SUstainable solutions for affordable REtroFIT of domestic buildings

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Other authors	**All partners contributed**

WP7 - Deliverable D7.3

Operational Tool

Dissemination Level

PU	**Public**	**X**
CO	Confidential, only for members of the consortium (including the Commission Services)	
CI	Classified, as referred to in Commission Decision 2001/844/EC	

Document History

Version	Date	Authors	Description
1	12/04/2024	ISQ, Bruna Onety	Creation of the document
2	28/06/2024	ISQ, Bruna Onety, Bruno Pereira, Luísa Pereira	First draft for partners
3	07/08/2024	All partners	Contribution from partners
4	09/08/2024	ISQ, Sérgio Tadeu	Coordinator review

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Abbreviations

BIS	Building Integrated System
CDD	Cooling Degree Days
DHW	Domestic Hot Water
ECM	Energy Conservation Measure
EPBD	Energy Performance of Buildings Directive
HDD	Heating Degree Days
IRR	Internal Rate of Return on Investment
NUTS	Nomenclature of territorial units for statistics
ROI	Return on Investment

Publishable summary

This deliverable aims to outline the general methodology of the SURe³FIT operational tool for optimising the renovation process and decision-making. It primarily serves as a user's guide.

The document is structured into two sections. The first one covers the key aspects and structure of the chosen tool methodology, including the indications of Excel files, tabs, and their functions. The second one consists of a detailed step-by-step guide, including a settings overview, the identification of the tool's inputs and outputs, and an example of graphical visualisation.

Introduction

Leading Beneficiary: ISQ

Participants:

Task description:

Task 7.3 involves developing operational tools for optimising the renovation process and decision-making. The goal is to create a user-friendly computer program that facilitates optimal retrofitting and the selection of technologies for various scenarios, including combinations of solutions for distinct functions such as insulation, windows, and technical systems.

This document has been created to assist in conducting this task by providing a user guide for the mentioned tools.

1 The SURe³FIT Operational Tool

The SURe³FIT is an operational tool designed to support decision-making during residential building energy renovation projects. It uses life-cycle energy estimation models and cost-benefit assessments for buildings, and it can perform combined simulations of Energy Conservation Measures (ECMs). While the proposed methodology directly incorporates economic and environmental criteria, the anticipated benefits extend to the social pillar of sustainability as well [e.g., enhancing indoor environmental quality and mitigating energy poverty among householders (Figure 1)].

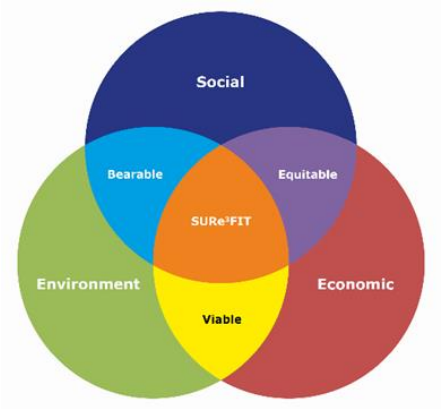


Figure 1 - e³ - Energy Efficiency in the Built Environment

The operational tool leverages data gathered during the Assessment phase of the retrofitting journey, as described in Deliverable D7.1. It should also be aligned with the objectives defined in the Identifying Needs step (within phase 3 – Implementation). By using the tool during Decision-making, stakeholders can maximize energy efficiency and sustainability in the building while minimising costs.

1.1 SURe³FIT tool methodology

The SURe³FIT tool proposes improvements to the cost-optimality methodology, established by the Delegated Regulation 244/2012 and EN 15459, as presented in selected scientific articles [1] and [2] and highlighted in sections 1.1.1 and 1.1.2 below.

For the energy estimation models, the calculation method is based on an adaptation of the Energy Performance of Buildings Directive (EPBD) [3]. Climate data considers Heating Degree Days (HDD) and Cooling Degree Days (CDD) based on the NUTS III classification, which can be accessed from sources such as the Eurostat website [4].

1.1.1 Environmental Assessment

The operational tool employs a robust approach to assess the environmental impact of energy renovation proposals. This assessment is based on a life cycle impact indicator, measured in kilograms of CO_2 equivalent emissions. This represents a significant improvement, as the conventional EPBD-based methodology only considers the primary energy consumption

associated with the building's operation. This key performance indicator (KPI) covers emissions related to both the energy consumption of the building during its use phase and the embodied impact of the ECMs.

Furthermore, to estimate emissions linked to various energy sources used for supplying the building's demand, the SURe³FIT tool relies on more accurate and updated emission and conversion factors, instead of those used in the EPBD-based methodology.

1.1.2 Economic Assessment

In a residential home retrofitting scenario, a life cycle cost analysis assesses the benefits and costs of retrofitting measures. This analysis considers factors such as the initial investment, ongoing maintenance costs, replacement costs (and residual values), and energy costs associated with the use phase of the building.

The SURe³FIT tool employs a net present value (NPV) approach, which makes it possible to estimate the present value of future costs. Rehabilitation proposals can be analysed considering three different intervals for the building's life cycle: 20, 30, or 50 years.

The suggested energy prices for electricity and natural gas are obtained from data provided by the European Commission and the national regulator for energy services [in Portugal, (ERSE, 2023)]. For pellets, current market costs are consulted. When projecting future energy prices, the tool relies on the energy price trends estimated by the EU.

It is important to mention that the proposed methodology offers another improvement: calculating additional financial indicators besides the financial cost indicator already proposed in the conventional methodology. These additional indicators include, for example, the Internal Rate of Return on Investment (IRR) and Return on Investment (ROI).

1.2 Tool Structure

The SURe³FIT tool is a modular application built on Microsoft Excel. It consists of six modules distributed across four separate Excel files, as illustrated in Figure 2. Table 1 provides a list of all tabs within these files, along with brief descriptions of their functionalities.

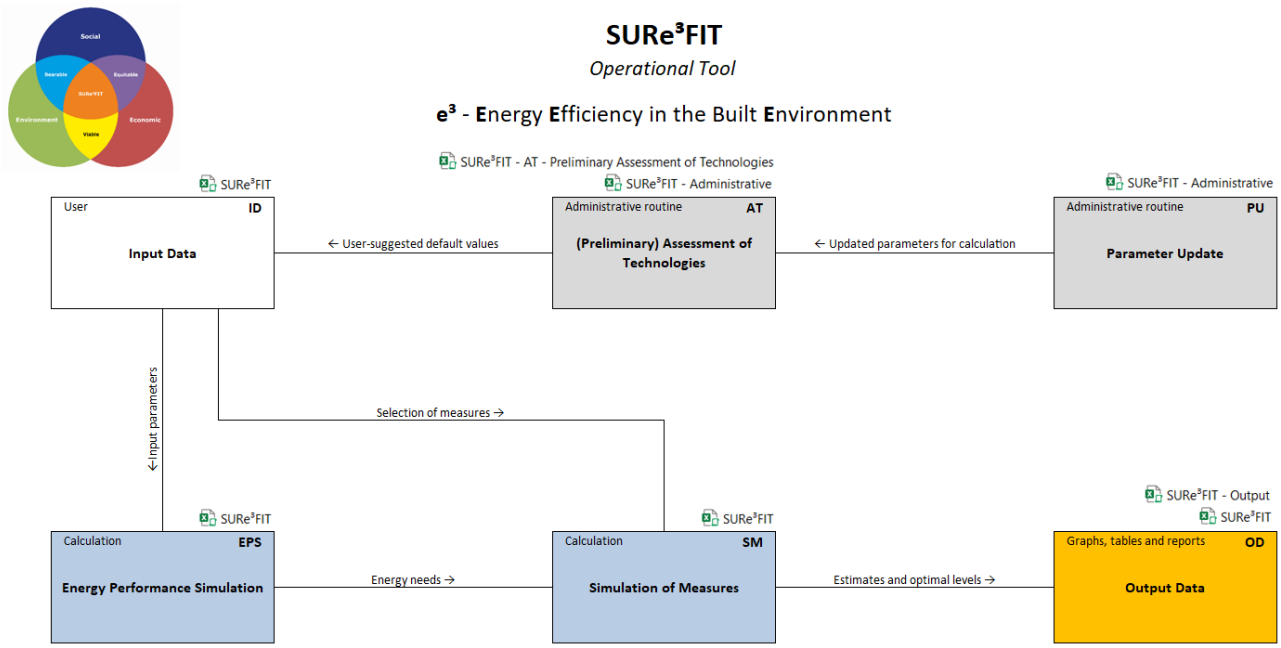


Figure 2 - SURe³FIT tool structure

Administrative files (grey modules in Figure 2):

- "SURe³FIT - Administrative" - This file is restricted to administrators and manages parameter updates within the tool.
- "SURe³FIT - AT - Preliminary Assessment of Technologies" - This administrator-only file facilitates preliminary assessments of relevant technologies.

