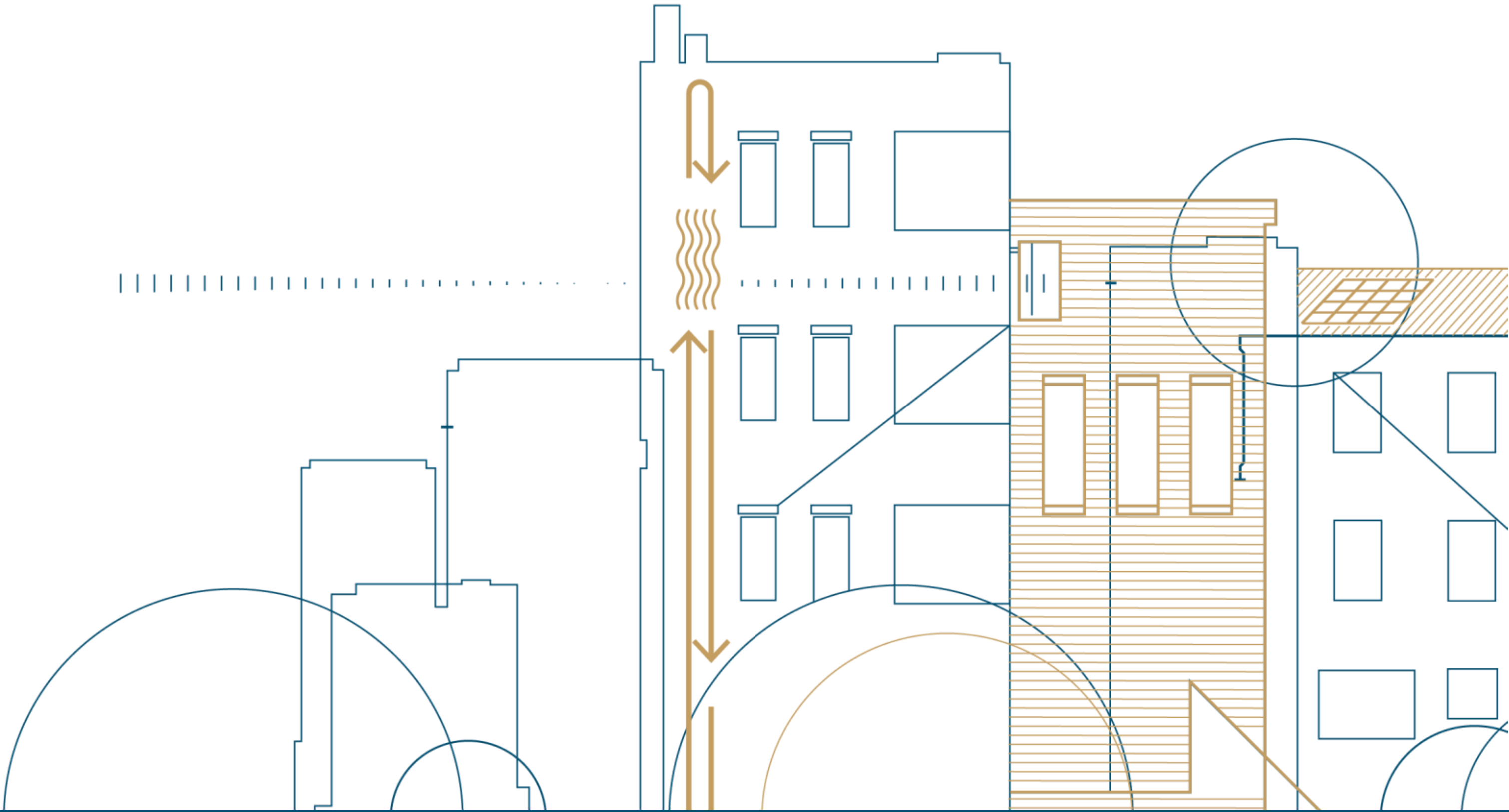
REHOUSE



D2.1

Taxonomy for Renovation Packages Characterisation

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EXECUTIVE SUMMARY

This report presents the taxonomy, or data model, with the detailed definition of the categorization of the different Renovation Packages (RP), consisting of several components with a promising technological innovation, of the REHOUSE project. The data model of the RP defined in this report will be used as a basis for the digitisation of the 8 RP defined in the REHOUSE project. It will have the flexibility to be adapted for potential standardisation and extended to different RP defined in other contexts, as well as generate potential synergies and expected impacts of the components of each of the RP. In this context, the use of this data model will be useful to other technicians who have to apply renovation solutions in deep renovation projects of buildings, based on renovation packages. This report is a summary of the work developed as part of the task 2.1-*Taxonomy of Renovation packages* of the REHOUSE project. The data model defined will be improved and adapted during the course of the REHOUSE project, according to the needs that will arise during its implementation, and the results of its adaptation will be included in subsequent project reports.

