Prescient building Operation utilizing Real Time data for Energy Dynamic Optimization

WP8 – Holistic sustainability strategy

D8.6 – DBRPs

Version 2.0

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PRELUDE CONSORTIUM PARTNERS

	Participant organization name	Country
1	AALBORG UNIVERSITET	DK
2	TAMPEREEN KORKEAKOULUSAATIO SR	FI
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EXECUTIVE SUMMARY

One of the objectives of the European PRELUDE project [1] is to develop a "Building Renovation Roadmap"(BRR) aimed at facilitating decision-making to foster and prioritize the most efficient refurbishment actions, the implementation of innovative solutions and the promotion of renewable energy sources in the renovation process of existing buildings.

In this context, Estia developed a set of inference rules to make this approach possible. Based on a diagnosis such as the Energy Performance Certificate, it intends to establish a list of priority actions.

The dynamics that drive this project permits to decrease the subjectivity of a human decisions making scheme. While simulation generates digital technical data, interpretation requires the translation of this data into natural language. The purpose of the developed tool is to automate the translation of the results to facilitate decision-making.

In medicine, the diagnostic phase is a process by which a disease is identified by its symptoms. Similarly, the idea of the process is to target the faulty elements potentially responsible for poor performance and to propose remedial solutions.

The system is based on the development of fuzzy logic rules [2-6]. This choice was made to allow the manipulation of imprecise quantities that can be described by vocabulary elements, and to associate membership functions with truth levels between 0 and 1.

The ultimate objective is to deliver incentive messages in a linguistic form, and address users who are not necessarily specialists.

For example, if performance is considered as “Low” and parameter x is considered as “unfavorable”, the algorithm will give an incentive to improve the parameter such as: "you COULD, SHOULD or MUST change or improve parameter x".

Regarding the building performance analysis, the following domains are addressed:

- Heating (incl. domestic hot water),
- Cooling,
- Electric lighting,
- Potential for renewable energy production.

Regarding the parameters, the analysis covers the following topics:

- Building location
- Construction typology
- Envelope
- Technical installations

In addition to the incentives provided to the user, information on the cost of the corresponding work is provided via a connection to the EPIQR+ database [4].

This document describes the methodology used, lists the fields studied and outlines the expected outcomes of the project.

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1. INTRODUCTION

In the context of climate change and the environmental and energy constraints we face, it is essential to develop methods to encourage the implementation of efficient solutions for building renovation. The shortcomings of the incentives aiming at energy efficient renovations are multiple. The main ones are the lack of prioritization of actions and lack of visibility on the costs of these actions. The two exposed shortcomings create barrier to trigger the renovation analysis and in consequence renovation itself.

1.1 Motivation

To answer the two exposed shortcomings, the proposed method will use both cost evaluation by the EPIQR+ method [7] and fuzzy logic. The use of fuzzy logic to develop an action list is motivated by the following aspects:

- **The users**

The various players (owners, architects, engineers, maintenance managers, users, etc.) involved in the renovation process have very different backgrounds and levels of expertise.

- **The available information**

Existing buildings do not always have a precise information base as to their dimensions, the composition of their various elements (structures, walls, equipment, technical installations) or the nature of the materials used.

So, in most cases, it is impossible to give a precise value to the various parameters. The use of Boolean logic is therefore not relevant to either analysis or diagnosis.

On the other hand, the use of words (adjectives) that contain a degree of imprecision makes it possible to overcome this limitation and describe the situation with a sufficient level of credibility to initiate an analysis process.

- **The incentives to deliver**

The use of words from everyday vocabulary makes it possible to address different categories of users, to describe the condition of buildings and to construct a list of recommendations.

These terms make it possible to process data with a certain degree of imprecision and to deliver incentives, the strength of which is reflected by various qualifying verbs.

2. DOMAINS COVERED / KEY PARAMETERS

The four following topics are addressed: Heating, Cooling, Lighting, and Renewable Energy Source. Each of them is tackled in a specific way and it is therefore possible to deliver an independent diagnosis focusing on one or other of these themes.

The principle is to consider a key parameter that determines if the situation is “more or less favorable” regarding these different topics.

2.1 HEATING: Energy consumption

In the case of heating, the data examined first and foremost is the energy consumption for heating. In most cases, this data is known (for example bills, EPC, …) and can be used as a basis for assessing the building's situation.

2.2 LIGHTING: Obsolescence

As with cooling, energy use for lighting is very difficult to quantify, so it was desirable to find another way of assessing a building's condition in this respect. We have therefore chosen to consider the obsolescence of the technologies in place in the studied project, and to position ourselves in relation to any new technologies that might be recommended.

2.3 RENEWABLE ENERGY SOURCES: Potential

As this topic has been the subject of specific development in Task 4.5 (RES Selector), Our approach to this subject is to establish a link with the work carried out by CORE-Innovation.

In the proof of concept, the results of the RES Selector is shown for each case study of the Prelude project.

3. DECISION PROCESS

3.1 Key Parameters

For each of the above topics (heating, cooling, lighting, renewables), we start by evaluating the key parameter, for example, the energy consumption associated with Heating, etc.

The objective is to create rating scales with fuzzy membership functions that describe the level of truth in each of the linguistic classes.

Figure 1 shows the type of scale used to qualify energy consumption for heating purposes.

Five categories have been defined, each corresponding to a language class.

Each of these classes is characterized by a membership function whose truth level is between 0 and 1. The values A, B, C, D and E correspond to points that characterize a membership value equal to 1.

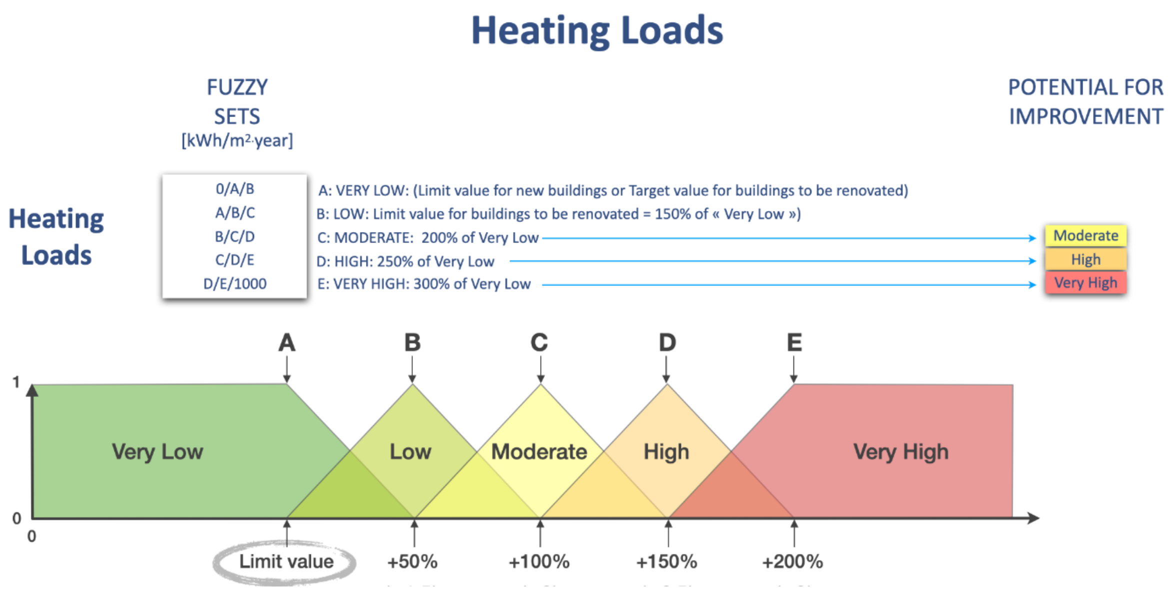


Figure 1: Fuzzy sets describing the heating energy consumption.

3.2 Associated parameters

If the heating consumption is “Very Low” or “Low”, we consider that no action is required.

If heat consumption is judged to be "Moderate", "High" or "Very High", we need to examine all the associated parameters that may explain this situation.

To do this, we propose to construct a scale for each of these parameters, indicating whether they are "*Very Unfavorable*", "*Unfavorable*", "*Slightly Unfavorable*", "*Favorable*" or "*Very Favorable*".

Example: Insulation thickness

Facade insulation is one of the parameters that can explain high energy consumption. We therefore propose to construct a scale where the insulation thickness is associated with a more or less *'favorable'* character according to the value measured in cm, as shown in Figure 2 hereafter.

In this example, a thickness of 7.5 cm straddles the "*Unfavorable*" and "*Slightly Unfavorable*" categories.

The membership functions described here mean that this insulation thickness is judged to be simultaneously "*Unfavorable*" with a truth level of 0.75 and "*Slightly Unfavorable*" with a truth level of 0.25

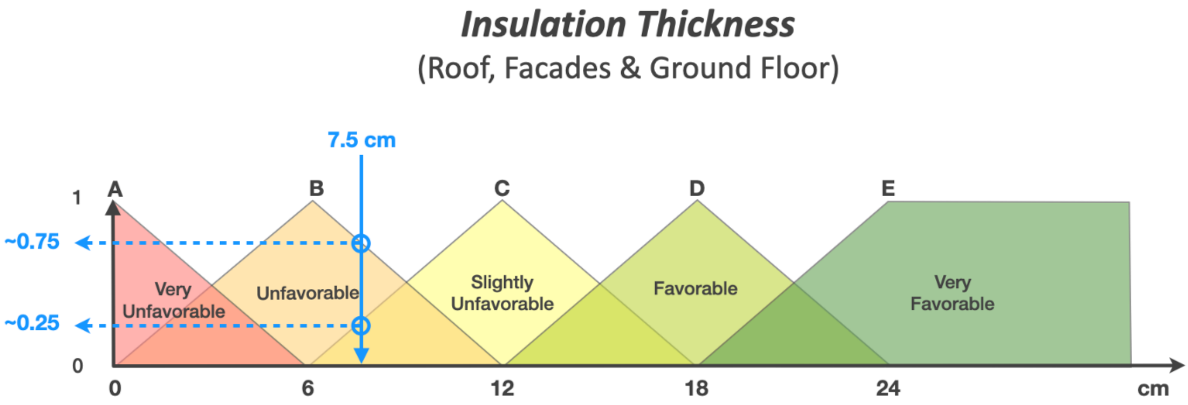


Figure 2: Fuzzy sets for the qualification of Insulation thickness

Once the status of the key parameter on the one hand, and the potential for improvement of a given associated parameter on the other have been defined, the principle consists in deducing the strength of the incentive level to be delivered to the user.

