4RinEU

Reliable models for deep renovation

D4.2

WP4

Cost-effectiveness rating system

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Foreword

Despite the low energy performances of the European building stock, the yearly renovation rate and decisions to perform a building deep renovation is strongly affected by uncertainties in terms of costs and benefits over the life cycle of the renovation.

The project 4RinEU faces these challenges, offering technology solutions and strategies to encourage the existing building stock transformation, fostering the use of renewable energies, and providing reliable business models to support a deep renovation.

The 4RinEU project minimizes failures in design and implementation, manages different stages of the deep-renovation process - from preliminary audit up to the end-of-life - and provides information on energy, comfort, impact on users, and investment performance.

The 4RinEU deep renovation strategy is based on 3 pillars:

- *technologies* - driven by robustness - to decrease net primary energy use (60 to 70% compared to pre-renovation), allowing a reduction of life cycle costs over 30 years (15% compared to a typical renovation);
- *methodologies* - driven by usability - to support the design and implementation of the technologies, encouraging all stakeholders' involvement and ensuring a reduction of renovation time;
- *business models* - driven by reliability - to enhance the level of confidence of deep-renovation investors, increasing the EU building stock transformation rate.

4RinEU technologies, tools and procedures are expected to generate significant impacts: energy savings, reduction of renovation time, improvement of occupants IEQ conditions, optimization of RES use, acceleration of EU residential building renovation rate. This will bring a revitalization of the EU construction sectors, making renovation easier, quicker and more sustainable.

4RinEU is a project funded by the European Commission under the Horizon 2020 Programme and runs for four years from 2016 to 2020.

The 4RinEU consortium is pleased to present this report which is one of the public deliverables from the project work.

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NOTE TO THE READER:

The tool described in this deliverable is to be intended as a proof of concept. Individuals interested in testing it may request a trial version by writing to the following address: 4RinEU@eurac.edu

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Executive Summary

A barrier for building owners and investors about to embark on a deep-renovation project is often uncertainty about which technology choices may fit with their building and, in particular, with their specific preferences. For example, for a building owner concerned mainly with economic viability, a good solution may look quite different than for a building owner interested in environmental impacts or in the impact of the renovation/installation process on those living in the building.

One of the core pieces of the 4RinEU project is, hence, a multicriteria ranking tool that shall guide users early in their decision process. With a focus on improving typical energy-efficiency potential and building place / construction impact, the tool cursorily assembles and organizes indicators from five topical areas: economics, energy, environment, building site management, and comfort and internal air quality. The tool shall help to narrow down the users' initial ideas to a number of suggestions for suitable deep-renovation technology packages in line with their preferences and priorities. It gives an overall picture and comparison of results of using one or another deep renovation package, without exactly assessing their performance with respect to given goals. Hence, the multicriteria ranking tool can help investors to see advantages (e.g., energy savings or smoother construction process) and disadvantages (e.g., risks and costs) of the various deep-renovation packages. The suggested solutions may then be considered further by experts for detailed design and projecting.

In addition, the ranking tool will give advice on typical risk moments that may occur with the suggested technology packages. Information on financial instruments available for the considered geocluster may ease the decision on embarking on a deep-renovation project.

This technical note accompanies the implemented ranking-tool prototype and describes its background and usage. It also describes requirements on the underlying repository that assembles most of the information processed in the tool.

1 Introduction

The multi-criteria ranking tool represents one of the core pieces of the 4RinEU project. As an early step in the decision process, it is aimed at building owners and investors, guiding them to narrow down their initial ideas about deep renovation of their building as illustrated in Figure 1.

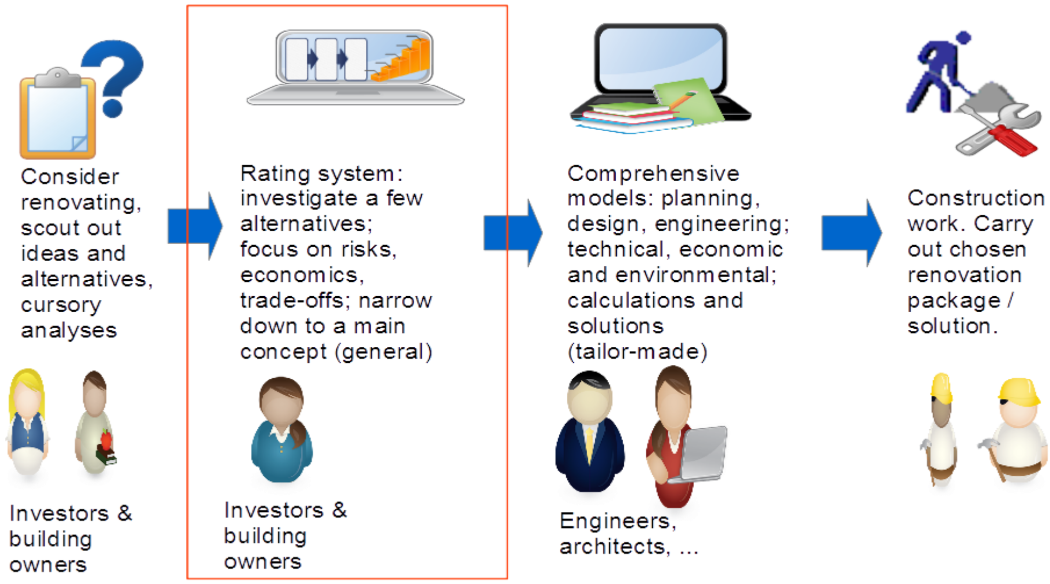

Figure 1. The 4RinEU ranking tool in the renovation process.

With focus on improving typical energy-efficiency potential and building place / construction impact, the tool cursorily assembles and organizes indicators from five topical areas:

1. economics,
2. energy,
3. environment,
4. building site management,
5. comfort and internal air quality.

Based on a selection of suitable deep renovation packages for their region and a typical building archetype, it will guide investors to a number of packages that are worth-while to detail out more, according to their specific preferences and percei-ved importance of the five topics. In addition, the tool will give advice on typical failures and risk moments that may occur with the analysed technology packages. Information on financial instruments available for the considered geocluster may ease the decision on embarking on a deep renovation project.

The multicriteria ranking tool gives an overall picture and a comparison of results of using one or another deep renovation package, without exactly assessing their performance with respect to given goals or even providing labelling. It can help investors (e.g., building owners - public or private, big real-estate or small owner) to see advantages (e.g., energy savings or smoother construction process) and disadvantages (e.g., risks and costs) of the various deep-renovation packages, set them up against each other and identify solutions with a good trade-off according to their own preferences. These suggestions may then be considered further for detailed design and projecting.

Development and testing of the tool have been done in close collaboration among 4RinEU partners SINTEF, EURAC, AIGUASOL and TRECODOME. This work has been carried out in parallel with and using insights from 4RinEU demonstration cases in three European geoclusters (Northern Europe – Norway, Continental Central Europe – Netherlands, Mediterranean – Spain) and for building archetypes typical for these regions. Early adopters in three additional European geoclusters (North-East Europe – Poland, Atlantic Zone – Ireland, Continental East Europe – Hungary) with their typical building archetypes were envisaged for hands-on testing of the tool. This approach provides valuable insight, for example, on requirements on the tool and on information availability and structure.

Within the scope of 4RinEU task 4.2, two prototype working versions ("proof of concept") of the tool have been implemented as MS Excel files. The versions are similarly structured but have a slightly different work and information flow. In both versions the user will, for each topical area, select one key performance indicator (KPI) and state how important that area/KPI appears to them. This way, the solutions can be compared more comprehensively, finding a trade-off between the five topics according to the user's specific preferences and needs.

One prototype version aims at somewhat more informed users that already have a rough idea how they may carry out a deep renovation for their building. Here, the user defines some deep-renovation packages that will then be ranked according to the user's preferences. The other prototype version does not require a preselection of renovation packages and, instead, finds the best ones (according to the user's preferences) among all packages for that geocluster and building archetype for which data exist. This guides users to renovation packages suitable for their specific needs and preferences.

It is easy to select and vary the KPIs and user preferences and then to re-run the analysis. Hence, in future work, the two prototype versions may also be combined for more comprehensive analyses. For example, a user may compare own selections of renovation packages against those the tool identifies as best ones. A user may also assess how packages identified as good in one situation would fare under varying preferences or for different KPI choices.

In the remainder of this technical note, focus will be only on the second prototype implementation finding a set of best-performing packages without requiring a pre-definition step. That prototype version is considered the main project deliverable.

Task 4.2 in the 4RinEU project is not concerned with creating, collecting or storing actual values for the model input parameters or indicators; this has been taken care of by other project tasks, in particular task 2.1 (simulations and repository of performance indicators), task 3.3 (deep-renovation package descriptions), task 4.1 (risk elements), task 4.5 (available financial instruments) as shown in Figure 2.

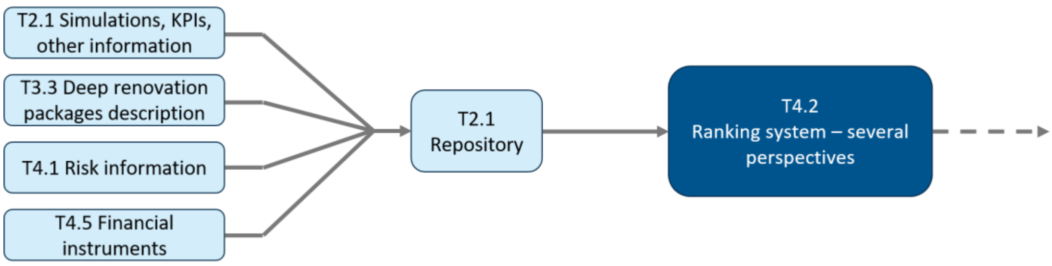

Figure 2. Main blocks of information to be combined in the ranking system.

This technical note accompanies the ranking-tool prototype and gives a closer description of its background and usage. Section 2 describes information serving as input to the tool, in particular information pre-loaded by the 4RinEU research team into the repository file. It also comments on output information from the ranking tool. Section 3 focuses on implementation details and Section 4 demonstrates the tool's functioning using a demo case example. Section 0 summarizes. Finally, the appendix contains a list of all considered performance indicators as stored in the repository and notes on the evaluation of cost and time data used in the repository.

2 Input and output information

The ranking tool relies on various types of input and, thus, combines information across many tasks of the 4RinEU project (see Figure 3. 4RinEU work packages and tasks delivering information to the ranking system.). Main elements are:

- geocluster-typical building archetypes and their properties,
- description of deep-renovation packages in technical terms,
- performance indicators (KPIs) and similar parameters
- risks for failures and damages at various stages in the process,
- financial instruments potentially applicable for the deep renovation project.

All information is stored in a structured way in an MS Excel file (a repository) from which the ranking tool extracts information as needed. This chapter describes both details of this data and of the repository.

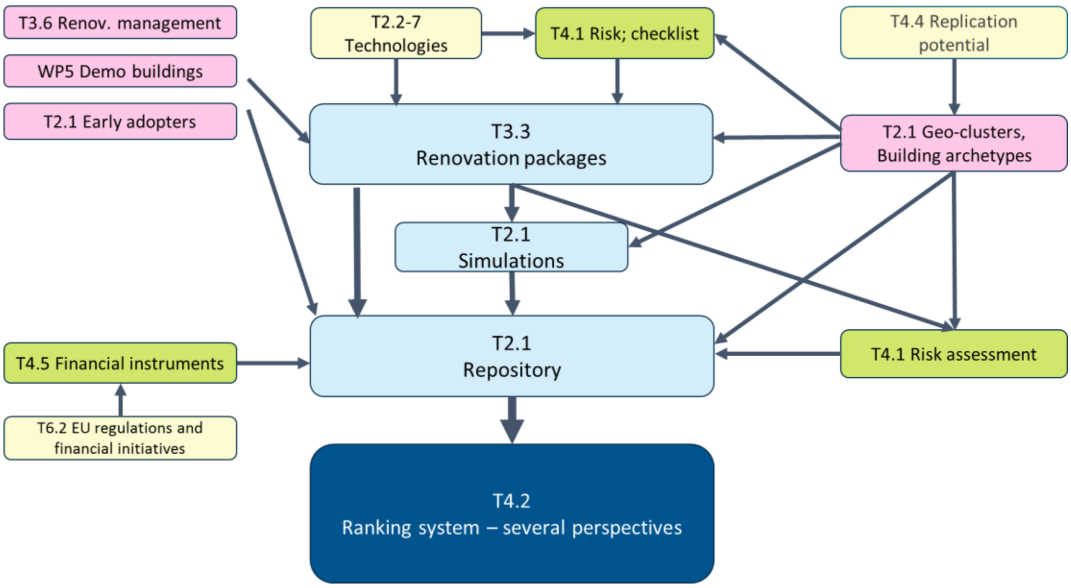

Figure 3. 4RinEU work packages and tasks delivering information to the ranking system.

