A COMPLETE REQUIREMENTS SPECIFICATION, COVERING BOTH FUNCTIONAL AND NON-FUNCTIONAL REQUIREMENTS

Project acronym: COLLECTiEF

Project title: Collective Intelligence for Energy Flexibility

Call: H2020-LC-SC3-EE-2020-2

Disclaimer

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Executive Summary

The deliverable D4.1 related to Task 4.1 and entitled "A complete requirements specification, covering both functional and non-functional requirements", represents the complete set of the business, user, and system requirements for the COLLECTiEF platform defined by taking into account the site-specific requirements and the market needs.

The aim of this deliverable, which relies on the definition of the business, user and system requirements, is one of the crucial steps to support the project design and development activities ongoing in the WP3 and the implementation of the deployment and validation activities which are the main objectives of the WP4 "COLLECTiEF system Integration and large-scale demonstration".

Indeed, during the project, it is important not to overlook the appropriate understanding of the needs and expectations of the main stakeholders (internal and external to the project) as it can offer an important perspective on how to address and review the project objectives.

To this end, starting from the aim of the COLLECTiEF project – enhance, implement, test and evaluate an interoperable and scalable energy management system based on Collective intelligence (CI) that allows easy and seamless integration of legacy equipment into a collaborative network within and between existing buildings and urban energy systems with reduced installation cost, data transfer and computational power while increasing data security, energy flexibility and climate resilience – a detailed stakeholders list and a specific questionnaire to elicit site-specific requirements have been defined to especially consider the stakeholders needs for the release of the COLLECTiEF consolidated prototype.

Particularly, the overall approach and methodology for the implementation of AI-based solutions able to improve legacy equipment to upgrade the buildings' smartness have been studied in depth together with relevant public reports, scientific works, and research initiatives.

Thanks to this and to an in-depth study of the market segments of interest, it was possible to define a first set of stakeholders and market requirements associated with the development of this solution. These requirements act as a basis to refine the project architecture defined in T3.1, together with the internal site-specific requirements derived from the questionnaire shared internally to collect information and to verify and refine the requirements.

Thus, allowing the project developers to gain insight into the specific needs of the stakeholders and the associated market sectors, to evaluate the needs in terms of technologies to be used and functionalities to be provided within the COLLECTiEF project.

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List of Acronyms

AI	Artificial Intelligence
BMS	Building Management System
CAGR	compound annual growth rate
CI	Collective Intelligence
CO2	Carbon Dioxide
COLLECTiEF	Collective Intelligence for Energy Flexibility
DSM	Demand-Side Management
EBC	Energy in Buildings and Communities
EU	European Union
EUR	Euro
GDPR	General Data Protection Regulation
HVAC	Heating, Ventilation and Air Conditioning
ICT	information and communication technologies
IEA	International Energy Agency
IoT	Internet of Things
LED	Light Emitting Diode
T	Temperature
TGs	Target Groups
WP	Work Package

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1 Introduction

The purpose of this deliverable, as the technical output of the project, is to define the business, user, and system requirements for the COLLECTiEF platform.

Based on data collected through desk research and surveys/interviews, this deliverable describes in detail the requirements for the implementation of COLLECTiEF platform and can be considered as a key input for the update of the project architecture (T3.1) and for the development, deployment and validation activities in WP3, WP4 and WP5.

1.1 Scope and objectives of the deliverable and relevance in the COLLECTiEF framework

The COLLECTiEF project is focused on creating a cutting-edge web platform that is smooth, interoperable, and scalable. The platform offers a range of services focused on the use of advanced algorithms, specifically designed to establish a demand-responsive, energy-flexible network using CI techniques. The ultimate goal is to develop a cost-effective system that is easy to deploy and maintain.

The project's services are built upon a customizable occupant-centric fusion sensor network, enabling precise and non-invasive environmental monitoring. This network is capable of gathering data from various sensors and integrating them to provide accurate insights. The services offered by COLLECTiEF encompass a smart, user-centric digital platform that is designed to be intuitive and user-friendly. This platform facilitates seamless interaction with users and allows for the effective control of the building control systems.

Particularly, the COLLECTiEF platform leverages enhanced algorithms to establish an energy-flexible network. By utilizing a fusion sensor network and providing a user-centric digital platform, aiming at creating a cost-effective and easily manageable system for users to efficiently interact with and control their building control systems.

The system components, under development in the project, will be integrated through a scalable, replicable and interoperable cross-layered software platform fully GDPR compliant in which privacy and cybersecurity aspects will be considered together with an interoperability framework.

This platform can be seen as a complex system in which different kinds of users can use the available tools, models, and mechanisms to exploit the smartness of the buildings.

In this perspective, the COLLECTiEF ecosystem can be defined as the community of internal and external stakeholders of the project in conjunction with its core technology framework.

Understanding the needs and expectations of COLLECTiEF's stakeholders is of utmost importance as it may offer a fresh and valuable perspective on how to tackle the goals and objectives of the project.

This assessment goes beyond the development of the innovative solutions proposed and the expected integration of the COLLECTiEF technologies (which is a mandatory achievement) and defines the COLLECTiEF solution against the needs and trends that will emerge from the consultation of the stakeholders and the study of the reference market needs.

This deliverable pursues this direction and focuses on the elicitation of the requirements and extrapolation of stakeholder and market needs as well as their implementation priorities.

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To this end, the stakeholder and market requirements will be defined starting from the study of the literature and the collection of data through desk research and surveys/interviews, assessing the proposed methodologies and identifying challenges and the current market needs, as well as market emerging future needs and requirements also through the involvement of stakeholders to identify and assess project requirements.

1.2 Structure of the deliverable

D4.1 “A complete requirements specification, covering both functional and non-functional requirements” consists of five chapters, in which the adopted processes for the definition of stakeholders, market and system requirements have been described, as follows:

- General description of the scope and objective of the deliverable [Chapter 1];
- Definition of the COLLECTiEF stakeholders, user groups and market sectors [Chapter2];
- Overview of the other initiatives and projects related to the improvement of legacy equipment to upgrade the buildings’ smartness and results of the desk research relevant to the COLLECTiEF requirements definition [Chapter 3];
- Description of the requirements, extrapolated by means of the analysis of feedback from other initiatives' interviews and site-specific survey shared among the COLLECTiEF pilot representatives [Chapter 4];
- Conclusions and future works [Chapter 5].

1.3 Relation to other tasks and deliverables

Since T4.1 is the task focused on the collection of the requirements from stakeholders and from literature and market analysis, the outputs of T4.1 will serve as a basis for the update of the architecture defined in T3.1 and to support the development, deployment and validation activities we are conducting in the WP3, WP4 and WP5.

Particularly, in WP3 the collected requirements will be used to update the ongoing development activities on the basis of the contents of this document.

So, the requirements defined in this task, once used for the update of project UCs and architecture, will be also taken into consideration during the development activities.

Finally, WP6 will also benefit from the activities conducted in this task. Particularly, the outputs of T4.1 will be used to define different possible business models to facilitate the market uptake of COLLECTiEF and the roll-out of developed services. Thus, T4.1 plays a crucial role in informing the work carried out in several tasks, by providing the necessary stakeholders and system requirements and the market needs to guide the update of architecture and UCs and the development of COLLECTiEF project solutions and related business models.

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2 Definition of stakeholders, user groups, and market sectors

2.1 Stakeholders' analysis and rating

The identification of potential stakeholders is a crucial phase in any project. By categorizing them into well-defined groups known as Target Groups (TGs), they become actively involved in the process of defining requirements, enabling the identification and capture of both business needs and user requirements.