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LIST OF ABBREVATIONS

ACRONYM	DESCRIPTION
BIPV	Building Integrated Photovoltaics
CapEx	Capital Expenditures
COP	Coefficient Of Performance
D	Deliverable
DBL	Digital Building Logbook
EC	European Commission
ECM	Energy Conservation Measure
HVAC	Heating, Ventilation, and Air Conditioning
IFC	Industry Foundation Classes
LCA	Life-Cycle Assessment
LCC	Life-Cycle Costing
LCI	Life-Cycle Inventory
ML	Machine Learning
OpEx	Operating Expenses
RES	Renewable Energy Systems
RP	Renovation Packages
SoTA	State-of-The-Art
TRL	Technology Readiness Level
WP	Work package

1 INTRODUCTION

1.1 PURPOSE AND SCOPE OF THE DOCUMENT

This deliverable shows the work carried out for the development of the taxonomy of the Renovation Packages (RP), defined as a data model in the scope of the REHOUSE project [1] and in this report, that will be used as a basis for the digitalisation of the 8 RP of the REHOUSE project. The output of this work will be used as main input of WP2-*Renovation Packages design, specification & digitalization (TRL6 demonstration)* of the REHOUSE project, in particular for the task 2.2-*Detailed specification of the RP* and task 2.3-*Modelling, Control and improvement of prefab/off-site construction RP* of REHOUSE.

The objectives to be addressed by the taxonomy defined are shown in Section 2. For a proper definition of the data model, a literature review has been carried out in Section 3, where other structure of data models for tools and platforms such as OptEEmAL, INTEMA or VERIFY have been take into consideration. Section 4 explains the RP characterization and Section 5 shows the formalization of the RP. In Section 7 and 8 are explained the interoperability and digitalization of the data model. Section 9 includes the main conclusions that summarize the findings, lessons learnt and next steps.

1.2 CONTRIBUTIONS OF PARTNERS

The contribution of the partners to the task 2.1 and deliverable 2.1 is shown in Table 1.

Table 1 Partners' contribution to T2.1

PARTICIPANT SHORT NAME	CONTRIBUTIONS
CARTIF	Leader of the task 2.1 and deliverable 2.1. Coordination of all the activities related to this deliverable. SoTA activities; Definition of the taxonomy/data model, development and digitalisation
CERTH	SoTA of the INTEMA and VERIFY tools. Support in the definition of the taxonomy/data model and in the validation of the data model
AMS	Support in the definition of the taxonomy/data model and in the validation of the data model
RINA-C	Support in the definition of the taxonomy/data model and in the validation of the data model
CEA	Support in the definition of the taxonomy/data model and in the validation of the data model
STEINBEIS	Support in the SoTA and in the definition of the taxonomy/data model.
NBK	Support in the definition of the taxonomy/data model and in the validation of the data model

1.3 RELATION TO OTHER ACTIVITIES IN THE PROJECT

The main connection of this deliverable to other activities, deliverables or tasks, developed in the framework of the REHOUSE project and which should be taken into consideration alongside this document in order to better understand its contents is described in Table 2.

Table 2: Connection with other activities of the REHOUSE project.

ACTIVITY	DESCRIPTION
T2.2	This task will follow the data model defined in T2.1 to advance in the TRL scale with a detailed iterative specification of the RP and their components.
T2.3	In the scope of this task, all the RP will be modelled with the common agreed data model defined in T2.1
T2.6	The RP models obtained within T2.3 (based on the data model coming from T2.1) will be one of the digital products to be considered within T2.6
T3.5	The RP models obtained within T2.3 (based on the data model coming from T2.1) should be stored in the common data repository to be deployed within T3.5
WP5	The data model described within this deliverable is one of the key inputs for a potential standardisation of the renovation packages, outlining a potential adaptation to other different contexts (see T5.4 – Standardisation of the Renovation Packages).

Figure 1 explains the workflow of the connection of the data model (taxonomy) with the rest of the tasks.

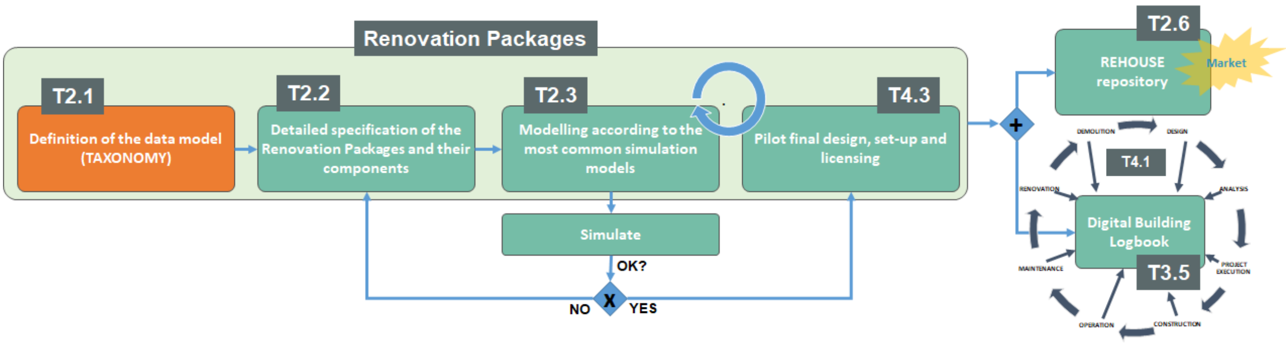

Figure 1: Visual image of the connection of task 2.1 with other activities.