2.1 Information serving as input to the ranking tool

To provide useful guidance, the ranking tool relies on a wealth of general information gathered outside the tool in the form of a repository. This information collection has been carried out by the 4RinEU research team in collaboration with the technical project partners. In the following paragraphs, we describe this information in more detail.

2.1.1 Geoclusters, building archetypes, renovation packages

Geoclusters, building archetypes and renovation packages form the basis for structuring the information in the repository and, hence, for retrieving this information and displaying it in the ranking tool.

The tool has been developed in parallel with and using insights from the 4RinEU demonstration cases in three European *geoclusters*:

- Geocluster Northern Europe (reference country Norway)
- Geocluster Continental Central Europe (reference country Netherlands)
- Geocluster Mediterranean (reference country Spain)

Further hands-on testing will be done by early adopters in three additional European geoclusters with their respective building archetypes:

- Geocluster North-East Europe (reference country Poland)
- Geocluster Atlantic zone (reference country Ireland)
- Geocluster Continental East Europe (reference country Hungary)

For each geocluster four *building archetypes* were defined: single- and multi-family house, apartment block, and terrace house. A brief geocluster-specific description of the building archetypes is included in the repository, to be loaded into the tool for the user to ascertain an appropriate selection. This information is provided by Task 2.1.

A *deep-renovation package* is described by a combination of a particular choice (or logical selection) of technology options in eight categories of components: energy hub (the 4RinEU hydronic unit to optimize the energy distribution system), heating generator, solar collector, façade system, windows/glazing, mechanical ventilation, ceiling fan, PV panels. These categories have been defined such as to apply for all geoclusters although their individual interpretation may vary from geocluster to geocluster. The choices are binary, which makes it possible to calculate unique ID numbers for each deep-renovation package purely based on the choices in all categories. In addition to these deep-renovation packages, also a no (or pre-) renovation situation and a standard renovation are defined in terms of technology options and given according ID numbers. Task 3.3 provides descriptions of the single technology choices and, hence, renovation packages as unique combinations of selections for these choices.

2.1.2 Performance indicators and similar information

Values for key indicators represent the most important body of information that is stored in the repository and retrieved depending on the chosen geocluster, building archetype, deep-renovation packages. This data consists of

- "as is" data (real or "near real" ones, estimates, ...) such as costs collected from demo cases, technology providers, national partners, literature
- simulated data, e.g., energy produced, are gained from technical simulations performed by EURAC and further project partners for the considered building archetypes and technical solutions
- calculated data such as net present value (NPV) are computed based on other provided information, either real/realistic or simulated data.

The 4RinEU project partners agreed on a list of 27 key performance indicators (KPIs), grouped into five topics areas: energy, environment, comfort and internal air quality (IAQ), economic issues, building site management. This contains the indicators deemed the most important and most informative for the user at this stage. Appendix A shows the full list of these KPIs and brief explanations. Within the 4RinEU project, the main responsibility for assembling the KPI values for all geoclusters and building archetypes has been with Task 2.1.

All this information needs to be collected – and kept as up to date as possible – in the repository for each deep-renovation package, each building archetype and each geocluster. Hence, a balance needs to be struck between level of detail (number of considered KPIs) and manageability (need to collect/update values). For example, with a set-up of seven technology categories with three choices in two categories and two choices in the other five, 288 different technology combinations are to be considered. In addition, there are six categories for user specifications, also here two with three choices and two choices for the remainder. This yields 41.472 sets of KPI values for deep-renovation packages to be created, in total 1.036.800 KPI values for each geocluster and building archetype. Adding just one new technology category with two choices doubles the number of possible deep-renovation packages to 576, and thus also the number of KPI values to be generated to 2.073.600 per geocluster and building archetype.

2.1.3 Risk management

Deliverable D4.1 "Risk assessment guidance" of the 4RinEU project discusses risk management for deep-renovation projects in a broader context. For the ranking tool implementation, we focus on some technical risks directly related to the technologies in the deep-renovation packages. In particular, we mention risks that may occur with a prefabricated multifunctional façade, a comfort ceiling fan, a plug and play energy hub, and PV cells and solar collectors. Information on each element has been gathered from the report D4.1 and stored in the repository in a structured manner. This comprises examples of typical risk or failures that may occur, potential outcomes (damages), and ways for remediation or, at least, mitigation. The information contains also general advice on issues to pay attention to for the concerned technology. This way, the user is directed to points that they should be aware of and seek further information on when planning their deep-renovation project in more detail. The main responsibility for providing input on risk management is with task 4.1.

While a more quantitative risk evaluation of each deep-renovation package would be desirable such that risk may be included directly in the ranking of packages, such an approach is far beyond the scope of the 4RinEU project. This is not at least since it requires many details to be gathered such as probability of the risk, costs of potential damages (and their repair) and costs of remediation or mitigation. Typically, such details are not readily available – especially not for innovative and complex technologies that are not commonplace – and exact values have little transfer value to other deep-renovation projects, even in the same geocluster and for the same building archetype.

2.1.4 Financial instruments

How to finance deep-renovation projects is an important issue to be scouted out early in the process as it may limit (but also extend) the range of relevant technology choices. There exists a number of schemes for, e.g., energy-efficiency investment in buildings with a varying degree of maturity and applicability for different kinds of deep-renovation projects, ownership or building types. Among the more mature instruments available we can find dedicated credit lines, energy-performance contracting, risk-sharing contracts or direct investments. There are also some emerging instruments that may be suitable in the context of deep renovation such as on-bill repayments, energy-efficiency investments funds, energy-service agreements or green bonds. Deliverable D4.5 "Regionally applicable financial instruments" of the 4RinEU project provides more comprehensive information on such instruments for each of the six considered geoclusters.

Often, the applicability of these financial schemes appears to depend on, for example, ownership and similar characteristics (commercial, public, rental, owner-occupied building) that are not necessarily reflected in the building archetypes defined for the technological characterisation in the 4RinEU project. In the Norwegian case, Boligbygg as a municipal corporation has no option to apply for instruments such as green loans for climate- or energy-focused investments. On the other hand, they may seek to include such investments into their annual budgets.

As evident from deliverable D4.5, many of the mentioned financial instruments are not specific to certain technology choices but mention broader categories such as "energy-ambitious major renovation process" or require certain targets to be met. A reason for this may be the fast pace of technology development and the large variety of suitable technology choices. Design and applicability conditions of the single schemes change rather often and new schemes are devised for specific targets and target groups (such as building-related loans for owner-occupiers in the Netherlands as mentioned in section 4.1 of deliverable D4.5), and actuality of the values and other information stored in the repository is difficult to guarantee. Moreover, the structure and functionality of these instruments varies widely for the different geoclusters, building archetypes and renovation package specifics, which makes it challenging to find a common way to incorporate them into economy calculations within the scope of the ranking tool.

For the 4RinEU repository and the ranking tool, this means that a description of financial instruments applicable for the single renovation packages is qualitative and general.[1] For each geocluster, major kinds of instruments or relevant institutions are listed, together with some typical examples of such instruments. This shall help pointing the user into the right direction, encouraging them to seek more specific and up-to-date information and advice there. The main responsibility for providing this input lies with task 4.5.

2.2 Repository

The repository contains all aforementioned information from which the ranking tool can select. For the prototype of the ranking tool, it is implemented as a collection of MS Excel files with several dedicated worksheets. This repository can be

[1] Including effects of these instruments on economic KPIs requires good information on the renovation packages and the evaluation criteria for the instruments. Collecting sufficient information (and keeping it up to date) on the latter is far beyond the scope and resources of 4RinEU. Also, this need for detailed information does not fit with the intended use of the ranking tool at an early stage in the decision process, as a cursory tool.

envisioned to serve as a source of information also for other 4RinEU deliverables (and beyond the project), not at least as it collects important insights gained in various work packages. Hence, it contains more information than used by the ranking tool. With increasing number of included KPIs and other data, reaction time or processing speed may become an issue. Then, it may be considered to construct a lighter version of the repository for sole use by the ranking tool, e.g., extracting only necessary worksheets. For the current proof-of-concept implementation this was not done. However, separate repository files were created for each combination of geocluster *GC* and building archetype *BA*. For the demo geoclusters used for repository and tool development, *GC* is to be replaced by "NL", "NO" or "ES". Building archetypes *BA* are, e.g., "SFH" for single family houses or "MFH" for multi-family houses. This section describes the worksheets and the structure required to deliver input to the ranking tool.

2.2.1 Worksheet "Building features_existing"

The sheet gives details for the concerned building archetype in the considered geocluster. It mentions the 4RinEU project-internal code (for easier relation to the simulations setup), building size class (SFH, MFH), construction period, reference floor area, and a number of further features such as building volume, number of apartments, or surface area and U value of windows, walls, roof and basement.

The ranking tool expects the geocluster to be in column A, internal code in column B, building class in column C, construction period in column D, etc. The first two rows in the sheet are assumed to be headers.

1	**Geocluster**	**Building 4RinEU Code**	Building features - existing situation (as implemented in the building simulations)														
2			Building Size Class:	Construction Period:	Reference Floor Area (heated area):	Volume [m3]	Number of apartments	U window glazing [W/(m2K)]	U window frame [W/(m2K)]	Uwall [W/(m2 K)]	Envelope surface [m2]	Uroof [W/(m2 K)]	Surface roof [m2]	U basement [W/(m2 K)]	Surface basement [m2]	Current heating boiler	Total Efficiency of the current heating system
3	NO	G1_NO_SFH_02	SFH	1955-1975	225	461	1	2,82	2,1	0,444	198	0,228	82,5	2,229	75	Traditional	67 %
4																	
5																	

2.2.2 Worksheets "*Dist*"

These worksheets contain all relevant information on the single (deep) renovation packages for the selected geocluster and building archetype. Due to the large number of variants of deep renovation packages, separate sheets have been created for three categories of distance *Dist* of the considered building to the place where the façade is prefabricated, "50 km" for distances up to 50 km, "50 km – 250 km" for distances between 50 km and 250 km, and "250 km" for larger distances. Each sheet holds information gathered for 13.824 deep renovation packages.

The sheets contain in row 2 the codes (ID numbers) of all renovation packages. In rows 11 to 20, descriptions of the single technology choices are listed that, in combination, define the deep-renovation packages: façade, windows, roof insulation, ground floor insulation, shading system, ceiling fan, cooling system, PV system, heating generation, and mechanical ventilation system. This results in 288 different combinations. The options to choose between for each technology may vary and be worded differently in the single geoclusters. Rows 23 to 28 show the choices for user specifications for the renovation project: cladding type, mounting system, removal of old façade cladding, anchoring type for the prefabricated façade, roof insulation type, and distance from the prefabricated-façade production site. Combined with the 288 variants of the deep renovation packages, this yields 13.824 different parameter sets per sheet. In rows 34 to 62, parameters defining the renovation packages are detailed out, while rows 65 to 108 contain more details on costs (not read in by the tool prototype). Finally, rows 115 to 139 list collected, simulated or calculated values for the KPIs considered in the tool. Values for the energy topic are read in from row 115 on, for environment from row 129 on, for comfort and air quality from row 131 on, for economics from row 137 on, and for building site management in row 139. Rows 140 to 152 mention more KPIs currently not read in by the tool.

The first sheet of a set, with *Dist* set to "50 km", contains information on the no/pre-renovation and standard-renovation processes as well, in columns C and D, while details on the 13.824 deep-renovation package variants start in column E. In the other two sheets of a set (with *Dist* being "50 km – 250 km" and "250 km", respectively), only deep-renovation packages are described, starting in column C.