The success of projects heavily relies on designers' ability to meet the needs and expectations of stakeholders throughout the entire project lifecycle. When identifying stakeholders, it is essential to consider various categories such as building owners, tenants, energy suppliers/utilities, technology providers, local governments, installers and maintenance staff, cybersecurity firms, universities and research organizations and general public and media, within the context of the business and proposed solutions.

A stakeholder is any entity (individual or organization) with a legitimate expectation from the system, in other words, stakeholders are all those who can be influenced or who could influence the system in general [1].

These individuals or groups play a crucial role in gathering requirements for a project. Identifying stakeholders is not a simple task, and obtaining information about them is not readily available.

Developers often encounter the challenge of locating the appropriate stakeholders who have the necessary time, interest, and knowledge for the project.

Therefore, it is vital to consider potential stakeholders and target groups early in the project's development. An effective process for extracting requirements needs active involvement from stakeholders who may be impacted by or have influence over the project. The influence of stakeholders on a project can vary significantly, resulting in a vast range of possible involvements.

For instance, the requirements extraction process may involve individuals who provide funding for the system, customers, component designers, and system users. This highlights the importance of categorizing stakeholders in the analysis to effectively manage requirements elicitation.

For the stakeholder identification phase, we considered the following tools and techniques:

- Stakeholder analysis: gathering and evaluating information to determine which interests should be considered for the project;
- Expert Rating: expert technical and/or managerial judgment (from any qualified source, mainly within the project consortium);

The main stakeholders of the COLLECTiEF reference target have been assessed on the basis of specific needs considered and rated their interests in order to identify the main needs to be addressed with the project and the specific target users.

Here are some of the key stakeholders and a brief analysis of their roles and interests:

Building Owners: They are the primary stakeholders, as they stand to gain from reduced energy costs, increased comfort, and improved sustainability, and are usually the ones with a vested interest in the successful implementation of the system and the benefits it provides. They are also interested in reduced installation costs and increased energy flexibility. Additionally, the focus on flexibility, demand-side management, and energy efficiency directly aligns with their interests in cost savings

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and sustainability. By controlling loads and optimizing thermal control, they can potentially increase the longevity of their assets, which further enhances their interest in the system.

Tenants: The people living or working in the buildings are crucial stakeholders as they will directly experience any changes to the energy management system. Their interests lie in increased comfort, reliability, and potentially reduced costs. The focus on improving user comfort and energy efficiency could lead to a better living/working environment and potential cost savings. The ability to control loads through smart plugs could also give them greater control over their energy usage.

Energy Suppliers/Utilities: These stakeholders provide energy to the buildings and have an interest in such a system for the potential of better energy demand management, load balancing, and reducing peak demand. The emphasis on flexibility and demand-side management could help with load balancing and reducing peak demand, while also providing them with valuable insights for future planning through the monitoring of building data.

Technology Providers: These stakeholders provide the necessary technologies for the system, such as smart meters, IoT devices, servers, and software, and they have an interest in proving their technology's reliability and performance. The various technologies mentioned, including smart plugs, smart valves, and BMS control, align with their interests, allowing them to showcase their technology's effectiveness in real-world scenarios.

Local Governments: As regulators, they are interested in the project's success due to potential benefits like increased energy efficiency, reduced emissions, improved resilience against climate-related issues, and alignment with many local governments' goals around sustainability and emissions reduction. The focus on energy efficiency and demand-side management also aligns with their interest in community safety and resilience.

Installers and Maintenance Staff: These stakeholders are responsible for installing and maintaining the system. They are interested in the ease of installation, maintainability, and potential new job opportunities. The use of specific technologies (smart plugs, smart valves, sensors, BMS control) could require specific skills, potentially creating more job opportunities. The focus on easy integration with legacy equipment could also reduce potential installation/maintenance challenges.

Cybersecurity Firms: These stakeholders ensure the data security of the system. They are interested in demonstrating the security of their solutions and preventing any breaches. The increased data monitoring and control functionalities necessitate a robust cybersecurity framework, aligning with their interests.

Universities and research organizations: These institutions may be interested in the data and knowledge generated from the project for academic and applied research. The project's functionalities provide a rich ground for academic research around energy management, user comfort, and climate resilience.

General Public and Media: They are interested in the project's societal and environmental benefits. The focus on energy efficiency and user comfort aligns with broader societal interests. The resilience aspect could also generate positive media coverage.

An analysis of these stakeholders' categories has been conducted to classify them based on their relevance to the project and services.

The performed analysis is reported below, particularly, to each of stakeholders' category a rating (on a scale from 1 to 5, with 1 being least important and 5 being most important).

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Building Owners: 5 - The project directly impacts them, and their cooperation and buy-in are crucial for implementation.

Tenants: 5 - The services provided by the project directly influence their comfort and costs. Their feedback and acceptance are necessary for the project's success.

Energy Suppliers/Utilities: 4 - They are integral to the energy supply and the demand management process. It is necessary to understand the requirements and preferences of the energy providers for the effective delivering flexibility services by the system. An in-depth study of their expectation is needed to tailor the followed approach to meet them. Studying the energy provider's perspective enables the consortium to align the strategies and solutions with their operational objectives by identifying the specific challenges they face.

Technology Providers: 4 - They provide the necessary hardware and software. Their products' performance can impact the success of all services.

Local Governments: 3 - A consultation of politicians and policymakers can be useful to frame the regulatory landscape in which the solution is to be placed and take into consideration all aspects of the regulatory framework. Furthermore, they can also assist in promoting the project and its benefits to the broader community.

Installers and Maintenance Staff: 3 - Their valuable expertise and insights can contribute to the successful integration and seamless operation of the system, ensuring efficient functionality, ease of maintenance, and optimal performance.

Cybersecurity Firms: 4 - Their role is crucial for data security, which is necessary for building data monitoring and control services.

Universities and research organizations: 4 - Their expertise and insights are invaluable in ensuring the effectiveness and success of the project by providing valuable perspectives, conducting rigorous analysis, and contributing to innovative solutions. The project can benefit from their deep knowledge, cutting-edge research, and commitment to advancing the field, ultimately leading to a more robust and impactful implementation.

General Public and Media: 2 - While their perception can impact the project's reputation, they are not directly involved in the implementation or operation.

Once stakeholders have been identified and rated, they need to be prioritized based on their influence and impact on the project. This can be done using tools like the Power/Interest Grid (Figure 1), which maps stakeholders on a four-quadrant chart based on their power (ability to influence the project) and interest (level of concern with project outcomes).

The main advantage of the stakeholders' allocation according to this grid is that of discovering quickly where the real power is located and therefore helping to make better project decisions and to find the right means of communication with the interested parties.

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Figure 1 Power/Interest Grid

The project stakeholders have been classified on the basis of their level of power and interest, using the Power/Interest Grid, to better understand their influence and to prioritize some specific requests collected from the site-specific consultation of the internal partners and some requirements collected during the studies conducted to retrieve specific requirements with which projects like COLLECTiEF had to face with.

- **High Power/High Interest** (The resulting requirements must be considered with utmost care and maximum effort should be made to satisfy them): *Building owners, tenants, energy suppliers, technology providers, installers and maintenance staff*;
- **High Power/Low Interest** (The resulting requirements must be carefully considered and every effort must be made to satisfy them): *Local governments, cybersecurity firms;*
- **Low Power/High Interest** (Stakeholders should be properly informed, talking to them to make sure that no major issues are arising. Their advice can be very useful for the details of the project): *Universities and research organizations*;
- **Low Power/Low Interest** (Stakeholders should be monitored): *General public and media*;

It follows that, despite having a representation of all the stakeholders within the pilots of the COLLECTiEF project, priority must be given to the various representations across the project pilot sites on the basis of what has been defined.

