DELIVERABLE REPORT

WP4 ICT infrastructure

D4.2

RENOVATION SPACE REPRESENTATIONAL MODEL V2.0

Due date

M15 31.12.2021

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135

PROJECT DETAILS

PROJECT ACRONYM	PROJECT TITLE
e-SAFE	Energy and Seismic AFfordable rEnovation solutions

GRANT AGREEMENT NO:	FUNDING SCHEME
893135	H2020-EU.3.3.1. - Reducing energy consumption and carbon footprint by smart and sustainable use. LC-SC3-EE-1-2018-2019-2020 - Decarbonisation of the EU building stock: innovative approaches and affordable solutions changing the market for buildings renovation
START DATE	
01.10.2020	

WORK PACKAGE DETAILS

WORK PACKAGE ID	WORK PACKAGE TITLE
WP4	ICT Infrastructure

WORK PACKAGE LEADER

Marilena Lazzaro (ENG)

DELIVERABLE DETAILS

DELIVERABLE ID	DELIVERABLE TITLE
D4.2	Renovation space representational model V2.0

DUE DATE	ACTUAL SUBMISSION DATE
M15 31.12.2021	07.01.2022

LEAD PARTNER

ENG

CONTRIBUTING PARTNER(S)

UNICT, UNIBO

LEAD AUTHOR(S)

Marilena Lazzaro (ENG), Gianpiero Evola (UNICT)

DISSEMINATION LEVEL

☒ P - Public
☐ PP - Restricted to other programme participants & EC: (Specify)
☐ RE - Restricted to a group (Specify)
☐ CO - Confidential, only for members of the consortium

TYPE

☒ R – Report
☐ DEM – Demonstrator
☐ DEC – Websites, patents filling, videos, etc.
☐ OTHER
☐ ETHICS – Ethics requirement
☐ OPRP – Open Research Data Pilot
☐ DATA – Data sets, microdata, etc.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

REPORT DETAILS

ACTUAL SUBMISSION DATE	NUMBER OF PAGES
07.01.2022	141
VERSION	**FILE NAME**
2.0	e-SAFE_D4.2_Renovation space representational model_V2.0_ENG.docx

DOCUMENT HISTORY

VER.	DATE	DESCRIPTION AND FILE NAME	AUTHOR(S) NAME
0.1	12.11.2021	Creation of the document, addition of Appendix 2 and Appendix 3 by UNICT. e-SAFE_D4.2_Renovation space representational model_V0.1	Marilena Lazzaro, Alessio Roppolo (ENG), Gianpiero Evola (UNICT), Giovanni Semprini (UNIBO)
0.2	23.12.2021	Revision of the document, improvement of the Use Cases, addition of tables with costs. e-SAFE_D4.2_Renovation space representational model_V0.2	Marilena Lazzaro (ENG), Gianpiero Evola (UNICT)
0.3	05.01.2022	Updated version addressing the peer review result from UNICT and UNIBO e-SAFE_D4.2_Renovation space representational model_V0.3	Marilena Lazzaro (ENG)
0.4	06.01.2022	Revision of the document e-SAFE_D4.2_Renovation space representational model_V0.4	Gianpiero Evola (UNICT)
1.0	07.01.2022	Submitted version e-SAFE_D4.2_Renovation space representational model_V1.0	Giuseppe Margani (UNICT)
2.0	30.04.2022	Minor errors in the text and in some equations were amended e-SAFE_D4.2_Renovation space representational model_V2.0	Gianpiero Evola (UNICT) Marilena Lazzaro (ENG)

DOCUMENT APPROVAL

VER.	NAME	POSITION IN THE PROJECT	BENEFICIARY	DATE	VISA
2.0	Gianpiero Evola	Technical Manager	UNICT	30.04.2022	GE
2.0	Giuseppe Margani	Project Coordinator	UNICT	30.04.2022	GM

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

CONTENTS

Executive Summary 6
Glossary of Terms 8
1. Introduction 9
1.1 Intended Audience 9
1.2 Relation to other activities 9
1.3 Document overview 9
2. e-SAFE Decision Support System 10
2.1 e-DSS abacus of solutions 11
2.1.1 **e-**CLT and **e-**PANELS: technical features for the DSS 12
2.1.2 **e-**CLT: feasibility check 13
2.1.3 **e-**EXOS: technical features for the **e-**DSS 14
2.1.4 Windows replacement and roof insulation 14
2.1.5 **e-**THERM: technical features for the **e-**DSS 15
2.2 e-DSS use cases 16
2.2.1 **e-**DSS Technician use cases 19
2.2.2 **e-**DSS Building Manager use cases 44
2.3 e-DSS requirements 47
2.3.1 Functional requirements 47
2.3.2 Non-functional requirements 49
2.4 e-DSS architecture 52
2.5 e-DSS representational model: data input 54
2.6 e-DSS test strategy 55
3. Renovation space representational model 57
3.1 Entity – Relationship model 57
4. Calculation of the energy needs 66
5. Conclusion 67
Acknowledgements 69
References 70
Internal references 70
External references 70
Appendix 1: Input data in the e-DSS 71
Appendix 2: equations for the energy needs 78
A2.1 Preliminary input from drop-down menu 78
A2.2 Calculation of the energy needs 80
A2.2.1 Building Geometry 80

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

A2.2.2 Heat transfer calculations 82
A2.2.3 Thermal energy needs for Domestic Hot Water (DHW) 88
A2.3 Electric energy production from photovoltaics (PV) 89
A2.4 Thermal energy production from Solar Thermal systems 90
A2.5 Annual energy demand of FUEL and ELECTRICITY 91
A2.6 Tables with System Efficiencies 94
A2.7 Output from the e-DSS 97
Appendix 3: relevant algorithms for the renovation stage 99
A3.1 Definition of the seismic zone 99
A3.2 Insulation thickness and U-value: e-CLT 99
A3.3 Insulation thickness and U-value: e-EXOS and e-PANEL 101
A3.4 Insulation thickness and U-value: the roof 102
A3.5 Update of the envelope performance 102
A3.6 Update of the technical systems 103
A3.7 Calculation of the renovation costs – envelope 104
A3.8 Calculation of the renovation costs – technical systems 106
A3.9 Calculation of the overall renovation costs 108
A3.10 Calculation of the time for the renovation works 108
A3.11 Comparison: current building vs. renovated building 109
Appendix 4: e-DSS database 110

e-SAFE has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 893135.

EXECUTIVE SUMMARY

This deliverable aims at providing the overall description model for the Decision Support System (**e-**DSS) that is conceived in **e-**SAFE as a tool to support the decision-making process in the co-design stage; this second version of the model will be used to work on the final version of the **e-**DSS (due at M30) focusing on the virtual pilots. Moreover, this deliverable describes the architecture, the functionalities, and the expected use of the **e-**DSS.

This second version of the model updates and completes the first one, which was described in Deliverable D4.1 [1] released at M9. The great majority of the features and functions described in this report are already implemented in the first release of the **e-**DSS (Deliverable D4.3 and Milestone MS4): some of the features, and especially those concerning pilot buildings outside Italy, will be implemented in the second release of the **e-**DSS (due at M30) that will be exploited in the co-design stage of the virtual pilots.

More in detail, the Renovation Space representational model, that is conceived as the **e-**DSS data model, is updated to cover the computation of costs and time for both the **e-**SAFE envelope renovation solutions (**e-**CLT, **e-**PANEL) and technical systems (**e-**TANK and **e-**THERM). Instead, since the investigation about the features of **e-**EXOS is still ongoing, a small update of the data model is expected in the following months; this update will be formally reported in the accompanying document of the final version of **e-**DSS (D4.5), which is due at M30. Moreover, entities such as the *Renovation Solution* have been improved by the addition of new attributes, and a new entity *Renovation Solution Intermediate Result* is introduced to monitor and assess the overall calculation process.

The functional specification of **e-**DSS, provided in this report, consists in the definition of:

- use cases: the **e-**DSS is described from the point of view of different stakeholders, underlining how the tool can be exploited in order to reach a specific goal. Technicians and building managers' use cases are specified by means of Unified Modeling Language (UML) use cases diagram [2] and the textual description is provided as well. In particular, the e-DSS technician use cases are classified according to macro functionalities of Project Management, Building Management and Building Renovation Management.
- **e-**DSS requirements: functional and non-functional requirements are defined to formalise the main software features and specify the features of e-DSS that are essential to ensure the usability and effectiveness of the entire software system.
- **e-**DSS architecture: the **e-**DSS is a web application implemented according to the Model, View and Control blocks (MVC) architectural pattern. MVC is detailed underlining the main macro functionalities and the implementation choice. The View component consists in the front-end that focuses on the visual elements of **e-**DSS and relies on Vue [3], an open-source framework for the development of User Interfaces. The Model and the Controller components belong to the back-end that relies on Node.js [4], an open-source and cross-platform JavaScript runtime environment. The back-end includes also the database that organises and store data; this is the Renovation Space Representational Model, a MYSQL database [5]. The interaction between the Client and the Server side is implemented as REST services based on Express framework [6].

The **e-**DSS abacus of solutions is the set of different **e-**SAFE components that can be used during the building renovation. High level information on **e-**CLT, **e-**PANEL, **e-**EXOS, **e-**THERM and **e-**TANK are provided to have a better understanding of their impact in the co-design process. Indeed, the **e-**DSS allows the users choosing between a combined seismic and energy

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

refurbishment or a simple energy refurbishment. In the first case, two different and alternative technological solutions can be devised for the improvement of the building's seismic response: cross-laminated timber panels (**e-**CLT) or a metallic exoskeleton (**e-**EXOS). In this second option, the building envelope is covered with the **e-**PANEL, which ensures the improvement of the energy performance. The **e-**PANEL is also partially applied in case of **e-**CLT application to insulate the portions of the opaque envelope where the windows are placed, and for specific architectural joints.

Moreover, this deliverable introduces the test strategy selected for the **e-**DSS. Functional and Usability tests will be performed in order to verify the software functionalities and the users' experience, respectively. Moreover, performance tests will be carried out because it is important to evaluate the behaviour of the application under workload conditions similar to the real users' experience.

Finally, this deliverable provides updated information about the equations needed for the estimation of the building energy performance before and after the renovation process. The main algorithms that are implemented in the **e-**DSS to manage the renovation process are detailed together with the criteria and the algorithms used to evaluate the feasibility of the **e-**SAFE technologies.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

GLOSSARY OF TERMS

ACRONYM	DESCRIPTION
BIM	Building Information Model
BM	Building Manager
COP	Coefficient of Performance
DHW	Domestic Hot Water
ENG	Engineering Ingegneria Informatica
FR	Functional Requirements
gbXM	Green Building XML schema
GUI	Graphical User Interface
IFC	Industry Foundation Class
NFR	Non-Functional Requirements
PGA	Peak Ground Acceleration
PV	Photovoltaic
PVGIS	Photovoltaic Geographical Information System
RC	Reinforced Concrete
SEER	Seasonal Energy Efficiency Ratio
ST	Solar Thermal system
UML	Unified Modeling Language
UNI	Italian National Unification

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

1. INTRODUCTION

This deliverable aims at providing the final representational model for the **e-**SAFE Decision Support System (**e-**DSS). This second version of the model will be used to work on the final version of the **e-**DSS due at M30 (D4.5).

The renovation space representational model is updated to support the Italian and the virtual pilots of the **e-**SAFE project. The complete list of entities, attributes and relationships is provided along with the relational scheme of **e-**DSS data model. Moreover, the functional and architectural specifications of **e-**DSS, which was introduced in D4.1, are refined and updated to support the development of the final version of **e-**DSS. The low-level **e-**DSS software specification, provided in this report, has driven the development of the preliminary version of **e-**DSS.

It is worth underlining that after the submission of D4.1, the equations concerning the calculation of building energy needs and the co-design process have been reviewed and updated. On the other hand, the **e-**SAFE abacus of solution is introduced for the first time: features of **e-**CLT, **e-**PANEL, **e-**EXOS and **e-**THERM are provided so that the reader can have a better understanding of their impact in the co-design renovation process.

1.1 Intended Audience

The intended audience of the report is primarily represented by the members of the project's consortium and European Commission (EC) representatives tasked with reviewing the project and its progress towards meeting the specified milestones. Moreover, it reports relevant information for carrying on the development activity of **e-**DSS tool and therefore of the renovation space representational model.

1.2 Relation to other activities

The outcome of this report is the base for the final version of the **e-**SAFE Decision Support System due at M30 (Deliverable D4.5). Moreover, it contains also relevant information for the finalisation of the first release of the **e-**DSS due at M15 (Deliverable D4.3).

1.3 Document overview

The report is structured as follows

Chapter 2 describes the **e-**DSS low-level functional specification providing use cases, functional and non-functional requirements, and the refined version of **e-**DSS architecture. Moreover, the **e-**SAFE components are introduced so that the reader can have a better understanding of their impacts in the co-design renovation process. The data input of **e-**DSS representational model are provided as well.

Chapter 3 provides the final version of the renovation space representational model of **e-**DSS tool aimed at supporting the design of the Italian and virtual pilots. The logical design is provided by means of the **e-**DSS relational schema. Details about entities and attributes are provided in Appendix 4.

Chapter 4 provides the updated version of algorithms and the equations representing the core of the **e-**DSS business logic. Details about the input data are provided in Appendix 1, while Appendix 2 and Appendix 3 contain the equations and explain the main hypotheses and assumptions.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

2. e-SAFE DECISION SUPPORT SYSTEM

The aim of this section is to provide the reader with updated and refined specifications about the **e-**SAFE Decision Support System (**e-**DSS).

The **e-**DSS is conceived as a simple but effective tool that must assist a technician when he/she wants to investigate the applicability of the **e-**SAFE renovation solutions to a certain building, while also assessing – with a reasonable degree of approximation – the energy performance of the building before and after the proposed renovation action, the environmental benefits in terms of decarbonization (i.e. reduction in CO_2 emission for space heating, space cooling and DHW preparation), the expected costs and time for the building renovation and the expected Time of Return of the investment, based also on the savings in the annual operating costs.

The **e-**DSS does not aim at assessing the seismic improvement accomplished through the proposed renovation solutions, since this result derives from a very complex structural analysis that goes beyond the scope of the tool. However, it is able to support the technician in the decision-making process about the most suitable solution for seismic improvement, in relation to the seismic zone, the height and the shape of the building, and the current state of conservation of the reinforced concrete (RC) structures.

The **e-**DSS is not just a calculation tool for the technician: indeed, it is also conceived as a means of communication between the technician and the building owners/residents during the co-design stage. Thanks to the **e-**DSS, the owners are made aware of the potential benefits of the renovation solutions, but also of the costs and the potential disruption. Through a specific functionality implemented in the **e-**DSS, and with the support of the Building Manager, they can interact with the technician and express their point of view, their doubts, and their requirements in terms of cladding, colour, windows and cost of the solutions. Based on this interaction, the technician can refine the preliminary design in order to meet the expectation and the needs of owners and residents.

The use of the **e-**DSS in the co-design process is envisaged according to the following steps:

- the technician is engaged by the Building Manager, who possibly provides him with drawings of the plans and the fronts of the building, if available;
- the technician creates a simplified 3D model of the building envelope by using an open source freeware tool able to generate IFC files, such as SketchUp;
- the technician imports the IFC file in the e-DSS, and fills in the fields regarding the current state of the building (geometry, energy features, performance of the technical systems);
- the e-DSS calculates the estimated energy performance and the operating costs of the current building;
- the technician starts a first preliminary renovation design with the dedicated function in the e-DSS, which helps him/her defining the most suitable solutions while also excluding those that are not technically feasible;
- the Building Manager (BM) accesses the e-DSS and is able to visualize the design prepared by the technician: he/she can now show it to the owners/residents, and collect their thoughts, suggestions, opinions and desires. Based on this input, which are noted by the BM in a dedicated section of the e-DSS, the technician can update its design proposal.

The co-design process is not intended to strictly match this list of actions: direct interaction between the technician and the residents/owners is highly recommended, in order to enhance communication and joint discussion.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

According to the process described above, a series of user scenarios can be envisaged. These user scenarios, already defined in D4.1 [1], are detailed in this section in terms of use cases, functional and non-functional requirements.

This section also describes the final version of **e-**DSS architecture. Indeed, the Model-View-Controller (MVC) high-level architecture of **e-**DSS, which was introduced in D4.1, is now fine-tuned: Model, View and Controller components are further specified and relevant information about software modules, data persistence, REST services and APIs addressing the interoperability are given.

It is important to underline that the functional and architectural specification of **e-**DSS, reported in this deliverable, addresses both the Italian pilot and the Virtual pilots: more information is provided in the following subsections. A further important specification is that the **e-**DSS does not aim at providing extremely precise results: its main scope consists in assisting the co-design process by showing the owners the potential outcomes of the **e-**SAFE solutions in terms of energy savings and reduction of the energy bills. The tool is not intended to be used for energy certification purposes or for detailed design calculations.

2.1 e-DSS abacus of solutions

This section introduces the different **e-**SAFE components that can be used during building renovation, and whose features must be introduced in the **e-**DSS to calculate costs and energy performance. The goal of this section is twofold:

- providing high level information on e-CLT, e-PANEL, e-EXOS, e-THERM in order to have a better understanding of their impact in the co-design process.
- providing high level technical information strictly related to the renovation space representational model in the DSS.

The **e-**DSS allows the users choosing between a combined seismic and energy refurbishment or a simple energy refurbishment. In the first case, two different and alternative technological solutions can be devised for the improvement of the building's seismic response: cross-laminated timber panels (**e-**CLT) or a metallic exoskeleton (**e-**EXOS). In this second option, the building envelope is covered with the **e-**PANEL, which ensures the improvement of the energy performance. The **e-**PANEL is also partially applied in case of **e-**CLT, to insulate the portions of the opaque envelope where the windows are placed and for specific architectural joints (Figure 1).

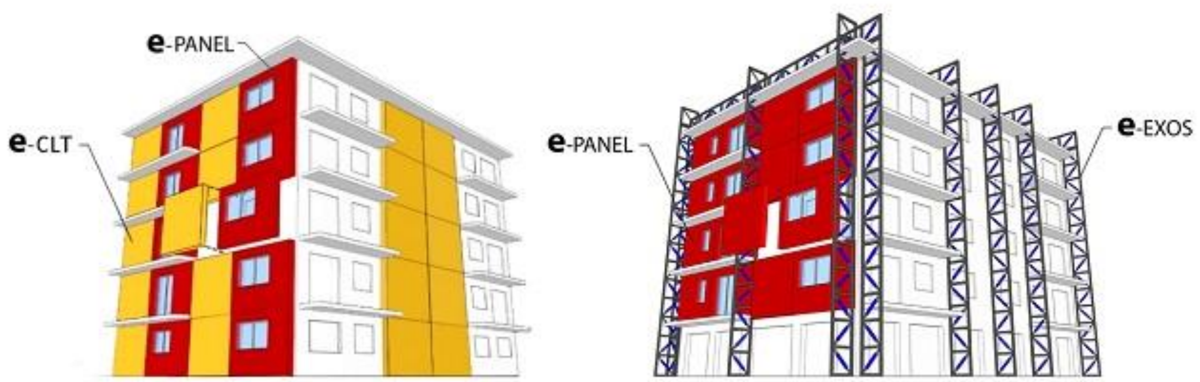

Figure 1: Integration of **e**-PANEL with **e**-CLT and **e**-EXOS

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

2.1.1 e-CLT and e-PANELS: technical features for the DSS

e-CLT is made of a Cross Laminated Timber boards connected to the existing RC structure through innovative friction dampers that dissipate the seismic energy in case of ground motions while also providing additional lateral stiffness. An additional outer layer of thermal insulation ensures further reducing the thermal resistance of the envelope (Figure 2). The component is then completed by suitable cladding materials (e.g., fiber cement, wooden slats, ceramic, aluminum, etc.).

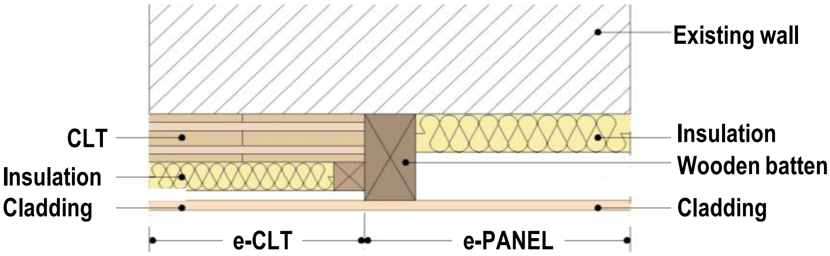

Figure 2: **e-**PANEL and **e-**CLT applied to the existing wall

The CLT board has a structural thickness equal to or higher than 10 cm, while the thickness of the insulation layer depends on the severity of the climate conditions, and must allow reaching the desired U-value. During the design stage with the **e-**DSS, the user has to specify the following variables:

- thickness of the CLT board
- type and thickness of the insulation layer
- type and thickness of the cladding material

As previously stated, the **e-**CLT does not entirely cover the opaque surfaces. The portions of the opaque envelope with windows, and some specific nodes, are covered with timber-based energy efficient panels (**e-**PANELs) embedding a wood-based insulating material. Here, the thickness of the insulating material does not need to be specified: indeed, its value is automatically calculated by **e-**DSS in order to ensure the same thermal transmittance value achieved by the **e-**CLT. Consequently, the air gap between insulation and cladding material is larger than in the **e-**CLT.

The **e-**DSS must thus differentiate the opaque surfaces covered with **e-**PANEL from those covered with **e-**CLT. This can be done by drawing them with a different color in the IFC file.

Then, starting from the different surfaces in each façade, the DSS calculates the overall **e-**CLT and **e-**PANEL surface in the entire building:

$$S_{\mathrm{CLT\_tot}} = \sum_i S_{\mathrm{CTL\_i}} \qquad\qquad S_{\mathrm{PANEL\_tot}} = \sum_i S_{\mathrm{PANEL\_i}}$$

The following relation then gives a first feasibility condition for the **e-**CLT technology. If this condition is not verified, **e-**CLT cannot be conveniently used:

$$\frac{S_{\mathrm{PANEL\_tot}}}{S_{\mathrm{PANEL\_tot}} + S_{\mathrm{CLT\_tot}}} < 0.6$$

Moreover, further conditions should be verified in order to allow the **e-**CLT installation:

- the building must not be subject to constraints that prevent altering its appearance (e.g., local regulations, cultural heritage restrictions);
- the building must have maximum 6 floors above ground;
- there must be sufficient space for crane's operations around the building, since these panels are mounted from the outside without the need for any scaffolding;

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

- the building must have maximum 2 facades attached to other buildings;
- there must be a limited number of balconies running through the building's perimeter, and a reduced surface of openings at the ground floor (less than 60% of the total envelope surface at the ground level).

In case of simple energy renovation, based on the **e-**PANEL technology, there are still some conditions to verify:

- the building must not be subject to constraints that prevent altering the appearance of the building (e.g., local regulations, cultural heritage restrictions);
- the building must have maximum 12 floors above ground;
- there must be sufficient space for crane's operations around the building, since these panels are mounted from the outside without the need for any scaffolding.

2.1.2 **e-**CLT: feasibility check

This subsection refers to the additional checks to understand if the **e-**CLT is an effective solution for seismic improvement; if not, the **e-**DSS should discourage the technician from adopting it.

The main issues that might discourage from using the **e-**DSS are:

- The existing structure (RC frame) is degraded
- The percentage of the perimeter occupied by balconies in a typical floor is very high
- The building is located in a highly seismic zone
- The number of floors is high (but still not higher than six)
- There are many facades attached to another building

In order to manage this evaluation, the **e-**DSS will attribute a score to the different above-mentioned issues according to the following criteria:

<u>Degradation of the existing structures (Reinforced Concrete frame)</u>

- "The structures are in very good state": → $C_{sd} = 0$
- "The structures are just slightly degraded": → $C_{sd} = 5$
- "The structures are degraded, but they can be easily recovered": → $C_{sd} = 10$
- "The structures are very degraded": → $C_{sd} = 20$

<u>Percentage of the perimeter occupied by balconies in a typical floor</u>

- "Below 30%": → $C_b = 0$
- "Between 30% and 50%": → $C_b = 10$
- "Above 50%": → $C_b = 20$

<u>Level of seismicity</u>

- "Low Seismicity Zone": → $C_{sz} = 0$
- "Medium Seismicity Zone": → $C_{sz} = 10$
- "High Seismicity Zone": → $C_{sz} = 20$

<u>Number of floors above the ground</u>

- "$n_{floors} < 5$" → $C_f = 0$
- "$n_{floors} = 5$" → $C_f = 5$
- "$n_{floors} = 6$" → $C_f = 10$

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Number of facades attached to another building

- "Zero" → $C_{fa} = 0$
- "Only one façade" → $C_{fa} = 10$
- "Two façades" → $C_{fa} = 20$

If the sum of these coefficients is too high ($C_{tot} = C_{sz} + C_f + C_{fa} + C_{sd} + C_b \geq 50$) the **e-**DSS must suggest that the **e-**CLT is not a very effective solution for the seismic renovation of the building, since it would not significantly improve its seismic response. **e-**EXOS might be a better choice.

2.1.3 **e-**EXOS: technical features for the **e-**DSS

If the building to be refurbished does not meet the feasibility conditions for **e-**CLT, the **e-**DSS user can then explore the use of the **e-**EXOS solution for combined seismic and energy renovation.

The **e-**EXOS improves the seismic resistance of the building, but it has no effect on the energy performance. To this aim, when adopting the **e-**EXOS solution the building envelope is entirely covered with the **e-**PANEL.

However, the following conditions must be verified in order to allow for **e-**EXOS installation:

- the building must not be subject to constraints that prevent altering the appearance of the building (e.g., local regulations, cultural heritage restrictions);
- there must be sufficient space for crane's operations around the building, since the e-PANELs are mounted from the outside without the need for any scaffolding;
- the building must have maximum one facade attached to other buildings;
- there is at least 3 m of free space around the building to install the exoskeleton without trespassing the property boundaries.

In case **e-**EXOS is a suitable solution, the **e-**DSS user has to specify:

- type and thickness of the insulation layer;
- type and thickness of the cladding material.

As above, the insulation thickness must allow reaching the desired U-value, according to possible prescriptions set by local regulations.

2.1.4 Windows replacement and roof insulation

As far as the glazed surface area is concerned, this is renovated through ad-hoc **e-**PANELs placed in correspondence of the existing openings and including the new high-performing windows (e.g., double or triple-glazed with low-emissive film) with thermal-break frames and shading devices embedded. During the design stage, the user has to specify the following variables:

- U-value of the new windows;
- g-factor of the new windows.

These data can refer to specific commercial products, or just be retrieved from tables with standard values.

Finally, the building envelope renovation can also include the roof refurbishment through the application of a thermal insulation layer of suitable thickness on the outer side, and the replacement of the existing waterproof membrane and external finishing layer.

During the design stage, the user has to specify the following variables in relation to the roof:

- type and thickness of the insulation layer
- type of finishing layer
- presence of the waterproof membrane

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

2.1.5 **e-**THERM: technical features for the **e-**DSS

Apart from the renovation of the building shell, the energy refurbishment of the building is achieved also through a comprehensive group of technical systems named **e-**THERM that is available to the users of **e-**DSS when choosing either the combined seismic and energy refurbishment or the simple energy refurbishment option (see Figure 3).

e-THERM provides space heating and cooling, as well domestic hot water (DHW), through highly efficient centralized reversible air-to-water heat pumps fed by PV panels that can be placed on the roof and on the facades with suitable orientation. Fan-coils for space heating and cooling are installed within each dwelling, together with modular plug-and-play tanks of 140 L capacity each to store DHW (**e-**TANK). Further thermal energy storage is provided at centralized level through well-insulated storage tanks to decouple energy production and energy demand in order to maximize energy efficiency. The size of the centralized storage tanks is defined during the design process, according to the available data.

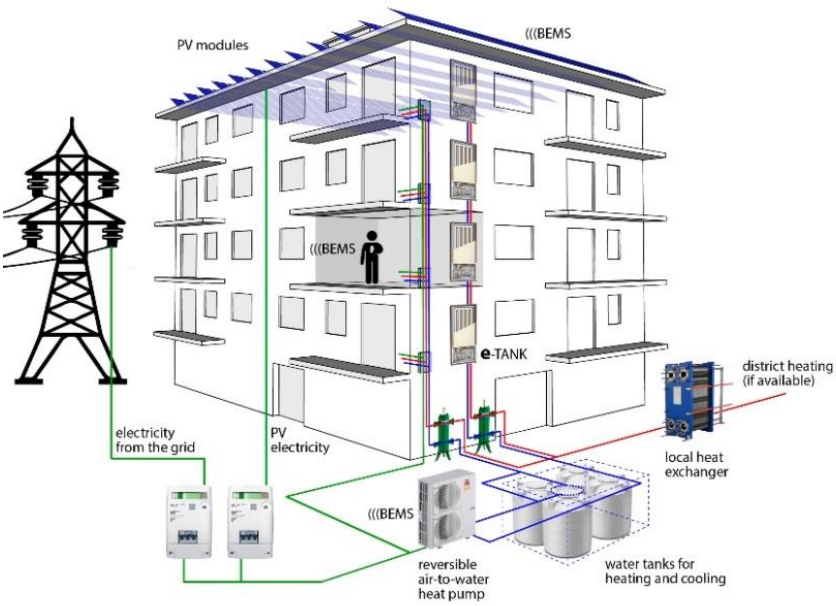

Figure 3: Schematic of the **e**-THERM concept

The **e-**THERM concept and architecture is thus already well defined. There are only few variables that should be specified by the user during the co-design process and that are relevant to the **e-**DSS in the calculation of the energy performance (and the costs):

- type and size of heat pump, with the corresponding efficiency values (COP and EER values);
- type, surface and orientation of the PV modules;
- number of fan coils that will be installed.

All other parameters needed in the calculation of the energy performance are automatically set by the **e-**DSS to suitable values, as detailed in Appendix 3.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

2.2 e-DSS use cases

Use cases are an effective and widely used technique for eliciting software requirements. The use case approach focuses on describing the system under analysis from the point of view of different stakeholders (end users) emphasizing how they can interact with the system in order to reach a specific goal. Therefore, the key elements of a use case are the following:

- the system that is under analysis and design;
- the actor, the type of end user interacting with the system. The actor can be a human, or external entities playing a specific role in the system's exploitation;
- the goal representing the main outcome provided by the system once the use case is executed.

Use cases are usually defined following a specific template. Table 1 defines the use case template adopted in the **e-**SAFE project:

Table 1: Use case template

USE CASE		
ID		<a sequential reference number>
Name		<short name of the use case>
Goal(s)		<the functionality or behaviour that is expected to be provided by the system once the use case is executed>
Actors		<the individuals and their means that trigger system reactions>
Trigger events		<the main action that starts the use case execution>
Preconditions		<those actions that must occur before the execution of the use case in order to obtain the described behaviour>
Basic Flow	**Description**	'Basic Flow' or 'Main Scenario' is the normal workflow in the system. It is the flow of transactions done by the Actors on accomplishing their goals. When the actors interact with the system, as it's the normal workflow, there won't be any error and the Actors will get the expected output.
	Post conditions	<those conditions that could occur once the use case has been executed and the system continues its operations>
Alternative flow and exceptions		Major alternative flows or exceptions that may occur in the flow of event

Moreover, use cases can be graphically represented through the UML use cases diagram [2]. The aim of this diagram is to provide a graphical representation of the main goals that the system under discussion has to achieve underlining who (the actors) interacts with the system itself.

The main actors of **e-**DSS are the technician (i.e. architect, engineer, designer etc.) and the building manager. Each actor interacts with the **e-**DSS in order to achieve its own ultimate objective; therefore, as already done in D4.1 for the **e-**DSS scenarios, it is useful to distinguish between technician and building manager use cases. However, there is a set of common functionalities that the **e-**DSS has to provide to **e-**DSS users; in this case it is possible to define use cases addressing the needs of both the technician and the building manager actors. Such a

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

situation can be graphically expressed in Figure 4: both technician and building manager are an **e-**DSS user and both need to perform the registration and login to the **e-**DSS in order to use it.

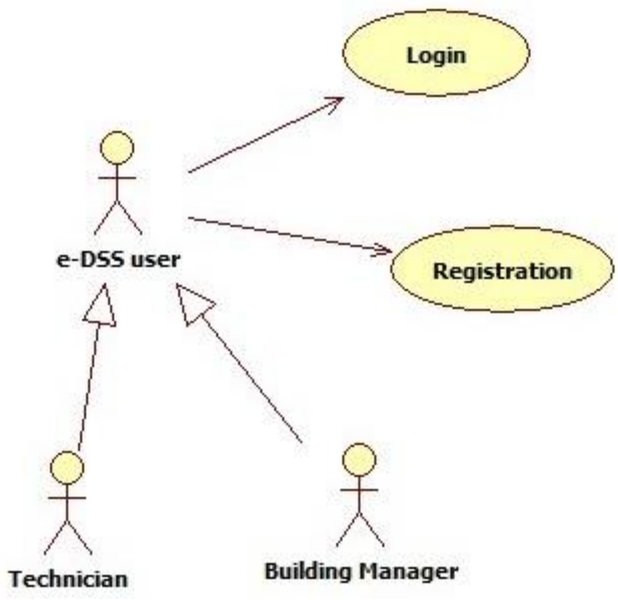

Figure 4: **e-**DSS user use cases diagram

The textual description of Registration (**e-**DSS_User_UC1) and Login (**e-**DSS_User_UC2) use cases is provided in the following page.

Then, Section 2.2.1 and Section 2.2.2 provide the use cases description and the related UML use case diagrams for the Technician and Building manager scenario respectively. These two scenarios were already identified in D4.1.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

<table>
<tr><th colspan="3">USE CASE</th></tr>
<tr><td colspan="2">ID</td><td>e-DSS_User_UC1</td></tr>
<tr><td colspan="2">Name</td><td>Registration to the e-DSS tool</td></tr>
<tr><td colspan="2">Goal(s)</td><td>As an e-DSS user, I need to register to the e-DSS tool so that I can exploit it.</td></tr>
<tr><td colspan="2">Actors</td><td>e-DSS user</td></tr>
<tr><td colspan="2">Trigger events</td><td>The e-DSS user clicks the “Registration” button.</td></tr>
<tr><td colspan="2">Preconditions</td><td>The e-DSS user has an email account.</td></tr>
<tr><td rowspan="2">Basic Flow</td><td>Description</td><td>The e-DSS user, if new, requests to register himself with the e-DSS.
The registration page of e-DSS asks for some personal details of the e-DSS user: name, surname, email and password; moreover, it is requested to specify its role (technician or building manager).
The e-DSS user enters the personal details and submits the registration form.
The system differentiates between different e-DSS user and accordingly saves them in the system database.</td></tr>
<tr><td>Post conditions</td><td>The e-DSS user is successfully registered with the e-DSS tool with the role of Technician or Building Manager.</td></tr>
<tr><td colspan="2">Alternative flow and exceptions</td><td>NA</td></tr>
</table>

<table>
<tr><th colspan="3">USE CASE</th></tr>
<tr><td colspan="2">ID</td><td>e-DSS_User_UC2</td></tr>
<tr><td colspan="2">Name</td><td>Login to the e-DSS tool</td></tr>
<tr><td colspan="2">Goal(s)</td><td>As a e-DSS user, I need to login to the e-DSS tool so that I can create a new e-DSS project</td></tr>
<tr><td colspan="2">Actors</td><td>e-DSS user</td></tr>
<tr><td colspan="2">Trigger events</td><td>The e-DSS user clicks the “Login” button</td></tr>
<tr><td colspan="2">Preconditions</td><td>The e-DSS user is already registered in the system</td></tr>
<tr><td rowspan="2">Basic Flow</td><td>Description</td><td>The e-DSS user types his/her email and password. The system checks if the given login parameters are valid and create a new session for the user that is redirected to the main menu of e-DSS tool.</td></tr>
<tr><td>Post conditions</td><td>The e-DSS user is successfully logged in with the e-DSS tool</td></tr>
<tr><td colspan="2">Alternative flow and exceptions</td><td>The e-DSS user provides invalid login parameters and the system asks for checking his/her credentials. The System shows an error message and the e-DSS user is redirected to the Registration/Login Page.</td></tr>
</table>

e-SAFE has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 893135.