	A	B	C	D	E	F
1		**Sim. N.**	G_0	G_0_STD_RENO	G1	G2
2		Code	SFH_NO_RP0	SFH_NO_RP0_STD_RENO	SFH_NO_RP1	SFH_NO_RP2
3						
4		**Geocluster**				
5		Building type	singlefamily	singlefamily	singlefamily	singlefamily
6		Country	Norway	Norway	Norway	Norway
7		Climate	Oslo	Oslo	Oslo	Oslo
8		Intervention status	PRE-RETROFIT	STANDARD RENOVATION	POST-RETROFIT	POST-RETROFIT
9						
10		**TRNSYS Calculations**				
11	1	Facade	PRE-RETROFIT EXTERNAL WALL	ROFIT GOOD PREFABRICATED FAC	T-RETROFIT GOOD PREFABRICATED FACADE (U-	POST-RETROFIT GOOD PREFABRICATED FACADE (U-0.2
12	2	Window	PRE-RETROFIT WINDOW	OST-RETROFIT low E double glazin	POST-RETROFIT low E double glazing	POST-RETROFIT low E double glazing
13	3	Roof insulation	PRE-RETROFIT ROOF	No	POST-RETROFIT ROOF INSULATION	POST-RETROFIT ROOF INSULATION
14	4	Ground floor insulation	PRE-RETROFIT GROUNDFLOOR	No	POST-RETROFIT GROUNDFLOOR INSULATION	POST-RETROFIT GROUNDFLOOR INSULATION
15	5	Shading system	No	No	No	Yes
16	6	Ceiling fan	No	No	No	No
17	7	Cooling system	No	No	No	No
18	8	PV system	No	No	No	No
19	9	Heating generation	raditional heating system - gas boil	raditional heating system - gas boil	Traditional heating system - gas boiler	Traditional heating system - gas boiler
20	10	Mechanical ventilation system	No mechanical ventilation	No mechanical ventilation	No mechanical ventilation	No mechanical ventilation
21						
22		**User Preferences**				
23	11	Cladding type	-	-	ventilated facade with timber cladding	ventilated facade with timber cladding
24	12	Mounting system	-	-	Lifting platform + crane	Lifting platform + crane
25	13	Removal of old facade cladding	-	-	no	no
26	14	Anchoring type for prefabricated facade	-	-	Facade mounted	Facade mounted
27	15	Roof insulation type	-	-	Normal insulation	Normal insulation
28	16	Distance from building site	-	-	≤ 50 km	≤ 50 km
29						1
30						G6913
31						
32						
33		**Detailed parameters**				
34	1	**Facade**				
35		U-value	U-value-0.44 W/m2K	U-value-0.2 W/m2K	U-value-0.2 W/m2K	U-value-0.2 W/m2K
36	2	**Window**				
37		Glazing U-value	U-value-2.82 W/m2K	U-value-1.1 W/m2K	U-value-1.1 W/m2K	U-value-1.1 W/m2K
38		Frame U-value	U-value-2.1 W/m2K	U-value-1.4 W/m2K	U-value-1.4 W/m2K	U-value-1.4 W/m2K
39		g-value	0,64	0,62	0,62	0,62
40	3	**Roof insulation**				
41		U-value	U-value-0.23 W/m2K	U-value-0.23 W/m2K	U-value-0.17 W/m2K	U-value-0.17 W/m2K
42	4	**Ground floor insulation**				
43		U-value	U-value-2.29 W/m2K	U-value-2.29 W/m2K	U-value-0.31 W/m2K	U-value-0.31 W/m2K
44	5	**Shading system**				
45		Control strategy	Shading system absent	Shading system absent	Shading system absent	control strategy based on internal temperature, external temperature an
46	6	**Ceiling fan**				
47		Control strategy	Ceiling fan absent	Ceiling fan absent	Ceiling fan absent	Ceiling fan absent
48	7	**Cooling system**				
49		Presence	Cooling system absent	Cooling system absent	Cooling system absent	Cooling system absent
50		Set point	Cooling system absent	Cooling system absent	Cooling system absent	Cooling system absent
51	8	**PV system**				
52		Presence	PV system absent	PV system absent	PV system absent	PV system absent
53		Reference Peak Power kW_peak	0	0	0	0
54		Placement			-	-
55	9	**Heating generation**				
56		Set point	20°C	20°C	20°C	20°C
57		Heating system	raditional heating system - gas boil	raditional heating system - gas boil	Traditional heating system - gas boiler	Traditional heating system - gas boiler
58		Total efficiency / COP	67%	67%	90%	90%
59	10	**Mechanical ventilation system**				
60		Ventilation type	No mechanical ventilation	No mechanical ventilation	No mechanical ventilation	No mechanical ventilation
61		Single machine air flow provided	-	-	-	-
62		Heat recovery efficency	-	-	-	-
63						
64						
65		**Detailed parameters cost & time on building site**				
66	1	**Facade**				
67		Overall cost for building archetype [€]	-	36977,1	29256,48	29256,48
68	2	**Window**				
69		Overall cost for building archetype [€]	-	12155,96	2990,00	2990,00

2.2.3 Worksheet "Risk"

The worksheet lists examples of issues to be considered for risk management for the technology categories Prefabricated multifunctional façade, Comfort ceiling fan, plug & play energy hub, and RES (PV panels and solar collectors). These examples are described in terms of the event (or its cause), potential damaging outcome, possible countermeasures to avoid the event and/or ensuing damage, and KPIs that may be affected. The worksheet lists also some general advice to be considered when choosing these technologies for a deep-renovation project.

In the prototype implementation, the sheet contains six examples for risk management of the façade solution (columns B to E), five for the ceiling fan (columns F to I), six for the energy hub (columns J to M), and six for the RES technologies (columns N to Q), located in rows 2 to 8. It also includes six general-advice items for the façade, four for the ceiling fan, three for the energy hub, and one for the RES technologies, located in rows 10 to 16.

Additionally, the worksheet contains three examples for risk-management issues and seven suggestions for general advice when using the EarlyReno tool (columns

R to U). These have, however, not been connected to the ranking tool as EarlyReno is not considered a technology category for defining deep-renovation packages.

	A	B	C	D	E	F	G	H	I
1	Technology	Prefab multifunctional facade				Energy hub			
2	Risk managemer	Event / cause	Possible outcome	Countermeasure	Affected KPI	Event / cause	Possible outcome	Countermeasure	Affected KPI
3		Element not fitting to building	Compromized stability or function	QC of scanning / measuring	LCC	DHW too hot	Scalding	Limit temperatures at "end point"	
4		Hidden moisture or moisture damage	Decay, mould, other damage	Thorough survey	LCC, Investment cost	Legionella spread	Serious infection		
5		Inadequate design process	Low moisture safety; lacking fire safety; air leakages	Integrated planning process, including manufacturer and all special planners.	Heating demand, cooling demand, LCC	Component damages	Leakage, malfunction	Choose high-quality component (plate exchanger SWEP, circulation pump); follow periodic maintenance scheme from producer; include alarm function in installation	LCC
6		Inadequate planning / site management	Errors in mounting of elements	Make and follow detailed plan for delivery, storage and	Heating demand, cooling demand, LCC	Flow too low	Insufficient heating	Predictable alarm related to sensors value	pmv (heating period)
7		Failure to store elements in dry and protected conditions	Moisture damage, mechanical damage		LCC	Network problems	Unpredictable function	Use standard and robust protocol	pmv (heating period)
8		Element damaged or delayed in transport		Prepare for provisional coverage		Temperature of the source not normal	Unpredictable / suboptimal function	Give specific alarm	pmv (heating period)
9	General advice to building owners								
10		Compare deep renovation with demolition and new building. Give attention to the timing of the deep renovation				Detailed management of energy loads and sources enables matching loads with the best (cheapest) available energy source, mapping demand and distributing costs			
11		An integrated planning process is recommended - early inclusion of element manufacturer and builder in the planning process will allow their experience to be exploited and reducing risk of unnecessary redesign				Design piping and size of pipes to avoid lack of flow			
12		Use appropriate collaboration contracts where possible				Pay attention to communication (bus) and electrical connection as well as hydronic system			
13		Be sure to include the behaviour of the complete building in the planning process							
14		Be consequent in the remediation of thermal bridges							
15		For the building process, the best result will be achieved without inhabitants in place							
16		If integration of PV or ST in the facade elements is planned: see section 2.11 in Deliverable D4.1 of the 4RinEU project							
17									
18									
19									

	J	K	L	M	N	O	P
1	Ceiling fan				PV & Solar thermal		
2	Event / cause	Possible outcome	Countermeasure	Affected KPI	Event / cause	Possible outcome	Cour
3	Fan blade hitting person	Injury (mostly head)	Ensure min. 2.3 m floor-to-blade distance		Wrong installation of the modules		Use o tool; s for the
4	Unstable installation	Injury	Follow installation instruction. For fan diameter > 1.2 m thorough structural analysis necessary		Wrong sizing of the PV/ST field and of the storage tank	Lower economic value of installation	Use o
5	To low airspeed in occupied zone	Low thermal comfort	Locate fans as a function of the most likely configuration of the furniture (e.g., sofas, tables); ensure > 0.25 m free space between blades and ceiling	Thermal comfort (cooling mo	Inaccurate load profile	Lower economic value of installation	Qualit input
6	Increased room air temperature	Low thermal comfort	Increase roof insulation	Thermal comfort (cooling mo	Unevaluated shadows	Less power and value than expected	Use E detail
7	Noise from fan motor or blades	Annoyance	Select high-quality products, ensure proper installation		Storms compromising the PV performances		
8					ST plants not connected with the	Lower utilizable heating power	
9							
10	Choose a product that is certified and designed for the specific type of building				Use Early Reno tool before design choices with higl		
11	Choose the best location(s)						
12	Carefully evaluate the floor-to-blades distance, and the ceiling temperature during the hot season						
13	Complete the installation according to seller's instructions						
14							
15							
16							
17							
18							
19							

Building features_existing | Risk | Financial | 50 km | 50 km - 250 km | 250 km

2.2.4 Worksheet "Financial"

This worksheet lists relevant financial instruments (or institutions providing such instruments) for all considered geoclusters, together with some explanations, sources for further information on the instrument and further comments such as applicability only for certain building-owner types. As this information is not very specific (e.g., in general not related to building archetype or deep-renovation package), the data for all geoclusters are put into one single sheet.

The first row of this worksheet contains the abbreviations for the geoclusters. The information for each geocluster is organized in four columns, with titles in row 2 "Institution/ instrument", "Explanation/example", "Applicable technology (of those mentioned in DRP description)", and "Comment". The single entries start in row 3.

	A	B	C	D	E	F	G	H	I
1	Geocluster	NO	Last update: April 2020			NL	Last update: April 2020		
2		Institution/ instrument	Explanation /example	Applicable technology (of those mentioned in DRP description)	Comment	Institution/instrument	Explanation/example	Applicable technology (of those mentioned in DRP description)	Comment
3		Enova			https://www.enova.no	Energy performance compensation			
4		Husbanken			https://husbanken.no	Housing valuation system			In Dutch: Woning Waardering
5		Kommunalbanken				Service fee	Charging for sustainability investments via service fee		
6		Municipality			Specific programmes in	SDE subsidy		PV	Only for non-private owners
7						ISDE subsidy for renewable energy technologies		Solar collector	
8						Subsidies for energy advice, investment in insulation and energy-efficiency measures			For associations of apartment users
9									
10									
11									
12									
13									
14									

	J	K	L	M	N
1	ES	Last update: April 2020			PL
2	Institution/ instrument	Explanation/ example	Applicable technology (of those mentioned in DRP description)	Comment	Institution/ instrument
3	PAREER-II	Subsidies, loans		National program for financing energy renovation in buildings	
4	FEDER-POPE 2014-2020			Only for public owners	
5	Triodos bank	Dedicated credit lines		Private owners; https://www.triodos.es/es/particulares/ahorro/hipoteca-triodos/	
6	SC Energy Efficiency Fund (SUMA			Focus on innovation sector; https://sumacapital.com	
7	Energy service contra	Providers: Geinsema, Prodiel, Enertika etc.		http://www.geinsema.com; http://prodiel.com; http://www.enertika.com	
8	KIPLAI	Operating lease		http://www.kiplai.com	
9	Reduced VAT			For all retrofitting activities	
10					
11					
12					
13					
14					

2.3 Output information from the tool

Immediate output from the tool is a set of suggestions for the user on which deep-renovation packages may be the most suitable to explore further, based on the user's preferences and evaluation criteria. In addition, the tool provides information on technical features of the suggested packages, establishing a base for the user to proceed with more detailed planning for exactly their building.