2 OBJECTIVES OF THE RP DATA MODEL

The data model of the RP is one of the main aspects of the REHOUSE project because it represents, in a conceptual model, the structure to be followed by the 8 RP that will be digitalised and implemented in the demo sites in the project. This data model can be considered as a kind of ontology, and will sets the basis for the standardisation of RP in other contexts.

The main purpose of the data model is to provide the information necessary to define a RP in detail. With this aim, the main objectives of the data model for the RP are:

- Rigorous definition of the features and aspects of a Renovation Package.
- Categorise the specific solutions, the area to be applied, and the associated co-benefits of their use.
- Define a standard data model so that it can be modified and adapted to other RP in a different context.

3 BACKGROUND AND METHODOLOGY

This section is focused on the literature searching and the information collection both from public sources and also within each REHOUSE partner know-how. Some existing tools and platforms have been taken into consideration as a basis for the definition of the data model of the Renovation Package of the REHOUSE project. This is the case of the OptEEmAL platform, INTEMA or VERIFY tools, explained in more detail in the next subsections.

In June of 2020, the European Union published the EU Taxonomy Study [2] with the aim of setting six climate and environmental objectives: *Climate change mitigation and adaptation; sustainable use and protection of water and marine resources; transition to a circular economy; pollution prevention and control; and protection and restoration of biodiversity and ecosystems*. The development of this taxonomy was intended to provide a clear definition or common language of what is considered as sustainable, for which it defined itself as a classification system. The taxonomy was validated in real buildings and projects, to test the robustness of the structure and criteria envisaged in the taxonomy for which it was created. This validation was done by the German Sustainable Building Council (DGNB) and published as "*EU Taxonomy Study - Evaluating the market-readiness of the EU taxonomy criteria for buildings.*" [3] This study was done to test the robustness of the Taxonomy's intended criteria and determine the costs and benefits of implementing the processes.

Commercial software used for energy simulation such as TRNSYS [4] has its own Standard Component Library. These libraries have a defined common structure that can be used for different elements, and the end-user can generate new components following that structure. In the case of TRNSYS, the main categories of the components are divided in [5]: *Controllers, Electrical, Ground Coupling, Heating, Ventilation, and Air Conditioning (HVAC), Hydrogen Systems, Hydronics, Loads and Structures, Obsolete, Output, Physical Phenomena, Solar Thermal Collectors, Thermal Storage, Utility, Weather Data Reading and Processing*. Each of these categories has different components. New components can be generated using the TRNSYS Model File (.tmf format).

The next subsections explain in detail the structure of the data model of OptEEmAL, INTEMA and VERIFY tools.

3.1 OptEEmAL

As part of the H2020 OptEEmAL project (*Optimised Energy Efficient Design Platform for Refurbishment at District Level*) [6], was defined a catalogue of Energy Conservation Measures (ECMs) to provide all the information necessary to calculate the performance of different possible renovation scenarios. A review of existing classification methodologies was carried out, identifying that the National Residential Efficiency Measures (NREL) was one of the most relevant, which was adapted for the definition of the ECMs for OptEEmAL project. These ECMs were classified into four typologies of refurbishment strategies: passive, active, control and renewable. The implementation of these strategies is divided in (1) strategies to improve the thermal properties of the building envelope, and (2) strategies to improve the heating/cooling and domestic hot water systems.

The first step in the creation of the catalogue was to analyse the requirements to be covered by the ECMs (functional and non-functional), taking into consideration the expected functionalities of the OptEEmAL platform [7].

In order to address the creation of a common structure, seven different levels were defined:

- The firsts 5 levels focused on the type of ECM, the location of the application on the building (e.g. façade, roof, floor and openings), and the description of the ECM, applying these levels to all ECMs.
- The level 6 focused on the layers included in each of the ECMs and the type of material used and applied only to passive ECMs.
- Level 7 was divided in two main parts, the common part to be applied in all of the type of ECMs, and the specific part different for each of the 4 typologies (passive, active, control and renewable). The common part was focused on the application level, describing the functional unit used for the ECM (e.g. square meter for passive, and capacity (nominal power, volume, etc.) for active and renewable), and the advantages, disadvantages, barriers, application scale, installation and maintenance data, and operation requirements, etc. This level 7 includes all the information needed for the calculation of the Life-Cycle Assessment (LCA), the environmental data, and Life-Cycle Costing (LCC), the economic data, of the solution. For the passive ECM, the last part of level 7 focused on the thermal properties of the individual layers as well as their thickness. For the active ECM, this last part of level 7 focused on the element specifications, e.g. for the chiller the nominal Coefficient Of Performance (COP). For the renewable ECM, e.g. for a solar collector the heat loss coefficient was included.

The ECMs created for OptEEmAL catalogue were digitalised in XML format. The information contained in each ECM is textual and numerical, so a database was created in the project to store the information of the catalogue.

Figure 2 shows an example of the types of Passive Strategies of the ECM catalogue.