2.2.1 **e-**DSS Technician use cases

The "**e-**DSS technician" use cases can be classified according to the following macro functionalities: Project Management, Building Management and Building Renovation Management. This classification is reflected in the use case UML diagrams that formalise the **e-**DSS functionalities that the technician needs to exploit. Specifically, the ovals represent the use cases, the stick figure is the Actor and the line between actors and use cases is the Association. The <extend> association is used when a use case conditionally adds alternative steps to another use case (base) describing the normal flow. While the base use case is defined independently and is meaningful by itself, the extension use case is not meaningful on its own. The extension use case consists of one or several behavior sequences describing additional steps that can incrementally augment the behavior of the base use case.

2.2.1.1 Project Management

This set of use cases defines the functionalities strictly related to the management of **e-**DSS project. As shows in Figure 5, the main use case is related to the creation of a new **e-**DSS project; moreover, there is also the possibility to edit or view an **e-**DSS project that already exists (previously created by the technician) and also to add a new renovation solution. Indeed, the **e-**DSS allows technician to address several renovation solutions for the same building. The use cases "Edit **e-**DSS project", "Add Renovation solution" and "View **e-**DSS Project" are formalised using the <extend> relationship since they extend the behaviour of the use case "Creation of a new **e-**DSS project" describing the normal flow. While the "Creation of a new **e-**DSS project" is meaningful on its own, the extending use cases ("Edit **e-**DSS project", "Add Renovation solution" and "View **e-**DSS Project") cannot exist without the base use case ("Creation of a new **e-**DSS project").

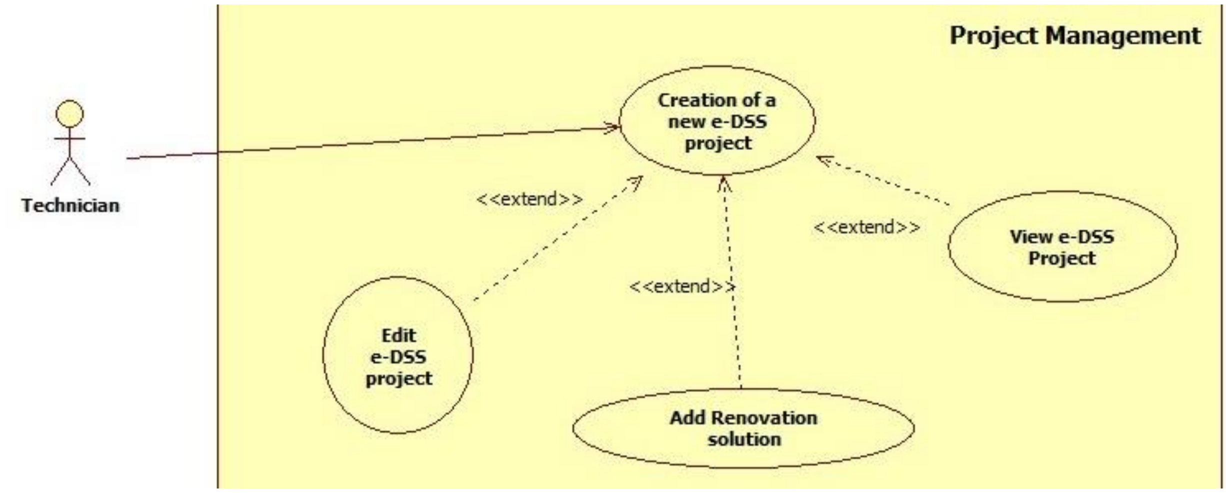

Figure 5: Technician use cases – Project management

The textual description of this set of use cases is provided as follow:

USE CASE	
ID	TC_UC1
Name	Creation of a new **e-**DSS project
Goal(s)	As a technician, I need to create a new **e-**DSS project so that I can know the energy performance of the building in its current state and I can start the co-design process of building renovation.
Actors	Technician

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Trigger events		The technician clicks the "Create New Project" link.
Preconditions		The technician is already logged in the system.
Basic Flow	**Description**	1. The technician accesses the **e-**DSS page dedicated to the data entry of relevant information describing the building in its actual status as follows: Building Information, Building geometric data, Building energy data, System energy data. 2. He/she clicks in each tab and follows the instruction of the wizard to insert the needed data. He/she clicks "Save" and the system stores all data in the database keeping the reference to the technician and to the project just created. 3. The technician clicks the "Calculate energy performance" button and the system runs the algorithms for the calculation of energy needs. The system accesses to the database in order to retrieve data involved in the equations. The system stores the outcome of the performed elaboration in the database and shows it to the technician through the "Results" tab of **e-**DSS page. 4. The technician clicks the "Download" button to download the report with the energy performance of the building in its current state. 5. The technician clicks "Renovation" tab to start the process of building renovation design.
	Post conditions	The technician successfully creates a new **e-**DSS project and has information about the energy performance of the building in its current state; he/she can start the process of building renovation design.
Alternative flow and exceptions		**Edit e-DSS project:** The technician wants to modify one of its own **e-**DSS projects. The menu page of **e-**DSS shows the list of **e-**DSS projects of the technician and the related information: Project name, Creation date, Building energy performance (if already computed or not), short description of the renovation solution). He/she clicks "Edit Project", the **e-**DSS shows all available information related to the building in its current state. The technician clicks the tab related to the update he/she needs to do, changes the data and clicks the "Save" button. At this point the **e-**DSS shows a warning "Are you sure do you want to save? Please note that the building energy performance you have calculated will be no more valid and a new calculation has to be performed". The technician clicks the "Save" button and the e-DSS shows a message reminding the importance to check information provided in the other tabs before proceeding with the calculation of building energy performance. The technician checks the information provided in the other tabs and clicks the "Building energy Performance tab" where a warning is shown in order to underline that the energy performance of the building previously computed is not more valid and he/she has to perform again the energy performance of the building. He/she clicks the "Calculate energy performance" button and a new computation is performed. The system updates the project information in the database. **Add Renovation Solution**: the technician wants to add a new

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

	renovation solution; he/she clicks "add renovation" and he/she is redirected to the "Renovation" tab. **View e-DSS Project**: The technician wants to see all the building information, the energy performance of the building in its current state, the renovation solution and the survey collecting the owner feedback. He/she clicks "view" and the system shows the related information through the **e-**DSS GUI. **Delete e-DSS Project:** The technician wants to delete the **e-**DSS project. He/she clicks "delete" and the system deletes the project from the database.

2.2.1.2 Building Management

This section collects the set of use cases describing the actions performed by the technician in order to provide, through the **e-**DSS GUI, relevant information about the current status of the building (e.g. geometric and energy data). The Building Management use cases (Figure 6) represent an important pre-condition for the building renovation co-design process. The Project Management use cases, provided in the previous section 2.2.1.1, instead, are related to the user operation of creating, editing and viewing an **e-**DSS project and associating a new renovation solution.

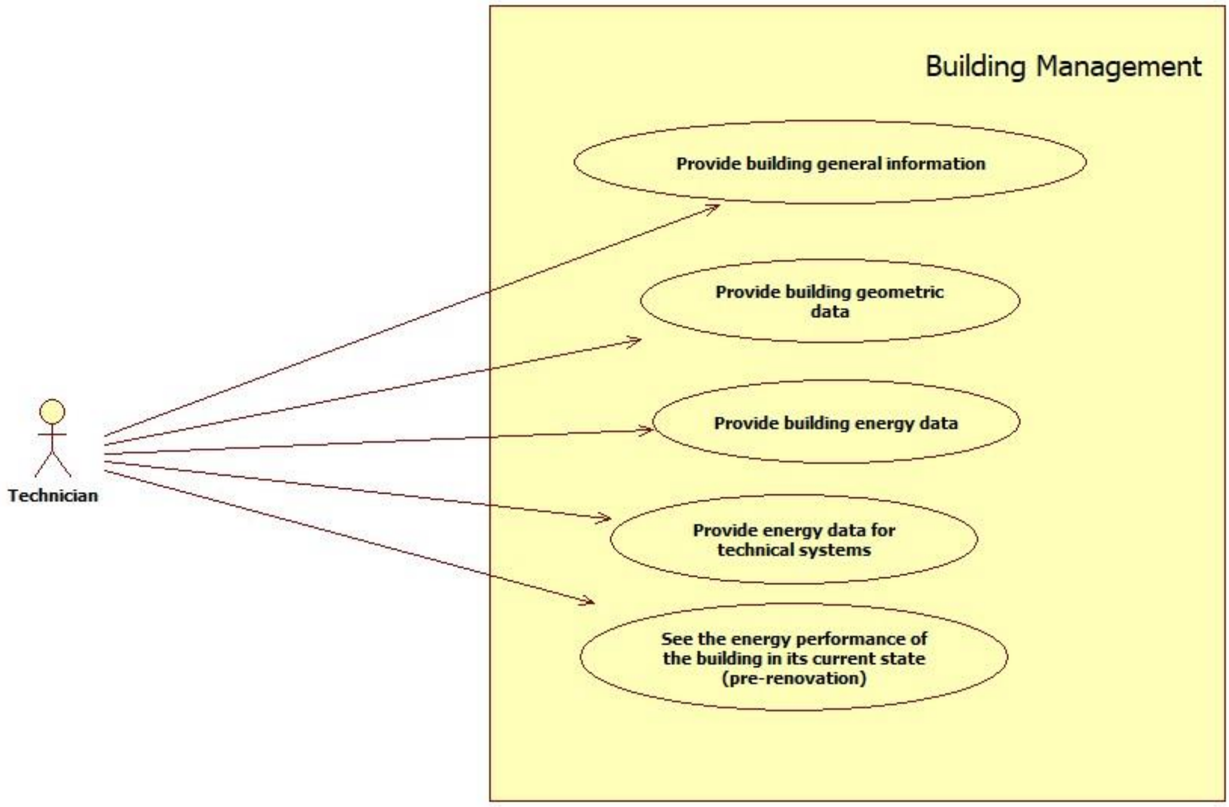

Figure 6: Technician use cases – Building management

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

The textual description of this set of use cases is provided in the following tables:

<table>
<tr><th colspan="3">USE CASE</th></tr>
<tr><td colspan="2">ID</td><td>TC_UC2</td></tr>
<tr><td colspan="2">Name</td><td>Provide building general information</td></tr>
<tr><td colspan="2">Goal(s)</td><td>As a technician, I need to provide the building general information so that I can know the energy performance of the building in its current state and I can be supported in the co-design process of building renovation.</td></tr>
<tr><td colspan="2">Actors</td><td>Technician</td></tr>
<tr><td colspan="2">Trigger events</td><td>The technician clicks “Building Information” tab</td></tr>
<tr><td colspan="2">Preconditions</td><td>The technician is already logged in the system.
The technician created a new e-DSS project.</td></tr>
<tr><td rowspan="2">Basic Flow</td><td>Description</td><td>The technician starts filling in the information required by the e-DSS about the current state of the building as follows:
1. He/she inserts the Project name.
2. He/she clicks “Use geo-localisation data” and the e-DSS automatically retrieves information about: latitude, longitude, altitude, country, region, province, municipality, address and seismic zone. The system establishes the seismic zone according to the Peak Ground Acceleration (PGA) value (more details are available in Appendix A3.1). The PGA values are retrieved by a third-party service.
3. He/she inserts the year of building’s construction and selects from a drop-down menu the predominant intended building use (Residential, Library, Offices, Hospital, Cinema/theatre, Museum/church, Restaurant, Commercial building, swimming pool, Gym, School, Industrial building).
4. The technician has also the possibility to select the indoor set-point temperatures for both the summer and winter season from a drop-down menu (integer values going from 18 °C to 28 °C).
5. Finally, the technician can select from a drop-down menu the full name of Building Manager.
6. He/she clicks “Save” and the system stores the filled information in the data base.</td></tr>
<tr><td>Post conditions</td><td>The technician successfully filled in all the fields of “Building information” tab in the e-DSS homepage.</td></tr>
<tr><td colspan="2">Alternative flow and exceptions</td><td>The technician can insert latitude, longitude, altitude, country, region, province, municipality and address manually.</td></tr>
</table>

e-SAFE has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 893135.

USE CASE		
ID		TC_UC3
Name		Provide building geometric data
Goal(s)		As a technician, I need to provide the building geometric data so that I can know the energy performance of the building in its current state and I can be supported in the co-design process of building renovation.
Actors		Technician
Trigger events		The technician clicks "Building geometric data" tab
Preconditions		The technician provided general building information in the "Building information" tab of **e-**DSS home page
Basic Flow	**Description**	The technician starts filling in the information required by the **e-**DSS about the geometric data of the building as follows: 1. He/she uploads the IFC file of the building, previously prepared through open source external software. The system extracts relevant information such as the number of heated floors and the number of dwellings, the opaque and glazed envelope surface, and shows this data in the related field of **e-**DSS page. The system creates the 3D rendering of the building and shows it to the technician. 2. He/she clicks "Dwellings" button and insert the following information: description, net surface of the dwelling, name and surname of each owner indicating the millesimal value and ownership quote. 3. He/she clicks "Save" and the system stores the filled information in the data base.
	Post conditions	The technician successfully fills in the field of "Building geometric data" tab in the **e-**DSS homepage.
Alternative flow and exceptions		The technician can insert the building geometric data manually if the IFC file is not compliant as expected.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

USE CASE		
ID		TC_UC4
Name		Provide building energy data
Goal(s)		As a technician, I need to provide information about the energy data available in the building so that I can know the energy performance of the building in its current state and I can be supported in the co-design process of building renovation.
Actors		Technician
Trigger events		The technician clicks "Building energy data" tab
Preconditions		The technician provided information about the building geometric data.
Basic Flow	**Description**	The technician starts filling in the information required by the **e-**DSS about building energy data as follows: 1. He/she selects from a drop-down menu the colour of the external finish (Light, Medium, Dark) and the type of external wall (Solid brick wall, Perforated bricks or tuff, Uninsulated hollow bricks with air cavity, Hollow bricks with partially insulated air cavity and Prefabricated concrete walls). 2. He/she selects from a drop-down menu the floor type (Concrete slab on ground, Uninsulated hollow-core concrete floor above crawl space, Uninsulated hollow-core concrete floor above cellar / garage), the **roof type** (Flat uninsulated hollow-core concrete roof, Pitched uninsulated hollow-core concrete roof, Pitched uninsulated roof with wooden structure, Generic partially insulated roof) and **windows type** (Single glazing, Double glazing, Low-e double glazing, Low-e triple glazing). 3. He/she checks the checkbox to indicate the **presence (or not) of roller shutter** and provides information about the type of roller shutter (Metal or non-available, Wood or plastics, Other). 4. Then, the technician indicates the **presence of balconies on the different façades**, by ticking on the suitable check-boxes. He/she also indicates the presence or not of **heat-recovery mechanical ventilation system** through a check-box. In case this system is available, the technician can modify the **recovery efficiency value** that is proposed by the system. 5. Finally, the technician can select from a drop-down menu the **floor boundary condition** (Basement with no windows, Basement with windows, Ground, Outdoors) and the **roof boundary condition** (Outdoors, Ventilated non-heated attic, Uninsulated non-heated attic, Insulated non-heated attic). 6. He/she clicks "Save"; the system stores all information in the database.
	Post conditions	The technician successfully fills in the fields of "Building energy data" tab in the **e-**DSS homepage
Alternative flow and exceptions		NA

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

USE CASE		
ID		TC_UC5
Name		Provide energy data for technical systems
Goal(s)		As a technician, I need to provide information about the features of the energy systems available in the building so that I can know the energy performance of the building in its current state and I can be supported in the co-design process of building renovation.
Actors		Technician
Trigger events		The technician clicks "System energy data" tab
Preconditions		The technician has provided information about the building energy data.
Basic Flow	**Description**	The technician starts filling in the information required by the **e-**DSS about energy data for technical systems as follows: 1. First of all, he/she ticks the checkbox to indicate the presence (or not) of Domestic Hot Water (DHW) production system in the building. In case there is a DHW production system, he/she has to provide information about the main features of the system that are: **type of system** (centralised or autonomous), the **type of service** provided (only DHW or combined heating and DHW) and **type of heat generator** (Conventional gas boiler, Condensation boiler, Electric boiler, Heat pump boiler), **the position** (indoors or outdoors), the energy source (fuel, electricity), **the type of distribution** (Well or Scarcely insulated Pipes) and th**e storage tank** (No, Well or Scarcely insulated). The system retrieves from the database the possible values for each item and he/she can select a value from a drop-down menu. 2. After that, he/she ticks the checkbox to indicate the presence (or not) of a Space heating system. In case this is available, he/she has to provide information about the main features of the system that are: the **type of system** (centralised or autonomous), the **type of heat generator** (Stove / fireplace, conventional boiler, condensation boiler, heat pump), the position (indoors or outdoors), the energy source (fuel, electricity), the **type of distribution** (Well or Scarcely insulated Pipe), the **storage tank** (No, Well or Scarcely insulated), the type of emission terminals for heating (Radiators, Fan coils, Split systems, Convector heater, Radiant floor, Radiant ceiling, Air diffuser, Direct emission) and the control logics for heating (Outdoor temperature, Zone temperature, Room temperature, Room and outdoor temperature). 3. Furthermore, if the selected type of heat generator is "Heat Pump", the technicians has to further indicate the **type of heat pump** (Air-to-air, water-to-water, air-to-water, and ground-to-water), the COP value in standard conditions). The system retrieves from the database the possible values for each item and the technician can select a value from a drop-down menu.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

<table>
<tr><td rowspan="2"></td><td></td><td>4. Moreover, he/she ticks the checkbox to indicate the presence (or not) of a Space cooling system. In case this is available, by default the e-DSS considers that the space cooling system is based on heat pump technology. So, he/she has to provide information about the main features of the system that are: the type of cooling system (centralised or autonomous), the type of heat pump (Air-to-air, water-to-water, air-to-water, and ground-to-water) the type of distribution for cooling (Well or scarcely insulated Pipe), the storage tank (No, Well or Scarcely insulated), the type of emission terminals for cooling (Fan coils, Split systems, Radiant floor, Radiant ceiling, Air diffuser) and the type of control logics (Outdoor temperature, Zone temperature, Room temperature, Room and outdoor temperature). The system retrieves from the database the possible values for each item and the technician can select a value from a drop-down menu.
5. After that, he/she ticks the checkbox to indicate the presence (or not) of a Photovoltaic (PV) system. In case there is a PV system, he/she has to provide information about the main features of the system that are: the type of PV modules (Monocrystalline silicon, Polycrystalline silicon, Amorphous silicon, Thin film), the installed PV surface, the type of PV installation (Roof integrated, Roof mounted, wall mounted), the orientation of PV modules (North, North-East, East, South-East, South, South-West, West, North-West). However, PV modules should not be placed facing North-East, North, North-West: then, if the technician makes one of these choices the DSS provides a warning. The system retrieves from the database the possible values for each item and the technician can select a value from a drop-down menu.
6. He/she then ticks the checkbox to indicate the presence (or not) of a Solar Thermal (ST) system. In case there is a thermal system, he/she has to provide information about the main features of the system that are: the type of ST collectors (Glazed flat plate, Unglazed flat plate and Evacuated tube), the overall surface of ST collectors, the type of ST installation (Roof integrated, Roof mounted, Wall mounted), the orientation of ST collectors (North, North-East, East, South-East, South, South-West, West, North-West). The system retrieves from the database the possible values for each item and the technician can select a value from a drop-down menu.
7. Finally, the technician indicates the electric energy production from other renewable sources (if any), clicks “Save” and the system stores the filled information in the data base.</td></tr>
<tr><td>Post conditions</td><td>The technician successfully fills in the fields of “System energy data” tab in the e-DSS homepage.</td></tr>
<tr><td colspan="2">Alternative flow and exceptions</td><td>NA</td></tr>
</table>

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

<table>
<tr><th colspan="3">USE CASE</th></tr>
<tr><td colspan="2">ID</td><td>TC_UC6</td></tr>
<tr><td colspan="2">Name</td><td>See the energy performance of the building in its current state (pre-renovation)</td></tr>
<tr><td colspan="2">Goal(s)</td><td>As a technician, I need to know the energy performance of the building in its current state so that I can show it to the building manager.</td></tr>
<tr><td colspan="2">Actors</td><td>Technician</td></tr>
<tr><td colspan="2">Trigger events</td><td>The technician clicks "Building Energy Performance (pre-renovation)" tab.</td></tr>
<tr><td colspan="2">Preconditions</td><td>The technician has provided information about the general building data, the building geometric data, the building energy data and the system energy data.</td></tr>
<tr><td rowspan="2">Basic Flow</td><td>Description</td><td>1. The technician clicks the "Calculate Energy Performance" button and the system runs the algorithms for the calculation of energy needs. Regarding the duration of heating/cooling season, the e-DSS, through a pop-up window, notifies to the technician which months are included (as a result of back-end calculation).
2. Then, the technician can either approve the resulting months or add/deduct months by ticking/unticking boxes for each month shown in pop-up window. The technician clicks "ok" to confirm his/her choice and the e-DSS saves this information. After few minutes, the GUI shows to the technician the following information as a result of the performed calculation:
o Overall heat transfer coefficient for the building envelope
o S/V ratio
o Annual energy demand for space heating
o Annual energy demand for space cooling
o Distribution of heat losses – distribution (pie-chart with the percentage of the different heat losses coefficients)
o Annual Electricity Production from PV
o Monthly Net Electric Energy Consumption
o Annual Net Electric Energy Consumption
o Annual Fuel Consumption
o Non-renewable Primary Energy consumption
o Total CO_2 Emissions
o Total operating costs
o Operating costs for each dwelling
3. The technician clicks the "Download" button and the textual report of e-DSS output (intermediated and final results of calculated algorithms) is available on his/her PC.</td></tr>
<tr><td>Post conditions</td><td>The technician has information about the energy performance of the building in its current state (pre-renovation)</td></tr>
<tr><td colspan="2">Alternative flow and exceptions</td><td>In case of the Italian pilot, the duration of heating and cooling season is established according to Italian regulations, therefore the Technician must not provide this kind of information through the e-DSS GUI.</td></tr>
</table>

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

2.2.1.3 Building Renovation Management

Building Renovation Management use cases (Figure 7) are about the usage of **e-**DSS for the building renovation co-design process. The "Building energy retrofit selection" use case is extended by the "Inapplicability of **e-**PANEL solution" use case as alternative flow that is executed only under certain conditions that are explained in the use case. The "Combined Seismic and Energy" use case is extended by the use case "Inapplicability of **e-**CLT and **e-**EXOS solutions" specifying the alternative flow that is executed only under certain conditions for which **e-**CLT and **e-**EXOS solutions cannot be applied.

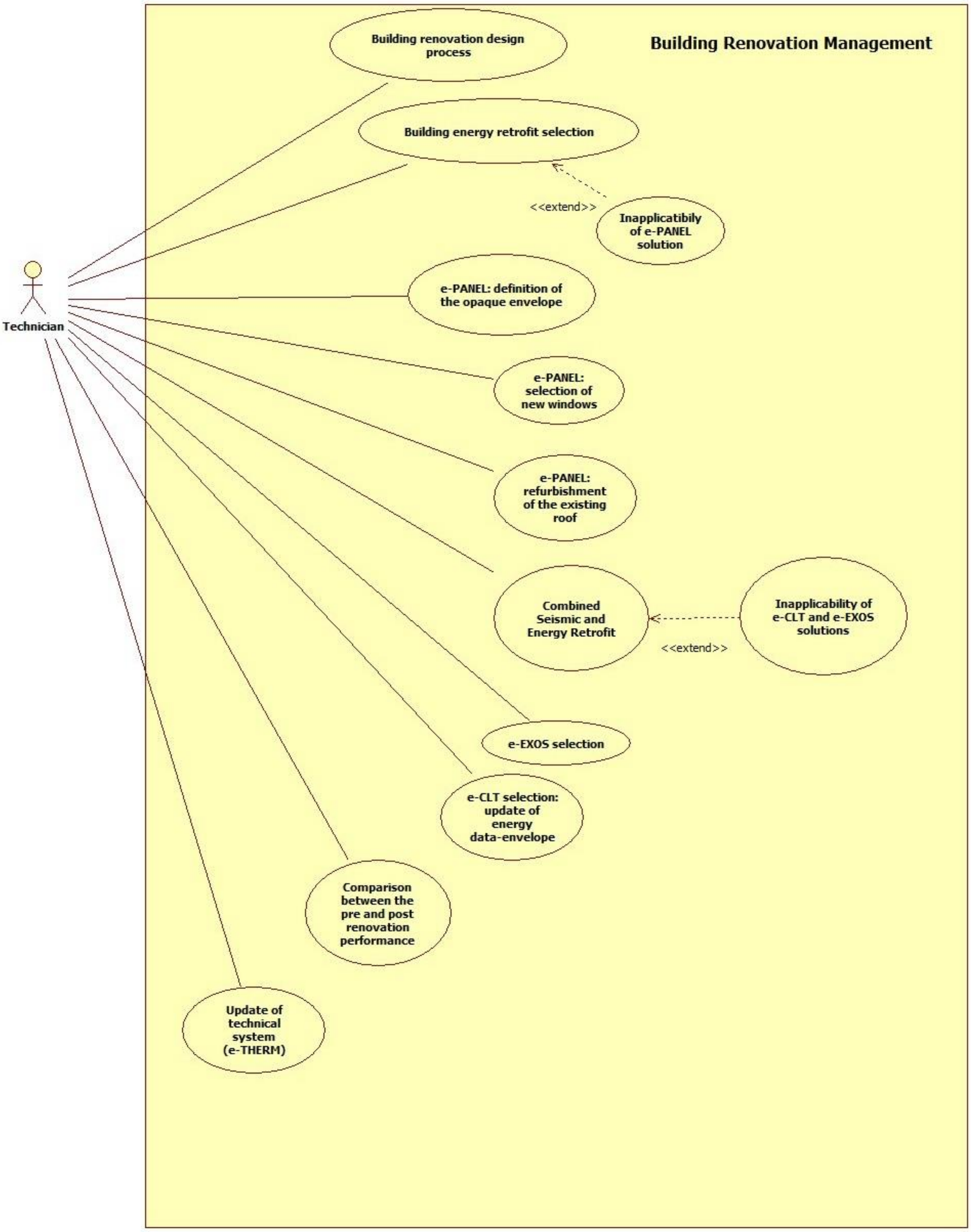

Figure 7: Technician use cases – Building Renovation Management

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

The textual description of this set of use cases is provided below:

USE CASE		
ID		TC_UC7
Name		Building renovation design process
Goal(s)		As a technician, I need to select the type of building renovation based on the **e-**SAFE technologies
Actors		Technician
Trigger events		The technician selects "Renovation" tab and clicks on "Start renovation process" button
Preconditions		The technician has already assessed the energy performance of the building in its current state
Basic Flow	**Description**	The technician has to indicate the type of retrofit he/she wants to perform. He/she can choose between two alternatives: • Energy retrofit • Combined seismic and energy retrofit Moreover, the system retrieves the seismic zone of the building and it notifies to the technician if the building is in high/average or low seismicity zone. The **e-**DSS GUI shows a message underlining it is necessary (or not) to consider the seismic renovation. He/she selects the checkbox related to the type of renovation he/she wants to perform.
	Post conditions	The technician has selected the type of renovation to be performed and therefore the building renovation co-design process starts.
Alternative flow and exceptions		No selection: the technician closes the tab without performing any selection. The system saves the **e-**DSS project in the database and he/she is redirected to the **e-**DSS homepage.

USE CASE		
ID		TC_UC8
Name		Building energy retrofit selection
Goal(s)		As a technician, I need to be supported in the co-design process of building energy retrofit and I want to know if **e-**SAFE solutions can be applied to the building.
Actors		Technician
Trigger events		The technician checks "Energy retrofit" checkbox.
Preconditions		The technician knows the energy performance of the building in its current state and he/she wants to improve it.
Basic	**Description**	The technician ticks "Energy retrofit" checkbox, and the system retrieves from the database those building data having an impact on

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Flow		the possibility to apply or not the **e-**SAFE solution. Indeed, the DSS first checks the **number of floors** (n_floors) above the ground, and if n_floors ≤ 12, through the **e-**DSS GUI, the DSS asks the technician some questions: • *"Is there sufficient space for the crane around the building?"* He/she selects "yes" • *"Are there any constraints (Cultural Heritage, local regulations) that forbid altering the outer appearance of the building"?* He/she selects "no" and the system notifies the possibility to apply the **e-**PANEL in order to perform the energy retrofit of the building.
	Post conditions	The **e-**PANEL solution can be applied to renovate the building
Alternative flow and exceptions		INAPPLICABILITY of **e-**SAFE solutions: 1) the number of floors above the ground is n_floors > 12 and the **e-**DSS GUI shows the following message: *"Sorry it seems that you cannot apply the **e-**SAFE solution because the building is too tall, Thank you and goodbye!".* The system saves this information in the database and the technician is redirected to the **e-**DSS homepage. This DSS project is accessible from the **e-**DSS home page. 2)The technician indicates that there is no sufficient space for the crane around the building and the **e-**DSS GUI shows the following message: "*Sorry it seems that you cannot apply the **e-**SAFE solution because there isn't sufficient space for the crane, Thank you and goodbye!".* The system saves this information in the database and the technician is redirected to the **e-**DSS homepage. This DSS project is accessible from the **e-**DSS home page. 3)The technician indicates that there are some constraints (Cultural Heritage, local regulations) that forbid altering the outer appearance of the building and the **e-**DSS GUI shows the following message: *"Sorry it seems that you cannot apply the **e-**SAFE solution because of some constrains, Thank you and goodbye!".* The system saves this information in the database and the technician is redirected to the **e-**DSS homepage. This DSS project is accessible from the **e-**DSS home page.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

<table>
<tr><th colspan="3">USE CASE</th></tr>
<tr><td colspan="2">ID</td><td>TC_UC9</td></tr>
<tr><td colspan="2">Name</td><td>e-PANEL: Definition of the opaque envelope</td></tr>
<tr><td colspan="2">Goal(s)</td><td>As a technician, I need to be supported in the co-design process of building energy retrofit (definition of the opaque envelope)</td></tr>
<tr><td colspan="2">Actors</td><td>Technician</td></tr>
<tr><td colspan="2">Trigger events</td><td>The technician ticked "Energy retrofit" checkbox</td></tr>
<tr><td colspan="2">Preconditions</td><td>The e-PANEL solution can be applied to the building renovation.</td></tr>
<tr><td>Basic Flow</td><td>Description</td><td>The system asks the technician to select the external finishing layer and the insulating material. He/she performs this selection through a drop-down menu containing only a predefined list of elements as follows:
• external finishing layer:
    ○ Fiber cement (with plaster)
    ○ Fiber cement (without plaster)
    ○ Pre-painted aluminium
    ○ Wooden slats
    ○ WPC slats (Wood Plastic Composite)
    ○ Clay slats
    ○ Gres (porcelain stoneware)
    ○ Ceramic / Clay
• Insulating material:
    ○ Wooden fibre
    ○ Cellular glass
    ○ Hemp fibre
    ○ Cellulose fibre
    ○ Sheep wool
    ○ EPS
    ○ XPS
    ○ Cork

At this point, the e-DSS GUI asks the technician to define the maximum allowable thermal transmittance for walls (U-value). Therefore, the following question is shown:

"What is the target U-value that you want to reach in the vertical opaque surfaces?" At the same time, the e-DSS suggests a possible value according to the existing regulations of the pilot country.

The technician introduces the desired value and the system runs the proper equations in order to calculate the minimum insulation layer thickness that must be adopted in order to get the target U-value inserted by the technician. The result of this calculation is shown to the technician as follows:

"You should adopt at least "s_ins_min" cm of insulation".

Where s_ins_min is the value calculated by the system. In any case, the final choice of the insulating material thickness (s_ins_PANEL) is up</td></tr>
</table>

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

		to the technician, who can either accept the value suggested by the DSS or introduce a higher value through a field of the GUI. The system stores this value in the database since it impacts on the calculation of the installation costs. Moreover, the *s_ins_PANEL* is used by the system to calculate the new thermal transmittance of the wall for each façade; the system stores this value in the database as well. The system calculates the average wall thermal transmittance (for all "i" values), stores it in the database and shows it to the technician through the **e-**DSS GUI.
	Post conditions	The features of the opaque building envelope, after energy retrofit, are fully defined.
Alternative flow and exceptions		NA

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

<table>
<tr><th colspan="3">USE CASE</th></tr>
<tr><td colspan="2">ID</td><td>TC_UC10</td></tr>
<tr><td colspan="2">Name</td><td>e-PANEL: Selection of new windows</td></tr>
<tr><td colspan="2">Goal(s)</td><td>As a technician, I need to be supported in the co-design process of building energy retrofit</td></tr>
<tr><td colspan="2">Actors</td><td>Technician</td></tr>
<tr><td colspan="2">Trigger events</td><td>The technician answers to the question "Coming to the windows, do you want to install a specific commercial solution?"</td></tr>
<tr><td colspan="2">Preconditions</td><td>The e-PANEL solution can be applied to the building renovation. The definition of the opaque building envelope is completed.</td></tr>
<tr><td rowspan="2">Basic Flow</td><td>Description</td><td>Once the definition of the opaque envelope is completed, the technician is guided through the selection process for the new windows. He/she has two possibilities:
• Applying a specific commercial product, for which he/she knows performance and cost;
• Choosing a predefined solution, since he/she does not know the specific commercial product to be used.
Therefore, the e-DSS GUI shows the following question:
"Coming to the windows, do you want to install a specific commercial solution?"
The technician ticks the "yes" checkbox and he/she inserts two values: the thermal transmittance (U_w_new) and the unit cost (c_win). The system sets "g_factor_new" = 0.65.</td></tr>
<tr><td>Post conditions</td><td>The choice of windows is performed.</td></tr>
<tr><td colspan="2">Alternative flow and exceptions</td><td>The technician chooses a predefined solution, since he/she does not know the specific commercial product to be used. He/she checks "no" as an answer to the trigger question and the e-DSS GUI shows the following question:
"Please specify the type of glazing and frame that you want to choose".
The technician, through a drop-down menu, selects one the following solutions: Glazing type (low-emissive double-glazing window or triple-glazed window) and Frame type (wood, PVC, metal with thermal break, metal-and-wood).
According to the selection made, the DSS assigns default values to "U_w_new" and "g_factor_new", and also to the unit cost (c_win)</td></tr>
</table>

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

USE CASE		
ID		TC_UC11
Name		**e-**PANEL: Refurbishment of the existing roof
Goal(s)		As a technician, I need to be supported in the co-design process of building energy retrofit
Actors		Technician
Trigger events		The technician answers to the question "*Do you want to refurbish the existing roof*?"
Preconditions		The **e-**PANEL solution can be applied to the building renovation. The technician completed both the building opaque envelope definition and the windows choice.
Basic Flow	**Description**	The last choice is about the refurbishment of the roof. The technician can select: the insulation of the roof, possible replacement of the pavement/tiles and possible replacement of the weather-protection membrane. The **e-**DSS GUI asks the following question: *"Do you want to refurbish the existing roof?"* The technician selects "yes" and he/she is guided in the selection of the insulating material. The system retrieves the possible options from the configuration file and he/she can choose from a drop-down menu one of the following values: Wooden fibre, Cellular glass, Hemp fibre, Flax fibre, Cellulose fibre, Sheep wool, XPS, Cork. Moreover, the technician inserts the thickness of the insulating material. After that, some more information is needed in order to determine the cost of the renovation process. Indeed, the **e-**DSS GUI asks the following question: *"Do you want to replace also the pavement/tiles?"* The technician selects "yes" and he/she is guided in the selection of pavement/tiles material. The system retrieves the possible options from the configuration file and he/she can choose from a drop-down menu one of the following values: ○ Clay tiles ○ Ceramic tiles ○ WPC slats *"Do you also envisage replacing the weather-protection membrane?"* The answer to these questions has an impact on the cost calculation.
	Post conditions	The refurbishment of the existing roof is completely defined.
Alternative flow and exceptions		Refurbishment of the existing roof: the technician doesn't want to refurbish the existing roof, he/she selects "no" and the system keeps the original "U_roof" value as in existing building (this information is provided by the technician during the execution of TC_UC4 - Provide Building energy data).

