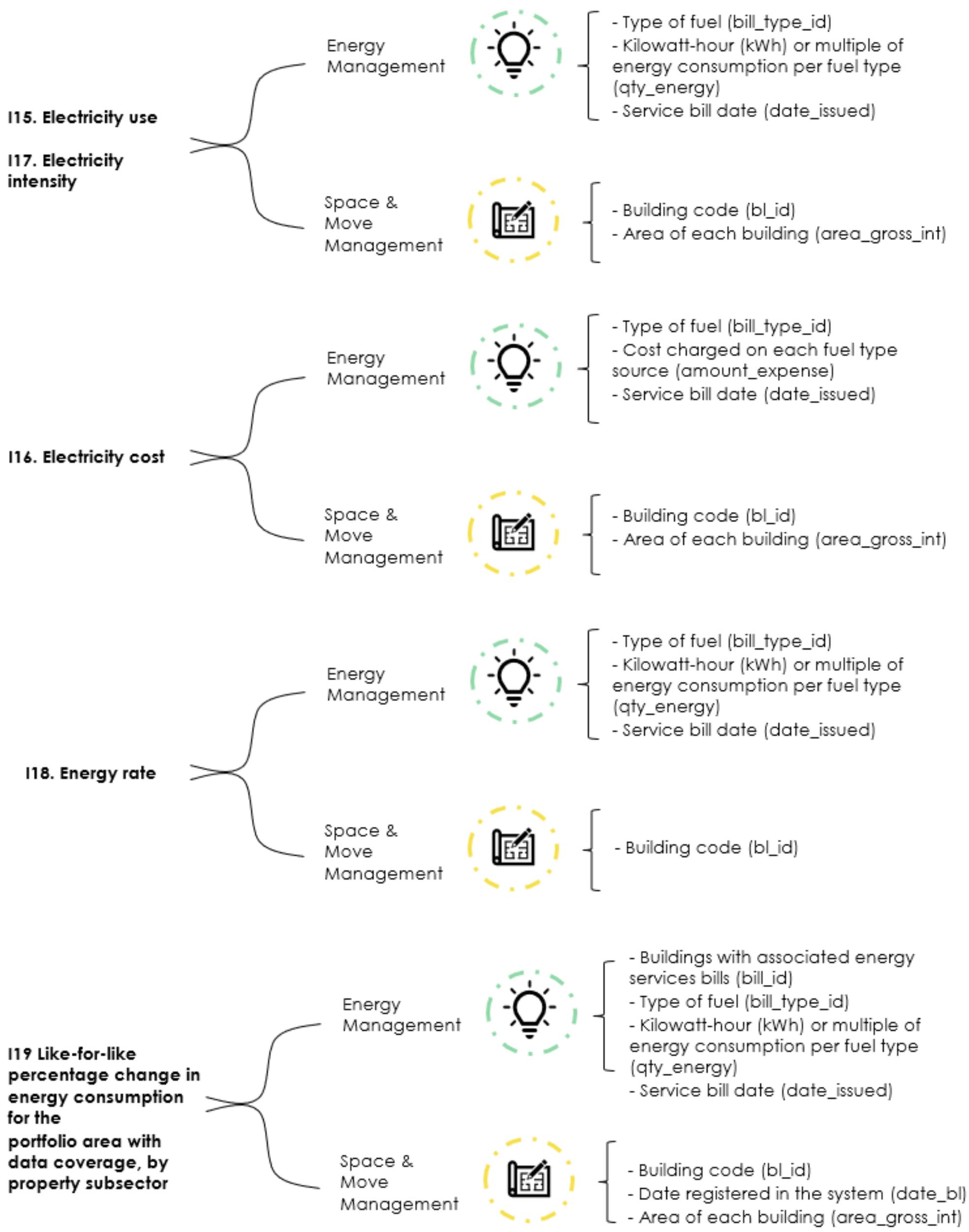


Figure 50 Scheme of data integration for the "Energy Monitoring" indicators - Part 2

The Dashboard proposed is divided into two tabs. The first tab is dedicated to energy consumption indicators, and the second tab, to the indicators that represent ratios between energy consumption with costs and square meters.