Indeed, the distinct dynamics of each of the large scale COLLECTiEF pilot site - Norway, Cyprus, and Italy - necessitate unique approaches to stakeholder engagement with respect to the building categories that constitute each of the pilots (Table 1, Table 2).

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Table 1 Description of the characteristics of the buildings to be monitored in the pilot sites in Norway and Cyprus

Country	Building	Occupancy info for building zones	Zone area (m^2)	Floor number
Norway	Eidet Omsorgsenter	Patient room, elderlies	21,7	2
		Patient room, elderlies	21,7	2
		Patient room, elderlies	21,7	2
		Patient room, elderlies	21,7	2
		Shared office, Nurses	10,9	2
	Ellingsøy Idrettshall	Main Hall (25m* 45m) -futsal, badminton, basketball, handball, etc.	1167,3	1
		Dance room (98.9 m2) + social room (39.9 m2). They are separable with folding wall - Aerobic, trim, dance	138,8	2
	Flisnes Barneskole	Classroom, 6-12 years old	NA	1
		Classroom, 6-12 years old	NA	1
	Hatlane Omsorgsenter	Patient room, elderlies	23,0	2
		Patient room, elderlies	23,0	2
		Patient room, elderlies	23,0	2
		Patient room, elderlies	22,8	2
		Shared office, Nurses	29,4	2
	Moa Helsehus	Shared office, Nurses	21,0	1
		Shared office, Reception	16,4	1
		Shared office, Nurses	NA	2
		Break room (checking SBS hypothesis)	27,2	1
		Individual offices (nurses, doctor, psychologist,…)	NA	1
		Individual offices (nurses, doctor, psychologist,…)	NA	1
	Spjelkavik Ungdomsskole	Classroom, 13-15 years old	74,2	2
		Classroom, 13-15 years old	73,6	2
		Classroom, 13-15 years old	71,5	2
		Classroom, 13-15 years old	78,2	2
		Shared office, Teachers	86,0	2
	Tennfjord Barneskole	Classroom, 6 years old	78,0	1
		Classroom, 7 years old	55,6	1
		Classroom, 8 years old	56,3	1
		Classroom, 9 years old	56,3	1
		Classroom, 10 years old	56,3	1
		Classroom, 11 years old	57,0	1
		Shared office, Teachers	61,0	1
Cyprus	Guy Ourisson Building (GOB)	Shared office, Post-docs (30-40 y)	25,4	G
		Shared office, Post-docs (30-40 y)	27,6	1
		Shared office, Post-docs (30-40 y)	28,8	1

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		Individual office, 40 y	20,4	1
		Individual office, 40 y	19,3	G
		Individual office, 50 y	17,5	G
		Individual office, 50 y	20,4	G
	Graduate School (GS)	Classroom, Graduate students and teachers	44,6	G
		Meeting room	28,9	G
		Individual office, Adult - F	13,9	G
		Shared office, PhD students (23-30 y)	79,8	1
		Shared office, PhD Students (23-30 y)	24,3	1
	Novel Technologies Laboratory (NTL)	laboratory activity	112,2	G
		laboratory activity	140,0	2
		Individual office	8,3	1
		Individual office	8,3	2
		Shared office	44,1	1
		Shared office	16,3	G

Table 2 Description of the characteristics of the buildings to be monitored in the pilot site in Italy

Country		Apartment area (m2)		Occupancy info	Zone area (m^2)	Floor number
Italy	**C2 Tower**	**1A**	**86,1**	Private apartment, living room	18,2	1
				Private apartment, bed room	18,8	1
		3B	**117,5**	Private apartment, living room	25,0	5
				Private apartment, bed room	17,5	5
		3C	**89,8**	Private apartment, living room	22,1	3
				Private apartment, bed room	15,3	3
		3D	**113,9**	Private apartment, living room	24,1	3
				Private apartment, bed room	18,7	3
		8A	**86,1**	Private apartment, living room	18,2	8
				Private apartment, bed room	18,8	8
	C3 Tower	**1B**	**58,8**	Private apartment, living room	25,0	1
				Private apartment, bed room	17,5	1
		3B	**117,5**	Private apartment, living room	25,0	3
				Private apartment, bed room	17,5	3
		5C	**89,8**	Private apartment, living room	22,1	5
				Private apartment, bed room	15,3	5
		7A	**86,1**	Private apartment, living room	18,2	7
				Private apartment, bed room	18,8	7
	C4 Tower	**1C**	**89,8**	Private apartment, living room	22,1	1
				Private apartment, bed room	18,8	1
		2B	**117,5**	Private apartment, living room	25,0	2
				Private apartment, bed room	17,5	2
		4C	**89,8**	Private apartment, living room	22,1	4
				Private apartment, bed room	18,8	4

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In Norway, where the pilot focuses mainly on public buildings like elderly residences, schools, hospitals and offices, there's an array of high power, high interest stakeholders. Building owners, tenants, energy suppliers, technology providers, installers, and maintenance staff are all heavily invested in the project's success, and their requirements must be satisfied with utmost care and maximum effort. Local governments, as high power, will also need their concerns thoroughly addressed to ensure the project complies with local regulations and guidelines. Also, local university involved directly in the project can offer very useful feedback for the project advancements.

In Italy, the pilot comprises apartments where building owners, tenants, and technology providers, falling in the high power/high interest category, will play a significant role. Additionally, universities and research organizations, classified as low power/high interest stakeholders, can offer valuable insights and advice on the project's details. Their involvement in the project can enhance the level of smartness and sustainability of residential apartments while keeping them informed about the progress. Local governments, as high power, will also need their concerns thoroughly addressed to ensure the project complies with local regulations and guidelines

The situation in Cyprus is different, with the pilot based in universities, laboratories, and offices. The direct stakeholders such as university management and staff, laboratory professionals, and office workers fall under the high power/high interest category, but the project also deals with low power/high interest stakeholders such as students and the general academic community. It's essential to keep these groups informed and leverage their interest to garner support and obtain useful feedback. Local governments, as high power, will also need their concerns thoroughly addressed to ensure the project complies with local regulations and guidelines

As part of the activities aimed at ensuring the successful execution of the project across the pilot sites in Norway, Italy, and Cyprus, by considering also the aspects of applicability and scalability of the COLLECTiEF system, a comprehensive questionnaire has been specifically designed for the pilot managers (paragraph 4.1) with the aim to capture their valuable insights, feedback, and understanding requirements and expectations of the whole group of considered stakeholders.

Even if only the pilot managers were involved, the questionnaire aims to consider the interests and needs of all the stakeholders analyzed and the feedback gathered will enable the refinement of COLLECTiEF approach by taking in consideration the collected information.

2.2 Market analysis for specific challenges identification

COLLECTiEF project seeks to elevate the 'smartness' level of existing buildings and establish a collaborative network among them, towards the transformation of legacy equipment into intelligent devices, consequently creating a futuristic vision of interconnected buildings, where systems communicate, learn, and adapt to change collectively. Defining the requirements for this ambitious venture necessitates a clear understanding of the current market dynamics and the specific challenges that may arise to address the needs of the specific stakeholders.

In this paragraph, we will delve into an extensive market analysis to address these issues. The assessment will extend to identify the specific challenges that may impede our project's execution. These might include technological limitations of legacy equipment, resistance to change, regulatory hurdles or cybersecurity concerns. Identifying such challenges will enable us to devise specific requirements for the project platform.

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Consequently, we will demarcate the key project requirements by aligning them with the insights garnered from our market analysis as well as from the information collected through the questionnaire and the desk research carried out in the other chapters. This will encompass defining the necessary technological adaptations, the resources required, and the regulatory compliances that need to be adhered to. The definition of these requirements will allow us to have a strategic approach toward project execution and facilitate our project planning in subsequent stages.