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

<table>
<tr><th colspan="3">USE CASE</th></tr>
<tr><td colspan="2">ID</td><td>TC_UC12</td></tr>
<tr><td colspan="2">Name</td><td>Combined Seismic and Energy Retrofit</td></tr>
<tr><td colspan="2">Goal(s)</td><td>As a technician, I need to be supported in the co-design process of combined seismic and energy building retrofit and I want to know if the e-SAFE solutions can be applied to the building.</td></tr>
<tr><td colspan="2">Actors</td><td>Technician</td></tr>
<tr><td colspan="2">Trigger events</td><td>The technician checks "Combined Seismic and Energy Retrofit".</td></tr>
<tr><td colspan="2">Preconditions</td><td>The technician knows the energy performance of the building in its current state and the building seismic zone</td></tr>
<tr><td rowspan="2">Basic Flow</td><td>Description</td><td>The technician checks "Combined Seismic and Energy Retrofit" and the system retrieves from the database the building data having an impact on the possibility to apply or not the e-SAFE solutions (e-EXOS and e-CLT).

Indeed, the DSS checks the number of floors (n_floors) above the ground, and if n_floors < 6 then, through the e-DSS GUI, it asks the technician the following questions:

Is there sufficient space for the crane around the building?

He/she selects "yes"

"Are there any constraints (Cultural Heritage, local regulations) that forbid altering the outer appearance of the building"?

He/she selects "no".

"In the ground floor, openings, doors and door-windows occupy more than 60% of the perimeter?"

He/she selects "no".

"How many facades are attached to other buildings?"

He/she inserts a numerical value equal to 0 (or 1).
Are there at least 3m of free space around the building, without trespassing the property's boundaries?

He/she selects "yes".

Once the technician has answered the questions, he/she clicks the "Confirm" button. The e-DSS runs the algorithm for checking the possibility to apply the e-SAFE solutions and it notifies that both e-CLT and e-EXOS can be used to renovate the building.
The technician makes his/her choice by clicking the "e-CLT" or the e-EXOS" buttons and the technician turn to the next step.</td></tr>
<tr><td>Post conditions</td><td>Both the e-CLT and the e-EXOS solution can be used to renovate the building</td></tr>
</table>

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Alternative flow and exceptions	INAPPLICABILITY of both **e-**SAFE solution (**e-**CLT and **e-**EXOS): 1) the number of floors above the ground is n_floors > 6 and the **e-**DSS GUI shows the following message: "*Sorry, it seems that you cannot apply neither **e-**CLT nor **e-**EXOS, therefore there isn't a combined seismic and energy renovation solution fitting this building. Please try with a simple energy renovation solution!*" The technician clicks "ok" and he/she can start a new renovation solution from the Renovation Project page. Moreover, the system saves the information about the impossibility of having a combined seismic and energy renovation solution for the building in the database. 2) The technician indicates that there isn't sufficient space for the crane around the building and **e-**DSS GUI shows the following message: "*Sorry it seems that you cannot apply the **e-**SAFE solutions because there isn't sufficient space for the crane, Thank you and goodbye!*". The technician clicks "ok" and he is redirected to the **e-**DSS homepage. The system saves the information about the impossibility of having a combined seismic and energy renovation solution for the building in the database 3) The technician indicates that there are some constraints (Cultural Heritage, local regulations) that forbid altering the outer appearance of the building and the **e-**DSS GUI shows the following message: "*Sorry it seems that you cannot apply the **e-**SAFE solutions because of some constrains, Thank you and goodbye!*". The technician clicks "ok" and he/she is redirected to the **e-**DSS homepage. The system saves the information about the impossibility of having a combined seismic and energy renovation solution for the building in the database. 4) The technician indicates that openings, doors, and door-windows in the ground floor occupy more than 60% of the perimeter and the **e-**DSS GUI shows the following message: "*Sorry, it seems that you cannot apply **e-**CLT*" The technician turns to the next question about the number of facades that are attached to other buildings 5) The technician indicates that the number of facades that are attached to other buildings is > 1 and the **e-**DSS shows the following message: "*Sorry, it seems that you cannot apply **e-**EXOS. Do you want to select **e-**CLT?*" The technician clicks "ok" and he/she turns to the next steps for verifying the applicability of **e-**CLT (number of facades that are attached to other buildings). 6) The technician indicates that the number of facades that are

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

	attached to other buildings is > 2 and the **e-**DSS shows the following message: "*Sorry, it seems that you cannot apply neither **e-**CLT nor **e-**EXOS, therefore there isn't a combined seismic and energy renovation solution fitting this building. Please try with a simple energy renovation solution!*" The technician clicks "ok" and he/she can start a new renovation solution from the Renovation Project page. The system saves the information about the impossibility of having a combined seismic and energy renovation solution for the building in the database. 7) The technician indicates that there aren't at least 3 m of free space around the building, without trespassing the property's boundaries. And the **e-**DSS shows the following message: *"Sorry, it seems that you cannot apply **e-**EXOS".* If the **e-**CLT solution can be applied (according to the other checks), the **e-**DSS will suggest the adoption of **e-**CLT, otherwise the system will propose to try with a simple energy renovation solution.
	POSSIBLE INEFFECTIVENESS of **e-**CLT: this alternative flow refers to the additional verifications needed for **e-**CLT to check if the **e-**CLT is an effective solution for seismic improvement. The **e-**DSS shows the following message and questions: *"Fine, it seems that you want to try the effectiveness of **e-**CLT.* *However, before proceeding with the next steps you should answer a few more questions:"* *1)"Is the existing structure (Reinforced Concrete frame) degraded"?* The technician can select from a drop-down menu one of the following answers: • No, the structures are in very good state • The structures are just slightly degraded • The structures are degraded, but they can be easily recovered • The structures are very degraded According to the selection made by the technician, the **e-**DSS assigns to C_{sd} a specific value (see section 2.1.2 for details). *2)"If looking at a typical floor, what is the percentage of the perimeter occupied by balconies"?* The technician can select from a drop-down menu one of the following answers: • < 30% • between 30% and 50% • >50% According to the selection made by the technician, the **e-**DSS assigns

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

	to C_b a specific value (see section 2.1.2 for details). Furthermore, according to other data already known by the DSS (C_{SZ}, C_f and C_{fa}) the **e-**DSS calculates the sum of $C_{tot} = C_{sz} + C_f + C_{fa} + C_{sd} + C_b$) and if $C_{tot} \geq 50$ The **e-**DSS shows the following message: *"Sorry, it seems that – although possible –* ***e-****CLT is not a very effective solution for your building, and would not significantly improve its seismic response"*

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

USE CASE		
ID		TC_UC13
Name		**e-**CLT selection: update of energy data-envelope
Goal(s)		As a technician, I need to be supported in the co-design process of combined seismic and energy building retrofit involving the **e-**CLT.
Actors		Technician
Trigger events		The technician selected "**e-**CLT".
Preconditions		**e-**CLT can be applied to the building
Basic Flow	**Description**	The technician selects "**e-**CLT" and he/she is redirected to the tab for the update of energy data of envelope. The following steps are performed: 1. he/she inserts the CLT panel thickness (in cm), then he/she selects the insulating material from a drop-down menu containing only a predefined list of elements as follows: o Insulating material: ▪ Wooden fibre ▪ Cellular glass ▪ Hemp fibre ▪ Cellulose fibre ▪ Sheep wool ▪ EPS ▪ XPS ▪ Cork 2. He/she selects the external finishing layer from a drop-down as follow: o external cladding material: ▪ Fiber cement with plaster) ▪ Fiber cement (without plaster) ▪ Pre-painted aluminium ▪ Wooden slats ▪ WPC slats (Wood Plastic Composite) ▪ Clay slats ▪ Gres (porcelain stoneware) ▪ Ceramic / Clay At this point, the **e-**DSS GUI asks the technician to define the maximum allowable thermal transmittance values (U_lim). Therefore, the following question is shown: *"What is the target U-value that you want to reach in the vertical opaque surfaces?"* At the same time, the **e-**DSS suggests a value for U_lim according to the existing rules of the pilot country. 3. The technician introduces the desired value and the system runs the proper equations in order to calculate the minimum insulation layer thickness (s_ins_min) that must be installed in the **e-**CLT and

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

		the GUI shows the message: "*You should adopt at least "s_ins_min" cm of insulation".* In any case, the final choice of the insulating material thickness in the CLT is up to the user, who can either accept the value suggested by the **e-**DSS or introduce a higher value. Therefore, he/she inserts the insulating material thickness (in cm). Actually, the insulation thickness applied to the **e-**PANEL (which is installed aside the **e-**CLT in those parts of the envelope with windows) is different from the value envisaged for the **e-**CLT. However, the technician does not need to insert it, since it is calculated by the DSS so as to ensure the same U-value as the **e-**CLT. 4. The system then stores both values of thickness (s_ins_CLT and s_ins_PANEL) as well as the average thermal transmittance for the entire opaque surface, since it is involved in the calculation of the energy performance. 5. The technician is then redirected to the next page for windows choice (USE CASE TC_UC10) and refurbishment of the existing roof (USE CASE TC_UC11).
	Post conditions	The energy data for the building envelope have been updated
Alternative flow and exceptions		NA

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

USE CASE		
ID		TC_UC14
Name		**e-**EXOS selection
Goal(s)		As a technician, I need to be supported in the co-design process of combined seismic and energy building retrofit involving the **e-**EXOS.
Actors		Technician
Trigger events		The technician selected "**e-**EXOS".
Preconditions		The **e-**EXOS solution can be applied to the building renovation
Basic Flow	**Description**	The technician selects "**e-**EXOS" and he/she is redirected to the tab for the update of energy data of envelope (USE CASE TC_UC9), since **e-**EXOS envisages the application of **e-**PANEL to the facades. The technician is finally redirected to the next page for windows choice (USE CASE TC_UC10) and refurbishment of the existing roof (USE CASE TC_UC11).
	Post conditions	**e-**EXOS was selected as solution for seismic retrofit and the technician can proceed with the energy retrofit process.
Alternative flow and exceptions		NA

USE CASE		
ID		TC_UC15
Name		Update of technical system (**e-**THERM)
Goal(s)		As a technician, I need to be supported in the update of technical system (**e-**THERM) for the building to be renovated
Actors		Technician
Trigger events		The technician answer to the **e-**DSS question about the update of technical system
Preconditions		The technician started the co-design process of building renovation
Basic Flow	**Description**	The **e-**DSS GUI shows the following question: *"Do you want to replace your technical systems with the more efficient **e-**THERM solutions?"* The technician's answer is "*yes*" The **e-**DSS asks to the technician to update the following data: 1. Type of Heat pump The technician selects one of the following values from a drop-down menu: Air-to-air (split system), Air-to-water, Water-to-water, Ground-to-water (geothermal) and the **e-**DSS shows the correspondent value of COP in standard conditions. It is up to the technician decides to keep this default value or to modify it.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

		2. Type of Cooling system The **e-**DSS shows the default value of SEER according to the selected heat pump and the technician evaluates to change or to keep it. 3. Type of PV modules The technician selects one of the following values from a drop-down menu: Monocrystalline silicon, Polycrystalline silicon, Amorphous silicon, Thin film (CIGS), Thin film (CdTe); the **e-**DSS sets the correspondent k_PV value 4. PV surface installed The technician inserts a numerical value. 5. Type of PV installation The technician selects one of the following values from a drop-down menu: Roof integrated, Roof mounted (with supporting frame) and Wall mounted and the **e-**DSS sets the consequent f_PV value. 6. Orientation of PV modules The technician selects the orientation of PV modules (North, North-East, East, South-East, South, South-West, West, North-West). However, PV modules should not be placed facing North-East, North, North-West: then, if the technician makes one of these choices the **e-**DSS provides a warning. The **e-**DSS sets the consequent f_esp value. Moreover, there are some data of technical systems that don't involve the user interaction and a default value will be applied; details are available as A3.6
	Post conditions	The technician has provided the needed information about the update of the technical system.
Alternative flow and exceptions		The technician doesn't want to replace the technical system. Therefore, the **e-**DSS keeps the old values for the parameters identified by the codes [28] to [41] as in Appendix 1. These values are available in the **e-**DSS database.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

<table>
<tr><th colspan="3">USE CASE</th></tr>
<tr><td colspan="2">ID</td><td>TC_UC15</td></tr>
<tr><td colspan="2">Name</td><td>Comparison between the pre and post renovation performance</td></tr>
<tr><td colspan="2">Goal(s)</td><td>As a technician, I need to see the final comparison – pre and post renovation performance – of the building so that I can show it to the building manager</td></tr>
<tr><td colspan="2">Actors</td><td>Technician</td></tr>
<tr><td colspan="2">Trigger events</td><td>The technician selected "Compare" button.</td></tr>
<tr><td colspan="2">Preconditions</td><td>The technician has concluded the building renovation co-design process</td></tr>
<tr><td rowspan="2">Basic Flow</td><td>Description</td><td>The technician selects "Compare" button and the system runs the algorithms.

The GUI shows to the technician the following information as results of the performed calculation:
• New Annual energy demand for space heating
• New Annual energy demand for space cooling
• Distribution of heat losses in the building envelope (pie-chart with the percentage of the different heat losses coefficients)
• New Annual Electricity Production from PV
• New Monthly Net Electric Energy Consumption
• New Annual Net Electric Energy Consumption
• New Annual Fuel Consumption
• Non-renewable Primary Energy consumption
• New Total CO_2 Emissions
• New Total operating costs
• New operating costs for each dwelling
And then, by comparing the values pre and post retrofit:
• Energy Savings and CO_2 emission savings
• Savings in the operating costs
• Total costs for the e-SAFE renovation
• Total time for the e-SAFE renovation
• Time of Return of the investment (in years)</td></tr>
<tr><td>Post conditions</td><td>The technician has a clear understanding of the energy and seismic performance before and after the renovation process</td></tr>
<tr><td colspan="2">Alternative flow and exceptions</td><td>NA</td></tr>
</table>

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

2.2.2 **e-**DSS Building Manager use cases

This section collects the use cases related to the exploitation of **e-**DSS from the building manager (Figure 8). The building manager is responsible for collecting the feedback from building owners since their desires and expectations have a relevant impact on the co-design process. Indeed, this information can be used by the technician to refine the renovation solution.

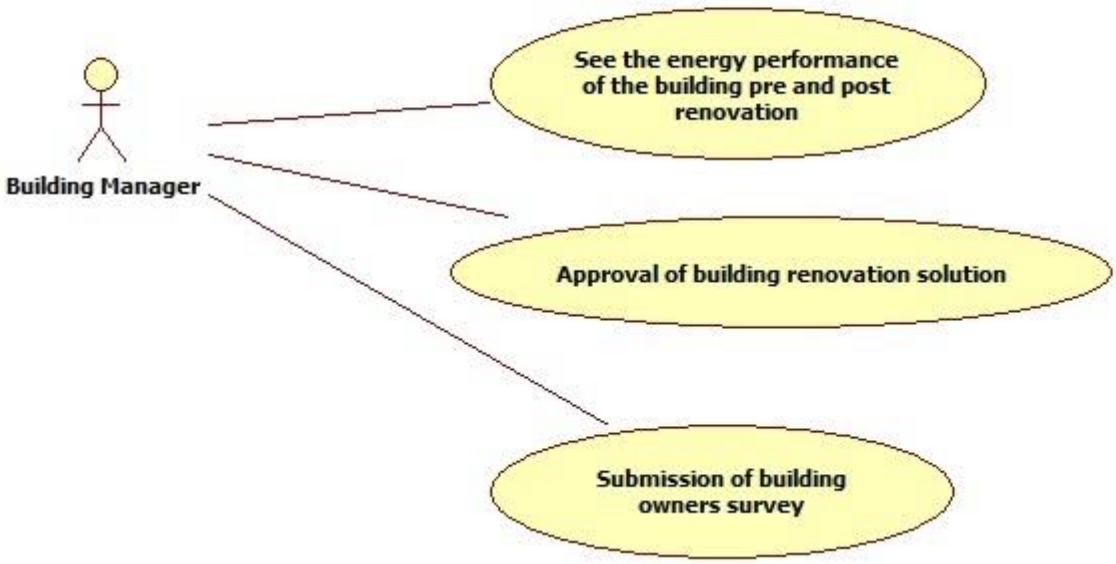

Figure 8: Building Manager use case

The related textual description is provided as follow:

USE CASE		
ID		BM_UC1
Name		See the energy performance of the building pre and post renovation
Goal(s)		As a building manager, I need to see the energy performance of the building pre and post renovation related to all available building renovation solutions.
Actors		Building manager
Trigger events		The building manager clicks the "Building renovation solution" link.
Preconditions		The building manager is already logged in the system. The energy performance of the building in its current state has already been evaluated. There is at least one renovation solution ready for the building.
Basic Flow	**Description**	The building manager accesses the **e-**DSS home page and he/she can see the list of renovation solutions of the building, proposed and implemented by the Technician. He/she selects one of the available renovation solutions and the **e-**DSS shows the followings tabs: Building Information, Building geometric data, Building energy data, System energy data, Building energy performance, Building energy performance post renovation. The building manager can see the

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

		information reported in each tab without the possibility to change them. In particular, the "Building energy performance" tab provides information about the energy performance of the building in its current state. The building manager can download the report clicking on the "Download" button. The "Building energy performance post renovation" tab shows the building renovation performance and the rendering of the building before and after retrofitting, one next to the other, so that he/she can compare them. Moreover, the building manager can download the report clicking on the "Download" button.
	Post conditions	The building has information about the energy performance of the building pre and post renovation
Alternative flow and exceptions		NA

USE CASE		
ID		BM_UC2
Name		Approval of building renovation solution
Goal(s)		As a building manager, I want to approve the building renovation solution
Actors		Building manager
Trigger events		The building manager selected the building renovation solution from the **e-**DSS home page
Preconditions		There is at least one renovation solution for the building.
Basic Flow	**Description**	The building manager accesses the **e-**DSS home page and he/she selects the building renovation solution and shows it to the building owners. The building owners agree on the proposed solution and the building manager clicks the "Approve" button of Building energy performance post renovation tab. He/she uploads the minutes of stakeholders' meeting. The **e-**DSS stores this information in the data base and the status of **e-**DSS project is properly updated so that the technician is aware of this decision.
	Post conditions	The renovation project is formally approved.
Alternative flow and exceptions		The building owners want to enhance the renovation solutions providing their feedbacks. The building manager clicks "Survey" button.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

USE CASE		
ID		BM_UC3
Name		Submission of building owners survey
Goal(s)		As a building manager, I want to collect the building owners' expectations so that the building renovation solution can be refined.
Actors		Building manager
Trigger events		Building manager clicked "Survey" button in the Building energy performance post renovation tab
Preconditions		There is at least one renovation solution for the building.
Basic Flow	**Description**	The building manager accesses the **e-**DSS page with the survey questions aimed to collect the owners' desires and expectations. A set of questions are proposed through the **e-**DSS GUI in order to collect information about: • Their willingness to apply the renovation works to the balconies (glass windows, flooring, parapets, etc.); • the need to restore/legalize possible past interventions implemented without the necessary building permissions (and the corresponding timing and cost); • the choice of the cladding, balcony flooring, windows, etc. • any other requisite or observation. The building manager summarizes the owners' expectations and fills in the survey in order to formalize the decisions taken by the majority of owners. Then, he/she clicks the "submit" button; the survey is stored in the database and it is made available to the technician.
	Post conditions	The survey is submitted and the technician can see it accessing to the **e-**DSS home page
Alternative flow and exceptions		NA

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

2.3 e-DSS requirements

Starting from the consolidated version of use cases, both functional and non-functional requirements are identified and therefore provided in this section.

Functional requirements focus on what the **e-**DSS should do, and formalize the software features affecting the users' experience. In the context of **e-**SAFE project, the functional requirements are defined according to the following template (Table 2):

Table 2: Functional Requirements template

FUNCTIONAL REQUIREMENT ID	DESCRIPTION	NOTE
Unique identifier of the functional requirement (e.g. FR1)	*Textual description of the functionality*	*Some important information to be reported*

While functional requirements focus on what the **e-**DSS should do, non-functional requirements (NFR) define the performance of **e-**DSS and they are essential to ensure the usability and effectiveness of the entire software system. Therefore, the implementation aspects are affected by non-functional requirements. They are described using the template of Table 3:

Table 3: Non -Functional Requirements template

ID	LABEL	DESCRIPTION	PRIORITY	REMARKS
Univocal identifier of the requirements	*Brief definition of the non-functional requirement*	*Description of the non-functional requirement*	*There are three levels defining if the non-functional requirement is mandatory (priority 1), desirable (priority 2) or optional (priority 3);*	*What it is important to underline to better specify the non-functional requirement*

Functional and non-functional requirements are reported in Sections 2.3.1 and 2.3.2 respectively.

2.3.1 Functional requirements

Table 4 collects the high-level FRs that the **e-**DSS should meet.

Table 4: **e-**DSS functional requirements

ID	DESCRIPTION	NOTE
FR1	The **e-**DSS shall allow the user registration and login. This would translate to an insert query on the database.	The **e-**DSS differentiates between different **e-**DSS users (technician and building manager)
FR2	The **e-**DSS shall show an error message if the user provides invalid login parameters	-
FR3	The **e-**DSS shall allow the creation of a new **e-**DSS project. This would translate to an insert query on the database.	--
FR4	The **e-**DSS shall allow the modification of an existing **e-**DSS project. This would translate to an update query on the database.	Modifications are carried out according to the respective user rights (only authorized technician)
FR5	The **e-**DSS shall allow the possibility to add a new renovation solution to the **e-**DSS project.	-
FR6	The **e-**DSS shall allow the possibility to modify an existing renovation solution. This would translate to an update query on the database.	Modifications are carried out according to the respective user rights (only authorized technician)
FR7	The **e-**DSS shall allow seeing all information associated to the **e-**DSS project. This would translate to a select query on the	-

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

	database.	
FR8	The **e-**DSS shall allow inserting the building general information	-
FR9	The **e-**DSS shall allow the interaction with third party services (e.g. geo-localization, PGA value, climate data)	-
FR10	The **e-**DSS shall allow inserting the building geometric information (manually or from IFC file)	-
FR11	The **e-**DSS shall allow inserting the building energy data	-
FR12	The **e-**DSS shall allow inserting the system energy data (energy data for technical systems)	-
FR13	The **e-**DSS shall implement the agreed checks on the data manually entered by the user	-
FR14	The **e-**DSS shall notify if some data manually provided by the user are wrong according to the implemented checks	-
FR15	The **e-**DSS shall allow to see the energy performance of the building in its current state (pre-renovation)	-
FR16	The **e-**DSS shall allow storing in the database all information provided by the user	-
FR17	The **e-**DSS shall allow retrieving data from the database to be shown through the **e-**DSS GUI	-
FR18	The **e-**DSS shall allow updating data in the database according to the user rights	-
FR19	The **e-**DSS shall address the accesses to the database according to the user role and rights	-
FR20	The **e-**DSS shall allow selecting the type of building renovation based on the **e-**SAFE technologies (Energy retrofit, Combined seismic and energy retrofit)	-
FR21	The **e-**DSS shall implement the checks about the applicability of **e-**SAFE solutions (e.g. number of floors)	These checks have to be done for each **e-**SAFE component
FR22	The **e-**DSS shall show clear messages and warnings through the GUI about the inapplicability of **e-**SAFE solutions	-
FR23	The **e-**DSS shall guide the user in the co-design process by means of an interactive process	-
FR24	The **e-**DSS shall allow the definition of the opaque envelope	-
FR25	The **e-**DSS shall allow the selection of new windows	-
FR26	The **e-**DSS shall allow the refurbishment of the existing roof	-
FR27	The **e-**DSS shall propose through the GUI only the feasible renovation solutions.	-
FR28	The **e-**DSS shall allow the update of energy data of envelope (**e-**CLT selection).	-
FR29	The **e-**DSS shall allow to update the technical system (**e-**THERM).	-
FR30	The **e-**DSS shall allow the calculation of building energy needs (actual building and for the building renovated through the **e-**SAFE solutions).	-
FR31	The **e-**DSS shall allow the creation of report about the final comparison – pre and post renovation performance – of the	-

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

	building.	
FR32	The **e-**DSS shall allow the download of reports.	-
FR33	The **e-**DSS shall grant the access to building renovation solutions only to authorized users (technician, building manager).	-
FR34	The **e-**DSS shall show through the GUI relevant information about the adopted renovation solutions.	Only authorized building manager
FR35	The **e-**DSS shall show the building renovation performance and the rendering of the building before and after retrofitting.	Only authorized building manager
FR36	The **e-**DSS shall allow to download the report about the energy performance of the building in its current status and after the renovation process.	Only authorized building manager
FR37	The **e-**DSS shall allow the approval of the building renovation solution.	Only authorized building manager
FR38	The **e-**DSS shall allow filling in and submitting the building owners survey.	Only authorized building manager

2.3.2 Non-functional requirements

Table 5 below collects the NFR that the **e-**DSS system should meet:

Table 5: **e-**DSS non-functional requirements

ID	LABEL	DESCRIPTION	PRIORITY	REMARKS
NFR1	Authentication and authorization mechanism	**e-**DSS system shall grant user access only after user authenticates and authorization is validated.	Priority 1 (mandatory)	This requirement relates to the security and privacy of data used for the different processes and the data which is presented to the end user. A multi-stakeholder system like the **e-**DSS should ensure that only authorized stakeholders exploit its features.
NFR2	Threats preventions	**e-**DSS system shall include prevention for the most common threats	Priority 1 (mandatory)	The requirement is related to the principles of security and privacy of the overall system in order to protect exposure of sensitive data to other systems or end users who do not hold authority for access to this information (e.g. protection from hacking).
NFR3	Data confidentiality	**e-**DSS system shall ensure confidentiality of personal data	Priority 1 (mandatory)	This concerns the principle of data security and privacy. There is information that the system will handle, which should not be accessible to all end users (such as the consumption profiles).
NFR4	Data integrity	**e-**DSS system shall ensure	Priority 1	The result of algorithms

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

		integrity of data	(mandatory)	is highly dependent on the input. In order to ensure the quality of results, the system should ensure data integrity.
NRF5	Availability	**e-**DSS system shall ensure the availability of all services.	Priority 1 (mandatory)	-
NFR6	Performance	**e-**DSS system shall respond to user's actions efficiently under certain workload.	Priority 1 (mandatory)	Performance is also about background processes invisible to users like algorithms computation.
NFR7	Response time	The response time to move between different sections of a form and/or tabs if not displayed on the same page should be 80% within 4 seconds.	Priority 1 (mandatory)	-
NFR8	View page time response	After the user request to view any web site page except the homepage, **e-**DSS system shall display the requested page and the associated content accordingly to the following service level: 80% within 4 seconds.	Priority 2 (desirable)	The speed of view page adds on to the overall system's performance and efficiency.
NFR9	Download time response	After the user requests to download any format of a chosen report, **e-**DSS system shall return the requested document accordingly to the following service level: 80% within 4 seconds.	Priority 2 (desirable)	The speed of downloading contributes to system efficiency and performance.
NFR10	Concurrency of users	**e-**DSS system shall allow for expected users to work concurrently with a maximum response time accordingly to the following service level: 80% within 4 seconds.	Priority 2 (desirable)	-
NFR11	Accessibility	**e-**DSS system shall follow the guidelines from Web Content Accessibility Guidelines (WCAG) 2.1 and Authoring Tool Accessibility Guidelines (ATAG) 2.0 issued by the World Wide Web Consortium (W3C).	Priority 1 (mandatory)	-
NFR12	Cross-browsing	**e-**DSS system interface should work in all most used browsers, and not be linked to any given version of any browser.	Priority 2 (desirable)	Interoperability is of major importance for such a system, since many tools of different manufacturers will be integrated and will need to collaborate.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

NFR13	Scalability	**e-**DSS system should handle an increase in workload without performance degradation.	Priority 1 (mandatory)	-
NFR14	Interoperability	**e-**DSS system should allow the interaction with external systems.	Priority 1 (mandatory)	The interaction with external systems is crucial for certain processes since there might be information required which are derived from 3rd party service.
NFR15	Ease of use	The GUI of **e-**DSS system should promote ease of use being well-designed and self-explanatory for the end user	Priority 2 (mandatory)	The GUI should provide a user-friendly functionality with minimum complexity in order to assist the end user perform the desirable operations mainly in the co-design process.
NFR16	Resilience	**e-**DSS system should maintain continuity of operation when abnormal situations occur.	Priority 1 (mandatory)	-
NFR17	Recoverability	**e-**DSS system should return to a functioning state after a system failure or a system restart.	Priority 1 (mandatory)	-
NFR18	Robustness	**e-**DSS system shall have the ability to not crash at the slightest disturbance.	Priority 1 (mandatory)	-
NFR19	Use of open standards	**e-**DSS system should utilize open standards in order to promote interoperability and accessibility.	Priority 2 (desirable)	-

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

2.4 e-DSS architecture

This section provides information about the refined version of **e-**DSS architecture. The high-level version of **e-**DSS architecture, as it was presented in D4.1, is therefore refined and information about the implementation choice is provided as well. **e-**DSS is a web application implemented according to the MVC architectural pattern; the latter has various advantages: efficient code reuse and parallel development of the application, faster development process, easy modification of the entire application adding or updating new type of views, a simplified testing process. All these benefits are strictly correlated to the MVC pattern that separate an application into three main components: Model, View, and Controller.

The **Model** represents the structure of data, the format and the constraints with which it is stored. It is responsible for the data persistence of the entire application. Therefore, the Model is essentially the database part of the application that is designed and developed according to the **e-**DSS representational model. The **View** is what is presented to the User: the **e-**DSS Graphical User Interface (GUI) displays the model data to the user in understandable way; it consists of static and dynamic pages which are rendered or sent to the user when the user requests them. On the other hand, the View handles the user interaction so that a user can also be allowed to make changes to the presented data. This means that Model component and View components are connected to each other: the View component gets data from the Model in order to be shown to the user who is allowed to make changes to the data that are then used to update the Model. It is important to underline that the overall business logic of the application is handled by the Controller; indeed, the view component displays the data to the users upon receiving the instruction/information from the controller/model. The **Controller** represents the brain of the **e-**DSS; it is responsible for handling the user's requests and response acting as the glue between the Model and the View; it is place where for example algorithms for the calculation of the energy needs and algorithms supporting the co-design and renovation process are implemented.

Figure 9 shows the refined version of **e-**DSS architecture. As depicted in the image, the Model, View and Control blocks are detailed underlining the main macro functionalities and the implementation choice. Starting from the View, the **e-**DSS GUI provides the main functionalities of:

- User Management: it is related to the user authentication such as the registration and the login and everything concerning the operation done by the user accessing the **e-**DSS.
- Building Management: it is related to the operation associated to the building in its current state such as the provision of geometric and energy data.
- Building Renovation Management: involves the features strictly related to the process of renovation co-design of the building, for example when the technician wants to compare the pre and post renovation performances of the building.
- Project Management: addresses the various phases of **e-**DSS project that can be modified by the technician or updated in case he/she wants to add a new renovation solution.

From the development point view, the **e-**DSS is web application involving the front-end part and the back-end part. The View component consists in the front-end which focuses on the visual elements of a web application; indeed, the front-end part of the **e-**DSS is what the user sees and it addresses the user interaction. The front-end is the code that is executed on the client side. This code (HTML, CSS, JavaScript and Vue framework [3]) runs in the user's browser and creates the user interface. The Model and the Controller components belong to the back-end that is manly related to the side of the **e-**DSS users can't see. It involves all the technology required to process the incoming request and generate and send the response to the client. Node.js [4] is the open source server environment that is selected to run the JavaScript code. The back-end includes also

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

the database that organises and store data; this is the Renovation Space Representational Model, a MySQL database [5]. The interaction between the Client and the Server side is implemented as REST services based on Express framework [6].

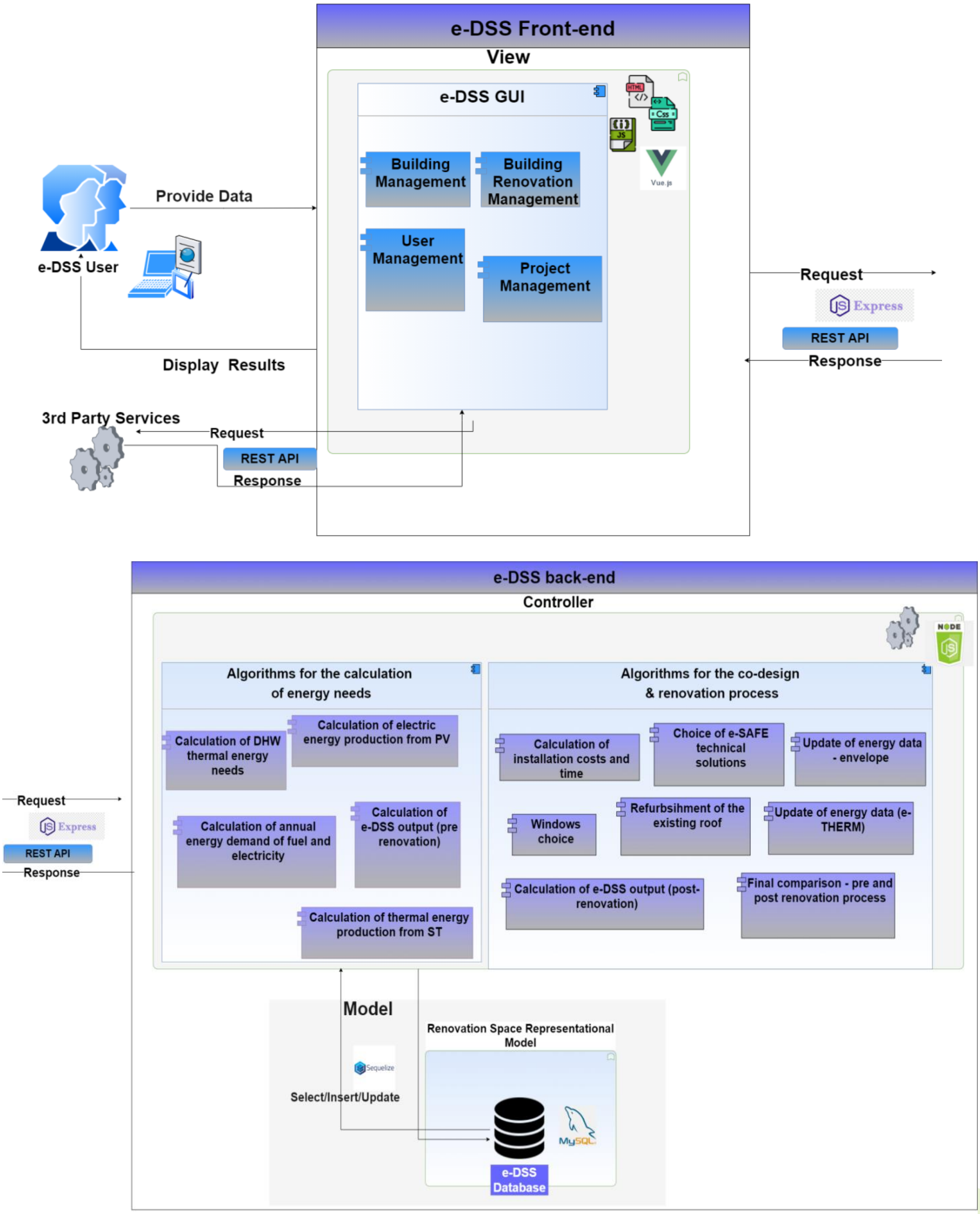

Figure 9: e-DSS Architecture

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

2.5 e-DSS representational model: data input

The user interaction has an important role in the renovation process. Relevant information about the building in its current state must be provided to have a clear understanding of the energy efficiency of the building as a starting point for addressing the co-design renovation process consciously.