We propose three distinct levels of incentive to act:

- Imperative
- Strong
- Slight

3.3 Decision table

Table 1 shows the principle of Fuzzy Associative Memory, i.e. the set of rules governing the incentive to improve a given parameter (ex. the facade insulation) based on the observation of heating energy consumption.

		Associated parameter status		
		Very Unfavorable	Unfavourable	Slightly unfavorable
Key parameter status	Moderate	Slight Incentive	-	-
	High	Strong Incentive	Slight Incentive	-
	Very High	Imperative Incentive	Strong Incentive	Slight Incentive

Table 1: Determination of the incentive levels to be delivered according to the measured performance on the one hand and the potential for improvement associated with a given parameter on the other.

In order to facilitate the delivery of the message to the user, we propose to transform the incentive level into a simple linguistic form by using different verbal injunctions.

- Imperative Incentive ➤ You **MUST** (check or modify the parameter)
- Strong Incentive ➤ You **SHOULD** (check or modify the parameter)
- Slight Incentive ➤ You **COULD** (check or modify the parameter)
- - ➤ None (No incentive)

For example (see Table 2):

- If the Heating loads are "**Very High**"
- And the Insulation thickness is "**Unfavorable**",
- Then the injunction to be issued would be: "You **SHOULD** improve the facade insulation".

		Insulation thickness		
		Very Unfavorable	Unfavourable	Slightly unfavorable
Heating loads	Moderate	COULD	-	-
	High	SHOULD	COULD	-
	Very High	MUST	SHOULD	COULD

Table 2: Linguistic values corresponding to different incentive levels.

3.4 Aggregation process / Incentives

As mentioned above, the description of the parameters of an existing building cannot be precise. This means that, in most cases, a parameter will belong simultaneously to two different classes: For example, *Heating loads* could be considered at the same time as "High" and "Very High » (the sum of the truth levels obtained in both cases being equal to 1.

Table 3 below shows an example where *Heating loads* are judged to be "***Moderate***" with a truth level of 0.60 and "***High***" (truth level of 0.40).

Simultaneously, the *Insulation thickness* is considered "***Very Unfavorable***" (truth level of 0.25) and "***Unfavorable***" (truth level of 0.75).

We therefore have 4 incentives that are simultaneously activated.

		Insulation thickness		
		Very Unfavorable 0.25	Unfavourable 0.75	Slightly unfavorable
Heating loads	Moderate 0.60	COULD	-	-
	High 0.40	SHOULD	COULD	-
	Very High	MUST	SHOULD	COULD

Table 3: Truth levels achieved for each of the subsets of fuzzy associative memory.

To aggregate these results, we use the minimum implication process, whereby the lowest truth value is retained for each activated rule.

Thus, in the case treated here, the levels of truths for each of the combinations are as follows:

- Heating Consumption = Moderate (0.60) & Insulation thickness = Very Unfavorable (0.25):

  COULD = Min (0.60,**0.25**)

- Heating Consumption = Moderate (0.60) & Insulation thickness =Unfavorable (0.75):

  NONE = Min (**0.60**,0.75)

- Heating Consumption = High (0.40) & Insulation thickness =Very Unfavorable (0.25):

  SHOULD = Min (0.40,**0.25**)

- Heating Consumption = High (0.40) & Insulation thickness =Unfavorable (0.75):

  COULD = Min (**0.40**,0.75)

When two identical incentive levels are simultaneously activated (in this case the "COULD" level, i.e. Slight incentive), the levels of truths add up.

In this instance, we thus have the following results:

- NONE: 0.60
- COULD: **0.65** (0.25 + 0.40)
- SHOULD: 0.25

The incentive selected is the one with the highest aggregate truth level.

Thus, the incentive delivered to the user would therefore be:

- ***"You COULD improve facade insulation".***

4. HEATING TOPIC

As mentioned before, regarding this topic, we decided to base the analysis on the effective annual energy consumption for heating.

4.1 Starting parameters: Energy consumption

As shown in Figure 3 below, the user is asked to indicate the consumption associated with the production of heat and to specify whether this consumption has been measured or only estimated, and finally to indicate whether the energy required for domestic hot water is included.

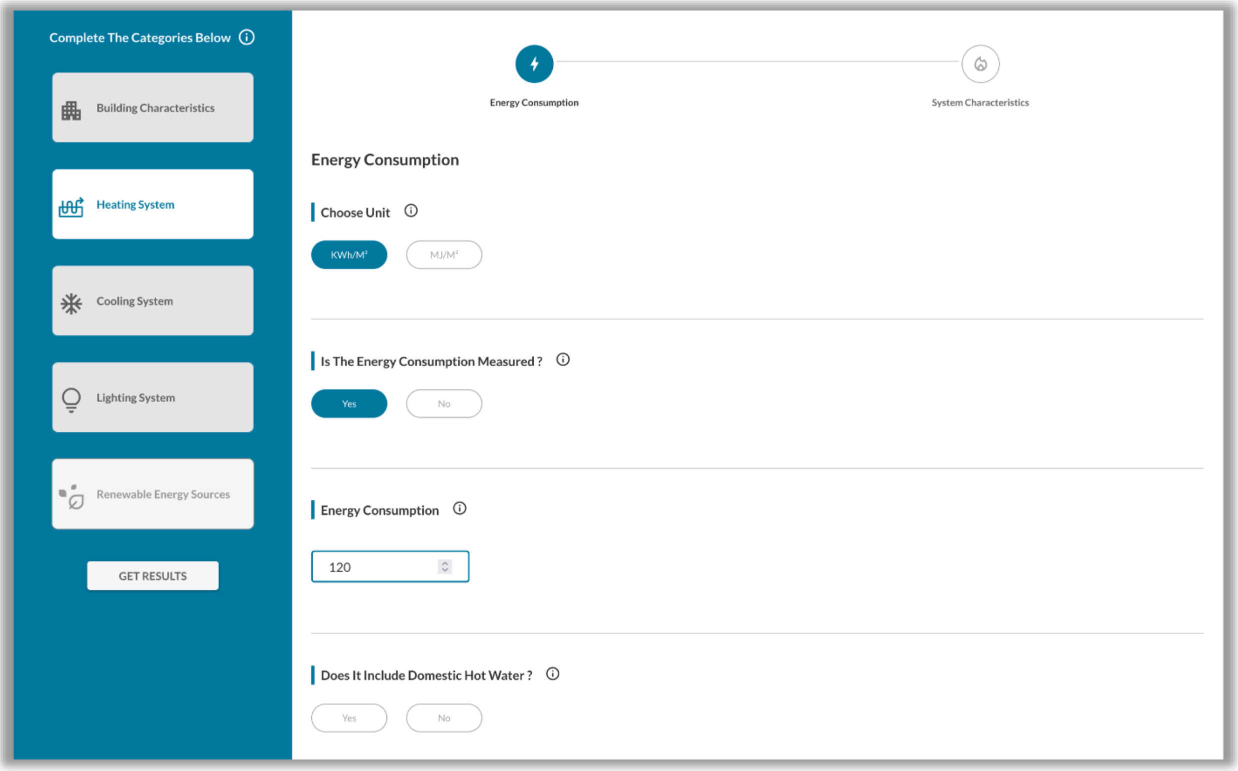


Figure 3: Interface for describing heating energy consumption

4.1.1 Analysis

Our approach is to use the ***limit*** values set by the Swiss Standard [8] as a reference base and to adapt the analysis according to the specific building location.

These limit values correspond to requirements that are achievable with the current technical means and that are economically feasible. It is used as the **target value for refurbished buildings.**

4.1.2 Main Formula

The target values [kWh/m^2.year] are calculated according to SIA 380/1 2016 [5] with:

$$Q_{H,li} = (Q_{H,li0} + \Delta Q_{H,li}(A_{th}/A_E)).f_{cor}$$

where :

- $Q_{H,li0}$ = Base value
- $\Delta Q_{H,li}$ = Increase factor
- A_{th}: Surface of the thermal envelope of the building in m^2
- A_E: Energy reference area in m^2
- f_{cor} = Climatic correction factor

Default values according to the building function

The energy requirements and comfort of occupants are linked to the purpose of the building. We propose to use the SIA [9] list of possible uses, with different default parameters for each (see Table 4 below).

If there is no precise input for A_{th} and A_E, the default value is given by last column of Table 1.

	QH,li0	ΔQH,li	Form Factor (A_{th}/A_E)
Collective housing	13	15	1.3
Individual housing	16	15	2
Office	13	15	1
School	14	15	1.2
Shop	7	14	1
Catering	16	15	1.5
Meeting place	18	15	1.2
Hospital	18	17	0.8
Industry	10	14	1
Warehouse	14	14	0.8
Sport hall	16	14	0.8
Indoor pool	15	18	1

Table 4: Default values used to calculate the limit values for heating consumption, according to the building's function [5]

4.1.3 Climatic correction factor

To consider climatic constraints (latitude, altitude, etc.), a correction factor is requested to modulate the limit value according to the location of the building

We propose to base this correction factor on the heating *degree-days* 12-20 ($H_{Dd\ 12\text{-}20}$) of the building's location.

This value corresponds to the sum, for all days of the year, of the difference between 20°C and the average daily temperature, provided the latter is less than 12°C; otherwise, the value is zero.

The reference value is 3400 $H_{Dd\ 12\text{-}20}$ which correspond to the mean Swiss climatic conditions.

- **fcor** = $1/((3400 + (Local_{Dd} - 3400)/2)/ Local_{Dd})$

  With $Local_{Dd}$ = degree-days of the building location

Examples

Aalborg :	$LocalH_{Dd}$ = 3754	f_{cor} = 1.049
Athens :	$LocalH_{Dd}$ = 974	f_{cor} = 0.445
Geneva :	$LocalH_{Dd}$ = 3191	f_{cor} = 0.968
Oslo :	$LocalH_{Dd}$ = 4330	f_{cor} = 1.120
Paris :	$LocalH_{Dd}$ = 2713	f_{cor} = 0.888
Wien :	$LocalH_{Dd}$ = 3281	f_{cor} = 0.982

As mentioned in §3.1, each 50% increase in consumption corresponds to a change in fuzzy class (cf. Figure 1).
We have built an excel file with the H_{Dd} values corresponding to 167 representative cities in Europe.

4.2 Associated parameters (Potential causes)

4.2.1 Building parameters

4.2.1.1 Insulation thickness

See § 3.2

The qualification of insulation thickness is adapted according to the different components of the building (facades, roof, ground floor).