Passive strategies	A-Envelope	A1-External	A1.1-Ventilated facade
			A1.2-ETICS
		A2-Internal Insulation	A2.1-Floor
			A2.2-Wall
			A2.3-Roof
		A3-Air Chamber Insulation	
	B- Window replacement		

Figure 2: Passive Strategies of the ECM catalogue. Source: [7] ©2016 OptEEmAL Consortium Partners.

3.2 INTEMA

INTEMA.building is a submodule of the general INTEMA Suite of tools. This module uses white-box models of energy-related physical assets as a basis, strengthened, when historical or real-time data are available, with black-box developed models; resulting in a grey-box model in the energy field. Using this open-access grey-box modelling approach, able to be strengthened as well through the use of black-box modelling approaches, simulations of various energy systems can be performed (district heating networks, electrical grids, combustion power systems etc.) In addition, also custom-made tools are being developed in various programming languages (Python [8], etc.) to support specific research needs.

Forecasting algorithms are as well integrated within the INTEMA platform to support the scheduling of the grid assets, based on each time requirements. These algorithms are based on either statistical or Machine Learning (ML) approaches, including several network types: Artificial Neural Networks (ANN), Support Vector Routing (SVR), Long short-term memory (LSTM), Gradient Boosted Trees (GBT), AutoRegressive Integrated Moving Average (ARIMA), and topologies (two-stage, ensembled, hybrid).

INTEMA.building is based on the open-source AixLib and BuildingSystems libraries, currently being developed to be fully customizable with a web-based user-friendly interface. The tool combines:

- The power-related modules of the ModelicaStandardLibrary,
- The well-validated open-source libraries for the building sector Buildings, AixLib, BuildingSystems.
- Custom-made in-house components (e.g. lithium-ion battery, PCM thermal battery).

All necessary passive (i.e. walls, windows) and active (i.e. photovoltaic panels, boilers, heat pumps, batteries) components, together with the corresponding controls, are combined to form the appropriate representation of the building system automatically, following a specific data model architecture.

INTEMA.building is based on its internal data model that structures the relevant information in a well organised, extendable and consisted way. The data model has many similarities with the data model that is being developed in the present deliverable, as both refer to building energy systems. Thus, passive entities like wall layer, window etc., as well as active elements such as photovoltaics and heat pumps are common between the two data structures. Still, there is several design choice differences that stems from the different requirements of the two implementations, i.e. the REHOUSE project data repository and the *INTEMA.building* as a generic building performance simulation platform. An adaptor component will be utilized when needed to link the two data models and bridge the differences that emerge.

The general view of INTEMA.building data model is presented in Figure 3 in an entity-relationship diagram form. The main node of the data model is the zone entity class. This comes from the fact the *INTEMA.building* supports multi-zones simulations capturing the energy exchanges between zones of different uses (e.g. residential and office), served by different systems or even neighbouring with unconditioned zones. Thus, each zone is related with the corresponding passive and active (HVAC and electrical) systems. Some additional important notes include:

- Building systems can belong to multiple users enabling collaboration
- Every asset (walls, windows, heat pumps etc.) is associated with a building system, an attribute that enables rapid access to all involved information of a particular system under consideration.

- The data model is extendable by design, as additional elements can be easily incorporated, e.g. a multi-source heat pump (RP#1).
- A material library is utilized for the definition of constructions and layers of walls and slabs.

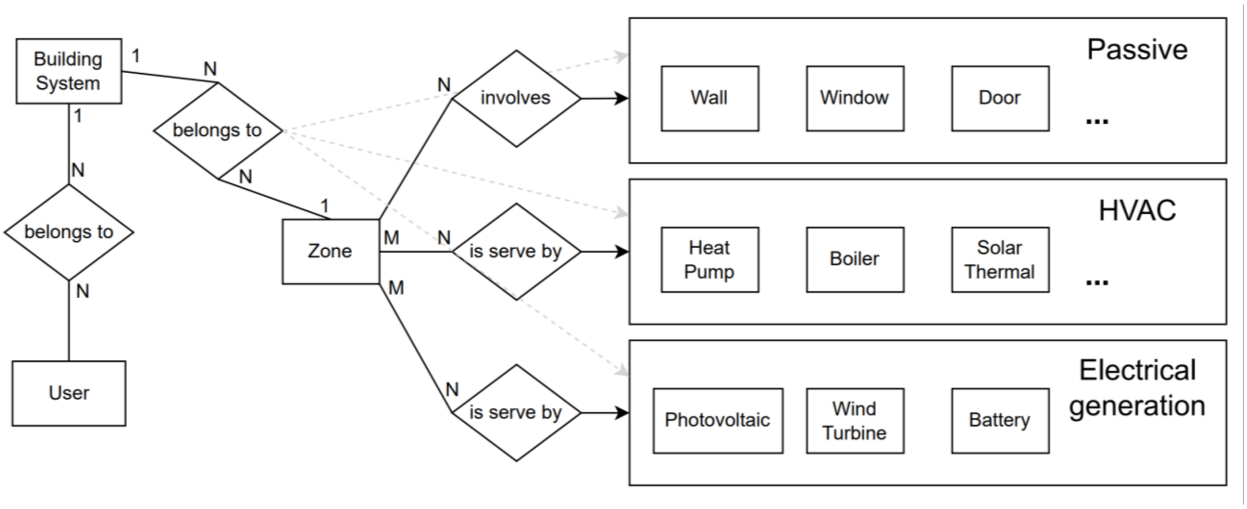

Figure 3. General entity-relationship diagram of INTEMA.building internal data model. Source: INTEMA project-CERTH

INTEMA.building is capable of importing Industry Foundation Classes (IFC)2X3 or IFC4 [9] files, according to the openBIM standard, using Python modules, to extract the necessary information and translate to its internal data model.