As anticipated in D4.1, many inputs are provided from the user through the **e-**DSS GUI and some others could be extrapolated by an IFC file that must be prepared by the technician as a preliminary operation. The information contained in this IFC file needed by the **e-**DSS does not have a high level of detail, and can be gathered through a preliminary and relatively quick survey. The availability of existing drawings, such as plans, elevations and sections, can further facilitate this preliminary step. In any case, a specific template will be shared with the technician as starting point for defining an IFC file compliant with the **e-**DSS.

This phase is usually performed with the support of a BIM software tool. The **e-**DSS is designed and developed in order to be compliant to the Industry Foundation Classes (IFC) [7], the open international standard for Building Information Model (BIM) data that are exchanged and shared among different software applications used by various stakeholders in the construction sector. This means that the requirement of interoperability with other software applications is addressed. However, the **e-**DSS also envisages the manual input of building data in case the IFC file is not available or is not compliant to the expected format. In the first case, some checks on input data are conceived in order to minimize the likelihood of errors during the calculation phase.

It is important to find a trade-off between the time spent by the technician to define the IFC file with the help of external software and the time spent to insert the building information needed for the co-design process in the **e-**DSS GUI. The usage of the first version of the **e-**DSS in the real pilot – and therefore its exploitation in the near future – will be useful for collecting the feedback from the technicians on the usability of the **e-**DSS tool. This feedback will be considered to review the design of the tool so as to improve its user-friendliness and enhance its high-scale exploitation. Summarizing, the IFC file is one possible way to input geometric information in the **e-**DSS: the definition of a template to be shared with the technician as a guideline for providing this file with the expected information is an ongoing activity, and will be prepared in view of the second release of the **e-**DSS (Deliverable D4.5 at M30).

Moreover, there are some data that are involved in the algorithms for the calculation of energy needs. Depending on the user choices, different values of coefficients and variables are used in the equations. These values, as reported in D4.1, come from the Italian National Unification (UNI) Norms and they are mainly related to the climate and air-conditioning systems for thermal comfort in buildings. For instance, the selection of the colour of the external finish corresponds to a specific value of the solar absorption coefficient that is used to calculate the solar gains through the opaque components. Obviously, it is necessary to extend this work to the European context in order to support the virtual pilots as well. Since the virtual pilot buildings will be selected only at M24, this section provides updates with regards of the work done until now but improvements are planned in the next period and will be formally reported in D4.5 due at M30. Therefore, the following UNI Norms were identified in D4.1:

- UNI 11300 Series concerns the "Energy performance of buildings" [8] and the equivalent European Norm is EN ISO 13790[11].
- UNI 10349:2016 [12] regulates the "climate data concerning the heating and cooling of the buildings" in Italy; once the two virtual pilots are selected, the equivalent rule will be applied.
- UNI 10339:1995 regulates the "Air-conditioning systems for thermal comfort in buildings – General, classification and requirements – Offer, order and supply specifications" [13]; as in the previous case, once the two virtual pilots are selected, the equivalent rule will be applied.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

2.6 e-DSS test strategy

This section describes the test strategy selected for the **e-**DSS.

A well-planned test strategy usually contains information about the types of tests and how they are performed. For **e-**DSS, the following testing techniques are taken in account:

- Functional tests: this kind of tests aims at verifying the software functionalities that have been implemented. Specific test cases will be therefore defined and executed during the testing phase of e-DSS by the development team. Test cases are strictly related to use cases defined in this deliverable.
- Usability tests: this kind of tests is particularly important in the field of web application testing. The main goal is to check the interaction between the user and the web application and measure some parameters like the navigation, the general appearance and the user satisfaction. They are usually performed by a small group of testers similar to the target audience of the web application. Indeed, usability tests will be performed by people involved in the real pilot of Catania where the first version of e-DSS is involved. Therefore, in e-SAFE, usability tests are conceived in order to verify that the e-DSS is easy to use and follow the users' expectations. Moreover, corrections will be applied if weaknesses will be identified during the usage of the tool.
- Performance tests: this kind of tests evaluates the behaviour of the application under workload conditions similar to those expected in reality. In the context of the project, non-functional requirements represent the starting point to perform this kind of tests that can be done manually or with the support of performance testing tool.

Moreover, in accordance with the ENG policy, a security assessment will be performed before the **e-**DSS publication on ENG server in order to identify and address possible **e-**DSS security vulnerabilities such as unauthorized access to data.

Another important aspect of a testing strategy is the definition of specific templates supporting the testing activity. For this reason, functional tests will be defined according to the following test case template:

Table 6: Test case template – functional tests

TEST CASE ID	TEST CASE DESCRIPTION	TEST STEPS	TEST DATA	EXPECTED RESULTS	ACTUAL RESULTS	PASS/FAIL
<a sequential reference number>	<the functionality or behaviour that is checked>	<List of steps (action) done by the user during the test>	<Data involved in the test>	<The expected results as it were defined in the related use case description>	<Report here results obtained executing the test>	<**Pass** if actual results are the same of expected results. **Fail** if they are different>

Moreover, as an outcome of the usability tests, the template shown in Table 7 will be adopted in order to properly formalise the bug fixing reporting.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Table 7: Bug Report template – Usability tests

ID number	<a unique reference number>
Name	<short name of the bug>
Reporter	<Full name>
Submit Date	<Date>
Summary	<Description of the bug>
Steps to reproduce	<Sequence of steps to reproduce the same situation in which the bug occurred>
Expected result	<Description of user feedback>
Actual result	<Results obtained using the **e-**DSS >
URL	<Please provide there the **e-**DSS url as it is in the browser>
Browser	<Name of the browser used>
Severity	S1 (Blocker) – a bug completely blocks the execution of defined functionality and we can't miss it S2 (Critical) – an error blocks some part of the functionality but there is another way to overpass it S3 (Major) – a bug which shows incorrect work of a particular part of the developed functionality. It happens not because a particular function is not working but because it works not properly S4 (Minor) – a bug which doesn't actually belong to the functionality of the product. Usually, Minor severity is marked for those errors which mostly belong to the usability of the developed software (graphical interface and the logic of interaction with the front-end part)
Assigned to	ENG development team
Priority	P1 (High) – a defect must be primarily fixed; P2 (Medium) – it can be fixed later when a bug report contains no bugs with a high level of priority; P3 (Low) – it's fixed last when all the bugs with a higher level of priority have been fixed.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

3. RENOVATION SPACE REPRESENTATIONAL MODEL

This chapter describes the final version of the renovation space representational model of the **e-**DSS, aimed to support the co-design activity in the Italian pilot and the virtual pilots. Updates of information reported in D4.1 are provided, in particular with regards to entities and attributes, and the relationship among the identified entities. As a result, also the **e-**DSS data model is updated.

3.1 Entity – Relationship model

After the submission of D4.1, a deep analysis was done to refine the entity – relational model of **e-**DSS in a way that allows covering also the virtual pilots.

The main update is related to the computation of costs and time for the **e-**SAFE envelope solutions (**e-**CLT, **e-**PANEL) and the **e-**THERM. The technical specification of **e-**EXOS are still being studied (e.g. computation of costs and time) and will be integrated in the final version of **e-**DSS due at M30.

Moreover, the co-design renovation process was revised in detail and this allowed improving the definition of the *Renovation Solution* as the central entity of the **e-**DSS renovation space representational model. The Renovation Solution is therefore detailed and the list of related attributes is updated as well. In this way, it is possible to have a clear understanding of the available **e-**SAFE renovation solutions, when they can be applied and what benefits are strictly dependent on their adoption. Moreover, some relevant information such as the time and costs for the installation of **e-**SAFE renovation solutions give an overall picture of the financial opportunities coming from the adoption of **e-**SAFE renovation system.

The entity *Renovation Solution Intermediate Result* is introduced in order to support the functional requirements of having information about the intermediate result of equations involved in the algorithms for the calculation of energy needs and algorithms for the co-design and renovation process. This is important to monitor and assess the overall calculation process.

The main outcome of this work is presented in the following figures depicting the updated version **e-**DSS relational schema, split in more images for the sake of readability. The complete list of the entities and their attributes is provided in Appendix 4, underlining the entities and attributes that have been added to the first version officially reported in D4.1.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

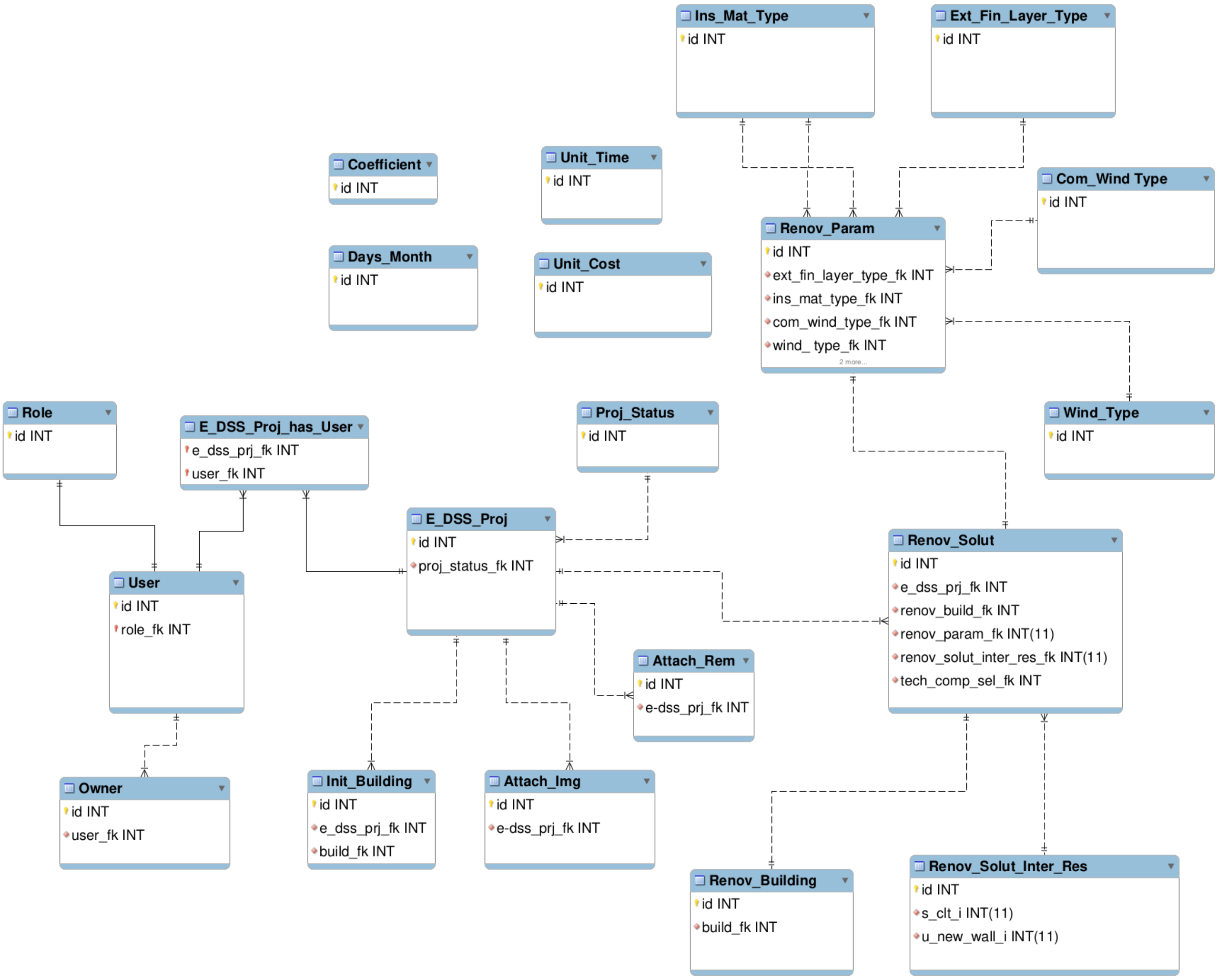

Figure 10: e-DSS relational scheme – part 1

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

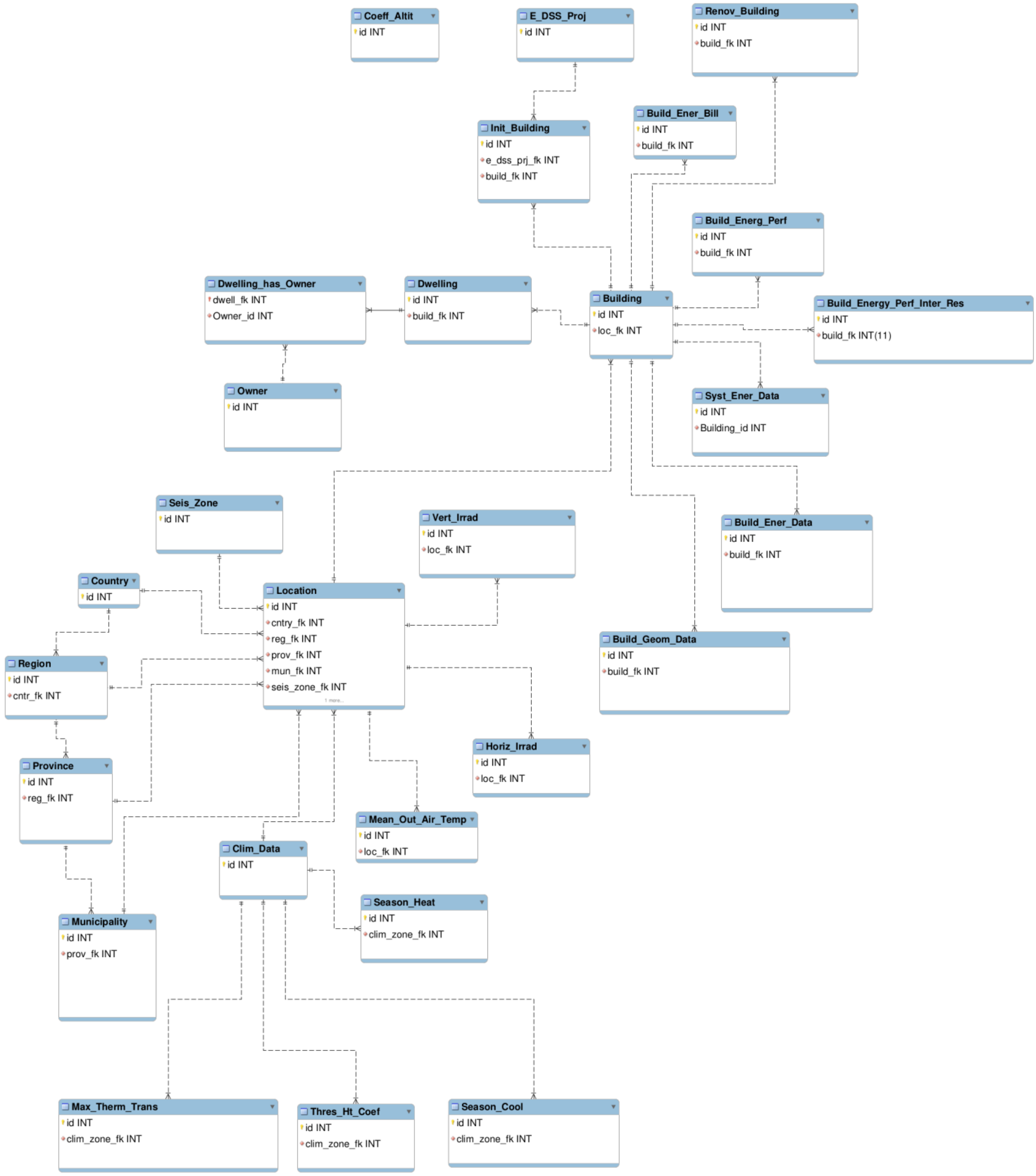

Figure 11: e-DSS relational scheme – part 2

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

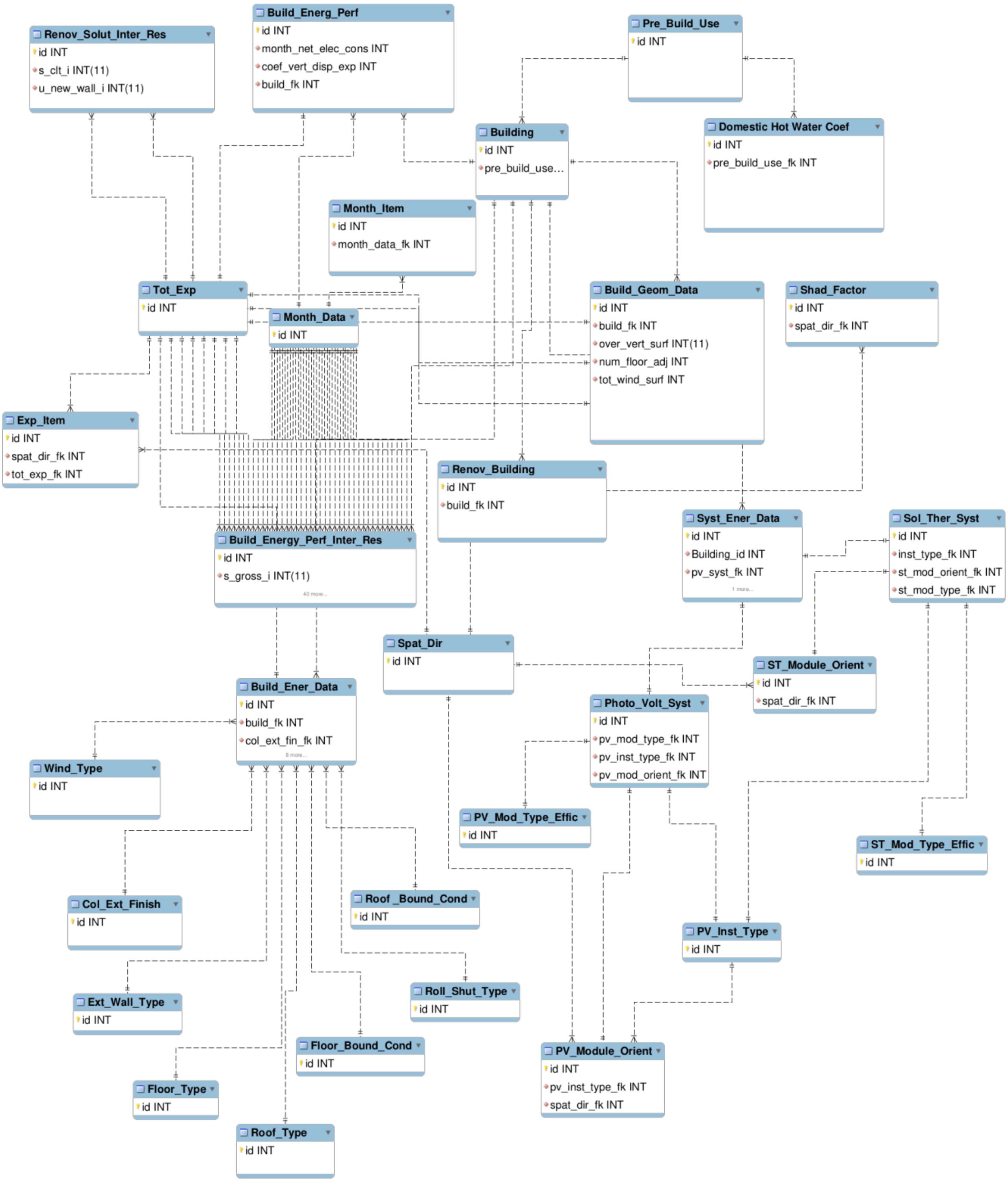

Figure 12: e-DSS relational scheme – part 3

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

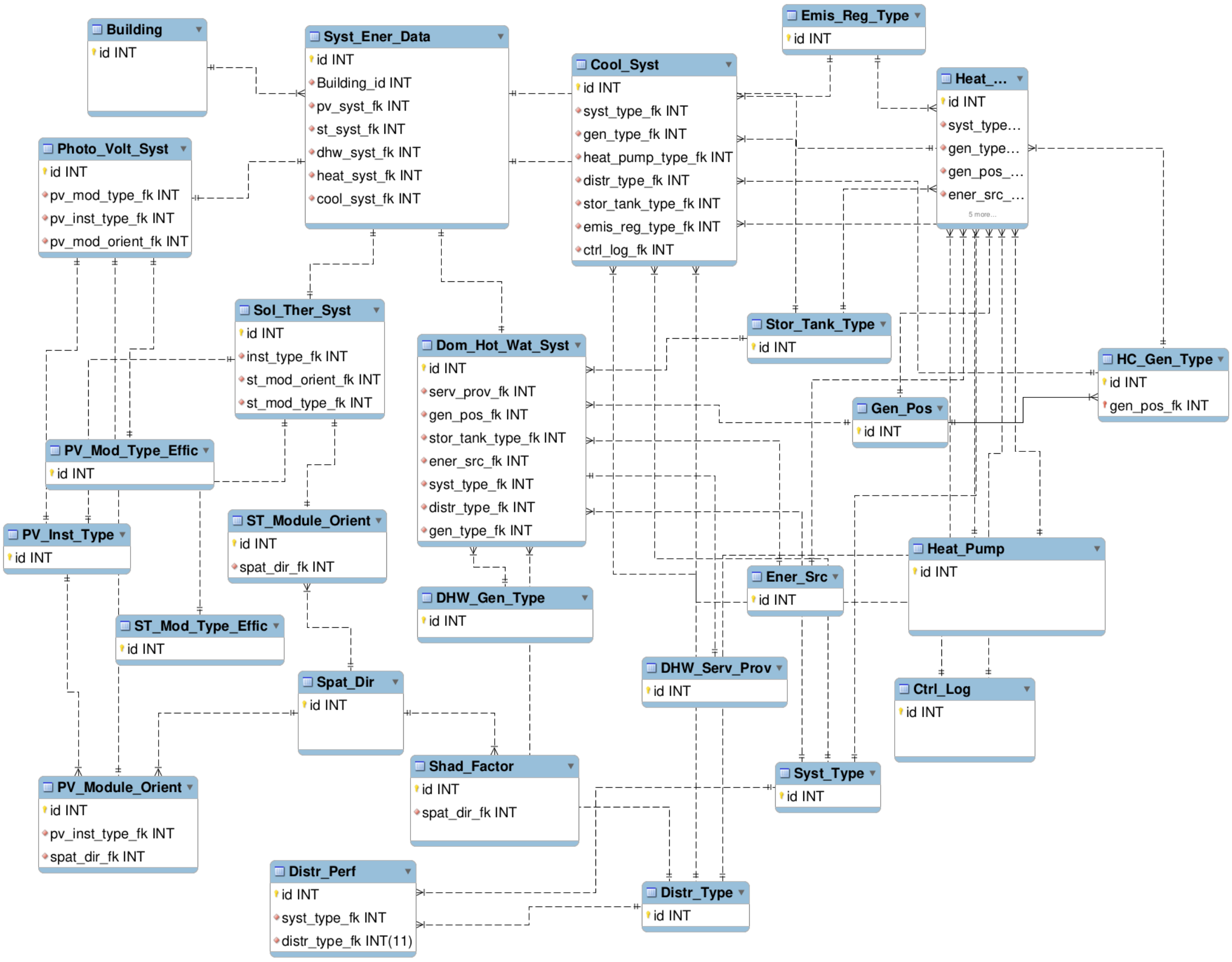

Figure 13: e-DSS relational scheme – part 4

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

As already done for D4.1, the relationships among the identified entities are defined in order to reflect the updated version of **e-**DSS relational schema. Indeed, Table 8 provides the updated list of relationships identified for each entity belonging to the data model, where it is specified: the relationship (**Has, IsA, Uses**), the name of involved entities (column **Entity 1** and column **Entity 2**) and the multiplicity of the relationship (**One-to-One, One-to-Many, Many-to-Many**).

For example, the **e-**DSS Project is composed by (**Has**) the Initial Building (this entity defines the building in its current state); on the contrary, the Initial Building cannot exist without the **e-**DSS Project. One **e-**DSS project can have only one Initial Building and one Initial Building is linked to only one **e-**DSS project (**One-to-One**).

The entity Initial Building is a particular case (**IsA**) of the building entity; one Initial Building is connected only to one building entity and one building entity is connected only to an Initial Building (**One-to-One**).

The entity Building Energy Data requires (**Uses**) the entity Windows Type since the selection of Windows Type is needed in order to compute the energy performance of the building in its current state. One Windows Type can be connected to many Building Energy data (for example the Single glazing could be present in more than one building) and one Building Energy data is connected only to one Windows Type **(One-to-Many).**

The entity Owner "belongs to" (**Has**) the entity Dwelling; one owner can rely to several dwellings and a dwelling can be linked to several owners **(Many-to-Many).**

Table 8: relationships of Renovation space representational ER model (updated)

Relationship	Entity 1	Entity 2	Multiplicity
Has	e-DSS Project	Initial Building	One-to-One
Has	e-DSS Project	Attached image	One-to-Many
Has	e-DSS Project	Attached Remark	One-to-Many
Has	e-DSS Project	Renovation Solution	One-to-Many
Has	e-DSS Project	User	Many-to-Many
Has	e-DSS Project	Proj_Status	One-to-Many
IsA	Initial Building	Building	One-to-One
IsA	Renovated Building	Building	One-to-One
Has	Building	Location	One-to-Many
Has	Building	Predominant Building Use	One-to-Many
Has	Building	Building Geometric Data	One-to-One
Has	Building	Building Energy Data	One-to-One
Has	Building	Systems Energy Data	One-to-One
Has	Building	Building Energy Performance	One-to-One
Has	Building	Building Energy Performance Intermediate Result	One-to-One
Has	Building	Building Energy Bill	One-to-One
Has	User	Owner	One-to-One

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Has	Building	Dwelling	One-to-Many
Has	Owner	Dwelling	Many-to-Many
Has	Building Energy Performance	Month Data	One-to-One
Has	Month Data	Month Item	One-to-Many
Has	Renovation Solution	Renovated Building	One-to-One
Has	Renovation Solution	Renovation Parameter	One-to-One
Has	Renovation Solution	Renovation Solution Intermediate Result	One-to-One
Uses	Building Energy Data	Colour of the external finish	One-to-Many
Uses	Building Energy Data	Type of external walls	One-to-Many
Uses	Building Energy Data	Floor Type	One-to-Many
Uses	Building Energy Data	Roof Type	One-to-Many
Uses	Building Energy Data	Windows Type	One-to-Many
Uses	Building Energy Data	Type of roller shutter	One-to-Many
Uses	Building Energy Data	Floor Boundary Condition	One-to-Many
Uses	Building Energy Data	Total Exposure	One-to-Many
Uses	Building Energy Data	Roof Boundary Condition	One-to-Many
Has	Building Geometric Data	Total Exposure	One-to-Many
Has	Total Exposure	Exposure Item	One-to-Many
Uses	Location	Coeff_Altitude	One-to-Many
Uses	Location	Country	One-to-Many
Uses	Location	Region	One-to-Many
Uses	Location	Province	One-to-Many
Uses	Location	Municipality	One-to-Many
Has	Country	Region	One-to-Many
Has	Region	Province	One-to-Many
Has	Province	Municipality	One-to-Many
Uses	Climate Data	Location	One-to-Many
Uses	Mean Outdoor Air Temperature	Location	One-to-Many
Uses	Vertical Irradiation	Location	One-to-Many
Uses	Horizontal Irradiation	Location	One-to-Many
Uses	Seis_Zone	Location	One-to-Many
Uses	Climate Data	Seasonal Heating	One-to-Many
Uses	Climate Data	Seasonal Cooling	One-to-Many

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Uses	Climate Data	Max Thermal Transmittance	One-to-Many
Uses	Climate Data	Threshold Ht Coefficient	Many-to-Many
Has	User	Role	One-to-Many
Uses	Domestic Hot Water Coefficient	Predominant Building Use	One-to-Many
Has	Systems Energy Data	PhotoVoltaic System	One-to-One
Has	Systems Energy Data	Solar Thermal System	One-to-One
Has	Systems Energy Data	Domestic Hot Water System	One-to-One
Has	Systems Energy Data	Heating System	One-to-One
Has	Systems Energy Data	Cooling System	One-to-One
Uses	Domestic Hot Water System	Type of System	One-to-Many
Uses	Domestic Hot Water System	DHW Service Provided	One-to-Many
Uses	Domestic Hot Water System	DHW Generator Type	One-to-Many
Uses	Domestic Hot Water System	Generator Position	One-to-Many
Uses	Domestic Hot Water System	Distribution Type	One-to-Many
Uses	Domestic Hot Water System	Storage Tank Type	One-to- Many
Uses	Domestic Hot Water System	Energy Source	One-to-Many
Uses	Distribution Performance	Type of System	One-to-Many
Uses	Distribution Performance	Distribution Type	One-to-Many
Uses	PhotoVoltaic System	PV Module Type Efficiency	One-to-Many
Uses	PhotoVoltaic System	PV-ST Installation Type	One-to-Many
Uses	PhotoVoltaic System	PV Module Orientation	One-to-Many
Uses	PV Module Orientation	PV-ST Installation Type	One-to-Many
Uses	Solar Thermal System	ST Module Type Efficiency	One-to-Many
Uses	Solar Thermal System	PV-ST Installation Type	One-to-Many
Uses	Solar Thermal System	ST Module Orientation	One-to-Many
Uses	Heating System	Type of System	One-to-Many
Uses	Heating System	HC Generator Type	One-to-Many
Uses	Heating System	Distribution Type	One-to-Many
Uses	Heating System	Storage Tank Type	One-to-Many

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Uses	Heating System	Emission and regulation type	One-to-Many
Uses	Heating System	Control logics	One-to-Many
Uses	Heating System	Generator Position	One-to-Many
Uses	Heating System	Heat Pump	One-to-Many
Uses	Cooling System	Type of System	One-to-Many
Uses	Cooling System	HC Generator Type	One-to-Many
Uses	Cooling System	Distribution Type	One-to-Many
Uses	Cooling System	Storage Tank Type	One-to-Many
Uses	Cooling System	Emission and regulation type	One-to-Many
Uses	Cooling System	Control logics	One-to-Many
Uses	Cooling System	Heat Pump	One-to-Many
Uses	Cooling System	Energy Source	One-to-Many
Uses	Renovation Parameter	Insulating Material Type	One-to-Many
Uses	Renovation Parameter	External Finishing Layer Type	One-to-Many
Uses	Renovation Parameter	External Roof Layer Type	One-to-Many
Uses	Renovation Parameter	Commercial Windows Type	One-to-Many
Uses	Spatial Direction	Exposure Item	One-to-Many
Uses	Spatial Direction	Vertical Irradiation	One-to-Many
Uses	Spatial Direction	Shading Factor	One-to-Many
Uses	Spatial Direction	PV Module Orientation	One-to-Many
Uses	Spatial Direction	ST Module Orientation	One-to-Many

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

4. CALCULATION OF THE ENERGY NEEDS

As already explained, the **e-**DSS includes a code for the calculation of the energy needs in the building that must be renovated, accounting for the energy consumption for space heating, space cooling and DHW preparation. The final aim of the code consists in evaluating the primary energy needs, the CO_2 emissions and the operating costs both for the actual building and for the building renovated through the **e-**SAFE solutions, and thus the potential savings ensured by **e-**SAFE. The input data needed to feed the proposed code are reported in Appendix 1, while Appendix 2 and Appendix 3 contain the equations and explain the main hypotheses and assumptions. These equations hold for both the actual (Appendix 2) and the renovated (Appendix 3) building: in the second case, however, a series of input data need to be updated.

All geometric data are imported from a BIM/IFC file prepared by the technician before using the **e-**DSS with a preliminary identification of the surfaces that will be treated with **e-**PANEL (e.g., in correspondence of the openings) and **e-**CLT. The next release of the software will make this process easier and semi-automated in order to reduce the burden from the user's side. Regarding the thermal features of the building envelope and the energy systems, they are mainly selected from drop-down menus according to the choices of the user. The user is not required to perform any preliminary calculation.

It is here worth mentioning that the algorithms rely on the quasi-stationary approach described in the Standards UNI 11300:1 [8], UNI 11300:2 [9] and UNI 11300:4 [10], which are in turn based on the European EN 13790 Standard [11]. Such an approach is grounded on stationary monthly energy balances, starting from average monthly values of the main climate data. As a result, the code calculates the monthly – and the annual – energy flows for the above listed energy services. In the current version of the tool, only the climate data for Italy – as gathered from UNI 10349-1:2016 Standard [12] – is implemented in the software. This also implies fixed conventional periods for space heating and cooling as dictated by Italian regulations. However, the second release of **e-**DSS will allow selecting the location of the building to be renovated everywhere within the EU boundaries, while also automatically extracting the relevant climate data from the freeware PVGIS EU web-service [14] and allowing the user to freely select the heating and cooling periods.

Further simplifications are introduced to the equations reported in the Standards, in order to limit the number of input data required to the user. Indeed, the code included in the **e-**DSS is not aimed at providing extremely precise results: its main scope consists in assisting the co-design process by showing the owners the potential outcomes of the **e-**SAFE solutions in terms of energy savings and reduction of the energy bills. According to preliminary estimations, the discrepancy between the **e-**DSS results and more precise commercial software tools is below 20%.

Please also observe that in case the selected building has no thermal systems in its current state, the code considers a fictitious ordinary thermal system with low energy performance. Indeed, no thermal system would mean zero energy consumption, but also the impossibility of ensuring thermal comfort: instead, the comparison between actual and renovated building must be based on the same level of comfort. Then, in this case, the **e-**DSS would answer the following question: "How much would I save if, instead of an ordinary thermal system, I decide to install the **e-**THERM solution to provide thermal comfort in my building?" One more important point is that energy balances are solved at the building scale, and not for each apartment. In case of many apartments with different thermal systems, the user will select the most frequent one.

Once a decision is made about the selected **e-**SAFE solutions, with the building owners and during the co-design stage, the designer (i.e. engineer or architect) will then use other software tools, not included in **e-**SAFE, to carry out its design calculations, generate all documents needed to get the necessary legal permissions and prepare the detailed design of the renovation system.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

5. CONCLUSION

This deliverable provides the low-level functional specification of **e-**DSS software tool, as well as detailed information about the final version of the Renovation space representational model.