4.2.1.2 Building thermal mass (Inertia): B_{tm}

Thermal mass (or thermal inertia) is the thermal storage potential of a building. In the absence of heating or cooling, the internal temperature of a *'light'* building will tend to follow the oscillations of the external temperature, whereas in a *'heavy'* building the variations in internal temperature will be more reduced. This parameter has an important influence on summer comfort and energy consumption.

Thermal inertia is most effective when used in conjunction with a passive solar design or bioclimatic design.

- For heating, the system control parameters (slope of the heating curve, switch-on/switch-off times, etc.) are modulated according to the thermal mass of the building, as described in the following paragraphs.
- For cooling (cf. 4.2.1.2), we will see that the thermal mass also has a significant influence on the overheating risk.

The interface allows the user to select the construction types of the different components of the building, i.e. facades, roof, ground-floor and intermediate floors.

Each of these types is associated with a term that describes whether the material is "Heavy" (high thermal mass), "Medium" (average thermal mass) or "Light" (low thermal mass).

In addition, the presence and position of any insulation is taken into account to give an overall 'score' for the thermal mass of the building.

A) Facades

For the Facades the selection of the material (Figure 4) and the insulation position is associated to a score between 1 and 3, as shown in Table 5.

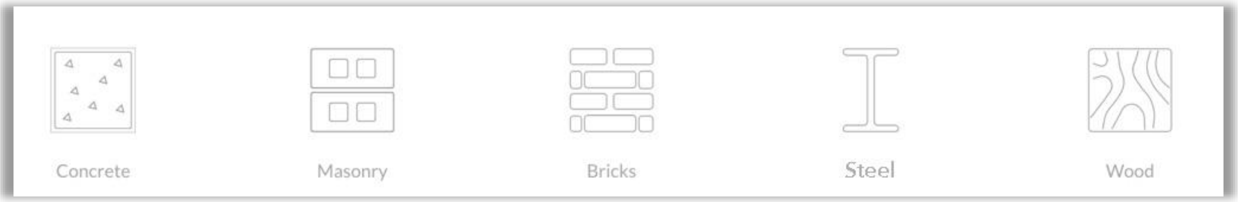


Figure 4 : Construction types for the facades

FACADES	INSULATION POSITION		
	OUTDOOR	INTERMEDIATE	INDOOR
CONCRETE	HEAVY (3)	HEAVY (3)	LIGHT (1)
MASONRY	HEAVY (3)	MEDIUM (2)	LIGHT (1)
BRICKS	MEDIUM (2)	LIGHT (1)	LIGHT (1)
STEEL	LIGHT (1)	LIGHT (1)	LIGHT (1)
WOOD	LIGHT (1)	LIGHT (1)	LIGHT (1)

Table 5: Definition of the Facades' thermal mass grade as a function of the material and the insulation position.

According to this table,

- a Steel Facade with outdoor insulation has a score of 1 (*Light*)
- while a Concrete Facade with outdoor insulation has a score of 3 (*Heavy*).

B) Roof

For the roof, the selection of the material (Figure 5) and the insulation position are associated to a score between 1 and 3, as shown in Table 6.

Figure 5: Construction type of the roof

ROOF & GROUND FLOOR	INSULATION POSITION		
	OUTDOOR	INTERMEDIATE	INDOOR
CONCRETE	HEAVY (3)	HEAVY (3)	LIGHT (1)
BEAMS & RIBS	HEAVY (3)	MEDIUM (2)	LIGHT (1)
MIX WOOD & CONCRETE	MEDIUM (2)	LIGHT (1)	LIGHT (1)
STEEL	LIGHT (1)	LIGHT (1)	LIGHT (1)
WOOD	LIGHT (1)	LIGHT (1)	LIGHT (1)

Table 6: Definition of the thermal mass grade of the Roof as a function of the material and the insulation position.

According to this table:

- a Steel Roof with outdoor insulation has a score of 1 (*Light*)
- while a Concrete Roof with Intermediate insulation has a score of 3 (*Heavy*).

C) Ground floor (same as for Roof)

For the Ground Floor, the selection of the material and the insulation position is associated to a score between 1 and 3, as shown in Table 6.

According to this table,

- a Mix Wood-Concrete Ground Floor with outdoor insulation has a score of 2 (*Medium*)
- while a Concrete Ground Floor- with Indoor insulation has a score of 1 (*Light*).

D) Intermediate floors

The intermediate slabs also have an influence on the thermal mass of the building. Table 7 shows the qualification of the Intermediate floors thermal mass as a function of the construction type.

INTERMEDIATE FLOORS	STAND ALONE
CONCRETE	HEAVY (3)
BEAMS & RIBS	HEAVY (3)
MIX WOOD &	MEDIUM (2)
STEEL	LIGHT (1)
WOOD	LIGHT (1)

Table 7: Thermal mass index for intermediate floors

Possible extension: The presence of false floors and/or ceilings cuts off contact with the slab and therefore reduces the accessible thermal mass. Table 8 shows the qualification of Intermediate floors thermal mass that takes into account the presence of false floor and/or ceiling.

		ADDITIONAL COMPONENTS		
INTERMEDIATE FLOORS	STAND ALONE	FALSE FLOOR	FALSE CEILING	FALSE FLOOR + FALSE CEILING
CONCRETE	HEAVY (3)	MEDIUM (2)	MEDIUM (2)	LIGHT (1)
BEAMS & RIBS	HEAVY (3)	MEDIUM (2)	MEDIUM (2)	LIGHT (1)
MIX WOOD &	MEDIUM (2)	LIGHT (1)	LIGHT (1)	LIGHT (1)
STEEL	LIGHT (1)	LIGHT (1)	LIGHT (1)	LIGHT (1)
WOOD	LIGHT (1)	LIGHT (1)	LIGHT (1)	LIGHT (1)

Table 8: Thermal mass index for intermediate floors depending on the existence of a false floor or false ceiling.

According to this table,

- a stand-alone Concrete Intermediate Floor (with no false floor or ceiling) has a score of 3 (Heavy)
- while the same Concrete Intermediate Floor with a false floor has a score of 2 (Medium).

To simplify the description procedure, we propose, for the initial version of the roadmap, to disregard the false floor & ceiling variants and to base ourselves solely on the elements presented in Table 7 above.

Components counting (C_c)

In order to consider the influence of all of the building's components, each of them is assigned a weight factor as follow:

- Facades (F) = 4
- Intermediate Floors (I_f) = (Nb of Floors -1)
- Roof (R) = 1
- Ground Floor (Gf) = 1

The total number of components is as follow:

- $Cc = 6 + I_f$

And the global thermal mass of a given building (B_{TM}) of the building is calculated as follow:

- $(B_{TM})_e = (F * TM_{grade} + I_f * TM_{grade} + R * TM_{grade} + Gf * TM_{grade}) / C_c$

With this method, the resulting (B_{TM}) is somewhere between 1 (*Light building*) and 3 (*Heavy building*).

4.2.1.3 Windows Characteristics

Opening Type

The type of opening determines the capacity for natural ventilation through the openings. For example, a French-style opening (Swing window) allows 100% of the window surface area to be used to transfer air between the inside and outside of the room.

On the other hand, a transom opening leaves only around 15% of the total surface area of the window free for air to pass through.

Figure 6 shows the interface allowing the user to select the main opening type of the building under study.

Figure 6: Interface for describing the Windows main opening type.

Proportion of the openable windows

In a standard building, not all windows can necessarily be opened. It is therefore important to specify the proportion of windows that can be opened to determine the potential for natural ventilation.

Figure 7 shows the interface allowing the user to select the appropriate ratio of openable windows.

Figure 7: Interface for describing the proportion of windows that can be opened.

Windows opening mode

Motorizing or automating the opening of windows can radically change the way they can be used for natural ventilation. Figure 8 shows the interface allowing the user to describe the situation in the building under study.

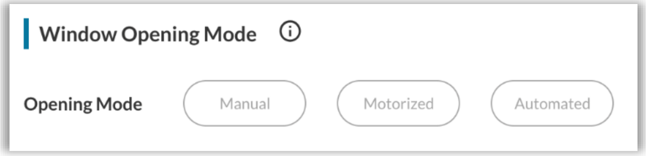


Figure 8: Interface for describing windows opening mode.

Windows' U-value (Ug, [W/m².K])

The glazing U-value gives information on the insulation performance of the glazing. The higher the value, the greater the heat exchange through the glazing and therefore the higher the heat requirement. If the user does not know the U-value of the building's glazing, he can select one of the 4 icons proposed (see Figure 9).

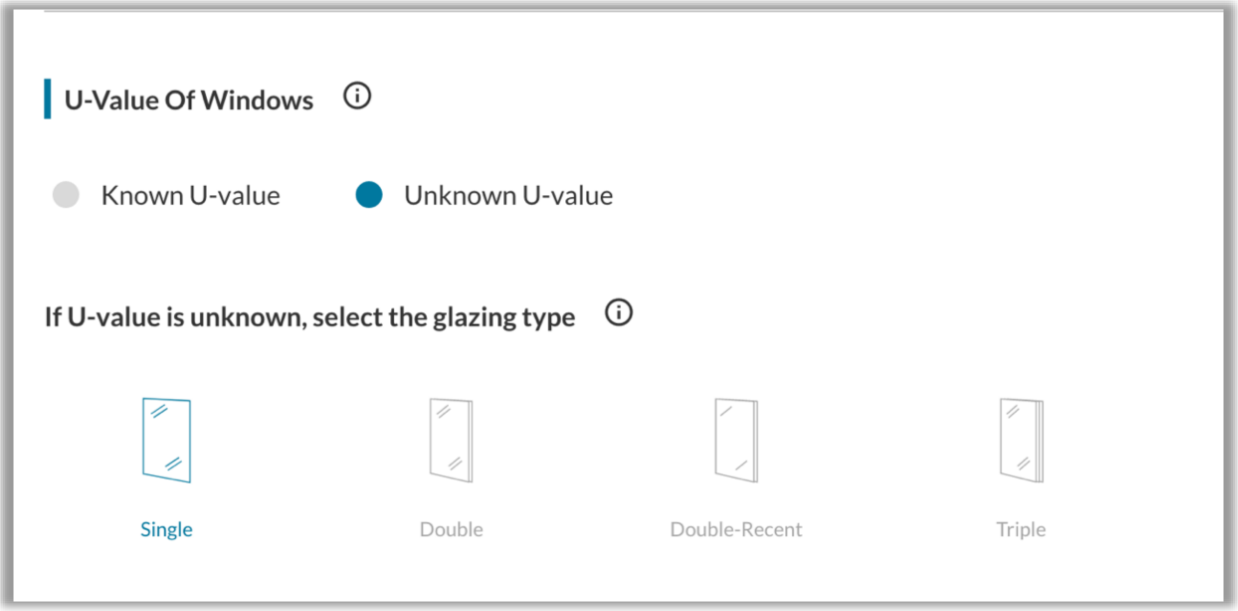


Figure 9: Interface for describing the glazing U-Value

INCENTIVE: The user is invited to c*hange the glazing*

4.2.1.4 Glazing g-value (-)

The g-value of the glazing determines the capacity of the glazing to reflect energy radiation and is decisive for the management of solar gains and internal gains.