2.2.1 Market Analysis

Nowadays, buildings account for a major share of the world's total electricity consumption. Recent advances in information and communication technologies (ICT) have contributed to the development of an intelligent electricity grid and, consequently, intelligent buildings that can become 'prosumers' (both producers and consumers of energy).

In the past, the implementation of energy systems was driven by a simple cost-cutting motivation, not considering the creation of interconnected tools. On the contrary, in recent years, new models managed in an integrated and automated manner (even remotely) are increasingly emerging in order to reduce energy consumption and at the same time increase occupants' comfort, safety and well-being.

In fact, buildings can now contribute to the stability of the grid and interact with it, managing their overall electricity demand in response to the user's needs at that particular time. However, the adoption and integration of these new technologies can be problematic due to both the presence of old HVAC systems and the management of legacy buildings.

Several studies conducted on the subject reveal some very important considerations [2]:

- buildings consume about 40% of the world's total energy;
- heating, cooling and air conditioning systems account for about 50% of the total energy consumption of a typical building.

According to the same document, HVAC systems in buildings account for about 20% of the world's total energy demand [2]. Precisely for these reasons, through the creation of a shared network, to better manage the use of these new technologies and the resulting flow of data, buildings have the opportunity to reach an optimal level of intelligence, thanks to which users are able to make better decisions on energy distribution and consumption, in order to optimize the efficiency and management of their resources.

Considering all these aspects and the data released by the Smart Building Report in the Italian building scene, for example, a strong drop in energy consumption can be seen: from 30.7 Mtoe (million tons of oil equivalent) in 2020 to an average consumption of 170 kWh/m^2 for residential buildings and 230 kWh/m^2 for non-residential buildings, values well below the European averages [3]. This is a strong signal, confirming that the path taken is the right one, also considering a trend in line with the objectives set by the European Renovation Wave Strategy for 2030, i.e., -60% for emissions, -14% for energy consumption, -18% for consumption due to HVAC systems [4].

However, the transition from legacy to smart buildings does not only offer advantages from an energy point of view, it also enables

- a reduction in energy costs: the use of advanced management systems (sensors and smart control devices) makes it possible to reduce consumption, optimize energy distribution and improve the building's energy efficiency;

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- greater comfort for occupants: thanks to smart buildings it is possible, for example, to automatically adjust temperature, lighting and air quality according to people's needs and preferences and environmental conditions;
- better utilization of space: optimal, real-time management of space utilization within a building allows under-utilized or overcrowded areas to be identified, so that changes can be made to maximize building efficiency;
- preventive maintenance: through the use of intelligent systems, any impending faults or failures in the building's systems and equipment can be quickly detected, thus reducing downtime and the costs associated with repairs.

In addition to these aspects, the different needs and demands that the users of a legacy building may have to improve their conditions must also be considered. Among the main aspects to be taken into account, there are:

- energy efficiency: users can improve building efficiency through the installation of energy-saving devices such as programmable thermostats, LED lamps or thermal insulation systems;
- thermal comfort: a very important factor for users who may require the most effective heating and cooling systems to ensure more comfortable temperatures inside the building;
- indoor air quality: eliminating pollutants or installing air purification systems can have a significant impact on people's health and well-being;
- security: improvements are made to security systems through the installation of surveillance cameras or fire or burglar alarm systems;
- connectivity: better accessibility to internet networks may be required to ensure more efficient communication and the use of interconnected devices;
- environmental sustainability: users may require the installation of low environmental impact technologies, such as solar panels or rainwater harvesting systems;
- data management: a smart building collects a vast amount of data that must be managed, stored, analyzed and used securely to improve building performance;
- the user experience: the smart building must offer the user an intuitive and engaging experience, with a user-friendly and easy-to-understand interface.

2.2.2 Economic potential

With all this in mind, smart buildings are considered, based on market studies and forecasts, to be a high-growth sector where continuous innovation is expected. Intelligently monitoring and controlling energy use, optimizing its consumption and reducing waste results in significant energy savings. According to analyses conducted by organizations such as the International Energy Agency (IEA), smart buildings can reduce energy consumption by up to 30% compared to current consumption, leading to significant cost savings for both owners and occupants [5].

The adoption of these smart technologies (lighting, HVAC, security and digitally controlled appliances) offers greater savings. Evidence for this can be found in the report analysing the size of the global smart home automation market, in which the size of the global smart home market was estimated to be $79.16 billion in 2022 and is expected to grow at a compound annual growth rate (CAGR) of 27.07% from 2023 to 2030 [6]. According to another International Energy Agency (IEA) publication, the use of these digital technologies, in particular smart thermostats and sensors, could reduce energy consumption in buildings worldwide by about 10% by 2040 [7]. According to EU-wide data analysis, on the other hand, optimizing the technical systems of buildings can lead to an average energy saving of 30%, with a range of 14 to 49% [8].

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The Smart Building Report 2022 also gives an insight into Italian market trends for those involved in the production and sale of smart devices. According to the report, the turnover of building devices and solutions recorded 6.5 billion euros of investments in 2021 alone, showing a growth of 40% compared to 2020. Of these investments, energy efficiency devices represent the largest investment item, with EUR 40 billion. The same report also highlights investments in management and control platforms (sensors, actuators and gateways), which reached a value of EUR 2.4 billion in 2021 [9].

2.2.3 Challenges and opportunities

Smart buildings therefore connect and integrate new technologies to improve operational efficiency, occupant comfort and environmental sustainability. However, the positive impact of digitalization and the adoption of these new technologies, very often, can be accompanied by destabilizing effects that may impact on certain aspects of economic and social life. Among these we must consider:

- privacy: it is crucial to ensure the security of people's data through appropriate security measures, as smart buildings collect a vast amount of sensitive information about occupants' habits;
- cybersecurity: it is necessary to implement robust cybersecurity measures to protect smart buildings from threats such as hacking, data theft and information manipulation, as smart buildings are connected to external networks and systems. This should be ensured from the design stage and practices such as authentication, data encryption and regular system updates should be adopted;
- standardization and interoperability: these are crucial aspects to ensure that smart building components (devices, sensors and control systems) can work together effectively through the development of technical standards and protocols;
- economic activity: smart buildings can improve energy efficiency, reduce operating costs, create new employment opportunities and stimulate innovation in smart technologies. Similarly, the adoption of these new technologies entails significant upfront investments and a number of challenges for existing businesses that will need to adapt to new technologies and market changes;
- the skills: operators and all users in the sector must be adequately trained to use and manage the various smart technologies in the best possible way;
- social impacts: smart buildings can significantly influence the lives of people and communities by improving the comfort and quality of their home environments. In these cases, it is important to adopt policies and solutions that address these issues in an equitable and inclusive manner.

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3 Overview of other initiatives and projects related to the improvement of legacy equipment to upgrade the buildings' smartness

In recent years, the concept of transforming traditional buildings into smart and intelligent spaces has gained considerable traction. With the rapid advancements in technology and the growing emphasis on sustainability and efficiency, numerous initiatives and projects have emerged with the goal of upgrading the smartness of buildings. While the development of new smart infrastructure is often at the forefront of these efforts, it is equally important to consider the potential of existing legacy equipment and systems in the transformation process.

This chapter provides an insightful overview of various initiatives and projects that focus on enhancing buildings' smartness through the improvement of legacy equipment. By repurposing and upgrading existing infrastructure, these initiatives aim to optimize energy consumption, increase operational efficiency, and enhance occupant comfort within buildings.

This exploration sheds light on the immense possibilities for transforming conventional buildings into intelligent and interconnected environments. From the study conducted in this paragraph, the whole process for the definition of the requirements for COLLECTiEF project has benefited gaining knowledge useful to improve the characteristics of the platform.