Taking advantage of the fact that the input of data regarding the consumption is linked with the registry of monthly utility bills, one consideration to highlight is the addition of a filter that allows displaying some graphs with the values of the indicators monthly. This form of visualization of the graphics can enable users to see the evolution or progress of consumption over time. Moreover, the values of the indicators are included with the annual frequency of calculation, following the guidelines set forth by the various international entities/sources.

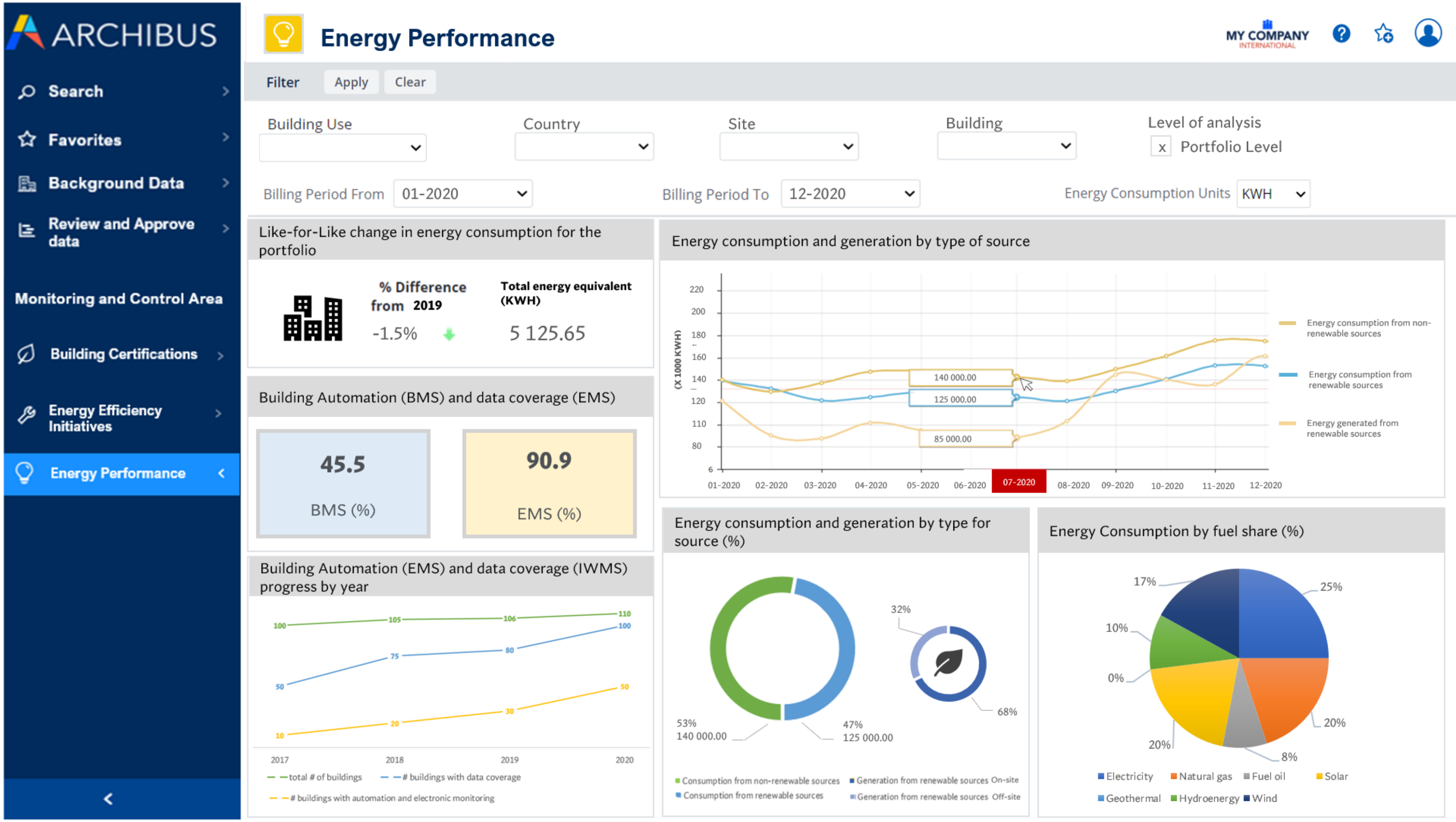
Another consideration to highlight regarding the development of the Dashboard is that, unlike those presented in the previous items, the measurement units for the indicators that represent ratios between energy consumption with costs and square meters (shown in the second Tab) at an asset-level and portfolio-level are the same in all cases. Therefore, the graphs proposed to represent these indicators are the same when applying the analysis filter at the portfolio level or selecting one from the drop-down list. For this reason, only a view of the second sheet of the proposed Dashboard is presented using the analysis at the portfolio level.