On the one hand, low g-values reduce the potential for solar gain in winter and thus increase the heating demand; on the other hand, low g-values reduce the risk of overheating in summer. Since we consider that the question of solar gains can only be satisfactorily solved by adaptive shading devices, we do not consider the g-value to be a decisive factor in guaranteeing against the risk of overheating.

In the application, a low g-value will thus be considered as an **aggravating factor** from the point of view of the heating energy demand, in the same way as the glazed area (see § 4.2.1.5).

If the user does not know the g-value of the building's glazing, he can select one of the 4 icons proposed (see Figure 10).

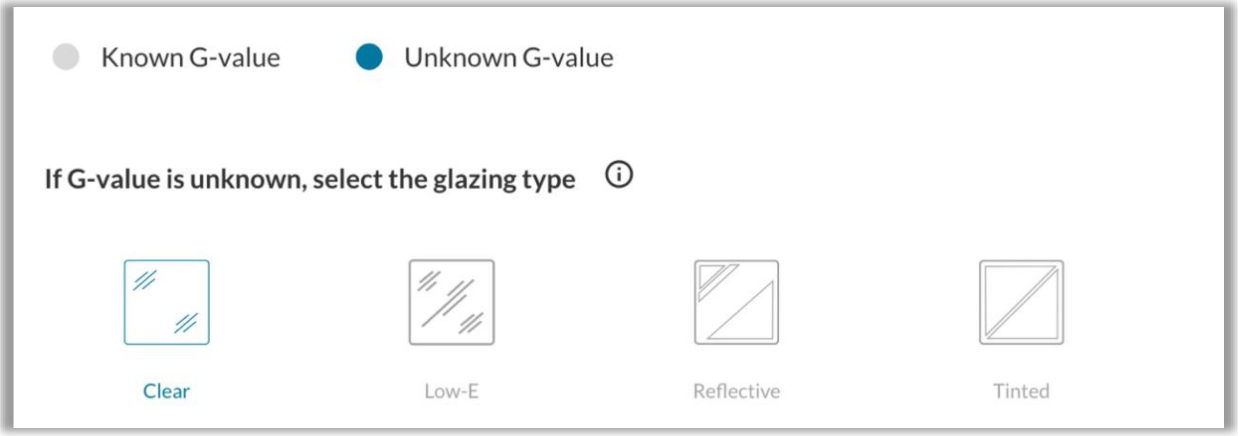


Figure 10: Interface for describing the glazing' g-value.

INCENTIVE: Insofar as the influence of the g value on solar gains can be considered as positive in winter (reducing heat requirements) and negative in summer (increasing the risk of overheating), no specific incentive is given for this parameter. However, it is considered when calculating the intrinsic risk of overheating associated with the building (cf. §5.1).

4.2.1.5 Glazed area (GA)

The greater the proportion of glazing in a building, the greater its heat exchange with the outside environment and therefore the greater its heating needs in winter and cooling needs in summer.

To describe the glazed area, the user has to select between 5 icons.

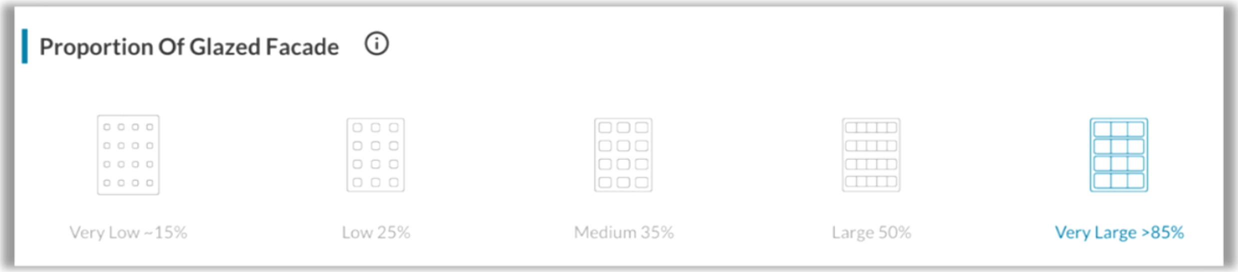


Figure 11: Interface for describing the glazed area.

The respective associated glazed percentage are as follow:

- Very Large: 80%
- Large: 50%
- Medium: 35%
- Low: 25%
- Very Low: 15%

"Very Large" is considered as *Very Unfavorable*

"Large" is considered as *Unfavorable*

"Medium" is considerate as Slightly *Unfavorable*

The glazed area should be considered as an **aggravating factor** when heat consumption (or cold consumption in summer) is high, and the U-value of the glazing is poor.

4.2.2 Technical parameters (heating system)

4.2.2.1 Energy vector

In the context of climate change, the use of fossil fuels must be reduced. The energy source used to produce heat (heating and domestic hot water) is therefore one of the parameters to be considered.

Figure 12: Interface allowing to select the energy vector

INCENTIVE: When the heating is provided by electric resistance or fossil energy (fuel or Gas), the users are invited to consider replacing their heat production system with one that uses renewable energy sources. If the energy is supplied by a district heating network, we consider that the user does not have the power to modify the network's characteristics, and we therefore decided not to give a recommendation on this subject.

For Heat-pump & wood, we consider that these options are favorable

4.2.2.2 Age of the boiler (B_{Age})

The age of the boiler is one of the factors that can explain excessive heat consumption.

INCENTIVE: If the heating energy consumption is critical (Very-High, High, or Moderate), the users are invited to replace the boiler.

4.2.2.3 Pipes insulation

Poor insulation of heat distribution pipes (heating or DHW) leads to significant heat loss during the transport of water between the boiler and the point of use.

In the case of domestic hot water, this also leads to significant additional water consumption by increasing the time it takes for the water to get hot enough to be used.

In addition, in summer, losses from uninsulated domestic hot water pipes can contribute to the overheating of the building. The decision rules associated with this topic are **Boolean**.

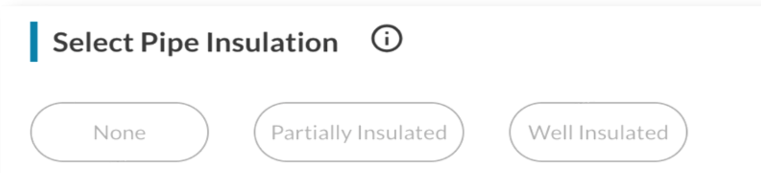


Figure 13: Interface for describing the pipe insulation

INCENTIVE: The users are invited to insulate the pipes or complete the insulation.

4.2.2.4 Heat distribution

The way in which heat is emitted influences the responsiveness of the heating system and its settings.

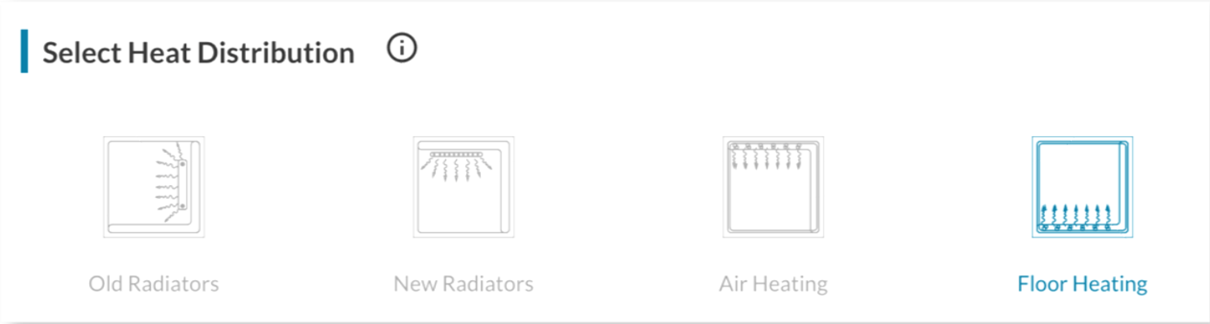


Figure 14: Interface allowing to select the heat distribution type

The heat distribution type is used to determine which the appropriate set of values for the Heating Curve slope and Night Shift (see below).

4.2.2.5 Heating curve slope (Hcs)

The heating curve defines the water temperature set point of an installation according to the outside temperature. This type of control allows the power output to be adapted to the actual heating requirements.

The heating curve is generally considered to be a straight line whose directing coefficient is called the slope of the water law.

Three types of heat emitters are considered as they each represent a specific level of inertia and are therefore associated with different heating curves

- Old radiators
- New radiators
- Floor heating (slab)

As tenants are not familiar with this concept therefore only building specialists can provide this value.

INCENTIVE: The user is invited to reduce the heating curve slope.

4.2.2.6 Nightshift

The reduction of the heating temperature during the night allows a significant decrease of the heating needs. If the user indicates that the heating control system has a night-shift function, he will be asked to enter the start time (H_{Start}) and the end time (H_{End}).

- H_{Start} corresponds to the time of day when the "Night" mode, i.e. temperature reduction, is applied.
- H_{End} corresponds to the time of day when the "Night" mode, i.e. temperature reduction, is turned off.

In both cases, different rules apply depending on the combination of the thermal mass of the building and the type of heat distribution.

INCENTIVE: The user is invited to consider the implementation of a night-shift mode outside the activity hours.

4.2.2.7 *Multiple boilers in a row*

When there are several heat producers (boilers), the cascade between the different boilers needs to be controlled. Generally, priority should be given to using the most efficient boiler that is best suited to the needs of the moment (winter/summer, for example) and to avoiding keeping the unnecessary boiler(s) at temperature.

Controlling cascaded boilers has two advantages:

- To limit the shutdown losses of boilers whose production is not needed.

- To limit the power used to increase burner operating time and limit losses and pollutant emissions when the burner is started and stopped (as with cascade regulation of 2-stage burners).

The possible actions are as follow:

- If possible, keep only one boiler in operation.
- Use the most efficient boiler and avoid keeping more than one boiler warm.
- Provide sufficient time for the boilers to be switched on to prevent all boilers from starting up unnecessarily.
- Manually switch-off an unnecessary boiler in an oversized installation.

INCENTIVE: As these settings are fairly technical, the user is invited to seek specialist help.