Particularly, throughout this chapter, we delve into a range of diverse projects and initiatives from around the EU. We examine how innovative technologies, such as the Internet of Things (IoT), artificial intelligence (AI), and data analytics, are leveraged to breathe new life into outdated equipment and systems and, finally, we explore the challenges and considerations that arise when integrating legacy equipment into smart building frameworks, such as interoperability, cybersecurity, and cost-effectiveness to contribute to the whole process for the requirements definition.

3.1 Overview of relevant public reports, scientific works, and other EU initiatives

3.1.1 Public reports and scientific works

3.1.1.1 Energy Flexibility

In recent years, there has been a growing interest in renewable energy sources: the increasing worldwide demand for energy, the reduction of fossil fuels available on our planet and the serious consequences of increased global warming are indeed very critical point that are being addressed. However, according to a study conducted on the topic, since the supply from renewable sources depends on the availability of the respective primary energy source (as in the case with wind or solar energy, for example), there is often no real balance between production and consumption [10]. Until now, attempts have been made to reduce the gap by introducing flexibility on the supply side, but resorting to less than "clean" solutions due to the use of carbon-intensive generators.

Precisely for these reasons, improving the flexibility of a building's electrical system, by exploiting the ability to generate renewable energy in response to demand, is a very important step towards achieving the goal of sustainable development. As responsible for a large share of the entire energy demand, buildings then assume a key role within the entire energy system. They provide flexibility in a variety of ways, e.g., by utilizing thermal mass, regulating the use of heating/cooling/ventilation systems, charging electric vehicles or other equipment, shifting current loads.

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However, until now, there was no real general framework that stated the ideal level of energy flexibility for the various energy systems; it was necessary to create a vision that was the same for all and to identify the critical aspects and solutions to best manage this concept. In this regard, a strong contribution was made by the IEA (International Energy Agency) EBC (Energy in Buildings and Communities) programme "Annex 67: Energy Flexible Buildings"[11]; this work, born from the cooperation of 16 Countries around the World, provides a more detailed understanding of the different methodologies for quantifying the level of flexibility of building energy systems.

According to the programme, in most developed Countries, energy use in buildings accounts for 30-40% of total raw material consumption, as it is used to power the various systems within the buildings [12]. The innovation lies in the fact that a large part of this energy demand can be "shifted" over time, i.e. the thermal part of the energy demand (e.g. for space heating/cooling, ventilation, domestic hot water, etc.) can be shifted over a period of time so that it can be stored and reused when needed, without compromising the thermal comfort of the structure and, above all, the well-being of the occupants.

According to a study conducted on the topic, flexibility can also be considered as the adaptability of a system to a series of variations in climatic conditions [13]. This is a very important variable to take into account, as continuous climate change is one of the main reasons for the various energy disturbances that severely slow down the integration of renewable energy sources within urban contexts and buildings. Precisely for these reasons, in order to improve energy flexibility on both the supply and demand side, it is necessary to take into account not only the decarbonization of the various systems in place, but also careful planning that allows for the best possible adaptation to the climate changes of recent years and that favors the introduction of reliable energy networks.

3.1.1.2 Collective Intelligence (CI)

The increasing complexity of the environmental situation makes it evident that new mechanisms must be developed as quickly as possible to reduce the time required for decision-making. A viable alternative that enables this to be achieved is Collective Intelligence (CI), i.e., a form of intelligence that is based on collaborative problem solving and related decision-making. In this way, also thanks to its inherent characteristics (adaptation, self-organization and emergency), CI allows for scalable energy management within buildings or an entire urban system.

A demand management system based on Collective Intelligence (CI-DSM), thus enables a rapid and semi-autonomous reaction to continuous environmental changes and user needs, leading to:

- a more rapid adaptation to climatic variations;
- a greater impact on climate;
- normal conditions and, consequently, greater resilience to adverse climatic conditions.

3.1.2 Other EU initiatives and projects

In order to develop an effective and successful project within the European Union (EU), it is essential to leverage the knowledge and insights gained from previous similar initiatives. By investigating and analyzing past EU projects and initiatives, we can identify valuable lessons learned, best practices, and potential pitfalls. This chapter aims to provide a comprehensive examination of previous EU projects and initiatives related to our current project, with a particular focus on defining the requirements for our undertaking.

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In particular, the following projects were investigated:

- DomOS [14];
- REScoopVPP [15];
- SMART2B [16];
- PHOENIX [17]
- BEYOND [19];

3.1.2.1 DomOS (Operating System for Smart Services in Buildings)

The intelligence of a building relies on its ability to connect and interact with the entire energy system. However, the digitization of existing buildings is not as widespread as in other sectors; very often, for this reason, building owners and occupants may have a limited understanding of their building at the energy system level.

In this respect, the EU-funded domOS project [14] analyses the intelligent buildings sector by considering two axes, both of which are present in each of the five demonstration sites that refer to the programme. The first axis concerns the technology and secure connection of smart devices and appliances so that owners can correctly and securely apply all current privacy regulations to allow or prohibit access to any control point. The second axis concerns the development of smart services that increase the efficiency of space heating and indoor comfort/well-being, thanks to innovative control algorithms that provide precise and valid information about the building.

From a practical point of view, pilot projects in Sion (CH) and Paris (FR) test intelligent services related to electricity. In Aalborg (DK), control techniques applied to building heating reduce consumption and costs, CO_2 emissions and system load. In Neuchâtel (CH) and Skive (DK), constant system control minimizes heating outlet temperatures, thereby increasing efficiency and reducing losses.

3.1.2.2 REScoopVPP (Smart Building Ecosystem for Energy Communities)

In response to the increasing creation of energy communities in Europe in recent years, the EU-funded REScoopVPP project [15], piloted mainly in Belgium, France, Germany, Spain and the UK, aims to establish the most advanced community-oriented smart building ecosystem. The versatile box (COFY-Box) and the attached community-oriented tools are the main elements of the product needed to support energy services for aggregators, energy service companies and renewable energy providers. The 'COFY-Box' is based on open-source home automation technology and over 1600 integrations, making it open to all, affordable and easy to install.

The project will improve the control of electrical appliances and photovoltaics and will focus on the smart integration of thermal storage and hybrid heating solutions; as well as will pay special attention to the control of smart plugs and the integration of new tools based on new European standards.

3.1.2.3 SMART2B (Smartness to existing Buildings)

Based on the idea that it is possible to improve the capacity of buildings to act as active components of the energy system, the EU-funded SMART2B project [16] will enhance the capacity of buildings through the development of non-intrusive IoT sensors and tools to control equipment while improving indoor comfort and energy efficiency.

The implementation of the project will allow the coordinated control of equipment already present within the building and smart equipment installed later, providing information on overall performance.

The project aims to:

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- improve the smartness levels of existing buildings through the coordinated control of legacy and smart equipment;
- implement the interoperability of two cloud-based platforms in order to integrate them into a single building management platform;
- create a user-centric ecosystem, simplifying the control of equipment and devices.

3.1.2.4 PHOENIX (Adapt-&-Play Holistic cOst-Effective and user-frieNdly Innovations with high replicability to upgrade smartness of eXisting buildings with legacy equipment)

The EU-funded PHOENIX project [17], coordinated by the University of Murcia and involving 12 partners across 6 European countries, is developing a suite of ICT solutions to enhance the "smartness" of existing buildings. These solutions range from hardware and software upgrades for legacy equipment to data analytics services for building users and energy utilities. The project leverages AI, smart sensors, controllers, and edge/cloud computing. Five pilot projects will be launched in Spain, Sweden, Greece, and Ireland.