Finally, the main characteristics that were selected and configurated in the Dashboard of this field of interest are:

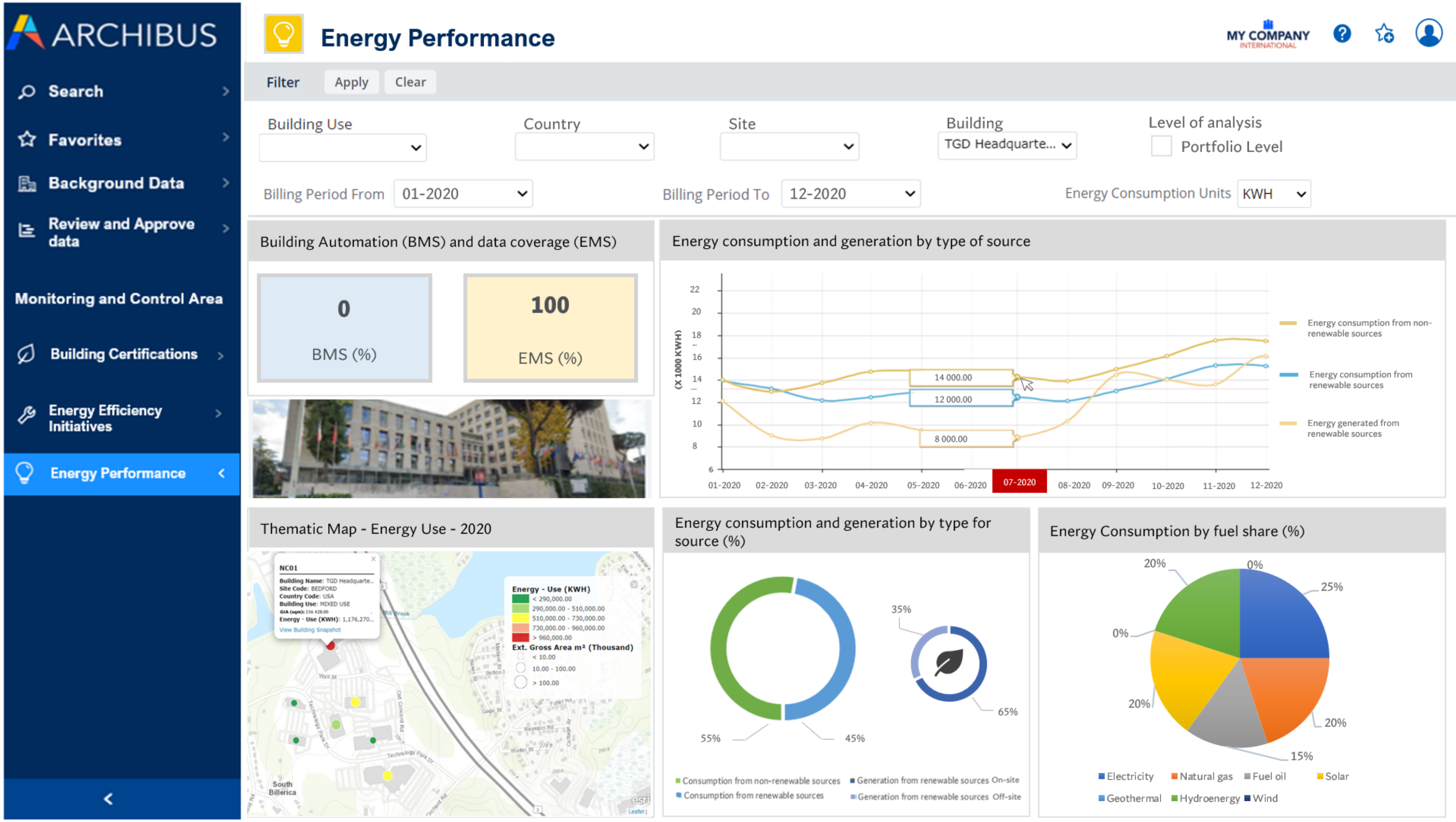
- A filter console that facilitates the search or analysis of the results either by a period of time, type of analysis (by single building and portfolio level), buildings with the same type of use, buildings located in the same country, or buildings located in the same site: Dashboard 5 (Tab 1 – display at Portfolio Level), Dashboard 6 (Tab 1 – display at Asset Level), and Dashboard 7 (Tab 2 – display at Portfolio and Asset Level).