4.2.3 Domestic hot water

4.2.3.1 *Energy consumption*

Depending on the use of the building, the energy consumption associated with the production of domestic hot water can account for a relatively large proportion of heating requirements.

As with heat requirements, we propose to base our approach on the recommendations of the SIA 2024-2021 standard [7].

Table 9 shows the "standard" consumption values for DHW production for the different types of building.

If this consumption is included in the user input (see §4.1), it must be subtracted in order to be able to qualify more precisely the specific needs linked to the space-heating of the building.

Building Function	Domestic Hot Water (kWh/m²)
COLLECTIVE HOUSING	16
INDIVIDUALHOUSING	12
OFFICES	2
SCHOOL	3
SHOPS	4
CATERING	59
MEETING PLACE	4
HOSPITAL	31
INDUSTRY	2
WAREHOUSE	1
SPORTSHALL	33
INDOOR POOL	94

Table 9: Energy demand for DHW production by building category (values based on energy reference area).

4.2.3.2 DHW setting parameters

The DHW setting parameters are numerous and sometimes complex, so they need to be adjusted by a professional. In our approach, to simplify the use of the Building Renovation Roadmap, we propose to focus on the following two questions:

- Set Point Temperature
- Reduce mode

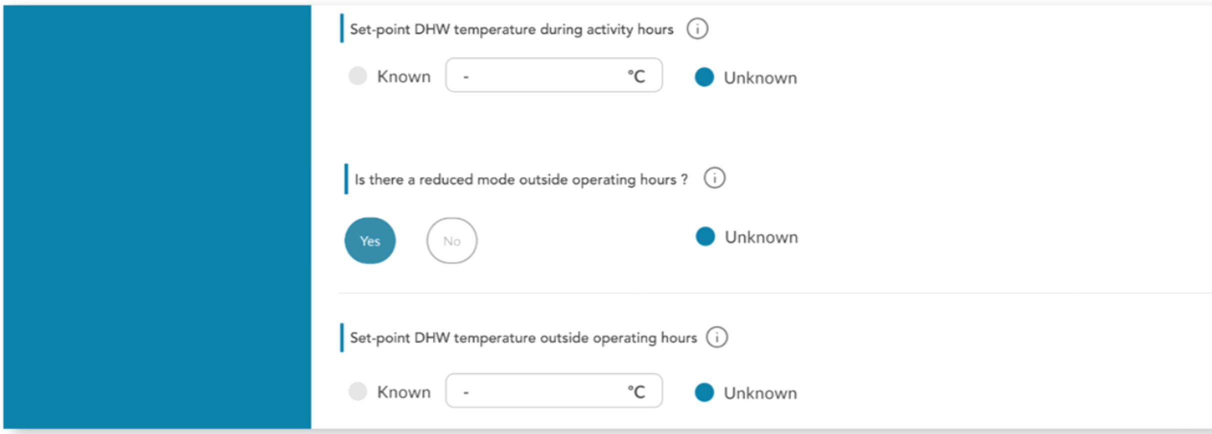


Figure 15: Front end interface dedicated to DHW.

INCENTIVE: If the user cannot answer to one or several of the questions regarding DHW (*Unknown buttons*), he is invited to call in a specialist to check the parameters of the DHW system.

Otherwise, the analysis is carried out as follows:

4.2.3.3 Set point temperature during activity hours

The user is asked to indicate the DHW set temperature during the day.

INCENTIVE: If the set temperature is judged to be too high, the user is encouraged to reduce it during the activity hours.

4.2.3.4 Reduce mode

The user is then asked to indicate whether a reduced mode is applied during periods of low activity (for example: during the night for homes, during the night and at weekends for workplaces or during the night, at weekends and during holidays for schools).

INCENTIVE: If there is no reduce mode, the user is prompt to implement a reduce mode outside activity hours.

4.2.3.5 Set point temperature outside activity hours

If there is a reduce mode outside activity hours, the user is prompted to enter a value (°C)

INCENTIVE: If the set point temperature is judged to be too high, the user is encouraged to reduce it outside the activity hours.

5 COOLING TOPIC

The cooling energy consumption is difficult to estimate since, in most cases, there is no separate metering for this consumption which is included with the other electricity demands items (lighting, ventilation, equipment, etc.).

The Building Renovation Roadmap is therefore not focused on cooling energy consumption, but on the ***overheating risk*** associated with the building characteristics.

We propose to classify these risks into 3 distinct categories:

- Intrinsic overheating risk
- Building parameters that can be improved
- Technical parameters of the cooling system

5.1 Intrinsic overheating risk (IOR)

Intrinsic risk corresponds to parameters that cannot be easily modified and includes the following five parameters:

5.1.1 Building location: Cooling degree-days (C_{DD})

Intuitively, the further south in Europe the building is located, the higher the risk; conversely, the further north in Europe the building is located, the lower the risk.

However, this approach is not sufficient insofar as the proximity or remoteness of the sea plays a non-negligible influence on maximum temperatures during the summer.

As with heating, we propose to use Cooling Degree-Days ($CDD_{20\text{-}20}$) to characterize the overheating risk due to building's location.

This scale is based on the sum, for all days of the year, of the difference between 20°C and the average daily temperature, provided the latter is above 20°C; otherwise, the value is zero ($CDD_{20\text{-}20}$).

The basic assumption is that when the outside temperature reaches or exceeds 20°, the combination of solar heat gain and internal heat gain leads to a significant risk of overheating.

Figure 16 shows a selection of European cities with their respective $CDD_{20\text{-}20}$ values (Meteonorm Data [7]).

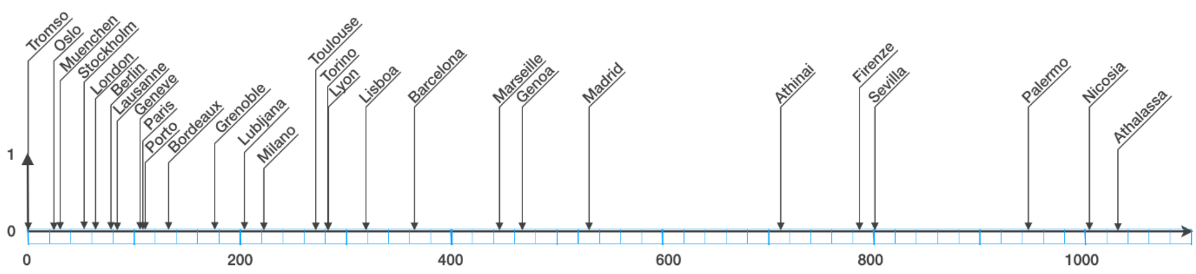


Figure 16: Cooling Degree-Days 20-20 ($CDD_{20\text{-}20}$) of some representative cities in EU.

This list shows that among the cities analyzed in Europe:

- the highest value is: 1159 (Athalassa, Cyprus)
- the lowest value is: 0 (Tromso, Norway).

We have built an excel file with the CDD_{20-20} values corresponding to some representative cities in Europe. (see "fcor-EUROPE.xls")

This list also included French overseas territories (e.g. Raizet in Guadeloupe and Cayenne in French Guyana). For these territories, the values for the CDD_{20-20} far exceed the maximum observed in the European Union. These are a very special case, where air conditioning is virtually compulsory for workplaces and where draughts linked to natural cross ventilation are sought for the comfort of residential premises.

Our experience shows that when CDD_{20-20} is below 100 (which is close to Lausanne or Geneva), the overheating risk can be considered as "Low". This is confirmed by the fact that Swiss standard considers that a cooling system can only be justified in cases where the internal gains are particularly high (e.g. manufacturing processes).

5.1.2 Building environment (B_E)

The building's immediate environment has a significant influence on the overheating risk.

A building located in a rural setting (dominated by vegetation) will not present the same risk as one located in the center of a major metropolis.

We propose to give the user the possibility of describing the urban environment of their building using a linguistic scale based on 5 levels representing the building environment (cf. Figure 17)

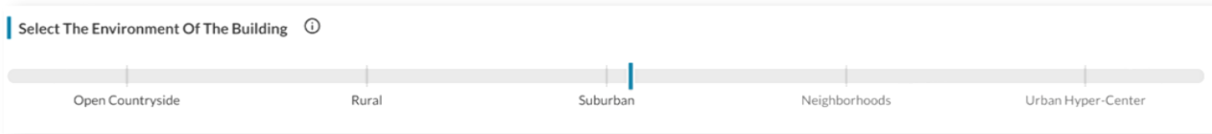


Figure 17: Linguistic scale for describing the building environment.

5.1.3 Building function: Internal gains (IG)

The use of the building has a strong influence on the risk of overheating through internal gains associated with the presence of occupants, appliances and lighting.

We have used the values provided by the SIA 2024 [9] for different building functions to construct our risk scale (see Table 10).

Building function (-)	**Internal heat gains** (kWh/m²/y)
Collective Housing	**20**
Individual Housing	**19**
Offices	**30**
School	**40**
Shops (hypermarket)	**27**
Catering	**50**
Meeting rooms (multipurpose	**39**
Hospital (medical premises)	**51**
Industry (fine work)	**22**
Warehouse	**11**
Sports Hall	**15**
Indoor Swimming Pool	**17**

Table 10: Internal gains associated to the different building function according to SIA 2024-2021.

5.1.4 Glazed area (G_A)

The proportion of glazed facade has a direct influence on the risk of overheating. This is why we use this parameter (already described in more detail in the "Heating" chapter, cf.§4.2.1.5) to address the issue of the risk of overheating.

5.1.5 Building thermal mass (B_{TM})

This parameter has already been described in the Heating Chapter (cf. 4.2.1.2). The influence of thermal on overheating risk is linked to the potential of free cooling. The indoor temperature of a “light” building will tend to follow the outdoor temperature trend while a “heavy building” will be able to store freshness during the night end then to reduce the maximum temperature during the day.

5.2 Building parameters that can be improved

These are the building parameters on which renovation or replacement measures can be proposed.

5.2.1 Shading device (ShD)

5.2.1.1 Shading device type (ShD_T)

There are many different types of mobile solar protection (Venetian blinds, fabric blinds, roller shutters, swing shutters, etc.). Each of these solutions has its own characteristics, with advantages and disadvantages. The question of air permeability is important insofar as it activates natural ventilation and therefore contributes to summer comfort.

Shading type is a Boolean choice:

- Venetian blinds
- Vertical fabric blinds
- Projection awnings
- Swing shutters
- Roller shutters
- No Shading

Figure 18: Interface allowing to select the shading device type.

INCENTIVE: The lack of movable solar protection is seen as a major drawback and leads to a strong incentive to implement movable shading devices.