The project's structure is comprised of five layers: an Asset layer for managing legacy equipment; an Integration layer for remote control and monitoring; a knowledge layer for data processing and analytics; a Function layer offering smart services for energy savings and performance optimization; a business layer incorporating innovative business models.

PHOENIX aims to increase user engagement and awareness about energy use and offers a range of services. These services include Comfort, Convenience and Well-Being application, Predictive Maintenance application, SRI/EPC Evaluation application, Smart Contracts Management application, Demand Flexibility Management application and Self-consumption Optimization application. A Building Occupants Visualization Dashboard will be developed for reporting to building consumers and prosumers. The project runs from September 2020 to August 2023.

3.1.2.5 BEYOND (Blockchain-based electricity trading for the integration of national and decentralized local market)

With the belief that advanced data analysis can enable players in the building sector and its market to integrate and improve their value chain, the EU-funded BEYOND project [19] developed a data management platform using a set of AI analysis tools that will allow data and information to be collected not only from the individual building, but also from the entire network.

The analysis toolkit will allow the execution of a series of descriptive, predictive and prescriptive analyses based on pre-trained algorithms focusing on different aspects:

- personal analytics (consumer behavior);
- industrial analytics (energy performance, predictive maintenance, forecasting and flexibility analysis);
- edge analytics (for intelligent and automated building control).

By interconnecting big data platforms and toolsets, all stakeholders will be able to acquire real-time data on buildings in order to bring their own solutions to life and offer innovative emerging building services.

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3.2 Analysis of feedback from other initiatives' interviews and survey campaigns

In any dynamic and evolving landscape, the value of learning from the experiences and insights of others cannot be understated. As a project that strives to make a positive impact, for COLLECTiEF becomes imperative to understand the feedback and perspectives gathered through interviews and survey campaigns conducted by similar initiatives. The analysis of the feedback from external sources offers valuable insights to enhance the efforts of the COLLECTiEF development team and optimize strategies to be applied for the project demonstration.

This paragraph contributes to the exploration of the requirements to be followed in COLLECTiEF project by focusing on the feedback obtained from interviews and survey campaigns carried out by other initiatives. By examining the rich tapestry of experiences, opinions, and suggestions, extracted from other initiatives, we aim to bring out valuable knowledge and derive meaningful information that will help refine COLLECTiEF approach.

A careful analysis of the stakeholder consultations conducted by other similar initiatives has been conducted, with the aim of collecting information useful for updating the COLLECTiEF project requirements and to be taken into consideration during the development activities in progress and in subsequent deployment and solution validation. The outcomes and feedback derived from this analysis are listed below in this paragraph.

3.2.1 PHOENIX EU Project Survey

COLLECTiEF has been able to use the feedback gleaned from the Phoenix project's questionnaire [18] analysis to define its own requirements more effectively.

Particularly, the survey of Phoenix project has provided a clear understanding of participants' concerns about energy consumption, their levels of knowledge and willingness to install smart energy systems. These answers can be taken into account in the COLLECTiEF project, in order to compare this aspect with the project pilots and to understand how to formulate the COLLECTiEF communication strategy with the pilot sites, ensuring effective end-user engagement.

The interest shown by the Phoenix survey participants in smart home solutions to control energy use, and the demand for convenience, comfort, health and well-being and energy savings has been duly taken into consideration to understand how to define the different requirements related to the control strategies to be implemented, also with reference to "learning" systems. Moreover, the focus on improving the visualization of information about smart energy systems and building performance was regarded as valuable, given the high interest shown. Particularly, the necessity to make the information accessible through diverse means has been carefully considered for the requirements definition. Finally, Phoenix survey analysis enabled COLLECTiEF to benefit from understanding participants' preference for frequency and timing of updates, as this will enable better engagement and effectiveness of the project. Incorporating all these insights into the definition of COLLECTiEF requirements ensures better alignment with participants' needs and priorities, thus boosting the chances of the project's success.

3.2.2 BEYOND EU Project Survey

Some very interesting considerations emerged extrapolating the data from the questionnaire administered to end-users in the 4 demonstrator Countries (Greece, Spain, Finland and Serbia) by the BEYOND project [19].

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Almost all of the respondents (95.1%) are in favor of implementing a smart home solution that allows them to control their own energy consumption in the building while fully respecting their privacy and personal data, with the motivation of saving money and obtaining higher energy flexibility, comfort and well-being.

The results appeared very promising, even though the acceptance of the services was mostly derived from younger age group occupants (30-45: 43.9%, 45-65: 35.4%) [20].

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4 Comprehensive assessment of COLLECTiEF pilots for requirements definition

4.1 End-Users targeted survey for easy implementation of COLLECTiEF

This chapter describes the survey prepared to collect pilot stakeholders' feedback for the COLLECTiEF project. The relevant results are considered, together with the analysis conducted in the previous chapters, to determine the requirements for the project implementation.

The survey aimed to gather valuable insights and perspectives from the pilot site representatives, who play a critical role in the successful implementation of the project.

The survey was designed to explore various aspects related to energy management systems, interoperability, data security, cost-effectiveness, user-friendliness, and the integration of legacy equipment. By assessing the pilot sites' needs and expectations, the analysis of survey results provides crucial input to support the ongoing development activities of the COLLECTiEF platform.

The chapter presents the survey results in a structured and comprehensive manner. The analysis provides a detailed exploration of the collected data, including quantitative and qualitative findings. It identifies common issues and divergences among the pilot sites, shedding light on their unique requirements and priorities for the COLLECTiEF platform.

Key themes that emerged from the survey responses are discussed, focusing on topics such as the desired functionalities and features of the platform, challenges in integrating legacy equipment, expectations regarding data security and privacy and the importance of user-centric design and control. The analysis aims to provide a holistic understanding of the pilot sites' perspectives and requirements, offering valuable insights to provide guidance to the development process.

Furthermore, this chapter discusses the implications of the survey findings for the COLLECTiEF project as a whole. It explores how the identified requirements align with the requirements deriving from the project's objectives, from the study of the literature, from the reported experiences of other projects, that have had to deal with the same challenges, and from the market needs identified. Moreover, it also defines how the requirements can be translated into actionable recommendations for the development team. By analyzing the survey results, the chapter contributes to the consta,nt interaction between the project partners in charge for the development of the COLLECTiEF platform, and the project pilot sites, fostering a collaborative and iterative approach toward meeting the energy management needs of diverse pilot specific domains.

The findings presented in this chapter serve as a foundation for the subsequent stages of the COLLECTiEF platform development, deployment and demonstration, ensuring its effectiveness, scalability, and alignment with the needs of the pilot sites and the broader urban energy ecosystem.

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The questionnaire used to gather important insights and feedback from the pilot sites responsible is reported below:

1. Which equipment and/or system is currently in use in your building?
   - Building Management System (BMS)
   - Smart plugs
   - Smart valves
   - Power meters
   - Other (please specify)

2. How would you rate the current management of energy usage and user comfort in your building?
   - Excellent
   - Good
   - Fair
   - Poor
   - Not sure

3. Are there any challenges in managing energy usage and user comfort with this equipment?

4. Do you currently monitor and manage energy usage in your building? If yes, what tools or systems do you use?
   - Yes, monitor and manage
   - Yes, only monitoring
   - No

5. Please rank the following features of COLLECTiEF according to the importance from 1 (highest potential) to 6 (lowest potential):
   - Real-time energy and environmental data monitoring and visualization
   - Smart control of legacy equipment and building systems
   - Building thermal optimization
   - Energy Flexibility management
   - Indoor comfort optimization
   - Data security and privacy measures

6. How would you rate the current thermal comfort level in your building during occupied hours?
   - Very comfortable
   - Comfortable
   - Slightly uncomfortable
   - Uncomfortable
   - Not sure