The user can get an overview over the performance of the single suggested packages by way of a table containing the values of five chosen indicators and a combined score. A graphical presentation of these values helps to grasp this comparison visually.[2] This way, the user can compare the suggested packages among each other as well as with the current (pre-renovation) state and with a standard renovation. In particular the latter may help the user to decide whether embarking on a deep-renovation project may be worth-while for them or not. Seeing the variance in the single suggestions' KPIs can also give an indication on topics where a deep-renovation project will have a high impact on, e.g., energy savings no matter which technical solution will be chosen. Investigating suggested technology choices for the single packages may indicate particularly well-suited choices.

It is easy to vary the choice of investigated KPIs and user prioritization for the single topics of interest and to re-run the analysis. Hence, the user may try various configurations and find out whether there will be types of deep-renovation packages that are less sensitive (more robust) against changes in user preferences (e.g., are among suggested packages under different preferences). These packages may then be most suitable for further exploration and detailed planning. The user may also examine the various suggestions under different preferences with respect to technical features or other properties that may be common for many of the suggested packages.

It is also advisable to check out the provided information on potential damages and other risks and on potentially applicable financial support. While some of this information may ease the deep-renovation project, other information may uncover potential challenges to it, e.g., indications that a preferable façade solution may be infeasible with the user's exact building type and style.

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[2] The prototype implementation contains a simple visualization through bar charts. However, during the project also other solutions conveying more information have been discussed such as visual presentations of, e.g., building details (insulation thickness or the like) or a kind of scatter plot describing the location of the selected KPIs within the range of the respective KPIs for all deep-renovation packages. One may also set up two or more aspects against each other as demonstrated in the FP7 EU project Cileccta (https://www.researchgate.net/publication/280307908_Sustainability_within_the_Construction_Sector_CILECCTA_-_Life_Cycle_Costing_and_Assessment).

In sum, the tool will provide the user with suggestions for technical solutions for suitable deep-renovation packages that they can take further, utilizing the expertise of engineers and architects as well as comprehensive technical calculations to develop detailed project plans for a deep renovation tailored to the user's situation, actual building and technical requirements.

3 Proof-of-concept implementation of the ranking tool

This chapter describes the proof-of-concept implementation of the ranking tool, focusing on the workflow when using the tool and details of the single worksheets. It also provides details on the calculation of the score used to rank the deep-renovation packages. Chapter 4 demonstrates the usage of the tool step by step using a realistic example.

3.1 Information to be provided by user

The user or consultant is assumed to have information on the considered case including suitable geocluster and building archetype. They have also an idea about their perceived importance/prioritization of the five key topical areas (economy, energy, construction process, environment and comfort) and about which KPIs are important for them to consider within each topic.

3.2 Work flow

As indicated in the introduction, while two working prototypes of the tool were implemented during the 4RinEU project, this technical note describes only one version. That version is aimed at users having no ideas yet about technology choices they may want to explore further. In other words, the ranking tool is supposed to find the best performing packages according to given user preferences.

An analysis with the tool starts with the user selecting a suitable geocluster and building archetype. The user states also characteristics for their specific renovation project. For each of the five topics, a KPI is chosen and a priority defined, indicating how important the user perceives that topic is for their evaluation. Then, the tool retrieves these indicator values and other relevant information from the repository for all deep-renovation packages about which KPIs have been stored for the considered geocluster and building archetype. Using the user's priority/weight factors and the values of the selected KPIs, the tool calculates a score for each package as described in section 3.4 and finds the five deep-renovation packages with the best scores. These scores and the selected KPIs for these packages are displayed in a table on the "Start" sheet, together with values for standard-renovation and pre-

/no-renovation solutions. The single solutions' performance is also presented graphically. Detailed information about these packages – indicator values, applicable financial instruments, relevant risk elements – is collected from the repository for the identified packages and displayed in the corresponding dedicated sheets "Result details", "Risk management" and "Financial instruments". Figure 4 illustrates these steps.

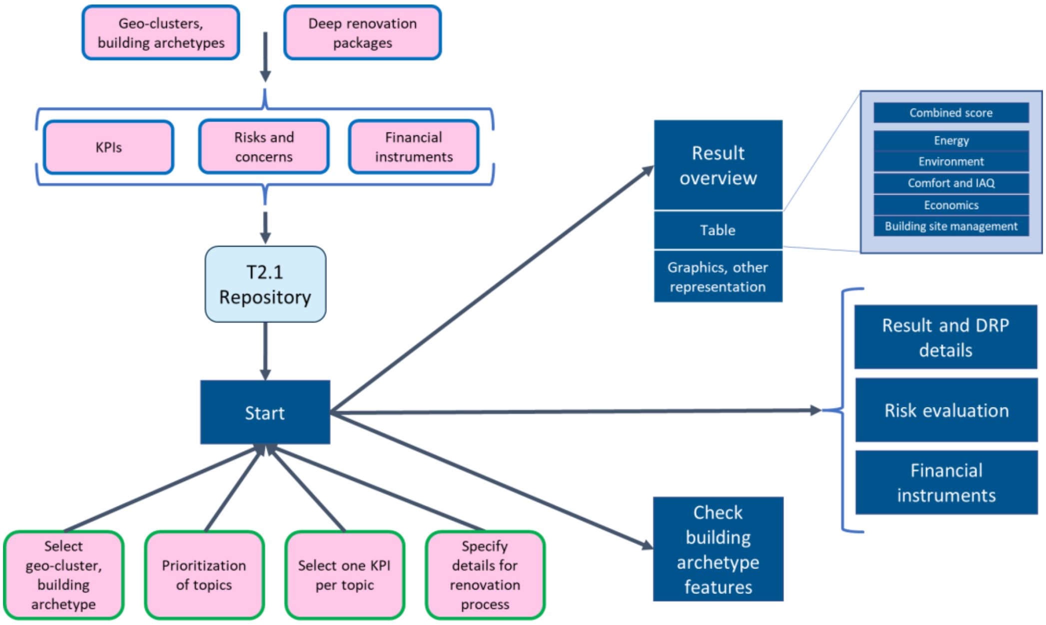

Figure 4. Detailed information flow, work steps and relations between the tool's worksheets. Blue-lined boxes indicate preparatory steps by the 4RinEU team to populate the repository and tool, green-lined boxes show user-provided information and dark blue boxes denote tool worksheets and information contained therein.

3.3 Worksheets in the ranking tool

The Excel file contains the following worksheets: "About", "Start", "Building features", "Result details", "Risk management", "Financial instruments", "KPIs and descriptions", and an auxiliary sheet "InputToTool2(Hidden)", hidden to the user. These sheets are described in more detail below. For the sake of comparison, the results sheets display not only values for the deep-renovation packages but also corresponding values for the do-nothing/pre-renovation and standard-renovation situations where these exist.

3.3.1 Worksheet "About"

This sheet contains a brief explanation of the tool implementation as deliverable of the 4RinEU project as well as a reference to this technical note.

3.3.2 Worksheet "Start"

This is the main sheet in the tool – all other worksheets include a button to return to this sheet. It serves as a kind of dashboard and is the only place where user input or interaction is expected. Here, the user may select the concerned geocluster and building archetype[3] from predefined sets. A button "Check building features" leads the user to the worksheet "Building features", to check details for the selected archetype (see section 3.3.3). Further, the user can select for each of the five topics of interest which KPI they deem most important and how much importance (weight) they assign to this KPI. The user can also give some details on their specific renovation project such as distance to where the façade elements are prefabricated, mounting and anchoring method, cladding type, whether old cladding is removed or not, roof insulation type.

A button "Run analysis" starts the actual analysis for the specified case, reading out selected KPIs and other relevant information from the repository, processing this information and displaying key results on this sheet. As part of the analysis, a combined score is calculated for each renovation package, based on the sum of the scaled KPI values for all topics of interest weighted by the user's prioritization. This procedure is described in detail in section 3.4. The tool finds the, according to the

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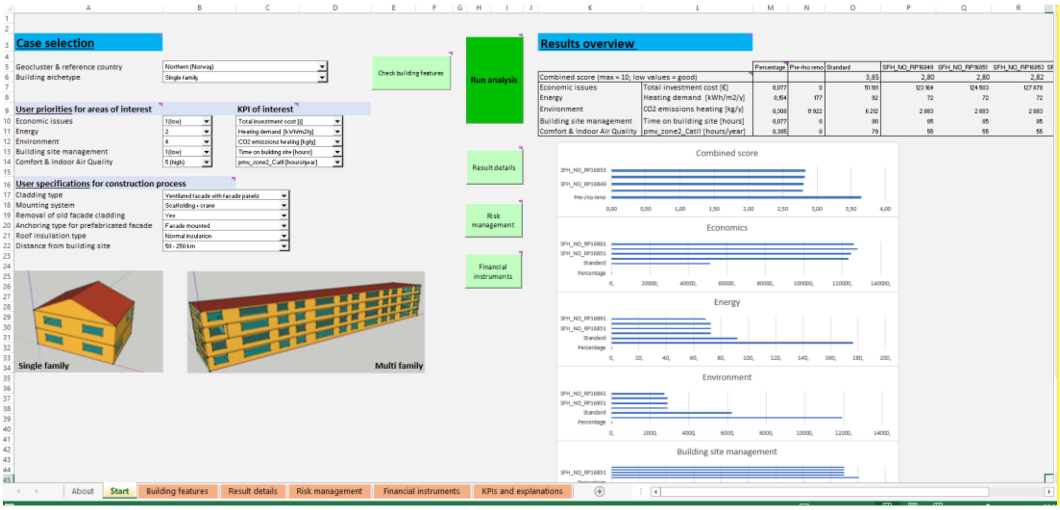
[3] The worksheet "Building features" is set up for four building archetypes for each geocluster. However, the implementation of the ranking tool and the accompanying repository demonstrate a proof of concept, taking only two archetypes into account, single- and multi-family houses.

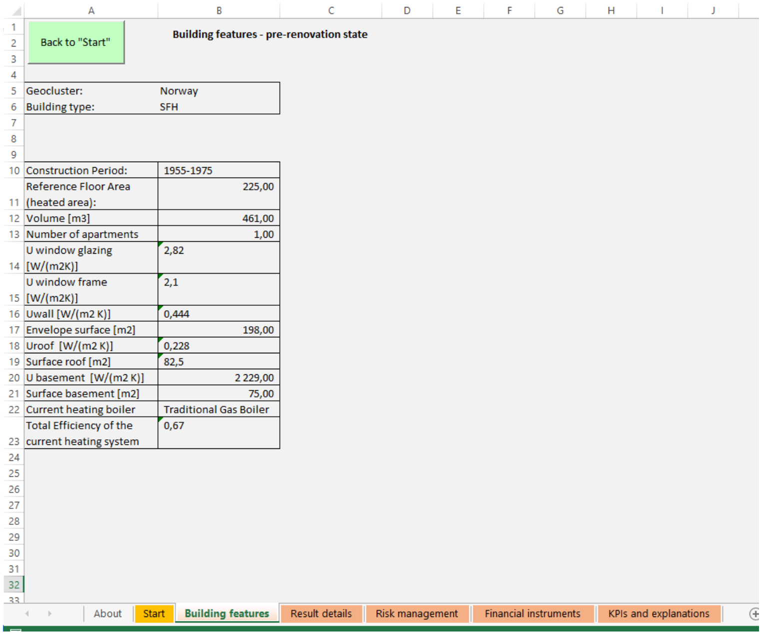
calculated scores, five best deep-renovation packages and displays the corresponding KPI and score values in a table, together with values for the no or pre-renovation state and for a standard renovation. In addition, the values are displayed graphically.

The sheet contains also buttons leading the user to the worksheets "Result details", "Risk management" and "Financial instruments" providing more information on the selected deep-renovation packages.



3.3.3 Worksheet "Building features"

The worksheet displays features for the chosen building archetype in the considered geocluster, reflecting the existing situation as implemented in the building simulations. This can give the user some indications about transferability of the information displayed in the tool to their specific building.