5.2.1.2 Shading device position (ShD_P)

Solar protections must be positioned on the outside to block the sun's rays before they pass through the glazing.

Shading position is a Boolean choice:

OUTDOOR or INDOOR

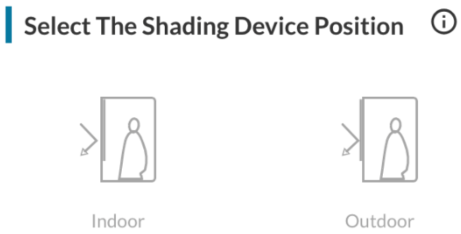


Figure 19: Interface allowing to select the shading device position.

INCENTIVE: If the solar protection is positioned indoors, this is considered as an **aggravating factor** in relation to the risk of overheating, and a strong incentive is given to correct this.

5.2.1.3 Shading device mobility (ShD_M)

We believe that it is not possible to fine tune solar gains with a fixed protection system (eaves or overhangs) insofar as to block the incident rays, it is necessary to control all possible positions of the sun (azimuth and height) outside the heating period, which results in a drastic reduction in accessibility to daylight and potential view to the outside.

INCENTIVE: If an intrinsic overheating risk has been identified the app will thus recommend implementing mobile shading devices.

5.2.1.4 Shading device activation

Observation of buildings equipped with mobile shading devices shows that their use is often far from optimal. In most cases, users tend to adjust the position of the solar protection only when they are faced with acute discomfort, and most of the time, this is linked to a glare problem. Very often, it can take several days before the position of the sun protection is readjusted.

Depending on the situation, this can result in:

- A loss of natural light even though the sun is no longer present, and the risk of glare therefore no longer exists,
- A reduction in solar gains in the cold season if the blinds are lowered when the premises are not occupied (weekends),
- An increase in the overheating risk if the blinds are raised when the occupants are absent during the summer or mid-season (early morning, evening, weekends, etc.).

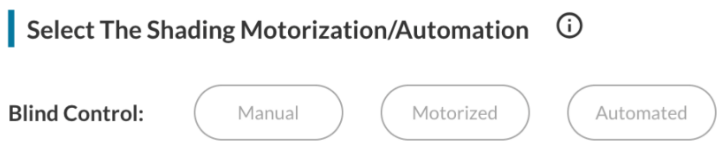


Figure 20: Interface allowing to select the shading device activation.

A) Shading device motorization (ShD_{MOT})

If the solar protection is motorized, it is easier to use, which means that the position is more accurately adjusted.

B) Shading device automation (ShD_{AUT})

If the solar protection is automated, it is possible to automate its position to take better account of solar gain.

There are two possible strategies:

- **Continuous automation**: the position of the blinds is continuously adjusted according to the energy flow incident on the facade.

This option is very effective but is sometimes rejected by users because every movement can be seen as a disturbance, especially in workplaces.

- **Automation with reset**: a few commands are given, primarily when users are absent, so as not to disrupt their activities.

This second option greatly reduces the risk of overheating in the workspaces by ensuring a minimum of 3 movements per day (before people arrive, during the lunch break, and after people leave).

INCENTIVE: To simplify the process, we propose only to suggest the implementation of an automation system, without going into further detail.

5.2.2 Effective openable area (E_{oa})

If windows can be opened, it is possible to activate natural ventilation and thus, depending on the use of the building, ensure summer comfort, provided that the opening surfaces represent a sufficient fraction of the glazed area.

Conversely, if no window can be opened, air conditioning is compulsory.

In addition to the possibility of opening the windows, the percentage of the glazed area that can be opened is a key factor.

5.2.2.1 Opening type – Openable ratio (O_R)

The effective surface area of a given opening, i.e. the free surface area allowing air to pass through the window, depends on the type of opening. Figure 21 shows the different possibilities with the associated openable area (O_R).

Figure 21: Opening type selection interface with associated effective opening percentage.

5.2.2.2 Relative openable area (R_{OA})

The natural ventilation potential of a given building depends on the presence and type of openings but must also be related to the energy reference area of this building. This leads us to calculate the Relative Openable Area as described hereafter.

The calculation of the Relative Opening area (R_{OA}) is the as follow:

$$R_{OA} = (Ext_A\ G_A . O_R\ .\ R_{OW})/A_E$$

Where Ext_A = Facade surface in contact with the outside (in Building characteristic parameters)

G_A = Glazed Area (% cf.:§ 4.2.1.5)

O_R = Openable ratio (%)

R_{OW} = Rate of Openable Windows (%)

A_E **=** Energy reference area (m^2, cf. 4.1.2)

This R_{OA} value is used to determine the building's natural ventilation potential.

INCENTIVE: if this potential is judged to be high or very high, an incentive is issued to activate natural ventilation during the night.

5.3 Technical parameters of the cooling system (if exists)

These are the parameters of the air conditioning system (technical characteristics and settings).

5.3.1 Compressor age (C_{Age}):

The Age of the Compressor is one of the factors that can explain excessive cooling energy consumption (developments in technology in recent years have made it possible to significantly increase the efficiency of heat pumps (COP) available on the market).

The user indicates the age of the machine.

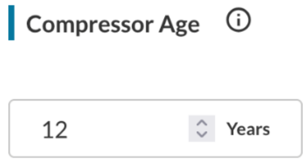


Figure 22: Interface allowing to indicate the compressor age.

INCENTIVE: “Replace the Cooling Unit”.

5.3.2 Heat-pump COP[1]:

The coefficient of performance of the cooling system is one of the criteria used to assess the efficiency of the installation.

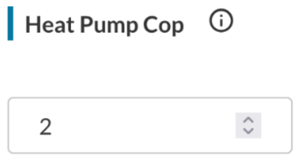


Figure 23: Interface allowing to indicate the heat-pump COP.

INCENTIVE: Depending on the user's answer, the incentive will be the same as in the previous paragraph i.e.: “Replace the Cooling Unit”

5.3.3 Temperature setpoint:

It is generally considered that when the temperature of the air in the room exceeds 27°C, there is a risk of discomfort (overheating).

In theory, the temperature at which it would therefore be desirable to switch on the air conditioning should be close to this value. However, it is often found that the temperature in some air-conditioned rooms is much lower, which leads to significant over-consumption of energy without guaranteeing thermal comfort for the occupants (who are obliged to wear a jumper or jacket to avoid "getting cold").

INCENTIVE: The user is invited to reduce the cooling set-point temperature “

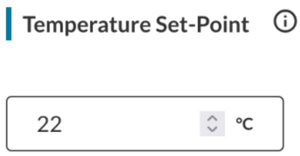


Figure 24: Interface allowing to indicate the cooling temperature set-point.

5.3.4 Night shift

Air conditioning of unoccupied premises is a major source of wasted energy.

As most cooling systems are based on air flow, the time required to satisfy user comfort is rather short, and we propose, as a first approach, not to take account of the thermal mass of the building when deciding on the switch-on and switch-off times.

[1] Coefficient of Performance

This setting must be linked to the use of the building. For example, for offices and shops, or any other use where the building is occupied only during the day, BRR suggests switching off the air conditioning at night.

The same applies to schools, for example, which are not occupied at weekends or during school holidays and therefore do not need to be cooled during these periods.

We propose to use the standard time slots in Swiss law as the basis for our recommendations in this area.

Figure 25: Interface allowing to indicate if there is a night-shift mode for cooling.

INCENTIVE: The user is invited to implement Nightshift for the cooling regulation outside the activity hours.

6 LIGHTING TOPIC

If there's one area where it's easy to reduce energy consumption, it's lighting. The recent development of new technologies (light sources & control modules) has led to a spectacular increase in energy efficiency, making it possible to cut lighting consumption by a factor of 2 or more.

As with cooling, electricity consumption linked to lighting is difficult to estimate because it is confused with other uses such as ventilation, air conditioning, household appliances, etc.

Within the framework of Building Renovation Roadmap, we propose to focus on the potential for improvement of the existing installation based on a simplified description.

6.1 Action list

In order to adapt the diagnosis to the various possible situations, we propose a series of standard messages that can be delivered according to the different uses and descriptions of the electrical lighting installation.

6.1.1 Lamps

The luminous efficacy of lamps is a key factor in energy consumption.

As a guide, the following values are representative of different electric lighting technologies:

- Incandescent: ~15 lm/W
- Halogen: ~25 lm/W
- Fluorescent: 60-100 lm/W
- Discharge lamps: 80-150 lm/W
- LEDs: 80-160 lm/W

The first action is to replace existing lamps with LED sources to reduce energy consumption. In many cases, (incandescent lamps, halogen, compact fluorescent lamps or fluorescent tubes) this can be done by keeping the existing luminaires.

INCENTIVE: The level of incentive to change lamp types is modulated according to the choice indicated by the user:

- Incandescent / Halogen: MUST
- Fluorescent: SHOULD

6.1.2 Luminaires

The efficiency of a luminaire is strongly influenced by the direction in which the light is emitted. For example, with luminaires where 100% of the light is directed towards the ceiling, it is sometimes necessary to multiply the installed power by up to 3 to obtain the same illuminance levels on the work plane or the floor level.

INCENTIVE: For certain building use, if the luminaires are exclusively indirect (100% upward light emission), we recommend replacing the luminaires to benefit from higher efficiency.

6.1.3 Switching mode

6.1.3.1 Switching OFF

It is very common for lights to remain on after users have left a room. The implementation of presence detectors to switch-off the lamps can reduce the lighting duration and therefore the associated electricity consumption.

Discharge lamps are specific in that they cannot be switched on and off instantaneously and cannot be regulated (100% of power demand). Depending on the use of the premises, they are therefore unsuitable, as they lead to very long switch-on times.

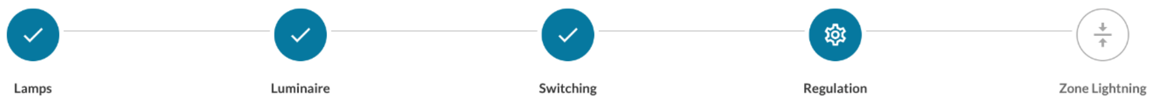
6.1.3.2 Switching-ON

Automatic lighting is a very useful function for some indoor spaces (staircases, internal corridors, toilets, etc.). On the other hand, if the spaces benefit from daylight, automatic switch-on can increase overall energy consumption, as the system may anticipate users' needs.

INCENTIVE: Depending on the room function, the user is invited to implement automated switching-OFF.

6.1.4 Regulation

6.1.4.1 Daylight sensors / Dimming



Daylight can meet part of the lighting needs and therefore limit electricity consumption linked to lighting. The principle is to use illuminance sensors to regulate the power demand according to the recommended illuminance level (depending on the activity).