3.3 VERIFY

Virtual integrated platform on life cycle analysis (VERIFY) is a web-based platform performing life-cycle environmental and cost oriented computations. VERIFY platform is supported by two different modules: 1) Life-Cycle Assessment (LCA) module, and 2) Life-Cycle Costing (LCC) module to perform environmental and cost analysis, of the examined energy systems. In addition, both modules can perform real-time LCA and LCC computations through dynamic injection and utilization of data information. VERIFY implements a variety of features such as:

- Multiple user accounts (device gem Ruby on Rails [10]).
- Effortless setup of energy plans through interactive forms (Bootstrap [11] framework).
- Monitoring and gathering of remote sensor data (MQTT [12], Sidekiq [13]).
- Framework for the environmental planning and the operation of the energy/smart grid systems through well-defined performance indicators (Python [8] programming language).
- Connection with external software tools through RESTful custom APIs (Ruby [14]).
- Big-data storage repository, formatted under SAREF [15] ontology scheme.

VERIFY performs LCA and LCC calculations based on ISO 14044 [16] methodology, focusing on global warming impact. Three main stages for the target energy related technologies/systems are involved: **a) manufacturing, b) operational,** and **c) end-of-life.**

A customized database offers an inventory of global warming indicators (provided in CO_2eq) and primary energy (provided in Megajoules-MJ) for conventional and innovative technologies/systems. Data injected through IoT sensorial network temporal levels, feed the real-time LCA and LCC computations providing hour/daily/monthly environmental and costing results.

VERIFY's main outcomes include:

- KPIs for the environmental assessment of integrated technologies of all related synergetic energy networks, accompanied by associated economic KPIs, aiming at motivating users towards environmental actions (minimize emissions, decarbonization environment, decrease CO_2 footprint) and promote social-oriented benefits.
- Policy making recommendations, leading to Renewable Energy Systems (RES) penetration maximization.

A process which will be followed in the REHOUSE project is presented and will assist in the development of the data model that is presented in this deliverable.

Specifically, for the LCA and LCC in VERIFY a Life-Cycle Inventory (LCI) has to be assembled, intended to be an LCA impacts database for construction products and RPs, to be used for its incorporation in the final results. The LCI plays an important role providing environmental LCA results (as form of databases to be used by VERIFY tool) related to materials, buildings solutions, energy systems and EOL options.

Currently, the main categories of construction products supported by VERIFY's LCI are summarised in Table 3. The building specifications for each building scenario setup in VERIFY will be mostly defined by these categories, in which the RPs will be incorporated.

Table 3: Categories of the Life Cycle Inventory supported by VERIFY

GENERAL SPECIFICATIONS	TYPE
Accessories	Ceramics/ Metals/ Plastics
Electric generators	Photovoltaic
Electrical storage	Li-ion/ lead acid / flow
Glazing	Frames: Aluminium/ PVC/ Wood Glazing: Normal glass/ Laminated glass/ Thermochromic
Insulation	Aerogel / Cellulose / Elastomer / Polystyrene / Foam Glass / Glass wool/ Natural wool / Polyurethane / Stone wool / Wood wool
Thermal sources	Air conditioning / Boiler / Heat pump / Infrared / Resistive
Various assets	Solar Panel
Water Storage	Hot water: copper / iron / steel

In the case of the LCC data, not only the direct and the indirect impact of the installation and usage of RPs is included but also the Operating Expenses (OpEx) during the lifecycle of the building. Similarly, as the LCA information, the idea is to gather into the database economic values (i.e. Capital Expenditures (CapEx) and OpEx) for indicative capacities of the technologies. This data collection might be conducted with the direct input from REHOUSE partners or through an extensive literature and market review.

After the LCI construction, LCA and LCC will be performed for REHOUSE's buildings, through VERIFY, under three input data scales:

- Estimated data information through APIs from external tools (synthetic data, no need for time-series data).
- Extended historical data (partial need for time-series data).
- Sensor real time data (automated time-series data import).

During the environmental and costing analysis when building retrofitting is applied, the current and planned components/technologies description must be provided. This description includes the exact components used to assemble the building, along with their exact specifications that are used in the building. The CO_2 emissions and primary energy details provided in the LCI for certain functional units of the technologies, are scaled accordingly to match the functional units used in every scenario.

In case that a specific technology does not exist in current building status (e.g. PV panels installation, building insulation) the dedicated input fields remain blank. Table 4 to Table 7 provide detail input specifications, regarding the renewable production, active and passive technologies that are available for the LCA and LCC analysis through VERIFY platform.