Back to "Start"

Building features - pre-renovation state

Geocluster:	Norway
Building type:	SFH

Construction Period:	1955-1975
Reference Floor Area (heated area):	225,00
Volume [m3]	461,00
Number of apartments	1,00
U window glazing [W/(m2K)]	2,82
U window frame [W/(m2K)]	2,1
Uwall [W/(m2 K)]	0,444
Envelope surface [m2]	198,00
Uroof [W/(m2 K)]	0,228
Surface roof [m2]	82,5
U basement [W/(m2 K)]	2 229,00
Surface basement [m2]	75,00
Current heating boiler	Traditional Gas Boiler
Total Efficiency of the current heating system	0,67

About | Start | Building features | Result details | Risk management | Financial instruments | KPIs and explanations

3.3.4 Worksheet "Result details"

This sheet assembles *all* KPIs in a common table for the considered five deep-renovation packages and the pre-/no and standard renovation solutions. It also replicates information given for these packages and for the renovation process on the "Start" sheet. In addition, corresponding technical details for the packages are read out from the repository and displayed, along with information about parameters used to estimate KPI values in the simulations.

Back to "Start"

Result details

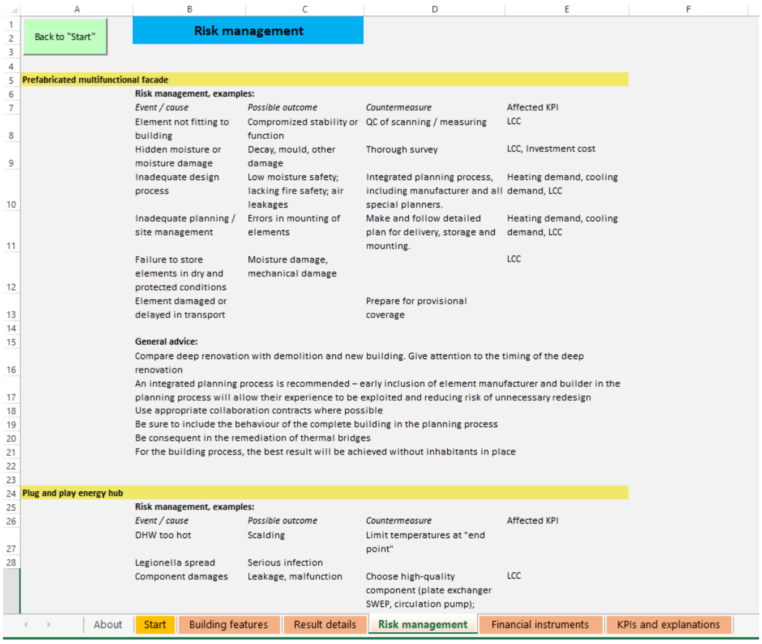
(out of 288 simulations for SFH, NO, 50 km - 250 km from building site)

Renovation package ID		Pre-renovation	Standard renovation	SFH_NO_RP16849	SFH_NO_RP16851	SFH_NO_RP16853	SFH_NO_RP16861	SFH_NO_RP16873
Ranking				1	2	3	4	5
Combined score (max = 10; low = good)			**3,648**	**2,797**	**2,804**	**2,822**	**2,829**	**2,831**
Total investment cost [l]		0,00	51181,06	123164,27	124503,02	127878,02	126053,09	126682,73
Heating demand [kWh/m2/y]		176,51	91,97	72,26	72,26	72,26	68,70	72,26
CO2 emissions heating [kg/y]		11922,19	6211,58	2883,35	2883,35	2883,35	2741,02	2883,35
Time on building site [hours]		0,00	90,25	85,04	85,04	85,04	85,04	88,40
pmv_zone2_CatII [hours/year]		0,00	79,00	55,00	55,00	55,00	67,00	55,00
Deep renovation package technologies								
Facade		PRE-RETROFIT EXTERNALWALL	POST-RETROFIT GOOD PREFABRICATED FACADE (U=0.2)	POST-RETROFIT GOOD PREFABRICATED	POST-RETROFIT GOOD PREFABRICATED	POST-RETROFIT GOOD PREFABRICATED	POST-RETROFIT VERY GOOD PREFABRICATED	POST-RETROFIT GOOD PREFABRICATED
Window		PRE-RETROFIT WINDOW	POST-RETROFIT low E double glazing	POST-RETROFIT low E double glazing	POST-RETROFIT low E double glazing	POST-RETROFIT low E double glazing	POST-RETROFIT low E double glazing	POST-RETROFIT low E double glazing
Roof insulation		PRE-RETROFIT ROOF	No	POST-RETROFIT ROOF INSULATION	POST-RETROFIT ROOF INSULATION	POST-RETROFIT ROOF INSULATION	POST-RETROFIT ROOF INSULATION	POST-RETROFIT ROOF INSULATION
Ground floor insulation		PRE-RETROFIT	No	POST-RETROFIT	POST-RETROFIT	POST-RETROFIT	POST-RETROFIT	POST-RETROFIT
Shading system		No	No	No	No	No	No	No
Ceiling fan		No	No	No	No	Yes	No	No
Cooling system		No	No	No	Yes	Yes	No	No
PV system		No	No	No	No	No	No	Yes
Heating generation		Traditional heating system - gas boiler	Traditional heating system - gas boiler	Heat pump	Heat pump	Heat pump	Heat pump	Heat pump
Mechanical ventilation system		No mechanical ventilation	No mechanical ventilation	No mechanical ventilation	No mechanical ventilation	No mechanical ventilation	No mechanical ventilation	No mechanical ventilation
Energy								
Total heating demand [kWh/y]	kWh	39715,55	20692,21	16259,50	16259,50	16259,50	15456,87	16259,50
Total cooling demand [kWh/y]	kWh	0,00	0,31	0,00	0,00	0,00	0,00	0,00
Heating demand [kWh/m²/y]	kWh/m²	176,51	91,97	72,26	72,26	72,26	68,70	72,26
Cooling demand [kWh/m²/y]	kWh/m²	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Heating consumption [kWh/y]	kWh	59020,73	30750,41	5419,83	5419,83	5419,83	5152,29	5419,83
Heating consumption [kWh/m²/y]	kWh/m²	262,31	136,67	24,09	24,09	24,09	22,90	24,09
Primary energy heating [kWh/y]	kWh	59020,73	30750,41	10839,67	10839,67	10839,67	10304,58	10839,67
Primary energy heating [kWh/m²/y]	kWh/m²	262,31	136,67	48,18	48,18	48,18	45,80	48,18
Cooling consumption [kWh/y]	kWh	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Cooling consumption [kWh/m²/y]	kWh/m²	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DHW demand [kWh/y]	kWh/year	3274,98	3274,98	2438,04	2438,04	2438,04	2438,04	2438,04
Ventilation consumption [kWh/y]	kWh	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Ceiling fan consumption [kWh/y]	kWh	0,00	0,00	0,00	0,00	0,00	0,00	0,00
PV power produced [kW/y]	kW	0,00	0,00	0,00	0,00	0,00	0,00	13758,92
Environment								
CO_2 emissions heating [kg/y]	kg CO_2/year	11922,19	6211,58	2883,35	2883,35	2883,35	2741,02	2883,35
CO_2 emissions cooling [kg/y]	kg CO_2/year	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Comfort & Indoor Air Quality								
CAT_1_PPM [hours/year]	hours	2874,00	2934,00	2254,00	2254,00	2254,00	2259,00	2254,00
CAT_2_PPM [hours/year]	hours	174,00	162,00	353,00	353,00	353,00	350,00	353,00
CAT_I_Adpt [hours/year]	hours	1,00	500,00	123,00	123,00	123,00	164,00	123,00
CAT_II_Adpt [hours/year]	hours	0,00	117,00	257,00	257,00	257,00	253,00	257,00
pmv_zone2_CatI [hours/year]	hours	0,00	45,00	0,00	0,00	0,00	0,00	0,00
pmv_zone2_CatII [hours/year]	hours	0,00	79,00	55,00	55,00	55,00	67,00	55,00
Economic issues								
Total investment cost [l]	l	0,00	51181,06	123164,27	124503,02	127878,02	126053,09	126682,73
Total investment cost, factor [l]	l	0,00	85146,38	204899,85	207127,04	212741,79	209705,78	210753,27
Approximated LCC 50 years [l]	l	0,00	96220,39	139547,09	141063,92	144887,85	142820,17	143533,57

About | Start | Building features | Result details | Risk management | Financial instruments | KPIs and explanations

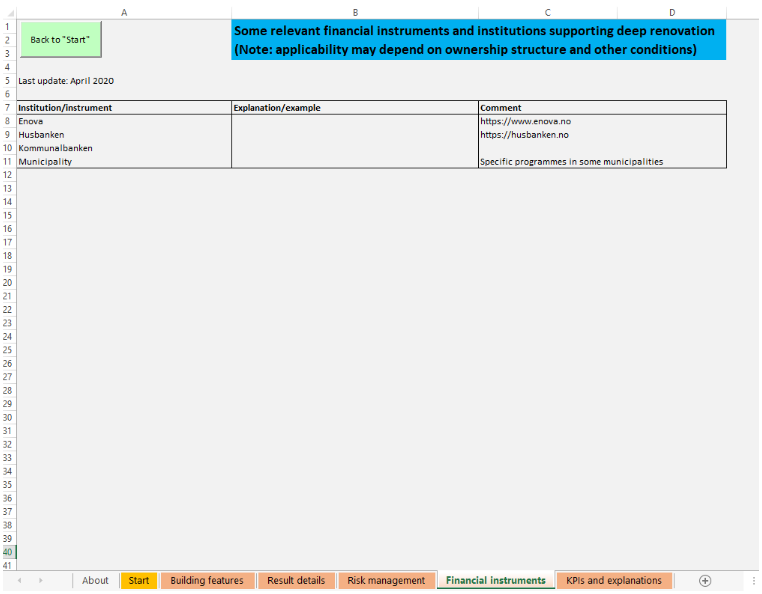
3.3.5 Worksheet "Risk management"

The sheet gives examples of important risk-management aspects and general advice to be considered for the relevant (deep) renovation packages. While advice for the prefabricated façade and the plug and play energy hub is always displayed, advice for the ceiling fan and RES is only displayed if some of the selected DRPs comprise this technology. Then also the ID numbers of the concerned packages are listed.



3.3.6 Worksheet "Financial instruments"

The sheet lists main types of financial instruments or institutions providing such instruments that may be available for deep-renovation projects in the considered geocluster, pointing the user to relevant instruments or sources of further information.



3.3.7 Worksheet "KPIs and descriptions"

The sheet replicates the information stated in Appendix A in this technical note, listing and describing all KPIs within the single topics of interest.

	A	B
1	**Topic and KPI name**	**Explanation**
2	**Energy**	
3	Total heating demand [kWh]	Yearly net energy demand for heating as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes"
4	Total cooling demand [kWh]	Yearly net energy demand for cooling as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes"
5	Heating demand per m^2 [kWh/m2]	Yearly net energy demand for heating as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Buil-ding Archetypes" and normalised according to the heated building surface
6	Cooling demand per m2 [kWh/m2]	Yearly net energy demand for cooling as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes" and normalised according to the heated building surface
7	Heating consumption [kWh/y]	Yearly final energy consumption for heating as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes" and normalised according to the heated building surface
8	Heating consumption [kWh/m^2/y]	Yearly final energy consumption for heating as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes" and normalised according to the heated building surface
9	Primary energy heating [kWh/y]	Yearly final energy consumption for cooling as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes"
10	Primary energy heating [kWh/m^2/y]	Yearly primary energy consumption for heating as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes" and normalised according to the heated building surface
11	Cooling consumption [kWh/y]	Yearly final energy consumption for cooling as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes"
12	Cooling consumption [kWh/m^2/y]	Yearly final energy consumption for cooling as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geo-clusters and Building Archetypes" and normalised according to the heated building surface
13	DHW demand kWh/year	Yearly energy demand for Domestic Hot Water production
14	Ventilation consumption [kWh/y]	Final energy consumption for mechanical ventilation
15	Ceiling fan consumption [kWh/y]	Final energy consumption for the operation of the comfort ceiling fans
16	PV power produced [kW/y]	Yearly energy produced by the photovoltaic system (if installed during renovation)
17	**Environment**	
18	CO_2 emissions heating [kg/y]	Yearly CO2 emissions for heating
19	CO_2 emissions cooling [kg/y]	Yearly CO2 emissions for cooling
20	**Comfort & IAQ**	
21	CAT_1_PPM [hours/year]	Number of hours in comfort category I (EN ISO 15251) according to the CO_2 concentration calculated in a sample room - number of hours in optimal indoor air quality conditions
22	CAT_2_PPM [hours/year]	Number of hours in comfort category II (EN ISO 15251) according to the CO_2 concentration calculated in a sample room - number of hours in acceptable indoor air quality conditions
		Number of hours in comfort category I (EN ISO 15251) according to the indoor temperature

About | Start | Building features | Result details | Risk management | Financial instruments | KPIs and descriptions

3.3.8 Worksheet "InputToTool(Hidden)"

This is an auxiliary worksheet needed for the ranking tool coding. After tool development and testing work are completed, it is hidden to the user.