To avoid disturbing users by switching on and off, it is recommended to use continuous regulation (dimming).

INCENTIVE: Depending on the room function, the user is invited to implement automated daylighting control (dimming).

6.1.4.2 Reduced lighting mode

For certain types of premises, it can be useful to have a reduced lighting mode. For example, when products are being placed in shops, or when premises are being cleaned in open-offices or industrial halls, it is not necessary to have 300 or 500 lux lighting, as is required during periods of activity. This measure is also very useful for outdoor lighting, which can be reduced during the off-peak hours of the night.

INCENTIVE: Depending on the room function, the user is invited to implement reduced mode.

6.1.5 Zone lighting

6.1.5.1 Multiple zones

In large premises, lighting requirements may vary from one area to another, either because the contribution of daylight is lower in certain places, or because not all parts of the space are occupied simultaneously. In these cases, it is useful to be able to control the luminaires independently or by groups so that they can be switched on and off or dimmed according to actual requirements.

6.1.5.2 Connected luminaires

In large premises such as shared offices, occupancy density is not always optimal. For example, sometimes only a few workplaces are occupied in the morning or at the end of the day. In this case, it is of course necessary to ensure that not all the lights are on. However, to provide a pleasant working environment for the few people present, it may be advisable to install "interconnected" luminaires.

The principle is to activate a few luminaires close together to avoid an "island" effect and to reduce luminance contrasts in the occupants' field of vision (a single lamp lit in a dark space).

INCENTIVE: Depending on the room function, the user is invited to implement zone-lighting.

6.2 BUILDING FUNCTION

The various options mentioned in the ACTION LIST do not apply to all types of building, and the issue of electric lighting cannot be dealt with in the same way for all uses.

- For example, inside dwellings, the equipment is very varied and difficult to characterize, so it is not possible to give relevant recommendations in this case.
- Or, while it may be possible to control lighting according to daylight in office buildings, this makes no sense in a shop.

  In addition, in certain types of building, the levels of requirements differ according to the different zones. For example, in an industrial building, production areas require higher illuminance levels than storage or loading areas.

We therefore propose to adapt the recommendations according to the building use and the type of zones concerned, as described in the followings.

In the following table, the various assignments are reviewed, with a list of the parameters that are analyzed.

Building function		Lamps	Luminaire	Switching mode	Regulation	Zone Lighting
INDIVIDUAL HOUSE		X	X			
COLLECTIVE HOUSING	Flats	X	X			
	Corridors & Stairs	X	X	X		
OFFICES	Individual Offices	X	X	X	X	
	Openspace Offices	X	X	X	X	X
	Meeting rooms	X	X	X		
	Corridors, Stairs & Sanitary	X	X	X		X
SCHOOLS	Classrooms	X	X	X	X	X
	Corridors, Stairs & Sanitary	X	X	X		X
SHOPS	Sales Areas	X			X*	
	Storage	X	X	X		
CATERING	Restaurant	X			X*	
	Kitchen	X	X			
MEETING PLACES	Meeting & Conference rooms	X			X*	
	Lobby	X			X*	
	Corridors, Stairs & Sanitary	X	X	X		
HOSPITALS	Bedrooms	X				
	Corridors, Stairs & Sanitary	X			X*	X
INDUSTRY	Work spaces	X	X		X*	
	Lobby	X		X		
	Corridors, Stairs & Sanitary	X	X	X		
WAREHOUSE	Storage	X	X		X*	X
	Offices	X	X	X	X	
SPORTS HALL	Sport Fields	X	X		X*	X
	Changing rooms	X	X	X		
	Corridors, Stairs & Sanitary	X	X	X		
INDOOR SWIMMING POOLS	Swimming Pool	X	X		X*	
	Changing rooms	X	X	X		
	Corridors, Stairs & Sanitary	X	X	X		

X* Reduced mode

Table 11: Action list according to the building function and the room type.

7 UNKNOWN VALUES

In order to make navigation and the description of the building more fluid, we propose to give the user the option of selecting the "Unknown" option in a certain number of cases.

This choice should allow the description of the building to continue and be considered in the analysis of the project.

7.1 Standard messages

It is possible that the user will select the "Unknown" option several times while describing the project. In order not to multiply the injunctions delivered, we propose to develop "Standard messages".

These should be sufficiently generic to be applicable to a several similar situations and to be displayed once, even if it is the result of several similar "unknown" occurrences.

For example, if the user has selected the "unknown" option several times for the composition of the walls and the position of the insulation, a single message will be displayed (cf. Message 1 below).

7.2 List of messages

The following is a list of occurrences and their implications for the final diagnosis and the verbal prompts that will result from these "unknown" choices.

- MESSAGE 1 => Building’s characteristics

You should carry out some additional investigations to gain a better understanding of the building characteristics. This would enable to better assess heat exchange through the walls as well as the heat storage capacity of the building's thermal mass.

- MESSAGE 2 => Heating system

You should call in a specialist to check the characteristics & settings of the HEATING system.

- MESSAGE 3 => Cooling system

You should call in a specialist to check the characteristics & settings of the COOLING system.

- MESSAGE 4 => Lighting system

You should call in a specialist to check the characteristics & settings of the LIGHTING system.

8 RENEWABLE ENERGY SOURCES

Reducing the use of fossil fuels, which is one of the levers for ensuring buildings sustainability, is an important challenge facing the construction sector.

It is therefore primordial to identify the potential for renewable energies when renovating buildings.

The tool developed as part of Task 4.5 Optimal RES Selector (WP4 - Proactive Optimization Functions) helps users in making data-driven decisions based on technoeconomic metrics, such as optimal investment cost and provide the evaluation results in terms of reporting and chart.

In the context of Task 8.5, the aim is to show how the case-studies of the Prelude project have been considered.

In a future version of the application, the method could be extended to other needs with specific assessments related to Renewable energy.

The logic used to look at this topic will be the same as for the other subjects describe upwards (fuzzy logic)

The main parameters for the analysis are described hereafter.

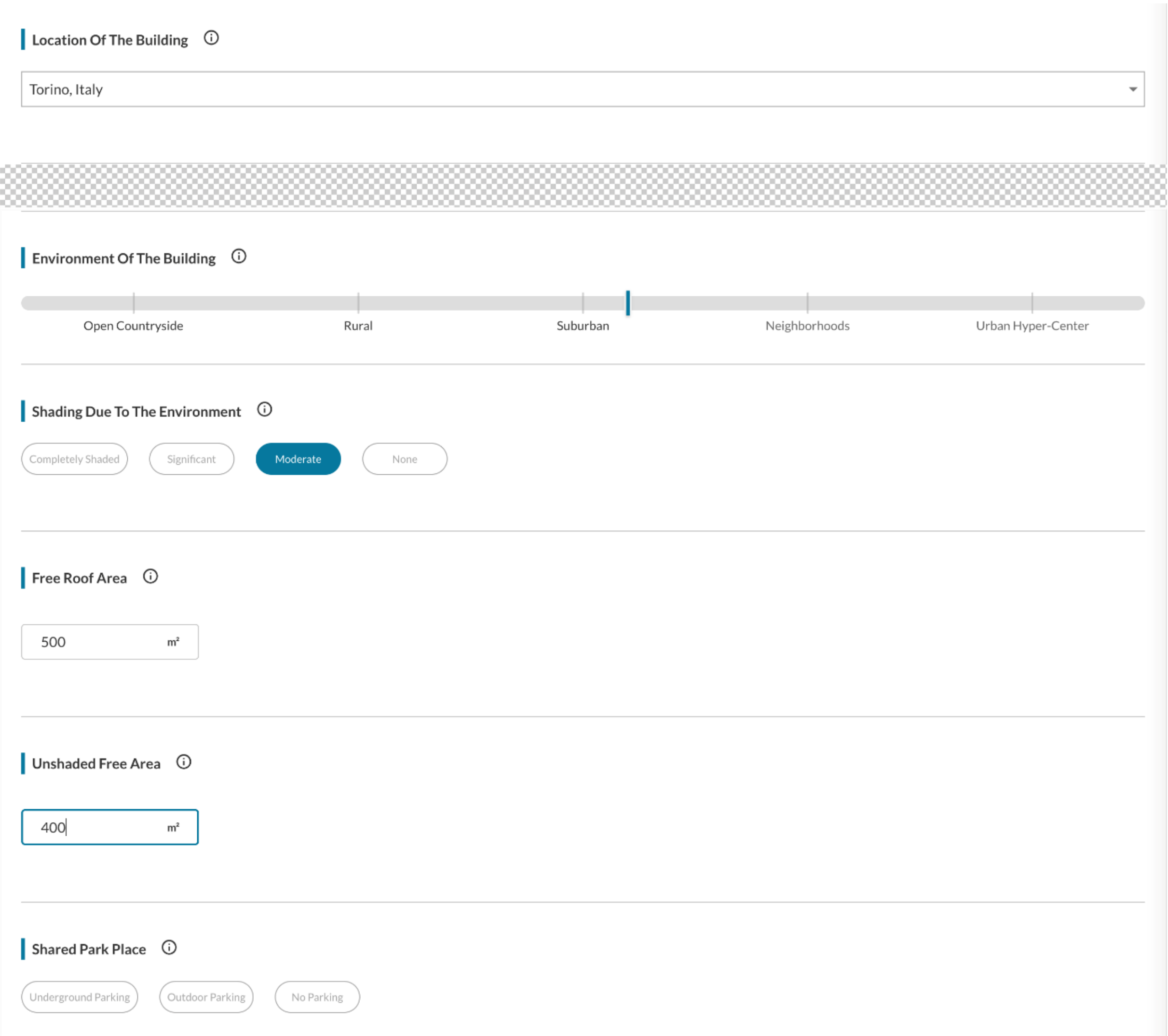


Figure 26: Overview of the parameters used to estimate the solar production potential

8.1 Climatic potential: Latitude N (°)

Sunshine is one of the key parameters for the potential production of renewable energy. By capturing the sun's rays using photovoltaic panels, we can produce electricity that can be used to power a heat pump and cover part of our heating or air-conditioning needs, or to charge batteries that can be used for any electrical needs (including charging vehicle batteries).
The heat from the sun's rays can also be used by thermal panels to cover part of the domestic hot water needs, for example.
One of the parameters used to determine the sunshine availability is the building's latitude. The higher the latitude, the shorter the daylight hours in winter and, consequently, the shorter the number of sunshine hours during this period. Conversely, the lower the latitude, the longer the number of hours of sunshine in winter.
We thus propose to use the latitude of the building to qualify the sunshine potential.