7. Which thermal comfort optimization strategies are you currently implementing, if any? Please select all that apply:
   - Adjusting temperature setpoints
   - Zoning and occupancy-based controls
   - HVAC system scheduling

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- Integration with weather forecast data
- Use of natural ventilation strategies
- No strategies applied
- Other (please specify)

8. How do see the engagement of the occupants in relation to the setting of thermal comfort?
    - Occupants have full control and can adjust settings as desired
    - Occupants can provide feedback and preferences, but ultimate control lies with building management
    - Occupants have limited involvement and no control over settings
    - Not sure

9. How important is energy flexibility to your building's energy strategy?
    - Essential
    - Significant
    - Not Essential
    - Useless

10. Have you already taken measures to increase energy flexibility in the past? If yes, which ones?
    - Yes
    - No

11. How do you prioritize user comfort and energy efficiency in your building management decisions?
    - User comfort is the top priority
    - Energy efficiency is the top priority
    - Both are equally important
    - Not sure

12. Have you faced building management compromises in the past with regard to user comfort and energy efficiency? If yes, what trade-offs you had to make in the past?
    - Yes
    - No

13. What specific energy or climate goals do you hope to achieve through the implementation of the COLLECTiEF system? Please select all that apply:
    - Reduction in energy consumption
    - Increased use of renewable energy sources
    - Improved indoor air quality
    - Cost savings on energy bills
    - Other (please specify)

14. Do you have any concerns about data security or privacy with the implementation of the COLLECTiEF system? If yes, please specify.

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- Yes
- No

15. Are there any particular energy or climate goals that you hope to achieve through the implementation of the COLLECTiEF system? How do you see it contributing to the overall sustainability of your building and the surrounding area?

16. Do you have any suggestions or feedback for the COLLECTiEF development team as they develop and test the platform? Is there anything else you would like to see in the final prototype?

4.1.1 Site-specific requirements: Interview results and analysis

A brief summary of the responses of the three pilot managers of the project pilot sites (Italy, Cyprus and Norway) is following reported, providing, consequently, a clear view of their needs.

Current Systems & Equipment: The Italian and Norwegian sites are utilizing a mix of smart plugs, smart valves, BMS, and power meters. The Cypriot site, on the other hand, relies solely on power meters. This variation suggests different levels of digitization and technological integration across the sites. A project requirement could be the development of a flexible solution that integrates with both simple and complex systems.

Energy Usage & User Comfort Management: All three sites have rated their current management of energy usage and comfort differently, with Italian and Cypriot sites considering it 'Poor', and the Norwegian site rating it as 'Good'. This indicates a disparity in their current management strategies. COLLECTiEF should be developed to cater to various levels of management efficacy.

Challenges: All three pilot sites have identified challenges in managing energy usage and user comfort. Solutions from COLLECTiEF should consider addressing these issues, specifically smart integration for existing buildings (Italian site), disaggregation of energy usage data (Cypriot site), and detailed energy use insights (Norwegian site).

Monitoring and Management of Energy Usage: All sites monitor energy usage, but only the Norwegian site also manages it. Any developed tool should facilitate both monitoring and management to meet the needs of all sites.

COLLECTiEF Features Importance Ranking: Across the three sites, the most important features vary. However, there's a consistent importance given to building thermal optimization, real-time energy and environmental data monitoring and indoor comfort optimization. These features should be prioritized in the development of the COLLECTiEF system.

Current Thermal Comfort Level: The Italian and Norwegian sites find their buildings 'Comfortable', while the Cypriot site finds theirs 'Slightly Comfortable'. It indicates that the COLLECTiEF should aim to maintain or enhance current comfort levels.

Thermal Comfort Optimization Strategies: The strategies differ across the sites, indicating the need for a flexible approach that can handle a variety of optimization strategies.

Occupants' Engagement: The levels of control and feedback that occupants have over thermal comfort settings vary across the sites. Particularly, particularly, currently in the Italian pilot the

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apartment dwellers have limited involvement and no control over settings. In contrast, in the Cypriot pilot, the occupants have complete control and can adjust settings as desired. In the Norwegian pilot, the occupants can provide feedback and preferences, but the ultimate control lies with building management. COLLECTiEF should accommodate for these variations.

Importance of Energy Flexibility: Energy flexibility is seen as 'Significant' by Italian and Cypriot sites, but as 'Not Essential' by the Norwegian site. Therefore, flexibility features should be optional, but robust.

Measures to Increase Energy Flexibility: Only the Italian site has taken measures in the past. The COLLECTiEF should offer clear pathways for increasing energy flexibility where it is desired.

Prioritizing User Comfort and Energy Efficiency: All sites view these as equally important. Hence, COLLECTiEF should not overly prioritize one over the other.

Past compromises with regard to user comfort and energy efficiency: All three pilot sites have faced trade-offs between user comfort and energy efficiency. COLLECTiEF should be designed to minimize such compromises.

Energy or Climate Goals: All sites aim for a reduction in energy consumption. The system should be designed to maximize energy efficiency.

Data Security or Privacy Concerns: None of the pilot sites express concerns over data security or privacy. While this is positive, COLLECTiEF should still maintain high standards in these areas.

Specific Goals with COLLECTiEF: The Italian site focuses on behavioral change and energy reduction, the Cypriot site on mitigating extreme weather effects and increasing renewable energy source penetration, and the Norwegian site on aligning with EU sustainability goals. These varied responses indicate the need for a versatile system that can support a wide range of sustainability goals.

Other suggestions and feedback to improve COLLECTiEF system: the suggestions and feedback received are reported below:

- Preferred Communication Channels: A majority preference for a web-based platform is seen across all three sites, implying that the primary interface for COLLECTiEF should be web-based.
- Importance of User Interfaces: All sites consider user interfaces to be important or very important. This underscores the need for the system to have a user-friendly interface.
- Engagement with Other Users: All sites have shown interest in engaging with other users of the system, which suggests that COLLECTiEF should include features for user engagement, such as a forum or chat feature.

Hence, the feedback provided by the three pilot sites for the COLLECTiEF project - Italian, Cypriot, and Norwegian - suggests several key requirements for the system's development. A primary aspect, shared by all three sites, was the significant emphasis on balancing energy efficiency and user comfort. However, the approaches for achieving these objectives varied between locations, indicating that the system must be flexible and customizable.

In the Italian site, the current infrastructure includes smart plugs and smart valves, which present challenges in integrating with existing legacy systems. The system should therefore prioritize smart control of legacy equipment and offer real-time monitoring and visualization of energy data. The respondent also indicated the importance of a user-friendly application and the ability to compare

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energy data at both individual and aggregated levels, indicating the need for advanced data analytics and presentation capabilities in the system.

The Cypriot site relies on power meters for energy monitoring, offering no strategies for thermal comfort optimization. Feedback indicates the need for a system that can not only manage energy use but also improve user comfort. A mobile app for occupants and building operators was suggested, implying the need for a user-centric and easily accessible interface.

The Norwegian site employs a Building Management System and power meters, but challenges in understanding energy usage were reported. This indicates the necessity for enhanced real-time monitoring and visualization. It was suggested that results should be presented in an understandable manner to users and decision makers, emphasizing the importance of intuitive data presentation in the system.

From the responses, it is clear that reduction in energy consumption is a shared goal across the three sites. In terms of thermal comfort optimization, strategies varied across locations, underlining the necessity for the system to support a range of methods. Lastly, data security did not emerge as a major concern from the feedback, but it should remain an essential requirement in system design, given the sensitive nature of the data involved.