Public files (white, blue, and orange modules in Figure 2):

- "SURe³FIT" - This core module performs the energy performance simulation and cost-benefit analysis for various building improvement measures, including envelope solutions, technical systems, and renewable energy options (currently limited to conventional solutions like solar collectors and photovoltaic panels, but designed for future expansion to analyse innovative technologies like PV-T and window heat recovery).
- "SURe³FIT – Output" - This file presents graphical visualisations of the numerical results generated in "SURe³FIT".

Detailed instructions on using these public modules, including a step-by-step guide, are described in section 2.

Table 1 - SURe³FIT tool: Excel files and respective tabs

Excel Tabs	Description
SURe³FIT - Administrative	
AT Insulations	Assessment of Technologies (insulations). It compares the cost of insulation materials according to their thermal resistance.
AT Windows	Assessment of Technologies (windows). It compares the cost of windows according to their thermal resistance.
AT System	Assessment of Technologies (systems). It compares the cost of systems for DHW, heating, cooling, ventilation, and lighting, according to the useful energy they serve.
AT FER	Assessment of Technologies (renewable energy). It compares the cost of thermal and photovoltaic solar systems according to their energy production.
AP Energy	Assessment of Parameters (energy). It encompasses the evolution of energy prices over the years.
AP Environmental	Assessment of Parameters (environment). It encompasses the evolution of carbon costs over the years.
SURe³FIT - AT - Preliminary Assessment of Technologies	
AT Systems	Assessment of Technologies (systems). It compares technical systems by varying buildings' useful energy needs (DHW, heating, and cooling), based on three indicators: global costs, primary energy, and total life-cycle impact.
ID Subtitle	It encompasses the subtitle of the technologies abbreviated in the “AT Systems” tab and the identification of their individual embodied impacts.
SURe³FIT	
ID Characterization	Input Data (characterisation). It encompasses inputs necessary for characterizing the building, e.g., geometry and constructive characterisation, location-related data, and an indication of energy consumption patterns.
ID Simulation	Input Data (characterisation). It encompasses inputs necessary for the simulations, e.g., ECMs and their respective data, energy conversion factors, maintenance groups, and energy prices.
EPS Needs	Energy Performance Simulation (energy needs). It simulates the thermal performance of the building and estimates its nominal useful energy needs for heating and cooling purposes.
SM Current indicators	Simulation of Measures (current indicators). It simulates the environmental and economic performance of the building.

SM ECMs	Simulation of Measures (Energy Conservation Measures). It simulates the environmental and economic performance of the proposed renovated building.
EPS	Energy Performance Simulation (results). It displays numerical outcomes of the EPS Needs calculations, corresponding to both the current and potential combinations of solutions for the renovated building.
SM	Simulation of Measures. It displays numerical outcomes of the SM Current indicators and SM ECMs calculations, including all environmental and economic parameters assessed in the SURe³FIT tool.
PU Climate data	Parameter update (climate data). It includes climate data and reference values.
PU IDs	Parameter update (IDs). It includes a list of parameters, e.g., construction periods, systems, and maintenance groups.
SURe³FIT - Output	
SM	Simulation of Measures. This tab includes a copy of the SM tab generated in the "SURe³FIT" file.
OD Output	It displays graphical outputs of the "SM Current indicators" and "SM ECMs" calculations and their numerical results, presented on the "SM" tab.

2 User's Guideline

This section provides a step-by-step guide for using the SURe³FIT tool, enhancing user-friendliness and indicating key rules.

2.1 Settings Overview

To ensure full functionality, please enable macros in your Excel settings before proceeding.

Colour-code input guide

The tool uses a colour-coded system throughout the files to visually guide data entry. Please follow these conventions:

- Gray fields: Headers, parameters, or equations (protected).
- Blue fields: Data received from other worksheets (protected).
- White fields: Input data.

2.2 Step-by-step guide

> ***Note:*** *Files, tabs, and cells not mentioned in the following steps do not require user interaction and will not interfere with the calculation process.*

Choosing Your Approach

The SURe³FIT tool offers two main options to use your building's energy needs, as illustrated in **Figure 2:**

i) Option I: Simulate Energy Data via the SURe³FIT Tool (recommended for users with limited data)

In addition to the cost-benefit assessments, Option I utilises the "Energy Performance Simulation" module to create a simplified energy model of your building. This is ideal if you lack initial data on your dwelling's energy performance. The simulation includes domestic hot water (DHW), cooling, and space heating energy needs.

> ***Note:*** *The climate data and reference values used for the energy estimation are specific to Portugal. If you plan to use this option for a different country, you will need to replace this data with relevant national values (e.g., Heating Degree Days (HDD) and Cooling Degree Days (CDD) as mentioned in*

Section 1.1). Additionally, you might need to adjust the methodology, such as comfort temperature settings.

ii) Option II: Manually Input External Energy Data

Option II allows you to bypass the "Energy Performance Simulation" module and manually enter energy data you got from an external tool. Despite the main difference lies in the Step 4 (“Input Energy data” instead of “Simulate Energy data”), there may be differences within other steps as well. It is recommended to follow the complete step-by-step process for the chosen option (Option I or II) as detailed in the following section.

2.2.1 Option I: Simulate Energy Data via the SURe³FIT Tool

This section guides you through using the SURe³FIT Tool’s “Energy Performance Simulation” and “Simulation of Measures” modules to analyse your building’s energy efficiency.

2.2.1.1 Step 1: Input building data

Open the “SURe³FIT” Excel file and navigate to the “ID Characterisation” tab. Here, you will find a section, “Building data”, for entering data/parameters that characterises your building (Figure 3), including:

- Location
- Year of construction
- Dwelling type and area

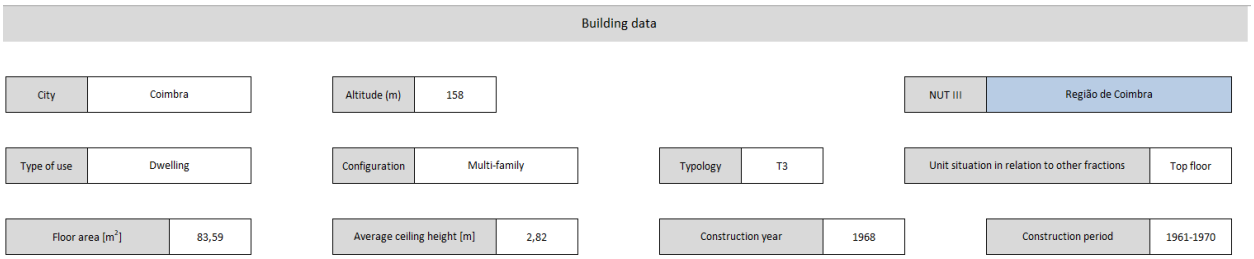


Figure 3 - Building data section (ID Characterisation tab): printscreen of the SURe³FIT Excel file

Next, you will find a section related to the building's Envelope. Here, you will specify, the areas and thermal properties of the various construction elements (Figure 4).

> ***Note:*** *If a specific element does not transmit heat (e.g., a sealed wall), enter a number close to "0" in the area cell.*

Envelope

Roof

Orientation	Area A_{roof} [m^2]	U_{asc} [$W/m^2.°C$]	U_{desc} [$W/m^2.°C$]	$U_{asc}xA_{roof}$ [$W/°C$]	$Q_{sunroof}$ [kWh/y]
Horizontal	83,59	2,25	1,71	188,08	2359,91

U [$W/m^2.°C$]
2,25

Walls

Orientation	Area A_{wall} [m^2]	UxA_{wall} [$W/°C$]	$Q_{sunwall}$ [kWh/a]
North	21,60	20,74	7,47
South	21,60	20,74	13,94
East	21,60	20,74	16,43
West	21,60	20,74	16,43
Total	86,41	82,96	54,25

U [$W/m^2.°C$]
0,96

Floor

Area A_{floor} [m^2]	UxA_{floor} [$W/°C$]
83,59	0,00

U [$W/m^2.°C$]
0,00

Windows

Orientation	Area A_w [m^2]	UxA_w [$W/°C$]	$Q_{sunw,w}$ [kWh/y]	$Q_{sunw,s}$ [kWh/y]
North	4,18	12,12	438,93	210,65
South	4,18	12,12	1625,67	393,21
East	4,18	12,12	910,37	463,42
West	4,18	12,12	910,37	463,42
Total	16,72	48,48	3885,34	1530,70

Glazed fraction F_g	Obstruction factor F_s	Protection factor g_l	Protection factor g_v	Glass solar factor g	Area / Floor [m^2]	U [$W/m^2.°C$]
0,70	1,00	0,63	0,32	0,75	20%	2,90

Figure 4 - Envelope section (ID Characterisation tab): printscreen of the SURe³FIT Excel file

> ***Note:*** *For walls (or other building elements) with multiple construction methods (e.g., brick and wood), combine the areas of each section with its corresponding thermal property value (U-value). This will allow you to enter a single average U-value that represents the overall performance of the entire element.*

Note: Do not worry about entering data for each direction (north, south, east, west) of your walls and windows. The total area of the element can be entered in any of the orientation fields without affecting the calculations.

The "ID Characterisation" tab offers a sneak peek at your building's initial energy performance, also including energy metrics and climate data information, based on the provided inputs.