- Interactive graphs that retrieve from ARCHIBUS® database the data input necessary to show or calculate the performance metrics based on the filters selected by the users. In addition, with the mouse cursor, the users can view the values in any graph or chart by clicking on the point of interest: Dashboard 5 (Tab 1 – display at Portfolio Level), Dashboard 6 (Tab 1 – display at Asset Level), and Dashboard 7 (Tab 2 – display at Portfolio and Asset Level).

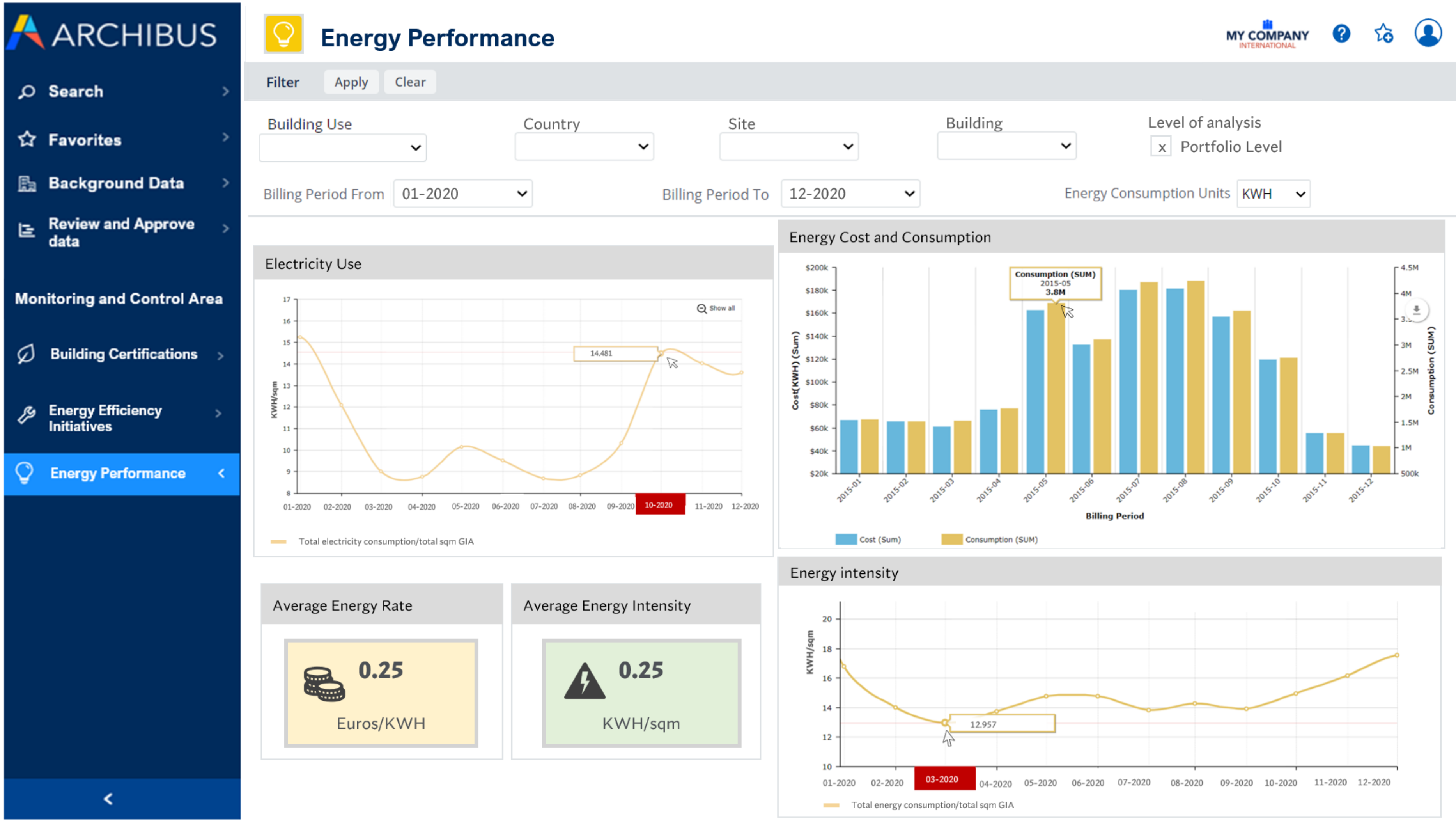
- A Geolocation map that allows visualizing the geographical location of the asset selected in the filter console and open, with one click, a pop-up window that shows basic information about the building along with energy data: Dashboard 6 (Tab 1 – display at Asset Level).