3.4 Calculation of combined score

To compare and rank the user-chosen deep-renovation packages and the standard renovation, a combined score is calculated. This score takes into account the user's prioritization of the five topics of interest and values of the respective KPIs chosen by the user. However, to achieve a fair score, some adjustments are required.

a) Stating user preferences for the single topics (on a scale from 1 to 5) is not a clear-cut, rational process. Users do typically not find such values independently for each topic but compare their perceived preferences against each other. For example, a user may start with the topic most important to them and work their way through the other topics, setting values in relation to that first preference. On the other hand, a user choice may not be unambiguous. E.g., choosing "3" for all topics to denote that all are equally important would mean the same as setting "5" for all topics. Hence, we normalize the priorities when calculating a total score for each package. We are interested in the *relative* importance of each topic against the others and divide, hence, all priority values p_j by the sum of the five chosen values:

$$p_j^{norm} = p_j / \sum_{k=1}^{5} p_k \in [0,1]$$

Thus, the normalized values p_j^{norm} state the *percentage* or *share of importance* a topic *j* has. These values are used as weighing factors.

b) The magnitude of the KPIs may vary considerably such that a simple summation using weighting factors would give undue priority to topics with high KPI values (e.g., NPV) and override the user-chosen priorities p_j. We normalize the KPIs by using the maximum value of the KPI over *all* packages (incl. standard and pre-/no renovation),

$$KPI_{j,r}^{norm} = KPI_{j,r} / max\,\{KPI_{j,k}, k = 1, \dots, \#DRPs\} \in [0,1]$$

This value can be interpreted as how much (percentage) of the maximum possible KPI value for the concerned topic *j* this package *r* achieves.

c) Combining normalized priority values p_j^{norm} and normalized KPIs $KPI_{j,r}^{norm}$ over all topics of interest *j*, gives a score for each considered deep-renovation package and the standard renovation *r*,

$$Score_r = \sum_{j=1}^{5} p_j^{norm} \cdot KPI_{j,r}^{norm} \in [0,1]$$

For the sake of clarity, this value is magnified by multiplying it with 10.

Observe that the calculation delivers correct scores only if all potentially considered KPIs are positive and are valued similarly, e.g., low KPI values are better than high values. For the energy KPI "Energy produced via PV system", higher values are considered better. If this KPI is chosen by the user, the above score calculation uses an adjusted value instead,

$$KPI_{j,r}^{norm} = 1 - KPI_{j,r} / max\,\{KPI_{j,k}, k = 1, \dots, \#DRPs\} \in [0,1]$$

For the pre-/no renovation state, not all topics of interest are relevant (such as many economics or building site management KPIs), and no score is calculated.

Example:

Topic	User prefe-rence, p_j	KPI	KPI value for given DRP, KPI_j	Maximum KPI value over all DRPs, $KPImax_j$
Economic issues	3	Total investment cost [1000 €]	990.81	1691.12
Energy	2	Global building energy demand heating [kWh]	117 000	360 000
Environment	2	CO_2 emissions heating [kg/year]	26 200	111 000
Building site management	3	Renovation time [hours]	844.56	2207
Comfort and IAQ	4	CAT 1 PPM	1060	4820

The above-described procedure leads to

Topic	Normalised user preference, p_j^{norm}	Normalised KPI value, KPI_j^{norm}	$p_j^{norm} * KPI_j^{norm}$
Economic issues	0.2143	0.5859	0.1256
Energy	0.1428	0.3171	0.0453
Environment	0.1428	0.2360	0.0337
Building site management	0.2143	0.3827	0.0820
Comfort and IAQ	0.2857	0.2199	0.0628

Summing up over the last column and multiplying by 10, we obtain a score of 3.494 for that given DRP.

4 Demonstration example

This section provides a step-by-step guide for using the ranking tool prototype implementation together with the repository. The demonstration is based on a use case for a multi-family house in the Netherlands.

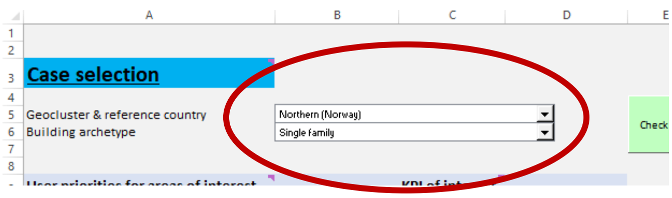
4.1 Setting up the ranking tool

These steps are typically not necessary every time an analysis is to be carried out.

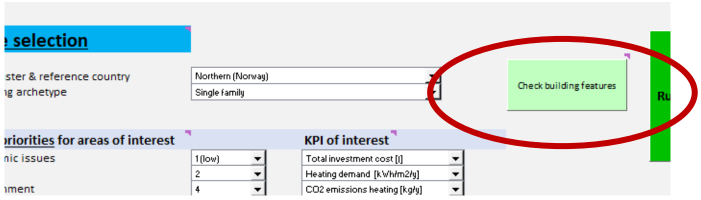
1. Ensure that there exist repositories for the geoclusters and building archetypes to be considered.
2. Ensure that these repositories have the structure and are named as described in section 2.2.
3. Ensure that the repositories contain all relevant information (see section 2.2): descriptions of building archetype and renovation packages, values for all KPIs, information on risk management for the technology choices, and information on financial instruments for the geocluster.
4. Ensure that the repositories and the ranking tool prototype are located in the same directory.

4.2 Starting an analysis – worksheet "Start"

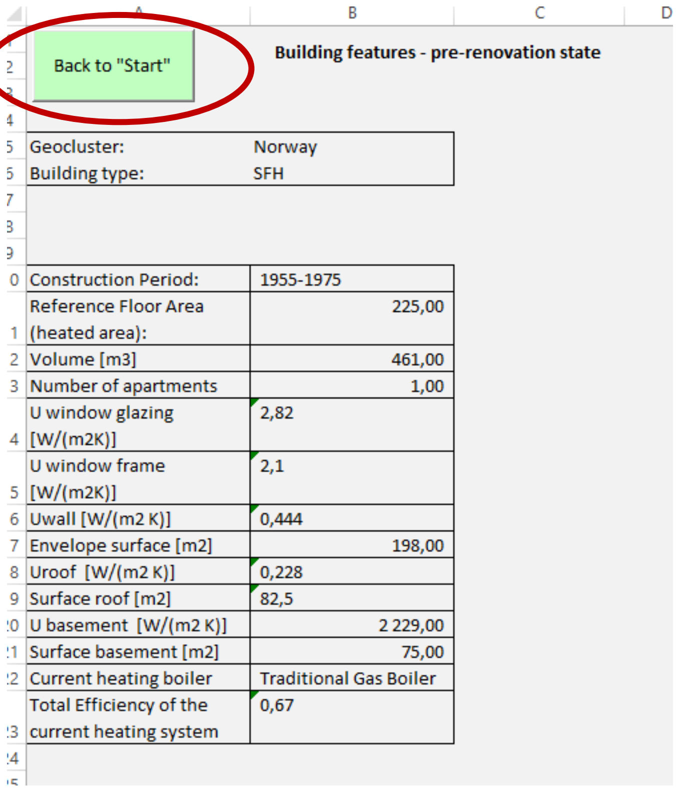
1. Select the geocluster with reference country and the building archetype closest to the case to be studied.



2. The user may check a detailed description of the chosen building archetype for that geocluster through the button [Check building features].

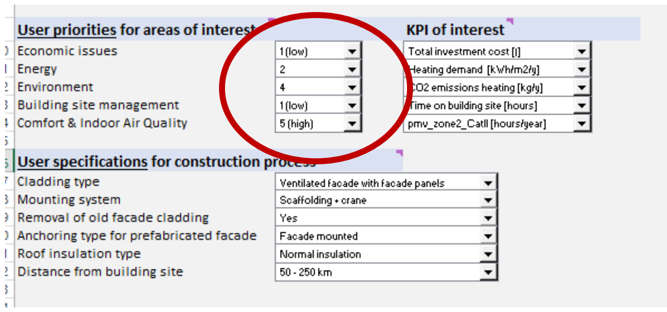


This leads the user to a new worksheet "Building features", see section 3.3.3.

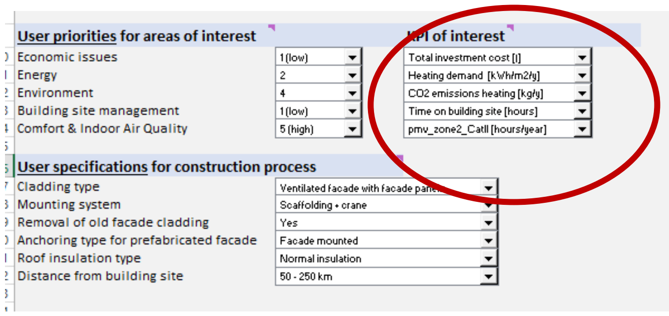


With the button [Back to "Start"], the user returns to the "Start" work sheet.

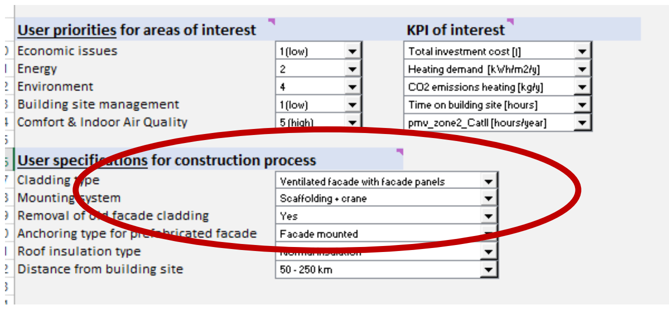
3. For each of the five topics, set priority or weight on a scale from 1 (low) to 5 (high).



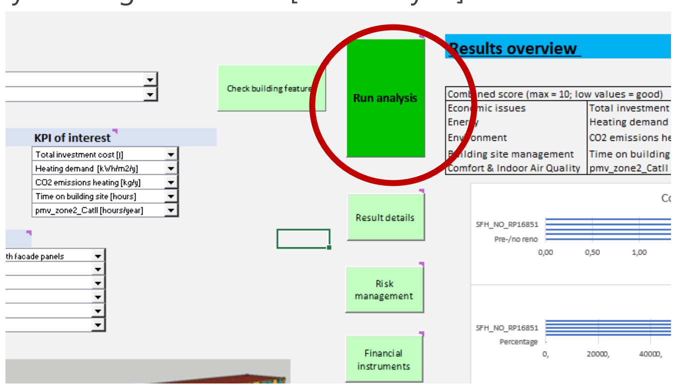
Select also – for each topic of interest – one main KPI for inclusion into the score calculation and, hence, ranking. Appendix A in this note and work-sheet "KPIs and descriptions" in the tool provide a detailed description of each KPI.