Additionally, you can adjust energy needs according to the energy consumption patterns, as presented in Figure 5. However, this adjustment is only recommended if your current energy use aligns with standard comfort regulations or if the indoor conditions will not change significantly after renovations.

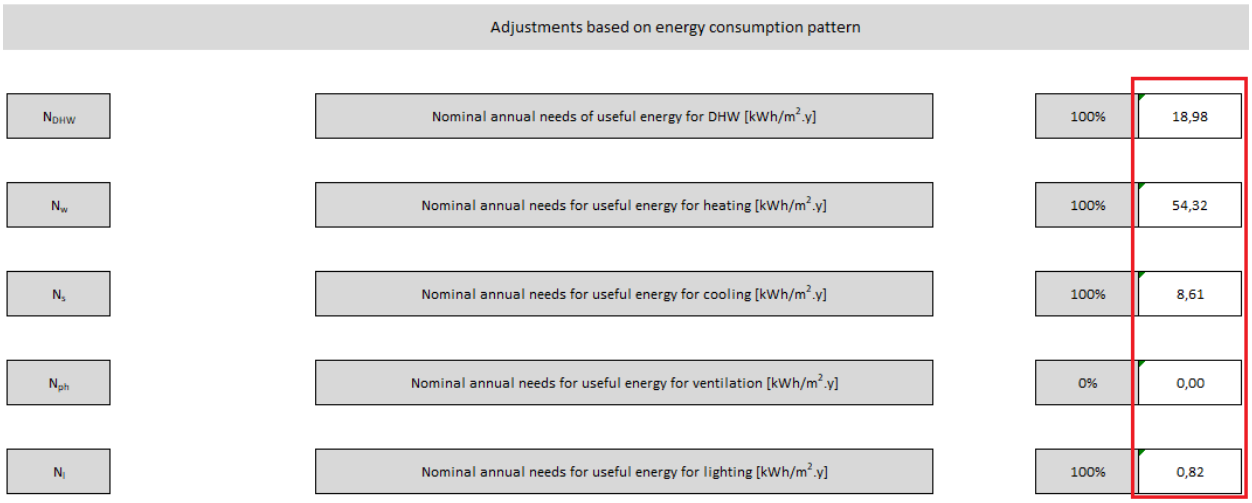


Figure 5 - Adjustments based on energy consumption pattern section (ID Characterisation tab): printscreen of the SURe³FIT Excel file

Note: *The tool uses "useful energy" for calculations, while your bills show "final energy." To adjust, convert your final energy data using building system efficiencies and input the result.*

2.2.1.2 Step 2: Identify the Energy Conservation Measures (ECMs) data

Then, switch to the “ID Simulation” tab. Here, you will identify/define the parameters/details of each ECM you want to evaluate. Table 2 lists the required data for each type of solution.

Please note:

- The first row (line 4) should contain data on the existing solutions in the building, as identified in the “ID characterisation” tab (baseline scenario,). Compare this to the other ECMs you will define in the following rows.

- Double-check this information and adjust any necessary values, such as technical systems data not previously identified in Step 1 of the "ID Characterisation" tab.

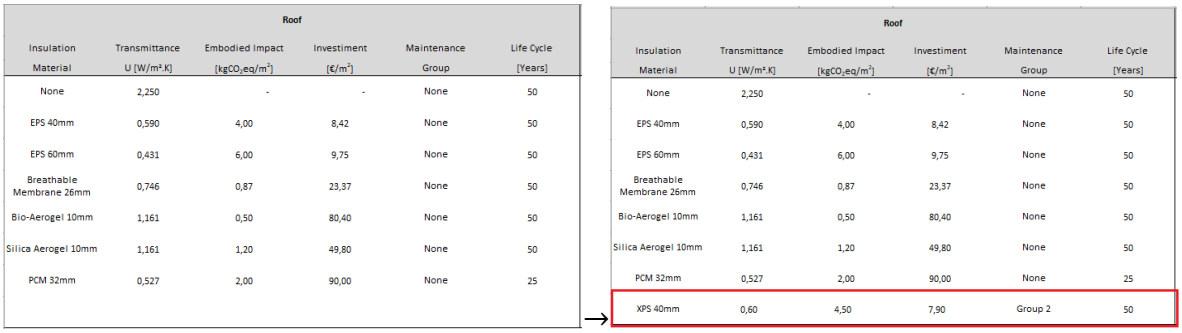
Table 2 - List of required input parameters for each ECM (per solution type)

Input	Envelope		Technical Systems	Renewable Systems
	Roof, wall, floor	Window	DHW, Heating, Cooling, Ventilation, Lighting	Solar systems, BIS, other renewables
U-value	x	x		
Glass g-value		x		
Embodied impact	x	x	x	x
Investment	x	x	x	x
Maintenance group	x	x	x	x
Life cycle	x	x	x	x
Energy source			x	
Efficiency			x	
Produced energy				x

If you want to change or create new ECMs other than those identified in this tab, fill in all the columns in the row for the new or adapted solution in the table (like the existing examples). See Figure 6 for an illustration. Otherwise, proceed directly to the Step 3.

Note: *Please remember that all white cells are editable. You are responsible for entering data. The provided default values are just a starting point for the tool's operation.*

Note: *The default values for "embodied impact" consider material supply, transportation, manufacturing, and the end-of-life phase for metals, which is considered only for metallic materials.*



Roof

Insulation Material	Transmittance U [W/m².K]	Embodied Impact [kgCO₂eq/m²]	Investiment [€/m²]	Maintenance Group	Life Cycle [Years]
None	2,250	-	-	None	50
EPS 40mm	0,590	4,00	8,42	None	50
EPS 60mm	0,431	6,00	9,75	None	50
Breathable Membrane 26mm	0,746	0,87	23,37	None	50
Bio-Aerogel 10mm	1,161	0,50	80,40	None	50
Silica Aerogel 10mm	1,161	1,20	49,80	None	50
PCM 32mm	0,527	2,00	90,00	None	25

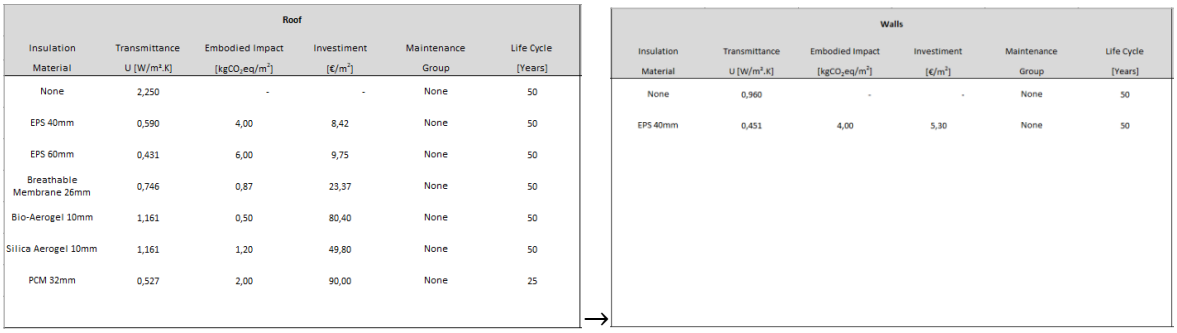
→

Roof

Insulation Material	Transmittance U [W/m².K]	Embodied Impact [kgCO₂eq/m²]	Investiment [€/m²]	Maintenance Group	Life Cycle [Years]
None	2,250	-	-	None	50
EPS 40mm	0,590	4,00	8,42	None	50
EPS 60mm	0,431	6,00	9,75	None	50
Breathable Membrane 26mm	0,746	0,87	23,37	None	50
Bio-Aerogel 10mm	1,161	0,50	80,40	None	50
Silica Aerogel 10mm	1,161	1,20	49,80	None	50
PCM 32mm	0,527	2,00	90,00	None	25
XPS 40mm	0,60	4,50	7,90	Group 2	50

Figure 6 - Adding ECMs (ID Simulation tab): printscreen of the SURe³FIT Excel file

You can choose which measures (ECMs) to simulate in the tool. If you want to skip simulating a particular measure, simply erase data already filled in its corresponding columns (see Figure 7).