Dashboard 5 Energy Performance - Tab 1 (Portfolio Level)



Dashboard 6 Energy Performance - Tab 1 (Asset Level)



Dashboard 7 Energy Performance - Tab 2 (Portfolio and Asset Level)

CHAPTER 7: FURTHER IMPROVEMENTS

7.1 Scalability of the proposal: Additional indicators

Across all Real Estate sectors, tenants, investors, and other stakeholders are looking for genuinely sustainable and environmental-friendly assets. According to the latest report of KPMG company regarding the Real Estate sector in the new reality, the COVID-19 pandemic has forced to reconsider and give a greater focus to the link between environment, society, and good governance (ESG) within the real estate investment, development and management (KPMG, 2020).

In this current context, it is important to highlight the trend within the Real Estate sector related to the perspective of sustainability that encompasses environmental impact objectives and specific social and good governance objectives (*Figure 51*).

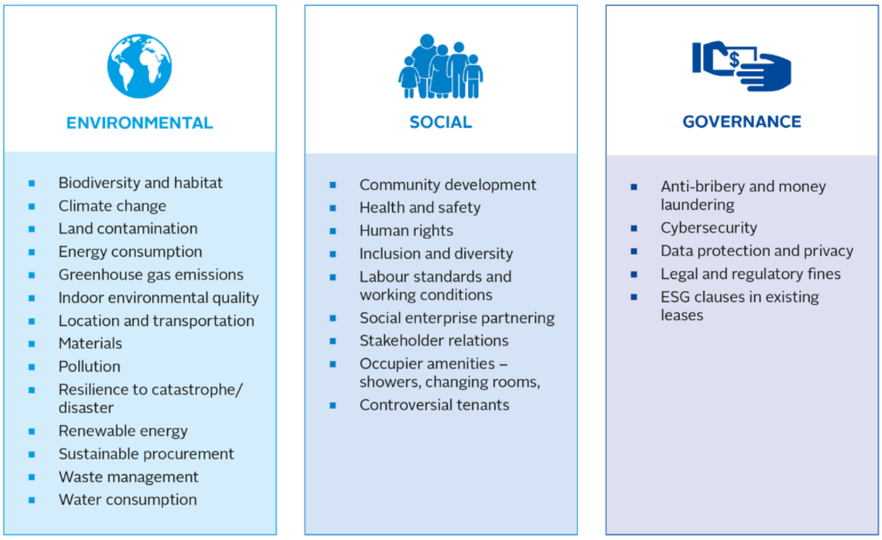


Figure 51 ESG targets
Source: Principles for Responsible Investment (PRI)[29]

Therefore, considering this new panorama of definition, management, and disclosure of objectives beyond environmental issues, it is possible to affirm the potentiality and scalability of the proposal of indicators and Dashboards presented in *Chapter 6.*

In the first place, concerning the selected indicators, it is possible to extend the list vertically in the environmental topic and horizontally in the social and governance scope.