4. Specify renovation-process characteristics for the user's project, see also Appendix B in this note.

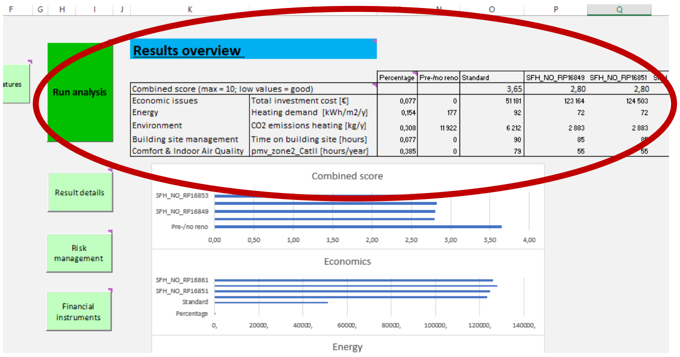


5. Run the analysis using the button [Run analysis].

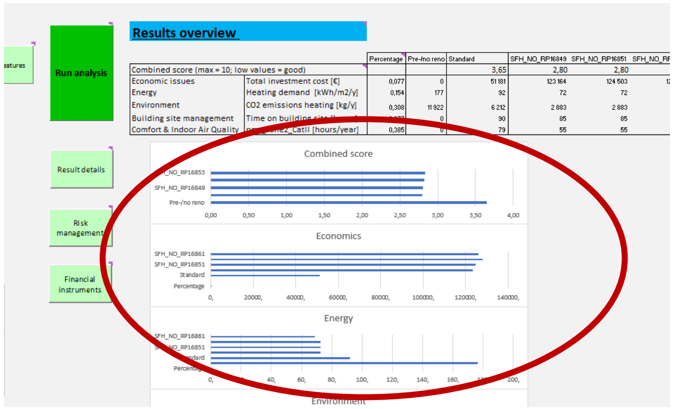


4.3 Examining analysis results

1. Once the analysis has been run, the ranking tool prototype displays various results. On the main, "Start" worksheet, a summary is displayed on the right hand side (see section 3.3.1): a table containing combined scores and values for the selected KPIs for the identified five best deep-renovation packages

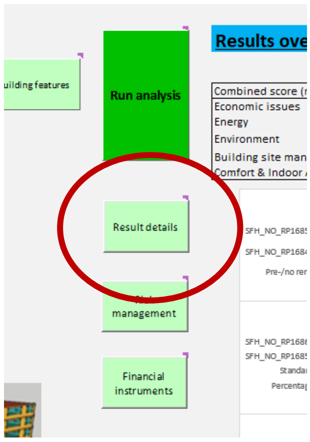


and a visualisation of these values.

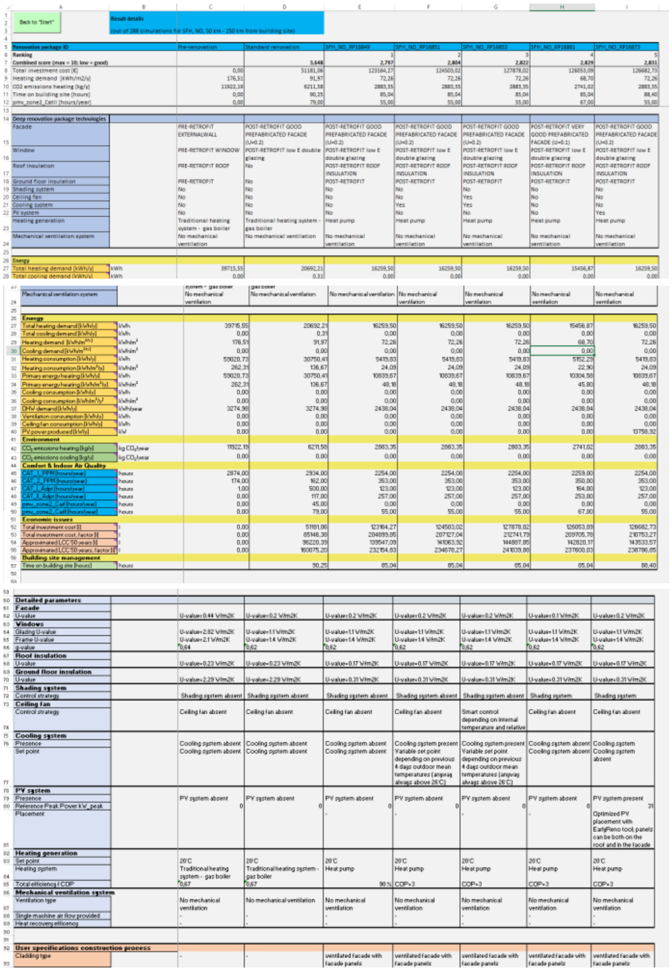


The table shows also the percentage used for each KPI in the score calculation, based on the individual priorities stated by the user.

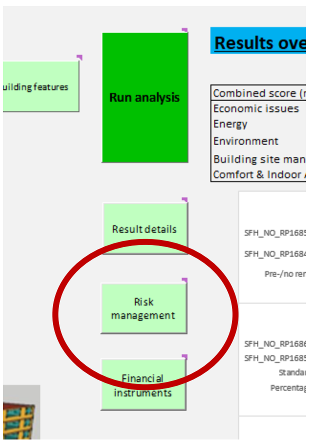
2. The button [Result details]



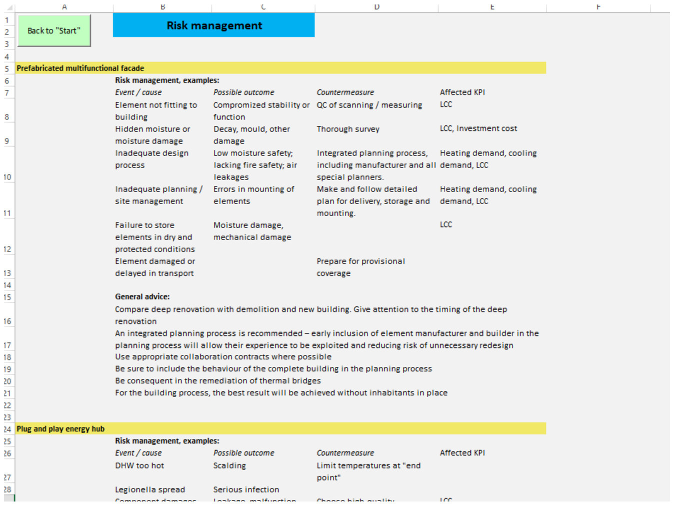
brings the user to the worksheet "Result details" (section 3.3.4). This sheet re-states information about the found packages (and the standard and pre-/ no renovation cases) such as combined score and the five user-selected KPIs. It then describes the relevant packages in terms of technology choices. Then all KPIs for the packages are listed. Finally, detailed parameters used for determining the KPI values are provided and the user specifications of the renovation process are repeated.



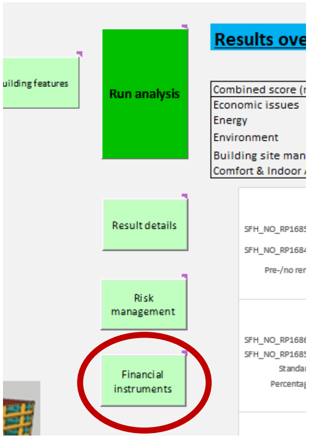
3. The button [Risk management]



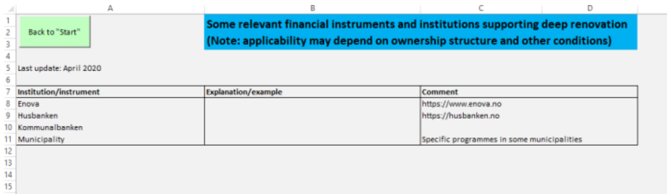
brings the user to the worksheet "Risk management" (see section 3.3.5), listing examples for risk management and general advice for selected technology choices.



4. The button [Financial instruments]



brings the user to the worksheet "Financial instruments" (section 3.3.6).



5 Summary

One of the core pieces of the 4RinEU project is the development of a multi-criteria ranking tool. It aims at guiding building owners and investors in the initial steps of a potential deep-renovation project, helping them to find suitable technology packages than conform with their individual preferences and priorities. These suggestions for technical solutions can then be taken further, utilizing the expertise of engineers and architects as well as comprehensive calculations. This way, deep-renovation project plans can be developed step by step, tailored to the users' situation, actual building and technical requirements.

Within task 4.2 of the 4RinEU project, two prototype implementations of the ranking tool have been discussed and one version has been developed in the form of MS Excel files, demonstrating the concept and basic ideas. It relies on input data provided via a repository, also this in form of an MS Excel file. This technical note accompanies the implementation, describing background and function as well as how this work is interconnected with other tasks of the project. In particular, this concerns task 2.1 (simulations and populating the repository with values for performance indicators), task 3.3 (definition of deep-renovation packages), task 4.1 (identification of risk elements and their management), and task 4.5 (relevant financial instruments). The technical note is also concerned with more technical details of the tool implementation such as the structure of the connected repository and a step-by-step description of how an analysis may be carried out.

The development and implementation process in the 4RinEu project uncovered challenges to be addressed on the way towards potential dissemination and commercialization of the concept. An important aspect is the balance between general applicability (e.g., using a few predefined building archetypes and technologies) and sufficient relevance of the suggestions to the users (who are concerned with real buildings and more tailor-made technologies). Also, to provide satisfactory guidance, the tool should offer a large set of deep-renovation packages. For all these packages, however, the repository needs to be populated with data that then needs to be kept up to date in order to be transferable to new analyses. Currently, much of this information relies on experience with the 4RinEU demo cases, simulations and on knowledge gained from technology providers. Finding reliable values is time consuming and can be challenging as costs are also part of the companies' "business secrets". As many of the considered technologies are rather innovative and new, a broadly spanning knowledge collection may prove to be complex. Further development work should dedicate significant efforts also on information collection, quality assurance and updating. An option may be linking the repository to widely recognized other data bases[4]; but neither for standard renovation cases, sufficient information appears readily available. Another issue is the variation in building and technical practices, accounting, regulations and other requirements across the different geoclusters that needs to be accommodated in a common repository and in the tool structure.

Further development for the ranking tool and the underlying repository may comprise a more direct connection of the tool with, e.g., the simulations via the repository. This can provide more tailor-made KPI values such that the user can adjust, e.g., building-archetype features to make them fit better with their actual building. Then, the tool may calculate some values rather than read pre-calculated values from the repository. This may, for example, be relevant for KPIs that are easily scalable (e.g., costs for air handling units whose number depends on the number of apartments) or that can be adjusted to longer lifetimes or interest rates (e.g., NPV). More or more detailed indicators may help to uncover the DRPs' potential for energy saving, peak shaving or the like by separating production and demand better. The division of the KPIs into the five topics of interest may be replaced by a version where the user can choose freely between all KPIs and assign priorities to them. The displayed KPI values may also be compared against, e.g., current policies or energy-saving requirements. However, this may pose similar challenges as for the "Financial instruments" topic: often such policies or requirements are specific to other features and contain more dimensions and conditions than handled by the tool. They are prone to frequent changes and updates. It may also be challenging to set simple numbers against which the renovation packages can be compared, not at last since the tool refers only to generalized building archetypes. Possibilities for the user to add more geocluster-specific information to see effects on various technology set-ups may be worth-while to consider.

In a longer-term perspective, a more dynamic tool implementation is envisaged, going from an Excel prototype over to a web-based application and connecting

[4] The best tool currently available in Norway is the Holte cost database, https://holte.no/en/, that is very well integrated with the total building process and BIM world. It has also been combined with the Gabi data base in the FP7 EU project CILECCTA.

the repository to either real-time simulations or established databases. Related examples are, e.g., the web-based tools developed in the E2ReBuild5 and CommONEnergy6 projects. Moreover, an implementation of the ranking tool as a plug-in to other, already existing tools, enhancing their functionality may be as viable as developing a stand-alone version. In either case, aspects such as confidentiality, access rights or licensing should be discussed thoroughly, together with viable business models for the ranking tool and the repository.