After the submission of D4.1, ENG in collaboration with UNICT has carried out a deep analysis of the **e-**DSS aimed at supporting both the Italian and the virtual pilots. This activity allowed to:

- update the **e-**DSS data model in order to support the virtual pilots;
- refine the specification of **e-**DSS in terms of use cases, functional and non-functional specification and low-level **e-**DSS architecture so as to deliver the **e-**DSS software tool;
- introduce the **e-**DSS abacus of solutions;
- define the **e-**DSS testing strategy.

Indeed, the **e-**DSS data model is improved and Italian and virtual pilots will rely on this version. Detailed information about the update with respect to deliverable D4.1 is provided through the **e-**DSS data model schema defining entities, attributes, and their relationships.

The **e-**DSS specification, which was introduced in D4.1, is further detailed in order to support the development activity of the tool. The **e-**DSS is a web application using Node.js as API back-end and Vue.js as a frontend. The **e-**DSS data base relies on MySQL as database relational management system and Express framework is used to implement the interaction between the Client and the Server side of **e-**DSS tool

Regarding the input data feeding the data base, as anticipated in D4.1, many inputs are provided from the user through the **e-**DSS GUI while some others could be extrapolated by an IFC file that must be prepared by the technician as a preliminary operation. Moreover, there are some data that are involved in the algorithms for the calculation of energy needs. Depending on the user choices on the input data, different values of coefficients and variables are used in the equations. These values, as reported in D4.1, mainly come from the Italian National Unification (UNI) Norms and they are related to climate data and air-conditioning systems specifications for thermal comfort in buildings. However, this report provides an update about the possibility to extend this work to the European context in order to support the virtual pilots as well. For example, climate data will be automatically extracted from the from the freeware PVGIS EU web-service. Since the virtual pilot buildings will be selected only at M24, it cannot be excluded that some updates about this topic will be formally reported in D4.5 due at M30.

Table 9 resumes the main expected differences between the first and the second release of the **e-**DSS.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Table 9: expected variations in the **e-**DSS from the first (D4.3) to the second release (D4.5)

	FIRST RELEASE	SECOND RELEASE
Deliverable	D4.3	D4.5
Due date	M15	M30
Weather data	Assigned as from UNI 10349:2016, and valid only for Italian locations.	Extracted from PVGIS EU web-service, starting from latitude and longitude of the site, and after some simple processing by the same **e-**DSS.
Geometry input	Manual. The 3D model in the IFC file has only a graphical function.	Some geometrical data (window surfaces, opaque surfaces, height) can be read from the IFC file. If this does not work, manual input will still be possible. We will evaluate the possibility to consider some simpler representations like gbXML [15]
Duration of the heating season	Established according to Italian regulations, as a function of the national climate zones	Based on the ratio of the monthly heat gains to the monthly heat losses, as explained in UNI 11300:1, but also with the possibility for the user to freely assign these periods.
Duration of the cooling season	Based on the ratio of the monthly heat gains to the monthly heat losses, as explained in UNI 11300:1,	As before, but also with the possibility for the user to freely assign these periods.
Status of the existing RC structure	Degradation can be described through four different levels, which determines a score.	The technician can also upload pictures representing the most degraded parts of the structure, as a warning for the building manager.
e-EXOS	Implemented only in terms of feasibility checks.	Implemented also in terms of costs and time of the renovation works.
e-CLT and **e-**EXOS	Not feasible above six floors.	The maximum number of floors can be modified according to the results of the ongoing research.
U-value	The technician inserts the target U-value that the walls should reach after renovation. The **e-**DSS shows a message reporting the suggested U-value according to the Italian regulations.	Adding target U-value according to the regulations in the European Country where the building is located.
Unit costs	Determined as for December 2021 and relating to the Italian market.	Updated and extended to other European countries.
Time of renovation	They are based on the unit time of installation for **e-**CLT and **e-**PANEL.	This approach, as well as the value of these unit times, will be verified and refined.
Comparison pre- vs. Post-renovation	It is based on the simple Time of Return	It will consider the discount rate, and will also include other advantages such as the lower losses in case of earthquakes
e-DSS uses cases	Technician use cases.	Technician and Building Manager use cases.
Edit **e-**DSS project	The technician can modify only the **e-**DSS projects for which the building renovation wasn't performed yet.	The technician can modify the **e-**DSS project; previous information and results are always available.

Finally, this deliverable provides information about the **e-**DSS testing strategy relying on functional, usability and performance tests. Moreover, in accordance with ENG policy, a security assessment will be performed before the **e-**DSS publication on ENG server in order to identify and address possible **e-**DSS security vulnerabilities such as unauthorized access to data.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

ACKNOWLEDGEMENTS

This deliverable was carried out in the framework of the *Energy and seismic affordable renovation solutions* (**e-**SAFE) project, which has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 893135.

REFERENCES

Internal references

[1] **e-**SAFE D4.1 Renovation Space Representational Model

External references

[2] UML use case diagrams [Online]. Available from: https://www.uml-diagrams.org/use-case-diagrams.html. [Accessed 11.10.2021]

[3] Vue.js - a progressive framework for building user interfaces [Online]. Available from: https://vuejs.org/v2/guide/ [Accessed 18.10.2021]

[4] Node.js - JavaScript runtime [Online]. Available from: https://nodejs.org/en/. [Accessed 18.10.2021]

[5] MySQL Database service [Online]. Available from: https://www.mysql.com/. [Accessed 18.10.2021]

[6] Expressjs framework. [Online]. Available from: https://expressjs.com/. [Accessed 18.10.2021]

[7] Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries — Part 1: Data schema [Online]. Available from: https://www.iso.org/standard/70303.html. [Accessed 25.10.2021]

[8] UNI 11300-1:2014. Prestazioni energetiche degli edifici - Parte 1: Determinazione del fabbisogno di energia termica dell'edificio per la climatizzazione estiva ed invernale. Ente Italiano di Normazione, 2014 (in Italian). [Accessed 03.11.2021]

[9] UNI 11300-2:2019. Prestazioni energetiche degli edifici - Parte 2: Determinazione del fabbisogno di energia primaria e dei rendimenti per la climatizzazione invernale, per la produzione di acqua calda sanitaria, per la ventilazione e per l'illuminazione in edifici non residenziali. Ente Italiano di Normazione, 2019 (in Italian). [Accessed 03.11.2021]

[10] UNI 11300-4:2016. Prestazioni energetiche degli edifici - Parte 4: Utilizzo di energie rinnovabili e di altri metodi di generazione per la climatizzazione invernale e per la produzione di acqua calda sanitaria. Ente Italiano di Normazione, 2016 (in Italian). [Accessed 03.11.2021]

[11] ISO 13790:2008 Energy performance of buildings — Calculation of energy use for space heating and cooling [Online]. Available from: https://www.iso.org/standard/41974.html. [Accessed 03.11.2021]

[12] UNI 10349-1:2016. Riscaldamento e raffrescamento degli edifici - Dati climatici - Parte 1: Medie mensili per la valutazione della prestazione termo-energetica dell'edificio e metodi per ripartire l'irradianza solare nella frazione diretta e diffusa e per calcolare l'irradianza solare su di una superficie inclinata. Ente Italiano di Normazione, 2016 (in Italian). [Accessed 03.11.2021]

[13] UNI 10339:1995. Impianti aeraulici a fini di benessere. Generalità, classificazione e requisiti. Regole per la richiesta d'offerta, l'offerta, l'ordine e la fornitura. Ente Italiano di Normazione, 2016 (in Italian). [Accessed 03.11.2021]

[14] PVGIS EU web-service [Online]. Available from: https://re.jrc.ec.europa.eu/pvg_tools/it/#MR. [Accessed 06.12.2021]

[15] Green Building XML schema [Online]. Available from: https://www.gbxml.org/. [Accessed 05.01.2022]

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

APPENDIX 1: Input data in the e-DSS

Table 10 provides the updated version of input data needed to feed the algorithms and the equations representing the core of the **e-**DSS business logic.

Table 10: User Inputs – updated

N.rif.	PARAMETER	*USER INPUTS and BIM/IFC*			
		GENERAL DATA	Source	Input from:	Note
1	CITY	Province		User Input/ GPS	
2	COMM	Municipality		User Input/ GPS	
3	ADDR	Address		User Input/ GPS	
4	ϴ_HEAT	Heating set point temperature		User Input/ GPS	UPDATED
5	C_{PER}	Year of construction		User Input	
6	B_{USE} \ RES	Predominant intended building use		User Input	
7	ϴ_COOL	Cooling set point temperature		User Input	UPDATED

		GEOMETRIC DATA	Source	Input from:	
8	n_floors	Overall number of floors above the ground		User input	UPDATED
9	n_heat	Number of heated floors		User input	ADDED
10	n_apt	Number of dwellings		User input	
11	H_tot	Building height		User input	
12	Length_i	Length of each façade (for each orientation i = 1-8)		User input	ADDED
13	n_Adj_floors_i	Number of heated floors touching an adjacent building (i = 1-8) (or touching the ground		User input	UPDATED
14	S_W,i	Total windows surface (for each orientation i = 1-8)		User input	
15	V_g	Overall GROSS heated volume		User input	
16	V_net	Overall NET heated volume		User input	
17	S_floor	GROSS surface of the ground floor		User input	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

18	S_net_k	NET surface of EACH dwellings (k = 1 … n_apt)		User input	UPDATED
18_1	mill_value	Millesimal Value		User input	NEW
18_2	own_quot	Ownership Quote		User input	NEW
18_3	full_name	Full Name		User input	NEW

		ENERGY DATA - building	Source	Input from:	
19	α_v \ α_ho	Solar absorption coefficient (colour of walls and roof)	UNI EN ISO 13790:2008	User input - drop down menu	
20	b_tr_U_f	Boundary condition - FLOOR	UNI EN ISO 13790:2008	User input - drop down menu	
21	b_tr_U_r, ROOF	Boundary condition - ROOF	UNI EN ISO 13790:2008	User input - drop down menu	
22	U_wall, C_mean	Type of WALLS		User input - drop down menu	
23	U_floor	Type of FLOOR		User input - drop down menu	
24	U_roof	Type of ROOF		User input - drop down menu	
25	U_w \ g_factor	Type of WINDOWS	UNI EN ISO 13790:2008	User input - drop down menu	
26	R_sh, BOX	Presence and type of ROLLER SHUTTER	UNI EN ISO 13790:2008	User input - drop down menu	
27	BOX	ROLLER SHUTTER BOXS (Yes / No)		User input - drop down menu	DELETED
27_1	BALC_i, F_sh_i_j	Balconies on each facade (i = 1-8) (Yes / No)		User input - drop down menu	
27_2	REC	Mechanical ventilation (with possible heat recovery)		User input - drop down menu	

		ENERGY DATA - systems	Source	Input from:	
28		Domestic Hot Water production system (Yes / No)		User input - drop down menu	
28_1		Service provided (only DHW, combined)	UNI EN ISO 13790:2008	User input - drop down menu	
28_2		Type of system (centralized, autonomous)	UNI EN ISO	User input - drop	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

			13790:2008	down menu	
29	eta_gen_W	Type of heat generator for DHW	UNI EN ISO 13790:2008	User input - drop down menu	
29_1	eta_gen_W	Position of the DHW heat generator (indoors, outdoors)	UNI EN ISO 13790:2008	User input - drop down menu	
29_2	LHW, EF, PEF	Energy source for DHW	UNI EN ISO 13790:2008	User input - drop down menu	
30_1	eta_dist_W	Type of distribution for DHW (insulated or not)	UNI EN ISO 13790:2008	User input - drop down menu	
30_2	C_st	Storage tank (no, scarcely or well insulated)	UNI EN ISO 13790:2008	User input - drop down menu	
31		Space Heating system (Yes / No)	UNI EN ISO 13790:2008	User input - drop down menu	
31_1		Type of Heating system (centralized, autonomous)	UNI EN ISO 13790:2008	User input - drop down menu	UPDATED
32	eta_gen_H	Type of heat generator for Space Heating (H)	UNI EN ISO 13790:2008	User input - drop down menu	
32_1	eta_gen_H	Position of the heat generator (indoors, outdoors)	UNI EN ISO 13790:2008	User input - drop down menu	
32_2	LHW, EF, PEF	Energy source for Heating (H)	UNI EN ISO 13790:2008	User input - drop down menu	
32_3	eta_gen_H	Tipe of Heat Pump (if [32] is a HP)		User input - drop down menu	UPDATED
	COP	COP value in standard condition		User input - drop down menu	
33_1	eta_dist_H	Type of distribution for Heating (insulated or not)	UNI EN ISO 13790:2008	User input - drop down menu	
33_2	C_st	Storage tank (no, scarcely or well insulated)		User input - drop down menu	
34_1	eta_emi_H	Type of emission terminals for Heating	UNI EN ISO 13790:2008	User input - drop down menu	
34_2	eta_ctrl_H	Control logics for Heating	UNI EN ISO 13790:2008	User input - drop down menu	
35		Space Cooling system (Yes / No)		User input - checkbox	
36	eta_gen_C	Type of Chiller		User input - drop down menu	
36_1	eta_dist_C	Type of Cooling system (centralized, autonomous)		User input - drop down menu	NEW

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

37_1	eta_dist_C	Type of distribution for Cooling (insulated or not)	UNI EN ISO 13790:2008	User input - drop down menu	
37_2	C_st	Storage tank (no, scarcely or well insulated)		User input - drop down menu	
38_1	eta_emi_C	Type of emission terminals for Cooling	UNI EN ISO 13790:2008	User input - drop down menu	
38_2	eta_ctrl_C	Type of control logics for Cooling	UNI EN ISO 13790:2008	User input - drop down menu	
39		Photovoltaic (PV) system (Yes / No)		User input - checkbox	
39_1	k_PV	Type of PV modules	UNI EN ISO 13790:2008	User input - drop down menu	
39_2	S_PV	PV surface		User input	
39_3	f_PV, f_esp	Type of PV installation (pitched roof, plane roof)		User input - drop down menu	
39_4	f_esp	Orientation of PV modules		User input - drop down menu	
40		Solar Thermal (ST) system (Yes / No)		User input - checkbox	
40_1	*k_ST*	Type of ST collectors	UNI EN ISO 13790:2008	User input - drop down menu	
40_2	*S_ST*	ST surface		User input	
40_3	*f_esp*	Type of ST installation (pitched roof, plane roof)		User input - drop down menu	
40_4	*f_esp*	Orientation of ST collectors		User input - drop down menu	
41	*E_other*	Electric energy from other renewable sources		User input	

Table 11: Database of Climate data

N.rif.	PARAMETER	*Climate DATABASE*			
		CLIMATE DATA	Source	Input from:	Note
42	θ_e_j	Mean outdoor air temperature (monthly)	UNI 10349	DATABASE	Through external service in the second
43	I_sol_hor_j	Mean daily global solar irradiation on horizontal surface	UNI 10349	DATABASE	
44	I_sol_i_j	Mean daily global solar irradiation on vertical surfaces (i = 1-8)	UNI 10349	DATABASE	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

					release
45	HDD	Heating Degree Days	UNI 10349	DATABASE	Deleted in the second release
46	Alt	Altitude	UNI 10349	DATABASE	
47	CZ	Climate zone	Depends on #45	DATABASE	Deleted in the second release
	Lat	Latitude		User Input/external service	NEW
	Long	Longitude		User Input/ external service	NEW

Table 12: Other energy data

		OTHER ENERGY DATA	Source	Input from:
48	ACH	Air Change Rate	TO BE SELECTED	Depends on #6
49	θ_END	Endogenous heat	TO BE SELECTED	Depends on #6
50	Psqm	Occupancy rate	TO BE SELECTED	Depends on #6
51	LPS	Ventilation rate (non-residential)	TO BE SELECTED	Depends on #6
52	f_ve	Correction factor (non-residential)	TO BE SELECTED	Depends on #6
53	C2	Correction coefficient (non-residential)	TO BE SELECTED	Depends on #46
54	H_days_j	Days in the Heating season	UNI EN ISO 13790:2008	Depends on #47
55	N_days_j	Days in the months		Tables
56	f_shade	Shading factor for movable devices	UNI 11300:1	Default value (0.75)

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Table 13: The **e**-SAFE solutions

N.rif.	PARAMETER	*Phase 2 - the **e**-SAFE solutions*			
		DATA	Source	Input from:	NOTE
57	s_CLT	CLT panel thickness		User Input	
58	lambda_ins	Insulating material: type		User input - drop down menu	
59	s_ins_CLT	Insulating material in **e**-CLT: thickness		User Input	NEW
60	s_ins_PANEL	Insulating material in **e**-PANEL: thickness		User input	NEW
61	lambda_clad	External finishing layer: type		User input - drop down menu	
62	s_clad	External finishing layer: thickness		Depends on #61	
63	U_w_new \ g_factor_new	New window type		User input - drop down menu	
64	lambda_ins_r	Insulating material for roof: type		User input - drop down menu	NEW
65	s_ins_roof	Insulating material for roof: thickness		User input	NEW
66	f_shade	Shading factor for movable devices	UNI EN ISO 13790:2008	Default value (0.5)	
67	S_CLT	**e**-CLT surface		User input/Calculated by the DSS	NEW
68	S_PANEL	**e**-PANEL surface		User input/Calculated by the DSS	NEW
69	c_clad	Unit cost of cladding		User input - drop down menu	NEW
70	c_ins	Unit cost of wall insulation		User input - drop down menu	NEW
71	c_win	Unit cost of windows (including shadings)		User input - drop down menu	NEW
72	c_ins_roof	Unit cost of roof insulation		User input - drop down menu	NEW
73	c_CLT	Base unit cost for **e**-CLT		DATABASE	NEW
74	c_PANEL	Base unit cost for **e**-PANEL		DATABASE	NEW
75	c_roof	Base unit cost for roof retrofit		User input - drop down menu	NEW
75_1	c_tiles	Unit cost of the tiles in the roof		DATABASE	NEW
76	Q_HP	Size of the Heat Pump (kW)	(we assume 5 kW per apt)	User input	NEW
77	n_fc	Number of fan coils in each apartment		User input	NEW
78	c_HP (a_HP, b_HP)	Unit cost for the Heat Pump		DATABASE	NEW

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

79	c_ST (a_ST, b_ST)	Unit cost for the storage tanks		DATABASE	NEW
80	c_AUX (a_AUX, b_AUX)	Unit cost for the pumps		DATABASE	NEW
81	c_NET (a_NET, b_NET)	Unit cost for the main pipe network		DATABASE	NEW
82	c_TANK	Unit cost for the **e-**TANK		DATABASE	NEW
83	c_FC	Unit cost for the fan coils		DATABASE	NEW
83_1	c_PIPE	Unit cost of the pipes between fan coils and collector		DATABASE	NEW
84	c_PV (a_PV, b_PV)	Unit cost for the PV system		DATABASE	NEW
84_1	c_BATT (a_ BATT, b_ BATT)	Unit cost for the batteries		DATABASE	NEW
84_2	c_BEMS	Unit cost for the **e-**BEMS (per apartment)		DATABASE	NEW
85	x	% CLT surface with string courses, similar to **e-**PANEL		DATABASE	NEW
86	y	Coefficient that includes all "masonry work" needed to install thermal systems		DATABASE	NEW
87	z	Coefficient that accounts for the cos increase due to the type of PV installation		DATABASE	NEW
88	U_lim	target thermal transmittance for walls		User Input	NEW
89	time_CLT	Unit time for installing **e-**CLT		DATABASE	NEW
90	time_PANEL	Unit time for installing **e-**PANEL		DATABASE	NEW

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

APPENDIX 2: equations for the energy needs

The **e-**DSS will implement simplified and parameterized algorithms in order to achieve the expected outputs (intermediate and final). This Appendix is dedicated to the detailed description of the equations used for describing the performances of the building before the renovation. In the following, the numbers within round brackets ( ) identify the equations, while those within square brackets [ ] refer to the input data listed in Appendix 1.

A2.1 Preliminary input from drop-down menu

[19] Colour of the external finish

Colour	Solar absorption coefficient (walls) α_v	Solar absorption coefficient (roof) α_o
Light	0.3	0.3
Medium	0.6	0.6
Dark	0.9	0.9

[22] Type of external walls → Thermal transmittance (U_wall) and mean thermal capacity (C_mean)

Wall type	U_wall (W/m^2·K)	C_mean (kJ/m^2·K)
Solid brick wall	1.55	135
Perforated bricks, tuff	1.35	135
Uninsulated hollow bricks with air cavity	1.10	120
Hollow bricks with partially insulated air cavity	0.80	120
Prefabricated concrete walls	2.80	135

[23] Floor type – Thermal transmittance (U_floor)

Floor type	U_floor
Concrete slab on ground	1.65
Uninsulated hollow-core concrete floor	1.25
Insulated concrete slab on ground	1.00
Insulated hollow-core concrete floor	0.80

[24] Roof type – Thermal transmittance (U_roof)

Roof type	U_roof
Flat uninsulated hollow-core concrete roof	1.50
Pitched uninsulated hollow-core concrete roof	1.80
Pitched uninsulated roof with wooden structure	1.80
Generic partially insulated roof	0.8

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

[25] Window type – Thermal transmittance (U_w), g-factor (g_factor)

Glazing	Frame	U_w	g_factor
Single glazing	Wood	4.9	0.87
	Metal	6	0.87
	PVC	5	0.87
	Metal with thermal break	5.1	0.87
	Wood / metal	5.2	0.87
Double glazing	Wood	2.8	0.75
	Metal	3.7	0.75
	PVC	2.9	0.75
	Metal with thermal break	3.0	0.75
	Wood / metal	3.1	0.75
Low-e double glazing	Wood	1.5	0.67
	PVC	1.3	0.67
	Metal with thermal break	1.7	0.67
	Wood / metal	1.7	0.67
Low-e triple glazing	Wood	1.0	0.5
	PVC	1.0	0.5
	Metal with thermal break	1.1	0.5
	Wood / metal	1.1	0.5

[26] Type of roller shutter – Thermal resistance (R_sh)

Type	R_sh
Metal	0
Wood or plastics	0.15
Other	0.1

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

A2.2 Calculation of the energy needs

A2.2.1 Building Geometry

As a preliminary step, the **e-**DSS must calculate both the overall gross surface (S_gross_i) and the overall heated surface (S_heat_i) of each façade, identified through the orientation (indicated by a subscript "i" ranging from 1 to 8, with: North = 1, North-East = 2, East = 3, South-East = 4, South = 5, South-West = 6, West = 7, North-West = 8).

$$S_{gross\_i} = Length_i * H_{tot} \tag{A.1}$$

$$S_{heat\_i} = \frac{n_{heat}}{n_{floors}} * S_{gross\_i} \tag{A.2}$$

Here, n_{floors} is the total number of floors above the ground in the building under investigation [8], n_{heat} is the number of heated floors in the building [9]: both values are provided by the user as an input. Furthermore, $Length_i$ and H_{tot} are the length of each façade [12] and the building height above the floor [11], respectively: here again, they are are provided by the user as an input.

Transparent envelope

For each orientation (indicated by the subscript "i"), the user must specify the total window surface (S_{w_i}) [14]. This should be done automatically through the IFC file, but in the first release of the tool such data input data will be manual. The overall window surface (S_w) for the entire building is then calculated as:

$$S_w = \sum_{i=1}^{8} S_{w\_i} \tag{A.3}$$

Adjacent buildings

If there are adjacent buildings, the DSS needs to calculate the heated surfaces in contact with those adjacent buildings for each orientation (S_{Adj_i}) through Eq. (A.4):

$$S_{Adj\_i} = \frac{n_{Adj\_floors\_i}}{n_{heat}} * S_{heat\_i} \tag{A.4}$$

Here, n_{heat} is the number of heated floors for the building under investigation [9], $n_{Adj\_floors\_i}$ is the number of heated floors that are in contact with an adjacent building [13], which is provided by the user for each orientation ($n_{Adj\_floors\_i} = 0$ if no adjacent buildings on that orientation), and S_{heat_i} is the total heated vertical surface of the building for each orientation, calculated as in Eq. (A.2).

Vertical external surfaces

The outside heated vertical surfaces are calculated, for each orientation, through Eq. (A.5):

$$S_{eff\_i} = S_{heat\_i} - S_{Adj\_i} \tag{A.5}$$

Opaque vertical external surfaces

The outside heated opaque vertical surfaces are calculated, for each orientation, with Eq. (A.6):

$$S_{eff\_op\_i} = S_{eff\_i} - S_{w\_i} - S_{box\_i} \tag{A.6}$$

Where:

$$S_{box\_i} = BOX * 0.15 * S_{w\_i} \tag{A.7}$$

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Here, BOX is a Boolean variable (BOX = 1 if the windows have roller shutter [26], otherwise BOX = 0). S_{box_i} is the external surface of the boxes, if any, which is roughly evaluated as the 15% of the window's surface.

Opaque horizontal external surfaces

In this category we include the ground floor (S_{floor}) and the roof (S_{roof}). The first surface is provided as an input [17]. As far as the roof is concerned, we should specify the type of boundary condition, making a choice between flat surface (external roof or non-heated attic) and pitched surface (with heated volumes below). In this second option, the pitch angle can also be specified (low angle = around 20°, high angle > 30°). These choices must be made through a drop-down menu, including the items reported in Table 14. Consequently, the **e-**DSS calculates:

Roof surface: $$S_{roof} = f_{roof} * S_{floor} \qquad (A.8)$$

Surfaces in contact with unheated spaces

A drop-down menu will allow attributing suitable correction factors (b_tr_U) to the heat transfer through the roof and the ground floor (UNI 11300-1:2014). The drop-down menu must propose the choices in Table 14. It is not necessary that the user visualize the corresponding values.

Table 14. Drop down menu for the boundary conditions of floors and roofs.

	Boundary	b_{tr_U}	f_{roof}
Floor of the first heated level [20]	Basement with no windows	0.5	-
"	Basement with windows	0.8	-
"	Ground	0.45	-
"	Outdoors	1	-
Roof of the last heated level [21]	Outdoors (flat roof)	1	1
"	Outdoors (pitched roof – low angle)	1	1.05
"	Outdoors (pitched roof – high angle)	1	1.15
"	Ventilated non-heated attic	1	1
"	Uninsulated non-heated attic	0.9	1
"	Insulated non-heated attic	0.7	1

The corresponding coefficients will be named as $b_{tr\_U\_r}$ for the roof and $b_{tr\_U\_f}$ for the floor.

Finally, to all vertical surfaces attached to adjacent buildings the following value is attributed:

$$b_{tr\_U\_ADJ} = 0.2$$

S/V ratio

As a final piece of information about the geometry of the building, the S/V ratio is defined as:

$$S/V = \frac{S_{d\_tot}}{Vg} \qquad (A.9)$$

Here, V_g is the gross heated volume of the building [15] and S_{d_tot} is the overall heated envelope surface, given by:

$$S_{d\_tot} = S_{floor} + S_{roof} + \sum_{i=1}^{8} S_{heat\_i} \qquad (A.10)$$

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

A2.2.2 Heat transfer calculations

A series of drop-down menu make the user select the type of walls [22], floor [23], roofs [24], windows [25], roller shutters [26], and the colour of the external finish (the corresponding tables are reported on the first page of this Appendix). According to the selection, the values of the relevant parameters are identified.

Transmission Heat Transfer Coefficient

As far as the vertical surfaces are concerned, the DSS calculates for each orientation "i" (from 1 to 8):

$$H_{tr\_i} = c_{th} * \left[\left(S_{eff\_op\_\ i} * U_{wall}\right) + \left(S_{w\_i} * U_{w\_corr}\right) + \left(S_{box\_i} * U_{box}\right) + \left(S_{ADJ\_i} * U_{wall} * b_{tr\_U\_ADJ}\right)\right] \quad (A.11)$$

Here, U_{wall}, U_{w_corr} and U_{box} are the thermal transmittance values of the vertical opaque components, the windows (including roller shutters, if any) and the boxes (if any). U_box = 6 (W/m^{2}K) by default. The calculation of U_{w_corr} follows Eq. (A.12):

$$U_{w\_corr} = 0.5 * (U_w + U_{ws}) \quad (A.12)$$

Here, U_w is the thermal transmittance of the only window [25] and U_{ws} is the thermal transmittance of the windows with shutter closed:

$$U_{ws} = \frac{1}{\frac{1}{U_w} + 0.55 * R_{sh} + 0.11} \quad (A.13)$$

Equation (A.13) adopts the R_{sh} values determined from the drop-down menu [26] (see the second page of this Appendix). Of course, if no roller shutter is selected, $U_{w\_corr} = U_w$.

Still in Eq. (A.11), the coefficient c_{th} takes into account – in a simplified way – the role of thermal bridges. Several cases may occur, according to the presence of balconies. From a drop-down menu, one can select if there are balconies and on what façade they are placed [27_1].

Drop down menu: "Are there balconies?"

NO → BALC_i = 0 for all "i" from 1 to 8

YES → "On which orientations?"

(list of the 8 orientations, where the user can tick the corresponding boxes)

Selected orientations → BALC_i = 1

Other orientations → BALC_i = 0

Then the algorithm states that:

- If BALC_i = 0 for all facades (i.e. for every "i"): c_{th} = 1.1
- If BALC_i = 1 for one façade (i.e. for one "i" value): c_{th} = 1.15
- If BALC_i = 1 on two facades (i.e. for two "i" values): c_{th} = 1.2
- If BALC_i = 1 for three façades (i.e. for three "i" values): c_{th} = 1.25
- If BALC_i = 1 on four or more facades (i.e. for at least four "i" values): c_{th} = 1.3

Similarly, the **e**-DSS calculates the transmission heat transfer coefficient in relation to horizontal surfaces, according to the following equations that refer to the floor and the roof, respectively:

$$H_{tr\_floor} = 1.1 * S_{floor} * U_{floor} * b_{tr\_U\_f} \quad (A.14)$$

$$H_{tr\_roof} = 1.1 * S_{roof} * U_{roof} * b_{tr\_U\_r} \quad (A.15)$$

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Finally, the overall transmission heat transfer coefficient associated with H_{tr} is:

$$H_{tr} = H_{tr\_floor} + H_{tr\_roof} + \sum_{i=1}^{8} H_{tr\_i} \qquad (A.16)$$

Ventilation Heat Transfer Coefficient

$$H_{ve} = 0.34 * [V_{net} * ACH * RES + (1 - RES) * 3.6 * Lps * f_{ve} * Psqm * S_{net} * C2] * (1 - REC) \quad (A.17)$$

In Eq. (A.17) V_{net} is the net volume of the heated zones [16], and S_{net} is the overall net floor surface of the building, i.e. the sum of the values specified in [18] for each dwelling. Both data are assigned during the definition of the building geometry.

$$\mathrm{S_{net}} = \sum_{k=1}^{n\_apt} \mathrm{S_{net\_k}} \qquad (A.18)$$

Furthermore, ACH (Air Changes per Hour) is assigned as a function of the intended building use [6], as well as Lps, f_{ve} e $Psqm$. Their values are reported in Table 15. The coefficient C2 depends on the altitude of the location [46] (see Table 16). RES is a Boolean variable: RES = 1 if the predominant building use is "Residential", while RES = 0 in all other cases. Finally, REC accounts for the possible presence of a controlled mechanical ventilation system with heat recovery [27_2], and its recovery efficiency.

From a drop-down menu: "Is the building provided with a Mechanical Ventilation System?"

NO → REC = 0

YES → Is there heat recovery?

NO → REC = 0

YES → REC = please insert the recovery efficiency (default = 0.8)

Table 15. Values of the parameters in Eq. (A.17) as a function of the intended building use [6]

Predominant building use [6]	ACH [1/h]	ϑ_{END} [W/m²]	$Psqm$ [pp/m²]	Lps [l/(s*pp)]	f_{ve}
Residential	0.30	2.50	0.05	-	-
Library	0.00	8.00	0.30	6	0.51
Hotel	0.00	6.00	0.05	11	0.26
Offices	0.00	6.00	0.06	11	0.59
Hospital	0.00	8.00	0.08	11	1.00
Cinema / theater	0.00	8.00	1.00	5.5	0.51
Museum / church	0.00	8.00	0.30	6	1.00
Restaurant	0.00	10.00	0.60	10	0.47
Commercial building	0.00	8.00	0.20	9	0.51
Swimming pool	0.00	10.00	0.30	2.5	0.34
Gym	0.00	5.00	0.20	6	0.18
School	0.00	4.00	0.45	5	0.47
Industrial building	0.000	6.00	-	-	-

Table 16. Coefficient C2 in Eq. (A.17)

Altitude [46]	C2
H < 500 m	1.00
500 m < H < 1000 m	1.06
1000 m < H < 1500 m	1.12
1500 m < H < 2000 m	1.18
2000 m < H < 2500 m	1.25

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Energy balances for the thermal energy needs

Equations (A.19) and (A.20), where the subscript "j" refers to each month (j = 1 ÷ 12), show the monthly energy balances needed to calculate the final energy demand for space heating (Q_H) and space cooling (Q_C).

$$Q_{H\_j} = \left[Q_{H\_loss\_j} - \eta_{\mathrm{H\_GN\_j}} * Q_{H\_gain\_j}\right] * H_{days\_j} \tag{A.19}$$

$$Q_{C\_j} = \left[Q_{C\_gain\_j} - \eta_{\mathrm{C\_ls\_j}} * Q_{C\_loss\_j}\right] * C_{days\_j} \tag{A.20}$$

The duration of the months included in the heating season (H_{days_j}) and the cooling season (C_{days_j}) will be detailed in a following Section of this Appendix, as well as the equations to calculate $\eta_{\mathrm{H\_GN\_j}}$ and $\eta_{\mathrm{C\_ls\_j}}$. All other parameters are calculated as follows:

$$Q_{H\_loss\_j} = Q_{H\_tr\_j} + Q_{H\_ve\_j} - Q_{H\_sol\_op\_j} \tag{A.21}$$

$$Q_{H\_gain\_j} = Q_{H\_end\_j} + Q_{H\_sol\_w\_j} \tag{A.22}$$

$$Q_{C\_gain\_j} = Q_{C\_end\_j} + Q_{C\_sol\_w\_j} \tag{A.23}$$

$$Q_{C\_loss\_j} = Q_{C\_tr\_j} + Q_{C\_ve\_j} - Q_{C\_sol\_op\_j} \tag{A.24}$$

The terms in the above equations are commented in the following sub-sections.