Roof

Insulation Material	Transmittance U [W/m².K]	Embodied Impact [kgCO₂eq/m²]	Investiment [€/m²]	Maintenance Group	Life Cycle [Years]
None	2,250	-	-	None	50
EPS 40mm	0,590	4,00	8,42	None	50
EPS 60mm	0,431	6,00	9,75	None	50
Breathable Membrane 26mm	0,746	0,87	23,37	None	50
Bio-Aerogel 10mm	1,161	0,50	80,40	None	50
Silica Aerogel 10mm	1,161	1,20	49,80	None	50
PCM 32mm	0,527	2,00	90,00	None	25

→

Walls

Insulation Material	Transmittance U [W/m².K]	Embodied Impact [kgCO₂eq/m²]	Investiment [€/m²]	Maintenance Group	Life Cycle [Years]
None	0,960	-	-	None	50
EPS 40mm	0,451	4,00	5,30	None	50

Figure 7 - Deleting ECMs (ID Simulation tab): printscreen of the SURe³FIT Excel file

Note: *If a building element has negligible heat transfer (e.g., the floor of an apartment on the top floor), you must fill in the corresponding line with "zeros" and "Nones", except the U-value. The U-value still needs a value (different from zero) to function in the simulation (see example below).*

Floor

Insulation Material	Transmittance U [W/m².K]	Embodied Impact [kgCO₂eq/m²]	Investiment [€/m²]	Maintenance Group	Life Cycle [Years]
None	0,001	-	-	None	-

Note: *The investment costs must be entered into the tool without VAT. These values can be specified in the next step, according to the table below.*

VAT	
General:	23%
Renewables:	23%
Electricity:	23%
Natural Gas:	23%

Simulating Combinations:

The SURe³FIT Tool can simulate thousands of Energy Conservation Measures (ECMs) combinations. This depends on the number of ECMs identified for each solution type (walls, roof, etc.) in the "ID Simulation" tab .

Table 3 outlines the maximum number of ECMs options allowed for each solution type based on the current Excel file format. This allows for a subsequent evaluation of the combination of all measures and the assessment of their cost-effectiveness.

Table 3 - Maximum number of ECMs per solution type

Solution type	Maximum number of ECMs
Roof	8
Walls	8
Floor	8
Windows	4
DHW + Heating + Cooling + Ventilation	8
Lighting	2
Solar Thermal + Solar Photovoltaic	5
Building Integrated Systems	3
Other Renewables	3

By integrating passive solutions for the roof, wall, floor, and windows, along with adjustments to the systems and lighting, the SURe³FIT Operational Tool can systematically assess up to 1,474,560 potential combinations of Energy Conservation Measures (ECMs) at its maximum capacity.

Note: *The combined systems mentioned above (DHW + Heating + Cooling + Ventilation) refers to how these systems are evaluated in the tool. Each option within this category combines all the equipment listed in each line for that system. For example, in the "reference scenario" (Line 4), the DHW, heating, cooling, and ventilation equipment are considered as a single measure. They are not combined individually with other options within those categories.*

Note: *If you are using the same equipment for different purposes (e.g., a heat pump for both cooling and heating), follow these steps:*

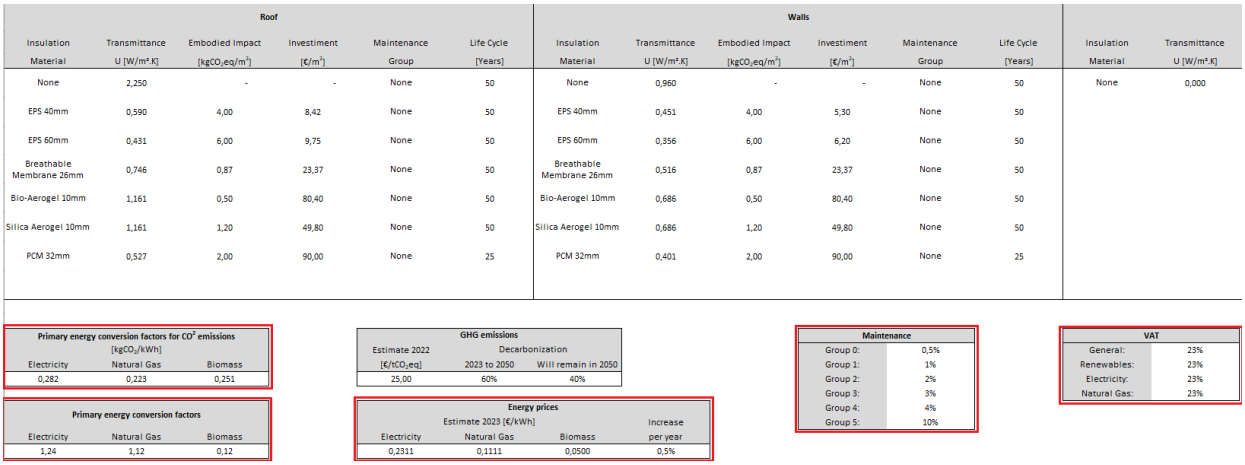
- *Enter the separate efficiencies for each function in the designated fields.*
- *Repeat the energy source and life cycle information for both uses.*
- *However, for only one of the functions (heating or cooling in this example), enter data for investment, maintenance group, and embodied impact.*
- *Leave these fields blank ("Nones" or "0") for the other function.*

Heating							Cooling						
Equipment	Source of Energy	Efficiency [η]	Embodied Impact [kgCO$_2$eq/set]	Investiment [€/set]	Maintenance Group	Life Cycle [Years]	Equipment	Source of Energy	Efficiency [η]	Embodied Impact [kgCO$_2$eq/set]	Investiment [€/set]	Maintenance Group	Life Cycle [Years]
HP	Electricity	4,00	1 321,28	1 179,01	Group 3	20	HP	Electricity	6,10	0,00	0,00	None	20

2.2.1.3 Step 3: Update parameters

In the same tab, “ID Simulation”, you can also update the parameters necessary for the economic and environmental indicators calculation (see Figure 8). Here is a breakdown of these parameters:

1. **“Primary energy conversion factors”**: conversion factor from "final energy" (the energy delivered to your building) to "primary energy" (the energy source used to generate it), Distinct factors apply depending on the energy source (e.g., electricity, natural gas).
2. **“Primary energy conversion factors for CO_2 emission**”: similar to the above, these factors convert primary energy use to CO_2 emissions for each energy source.
3. **“Energy prices”:** current price per kWh (including VAT and all fees and taxes involved) for each energy source (e.g., electricity, natural gas).
4. **“VAT”:** the Value Added Tax, or VAT, is a based consumption tax, levied on the added value of goods and services, with rates that typically vary by region.
5. **“Maintenance costs”:** indicates the annual maintenance cost percentage (as a proportion of the initial investment) for each maintenance group associated with ECMs.



Roof					
Insulation Material	Transmittance U [W/m².K]	Embodied Impact [kgCO₂eq/m³]	Investment [€/m³]	Maintenance Group	Life Cycle [Years]
None	2,250	-	-	None	50
EPS 40mm	0,590	4,00	8,42	None	50
EPS 60mm	0,431	6,00	9,75	None	50
Breathable Membrane 26mm	0,746	0,87	23,37	None	50
Bio-Aerogel 10mm	1,161	0,50	80,40	None	50
Silica Aerogel 10mm	1,161	1,20	49,80	None	50
PCM 32mm	0,527	2,00	90,00	None	25

Walls					
Insulation Material	Transmittance U [W/m².K]	Embodied Impact [kgCO₂eq/m³]	Investment [€/m³]	Maintenance Group	Life Cycle [Years]
None	0,960	-	-	None	50
EPS 40mm	0,451	4,00	5,30	None	50
EPS 60mm	0,356	6,00	6,20	None	50
Breathable Membrane 26mm	0,516	0,87	23,37	None	50
Bio-Aerogel 10mm	0,686	0,50	80,40	None	50
Silica Aerogel 10mm	0,686	1,20	49,80	None	50
PCM 32mm	0,401	2,00	90,00	None	25

Insulation Material	Transmittance U [W/m².K]
None	0,000

Primary energy conversion factors for CO^2 emissions [$kgCO_2/kWh$]		
Electricity	Natural Gas	Biomass
0,282	0,223	0,251

Primary energy conversion factors		
Electricity	Natural Gas	Biomass
1,24	1,12	0,12

GHG emissions		
Estimate 2022	Decarbonization	
[€/tCO_2eq]	2023 to 2050	Will remain in 2050
25,00	60%	40%

Energy prices			
Estimate 2023 [€/kWh]			Increase
Electricity	Natural Gas	Biomass	per year
0,2311	0,1111	0,0500	0,5%

Maintenance	
Group 0:	0,5%
Group 1:	1%
Group 2:	2%
Group 3:	3%
Group 4:	4%
Group 5:	10%

VAT	
General:	23%
Renewables:	23%
Electricity:	23%
Natural Gas:	23%

Figure 8 - Updating parameters (ID Simulation tab): printscreen of the SURe³FIT Excel file

2.2.1.4 Step 4: Simulate the energy data of the dwelling

Once you have defined your ECMs and economic/environmental parameters, it is time to simulate your dwelling's energy performance. Here is what to do:

1. Switch to the "SM ECMs" tab.
2. Click the "Energy Performance Simulation (EPS)" button.

This will launch the simulation for all the different ECM combinations you defined in the "ID Simulation" tab (see Figure 9).