[5] http://era.empa.ch/faces/wizard.xhtml?faces-redirect=true

[6] https://eeg.tuwien.ac.at/commonenergy_economic_assessment_tool/#page=input_group1&reload=false

Appendix

A. KPIs with values stored in the repository

Topic and KPI name	Explanation
Energy	
Total heating demand [kWh/year]	Yearly net energy demand for heating as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geoclusters and Building Archetypes"
Total cooling demand [kWh/year]	Yearly net energy demand for cooling as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geoclusters and Building Archetypes"
Heating demand per m^2 [kWh/m^2/year]	Yearly net energy demand for heating as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geoclusters and Building Archetypes" and normalised according to the heated building surface
Cooling demand per m^2 [kWh/m^2/year]	Yearly net energy demand for cooling as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geoclusters and Building Archetypes" and normalised according to the heated building surface
Heating consumption [kWh/y]	Yearly final energy consumption for heating as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geoclusters and Building Archetypes" and normalised according to the heated building surface
Heating consumption [kWh/m2/y]	Yearly final energy consumption for heating as calculated considering the boundaries set in Annex A of Deliverable 2.1"Geoclusters and Building Archetypes" and normalised according to the heated building surface
Primary energy heating [kWh/y]	Yearly final energy consumption for cooling as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geoclusters and Building Archetypes"
Primary energy heating [kWh/m2/y]	Yearly primary energy consumption for heating as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geoclusters and Building Archetypes" and normalised according to the heated building surface
Cooling consumption [kWh/y]	Yearly final energy consumption for cooling as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geoclusters and Building Archetypes"
Cooling consumption [kWh/m^2/y]	Yearly final energy consumption for cooling as calculated considering the boundaries set in Annex A of Deliverable 2.1 "Geoclusters and Building Archetypes" and normalised according to the heated building surface
DHW demand [kWh/year]	Yearly energy demand for Domestic Hot Water production
Ventilation consumption [kWh/y]	Final energy consumption for mechanical ventilation
Ceiling fan consumption [kWh/y]	Final energy consumption for the operation of the comfort ceiling fans
PV power produced [kW/y]	Yearly energy produced by the photovoltaic system (if installed during renovation)

Environment	
CO_2 emissions heating [kg/y]	Yearly CO_2 emissions for heating
CO_2 emissions cooling [kg/y]	Yearly CO_2 emissions for cooling
Comfort & IAQ	
CAT_1_PPM [hours/year]	Number of hours in comfort category I (EN ISO 15251) according to the CO_2 concentration calculated in a sample room - number of hours in optimal indoor air quality conditions
CAT_2_PPM [hours/year]	Number of hours in comfort category II (EN ISO 15251) according to the CO_2 concentration calculated in a sample room - number of hours in acceptable indoor air quality conditions
CAT_I_Adpt [hours/year]	Number of hours in comfort category I (EN ISO 15251) according to the indoor temperature and relative humidity conditions in summer period calculated in a sample room - number of hours in optimal thermal comfort conditions (evaluated in cooling period)
CAT_II_Adpt [hours/year]	Number of hours in comfort category II (EN ISO 15251) according to the indoor temperature and relative humidity conditions in summer period calculated in a sample room – number of hours in acceptable thermal comfort conditions (evaluated in cooling period)
pmv_zone2_CatI [hours/year]	Number of hours in comfort category I (EN ISO 15251) according to the Predicted Mean Vote of the occupants during winter period calculated in a sample room – number of hours in optimal thermal comfort conditions (evaluated in heating period)
pmv_zone2_CatII [hours/year]	Number of hours in comfort category II (EN ISO 15251) according to the Predicted Mean Vote of the occupants during winter period calculated in a sample room – number of hours in acceptable thermal comfort conditions (evaluated in heating period)
Economic issues	
Total investment cost [€]	Investment costs related to technology and/or installation works and materials on building site
Total investment cost, factor [€]	Investment costs related to technology and/or installation works and materials on building site; adjusted using a country-specific proportional cost factor
Approximated LCC 50 years [€]	Life Cycle Cost of the building calculated for 50 years after renovation considering investment cost for the interventions, energy supply during operation and maintenance
Approximated LCC 50 years, factor [€]	Life Cycle Cost of the building calculated for 50 years after renovation considering investment cost for the interventions, energy supply during operation and maintenance; adjusted using a country-specific proportional cost factor
Building site management	
Time on building site [hours]	Number of hours needed for the installation of 4RinEU renovation packages - installation/mounting works

B. Cost and time KPI evaluation

For each renovation package, estimations of the investment costs due to the use of different technologies and time needed at the building site to perform the retrofit have been provided.

The total cost of each renovation package has been calculated as the sum of:

(I) the costs related to the integration of different technologies in the package – this amount includes the material or device costs as well as the assembly/integration and installation costs of the technologies which are included in the renovation package.

(II) the costs related to the choice of specific user preferences adopted during the retrofit intervention. These costs are mainly due to the time needed at the building site to implement such chosen preferences. The preferences are characteristics related to the renovation package and the retrofit intervention in general. The tool user can define them depending on their needs or just to compare different renovation scenarios. Their choice is not affecting the performance of the renovation package but only influences costs and time of the renovation.

The estimation of the total time at the building site considers time for both installing specific technologies and performing activities specified in the user-preference list.

In order to extend the analysis to different building typologies, it was necessary to estimate the time and cost for most of the integrated technologies, normalizing them per square meter of façade area. This normalization has been performed using a reference façade area of 36 m^2 including three windows of 2.4 m^2 each.

Costs and times used for calculation come from different sources: concerning the prefabricated façade integrations, assembly, transportation and installation, all inputs have been estimated by 4RinEU partner Gumpp&Maier GmbH, thanks for both calculations and well-founded experience in the construction field. For other renovation activities and technologies, data have been taken from commercial sources, technical sheets and building sector websites providing time and costs estimations.

To take into account differences between European construction costs, proportionality cost factors have been used to convert calculated costs (referring mainly to the German market) to other European countries. The factors have been provided by the European Construction Cost (ECC) (http://constructioncosts.eu/cost-index/) as reported in

Table 1. Here, reference costs are for the United Kingdom (100%).

Table 1 Construction cost indexes throughout Europe (source http://constructioncosts.eu/cost-index/)

Country	Construction Cost Index
Germany	96.62%
Norway	160.74%
Netherland	82%
Spain	70.52%
Hungary	53.24%
Ireland	79.18%
Poland	65.61%

In Table 2, the costs and installation time related to the technologies composing the different renovation packages are reported.

Table 2 Technologies related costs

<table>
<tr><td rowspan="3">Facade</td><td>ETICS retrofit (U=0.2 W/m²K)</td><td>158.7 €/m²</td><td>The costs refer to vertical façade area and include material and mounting.</td></tr>
<tr><td>Timber Prefabricated Façade retrofit – good thermal insulation (U=0.2 W/m²K)</td><td>147.76 €/m²</td><td rowspan="2">The costs refer to vertical façade area and include prefabrication, material and mounting (costs for modules’ external finishing are missing; refer to “cladding type” in Table 3)</td></tr>
<tr><td>Timber Prefabricated Façade retrofit – very good thermal insulation (U=0.1 W/m²K)</td><td>162.35 €/m²</td></tr>
<tr><td rowspan="2">Window</td><td>Low E double glazing new windows (U=1.24 W/m²K)</td><td>130 €/m²</td><td rowspan="2">The costs refer to window area and include material, removal and mounting of new windows.</td></tr>
<tr><td>Triple glazing new windows (U=0.61 W/m²K)</td><td>300 €/m²</td></tr>
<tr><td rowspan="3">Roof insulation</td><td>No roof insulation</td><td>-</td><td></td></tr>
<tr><td>Standard roof insulation (U=0.15 W/m²K)</td><td>153.69 €/m²</td><td rowspan="2">The costs refer to roof area and include material, preparation of the roof and mounting of new insulation/timber prefabricated roof</td></tr>
<tr><td>Timber prefabricated roof</td><td>172.46 €/m²</td></tr>
<tr><td rowspan="2">Ground floor insulation</td><td>No ground floor insulation</td><td>-</td><td></td></tr>
<tr><td>Ground floor insulation retrofit</td><td>55 €/m²</td><td>The costs refer to basement area and include material, preparation and mounting.</td></tr>
<tr><td rowspan="2">Shading system</td><td>No shading system</td><td>-</td><td></td></tr>
<tr><td>Automated shading system</td><td>62.03 €/m²</td><td>The costs refer to vertical façade area and include material, preparation and mounting. The estimation</td></tr>
</table>

			considers one shading system per window.
Ceiling fan	No ceiling fan	-	
	Smart ceiling fan	15 €/m^2	The costs refer to **horizontal surface** and include material and installation of the smart ceiling fan. The estimation considers one ceiling fan every 100 m^2 of horizontal surface
Cooling system	No cooling system	-	
	Cooling system	5.95 €/m^2	The costs refer to **horizontal surface** and include material and installation of the cooling system. The estimation considers the use of a 12000 BTU cooling system per 100 m^2 of horizontal surface.
PV system	No PV system	-	
	Façade integrated PV system	15.75 €/m^2	The costs refer to **vertical façade** area and include material, preparation and mounting of a façade-integrated PV system. The estimation considers an average installed capacity of 21.6 W_{peak} per m^2 vertical surface.
		0.017 h/m^2; 2.02 €/m^2	The costs refer to **vertical façade** area and include costs related to two workers at the building site for the electrical connection of PV integrated systems.
Heating generation	Heat pump	25 €/m^2	The costs refer to **horizontal surface.** The estimation considers an average of 21.9 W_{peak} per m^2 horizontal surface.
	Traditional heating system – gas boiler	7 €/m^2	The costs refer to **horizontal surface.** The estimation considers the use of a 24 kW traditional heating system per 100 m^2 of horizontal surface.
Mechanical ventilation system	No mechanical ventilation	-	
	Façade-integrated decentralized ventilation system with heat recovery	41 €/m^2	The costs refer to **vertical façade** area and include costs related to devices and prefabrication within the façade. It has been estimated that a reasonable ACH in the building is reached using

			~0.06 units per square meter of vertical façade area and considering ~50 m³/h as air flow capacity of the unit.
		0.017 h/m²; 2.02 €/m²	The costs refer to **vertical façade** area and include costs related to two workers at the building site for the electrical connection of the ventilation systems
	Centralized balanced AHU with heat recovery (only ducts are facade integrated)	30.5 €/m²	The costs refer to **vertical façade** area and include costs related to devices and air ducts, as well as prefabrication costs. It has been estimated that a reasonable ACH in the building is reached using ~0.004 units per square meter of vertical façade area and considering ~600 m³/h as air flow capacity of the unit.
		0.39 h/m²; 23.3 €/m²	The costs refer to **vertical façade** area and include costs for two workers at the building site for the electrical and mechanical connections of the ventilation systems.

In
Table 3, the times (and related derived costs) needed at the building site for implementing each specific user preference are reported.

Table 3 User-preferences related costs and times

Cladding type	Ventilated facade with timber cladding	147.58 €/m²	The costs refer to **vertical façade** area and include costs related to the material and the prefabrication within the façade.
	Ventilated facade with facade panels (e.g,. Trespa panels)	253.55 €/m²	
	Rendered façade (Plaster façade on top of non-combustible insulation plaster board)	106.53 €/m²	
Mounting system	Lifting platform + crane	0.41 h/m²; 31.83 €/m²	The costs refer to **vertical façade** area and include the cost related to works at the building site for the installation of the prefabricated façade.
	Scaffolding + crane	0.27 h/m²; 33.15 €/m²	The costs refer to **vertical façade** area and include the

			cost related to works at the building site for the installation of the prefabricated façade.
Removal of old facade cladding	No removal	-	
	Yes removal	0.15 h/m²; 9.09 €/m²	The costs refer to **vertical façade** area and include the cost related to works at the building site for the removal of old façade cladding.
Anchoring type for prefabricated facade	Facade mounted	0.25 h/m; 65.21 €/m	The costs refer to building **length** and include the cost related to works at the building site for anchoring the prefabricated façade at the bottom of the building. This anchoring type relies on using a steel beam screwed to the existing building, working as support for the new prefabricated envelope.
	New Foundation	1.08 h/m; 425.46 €/m	The costs refer to building **length** and include the cost related to works at the building site for anchoring the prefabricated façade at the bottom of the building. This anchoring considers the construction of a new concrete foundation for supporting the new prefabricated envelope.
Distance from building site	≤ 50 km	12.6 €/m²	The costs refer to **vertical façade** area and include only transport of the prefabricated façade.
	> 50 km & ≤ 250 km	37.22 €/m²	The costs refer to **vertical façade** area and include transport of the prefabricated façade and one overnight stay for a worker.
	> 250 km	44.52 €/m²	The costs refer to **vertical façade** area and include costs for long-distance transport of the prefabricated façade, one overnight stay for a worker and a driver for the truck.

After estimating the initial investment cost for each renovation package and intervention typology, an evaluation of the expenses' dues after a 50-year-long period has been provided.

Since performing a detailed Life Cycle Cost (LCC) analysis for each renovation package would have been highly time-consuming, the final cost after the considered period has been calculated as a percentage of the initial investment cost.

The proportionality factor has been chosen evaluating the result of a fully developed LCC analysis based on a reference example (see preliminary LCC analysis presented in 4RinEU Deliverable 2.2 "Prefabricated multifunctional façade and technical booklet", Chapter 6).

Therefore, it has been assumed that for a renovation performed in a standard way, providing only external insulation and new windows, the expenditures after 50 years would be +88% with respect to the initial investment cost: this amount is mainly due to the fact that, during that service time, the insulation would probably undergo one substitution. In the case of retrofits performed with the prefabricated façade approach, after the 50 years period, expenditures would amount to +13.3% of the initial investment costs. This lower percentage is mainly related to the fact that no relevant cost items are expected during the evaluated period, apart from regular maintenance of the external façade layer and integrated technologies.