Table 4: The data required for setting up a single solar panel. One or multiple Photovoltaics can be provided

COMPONENT: SOLAR PANELS	INPUT
Installed Power	KWp
Number of Panels	#
Mounting Type	ground/roof flat/roof slanted/building integrated
Type	Monocrystalline/Polycrystalline
Model Type	model id/name
Tilt angle	degrees

Table 5: The data required for setting up a temperature-related component. One or multiple of these components (boiler, heat-pump, air-condition) can be provided by user.

COMPONENT: BOILER, HEATPUMP, AIR CONDITION	INPUT DATA CURRENT INFRASTRUCTURE
Thermal Rating	kW
Usage	%
Heat Efficiency	Efficiency heat (value)
Cool Efficiency	Efficiency cool (value)

Table 6: The data required for setting up an insulation component. One or multiple insulation components can be provided by user.

COMPONENT: INSULATION	INPUT DATA CURRENT INFRASTRUCTURE
Insulation Surface	m^2
Material	Natural Wool/ Glass wool/ Polyurethane, etc.
Thickness	mm
Application area	Orientation (N/S/E/W/NE/NW wall, ceiling, floor)
Insulation Surface	m^2

Table 7: The data required for setting up a glazing component. One or multiple glazing components can be provided by user.

COMPONENT: GLAZING	INPUT DATA CURRENT INFRASTRUCTURE
Opening Surface	m^2
Layers	1,2,3
Layer Thickness	mm
Glass Type	Normal/thermochromic
Frame Material	PVC, wood, aluminium
Frame Coverage	%
Orientation	Orientation (N/S/E/W/NE/NW, etc.)

During the operation phase of the VERIFY platform, timeseries data regarding the energy production, consumption, storage within the building must be provided prior to LCA and LCC analysis performance. Timeseries data can be either uploaded manually (by the use-case setup user), in .csv format (at least a period of one year in a one-hour interval) or retrieved through large data repositories via dedicated API. The set of operation data must be related both to the installed and planned equipment.

3.4 METHODOLOGY

For the definition of the data model of the RPs of project REHOUSE, previous projects identified in the background of this report have been taken into consideration. Projects such as OptEEmAL with the ECM catalogue, a project also coordinated by CARTIF, as it is also the case for the REHOUSE project, and with an active participation in the development of the ECM structure of the OptEEmAL catalogue. The INTEMA and VERIFY projects, in which CERTH has participated, have also been considered in the definition of the taxonomy of the REHOUSE project. One of the main differences between a RP and an ECM defined in the OptEEmAL project is that a RP can contain different elements, where an ECM could be considered as an element. A RP has a more complex structure because it can have different typologies of refurbishment strategies included, such as passive, active and control strategies in the same RP.

The data model of the REHOUSE RPs has focused on covering all the requirements defined by the previous examples, to be more flexible and standardised for potential standardisation and future extensions and replications. The REHOUSE project has also specific requirements that have been included in the data model. The definition of the requirements of the data model has followed an Integrated Project Delivery (IPD) approach, involving in the data model all partners responsible in some way for the implementation of the RP, even if these partners were not involved in the digitalisation of the RP, as was the case of PSYC, RENEL, NTUA, StT, RI, TWR and WOODS. The partners involved in task 2.1 has been in charge of the validation of the 8 RP of the project, with the support of other partners of the consortium involve in each of the RP, as shown in Table 8. CARTIF has defined the data model and supported partners’ understanding of it, as well as updating the data model according to the inputs received from each of the RPs responsible.

Table 8: Partners in charge of validating the RP. Note: H&C- Heating&Cooling; BIPV-Building Integrated Photovoltaics.

RP			CONTRIBUTORS PARTNERS TASK2.1	SUPPORT PARTNER
1		Multi-source Heat Pump	CERTH	PSYC
2		Adaptable/ dynamic Building Envelope	CERTH	RENEL
3		Smart-Wall	AMS	NTUA
4		Centralised Holistic H&C Renovation Kit	RINA-C	StT
5		Multipurpose Façade System with bio-based Insulation and BIPV	RINA-C	RI
6		PanoRen	CEA	TWR
7		Activated Cellulose Thermal Insulation made of Wood Waste	CERTH	WOODS
8		Intelligent Windows System	CERTH	WOODS

The data model has been represented as an entity-relationship diagram, which makes it easy to understand its structure and relations between entities. The elements of an entity-relationship diagram are shown in Table 9.

Table 9: Symbols that represent an entity-relationship diagram.

ENTITY	relationship	entity attribute
A real-world object with an independent existence that can be differentiated from other objects.	Relationships between entities.	Property or characteristic of an entity.

4 RP CHARACTERISATION

This section contains a text description of what a RP is, together with its main features in order to help the reader understand the data model defined (and presented) in section 5.

A RP is a set of components with a promising technological innovation (typically energy conservation measures) that is deployed in a building or a demo-site.