Transmission (Q_{H_tr} and Q_{C_tr})

For any given month "j", the thermal energy transmitted through the envelope is:

$$Q_{H\_tr\_j} = 24 * \left[H_{tr} * \left(\theta_{HEAT} - \theta_{e\_j}\right) + 11 * \emptyset_{r\_tot}\right]/1000 \tag{A.25}$$

Here, θ_{e_j} is the monthly mean outdoor air temperature [42] (the value comes from the database with the climate data). In Equation (A.25) we assume:

$$\emptyset_{r\_tot} = ROOF * \emptyset_{r_{\mathrm{roof}}} + 0.5 * \sum_{i=1}^{8} \emptyset_{r\_\mathrm{i}} \tag{A.26}$$

ROOF is a Boolean variable where ROOF = 1 if the selected information in Table 14 [21] (drop down menu) corresponds to "Outdoors" (while ROOF = 0 in all other cases). Moreover, provided that $R_{se\_ho} = 0.04$ and $R_{se\_v} = 0.04$, one can calculate (EN ISO 13790:2008 and EN ISO 52016-1:2018):

$$\emptyset_{r\_\mathrm{roof}} = R_{se\_ho} * 4.14 * S_{roof} * U_{roof} \tag{A.27}$$

$$\emptyset_{r\_\mathrm{i}} = R_{se\_v} * 4.14 * (S_{eff\_op\_i} * U_v + S_{box\_i} * U_{box} + S_{w\_i} * U_{w\_corr}) \tag{A.28}$$

Conversely, in the cooling season:

$$Q_{C\_tr\_j} = 24 * \left[H_{tr} * \left(\theta_{COOL} - \theta_{e\_j}\right) + 11 * \emptyset_{r\_tot}\right]/1000 \tag{A.29}$$

Ventilation (Q_{H_ve} and Q_{C_ve})

$$Q_{H\_ve\_j} = 24 * \left[H_{ve} * \left(\theta_{HEAT} - \theta_{e\_j}\right)\right]/1000 \tag{A.30}$$

$$Q_{C\_ve\_j} = 24 * \left[H_{ve} * \left(\theta_{COOL} - \theta_{e\_j}\right)\right]/1000 \tag{A.31}$$

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Solar gains through the windows ($Q_{H\_sol\_w}$ *and* $Q_{C\_sol\_w}$)

$$Q_{H\_sol\_w\_j} = f_{shade} * g_{factor} * \sum_{i=1}^{8}\left(I_{sol\_i\_j} * S_{w\_i} * F_{sh\_i\_j}\right) * (1 - F_F)/3.6 \quad \text{(A.32)}$$

$$Q_{C\_sol\_w\_j} = f_{shade} * g_{factor} * \sum_{i=1}^{8}\left(I_{sol\_i\_j} * S_{w\_i} * F_{sh\_i\_j}\right) * (1 - F_F)/3.6 \quad \text{(A.33)}$$

In Eq. (A.32) and (A.33), g_{factor} has already been attributed through the drop down menu regarding the window type [25], and $I_{sol\_i\_j}$ is the monthly mean of the global daily solar irradiation (MJ/m^2) for the "i-th" orientation and the "j-th" month [44] (from the Database containing the "Climate Data"). F_F = 0.2 is the Frame Factor. Moreover, *f_shade* is a corrective factor that accounts for possible mobile shading devices (e.g. blinds and curtains). By default, we assume *f_shade* = 0.75.

Finally, $F_{sh\_i\_j}$ is a Shading Factor associated with balconies: its value changes every month, and depends on the orientation, according to Table 17. This factor must be introduced only when the facade "i" actually has balconies [27_1].

BALC_i = 0 → $Fs_{h\_i\_j}$ = 1 for all "j" from 1 to 12

BALC_i = 1 → $Fs_{h\_i\_j}$ = see Table 17

Table 17. Shading factors associated with balconies
(the values correspond to latitude 42°N and obstruction angle 30°)

		Shading Factor $F_{sh\_i\_j}$		
		S, SE, SO (i = 4,5,6)	**E, O, NE, NO (i = 2-3, 7-8)**	**N (i =1)**
January	j = 1	0.88	0.87	0.80
February	j = 2	0.84	0.84	0.80
March	j = 3	0.78	0.82	0.80
April	j = 4	0.70	0.80	0.80
May	j = 5	0.65	0.79	0.83
June	j = 6	0.63	0.77	0.82
July	j = 7	0.61	0.78	0.83
August	j = 8	0.66	0.78	0.81
September	j = 9	0.74	0.82	0.80
October	j = 10	0.82	0.84	0.80
November	j = 11	0.87	0.86	0.80
December	j = 12	0.89	0.87	0.80

Finally, the solar gains through the opaque components are:

$$Q_{H\_sol\_op\_j} = \left[\sum_{i=1}^{8}\left(I_{sol\_i\_j} * \left(S_{eff\_op\_i} * U_{wall} + S_{box\_i} * U_{box}\right) * R_{se_v} * \alpha_v\right) + ROOF * I_{sol\_hor\_j} * S_{roof} * U_{roof} * R_{se\_ho} * \alpha_{ho}\right]/3.6 \quad \text{(A.34)}$$

$$Q_{C\_sol\_op\_j} = \left[\sum_{i=1}^{8}\left(I_{sol\_i\_j} * \left(S_{eff\_op\_i} * U_{wall} + S_{box\_i} * U_{box}\right) * R_{se_v} * \alpha_v\right) + ROOF * I_{sol\_hor\_j} * S_{roof} * U_{roof} * R_{se\_ho} * \alpha_{ho}\right]/3.6 \quad \text{(A.35)}$$

Here, α_v and α_{ho} are assigned through the drop-down menu described at the beginning of this document [19], whereas $I_{sol\_hor\_j}$ is the monthly mean of the global daily solar irradiation on the horizontal plane (MJ/m^2) for the j-th month (from the Database containing the "Climate Data") [43].

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Endogenous heat (Q_{H_end} *and* Q_{C_end})

$$Q_{H\_end\_j} = (24 * \theta_{END} * S_{net})/1000 \qquad \text{(A.36)}$$

$$Q_{C\_end\_j} = (24 * \theta_{END} * S_{net})/1000 \qquad \text{(A.37)}$$

Where θ_{END} is derived from Table 15 and depends on the intended building use [6].

Utilization factors for heat gains (η_{H_GN}) and heat losses (η_{C_ls})

The utilization factors η_{H_GN} and η_{C_GN} are calculated for every month of the year. As a first step, the DSS must calculate the "time constant" of the building.

Time constant: $$tau = (1000 * S_{d\_tot} * C_{mean})/(3600 * (H_{tr} + H_{ve})) \qquad \text{(A.38)}$$

Then, for each "j" ranging from 1 to 12:

$$\begin{cases} a_{\mathrm{H}} = 1 + \frac{tau}{15} \\ \gamma_{H\_j} = \max\left(\frac{Q_{H\_gain\_j}}{Q_{H\_loss\_j}}; 0\right) \\ \eta_{H\_GN\_j} = \min\left(\frac{1 - \gamma_{\mathrm{H\_j}}{}^{a_{\mathrm{H}}}}{1 - \gamma_{\mathrm{H\_j}}{}^{(a_{\mathrm{H}}+1)}}; 1\right) \end{cases} \qquad \text{(A.39)}$$

$$\begin{cases} a_C = \max\left[\left(8.1 + \frac{tau}{17} - 13 * \frac{S_w}{S_{net}}\right); 0\right] \\ \gamma_{C\_j} = \frac{Q_{C\_gain\_j}}{Q_{C\_loss\_j}} \\ \text{if } \gamma_{C\_j} < 0 \quad \text{then} \quad \eta_{C\_ls\_j} = 1 \\ \text{if } \gamma_{C\_j} > 0 \quad \text{then} \quad \eta_{C\_ls\_j} = \min\left(\frac{1 - \gamma_{C\_j}{}^{-a_C}}{1 - \gamma_{C\_j}{}^{(-a_C - 1)}}; 1\right) \end{cases} \qquad \text{(A.40)}$$

Duration of heating and cooling season

The duration (in days) of the heating season, whose values are needed in Equation (A.19), is determined as follows.

For each month "j" one must check if the following condition holds:

$$\text{Is} \quad \left(\gamma_{\mathrm{H\_j}} < \frac{a_H + 1}{a_H}\right) \; AND \; \left(\gamma_{\mathrm{H\_j}} \neq 0\right) \quad ? \qquad \text{(A.41)}$$

If the condition is true: $\mathrm{H_{days\_j}} = \mathrm{N_{days\_j}}$ (see Table 18)

Otherwise: $\mathrm{H_{days\_j}} = 0$

As far as the cooling season is concerned, whose duration is needed in Equation (A.20), one has to perform a preliminary calculation. Indeed, for each month "j" one must check if the following condition holds:

$$\text{Is} \quad \frac{1}{\gamma_{\mathrm{C\_j}}} < \frac{a_C + 1}{a_C} \quad ? \qquad \text{(A.42)}$$

If the condition is true: $\mathrm{C_{days\_j}} = \mathrm{N_{days\_j}}$ (see Table 18)

Otherwise: $\mathrm{C_{days\_j}} = 0$

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Regarding the duration of heating/cooling season, the **e-**DSS notifies to the technician which months will be included (as a results of the above calculations). Then, the technician can either approve the resulting months or add/deduct months.

Table 18. Monthly number of days ($N_{days\_ j}$) [46]

Month	$N_{days\_ j}$
January	31
February	28
March	31
April	30
May	31
June	30
July	31
August	31
September	30
October	31
November	30
December	31

Once again, this feature will be implemented in the second release of the **e-**DSS. Please note that, in the first **e-**DSS release, the duration of the heating season will be based on what is allowed by Italian regulations for climate zone B, i.e. the climate zone to which the real pilot belong, that is to say from December to March.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

A2.2.3 Thermal energy needs for Domestic Hot Water (DHW)

Thermal energy needs for Domestic Hot Water (DHW) are calculated based on Equation (A.43):

$$Q_{W\_j} = 1.162 * N_{days} * V_W * (40 - \theta_{em}) \quad \text{(A.43)}$$

Where:

Monthly mean air temperature: $\theta_{em} = \frac{1}{12}\sum_{j=1}^{12} \theta_{e\_j}$ (A.44)

Daily DHW volume:

$$V_W = \left[RES * \left(a * \frac{S_{net}}{n_{apt}} + \mathrm{b}\right) * n_{apt} + (1 - RES) * a * Nu\right]/1000 \quad \text{(A.45)}$$

In Eq. (A.45), n_{apt} is the number of dwellings in the building (input [10]), while Nu is:

$$Nu = Psqm * S_{net} \quad \text{(A.46)}$$

The number of people per square meter (Psqm) is determined through Table 15 depending on the intended building use, while a and b are derived from Table 19, still depending on the intended building use [6].

Table 19. Coefficients for DHW calculations

Predominant building use [6]		**a**	**b**
Residential	$\frac{S_{net}}{n_{apt}} > 200$	0	250
	$50 < \frac{S_{net}}{n_{apt}} \leq 200$	1.067	36.67
Hotel	-	60	0
Hospital	-	60	0
School	-	0.2	0
Swimming pools	-	50	0
Gym	-	50	0
Offices	-	0.2	0
Commercial building	-	0.2	0
Restaurant	-	50	0
Industrial building	-	0	0
Cinema / theater	-	0	0
Museum / church	-	0	0
Library	-	0	0

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

A2.3 Electric energy production from photovoltaics (PV)

First, a drop-down menu asks the user if a PV system is available. In case of positive response, the user must specify some information.

Drop down menu: "Is there a PV system?" [39]?

NO → $E_{PV\_j} = 0$ for every "j" (i.e. every month, from 1 to 12)

YES → Typology of PV modules (drop down menu, see Table 20) [39_1]

Overall PV surface (S_{PV} = manual user input) [39_2]

Type of installation (drop down menu, see Table 21) [39_3]

Orientation of the PV modules (i = 1 ÷8) [39_4]

Based on the data provided by the users, the DSS calculates the solar irradiation available on the PV plane (H_sol_j, in kWh/m^2). In Eq. (A.47), f_{esp} is a coefficient that accounts for the orientation of the PV modules (see Table 21), $I_{sol\_hor\_j}$ is the daily solar irradiation on a horizontal plane (available in the database containing the "Climate Data"), and N_{days_j} is the number of days in the month.

$$H_{sol\_j} = N_{days\_j} * (I_{sol\_hor\_j} * f_{esp})/3.6 \quad \text{(A.47)}$$

Then, the DSS calculates the expected monthly (Equation A.48) and annual (Equation A.49) electricity production:

$$E_{PV\_j} = H_{sol\_j} * S_{PV} * k_{PV} * f_{PV} \quad \text{(A.48)}$$

$$E_{PV} = \sum_{j=1}^{12} E_{PV\_j} \quad \text{(A.49)}$$

In Eq. (A.48), S_{PV} is the surface of the PV modules (user input [39_2]), k_{PV} is the nominal efficiency of the PV modules (default values in Table 20, but the user must be also allowed to introduce a manual input, if a specific model of PV modules is considered) and f_{PV} is a coefficient that takes into account the effects of temperature on PV efficiency and the losses in the inverter.

Table 20. Typology of PV modules and their efficiency k_{PV} – default values [39_1]

Typology of PV modules	k_{PV}
Monocrystalline silicon	0.20
Polycrystalline silicon	0.18
Amorphous silicon	0.07
Thin film (CIGS)	0.11
Thin film (CdTe)	0.10

Table 21. Coefficients f_{PV} and f_{esp} ([39_3] e [39_4])

Type of installation	f_{PV}	f_{esp} (orientation factor)				
		S	SE - SW	E - W	NE - NW	N
Roof integrated	0.75	1.10	1.06	0.96	-	-
Roof mounted (with supporting frame)	0.80	1.12	1.05	0.90	-	-
Wall mounted	0.70	0.70	0.68	0.56	-	-

PS: the PV modules must not be installed facing NE-N-NW. If the user selects one of these orientations, the DSS will provide a *warning* to warn the user that the selected option is not technically and economically feasible.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

A2.4 Thermal energy production from Solar Thermal systems

First, a drop-down menu must ask the user if a Solar Thermal (ST) system is available. In case of positive response, the user must specify some information.

Drop down menu: "Is there a Solar Thermal system?" [40]?

NO → $E_{ST\_j} = 0$ for every "j" (i.e. every month, from 1 to 12)

YES →Typology of ST collectors (drop down menu, see Table 22) [40_1]

Overall surface of ST collectors (S_{ST} = manual user input) [40_2]

Type of installation (drop down menu, see Table 21) [40_3]

Orientation of the ST collectors (i = 1 ÷8, see Section 1.1) [40_4]

Based on the data provided by the users, the **e-**DSS calculates the solar irradiation available on the ST plane (H_sol_j, in kWh/m^2), as in Eq. (A.47), by using the same f_{esp} coefficients already shown in Table 21.

Then, the monthly solar thermal energy made available by the ST collectors is:

$$E_{ST\_j} = 0.8 * H_{sol\_j} * S_{ST} * k_{ST} \tag{A.50}$$

In Eq. (A.50), S_{ST} is the overall surface of ST collectors in m^2 (user input [40_2]), and k_{ST} is their efficiency (see Table 22 for its default values, depending on the type of ST collectors [40_1]). The coefficient 0.8 takes into the heat losses in the storage tank and the distribution pipes.

Table 22. Coefficients k_{ST}

Type of ST collectors	k_{ST}
Glazed flat plate collectors	0.4
Unglazed flat plate collectors	0.2
Evacuated tube collectors	0.6

PS: the solar collectors must not be installed facing NE-N-NW. If the user selects one of these orientations, the DSS will provide a *warning* to warn the user that the selected option is not technically and economically feasible.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

A2.5 Annual energy demand of FUEL and ELECTRICITY

Now, it is possible to calculate the monthly and annual demands of fuel and/or electricity for the different services (heating, cooling, DHW). In this stage, the features of the technical systems must also be introduced.

DOMESTIC HOT WATER

Drop down menu: "Is the building provided with a DHW production system?" [28]?

NO → A default efficiency is considered:

$$eta_{glob\_W} = 0.65 \tag{A.51}$$

→ The energy source (Table 23) is set to "Electricity"

YES → A series of information is required, through drop down menus:

- Service provided ("only DHW", "combined heating and DHW") [28_1]
- "centralized system" or "autonomous system"? [28_2]
- Type of heat generator (see Table 24 and Table 26) [29]
  - Type of energy source (see Table 23) [29_2]
  - Position of the heat generator ("indoors", "outdoors") [29_1]
- Type of distribution ("well insulated", "scarcely insulated" pipes) [30_1]
- Storage tank ("well insulated" or "scarcely insulated") [30_2]

According to the choices, the **e**-DSS selects a "generation efficiency (eta_{gen_W})" and a "distribution efficiency (eta_{dist_W})" (depending also on n_{heat} , n_{apt} and U_{wall}, which are known from the previous steps). Finally, the DSS calculates a "global efficiency" as in Eq. (A.52):

$$eta_{glob\_W} = eta_{gen\_W} * eta_{dist\_W} * (1 - C_{st}) \tag{A.52}$$

The coefficient C_{st} accounts for the presence of storage tanks, and their insulation level. Actually, the information required in [30_2] can have three values:

- No storage tank: $C_{st} = 0$
- Well insulated storage tank: $C_{st} = 0.1$
- Scarcely insulated storage tank: $C_{st} = 0.2$

Net monthly thermal energy needs for Domestic Hot Water:

$$Q_{W\_net\_j} = max[Q_{W\_j} - E_{ST\_j}; 0] \tag{A.53}$$

The above equation considers that the thermal energy produced by solar collectors is attributed as a priority to the DHW service (up to compensating the entire thermal energy demand).

Fuel and/or electricity monthly consumption:

- If the selected "energy source" is "ELECTRIC ENERGY":

  ➔ **Electricity consumption:** $E_{W\_j} = \frac{Q_{W\_net\_j}}{eta\_glob\_W}$ (in kWh)

  ➔ **Fuel consumption:** $G_{W\_j} = 0$ (in kg or m³)

- If the selected "energy source" is NOT "ELECTRIC ENERGY":

  ➔ **Electricity consumption:** $E_{W\_j} = 0$ (in kWh)

  ➔ **Fuel consumption:** $G_{W\_j} = \frac{Q_{W\_net\_j}}{eta\_glob\_W} * \frac{1}{LHW}$ (in kg or m³)

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

In case of fuel consumption, LHW is the Lower Heating Value for the fuel (see Table 23).

SPACE HEATING SYSTEM

Drop down menu: "Is the building provided with a space heating system?" [31]?

NO → A default efficiency is considered:

$$eta_{glob\_H} = 0.70 \qquad (A.54)$$

→ The energy source (Table 23) is set to "Natural gas"

YES → A series of information is required, through drop down menus:

- "Centralized system" or "autonomous system"? [31_1]
- Type of heat generator (see Table 24 and Table 25) [32], [32_3]
  - Type of energy source (see Table 23) [32_2]
  - Position of the heat generator ("indoors", "outdoors") [32_1]
- Type of distribution ("well insulated" or "scarcely insulated" pipes) [33_1] (see Table 28, depending also on n_{heat} , n_{apt} and U_{wall})
- Storage tank ("well insulated" or "scarcely insulated") [33_2]
- Type of emission terminal (Table 29) [34_1]
- Type of control logics (Table 30) [34_2]

If the selected option [28_1] for Domestic Hot Water is "Combined heating and DHW", some of the above data ([31_1], [32], [32_1], [32_2]) will not be asked, since they are the same as for DHW. However, the generation efficiency (eta_{gen_H}) must still be calculated through Table 24 and Table 26: indeed, even if the system is the same as for DHW, the operating conditions in heating mode are different.

According to the choices, the DSS selects from the tables a "generation efficiency (eta_{gen_H})", a "distribution efficiency (eta_{dist_H})", an "emission efficiency (eta_{emi_H})" and a "control efficiency (eta_{ctrl_H})", and finally calculates a "global efficiency" as in Eq. (A.55):

$$eta_{glob\_H} = eta_{gen\_H} * eta_{emi\_H} * eta_{ctrl\_H} * eta_{dist\_H} * (1 - C_{st}) \qquad (A.55)$$

The coefficient C_{st} accounts for the presence of storage tanks, and their insulation level. Actually, the information required in [33_2] can have three values:

- No storage tank: $C_{st} = 0$
- Well insulated storage tank: $C_{st} = 0.1$
- Scarcely insulated storage tank: $C_{st} = 0.2$

Net monthly thermal energy needs for Space Heating:

$$\mathrm{Q_{H\_net\_j}} = \max[\mathrm{Q_{H\_j}} - \max(\mathrm{E_{ST\_j}} - \mathrm{Q_{W\_j}}; 0); 0] \qquad (A.56)$$

Here again, the thermal energy produced by the solar collectors is attributed as a priority to the DHW service (up to compensating the entire thermal energy demand). Then, the exceeding energy is attributed to the space heating system.

Fuel and/or electricity monthly consumption:

- If the selected "energy source" is "ELECTRIC ENERGY":

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

➔ **Electricity consumption:** $E_{H\_j} = \frac{Q_{H\_net\_j}}{eta\_glob\_H}$ (in kWh)

➔ **Fuel consumption:** $G_{H\_j} = 0$ (in kg or m^3)

- If the selected "energy source" is NOT "ELECTRIC ENERGY":

➔ **Electricity consumption:** $E_{H\_j} = 0$ (in kWh)

➔ **Fuel consumption:** $G_{H\_j} = \frac{Q_{H\_net\_j}}{eta\_glob\_H} * \frac{1}{LHW}$ (in kg or m^3)

In case of fuel consumption, LHW is the Lower Heating Value for the fuel (see Table 23).

SPACE COOLING SYSTEM

Drop down menu: "Is the building provided with a space cooling system?" [35]?

NO → A default efficiency is considered:

$$eta_{glob\_C} = 2.2 \quad \text{(A.57)}$$

YES → A series of information is required, through drop down menus:

- Type of chiller (Table 26 in the "heat pumps" section) [36]
- "centralized system" or "autonomous system"? [36_1]
- Type of emission terminal (Table 29) [38_1]
- Type of control logics (Table 30) [38_2]
- Type of distribution ("well insulated" or "scarcely insulated" pipes) [37_1] (see Table 28, depending also on n_{heat} , n_{apt} and U_{wall})
- Storage tank ("well insulated" or "scarcely insulated") [37_2]

According to the choices, the DSS selects from the tables a "generation efficiency (eta_{gen_C})", a "distribution efficiency (eta_{dist_C})", an "emission efficiency (eta_{emi_C})" and a "control efficiency (eta_{ctrl_C})", and finally calculates a "global efficiency" as in Eq. (A.58):

$$eta_{glob\_C} = eta_{gen\_C} * eta_{emi\_C} * eta_{ctrl\_C} * eta_{dist\_C} * (1 - C_{st}) \quad \text{(A.58)}$$

The coefficient C_{st} accounts for the presence of storage tanks, and their insulation level. Actually, the information required in [37_2] can have three values:

- No storage tank: $C_{st} = 0$
- Well insulated storage tank: $C_{st} = 0.1$
- Scarcely insulated storage tank: $C_{st} = 0.2$

In the space cooling system, the energy source is by default the electric energy:

➔ **Electricity consumption:**

$E_{C\_j} = \frac{Q_{C\_j}}{eta\_glob\_C}$ (in kWh)

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

A2.6 Tables with System Efficiencies

Energy source

Table 23. Lower Heating Values (LHW), Emission Factors (EF) and Primary Energy Factors (PEF)

Energy sources	LHW	EF_{fuel}	PEF_{fuel}	c_{fuel}
Biomass / wood	5.2 kWh/kg	0 kg_{CO2}/kg	0.20	0.3 €/kg
LPG (Propane / Buthane)	12.8 kWh/kg	3.0 kg_{CO2}/kg	1.05	1.2 €/kg
Natural gas	9.8 kWh/m^3	2.0 kg_{CO2}/m^3	1.05	0.8 €/m^3
Diesel	10 kWh/kg	2.8 kg_{CO2}/kg	1.07	1.5 €/kg
	LHW	EF_{el}	PEF_{el}	c_{el}
Electricity	-	0.44 kg_{CO2}/kWh	1.96	0.25 €/kWh

Actually, prices are highly variable. Then, the users should be allowed to manually input the values, if he/she does not agree with the default values.

System efficiencies - GENERATION

Table 24. Generation efficiency for space heating (eta_{gen_H})

Heat generator [32]	Position [32_1]	
	Outdoors	**Indoors**
Stove / fireplace	-	0.78
Conventional boiler	0.82	0.86
Condensation boiler	0.96	0.98
Heat pump	**See section below**	

Table 25. Generation efficiency for Domestic Hot Water (eta_{gen_W})

Boiler [29]	eta_{gen_W}
Conventional gas boiler	0.75
Condensation boiler	0.88
Electric boiler	0.70
Heat pump boiler	2.50

In case of Heat Pump as a heating or cooling system

Space Heating

First we get the nominal COP (called COP_{ref}), i.e. the COP measured at the reference conditions. The value for COP_{ref} can be introduced by the user (e.g. from the technical sheets of a specific Heat Pump) or taken by default from Table 26. Then we calculate the exergy efficiency:

$$eta_{exe\_H} = COP_{ref} * \frac{(T_{H\_ref} - T_{C\_ref})}{(T_{H\_ref} + 273.15)} \quad (A.59)$$

Finally, we calculate the monthly generation efficiency, for the average real working conditions:

$$eta_{gen\_H\_j} = eta_{exe\_H} * \frac{(T_H + 273.15)}{(T_H - T_{C\_j})} \quad (A.60)$$

Here T_H is the real hot side temperature, selected as a function of the type of terminals (see Table 27), while T_C is the real cold side temperature, selected as a function of the type of Heat Pump

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

(see Table 26). This value might change with the months, since in case of "air-source" heat pumps it corresponds to the monthly mean outdoor air temperature.

Domestic Hot Water

Exactly the same equations as for space heating, but in this case T_H = 50°C. The result is called:

$$eta_{gen\_H\_j}$$

Space Cooling

In this case we keep a simplified approach, and we take the value constant (SEER is taken from Table 26):

$$eta_{gen\_C} = SEER$$

Please observe that in the heat pumps the generation efficiency changes every month, which is not the case with any other heat generation system.

Table 26. Reference value of COP and SEER, and corresponding temperatures [32_3, 36]

In case of Heat Pump	COP_{ref}	SEER		T_{H_ref}	T_{C_ref}	T_C
Air-to-air (split system)	3.5	2.8		20 °C	7 °C	= θe,j
Air-to-water	3.8	2.7		35 °C	7 °C	= θe,j
Water-to-water	4.8	4.0		35 °C	7 °C	10 °C
Ground-to-water (geothermal)	4.5	3.8		35 °C	7 °C	10 °C

Table 27. Temperature of the hot side (depending on [34_1])

Type of emission terminal	T_H
Radiators (placed on non-insulated walls)	50 °C
Radiators (placed on INSULATED walls)	50 °C
Fan coils	45 °C
Split systems	20 °C
Radiant floor	35 °C
Radiant ceiling	30 °C

System efficiencies – DISTRIBUTION

If the selected heating and/or cooling system is "Heat Pump" → "Air-to-air (split system)", by default:

$$\mathbf{eta}_{\mathbf{dist\_H}} = 1 \qquad \mathbf{eta}_{\mathbf{dist\_C}} = 1$$

Otherwise, the distribution efficiency is set according to Table 28. In case of multi-family buildings (i.e. n_{apt} > 1, which is already read by the **e-**DSS as an input [10]), the distribution efficiency depends on the number of floors and the insulation level of the pipes [33, 37]. Please observe that in multi-family buildings with "Autonomous" systems, it is not necessary to indicate the insulation level.

In case of single-family buildings (i.e. n_{apt} = 1), the distribution efficiency is different from the case of multi-family buildings (see Table 28).

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Table 28. Distribution efficiency (the table applies to all system: C, W and H)

Multi-family building ($n_{apt} > 1$) (non-insulated walls – $U_{wall} > 1\ W/m^2K$)		n_{heat} [8]			
		> 4	3	2	1
Autonomous system	-	0.98	0.98	0.96	0.94
Centralized system	Scarcely insulated pipes	0.92	0.91	0.90	0.88
	Well insulated pipes	0.96	0.96	0.95	0.95

Multi-family building ($n_{apt} > 1$) (INSULATED walls - $U_{wall} < 1\ W/m^2K$)		n_{heat} [8]			
		> 4	3	2	1
Autonomous system	-	0.99	0.99	0.99	0.99
Centralized system	Scarcely insulated pipes	0.98	0.97	0.95	0.90
	Well insulated pipes	0.99	0.99	0.98	0.97

Single-family building ($n_{apt} = 1$) (non-insulated walls – $U_{wall} > 1\ W/m^2K$)		n_{heat} [8]	
		> 1	1
Autonomous system	Scarcely insulated pipes	0.94	0.92
	Well insulated pipes	0.98	0.965

Single-family building ($n_{apt} = 1$) (INSULATED walls - $U_{wall} < 1\ W/m^2K$)		n_{heat} [8]	
		> 1	1
Autonomous system	Scarcely insulated pipes	0.96	0.94
	Well insulated pipes	0.99	0.99

System efficiency – EMISSION and CONTROL

Table 29 reports the emission efficiency eta_{emi}, while Table 30 reports on the control efficiency eta_{ctrl} as a function of the selected emission system and control logics, respectively.

Table 29. Emission efficiency

Type of emission terminal	eta_emi_H	eta_emi_C
Radiators (placed on non-insulated walls)	0.93	-
Radiators (placed on INSULATED walls)	0.97	
Fan coils	0.95	0.98
Split systems	0.94	0.97
Convector heater	0.95	-
Radiant floor	0.98	0.97
Radiant ceiling	0.95	0.98
Air diffuser	0.92	0.97
Direct emission (e.g. stove)	0.9	-

Table 30. Control efficiency

Control logics based on	eta_ctrl_H, eta_ctrl_C
Outdoor temperature	0.92
Zone temperature	0.94
Room temperature	0.95
Room and outdoor temperature	0.97

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

A2.7 Output from the e-DSS

Building-related outputs

The results provided (visualized) by the DSS at the end of the calculation will be:

Overall heat transfer coefficient: $\mathbf{H'_t = \frac{H_{tr}}{S_{d\_tot}}}$

S/V ratio: S/V

Annual energy demand for space heating: $Q_H = \sum_{j=1}^{12} Q_{H\_j}$ (in kWh/year)

Annual energy demand for space cooling: $Q_C = \sum_{j=1}^{12} Q_{C\_j}$ (in kWh/year)

Heat losses – distribution: pie-chart with the percentage of the different heat losses coefficients (H_{tr_floor}, H_{tr_roof}, H_{tr_1}, H_{tr_2}, H_{tr_3}, H_{tr_4}, H_{tr_5}, H_{tr_6}, H_{tr_7}, H_{tr_8}) calculated with respect to the total H_{tr} (Eq. A.16).

Annual ELECTRICITY PRODUCTION FROM PV:

$\mathrm{E_{PV\_new}}$ (kWh/year)

Annual NET ELECTRIC ENERGY CONSUMPTION:

$$\mathrm{E_{tot\_j} = max\left[\left(E_{H\_j} + E_{C\_j} + E_{W\_j}\right) - E_{PV\_j}; 0\right]} \quad \text{(in kWh/year)} \qquad \text{(A.61)}$$

$$\mathrm{E_{tot} = \sum_{j=1}^{12} E_{tot\_j} - E_{other}} \quad \text{(in kWh/year)}$$

Annual FUEL CONSUMPTION:

$$\mathrm{G_{tot} = \sum_{j=1}^{12}\left(G_{H\_j} + G_{W\_j}\right)} \quad \text{(in kg/year or m}^3\text{/year)}$$

Non-renewable PRIMARY ENERGY

$$\mathrm{EP_{TOT\_nren} = G_{tot} * LHW * PEF_{fuel} + E_{tot} * PEF_{el}} \quad \text{(in kWh/year)}$$

TOTAL CO2 EMISSIONS

$$\mathrm{EM_{TOT} = G_{tot} * EF_{fuel} + E_{tot} * EF_{el}} \quad \text{(in kgCO}_2\text{/year)}$$

Total operating costs

$$\mathrm{C_{op} = G_{tot} * c_{fuel} + E_{tot} * c_{el}} \quad \text{(in €/year)}$$

PS: if the building has no cooling / heating system, the calculation considers a fictitious system with low energy performance. This circumstance is quite typical in Southern Italy (low-income houses, especially). In this case, the operating costs do not correspond to reality: however, if we wish to make the customer aware of the advantages of the **e-**SAFE solutions, it is still interesting

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

that we compare the operating costs of **e-**SAFE with those that the current building would incur to ensure the same thermal comfort, but with a traditional system low-performing system.

One final step consists in assessing the operating costs for each dwelling, even if in an approximate way, i.e. proportionally to the net surface of the dwelling [18]. In particular, for each dwelling identified by the subscript "k" (from 1 to n_apt) we have:

$$\mathrm{C_{op\_k}} = \mathrm{C_{op}} * \frac{\mathrm{S_{net\_k}}}{\sum_{k=1}^{n\_apt} \mathrm{S_{net\_k}}} \qquad \text{(in €/year per apartment)}$$

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

APPENDIX 3:
relevant algorithms for the renovation stage

This Appendix reports about the main algorithms that are implemented in the **e-**DSS to manage the renovation process. However, the Appendix does not include the criteria and the algorithms used to evaluate the feasibility of the **e-**SAFE technologies, which are described in Section 2.1.

A3.1 Definition of the seismic zone

The seismic zone of the city where the building is can be defined through the service available at http://www.efehr.org/en/hazard-data-access/hazard-maps/. Here, starting from the coordinates (Latitude and Longitude) – already added by the user or -taken from Google Maps in the initial stage – it is possible to get a value for the Peak Ground Acceleration (PGA), based on the following settings:

- Model: GSHAP
- Intensity Measure Type: Peak Ground Acceleration
- Probability of Exceedance: 10% in 50 years (475 years)
- Site Class: rock
- Aggregation Level: (arithmetic) mean

The numerical value of PGA should be retrieved through the metadata available from:

http://www.efehr.org/en/Documentation/.galleries/dwn-webservices/wadl_doc.html)

Finally, the seismic zone is attributed as follows:

- If PGA > 0.25 g → the site in "High Seismicity Zone"
- If 0.15 g >= PGA >= 0.25 g → the site in "Medium seismicity Zone"
- If PGA < 0.15 g → the site in "Low Seismicity Zone"

A3.2 Insulation thickness and U-value: e-CLT

When working with the **e-**CLT, the **e-**DSS calculates the minimum insulation thickness that must be adopted in order to get a certain target U-value, inserted by the user. The target U-value may come from national regulations, or other performance targets identified by the technician himself. For instance, the maximum allowable thermal transmittance values in Italy are reported in Table Table 31, and depend on the specific climate zone:

Table 31 - Maximum allowable thermal transmittance for external walls in Italy

CLIMATE ZONE	U_LIM
A	0.40 (W/m^2K)
B	0.40 (W/m^2K)
C	0.36 (W/m^2K)
D	0.32 (W/m^2K)
E	0.28 (W/m^2K)
F	0.26 (W/m^2K)

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

In practice, the **e-**DSS first asks:

"What is the target U-value that you want to reach in the vertical opaque surfaces?"

The user then introduces the desired value (U_lim). The minimum insulating material thickness (s_ins_min) that must be installed in the **e-**CLT can be calculated through a "while" cycle:

$$\begin{cases} s_{ins\_CLT} = 0 \\ U_{wall\_new} = U_{wall} \\ \text{while } U_{CLT} > U_{lim} \\ \begin{cases} s_{ins\_CLT} = s_{ins\_CLT} + 2\ (cm) \\ U_{CLT} = \left(\dfrac{1}{U_{wall}} + \dfrac{0.01 \cdot s_{CLT}}{0.13} + \dfrac{0.01 \cdot s_{ins\_CLT}}{lambda_{ins}} + \dfrac{0.01 \cdot s_{clad}}{lambda_{clad}} + 0.09 \right)^{-1} \end{cases} \\ s_{ins\_min} = s_{ins\_CLT} \end{cases} \tag{A.61}$$

This calculation accounts for the following technological constraints:

1. the thermal resistance for the scarcely ventilated air gap behind the cladding corresponds to R = 0.09 m^2·K/W
2. the CLT has default thermal conductivity, corresponding to 0.13 W/(m·K)
3. only commercial thickness is allowed for the insulation (multiple of 2 cm)

Hence, the **e-**DSS communicates the result:

"You should adopt at least "s_ins_min" cm of insulation".

In any case, the final choice of the insulating material thickness in the **e-**CLT is up to the user, who can either accept the value suggested by the **e-**DSS or introduce a higher value.