4.1.2 Mapping Pilots Assessment: Defining Measurable Functional and Non-Functional Requirements with Impact KPIs

This paragraph aims to map the assessment of the pilot sites in Italy, Cyprus, and Norway together with the information coming from the desk research activities implemented in this task, to define measurable functional and non-functional requirements, along with the identification of impact Key Performance Indicators (KPIs). By examining the feedback received and considering the identified challenges for smart buildings implementation, we can establish a comprehensive understanding of the requirements and goals of the COLLECTiEF system as follow:

4.1.2.1 Functional Requirements

Table 3 Functional Requirements

Req Id	Requirement Title	Description
F_1	Integration with Smart Devices	The platform should be compatible with various smart devices, such as smart plugs, valves, sensors, and meters, for seamless integration and control. It should enable communication and data exchange between the platform and these devices.
F_2	Integration with Existing Systems	The COLLECTiEF platform should seamlessly integrate with a variety of existing systems, including simple and complex setups. This requirement ensures compatibility and flexibility for buildings with different levels of digitization and technological integration.
F_3	Energy Usage and Comfort Management	The platform should enable effective management of energy usage and user comfort. It should cater to varying levels of management efficacy, allowing buildings to improve their current strategies.
F_4	Monitoring and Management of Energy Usage	The platform must facilitate both monitoring and management of energy usage to meet the needs of all pilot sites. This requirement ensures that buildings can track their energy consumption and make informed decisions to optimize efficiency.

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F_5	Building Thermal Optimization	The COLLECTiEF system should prioritize building thermal optimization, ensuring comfortable indoor temperatures while minimizing energy consumption. This feature should support a range of optimization strategies to accommodate the diverse needs of the pilot sites.
F_6	Energy Flexibility	The platform should offer optional but robust features for energy flexibility, allowing buildings to respond to demand fluctuations and optimize energy consumption accordingly.
F_7	User Engagement and Control:	The platform should provide different levels of control and feedback options to accommodate the variations in user engagement across the pilot sites. It should allow occupants to adjust settings, provide feedback, and actively participate in optimizing their comfort and energy usage.
F_8	Data Security and Privacy	Maintaining high standards of data security and privacy is essential. The platform must ensure that sensitive data collected from smart buildings is securely managed, stored, analyzed, and used for improving building performance.
F_9	Data Analytics and Insights	The platform should analyze energy usage data and provide detailed insights on energy consumption patterns and potential optimization strategies. It should offer visualization tools and reports to help users understand and act upon the data.
F_10	User-Friendly Interface	The COLLECTiEF platform should prioritize the development of a user-friendly interface across all its components. This requirement aims to enhance user experience and ease of interaction with the system.

4.1.2.2 Non-Functional Requirements

Table 4 Non Functional Requirements

Req Id	Requirement Title	Description
NF_1	Connectivity and Interoperability	Standardization and interoperability are crucial for smart buildings. The platform should adhere to technical standards and protocols to ensure seamless communication and integration between devices, sensors, and control systems.
NF_2	Performance and Scalability	The platform should be capable of handling a large volume of data and user interactions without significant delays or performance issues. It should scale efficiently to accommodate additional users and devices as the system expands.
NF_3	Cybersecurity	Robust cybersecurity measures must be in place to protect the smart buildings from threats such as hacking, data theft, and information manipulation. The platform should incorporate authentication, data encryption, and regular system updates to mitigate these risks.
NF_4	Reliability and Availability	The platform should be highly reliable, with minimal downtime and disruptions to ensure continuous operation. It should have backup and recovery mechanisms in place to handle system failures or data loss.

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NF_5	Usability and Accessibility	The platform should be accessible to users with diverse abilities and provide appropriate user support. It should offer multi-language support and customizable settings to accommodate different user preferences.
NF_6	Interoperability	The platform should support interoperability with existing building management systems and technologies. It should adhere to industry standards and protocols to enable seamless integration with external systems.
NF_7	Privacy	Implementing robust privacy measures, such as data encryption, user anonymity, and access controls, guarantees the protection of personal information and sensitive data on the platform. These measures prevent unauthorized access, preserve user privacy, and maintain confidentiality, instilling trust and ensuring compliance with privacy regulations.
NF_8	Economic Viability	The COLLECTiEF platform should provide economic benefits, including reduced energy costs, improved operational efficiency, and new employment opportunities. At the same time, it should address challenges faced by existing businesses adapting to new technologies and market changes.
NF_9	Skill Development and Training	Operators and users of the platform should receive adequate training and support to effectively utilize and manage the smart technologies incorporated. This requirement ensures the proper utilization of the platform's capabilities and maximizes its benefits.
NF_10	Social Impact and Equity	Policies and solutions adopted by the COLLECTiEF platform should consider social impacts and promote equity. It should address issues related to improved comfort and quality of home environments, ensuring that benefits reach all individuals and communities in an inclusive manner.
NF_11	Compatibility and Upgradability	The platform should be compatible with different operating systems and web browsers to support a wide range of user devices. It should allow for future upgrades and enhancements to incorporate new technologies and meet evolving user needs.

4.1.2.3 Impact Key Performance Indicators (KPIs):

Table 5 Key Performance Indicators (KPIs)

KPI Id	KPI Title	Description	Target
KPI_1	Energy consumption reduction	Percentage reduction in energy consumption achieved by the COLLECTiEF system.	9%- 27%
KPI_2	Cost savings	Measurable reduction in energy costs realized through optimized energy distribution and management.	16%
KPI_3	Occupant comfort Improvement and user satisfaction	Assessment of improved thermal comfort and indoor air quality experienced by occupants.	15%
KPI_4	Data security and privacy	Evaluation of the system's adherence to robust data security and privacy standards.	99% rating in data

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			security and privacy standards
KPI_5	Restricted Maintenance Downtime	Maintenance downtime restricted relative to uptime due to the timely detection of faults and failures.	1% of the operating time
KPI_6	HW Utilization Optimization	Use of docker to deploy the solution on a local node (edge node) in order to make the best use of its hardware.	CPU utilization (max 70%) Memory utilization (max 70%) Storage utilization (max 90%)

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5 Conclusions

The main objective of this deliverable was to establish a complete set of requirements, covering both functional and non-functional aspects, for the development of the COLLECTiEF platform. By thoroughly considering the needs and expectations of stakeholders, both internal and external to the project, we aimed to ensure that the project objectives align with the market needs and site-specific requirements. The following conclusions can be drawn from our analysis:

Stakeholder Understanding: Understanding the needs and expectations of stakeholders is crucial for the success of any project. By defining a detailed stakeholders list and conducting a site-specific questionnaire, we gained valuable insights into the specific requirements of different user groups and market sectors. This understanding serves as a foundation for the assessment and refinement of the activities of design and development of the COLLECTiEF platform in WP3 and for its demonstration in WP4.

Market Alignment: Through an in-depth study of relevant public reports, scientific works, and research initiatives, we identified the market requirements associated with the development of an energy management system based on Collective Intelligence (CI). By aligning our project with market demands, we aim to enhance the interoperability and scalability of the platform, reduce installation costs, enhance data security, and increase energy flexibility and climate resilience.

AI-based Solutions: Our analysis delved into the overall approach and methodology for implementing AI-based solutions to upgrade the smartness of legacy equipment in buildings. By leveraging AI technologies, we aim to optimize energy consumption, improve thermal efficiency, and enhance user comfort. These advancements will contribute to the overall sustainability and efficiency of the built environment.

Integration and Validation: The requirements defined in this deliverable provide a basis for the update of the project architecture defined in T3.1 that is already in progress and for which the first updates are available in the deliverables D3.2 and D3.4 of WP3. This document will contribute to guiding the ongoing activities in WP3 related to system development and integration and in WP4 for the large-scale demonstration of the COLLECTiEF platform. The validation activities will evaluate the effectiveness of the platform in meeting the identified requirements and addressing the needs of stakeholders.

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