8.2 Shading due to the environment (-)

In addition to climate-related potential, the influence of environmental masks (mountains, nearby buildings, vegetation) must also be considered.

In Europe, the sun is mainly located in the southern half of the celestial vault, so the sun's potential should primarily be observed in this zone.

The user is asked to move a cursor to indicate the situation in relation to the angular height of the external environment masks. (see Figure 26).

8.3 Available roof area (A_{RA})

To refine the RES potential, it is important to know the surface that could be used to install solar panels (PV or thermal). The user is then asked to indicate the available roof area (A_{RA}, m^2). This includes the roof surface available on car parks.

We propose to relate this surface area to that of the building's energy reference area (E_{RA}), which will make it possible to eventually evaluate the potential for self-consumption.

So, the quantity used to qualify the potential for solar energy production is the Relative Available Area (R_{AA}).

$$R_{AA} = A_{RA} / E_{RA} \ (\%)$$

8.4 Incentives

Aggregation

The analysis would consist of delivering a linguistic message indicating whether a more detailed study is appropriate.

We consider the importance of obstruction masks (external environment). This parameter, if very unfavorable, is used as a sort of veto to tell the user that the installation of solar panels is inappropriate (cf. §" Unfavorable conditions" below).

Otherwise, the three parameters are aggregated to assess the strength of the message that will prompt the user to carry out a detailed study and therefore use the RES Selector developed as part of task 4.5.

The message delivered can therefore take the following forms:

- **Unfavorable conditions**

Given the characteristics of the building and its surroundings, it is **not appropriate** to consider the installation of a solar production system.

- **Moderately favorable conditions**

Given the characteristics of the building and its surroundings, you **could** carry out a detailed study of the solar potential.

- **Favorable conditions**

Given the characteristics of the building and its environment, you **should** carry out a detailed study of the solar potential.

- **Very favorable conditions**

Given the characteristics of the building and its surroundings, you **must** carry out a detailed study of the solar potential.

9 COSTS

To facilitate the decision-making process when faced with the problem of renovation, the BRR proposes to provide an estimate of the costs associated with the work recommended at the end of the diagnostic process.

To do this, we have established a link with the EPIQR+ database [11], [12].

9.1 Origin and reliability of costs

The EPIQR+ method was developed as a desktop tool between 1996 and 1998 within the framework of the European research program JOULE II [13] and with the support of the Swiss Federal Office for Education and Science [14]. It allows a precise diagnosis of the state of deterioration of an existing building and the elaboration of renovation scenarios including the different costs of the necessary works. As part of the PRELUDE project [15], [16], [17] a web version of this tool has been developed to integrate both smart technologies and energy optimization actions.

The EPIQR+ database was built based on work costs observed in Switzerland. It enables renovation work to be costed with a reliability of plus or minus 15%. It is based on several thousand renovation projects carried out over the last 25 years.

9.2 Country-specific adaptation

To adapt costs to local conditions in the various European countries, we use the Eurostat country price index [18].

9.3 Adaptation according to dimensional coefficients

The calculation of the cost of the works is adapted according to the dimensional characteristics of the building, which have been described by the user of the application, i.e.:

- Energy reference area (A_E)

The energy reference area corresponds to the gross heated floor area (cf. §04.1.1)

- Number of floors

This corresponds to the number of heated floors in the building under study.

- Envelope surface (A_{th})

This corresponds to the surfaces of facades in contact with the exterior (cf. 0)

- Proportion of glazed facade (GA)

This corresponds to the proportion of the building's facade surface that is fitted with glazing. (cf. §4.2.1.5)

TOPICS	WORKS	AVAILABLE COSTS
HEATING	Improve Facade Insulation	x
	Improve Roof Insulation	x
	Improve Ground Floor Insulation	x
	Change the Glazings	x
	Replace the boiler	x
	Reduce Heat curve slope	x
	Insulate the pipes	x
	Complete pipe insulation	x
	Implement Nightshift	x
	Bring forward Nightshift start time	x
	Delay Nightshift end time	x
	Multiple boilers	
	Thermostats (radiators)	x
COOLING	Implement shading devices	x
	Replace shading devices	x
	Motorize Shading devices	
	Automatize shading devices	x
	Increase openable area	x
	Automatize windows	
	Replace the Compressor	
	Reduce cooling set point temperature	
	Implement Nightshift	
LIGTHING	Change the luminaires	x
	Implement automated Switching-OFF	x
	Implement Daylight control (Dimming)	x
	Implement reduced mode	x
	Implement Zone-lighting	x
RENEWABLE ENERGY SOURCES	Photovoltaic panels	x

Table 12: List of actions resulting from the diagnosis and indication of available costs (x)

In the right-hand column, the boxes with an X represent actions for which the cost of the work can be estimated.

Empty boxes represent actions for which a cost estimate would require a more detailed study outside the scope of the Renovation Roadmap (for example, automating openings would require a specific analysis of various representative rooms in the building, and dynamic simulations to assess their refreshment potential).

9.4 Limits

As the description of the building does not include all the construction details, the cost calculation has certain limitations. For example, during the description process, the user is not asked about the precise type of roof (flat roof, pitched roof, ventilated roof, etc.). In this case, the cost indicated corresponds to a 'standard' cost for a housing building, and an information bubble is displayed next to the cost to inform the user.

Moreover, some actions simply cannot be costed because of the multitude of possible variations depending on the type and complexity of the building. For example, establishing a cost to automatize windows would require defining a precise project (number and location of openings, instructions associated with the assignment, schedule, etc.), which is clearly outside the scope of the application.

Table 12 summarizes the list of actions resulting from the diagnosis and indicates those whose associated costs can be assessed as part of this project.

10 RESULTS / DISPLAY OF THE ANALYSIS

Once all the building's parameters have been described, the application displays a list of recommended actions to improve the building's performance.

For each theme, the first line describes how the key parameter has been assessed (e.g. The heating consumption is 'Very High').

Next, the incentives are presented in order of importance: 'Must', 'Should', 'Could'.

To make it easier to visualize the results, each level of incentive is assigned a specific colour (red for MUST, orange for SHOULD and yellow for COULD).

Finally, for each incentive, if the cost of the associated work is available, it is displayed on the right.

Figure 27 shows an example of how the results of the BRR diagnosis are displayed with the indicative costs associated with the recommended works.

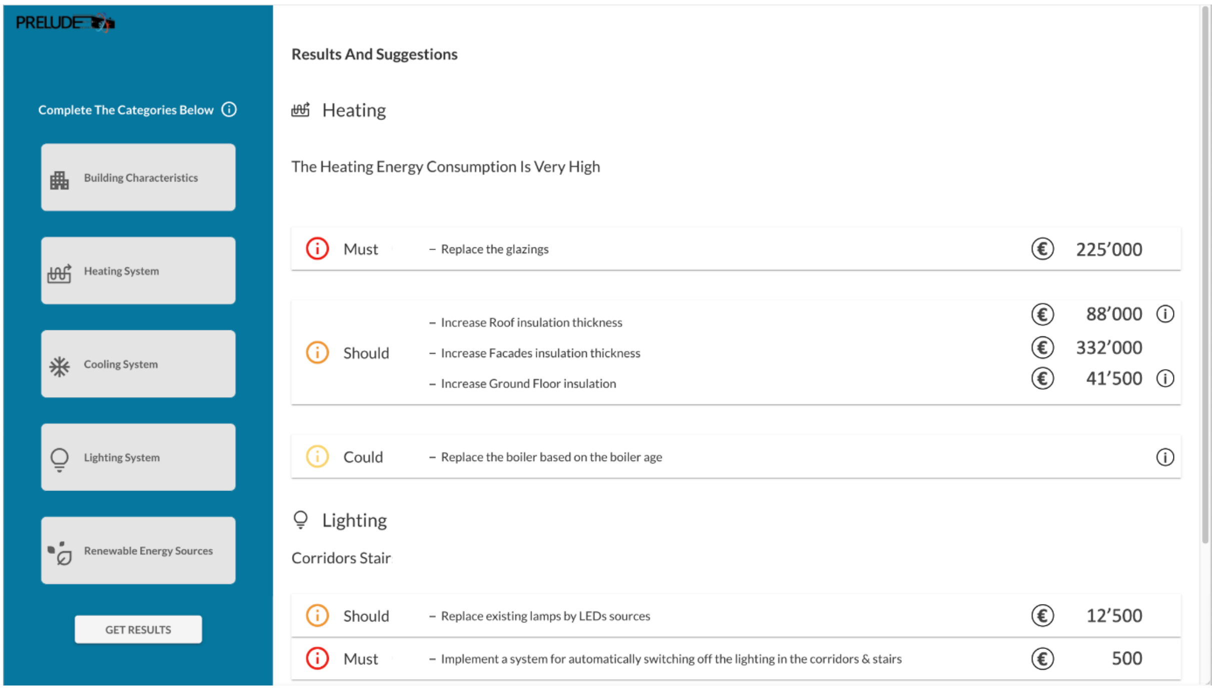


Figure 27: Example of results display, with the incentives & associated work costs.

11 FEEDBACK FROM PRELUDE PARTNERS

PRELUDE project partners were invited to use the application. The main feedback was as follows:

The questionnaire is quite long:

- The possibility of simplifying the description procedure should therefore be considered.

The questions asked on some technical subjects are sometimes very precise, which limits their use to highly qualified users.

- In future developments, it might be advisable to consider two distinct approaches: One dedicated to 'generalist' users such as architects, and another for advanced users.
- Another way of responding to this comment could be to fill in certain fields with default values, or to allow certain values to be left as 'unknown'.

These remarks could involve refining the main target of the application, even if it means restricting the analysis by tailoring it specifically to a more specific category of end user.

12 CONCLUSIONS

Buildings are very complex objects, and few people are able to master all the subjects that condition their energy and environmental performance.

The Building Renovation Roadmap as we conceived it aims to synthesize a body of disparate knowledge and to propose concrete actions.

The ideal framework in which we wish to position this tool is the moment of the realization of the energy performance certificate (EPC).

In concrete terms, the tool, which is available in the form of a web-app, should make it possible to draw up a list of prioritized actions that will help the actors involved in the renovation process to target the most decisive actions.

The information about the costs associated to the recommended actions will help prioritize the actions depending on the available budget.

We believe that the information on the costs of the work associated with the actions recommended by the application constitutes an additional asset to facilitate decision-making and could motivate users to take action to initiate renovation operations.

The first version, which is a proof of concept, will be tested with potential customers to verify its interest and to refine the shape of the tool as well as the number of parameters.

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