With the value finally introduced by the user (that is called "s_ins_CLT" from now on), the **e-**DSS calculates the new thermal transmittance of the wall (U_wall_new_i), by considering – for each façade "i" existing in the building – the surfaces of **e-**PANEL and **e-**CLT:

$$\begin{cases} s_{ins\_PANEL} = s_{ins\_CLT} + \text{round}\left(\dfrac{s_{CLT}}{0.13} \cdot lambda_{ins} \right) \\ U_{CLT} = \left(\dfrac{1}{U_{wall}} + \dfrac{0.01 \cdot s_{CLT}}{0.13} + \dfrac{0.01 \cdot s_{ins\_CLT}}{lambda_{ins}} + \dfrac{0.01 \cdot s_{clad}}{lambda_{clad}} + 0.09 \right)^{-1} \\ U_{PANEL} = \left(\dfrac{1}{U_{wall}} + \dfrac{0.01 \cdot s_{ins\_PANEL}}{lambda_{ins}} + \dfrac{0.01 \cdot s_{clad}}{lambda_{clad}} + 0.09 \right)^{-1} \\ U_{frame} = \left(\dfrac{1}{U_{wall}} + \dfrac{0.01 \cdot (s_{ins\_CLT} + s_{CLT} + 2)}{0.13} + \dfrac{0.01 \cdot s_{clad}}{lambda_{clad}} \right)^{-1} \\ \text{for } i = 1 \ldots 8 \\ \left\{ U_{wall\_new\_i} = \dfrac{S_{CLT\_i} \cdot U_{CLT} + 0.5 \cdot S_{PANEL\_i} \cdot U_{PANEL} + 0.5 \cdot S_{PANEL\_i} \cdot U_{frame}}{S_{PANEL\_i} + S_{CLT\_i}} \right. \\ U_{wall\_new\_av} = \text{mean}(U_{wall\_new\_i}) \end{cases} \tag{A.62}$$

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

This calculation accounts for the following technological constraints:

- the surfaces covered with **e-**PANEL have a thicker insulation layer in order to guarantee the same thermal resistance as the **e-**CLT
- the surfaces covered with **e-**PANEL show a significant amount of non-insulated wood frame (assumed as 50% of the total)
- the wood frame has default thermal conductivity, corresponding to 0.13 W/(m·K)
- the wood frame is thicker than the sum of CLT and thermal insulation, and the difference corresponds to the thickness of the air gap in the **e-**CLT (2 cm): indeed, it is on the wood frame that the cladding material is attached.

As an output, the DSS stores the single "U_wall_new_i" values for each façade, since these will be used for calculating the new energy performance. Furthermore, the **e-**DSS provides (as a visible output) the average wall thermal transmittance for the entire building (U_wall_new_av). The **e-**DSS also stores the "s_ins_PANEL" value elaborated in the above algorithm, since – together with the "s_ins_CLT" – this will be used for the calculation of the installation costs.

A3.3 Insulation thickness and U-value: e-EXOS and e-PANEL

The same approach described in the **e-**CLT case is followed, including the choice of a target U-value and the warning with the suggested minimum insulating layer thickness, but in case of **e-**PANEL the equations are as follows:

$$\begin{cases} s_{ins\_PANEL} = 0 \\ U_{wall\_new} = U_{wall} \\ \text{while } U_{new\_wall} > U_{lim} \\ \begin{cases} s_{ins\_PANEL} = s_{ins\_PANEL} + 2 \\ U_{PANEL} = \left(\dfrac{1}{U_{wall}} + \dfrac{0.01 \cdot s_{ins\_PANEL}}{lambda_{ins}} + \dfrac{0.01 \cdot s_{clad}}{lambda_{clad}} + 0.09 \right)^{-1} \\ U_{frame} = \left(\dfrac{1}{U_{wall}} + \dfrac{0.01 \cdot (s_{ins\_PANEL} + 2)}{0.13} + \dfrac{0.01 \cdot s_{clad}}{lambda_{clad}} \right)^{-1} \\ U_{wall\_new} = 0.5 \cdot U_{PANEL} + 0.5 \cdot U_{frame} \end{cases} \\ s_{ins\_PANEL\_min} = s_{ins\_PANEL} \end{cases} \quad (A.63)$$

This calculation accounts for the following technological constraints:

- the thermal resistance for the scarcely ventilated air gap behind the cladding corresponds to R = 0.09 m^2·K/W
- only commercial thickness is allowed for the insulation (multiple of 2 cm)
- the surfaces covered with **e-**PANEL show a significant amount of non-insulated wood frame (assumed as 50% of the total)
- the wood frame has default thermal conductivity, corresponding to 0.13 W/(m·K)
- the wood frame is thicker than the thermal insulation, and the difference corresponds to the thickness of the air gap in the **e-**PANEL (2 cm): indeed, it is on the wood frame that the cladding material is attached.

Hence, the **e-**DSS communicates the result:

"*You should adopt at least "s_ins_min" cm of insulation*".

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

In any case, the final choice of the insulating material thickness in the **e-**PANEL is up to the user, who can either accept the value suggested by the **e-**DSS or introduce a higher value.

With the value finally introduced by the user (that is called "s_ins_PANEL" from now on), the **e-**DSS calculates the new thermal transmittance of the wall (U_wall_new) as follows:

$$\left\{\begin{array}{l} U_{PANEL} = \left(\dfrac{1}{U_{wall}} + \dfrac{0.01 \cdot s_{ins\_PANEL}}{lambda_{ins}} + \dfrac{0.01 \cdot s_{clad}}{lambda_{clad}} + 0.09\right)^{-1} \\ U_{frame} = \left(\dfrac{1}{U_{wall}} + \dfrac{0.01 \cdot (s_{ins\_PANEL} + 2)}{0.13} + \dfrac{0.01 \cdot s_{clad}}{lambda_{clad}}\right)^{-1} \\ U_{wall\_new} = 0.5 \cdot U_{PANEL} + 0.5 \cdot U_{frame} \end{array}\right\} \qquad (A.64)$$

As an output, the **e-**DSS assigns the "U_wall_new" value to all façades in the building, in order to calculate the new energy performance.

A3.4 Insulation thickness and U-value: the roof

In all cases of envelope renovation, it is possible that the user also wants to renovate the roof.

In this case, after selecting the desired insulating material and its thickness (s_ins_roof), the **e-**DSS calculates the new thermal transmittance (U_roof_new):

$$U_{roof\_new} = \left(\frac{1}{U_{roof}} + \frac{0.01 \cdot s_{ins\_roof}}{lambda_{ins\_r}} + 0.1\right)^{-1} \qquad (A.65)$$

This calculation accounts for the following technological constraints:

- the thermal resistance for the new tiles is set by default to R = 0.1 $m^2 \cdot K/W$
- the thermal resistance of possible cement screed is not included, in order to simplify the algorithm. However, cement screed is frequently avoided in the roofs

As an output, the **e-**DSS assigns the "U_roof_new" value to the roof, in order to calculate the new energy performance. In this stage, the user can also select if he/she intends to replace the tiles and the weather-protection membrane. However, this choice has only effect on the costs, and not on the energy performance.

A3.5 Update of the envelope performance

Once the previous input stages are completed, the **e-**DSS replace the following new values to the original ones in the calculation of the energy needs:

- Wall thermal transmittance: U_wall → replaced by U_wall_new
- Windows thermal transmittance: U_w → replaced by U_w_new
- Glazing transparency: g_factor → replaced by g_factor_new
- Roof thermal transmittance: U_roof → replaced by U_roof_new
- Mean thermal capacity: C_mean = 135 (whatever the initial value)
- BOX insulation: U_box = 6 → replaced by U_box = U_w_new
- Mobile shading: f_shade = 0.75 → replaced by f_shade = 0.5

Please note that the parameters regarding the windows are set directly by the user, meaning that there is no calculation performed by the **e-**DSS. The shutter boxes (if any) are replaced by the windows, provided with shadings (whose shading factor is set by default).

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

A3.6 Update of the technical systems

The great majority of the data regarding the technical systems will be modified through a default value, since we already know most of the features of the **e-**THERM concept. Those parameters that need a specific user input are highlighted in **bold letters**. In order:

1. Domestic Hot water → YES
2. Service provided → combined heating and DHW
3. Type of system → Centralized system
4. Type of generator → Heat pump (eta_gen_W = 2.50)
5. Position of DHW generator → Outdoors
6. Energy source for DHW → Electricity
7. Type of distribution for DHW → Well-insulated, with U_wall_new < 1 W/(m^2·K)
8. Storage tank for DHW → Well-insulated (C_st = 0.1)
9. Space Heating System → YES
10. Type of system → Centralized
11. Type of Heat generator → Heat pump
12. Position of heat generator → Outdoors
13. Energy source for Heating → Electricity
14. **Type of Heat pump → user input**
15. **COP value in standard cond. → user input**
16. Type of distribution for Heating → Well-insulated, with U_wall_new < 1 W/(m^2·K)
17. Storage tank for Heating → Well-insulated (C_st = 0.1)
18. Type of emission terminals → Fan coils
19. Control logics for Heating → Room and outdoor temperature
20. Space Cooling System → YES
21. Type of Cooling system → Heat pump (same type as for Heating)
22. **SEER value → user input**
23. Type of distribution for Cooling → Well-insulated, with U_wall_new < 1 W/(m^2·K)
24. Storage tank for Cooling → Well-insulated (C_st = 0.1)
25. Type of emission terminals → Fan coils
26. Control logics for Cooling → Room and outdoor temperature
27. PV system → YES
28. **Type of PV modules → user input (consequent k_PV value)**
29. **PV surface installed → user input (consequent S_PV value)**
30. **Type of PV installation → user input (consequent f_PV value)**
31. **Orientation of PV modules → user input (consequent f_esp value)**
32. Solar Thermal (ST) system → NO
33. Electricity from other renewables → 0

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

A3.7 Calculation of the renovation costs – envelope

The costs related to the building renovation based on the **e-**SAFE technologies are calculated as in Eq. (A.66), by summing up the costs associated with **e-**CLT, **e-**PANEL, windows and roof renovation.

$$C_{env} = C_{CLT} + C_{PANEL} + C_{win} + C_{roof} \tag{A.66}$$

At the current stage, the costs associated with **e-**EXOS are not computed. Indeed, the first release of the **e-**DSS is calibrated for the real pilot, where **e-**EXOS is not a relevant solution. Furthermore, **e-**EXOS is still under investigation and, according to the GANTT, it will be fully defined by M24. The costs of **e-**EXOS will be included in the second release of the **e-**DSS (Deliverable D4.5), which will be ready at M30 and will be exploited in the renovation of the virtual pilots.

The single terms in Eq. (A.66) can be further detailed as follows:

$$C_{CLT} = S_{CLT\_tot} \cdot (1 - x) \cdot \left(c_{CLT} + c_{clad} + c_{ins} \cdot s_{ins\_CLT}\right) \tag{A.67}$$

$$C_{PANEL} = \left(S_{PANEL\_tot} + S_{CLT\_tot} \cdot x\right) \cdot \left(c_{PANEL} + c_{clad} + c_{ins} \cdot s_{ins\_PANEL}\right) \tag{A.68}$$

$$C_{win} = (S_w + S_{box}) \cdot c_{win} \tag{A.69}$$

$$C_{roof} = S_{roof} \cdot \left(c_{roof} + c_{tiles} + c_{ins\_roof} \cdot s_{ins\_roof}\right) \tag{A.70}$$

In the above equations:

- S_{CLT_tot} = total surface of **e-**CLT (m^2)
- S_{PANEL_tot} = total surface of **e-**PANEL (m^2)
- S_w = total surface of windows (m^2)
- c_{clad} = unit cost of cladding (€/m^2)
- c_{ins} = unit cost of wall insulation (€/m^2 per cm)
- c_{win} = unit cost for windows, including shadings (€/m^2)
- c_{ins_roof} = unit cost of roof insulation (€/m^2 per cm)
- s_{ins_CLT} = thickness of CLT insulation (cm)
- s_{ins_PANEL} = thickness of PANEL insulation (cm)
- s_{ins_roof} = thickness of roof insulation (cm)
- x = percentage of CLT surface with string courses, similar to **e-**PANEL (x = 0.15)

All unit costs depend on the materials selected during the renovation co-design process, and are reported in the database from which the user selects the materials. The unit costs will be regularly updated in order to follow market prices.

Furthermore:

- c_{CLT} = base unit cost for **e-**CLT (€/m^2)
  - It includes the CLT panels, the connecting devices and the dampers, the water proof membrane, their assembly (including insulation and cladding) and the final installation on site. The only prices excluded from this item are the material costs for insulation and cladding, which depend on the choice of the specific materials.
- c_{PANEL} = base unit cost for **e-**PANEL (€/m^2)
  - It includes the timber frames, the water proof membrane, their assembly (including insulation and cladding), screws and glues, and the final installation on site. The only

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

prices excluded from this item are the material costs for insulation and cladding, which depend on the choice of the specific materials.

- c_{roof} = base unit cost for roof retrofit (€/m^2)
    - It includes the weather protection membrane (if any), the cement screed and the mortar (if any) and the corresponding workmanship, together with dismantling the previous materials. It does not include the material cost for roof insulation and the pavement/tiles, which depend on the choice of the specific material.
- c_{tiles} = unit cost for tiles (€/m^2), depending on the selected material

These unit costs will be also included in the database, and will be regularly updated in order to follow market prices.

Table 32 - Possible insulating materials, with their thermal conductivity and unit cost

MATERIAL	LAMBDA_INS [W/(m·K)]	C_INS [€/m^2 per cm]
Wooden fibre	0.04	3
Cellular glass	0.055	7.8
Hemp fibre	0.038	1.4
Cellulose fibre	0.037	1.4
Sheep wool	0.035	3.9
EPS	0.037	2
XPS	0.035	3.7
Cork	0.039	9

Table 33 - Possible cladding materials, with their thermal conductivity, thickness and unit cost

MATERIAL	LAMBDA_CLAD [W/(m·K)]	S_CLAD [cm]	C_CLAD [€/m^2]
Fiber cement (with plaster)	0.32	1.5	45
Fiber cement (without plaster)	0.32	1.5	24.4
Pre-painted aluminum	200	0.2	69
Wooden slats	0.13	2	190
WPC slats (Wood Plastic Composite)	0.13	2	90
Clay slats	0.4	1.5	135
Gres (porcelain stoneware)	1	1.5	195.6
Ceramic / Clay	1	1.5	140

Table 34 - Possible windows, their performance and costs

MATERIAL	UW_NEW [W/(m^2·K)]	G_FACTOR_NEW [-]	C_WIN [€/m^2]
Wood	1.5	0.67	550
PVC	1.3	0.67	475.3
Aluminium with thermal break	1.7	0.67	493.2
Metal and wood	1.7	0.67	550

Table 35 - Possible roof tiles - costs

MATERIAL	C_TILES [€/m^2]
Clay tile	44.89
Ceramic tile	55
WPC slats (Wood Plastic Composite)	207.34

Table 36 - Other unit costs

C_PANEL [€/m^2]	C_CLT [€/m^2]	C_ROOF_MEMBRANE [€/m^2]	C_ROOF_NO_MEMBRANE [€/m^2]	X [-]
270	530	115.3	97.3	0.15

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

A3.8 Calculation of the renovation costs – technical systems

The costs for the installation of the technical systems included in the **e-**THERM concept are computed as in Eq. (A.71). Here, the coefficient 1.2 accounts for shipping and commissioning.

$$C_{THERM} = 1.2 \cdot [(1+y) \cdot (C_{HP} + C_{ST} + C_{AUX} + C_{NET} + C_{UNIT} + C_{BEMS}) + (1+z) \cdot C_{PV} + C_{BATT}] \quad \text{(A.71)}$$

The single terms in Eq. (A.71) can be further detailed as follows:

- Costs for heat pumps, storage tanks and auxiliary systems

  $$C_{HP} = a_{HP} + b_{HP} \cdot Q_{HP} \quad \text{(A.72)}$$

  $$C_{ST} = a_{ST} + b_{ST} \cdot Q_{HP} \quad \text{(A.73)}$$

  $$C_{AUX} = a_{AUX} + b_{AUX} \cdot Q_{HP} \quad \text{(A.74)}$$

  Where:

  - Q_{HP} = thermal power of the Heat Pump (kW)
  - a_{HP} and b_{HP} = coefficients for the Heat Pump
  - a_{ST} and b_{ST} = coefficients for the Storage Tanks
  - a_{AUX} and b_{AUX} = coefficients for the auxiliary systems

  The rationale of this approach is that the size, and then the cost, of the storage tanks can be deemed proportional to the thermal power of the heat pump, whose size is specified by the technician during the renovation co-design process. Similarly, the size and the cost of the circulation pumps are proportional to the water flow rate, which in turn depends on the thermal power of the Heat Pump. All costs include the installation.

- Costs for the distribution network

  $$C_{NET} = c_{NET} \cdot (10 \cdot n_{apt} + 6 \cdot n_{floors}) \quad \text{(A.75)}$$

  $$c_{NET} = a_{NET} + b_{NET} \cdot Q_{HP} \quad \text{(A.77)}$$

  Where:

  - c_{NET} = unit cost for pipes, including insulation (€/m)
  - n_{apt} = number of apartments
  - n_{floors} = number of floors

  The rationale of this approach is that the length of the pipes in the distribution network depends on the number of floors (approximately 6 m of pipes per floor, to account for the main vertical columns) and on the number of apartments (approximately 10 m of pipes per apartment, connecting the main column to the hydronic unit inside the **e-**TANK). Similarly, the size and the cost of the pipes are proportional to the water flow rate, which in turn depends on the thermal power. All costs include the installation.

  During the development of the second release, the above-mentioned predefined length of the pipes will be further verified, and possibly replaced by a range of values from which the user can choose.

- Costs for the fan-coils and the **e-**TANK

  $$C_{UNIT} = c_{TANK} \cdot n_{apt} + (c_{FC} + 10 \cdot c_{PIPE}) \cdot (n_{apt} \cdot n_{fc}) \quad \text{(A.78)}$$

  Where:

  - c_{TANK} = unit cost for the **e-**TANK (€/unit)

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

- c_{FC} = unit cost for the fan-coils (€/unit)
- c_{PIPE} = unit cost of the pipes between fan-coil and collector (€/m)
- n_{apt} = number of apartments
- n_{fc} = number of fan-coils in each apartment

The number of fan-coils installed in each apartment is specified by the technician during the renovation co-design process. The unit cost of the **e-**TANK (one per apartment), provided by PINK, includes the hydronic unit with the collector, the valves and the control unit. The unit cost of the fan-coils includes the pipes between the hydronic unit and the fan-coils (estimated in 10 m of pipes per fan-coil), and the PVC pipes to discharge the condensate. All costs include the installation.

- Costs for monitoring and control

$$C_{BEMS} = c_{BEMS} \cdot n_{apt} \tag{A.79}$$

This cost includes central control unit and all monitoring devices (sensors) installed in the apartments. It can be considered proportional to the number of apartments. At this stage, the unit costs (c_{BEMS}) are estimated with a certain degree of approximation: more reliable values will be known only after the demonstration activities, and depend on the number of sensors needed.

- Costs for the PV system, including batteries:

$$\mathrm{kWp} = S_{PV} \cdot k_{PV} \tag{A.80}$$

$$C_{PV} = a_{PV} + b_{PV} \cdot \mathrm{kWp} \tag{A.81}$$

$$C_{BATT} = a_{BATT} + b_{BATT} \cdot Q_{HP} \tag{A.82}$$

Where:

- kWp = installed peak PV power (kW)
- S_{PV} = surface of PV modules (m^2)
- k_{PV} = nominal efficiency of the PV modules (kW/m^2)
- a_{PV} and b_{PV} = coefficients for the PV modules, including inverters
- a_{BATT} and b_{BATT} = coefficients for the batteries

- y = coefficient that includes all "masonry works" needed to install the thermal system (simple y = 0.05; medium y = 0.1; complex y = 0.15).
- z = coefficient that accounts for the type of installation (Roof integrated z = 0.1, roof mounted z = 0.5, wall mounted z = 0.6).

Table 37 - Unit costs for Thermal Systems

ISSUE	COST
c_TANK	900 [€/unit]
c_FC	510 [€/unit]
c_PIPE	4 [€/m]
c_BEMS	2600 [€/apt]

ISSUE	a	b
HP	5000	400
ST	430	25
AUX	3500	30
NET	50	0.9
PV	5000	1200
BATT	1300	140

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

A3.9 Calculation of the overall renovation costs

Finally, the overall costs for the building renovation with the **e-**SAFE solutions are defined through Eq. (A.83):

$$C_{INST} = C_{THERM} + C_{env} \tag{A.83}$$

Then, the **e-**DSS also assesses the renovation costs associated to each apartment, by splitting the overall installation costs proportionally to the net surface of the dwellings:

$$C_{INST\_k} = C_{INST\_k} \cdot \frac{S_{net\_k}}{\sum_{k=1}^{n\_apt} S_{net\_k}} \tag{A.84}$$

This final piece of information is very useful during the co-design stage, since the Building Manager can show it to the residents and discuss with them the convenience of the proposed solutions.
In Eq. (A.84), the costs may also be distributed based on millesimal values as weighting factors. In fact, millesimal values account not only for the net surface area of each dwelling, but also for additional attributes (e.g., the position of the dwelling in height, the presence of accessories, etc.) that are considered by law when sharing various costs in multifamily buildings. This feature will be introduced in the second **e-**DSS release.

A3.10 Calculation of the time for the renovation works

The time needed for completing the renovation works (measured in weeks) is calculated just by adding the time to install the **e-**CLT (t_{CLT} = 1.2 h/m^2) and the time to install the **e-**PANEL including the windows (t_{CLT} = 0.6 h/m^2). All other renovation works (roofs, technical systems) will be performed in parallel, since there is very little superposition. However, in order to include possible delays, a multiplying factor is applied, equal to 1.1.

$$\mathrm{Time} = 1.1 \cdot (\mathrm{Time}_{CLT} + \mathrm{Time}_{PANEL}) = 1.1 \cdot \left[\left(t_{CLT} \cdot S_{CLT} + t_{PANEL} \cdot (S_{PANEL} + S_W) \right) / 35 \right] \tag{A.85}$$

At the current stage, the time associated with **e-**EXOS is not computed. Indeed, the first release of the **e-**DSS is calibrated for the real pilot, where **e-**EXOS is not a relevant solution. Furthermore, **e-**EXOS is still under investigation and, according to the GANTT, it will be fully defined by M24. The time for **e-**EXOS will be included in the second release of the **e-**DSS (Deliverable D4.5), which will be ready at M30 and will be exploited in the renovation of the virtual pilots.

In Eq. (A.85), t_{CLT} and t_{PANEL} are the unit time for the installation of the **e-**CLT and the **e-**PANEL, respectively, expressed in h/m^2. At this stage, these unit durations are estimated with a certain degree of approximation: more reliable values will be known only through the demonstration activities in the real pilot, which will allow updating them in view of the second **e-**DSS release (Deliverable D4.5).

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

A3.11 Comparison: current building vs. renovated building

As a final step, the **e-**DSS shows the following results:

- ENERGY SAVINGS and ENVIRONMENTAL BENEFITS:

  Electricity savings: $E_{save} = E_{tot} - E_{tot\_new}$ (kWh/year)

  Fuel savings: $G_{save} = G_{tot} - G_{tot\_new}$ (kg or m^3/year)

  Non-renewable PE saving: $EP_{save} = EP_{tot\_nren} - EP_{tot\_nren\_new}$ (kWh/year)

  CO_2 emissions savings: $EM_{save} = EM_{TOT} - EM_{TOT\_new}$ (kgCO_2/year)

- Savings in the operating costs

  Annual savings on the energy bill: $C_{op\_save} = C_{op} - C_{op\_new}$ (in €/year)

- Total costs for the **e-**SAFE renovation

  The **e-**DSS resumes the values obtained for C_{INST} and $C_{INST,k}$ (in €)

- Total time for the **e-**SAFE renovation

  The **e-**DSS resumes the value obtained for: Time (in weeks)

- Time of Return of the investment

  The **e-**DSS calculates and shows: $TR = C_{INST}/C_{op\_save}$ (in years)

The next release of the DSS will include a more detailed calculation of the "Time of Return", including the discount rate. Moreover, other benefits of the renovation will be quantified, such as the savings associated with the increased seismic resistance and the consequent avoided losses in case of earthquake.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

APPENDIX 4: e-DSS database

This section provides the complete list of entities and attributes of the final version of the **e-**DSS renovation space model. Moreover, the field “Note” indicates the update with respect to the first version provided in D4.1.

e-SAFE has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No. 893135.

Entity Name	Attribute Name	Attribute Description	Attribute type	Note
User	id	Identifier	Integer	
User	name	Name	String	
User	surn	Surname	String	
User	email	Email Address	String	
User	pwd	Password (encoded md5)	String	
User	role_fk	Role FK	Integer	
Owner	id	Identifier	Integer	
Owner	mill_value	Millesimal Value	Decimal	
Owner	own_quot	Ownership Quote	Decimal	
Owner	user_fk	User FK	Integer	
Location	id	Identifier	Integer	
Location	cntry_fk	Country FK	Integer	
Location	reg_fk	Region FK	Integer	
Location	prov_fk	Province FK	Integer	
Location	mun_fk	Municipality FK	Integer	
Location	addr	Address	String	
Location	alt	Altitude	Decimal	
Location	lat	Latitude	Decimal	
Location	long	Longitude	Decimal	
Location	seis_zone_fk	Seismic Zone FK	Integer	
Location	clim_data_fk	Climate_Data FK	Integer	
Systems Energy Data	id	Identifier	Integer	
Systems Energy Data	dhw_syst_fk	Domestic Hot Water System FK	Integer	
Systems Energy Data	pv_syst_fk	PhotoVoltaic System FK	Integer	
Systems Energy Data	st_syst_fk	Solar Thermal System FK	Integer	
Systems Energy Data	heat_syst_fk	Heating System FK	Integer	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Systems Energy Data	cool_syst_fk	Cooling System FK	Integer	
Systems Energy Data	oth_ren_ener	Other Renewable Energy Source	Decimal	
Systems Energy Data	avg_year_ener_prod	Average yearly energy produced from RES	Decimal	
Systems Energy Data	build_fk	Building FK	Integer	
Building Energy Data	id	Identifier	Integer	
Building Energy Data	col_ext_fin_fk	Colour of the External Finish – FK	Integer	
Building Energy Data	ext_wall_type_fk	Type of external walls – FK	Integer	
Building Energy Data	floor_type_fk	Floor Type – FK	Integer	
Building Energy Data	roof_type_fk	Roof Type – FK	Integer	
Building Energy Data	wind_ type_fk	Windows Type - FK	Integer	
Building Energy Data	roll_shut_type_fk	Type of roller shutter – FK	Integer	
Building Energy Data	pres_vent_syst	Presence of mechanical ventilation systems with recovery	Boolean	
Building Energy Data	rec_eff	Recovery Efficiency	Decimal	
Building Energy Data	pres_roll_shutter	Presence of Roller Shutter	Boolean	
Building Energy Data	pres_balc	Presence of balconies - Total Exposure FK	Integer	
Building Energy Data	floor_bound_cond_fk	Floor Boundary Condition – FK	Integer	
Building Energy Data	roof_bound_cond_fk	Roof Boundary Condition – FK	Integer	
Building Energy Data	build_fk	Building FK	Integer	
Building Geometric Data	id	Identifier	Integer	
Building Geometric Data	gros_surf_grnd_floor	Gross Surface of the ground floor	Decimal	
Building Geometric Data	lengt_facad	Length of façade – Total Exposure FK	Integer	UPDATED
Building Geometric Data	over_gros_vol	Overall Gross Heated Volume	Decimal	
Building Geometric Data	over_net_vol	Overall Net Heated Volume	Decimal	
Building Geometric Data	build_hght	Building height	Decimal	
Building Geometric Data	num_floor_adj	Number of floors Adjacent Buildings - Total Exposure FK	Integer	
Building Geometric Data	num_floor	Number of floors above the ground	Integer	NEW
Building Geometric Data	num_heat_floor	Number of heated floors	Integer	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Building Geometric Data	tot_wind_surf	Total Wndows Surface – Total Exposure FK	Integer	
Building Geometric Data	num_dwel	Number of dwellings	Integer	
Building Geometric Data	graph_repr	Graphical representation	BIM File	
Building Geometric Data	build_fk	Building FK	Integer	
Total Exposure	id	Identifier	Integer	
Exposure Item	id	Identifier	Integer	
Exposure Item	spat_dir_fk	Spatial Direction FK	Integer	UPDATED
Exposure Item	value	value	Decimal	
Exposure Item	tot_exp_fk	Total Exposure FK	Integer	
Spatial Direction	id	Identifier	Integer	
Spatial Direction	dir_num	Direction Number	Integer	
Spatial Direction	dir_desc_ita	Italian Direction	String	
Spatial Direction	dir_desc_eng	English Direction	String	
Building	id	Identifier	Integer	
Building	year_const	Year of construction	Integer	
Building	pre_build_use_fk	Predominant Building Use FK	String	
Building	loc_fk	Location FK	Integer	
Design Alternative	id	Identifier	Integer	DELETED
Design Alternative	des_alter	Design alternatives	String	DELETED
				DELETED
Context Constraint	id	Identifier	Integer	DELETED
Context Constraint	cont_constr	Context Constraint	String	DELETED
				DELET

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

				ED
Law Constraint	id	Identifier	Integer	DELETED
Law Constraint	law_constr	Law Constraint	String	DELETED
Unit Cost	id	Identifier	Integer	
Unit Cost	c_roof	Base unit cost for roof retrofit	Decimal	NEW
Unit Cost	c_clt	Base unit cost for **e-**CLT	Decimal	NEW
Unit Cost	c_panel	Base unit cost for **e-**PANEL	Decimal	NEW
Unit Cost	c_hp	Unit cost for Heat Pump	Decimal	NEW
Unit Cost	c_st	Unit cost for storage	Decimal	NEW
Unit Cost	c_aux	Unit cost for pumps	Decimal	NEW
Unit Cost	c_net	Unit cost for pipe network	Decimal	NEW
Unit Cost	c_tank	Unit cost for **e-**TANK	Decimal	NEW
Unit Cost	c_fc	Unit cost for internal units (Fan Coils)	Decimal	NEW
Unit Cost	c_pv	Unit cost for the PV system	Decimal	NEW
Unit Time	id	Identifier	Integer	NEW
Unit Time	t_clt	Unit time for installing **e-**CLT	Decimal	NEW
Sustainability Parameter	id	Identifier	Integer	DELETED
Sustainability Parameter	sust_param	Sustainability Parameter	String	DELETED
E-DSS Project	id	Identifier	Integer	
E-DSS Project	ener_goal	Only an energy refurbishment	Boolean	DELETED
E-DSS Project	seis_goal	Combined seismic and energy refurbishment	Boolean	DELETED
E-DSS Project	proj_name	Project Name	String	
E-DSS Project	created_date	Date of Creation	Date	
E-DSS Project	proj_status_fk	Project Status FK	Integer	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Seasonal Heating	id	Identifier	Integer	
Seasonal Heating	clim_zone_fk	Climate Zone FK	Integer	
Seasonal Heating	month	Month	Integer	
Seasonal Heating	num_heat_days	Number of Heating Days	Integer	
Seasonal Cooling	id	Identifier	Integer	
Seasonal Cooling	clim_zone_fk	Climate Zone FK	String	
Seasonal Cooling	month	Month	Integer	
Seasonal Cooling	num_cool_days	Number of Cooling Days	Integer	
Renovation Solution	id	Identifier	Integer	
Renovation Solution	ener_seis_goal	Energy Retrofit or Combined Seismic and Energy Retrofit Renovation Process	Boolean	NEW
Renovation Solution	sol_appl	Solution Applicable	Boolean	NEW
Renovation Solution	proc_resp_msg	Process Response Message	String	NEW
Renovation Solution	u_new_wall_av	Average wall Thermal Transmittance for the entire building	Decimal	NEW
Renovation Solution	elec_sav	Electricity savings	Decimal	NEW
Renovation Solution	fuel_sav	Fuel savings	Decimal	NEW
Renovation Solution	nrpe_sav	Non-renewable primary energy savings	Decimal	NEW
Renovation Solution	co2_emis_sav	CO2 emissions savings	Decimal	NEW
Renovation Solution	oper_cost_sav	Savings in the operating costs	Decimal	NEW
Renovation Solution	time_ret_inv	Time of Return of the investment	Decimal	NEW
Renovation Solution	over_c_inst	Overall Installation Costs for the entire building	Decimal	NEW
Renovation Solution	time_inst	Time for installation	Decimal	NEW
Renovation Solution	**e**-dss_prj_fk	E-DSS Project FK	Integer	
Renovation Solution	renov_build_fk	Renovated Building FK	Integer	
Renovation Solution	renov_param_fk	Renovation Parameter FK	Integer	NEW
Renovation Solution	renov_solut_inter_res_fk	Renovation Solution Intermediate Result FK	Integer	NEW

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Renovation Parameter	id	Identifier	Integer	
Renovation Parameter	suff_ope_spac_cran	Sufficient operation space for the crane around the building	Boolean	NEW
Renovation Parameter	cons_alt_app_build	Constraints (Cultural Heritage, local regulations) that forbid altering the outer appearance of the building	Boolean	NEW
Renovation Parameter	open_grnd_occ_perim	Openings, doors, and door-windows in the ground floor occupy more than 60% of the perimeter	Boolean	NEW
Renovation Parameter	num_fac_att_build	Number of facade attached to another building	Integer	NEW
Renovation Parameter	free_spac_around_build	Amount of free space around the building, without trespassing the property's boundaries	Decimal	NEW
Renovation Parameter	conf_try_eclt_exos	Confirmation that you want to try **e-**CLT (or **e-**EXOS)	Boolean	NEW
Renovation Parameter	choic_eclt_exos	Choice between **e-**CLT or **e-**EXOS	Boolean	NEW
Renovation Parameter	lev_degr_exis_struct	Level of degradation of the existing structure (reinforced concrete frame)	Integer	NEW
Renovation Parameter	lev_occ_balc_perim	Occupancy level of balconies on the perimeter of a typical floor	Integer	NEW
Renovation Parameter	clt_pan_thick	CLT panel thickness	Decimal	
Renovation Parameter	ext_fin_layer_type_fk	External Finishing Layer Type FK	Integer	
Renovation Parameter	lamb_clad	External Finishing Layer - Thermal Conductivity - lambda_clad	Decimal	
Renovation Parameter	s_clad	External Finishing Layer: Thickness - s_clad	Decimal	
Renovation Parameter	c_clad	External Finishing Layer Unitary Cost - c_clad	Decimal	
Renovation Parameter	ins_mat_type_fk	Insulating Material Type FK	Integer	
Renovation Parameter	lamb_ins	Insulating Material : Thermal Conductivity – lambda_ins	Decimal	
Renovation Parameter	c_ins	Insulating Material Unitary Cost – c_ins	Decimal	
Renovation Parameter	u_lim	Maximum allowable thermal transmittance – u_lim	Decimal	NEW
Renovation Parameter	s_ins_clt	Insulating material in **e-**CLT: thickness	Decimal	NEW
Renovation Parameter	s_ins_panel	Insulating material in **e-**PANEL: thickness	Decimal	NEW
Renovation Parameter	u_w_new	New Windows Thermal transmittance	Decimal	NEW
Renovation Parameter	c_win	Unit cost of windows (including shadings) – c_win	Decimal	NEW
Renovation Parameter	com_wind_type_fk	Commercial Windows Type FK	Integer	NEW