4.1 MAIN FEATURES OF A RENOVATION PACKAGE

A RP should define specific solutions, application areas, associated co-benefits and main expected impacts of its different elements as a bases for a potential standardisation and to outline potential adaptations to different context. Considering this issue, the RP data model has been defined in a very general way in order to be able to describe, not only the 8 RP considered within the REHOUSE project, but also other different RP someone may want to describe in the future using REHOUSE RP data model. Besides, and as the RP are being defined at this moment, one of the main objectives of the defined data model is to be as flexible as possible in order to make it easy to modify and/or to extend it.

Within the RP concept that is being addressed in the scope of the REHOUSE project, other features (apart from the ones that make up the RP) should be described in order to completely detail a specific RP. Those kinds of features are related to associated co-benefits and expected impacts, and also to the building assessment information (distinguishing between the different phases in the building lifecycle). Besides, the different single materials that the elements are composed by are also being considered in the data model.

4.2 ELEMENTS OF A RENOVATION PACKAGE

As it will be deeply explained in section 5, a RP may contain passive, active, and protection & control elements. Passive elements are part of passive building strategies, forming part of the architectural structure of the building, as well as building elements (non-active) to minimise energy consumption and improve the thermal comfort of the buildings. On the contrary, an active element uses or produces energy in order to achieve a result, and are part of the building's active strategies, including those integrating renewable energy. Last but not least, protection & control elements are devoted to the description of other complex elements not passive nor active (e.g. automatic fire suppression system).

In the scope of the passive elements, different layers can be considered, being able to specify a lot of useful attributes for each of them (e.g. thickness, density, specified heat). Besides, opening objects (such as windows or doors) can be described using the data model, and also what has been called as "other openings" (e.g. cavities). For the opening objects, both the glazing and the frames can be described, and also the door panels.

Concerning active elements, different categories have been identified: solar-thermal systems, PV systems, heating/cooling systems, ventilation systems and storage systems. Multiple features can be specified for each of the aforementioned categories.

5 RP FORMALISATION

This section presents the formalisation of the data model to address the requirements defined in the characterisation section. First of all, the description of the process of generating the data model is addressed. Section 5.1 presents the diagram of the data model, and section 5.2 describes all the entities and attributes contained in the data model.

5.1 DATA MODEL DIAGRAM

As stated in the previous chapter, and in order to make easy the process of improving the initial diagram with the collaboration of all the involved partners, an entity-relationship diagram was used for this collaborative work because that kind of diagrams are easy to understand by most of the people. Figure 4, Figure 5, Figure 6, Figure 7, and Figure 8 show the final version of the diagram as a result of various iterations in order to catch the needs of all the involved partners. Seven images have been used to show the diagram in order to try to guarantee an optimal visualization of it. It is important to notice that the aforementioned images contain notes giving information about the possible values of some attributes.

As shown in the images below, a Renovation Package can contain several elements, and each of those elements can be of one of the following types/categories: **PASSIVE** (Figure 4); **ACTIVE** (Figure 5 and Figure 6); and **PROTECTION AND CONTROL** (Figure 7). Besides, there are different features of a renovation package that should be described, as the **LCC** and **LCA** parameters (Figure 8) and the associated **co-benefits** and **impacts** (Figure 10).

As shown in Figure 4, **PASSIVE ELEMENTS can have multiple LAYERS** (described by different attributes that will be detailed within section 5.2), and also **multiple OPENINGS**. From its side, openings can be windows or doors, called *OPENING OBJECTS*, or *OTHER OPENINGS* (e.g. cavities). Last but not least, an opening object can contain a GLAZING, a FRAME or a PANEL, each of them with its own features.