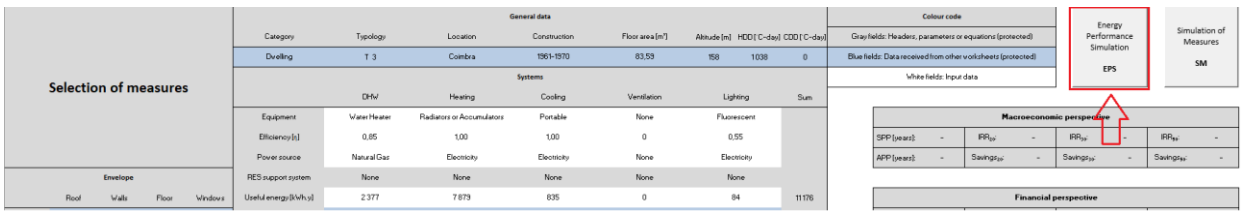


Figure 9 - Energy Performance Simulation button (SM ECMs tab): printscreen of the SURe³FIT Excel file

Viewing results:

- "EPS" tab: Unhide this tab to access the numerical results for the energy needs of each ECM combination (Figure 10).
- Simulation Summary: The top right corner of the "EPS" tab displays the number of simulated combinations and the total simulation time (Figure 11).

City	HDD	CDD	Roof U	Walls U	Floor U	Windows U	Windows g	DHW Useful	Heat. Useful	Cool. Useful	Venti. Useful	Light. Useful
Porto	1181	0	0,50	1,10	0,00	2,44	0,72	1782,96	5103,47	800,99	0,00	76,56
Porto	1181	0	0,50	1,10	0,00	1,87	0,58	1782,96	4831,15	800,99	0,00	76,56
Porto	1181	0	0,50	1,10	0,00	1,69	0,58	1782,96	4744,92	800,99	0,00	76,56
Porto	1181	0	0,50	1,10	0,00	0,60	0,42	1782,96	4222,75	800,99	0,00	76,56
Porto	1181	0	0,50	0,48	0,00	2,44	0,72	1782,96	3621,27	795,76	0,00	76,56
Porto	1181	0	0,50	0,48	0,00	1,87	0,58	1782,96	3348,95	795,76	0,00	76,56

Figure 10 - Numerical results of the Energy Performance Simulation (EPS tab): printscreen of the SURe³FIT Excel file

Combinations	Start	End	Duration
196	14/05/2024 14:06	14/05/2024 14:06	00:00:07

Figure 11 - Number of combinations and simulation duration for the Energy Performance Simulation (EPS tab): printscreen of the SURe³FIT Excel file

2.2.1.5 Step 5: Assess the ECMs

Now that the energy data simulation is complete, let us analyse the performance of your ECMs. Here is how:

1. Return to the “SM ECMs” tab.
2. Click the “Simulation of Measures SM” button to assess all the results for the ECMs identified in the “ID Simulation” tab (Figure 12).

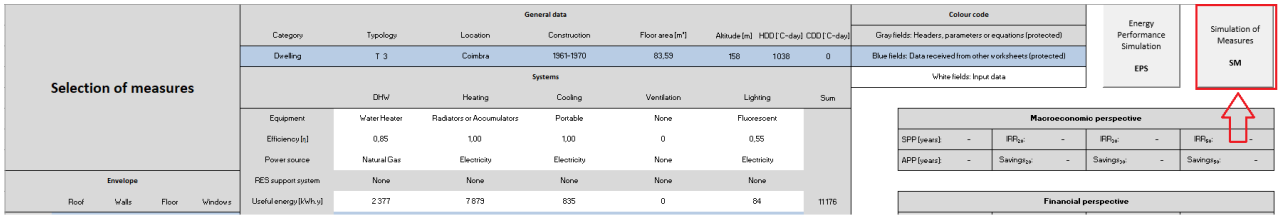


Figure 12 - Simulation of Measures button (SM ECMs tab): printscreen of the SURe³FIT Excel file

Viewing results:

- “SM” tab: Navigate to the “SM” tab to visualize the numerical results for each ECM combination, across three building lifespan scenarios: 20, 30, and 50 years.
- Detailed Information: Section 2.3 provides more information on the output data.

2.2.2 Option II: Manually Input External Energy Data

If you are using an external tool to calculate your building's energy needs, follow these steps to utilize the SURe³FIT tool's "Simulation of Measures" module. Please ignore it if it does not make sense.

2.2.2.1 Step 1: Input building data

1. Open the "SURe³FIT" Excel file and navigate to the "ID Characterisation" tab.
2. For Option II, you only need to enter the total area of each building element (walls, roof, floor, windows) as shown in Figure 13.

> ***Note:*** *If a specific element does not transmit heat (e.g., a sealed wall), enter a number close to "0" in the area cell.*

Building data

City	Braga	Altitude (m)	170			NUT III	Cávado
Type of use	Dwelling	Configuration	Multi-family	Typology	T2	Unit situation in relation to other fractions	Ground floor
Floor area [m²]	67,25	Average ceiling height [m]	2,55	Construction year	1983	Construction period	1981-1990

Roof

Orientation	Area A_{roof} [m²]	U_{asc} [W/m².°C]	U_{desc} [W/m².°C]	$U_{asc}xA_{roof}$ [W/°C]	$Q_{sunroof}$ [kWh/y]
Horizontal	83,59	2,25	1,71	188,08	2359,91

U [W/m².°C]
2,25

Walls

Orientation	Area A_{wall} [m²]	UxA_{wall} [W/°C]	$Q_{sunwall}$ [kWh/a]
North	21,60	20,74	7,47
South	21,60	20,74	13,94
East	21,60	20,74	16,43
West	21,60	20,74	16,43
Total	86,41	82,96	54,25

U [W/m².°C]
0,96

Windows

Orientation	Area A_w [m²]	UxA_w [W/°C]	$Q_{sunw,w}$ [kWh/y]	$Q_{sunw,s}$ [kWh/y]
North	4,18	12,12	438,93	210,65
South	4,18	12,12	1625,67	393,21
East	4,18	12,12	910,37	463,42
West	4,18	12,12	910,37	463,42
Total	16,72	48,48	3885,34	1530,70

Glazed fraction F_g	Obstruction factor F_s	Protection factor g_c	Protection factor g_v	Glass solar factor g	Area / Floor [m²]	U [W/m².°C]
0,70	1,00	0,63	0,32	0,75	20%	2,90

Figure 13 - Identifying building areas (ID Characterisation tab): printscreen of the SURe³FIT Excel file

> ***Note:*** *Do not worry about entering data for each direction (north, south, east, west) of your walls and windows. The total area of the element can be entered in any of the orientation fields without affecting the calculations.*

2.2.2.2 Step 2: Identify the Energy Conservation Measures (ECMs) data

Then, switch to the "ID Simulation" tab. Here, you will identify/define the parameters/details of each ECM you want to evaluate. Table 4 lists the required data for each type of solution. Please note:

- The first row (line 4) should contain data on the existing solutions in the building, as identified in the "ID characterisation" tab (baseline scenario,). Compare this to the other ECMs you will define in the following rows.
- Double-check this information and adjust any necessary values, such as technical systems data not previously identified in Step 1 of the "ID Characterisation" tab.

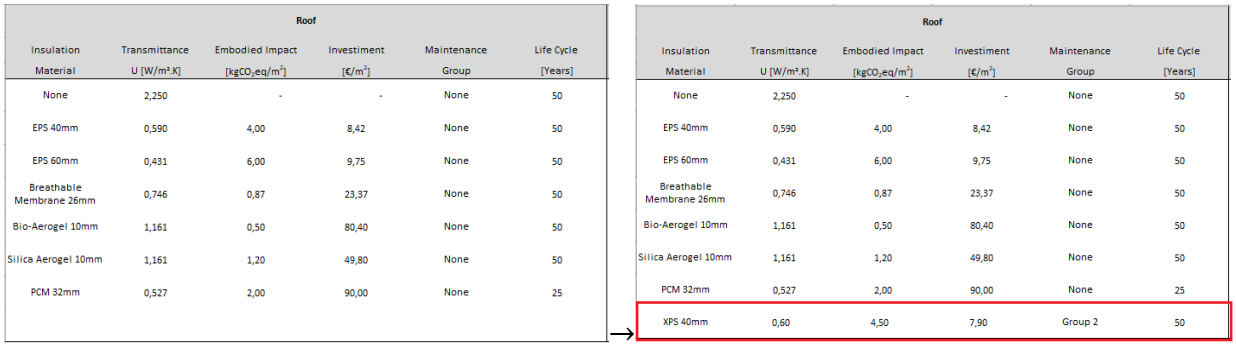
Table 4 - List of required input parameters for each ECM, per solution type

Input	Envelope		Technical Systems	Renewable Systems
	Roof, wall, floor	Window	DHW, Heating, Cooling, Ventilation, Lighting	Solar systems, BIS, other renewables
U-value	x	x		
g-value		x		
Embodied impact	x	x	x	x
Investment	x	x	x	x
Maintenance group	x	x	x	x
Life cycle	x	x	x	x
Energy source			x	
Efficiency			x	
Produced energy				x

If you want to change or create new ECMs other than those identified in this tab, fill in all the columns in the row for the new or adapted solution in the table (like the existing examples). See Figure 6 for an illustration. Otherwise, proceed directly to the Step 3.