To achieve this, it is necessary to follow the procedure developed in the theoretical part of this thesis: identification of sources, selection and consolidation of indicators, definition of calculation method and normalization of data input needed.

[29] For further details about ESG see: https://www.unpri.org/an-introduction-to-responsible-investment/an-introduction-to-responsible-investment-real-estate/5628.article

In this way, as was presented for the energy consumption and efficiency indicators, it is possible to integrate more functionalities within ARCHIBUS® and generate new reports that monitor, control, and disclose ESG performance at the organizational level (*Figure 52*).

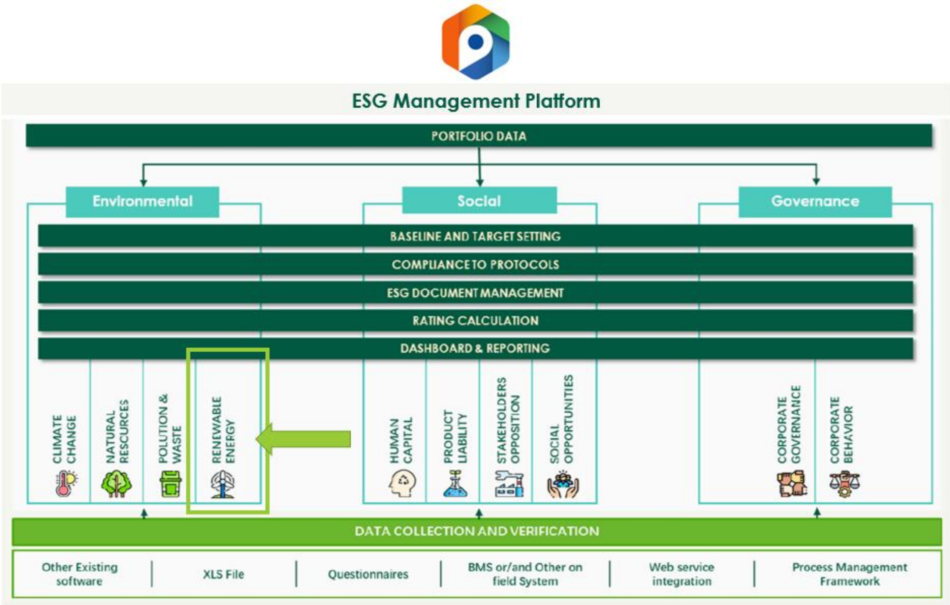


Figure 52 ESG Management Platform Overview

In the second place, by expanding the indicator calculation coverage within the platform, it is possible to take advantage of the certification of projects or organisations based on their ESG performance.

To achieve this, it is necessary to recreate the structure/format of the reports following the guidelines of one or more internationally recognized certification associations, such as GRESB, inside the platform. In addition, the reports must have the support of procedures for the retrieve and organisation of document evidence inside the platform, which will allow the organisations to get the score to be certified (
Figure 53).