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Renovation Parameter	wind_ type_fk	New Windows Type - FK	Integer	NEW
Renovation Parameter	g_factor_new	G Factor New	Decimal	NEW
Renovation Parameter	ins_com_wind	Flag: do you want to install a specific commercial solution	Boolean	NEW
Renovation Parameter	ins_mat_type_roof_fk	Insulating Material Type for Roof FK	Integer	NEW
Renovation Parameter	lamb_ins_roof	Insulating Material : Thermal Conductivity for Roo – lambda_ins_roof	Decimal	NEW
Renovation Parameter	c_ins_roof	Insulating Material Unitary for Roof Cost – c_ins_roof	Decimal	NEW
Renovation Parameter	s_ins_clt_roof	Insulating Material Thickness for Roof	Decimal	NEW
Renovation Parameter	ref_exis_foof	Flag: Do you want to refurbish the existing roof	Boolean	NEW
Renovation Parameter	repl_pav_tiles	Flag:Do you want to replace also the pavement/tiles	Boolean	NEW
Renovation Parameter	repl_prot_memb	Flag:Do you also envisage to replace the weather-protection membrane	Boolean	NEW
Renovation Parameter	ext_fin_roof_type_fk	External Finishing Roof Type FK	Integer	NEW
Renovation Parameter	c_fin_roof	Unitary Cost for External Finishing Roof – c_fin_roof	Decimal	NEW
Renovation Parameter	repl_tech_syst_e_therm	Flag:Do you want to replace your technical systems with the more efficient **e-**THERM solutions	Boolean	NEW
Renovation Parameter	q_hp	Thermal power of Heat Pump	Decimal	NEW
Renovation Parameter	n_fc	Number of fan coils installed in each apartment	Integer	NEW
Renovation Solution Intermediate Result	id	Identifier	Integer	
Renovation Solution Intermediate Result	ener_retro_sol_appl	Flag: Energy Retrofit solution applicable	Boolean	NEW
Renovation Solution Intermediate Result	e_panel_sol_appl	Flag: **e-**PANEL solution applicable	Boolean	NEW
Renovation Solution Intermediate Result	e_clt_sol_appl	Flag: **e-**CLT solution applicable	Boolean	NEW
Renovation Solution Intermediate Result	e_exos_sol_appl	Flag: **e-**EXOS solution applicable	Boolean	NEW
Renovation Solution Intermediate Result	comb_seis_ener_retro_sol_appl	Flag:Combined Seismic and Energy Retrofit solution applicable	Boolean	NEW

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Renovation Solution Intermediate Result	s_clt_i	Amount of surface covered with **e-**CLT for each façade – Total Exposure FK	Integer	NEW
Renovation Solution Intermediate Result	s_clt_tot	Overall **e-**CLT surface in the entire building	Decimal	NEW
Renovation Solution Intermediate Result	s_panel_tot	Overall **e-**PANEL surface in the entire building	Decimal	NEW
Renovation Solution Intermediate Result	c_sd	Coefficient for the existing structure (Reinforced Concrete frame) degraded	Integer	NEW
Renovation Solution Intermediate Result	c_b	Coefficient for percentage of the perimeter occupied by balconies	Integer	NEW
Renovation Solution Intermediate Result	c_sz	Coefficient for seismic zone level	Integer	NEW
Renovation Solution Intermediate Result	c_f	Coefficient for number of floors above the ground	Integer	NEW
Renovation Solution Intermediate Result	c_fa	Coefficient for number of facades attached to another building	Integer	NEW
Renovation Solution Intermediate Result	c_tot	Total Coefficient	Integer	NEW
Renovation Solution Intermediate Result	s_ins_min	Minimum insulating material thickness	Decimal	NEW
Renovation Solution Intermediate Result	u_new_wall	New Thermal transmittance values of the vertical opaque components	Decimal	NEW
Renovation Solution Intermediate Result	u_clt	**e-**CLT Thermal Transmittance	Decimal	NEW
Renovation Solution Intermediate Result	s_ins_clt	Insulating Material in **e-**CLT: thickness	Decimal	NEW
Renovation Solution Intermediate Result	u_new_wall_i	New Thermal Transmittance of the wall for each façade – Total Exposure FK	Integer	NEW
Renovation Solution Intermediate Result	s_ins_panel	Insulating Material in **e-**PANEL: thickness	Decimal	NEW
Renovation Solution Intermediate Result	u_panel	**e-**PANEL Thermal Transmittance	Decimal	NEW
Renovation Solution Intermediate Result	u_frame	Frame Thermal Transmittance	Decimal	NEW

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Renovation Solution Intermediate Result	s_ins_panel_min	Minimum Insulating Material in **e-**PANEL: thickness	Decimal	NEW
Renovation Solution Intermediate Result	g_factor_new	New Windows g_factor	Decimal	NEW
Renovation Solution Intermediate Result	u_roof_new	New Roof Thermal Transmittance	Decimal	NEW
Renovation Solution Intermediate Result	c_mean_new	New Mean thermal capacity	Decimal	NEW
Renovation Solution Intermediate Result	u_box_new	New Box Thermal transmittance	Decimal	NEW
Renovation Solution Intermediate Result	f_shade_new	New Corrective factor for mobile shading devices	Decimal	NEW
Renovation Solution Intermediate Result	over_c_env	Cost for the envelope renovation	Decimal	NEW
Renovation Solution Intermediate Result	over_c_clt	Costs for **e-**CLT panels	Decimal	NEW
Renovation Solution Intermediate Result	over_c_panel	Costs for **e-**PANEL panels	Decimal	NEW
Renovation Solution Intermediate Result	over_c_win	Costs for windows	Decimal	NEW
Renovation Solution Intermediate Result	over_c_roof	Costs of roof insulation	Decimal	NEW
Renovation Solution Intermediate Result	over_c_therm	Costs for the **e-**THERM installation	Decimal	NEW
Renovation Solution Intermediate Result	over_c1	Costs for Heat pump, storage tanks and auxiliary systems	Decimal	NEW
Renovation Solution Intermediate Result	over_c2	Costs for Distribution network	Decimal	NEW
Renovation Solution Intermediate Result	over_c3	Costs for Terminal units and **e-**TANK	Decimal	NEW
Renovation Solution Intermediate Result	over_c4	Cost for PV system	Decimal	NEW
Renovation Solution Intermediate Result	time_inst_clt	Time for installation **e-**CLT panels	Decimal	NEW

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Renovation Solution Intermediate Result	time_inst_panel	Time for installation **e-**PANEL panels	Decimal	NEW
Renovation Solution Intermediate Result	c_superposition	Final coefficient to account for delays or for a not full superposition of other works to **e-**CLT and **e-**PANEL installation	Decimal	NEW
Feasibility Check Parameter	id	Identifier	Integer	DELETED
Feasibility Check Parameter	name	name parameter	String	DELETED
Feasibility Check Parameter	value	value parameter	Decimal	DELETED
				CC
Technical Component Selection	id	Identifier	Integer	DELETED
Technical Component Item	id	Identifier	Integer	DELETED
Technical Component Item	tech_comp_fk	Technical Component FK	Integer	DELETED
Technical Component Item	tech_comp_sel_fk	Technical Component Selection FK	Integer	DELETED
Technical Component	id	Identifier	Integer	DELETED
Technical Component	type	Type (**e-**PANEL, **e-**CLT, **e-**EXOS, **e-**THERM)	String	DELETED
Technical Component Geometric Data	id	Identifier	Integer	DELETED
Technical Component Geometric Data	graph_repr	Graphical representation	BIM File	DELETED
Technical Component Geometric Data	tech_comp_fk	Technical Component FK	Integer	DELETED
Technical Component Energy_Data	id	Identifier	Integer	DELETED

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Technical Component Energy_Data	tech_comp_fk	Technical Component FK	Integer	DELETED
Technical Component Economic Data	id	Identifier	Integer	DELETED
Technical Component Economic Data	tech_comp_fk	Technical Component FK	Integer	DELETED
Building Energy Performance Intermediate Result	id	Identifier	Integer	NEW
Building Energy Performance Intermediate Result	s_gross_i	Overall gross surface of each façade – Total Exposure FK	Integer	NEW
Building Energy Performance Intermediate Result	s_heat_i	Overall heated surface of each façade – Total Exposure FK	Integer	NEW
Building Energy Performance Intermediate Result	s_w	Overall window surface for the entire building	Decimal	NEW
Building Energy Performance Intermediate Result	s_adj_i	Heated surfaces in contact with those adjacent buildings for each orientation – Total Exposure FK	Integer	NEW
Building Energy Performance Intermediate Result	s_eff_i	Outside heated vertical surfaces for each orientation – Total Exposure FK	Integer	NEW
Building Energy Performance Intermediate Result	s_eff_op_i	Outside heated opaque vertical surfaces for each orientation – Total Exposure FK	Integer	NEW
Building Energy Performance Intermediate Result	s_box_i	External surface of the boxes – Total Exposure FK	Integer	NEW

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Building Energy Performance Intermediate Result	b_tr_u_adj	Vertical surfaces attached to adjacent buildings - Correction factors	Decimal	NEW
Building Energy Performance Intermediate Result	s_roof	Gross surface of the Roof floor	Decimal	NEW
Building Energy Performance Intermediate Result	s_d_tot	Overall heated envelope surface	Decimal	NEW
Building Energy Performance Intermediate Result	u_box	Box Thermal transmittance	Decimal	NEW
Building Energy Performance Intermediate Result	c_th	Thermal bridges Coefficient	Decimal	NEW
Building Energy Performance Intermediate Result	u_w_corr	Windows ((including roller shutters) Thermal transmittance	Decimal	NEW
Building Energy Performance Intermediate Result	u_ws	Thermal transmittance of the windows with shutter closed	Decimal	NEW
Building Energy Performance Intermediate Result	h_ve	Ventilation Heat Transfer Coefficient	Decimal	NEW
Building Energy Performance Intermediate Result	s_net	Overall Net floor surface of the building	Decimal	NEW
Building Energy Performance Intermediate Result	res	Flag if the predominant building use is Residential	Boolean	NEW
Building Energy Performance Intermediate Result	q_h_j	Monthly energy demand for space heating – Month Data FK	Integer	NEW

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Building Energy Performance Intermediate Result	q_c_j	Monthly energy demand for space cooling – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	q_h_loss_j	Heat losses in heating mode – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	q_h_gain_j	Heat losses in cooling mode – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	q_c_gain_j	Heat gains in heating mode – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	q_c_loss_j	Heat gains in cooling mode – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	q_h_tr_j	Thermal energy transmitted through the envelope – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	phi_r_tot	phi_r_tot	Decimal	NEW
Building Energy Performance Intermediate Result	roof	Flag if the selected Roof Boundary Condition is Outdoors	Boolean	NEW
Building Energy Performance Intermediate Result	r_se_ho	Coefficient r_se_ho	Decimal	NEW
Building Energy Performance Intermediate Result	r_se_v	Coefficient r_se_v	Decimal	NEW
Building Energy Performance Intermediate Result	phi_r_roof	phi_r_roof	Decimal	NEW

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Building Energy Performance Intermediate Result	phi_r_i	phi_r_i – Total Exposure FK	Integer	NEW
Building Energy Performance Intermediate Result	q_c_tr_j	Thermal energy transmitted through the envelope – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	q_h_ve_j	Heating demand for Ventilation – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	q_c_ve_j	Cooling demand for Ventilation – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	q_h_sol_w_j	Solar gains through the windows – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	q_c_sol_w_j	Solar gains through the windows – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	q_h_sol_op_j	Solar gains through the opaque components – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	q_c_sol_op_j	Solar gains through the opaque components – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	q_h_end_j	Endogenous heat – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	q_c_end_j	Endogenous heat – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	tau	Time constant of the building	Decimal	NEW

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Building Energy Performance Intermediate Result	a_h	a_h	Decimal	NEW
Building Energy Performance Intermediate Result	upsilon_h_j	upsilon_h_j – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	eta_h_gn_j	Utilization factors for heat gains – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	a_c	a_c	Decimal	NEW
Building Energy Performance Intermediate Result	upsilon_c_j	upsilon_c_j – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	eta_c_ls_j	Utilization factors for heat losses – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	c_days_j	Duration of the months included in the cooling season – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	q_w_j	Thermal energy needs for Domestic Hot Water – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	theta_em	Monthly mean air temperature	Decimal	NEW
Building Energy Performance Intermediate Result	v_w	Daily DHW volume	Decimal	NEW
Building Energy Performance Intermediate Result	nu	Number of people in the Building	Decimal	NEW

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Building Energy Performance Intermediate Result	h_sol_j	Solar irradiation available on the PV plane – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	e_pv_j	Expected monthly electricity production – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	e_pv	Expected annual electricity production	Decimal	NEW
Building Energy Performance Intermediate Result	e_st_j	Monthly solar thermal energy made available by the ST collectors – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	eta_glob_w	DHW Global efficiency	Decimal	NEW
Building Energy Performance Intermediate Result	c_st	Coefficient accounts for the presence of storage tanks and their insulation level	Decimal	NEW
Building Energy Performance Intermediate Result	q_w_net_j	Net monthly thermal energy needs for Domestic Hot Water – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	e_w_j	Electricity consumption – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	g_w_j	Fuel consumption – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	eta_glob_h	Global efficiency for Space Heating	Decimal	NEW
Building Energy Performance Intermediate Result	q_h_net_j	Net monthly thermal energy needs for Space Heating– Month Data FK	Integer	NEW

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Building Energy Performance Intermediate Result	eta_glob_c	Global efficiency for Space Cooling	Decimal	NEW
Building Energy Performance Intermediate Result	e_h_j	Electricity consumption – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	g_h_j	Fuel consumption – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	e_c_j	Electricity consumption – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	eta_exe_h	Exergy efficiency for Space Heating	Decimal	NEW
Building Energy Performance Intermediate Result	eta_gen_h_j	Monthly Exergy efficiency for Space Heating – Month Data FK	Integer	NEW
Building Energy Performance Intermediate Result	eta_gen_c	Generation efficiency	Decimal	NEW
Building Energy Performance Intermediate Result	build_fk	Building FK	Integer	NEW
Building Energy Performance	id	Identifier	Integer	
Building Energy Performance	over_heat_tran_coef	Overall heat transfer coefficient	Decimal	
Building Energy Performance	s_v_ratio	S/V Ratio	Decimal	
Building Energy Performance	ann_heat_demand	Annual energy demand for space heating	Decimal	
Building Energy	ann_cool_demand	Annual energy demand for space cooling	Decimal	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Performance				
Building Energy Performance	ann_elec_prod_pv	Annual Electricity Production from PV	Decimal	NEW
Building Energy Performance	ann_net_elec_cons	Annual net electric energy consumption	Decimal	
Building Energy Performance	month_net_elec_cons	Monthly net electric energy consumption – Month Data FK	Integer	NEW
Building Energy Performance	ann_fuel_cons	Annual fuel consumption	Decimal	
Building Energy Performance	prim_energ_demand	Primary energy demand (non-renewable)	Decimal	
Building Energy Performance	tot_co2_emis	Total CO2 emissions	Decimal	
Building Energy Performance	tot_oper_cost	Total Operating Costs	Decimal	NEW
Building Energy Performance	over_coef_heat_tranf	Overall Coefficient of heat transfer by transmission – H_tr	Decimal	
Building Energy Performance	coef_hor_disp_floor	Coefficient for horizontal dispersing surfaces – H_tr_floor	Decimal	
Building Energy Performance	coef_hor_disp_roof	Coefficient for horizontal dispersing surfaces – H_tr_roof	Decimal	
Building Energy Performance	coef_vert_disp_exp	Coefficient for vertical dispersing surfaces – Total Exposure FK	Integer	
Building Energy Performance	build_fk	Building FK	Integer	
Month Data	id	Identifier	Integer	NEW
Month Item	id	Identifier	Integer	NEW
Month Item	month	Month	Integer	NEW
Month Item	value	Value	Decimal	NEW
Month Item	month_data_fk	Month Data FK	Integer	NEW

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Initial Building	id	Identifier	Integer	
Initial Building	build_fk	Building FK	Integer	
Initial Building	e-dss_prj_fk	E-DSS Project FK	Integer	
Renovated Building	id	Identifier	Integer	
Renovated Building	build_fk	Building FK	Integer	
Building Energy Bill	id	Identifier	Integer	
Building Energy Bill	tot_oper_cost	Total Operating Costs	Decimal	
Building Energy Bill	build_fk	Building FK	Integer	
Colour of the External Finish	id	Identifier	Integer	
Colour of the External Finish	col_ext_fin_ita	Italian Colour of the External Finish	String	
Colour of the External Finish	col_ext_fin_eng	English Colour of the External Finish	String	
Colour of the External Finish	wall_absor_coef	Solar absorption coefficient (walls)	Decimal	
Colour of the External Finish	roof_absor_coef	Solar absorption coefficient (roof)	Decimal	
Type of external walls	id	Identifier	Integer	
Type of external walls	wall_type_ita	Italian Walls Type	String	
Type of external walls	wall_type_eng	English Walls Type	String	
Type of external walls	u_wall	Thermal transmittance	Decimal	
Type of external walls	c_mean	Mean thermal capacity	Decimal	
Floor Type	id	Identifier	Integer	
Floor Type	floor_type_ita	Italian Floor Type	String	
Floor Type	floor_type_eng	English Floor Type	String	
Floor Type	u_floor	Thermal transmittance	Decimal	
Roof Type	id	Identifier	Integer	
Roof Type	roof_type_ita	Italian Roof Type	String	
Roof Type	roof_type_eng	English Roof Type	String	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Roof Type	u_roof	Thermal transmittance	Decimal	
Windows Type	id	Identifier	Integer	
Windows Type	glaz_type_ita	Italian Glazing Type	String	
Windows Type	glaz_type_eng	English Glazing Type	String	
Windows Type	frame_type_ita	Italian Frame Type	String	
Windows Type	frame_type_eng	English Frame Type	String	
Windows Type	u_w	Thermal transmittance	Decimal	
Windows Type	g_factor	G Factor	Decimal	
Type of roller shutter	id	Identifier	Integer	
Type of roller shutter	roll_shut_type_ita	Italian Roller Shutter Type	String	
Type of roller shutter	roll_shut_type_eng	English Roller Shutter Type	String	
Type of roller shutter	r_sh	Thermal resistance	Decimal	
Floor Boundary Condition	id	Identifier	Integer	
Floor Boundary Condition	floor_bound_cond_ita	Italian Floor Boundary Condition	String	
Floor Boundary Condition	floor_bound_cond_eng	English Floor Boundary Condition	String	
Floor Boundary Condition	b_tr_u_f	Correction Factor	Decimal	
Roof Boundary Condition	id	Identifier	Integer	
Roof Boundary Condition	roof_bound_cond_ita	Italian Roof Boundary Condition	String	
Roof Boundary Condition	roof_bound_cond_eng	English Roof Boundary Condition	String	
Roof Boundary Condition	b_tr_u_r	Correction Factor	Decimal	
Roof Boundary Condition	f_roof	Factor for Surface of Roof	Decimal	
Predominant Building Use	id	Identifier	Integer	
Predominant Building Use	pre_build_use_ita	Italian Predominant Building Use	String	
Predominant Building Use	pre_build_use_eng	English Predominant Building Use	String	
Predominant Building Use	ach	Air Changes per Hour	Decimal	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Predominant Building Use	d_end	Endogenous Gains	Decimal	
Predominant Building Use	psqm	Occupancy rate – Number of people per square meter	Decimal	
Predominant Building Use	lps	Lps - Ventilation rate (non residential)	Decimal	
Predominant Building Use	f_ve	F_ve - Correction factor (non residential)	Decimal	
Coeff_Altitude	id	Identifier	Integer	
Coeff_Altitude	alt_min	Altitude min	Decimal	
Coeff_Altitude	alt_max	Altitude max	Decimal	
Coeff_Altitude	coeff_c_2	Coefficent C2 - Correction coefficient (non residential)	Decimal	
Climate_Data	id	Identifier	Integer	
Climate_Data	clim_zone	Climate zone	String	
Climate_Data	degr_day	Heating Degree Days	Integer	
Mean outdoor air temperature	id	Identifier	Integer	
Mean outdoor air temperature	loc_fk	Location – FK	Integer	
Mean outdoor air temperature	month	Month	Integer	
Mean outdoor air temperature	mean_temp	Mean Temperature	Decimal	
Vertical Irradiation	id	Identifier	Integer	
Vertical Irradiation	loc_fk	Location – FK	Integer	
Vertical Irradiation	month	Month	Integer	
Vertical Irradiation	spat_dir_fk	Spatial Direction FK	Integer	UPDATED
Vertical Irradiation	vert_rad	Vertical Irradiation	Decimal	
Horizontal Irradiation	id	Identifier	Integer	
Horizontal Irradiation	loc_fk	Location – FK	Integer	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Horizontal Irradiation	month	Month	Integer	
Horizontal Irradiation	horiz_rad	Horizontal Irradiation	Decimal	
Shading Factor	id	Identifier	Integer	
Shading Factor	month	Month	Integer	
Shading Factor	spat_dir_fk	Spatial Direction FK	Integer	UPDATED
Shading Factor	Shad_Factor	Shading Factor	Decimal	
Domestic Hot Water Coefficent	id	Identifier	Integer	
Domestic Hot Water Coefficent	pre_build_use_fk	Predominant Building Use FK	Integer	
Domestic Hot Water Coefficent	cond_res	Condition for Residential	Decimal	
Domestic Hot Water Coefficent	coeff_a	Coefficient A	Decimal	
Domestic Hot Water Coefficent	coeff_b	Coefficient B	Decimal	
Days in Month	id	Identifier	Integer	
Days in Month	month	Month	Integer	
Days in Month	num_days	Number of Days	Integer	
PV Module Type Efficiency	id	Identifier	Integer	
PV Module Type Efficiency	pv_mod_type_ita	Italian PV Module Type	String	
PV Module Type Efficiency	pv_mod_type_eng	English PV Module Type	String	
PV Module Type Efficiency	k_pv	Efficiency	Decimal	
PV-ST Installation Type	id	Identifier	Integer	
PV-ST Installation Type	pv_st_inst_type_ita	Italian PV-ST Installation Type	String	
PV-ST Installation Type	pv_st_inst_type_eng	English PV-ST Installation Type	String	
PV-ST Installation Type	f_pv	Correction Coefficient	Decimal	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

PV Module Orientation	id	Identifier	Integer	
PV Module Orientation	pv_inst_type_fk	PV-ST Installation Type FK	Integer	UPDATED
PV Module Orientation	spat_dir_fk	Spatial Direction FK	Integer	UPDATED
PV Module Orientation	f_esp	Correction Coefficient	Decimal	
ST Module Orientation	id	Identifier	Integer	
ST Module Orientation	spat_dir_fk	Spatial Direction FK	Integer	UPDATED
ST Module Type Efficiency	id	Identifier	Integer	
ST Module Type Efficiency	st_mod_type_ita	Italian ST Module Type	String	
ST Module Type Efficiency	st_mod_type_eng	English ST Module Type	String	
ST Module Type Efficiency	k_st	Efficiency	Decimal	
Energy Source	id	Identifier	Integer	
Energy Source	pow_src_type_ita	Italian Power Source Type	String	
Energy Source	pow_src_type_eng	English Power Source Type	String	
Energy Source	lhw	LHW - Lower Heating Values	Decimal	
Energy Source	ef	EF – Emission Factors	Decimal	
Energy Source	pef	PEF - Primary Energy Factors	Decimal	
Energy Source	c	C	Decimal	
DHW Service Provided	id	Identifier	Integer	
DHW Service Provided	dhw_serv_prov_ita	Italian DHW Service Provided	String	
DHW Service Provided	dhw_serv_prov_eng	English DHW Service Provided	String	
DHW Generator Type	id	Identifier	Integer	
DHW Generator Type	dhw_gen_type_ita	Italian DHW Generator Type	String	
DHW Generator Type	dhw_gen_type_eng	English DHW Generator Type	String	
DHW Generator Type	eta_gen_w	ETA Gen W - Generation efficiency	Decimal	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Distribution Performance	id	Identifier	Integer	
Distribution Performance	syst_type_fk	Type of System FK	Integer	
Distribution Performance	distr_type_fk	Distribution Type FK	Integer	
Distribution Performance	u_wall	Thermal transmittance	Decimal	NEW
Distribution Performance	n_dwel	Number of Dwellings	Decimal	
Distribution Performance	n_floors	Number of Floors	Decimal	
Distribution Performance	eta_dist_eff	ETA Distribution efficiency	Decimal	
HC Generator Type	id	Identifier	Integer	
HC Generator Type	hc_gen_type_ita	Italian HC Generator Type	String	
HC Generator Type	hc_gen_type_eng	English HC Generator Type	String	
HC Generator Type	gen_pos_fk	Generator Position FK	Integer	UPDAT ED
HC Generator Type	eta_gen_h_c	ETA Gen H-C Factor generation efficiency	Decimal	
Type of System	id	Identifier	Integer	
Type of System	syst_type_ita	Italian Type of System	String	
Type of System	syst_type_eng	English Type of System	String	
Generator Position	id	Identifier	Integer	
Generator Position	gen_pos_ita	Italian Generator Position	String	
Generator Position	gen_pos_eng	English Generator Position	String	
Distribution_Type	id	Identifier	Integer	
Distribution_Type	distr_type_ita	Italian Distribution Type	String	
Distribution_Type	distr_type_eng	English Distribution Type	String	
Storage Tank_Type	id	Identifier	Integer	
Storage Tank_Type	stor_tank_type_ita	Italian Storage Tank Type	String	
Storage Tank_Type	stor_tank_type_eng	English Storage Tank Type	String	
Storage Tank_Type	coeff_c_st	Coefficient C_ST	Decimal	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Heat Pump	id	Identifier	Integer	
Heat Pump	heat_pump_type_ita	Italian Heat Pump Type	String	
Heat Pump	heat_pump_type_eng	English Heat Pump Type	String	
Heat Pump	cop_ref	COP - Coefficient of Performance	Decimal	
Heat Pump	seer	SEER - Seasonal energy efficiency ratio	Decimal	
Heat Pump	t_h_ref	T_H_ref – temperature	Decimal	
Heat Pump	t_c_ref	T_C_ref – temperature	Decimal	
Heat Pump	t_c	T_C – temperature	Decimal	
Emission and regulation type	id	Identifier	Integer	
Emission and regulation type	val_unit_cost_ita	Italian Emission and regulation type	String	
Emission and regulation type	val_unit_cost_eng	English Emission and regulation type	String	
Emission and regulation type	eta_emi_h	ETA Emi_H – Emission Efficiency Heating	Decimal	
Emission and regulation type	eta_emi_c	ETA Emi_C - Emission Efficiency Cooling	Decimal	
Emission and regulation type	t_h	Temperature of the hot side	Decimal	
Control logics	id	Identifier	Integer	
Control logics	ctrl_log_ita	Italian Control logics	String	
Control logics	ctrl_log_eng	English Control logics	String	
Control logics	eta_ctrl_H_C	ETA Ctrl H-C - Control Efficiency – Heating – Cooling	Decimal	
Country	id	Identifier	Integer	
Country	name_ita	Italian Country Name	String	
Country	name_eng	English Country Name	String	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Region	id	Identifier	Integer	
Region	name_ita	Italian Region Name	String	
Region	name_eng	English Region Name	String	
Region	cntr_fk	Country FK	Integer	
Province	id	Identifier	Integer	
Province	name_ita	Italian Province Name	String	
Province	name_eng	English Province Name	String	
Province	reg_fk	Region FK	Integer	
Municipality	id	Identifier	Integer	
Municipality	name_ita	Italian Municipality Name	String	
Municipality	name_eng	English Municipality Name	String	
Municipality	prov_fk	Province FK	Integer	
Role	id	Identifier	Integer	
Role	role_ita	Italian Role	String	
Role	role_eng	English Role	String	
PhotoVoltaic System	id	Identifier	Integer	
PhotoVoltaic System	pres_pv_syst	Presence of Photovoltaic (PV) system	Boolean	
PhotoVoltaic System	pv_mod_type_fk	PV Module Type Efficiency FK	Integer	
PhotoVoltaic System	eff_mod_pv_stc	Efficiency of PV modules under STC conditions	Decimal	
PhotoVoltaic System	inst_pv_surf	PV surface	Decimal	
PhotoVoltaic System	pv_inst_type_fk	PV-ST Installation Type FK	Integer	
PhotoVoltaic System	pv_mod_orient_fk	PV Module Orientation FK	Integer	
Solar Thermal System	id	Identifier	Integer	
Solar Thermal System	pres_st_syst	Presence of solar thermal system (ST)	Boolean	
Solar Thermal System	st_mod_type_fk	ST Module Type Efficiency FK	Integer	
Solar Thermal System	inst_st_surf	Installed ST surface	Decimal	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Solar Thermal System	inst_type_fk	PV-ST Installation Type FK	Integer	
Solar Thermal System	st_mod_orient_fk	ST Module Orientation FK	Integer	
Domestic Hot Water System	id	Identifier	Integer	
Domestic Hot Water System	pres_dhw_syst	Presence of Domestic Hot Water production system	Boolean	
Domestic Hot Water System	syst_type_fk	Type of System FK	Integer	
Domestic Hot Water System	gen_type_fk	Generator Type FK	Integer	
Domestic Hot Water System	serv_prov_fk	DHW Service Provided FK	Integer	
Domestic Hot Water System	gen_pos_fk	Generator Position FK	Integer	
Domestic Hot Water System	ener_src_fk	Energy Source FK	Integer	
Domestic Hot Water System	distr_type_fk	Distribution Type FK	Integer	
Domestic Hot Water System	stor_tank_type_fk	Storage Tank Type FK	Integer	
Domestic Hot Water System	dhw_lhw	DHW LHW - Lower Heating Values	Decimal	
Domestic Hot Water System	dhw_ef	DHW EF – Emission Factors	Decimal	
Domestic Hot Water System	dhw_pef	DHW_PEF - Primary Energy Factors	Decimal	
Domestic Hot Water System	dhw_c	DHW C	Decimal	
Heating System	id	Identifier	Integer	
Heating System	pres_heat_syst	Presence of Heating System (H)	Boolean	
Heating System	syst_type_fk	Type of System FK	Integer	
Heating System	gen_type_fk	Generator Type FK	Integer	
Heating System	gen_pos_fk	Generator Position FK	Integer	
Heating System	ener_src_fk	Energy Source FK	Integer	
Heating System	heat_pump_type_fk	Heat Pump Type FK	Integer	
Heating System	distr_type_fk	Distribution Type FK	Integer	
Heating System	seer	SEER - Seasonal energy efficiency ratio	Decimal	
Heating System	stor_tank_type_fk	Storage Tank Type FK	Integer	
Heating System	emis_reg_type_fk	Emission and regulation type FK	Integer	
Heating System	ctrl_log_fk	Control logics FK	Integer	
Heating System	h_lhw	H LHW - Lower Heating Values	Decimal	
Heating System	h_ef	H EF – Emission Factors	Decimal	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Heating System	h_pef	H_PEF - Primary Energy Factors	Decimal	
Heating System	h_c	H C	Decimal	
Cooling System	id	Identifier	Integer	
Cooling System	pres_cool_syst	Presence of Cooling System (C)	Boolean	
Cooling System	syst_type_fk	Type of System FK	Integer	
Cooling System	gen_type_fk	Generator Type FK	Integer	
Cooling System	heat_pump_type_fk	Heat Pump Type FK	Integer	
Cooling System	distr_type_fk	Distribution Type FK	Integer	
Cooling System	cop_ref	COP at reference conditions for the Heat Pump	Decimal	
Cooling System	stor_tank_type_fk	Storage Tank Type FK	Integer	
Cooling System	emis_reg_type_fk	Emission and regulation type FK	Integer	
Cooling System	ctrl_log_fk	Control logics FK	Integer	
Cooling System	c_lhw	C LHW - Lower Heating Values	Decimal	
Cooling System	c_ef	C EF – Emission Factors	Decimal	
Cooling System	c_pef	C_PEF - Primary Energy Factors	Decimal	
Cooling System	c_c	C C	Decimal	
Insulating material Type	id	Identifier	Integer	
Insulating material Type	ins_mat_type_ita	Italian Insulating material Type	String	
Insulating material Type	ins_mat_type_eng	English Insulating material Type	String	
Insulating material Type	lamb_ins	lambda_ins	Decimal	
Insulating material Type	unit_cost	Unitary cost	Decimal	
Insulating material Type	com_thick_rang	Commercial thickness range	String	
External Finishing Layer Type	id	Identifier	Integer	
External Finishing Layer Type	ext_fin_layer_type_ita	Italian External Finishing Layer Type	String	
External Finishing Layer Type	ext_fin_layer_type_en g	English External Finishing Layer Type	String	
External Finishing Layer Type	lamb_clad	lambda_clad	Decimal	
External Finishing Layer Type	s_clad	s_clad	Decimal	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

External Finishing Layer Type	unit_cost	Unitary cost – c_clad	Decimal	
External Finishing Roof Type	id	Identifier	Integer	NEW
External Finishing Roof Type	ext_fin_roof_type_ita	Italian External Finishing Roof Type	String	NEW
External Finishing Roof Type	ext_fin_roof_type_eng	English External Finishing Roof Type	String	NEW
External Finishing Roof Type	lamb_fin_roof	Thermal Conductivity for External Finishing Roof	Decimal	NEW
External Finishing Roof Type	s_fin_roof	Thickness for External Finishing Roof	Decimal	NEW
External Finishing Roof Type	unit_cost	Unitary Cost for External Finishing Roof – c_fin_roof	Decimal	NEW
Max Thermal Transmittance	id	Identifier	Integer	
Max Thermal Transmittance	clim_zone_fk	Climate Zone FK	Integer	
Max Thermal Transmittance	u_lim	U_lim	Decimal	
Commercial Windows Type	id	Identifier	Integer	
Commercial Windows Type	com_wind_type_ita	Italian Commercial Windows Type	String	
Commercial Windows Type	com_wind_type_eng	English Commercial Windows Type	String	
Commercial Windows Type	u_w	Thermal transmittance	Decimal	
Commercial Windows Type	g_factor	G Factor	Decimal	
Commercial Windows Type	cost	Cost	Decimal	
Threshold Ht Coefficient	id	Identifier	Integer	
Threshold Ht Coefficient	clim_zone	Climate zone	String	
Threshold Ht Coefficient	s_v	S/V Ratio timit	Decimal	
Threshold Ht Coefficient	ht_thres	Ht Threshold	Decimal	
Dwelling	id	Identifier	Integer	
Dwelling	descr_dwell	Description of Dwelling	String	NEW
Dwelling	net_surf_dwell	Net Surface of the dwelling	Decimal	
Dwelling	oper_cost	Operating Costs of the dwelling	Decimal	
Dwelling	build_fk	Building FK	Integer	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

Proj_Status	id	Identifier	Integer	
Proj_Status	status_ita	Italian Status	String	
Proj_Status	status_eng	English Status	String	
Seis_Zone	id	Identifier	Integer	
Seis_Zone	pga_lim_low	Lower Limit of PGA	Decimal	
Seis_Zone	pga_lim_upp	Upper Limit of PGA	Decimal	
Seis_Zone	desc_ita	Italian Seismic Zone Description	String	
Seis_Zone	desc_eng	English Seismic Zone Description	String	
Attach_Img	id	Identifier	Integer	
Attach_Img	desc_ita	Italian Attach Image Description	String	
Attach_Img	desc_eng	English Attach Image Description	String	
Attach_Img	attach_img_data	Attach Image Data	LONGBL OB	
Attach_Img	e-dss_prj_fk	E-DSS Project FK	Integer	
Attach_Rem	id	Identifier	Integer	
Attach_Rem	desc_ita	Italian Attached Remark Description	String	
Attach_Rem	desc_eng	English Attached Remark Description	String	
Attach_Rem	attach_rem_data	Attach Remark Data	LONGTE XT	
Attach_Rem	e-dss_prj_fk	e-DSS Project FK	Integer	

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.

e-SAFE has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 893135.