Note: *Please remember that all white cells are editable. You are responsible for entering data. The provided default values are just a starting point for the tool's operation.*

Note: *The default values for "embodied impact" consider material supply, transportation, manufacturing, and the end-of-life phase for metals, which is considered only for metallic materials.*

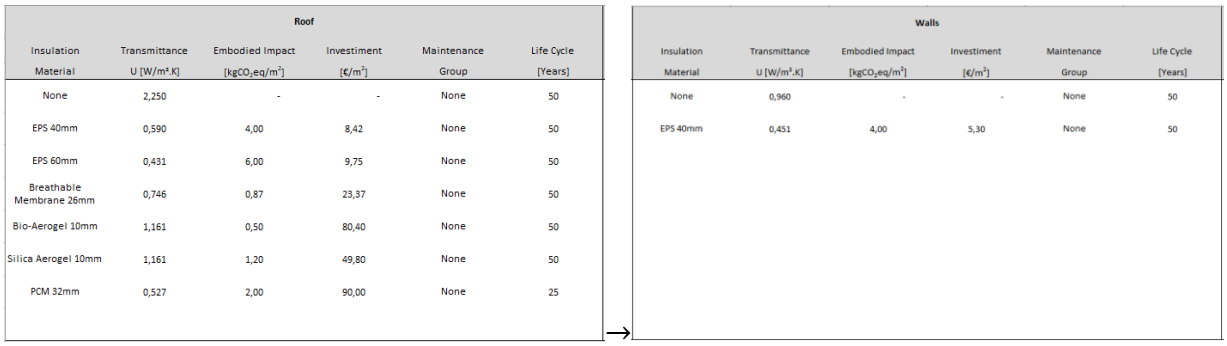


Roof					
Insulation Material	Transmittance U [W/m².K]	Embodied Impact [kgCO₂eq/m²]	Investiment [€/m²]	Maintenance Group	Life Cycle [Years]
None	2,250	-	-	None	50
EPS 40mm	0,590	4,00	8,42	None	50
EPS 60mm	0,431	6,00	9,75	None	50
Breathable Membrane 26mm	0,746	0,87	23,37	None	50
Bio-Aerogel 10mm	1,161	0,50	80,40	None	50
Silica Aerogel 10mm	1,161	1,20	49,80	None	50
PCM 32mm	0,527	2,00	90,00	None	25

Roof					
Insulation Material	Transmittance U [W/m².K]	Embodied Impact [kgCO₂eq/m²]	Investiment [€/m²]	Maintenance Group	Life Cycle [Years]
None	2,250	-	-	None	50
EPS 40mm	0,590	4,00	8,42	None	50
EPS 60mm	0,431	6,00	9,75	None	50
Breathable Membrane 26mm	0,746	0,87	23,37	None	50
Bio-Aerogel 10mm	1,161	0,50	80,40	None	50
Silica Aerogel 10mm	1,161	1,20	49,80	None	50
PCM 32mm	0,527	2,00	90,00	None	25
XPS 40mm	0,60	4,50	7,90	Group 2	50

Figure 14 - Adding ECMs (ID Simulation tab): Printscreen of the SURe³FIT Excel file

You can choose which measures (ECMs) to simulate in the tool. If you want to skip simulating a particular measure, simply erase data already filled in its corresponding columns (see Figure 15).



Roof					
Insulation Material	Transmittance U [W/m².K]	Embodied Impact [kgCO₂eq/m²]	Investiment [€/m²]	Maintenance Group	Life Cycle [Years]
None	2,250	-	-	None	50
EPS 40mm	0,590	4,00	8,42	None	50
EPS 60mm	0,431	6,00	9,75	None	50
Breathable Membrane 26mm	0,746	0,87	23,37	None	50
Bio-Aerogel 10mm	1,161	0,50	80,40	None	50
Silica Aerogel 10mm	1,161	1,20	49,80	None	50
PCM 32mm	0,527	2,00	90,00	None	25

Walls					
Insulation Material	Transmittance U [W/m².K]	Embodied Impact [kgCO₂eq/m²]	Investiment [€/m²]	Maintenance Group	Life Cycle [Years]
None	0,960	-	-	None	50
EPS 40mm	0,451	4,00	5,30	None	50

Figure 15 - Deleting ECMs (ID Simulation tab): Printscreen of the SURe³FIT Excel file

Note: *If a building element has negligible heat transfer (e.g., the floor of an apartment on the top floor), you must fill in the corresponding line with "zeros" and "Nones", except the U-value. The U-value still needs a value (different from zero) to function in the simulation (see example below).*

Floor					
Insulation Material	Transmittance U [W/m².K]	Embodied Impact [kgCO$_2$eq/m^2]	Investiment [€/m^2]	Maintenance Group	Life Cycle [Years]
None	0,001	-	-	None	-

Note: *The investment costs must be entered into the tool without VAT. These values can be specified in the next step, according to the table below.*

VAT	
General:	23%
Renewables:	23%
Electricity:	23%
Natural Gas:	23%

Simulating Combinations:

The SURe³FIT Tool can simulate thousands of Energy Conservation Measures (ECMs) combinations. This depends on the number of ECMs identified for each solution type (walls, roof, etc.) in the "ID Simulation" tab.

Table 5 outlines the maximum number of ECM options allowed for each solution type based on the current Excel file format. This allows for a subsequent evaluation of the combination of all measures and the assessment of their cost-effectiveness.

Table 5 - Maximum number of ECMs per solution type

Solution type	Maximum number of ECMs
Roof	8
Walls	8
Floor	8
Windows	4
DHW + Heating + Cooling + Ventilation	8
Lighting	2
Solar Thermal + Solar Photovoltaic	5
Building Integrated Systems	3
Other Renewables	3

By integrating passive solutions for the roof, wall, floor, and windows, along with adjustments to the systems and lighting, the SURe³FIT Operational Tool can systematically assess up to 1,474,560 potential combinations of Energy Conservation Measures (ECMs) at its maximum capacity.

Note: *The combined systems mentioned above (DHW + Heating + Cooling + Ventilation) refers to how these systems are evaluated in the tool. Each option within this category combines all the equipment listed in each line for that system. For example, in the "reference scenario" (Line 4), the DHW, heating, cooling, and ventilation equipment are considered as a single measure. They are not combined individually with other options within those categories.*

Note: *If you are using the same equipment for different purposes (e.g., a heat pump for both cooling and heating), follow these steps:*

- *Enter the separate efficiencies for each function in the designated fields.*
- *Repeat the energy source and life cycle information for both uses.*
- *However, for only one of the functions (heating or cooling in this example), enter data for investment, maintenance group, and embodied impact.*
- *Leave these fields blank ("Nones" or "0") for the other function.*

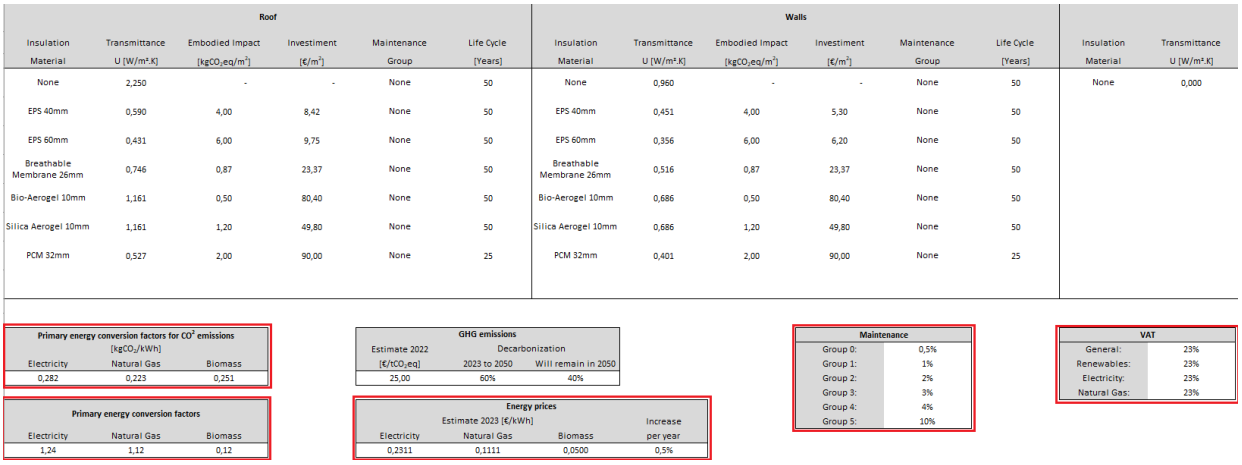
Heating							Cooling						
Equipment	Source of Energy	Efficiency [η]	Embodied Impact [kgCO₂eq/set]	Investiment [€/set]	Maintenance Group	Life Cycle [Years]	Equipment	Source of Energy	Efficiency [η]	Embodied Impact [kgCO₂eq/set]	Investiment [€/set]	Maintenance Group	Life Cycle [Years]
HP	Electricity	4,00	1 321,28	1 179,01	Group 3	20	HP	Electricity	6,10	0,00	0,00	None	20

2.2.2.3 Step 3: Update parameters

In the same tab, “ID Simulation”, you can also update the parameters necessary for the economic and environmental indicators calculation (see Figure 16). Here is a breakdown of these parameters:

1. **“Primary energy conversion factors”**: conversion factor from "final energy" (the energy delivered to your building) to "primary energy" (the energy source used to generate it), Distinct factors apply depending on the energy source (e.g., electricity, natural gas).
2. **“Primary energy conversion factors for CO_2 emission**”: similar to the above, these factors convert primary energy use to CO_2 emissions for each energy source.
3. **“Energy prices”:** current price per kWh (including VAT and all fees and taxes involved) for each energy source (e.g., electricity, natural gas).