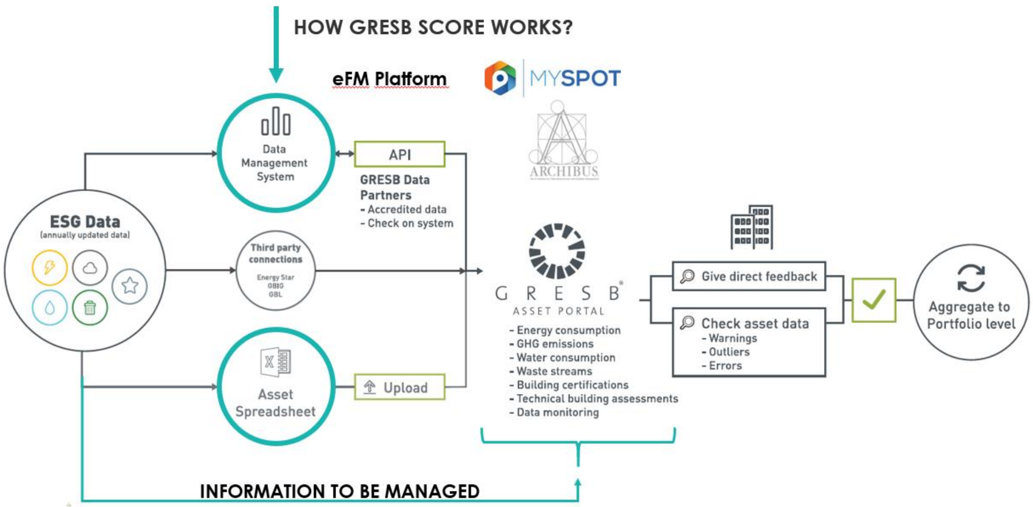


Figure 53 ARCHIBUS® and GRESB integration

7.2 Smart Building - IoT sensors integration

As explained in item *6.4 Energy Monitoring: Overview Dashboard*, the collection process of the energy consumption information, which is needed to obtain the Dashboards proposed, focuses on the monthly utility bills associated within a building.

This makes it possible to obtain reports and the value of the indicators not only on an annual basis but also at a monthly one, which, on one side, allows users to take improvement measures more strategically. However, the information collection process through utility bills, considered as a static and resource-consuming process, raises two potential risks to the "Energy Monitoring" Dashboard proposed (Atta, 2021):

- Lack of reliable data within the database if the data input is not updated regularly.
- Loss of effectiveness of the Dashboards if the information reaches the relevant users at the wrong time.

The threats identified can be counteracted by implementing further improvements in the proposal related to Real-Time Data availability and accessibility. In this context, it is important to highlight some new innovative digital and technological developments in real estate information management that can be integrated with the IWMS platform.

In first place, the Smart Building Systems, a new concept of highly automated building where all the facilities, building systems (including heating, ventilation, and air-conditioning systems) and processes are interconnected. The real development of this concept happens with the rise of the Internet of Things (IoT), a new reality where *"objects interact with the surrounding reality collecting and sharing information between the internet network and the real world [...] without the interference from the human being"* (Vasta, G., Ravazza, 2017).

One of the key functions of Smart Buildings and IoT is the use of sensors which can increase the accuracy and reliability of measurements through the collection of data from nearby wireless base stations installed in specific locations inside a building (Weng & Agarwal, 2012). So, merging the IWMS platform with sensors can allow to control environmental conditions; reduce energy usage (HVAC, plug-loads, and lightning), water consumption and carbon emissions; and know the building status in real-time.

Currently, in addition to the many applications provided and presented in the previous chapters, ARCHIBUS® has the potential unparalleled interoperability with CAD, BIM, GIS, IoT (sensors) and many other building and enterprise systems. In specific, the Energy Module can be supported with the use Electronic Data Interchange (EDI) to confront billing information, which can include uncover anomalies, against measured values from submeters, sensors and Building Energy Management Systems data (BMS) (*Figure 54*).