4. **"VAT":** the Value Added Tax, or VAT, is a based consumption tax, levied on the added value of goods and services, with rates that typically vary by region.
5. **"Maintenance costs":** indicates the annual maintenance cost percentage (as a proportion of the initial investment) for each maintenance group associated with ECMs.



Roof					
Insulation Material	Transmittance U [W/m².K]	Embodied Impact [kgCO₂eq/m²]	Investment [€/m²]	Maintenance Group	Life Cycle [Years]
None	2,250	-	-	None	50
EPS 40mm	0,590	4,00	8,42	None	50
EPS 60mm	0,431	6,00	9,75	None	50
Breathable Membrane 26mm	0,746	0,87	23,37	None	50
Bio-Aerogel 10mm	1,161	0,50	80,40	None	50
Silica Aerogel 10mm	1,161	1,20	49,80	None	50
PCM 32mm	0,527	2,00	90,00	None	25

Walls					
Insulation Material	Transmittance U [W/m².K]	Embodied Impact [kgCO₂eq/m²]	Investment [€/m²]	Maintenance Group	Life Cycle [Years]
None	0,960	-	-	None	50
EPS 40mm	0,451	4,00	5,30	None	50
EPS 60mm	0,356	6,00	6,20	None	50
Breathable Membrane 26mm	0,516	0,87	23,37	None	50
Bio-Aerogel 10mm	0,686	0,50	80,40	None	50
Silica Aerogel 10mm	0,686	1,20	49,80	None	50
PCM 32mm	0,401	2,00	90,00	None	25

Insulation Material	Transmittance U [W/m².K]
None	0,000

Primary energy conversion factors for CO^2 emissions [kgCO₂/kWh]		
Electricity	Natural Gas	Biomass
0,282	0,223	0,251

Primary energy conversion factors		
Electricity	Natural Gas	Biomass
1,24	1,12	0,12

GHG emissions		
Estimate 2022	Decarbonization	
[€/tCO₂eq]	2023 to 2050	Will remain in 2050
25,00	60%	40%

Energy prices			
Estimate 2023 [€/kWh]			Increase
Electricity	Natural Gas	Biomass	per year
0,2311	0,1111	0,0500	0,5%

Maintenance	
Group 0:	0,5%
Group 1:	1%
Group 2:	2%
Group 3:	3%
Group 4:	4%
Group 5:	10%

VAT	
General:	23%
Renewables:	23%
Electricity:	23%
Natural Gas:	23%

Figure 16 - Updating parameters (ID Simulation tab): printscreen of the SURe³FIT Excel file

2.2.2.4 Step 4: Input the energy data of the dwelling

Navigate to the tab "SM ECMs" and click on the "Energy Performance Simulation EPS" button to run the calculations of the energy needs of the dwelling, for all different combinations of ECMs identified in the "ID Simulation" tab (Figure 17).

While Option II uses an external tool for calculating energy needs, you can still leverage the SURe³FIT tool for further analysis. Here is how:

1. Navigate to the "SM ECMs" tab.
2. Click the "Energy Performance Simulation (EPS)" button (see Figure 17).

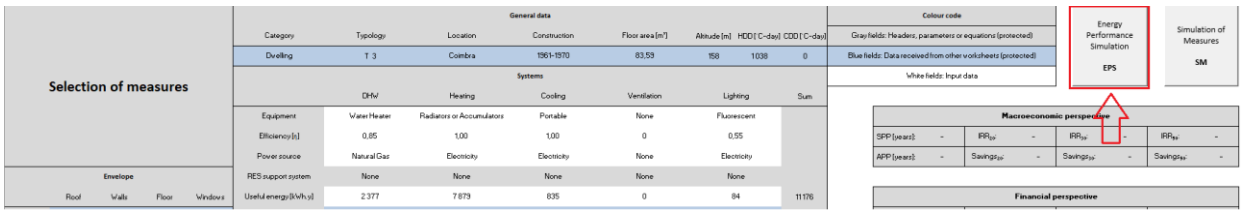


Figure 17 - Printscreen of the SURe³FIT Excel file: Energy Performance Simulation button (SM ECMs tab)

3. Unhide the "EPS" tab.

Note: *Although you do not directly use the EPS results in this option, clicking this button is necessary to generate the correct matrix for the number of ECMs defined earlier.*

4. Input the **useful energy data** in the following columns highlighted in red (see Figure 18), related to each ECM previously indicated in the tab "ID Simulation", following the parameter descriptions in the yellow-highlighted columns.

Note: *If you only have "final energy data" (e.g., energy bills), you can still use it:*

- *Enter this data in the same red-highlighted cells mentioned above.*
- *In the "ID Simulation" tab, set the system efficiencies to "1" for all options. "*

City	HDD	CDD	Roof U	Walls U	Floor U	Windows U	Windows g	DHW Useful	Heat. Useful	Cool. Useful	Venti. Useful	Light. Useful
Coimbra	1038	0	2,25	0,96	0,00	2,90	0,75	2377,29	7757,43	809,05	0,00	84,22
Coimbra	1038	0	2,25	0,96	0,00	1,87	0,58	2377,29	7328,37	809,05	0,00	84,22
Coimbra	1038	0	2,25	0,96	0,00	1,69	0,58	2377,29	7253,39	809,05	0,00	84,22
Coimbra	1038	0	2,25	0,96	0,00	0,61	0,50	2377,29	6805,17	809,05	0,00	84,22
Coimbra	1038	0	2,25	0,45	0,00	2,90	0,75	2377,29	6661,49	804,17	0,00	84,22
Coimbra	1038	0	2,25	0,45	0,00	1,87	0,58	2377,29	6232,43	804,17	0,00	84,22
Coimbra	1038	0	2,25	0,45	0,00	1,69	0,58	2377,29	6157,45	804,17	0,00	84,22
Coimbra	1038	0	2,25	0,45	0,00	0,61	0,50	2377,29	5709,23	804,17	0,00	84,22
Coimbra	1038	0	2,25	0,36	0,00	2,90	0,75	2377,29	6456,94	803,26	0,00	84,22

Figure 18 - Inputting energy data for the ECMs combinations (EPS tab): printscreen of the SURe³FIT Excel file

Note: *Since you are not using the "ID Characterisation" tab for detailed building information in Option II, you can disregard the location data in the "EPS" tab.*

2.2.2.5 Step 5: Assess the ECMs

Now that the energy data is complete, let us analyse the performance of your ECMs. Here is how:

1. Return to the "SM ECMs" tab.
2. Click the "Simulation of Measures SM" button to assess all the results for the ECMs identified in the "ID Simulation" tab (Figure 19).

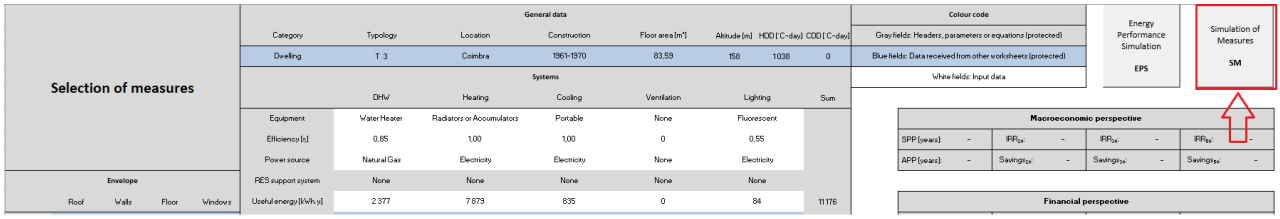


Figure 19 - Simulation of Measures button (SM ECMs tab): printscreen of the SURe³FIT Excel file

Viewing Results:

- "SM" tab: Navigate to the "SM" tab to visualise the numerical results for each ECM combination, across three building lifespan scenarios: 20, 30, and 50 years.
- Detailed Information: Section 2.3 provides more information on the output data.

2.3 Outputs

The data displayed in the "SM" tab are presented in table form. Each row identifies the building data and inputs characterizing each ECM combination under analysis (Figure 20) and the respective indicators simulated by the tool (Figure 21).

City	Altitude	HDD	CDD	Area	Roof Insulation	Roof U	Roof Emb. Imp.	Roof Inv.
Coimbra	158	1038	0	83,59	EPS 40mm	0,59	4,00	8,42

Figure 20 - Some building data and ECM inputs (SM tab). printscreen of the SURe³FIT Excel file

E. Final	E. Primary	MAC % Rate	MAC 20	MAC 30	MAC 50
3304,37	3833,02	1,00	9926,38	14440,95	22601,89

Figure 21 - Some parameters simulated (SM tab): printscreen of the SURe³FIT Excel file

2.3.1 Indicators

The SURe³FIT tool calculates various economic and environmental parameters to help you assess the impact of different ECM combinations. Here is a breakdown of the key parameters presented in the "SM" tab.