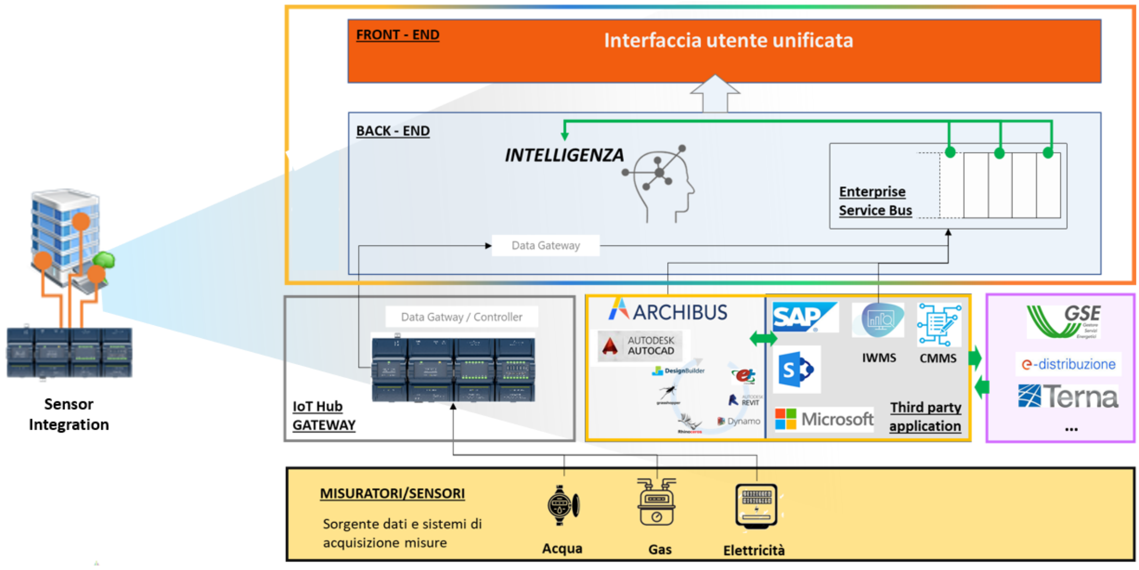


Figure 54 Overall architecture of the integration between sensors, ARCHIBUS®, IoT server and BMS

With this further integration, the Dashboards proposed will allow users to view the updated real-time information contained in a dynamic database in a user-friendly and easy-to-understand structure, transforming the threats identified in an opportunity of improvement the decision-making process towards nearly Zero Energy Building in existing buildings.

CONCLUSIONS

The literature analysed showed the substantial potential of using digital tools in the control and disclosure of energy performance management. Also, it emphasized the importance of the properly definition of a list of indicators that allow organizations to evaluate and take the corresponding actions to reach energy efficiency improvements during the operation of buildings, the stage with the greatest amount of carbon emissions.

Therefore, it can be affirmed that by understanding how people use buildings and providing more accurate information about their energy consumption patterns it is possible to allow the real estate operators to achieve their environamental goals and targets and repair past harm to the atmosphere.

Moreover, the literature revealed that currently, there is no list of standard indicators that real estate companies can use to measure, monitor and create awareness in a transparent way about their energy efficiency improvements among their key stakeholders. Thereby, using the indicators presented by different recognized international organizations, it was possible to perform a process of consolidation of energy consumption and efficiency indicators by three fields of interest selected: Building Certifications, Energy Efficiency Initiatives and Energy Monitoring.

Consequently, with the list of consolidated indicators proposed, it was possible to achieve the main objective defined for this thesis, that is, to identify the best combination of fields inside an IWMS database necessary to calculate the complete list of energy consumption and efficiency indicators within one of the most recognized software in the market, ARCHIBUS® platform.

By understanding how the data input should be related within ARCHIBUS® allowed the development of an applicative case study. Within the case study, it was possible to meet the scope selected and implement an improved process workflow within the Energy Management module, which is dedicated to the analysis of energy performance. Likewise, more effective dashboards were designed with respect to what the module proposed in the current scenario. Inside the dashboards, the complete list of quantitative and qualitative

Finally, during the last step of the applicative case study, some shortcomings were identified related to the specific scope of indicators and the static nature of the data input defined for the data collection process. Nevertheless, these shortcomings in the proposal opened the space to evaluate further developments regarding the possibility of exploiting the scalability of the ARCHIBUS® software solution to expand the calculation of indicators at an ESG level. In addition, the possibility of changing the static nature of the indicators for a dynamic nature or real-time information availability by integrating the platform with IoT and BMS systems.

Concluding, nowadays the strategic management of energy performance is crucial to maintain continuous improvement concerning the objectives of nearly Zero Energy Building (nZEB) consumption that must be achieved in the coming years. The success of this management not only focuses on proper monitoring and control, in fact, it must be followed by an initial plan of targets, a standard process for collecting the necessary data and an appropriate strategy to build engagement within all stakeholders throughout the real estate projects life cycle. Undoubtedly, the insights presented in this thesis should serve as a first step that real estate companies can use in restructuring their processes towards a more sustainable approach, which will bring environmental benefits, increase the property value of buildings and reduce the costs across many end-uses.

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