Note: *The presence of the numbers 20, 30, or 50 after each parameter's name indicates the building life cycle analysis lifespan for which it was calculated.*

Economic indicators:

- **MAC**: Global cost - macroeconomic perspective: this represents the total economic impact from a broader societal perspective.
- **FIN**: Global cost - private perspective: this reflects the overall financial cost from the building owner's viewpoint.
- **FIN Sav**: Difference between the energy costs (financial perspective) of the baseline scenario and the ECM proposed, per square meter. Positive values indicate savings.
- **IRR %** (Internal Rate of Return): This metric indicates the profitability of an investment based on its discounted cash flows.
- **SPP** (Simple Payback Period): This is the time it takes for the energy cost savings from an ECM to recover its initial investment cost.

- **APP** (Adjusted Payback Period): This considers the time value of money when calculating the payback period.
- **ROI %** (Return on Investment): This measures the percentage return on the investment compared to its cost.
- **Addi. Inv**: Difference between the investment (financial perspective) of the baseline scenario and the ECM proposed, per square meter.
- **FIN 20-BAU**: Difference between the global cost (financial perspective) of the baseline scenario and the ECM proposed, per square meter, calculated for a 20-year lifespan (similar calculations exist for 30 and 50 years).

Note: *The annual cash flow considered for the SPP, APP, and IRR considers the difference between the yearly global cost between the baseline scenario and the ECM proposed. The ROI compares the profitability of the ECM investment relative to the baseline scenario.*

Environmental indicators:

- **E. Useful Pat**. (Useful energy): This represents the annual useful energy associated with the building's use phase (kWh.y).
- **E. Final** (final energy), This represents the annual final energy associated with the building's use phase (kWh.y).
- **E. Primary** (primary energy): It represents the total annual primary energy associated with the building's use phase (kWhEP.y).
- **Phase of use impact**: It encompasses the environmental impact associated with energy consumption during the building's use phase ($kgCO_2eq/m^2$).
- **Emb Imp.** (Embodied impact) . It includes the embodied impact associated with the materials, transport, installation, and end-of-life of building elements ($kgCO_2eq/m^2$).
- **Life cycle** (total life cycle impact) . It considers the combination of the Embodied impact and Phase of use indicators ($kgCO_2eq/m^2$).

2.3.2 Graphical Visualization

To enhance the interpretation of these indicators and facilitate the comparison between ECMs, you can convert the numerical results into graphs. The "Output data" file included with the SURe³FIT tool demonstrates this process. Data is indexed based on a chosen indicator (e.g., ROI) for each type of ECM (e.g., walls). This indexed data is then used to generate the final graph (see Figure 22) that helps visualise the best combinations for the nexus of total life cycle versus financial cost.

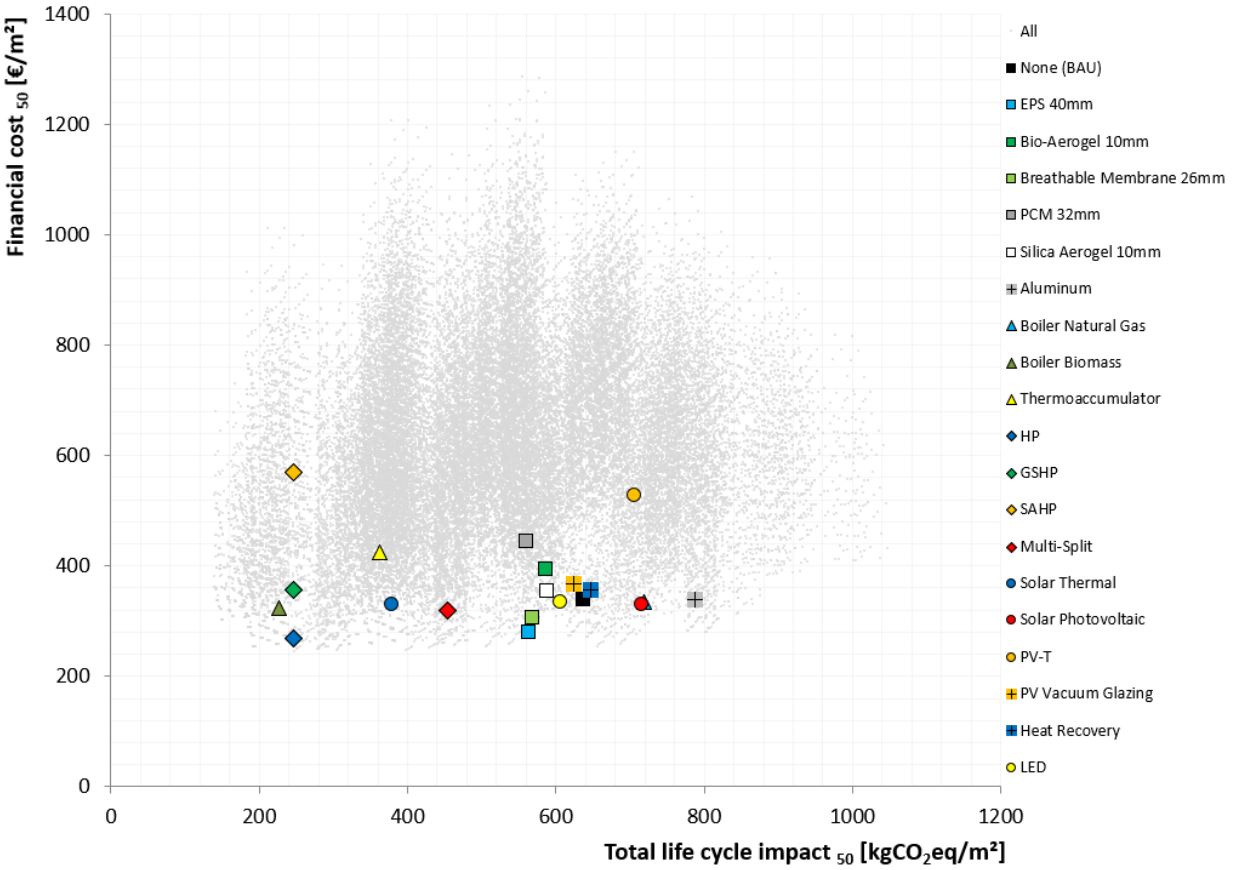


Figure 22 - Graph - financial cost x total life cycle impact (OD Output tab): printscreen of the SURe³FIT - Output Excel file

3 Conclusions

Within the scope of Task 7.3, the SURe^{3}FIT tool was developed, seeking to promote **e**nergy **e**fficiency in the built **e**nvironment (**e^3**). It consists of a set of spreadsheets designed in Microsoft Excel®, using Visual Basic macros that enable the simultaneous study of several packages of measures. The calculation of the cost-optimal of these energy conservation measures and the use of renewable energy sources is solved following the requirements of the methodological framework proposed by the European Commission (EC).

It is known that the numerous possible combinations of measures and the interaction of variables used in cost-optimal calculations make it difficult to obtain best solutions for the energy retrofit of buildings, within the limits imposed by the regulations. This also hinders the action of different stakeholders: authorities, experts, suppliers of products and services and building owners. The tool presented was created to assist decision-making process in this field of study.

Considering that the EC recommends that the global cost of efficiency measures be assessed using the Net Present Value (NPV) criterion, this tool complements this approach and also proposes assessing them using other criteria, with emphasis on return on investment (ROI), as well as analysing the environmental impact of the solutions under study throughout their life cycle. The framework of the modules that make up the tool and that allow the selection of solutions based on the aforementioned integrated analysis of environmental and economic criteria has been described.

It should be noted that, in order to disseminate the use of this tool, it is certainly necessary to develop interfaces, depending on the user. For example, qualified experts are capable of more technical use, while suppliers are more interested in the commercial aspects of positioning their products and services in the market. Building owners, on the other hand, need an interface that facilitates the intuitive use of the tool. Investors need criteria that relate the limit of the amount of capital invested to the ROI in energy efficiency measures. In this way, stakeholders and decision-makers can consider the use of this tool according to their particular interests.

Thus, this document presents an approach that is geared towards the interests of building owners (in their role as investors), but which needs to be supported by other stakeholders, namely qualified experts who are used to issuing energy performance certificates and/or one-stop-shop consultants for this purpose, where possible.

Finally, it should be made clear that decision-making based on using this tool must be supported by comprehensive and detailed information. The quality of the results is obviously dependent on the accuracy of the parameters provided. Only by fully understanding this topic will it be possible to demonstrate the affordable solutions for sustainable retrofit of domestic buildings.

Note: *The files referred to in this deliverable, including the application example shown in this guide, are available on the project page: **http://surefitproject.eu/documents**. If you have any questions about the content of this document and the tool itself, please contact the Instituto de Soldadura e Qualidade [I&D+i - sftadeu@isq.pt].*

4 References

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