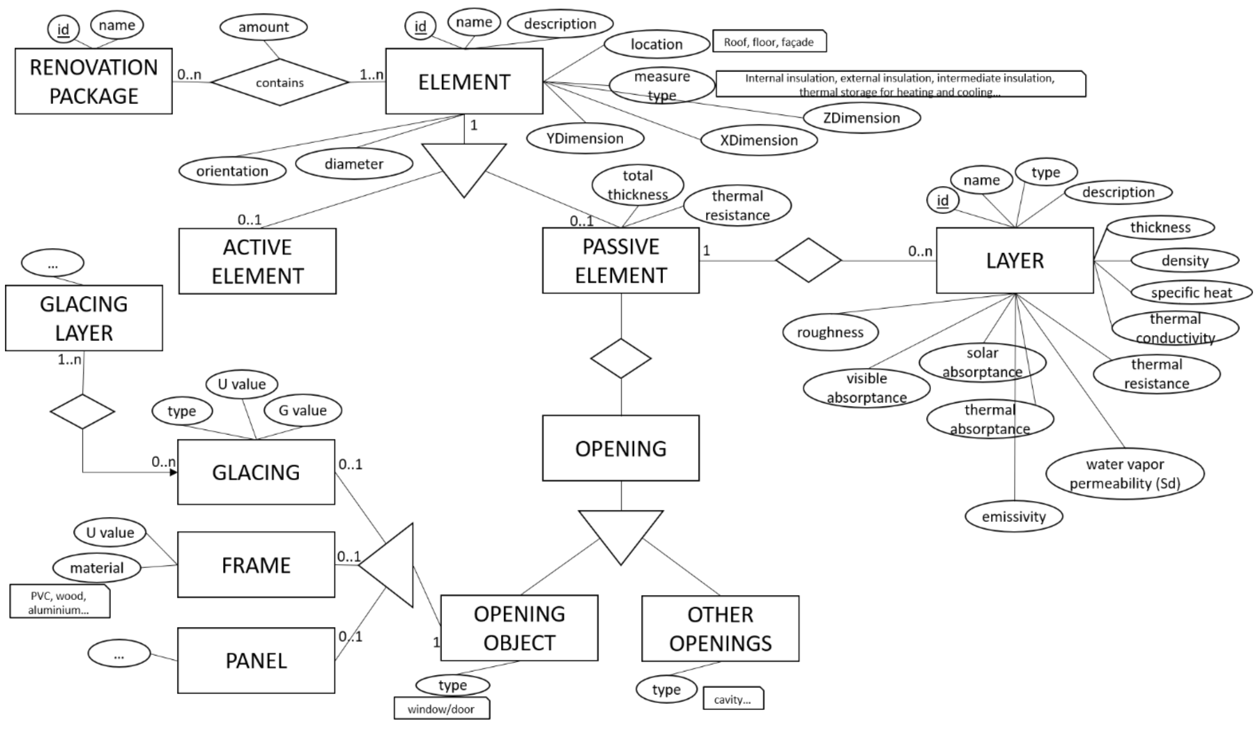

Figure 4: Passive Elements (Renovation Packages data model)

Figure 5 shows the different types of active elements that have been distinguished. From this point of view, an active element can be a **SOLAR-THERMAL SYSTEM**, a **PHOTOVOLTAIC SYSTEM**, a **HEATING/COOLING SYSTEM**, a **VENTILATION SYSTEM** or a **STORAGE SYSTEM**. Besides, a STORAGE SYSTEM can be based on *THERMAL* or on *ELECTRICAL STORAGE*.

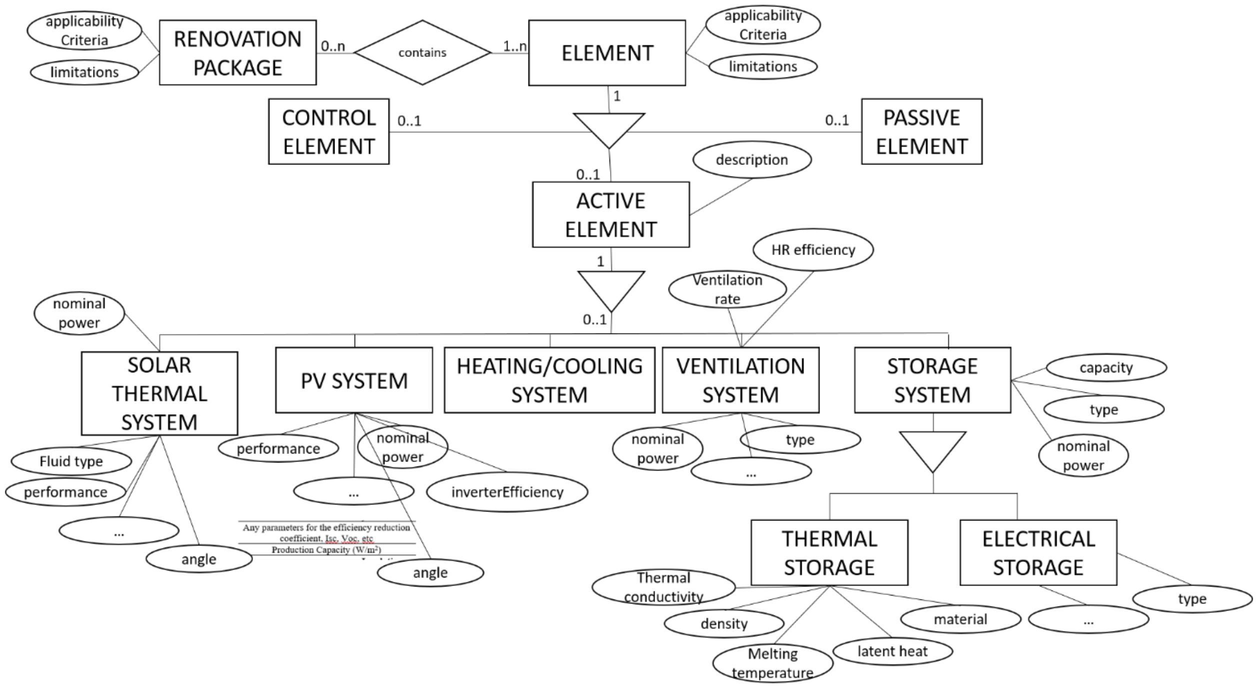

Figure 5: Active Elements (Renovation Packages data model)

As stated in Figure 6, a **HEATING/COOLING SYSTEM** may contain *GENERATION ELEMENTS*, *DISTRIBUTION ELEMENTS* and *TERMINAL UNITS*. In this case, a heating/cooling system may contain multiple of these entities (generation and/or distribution elements and terminal units) because that way the model is able to group all the elements linked to the same heating/cooling system.

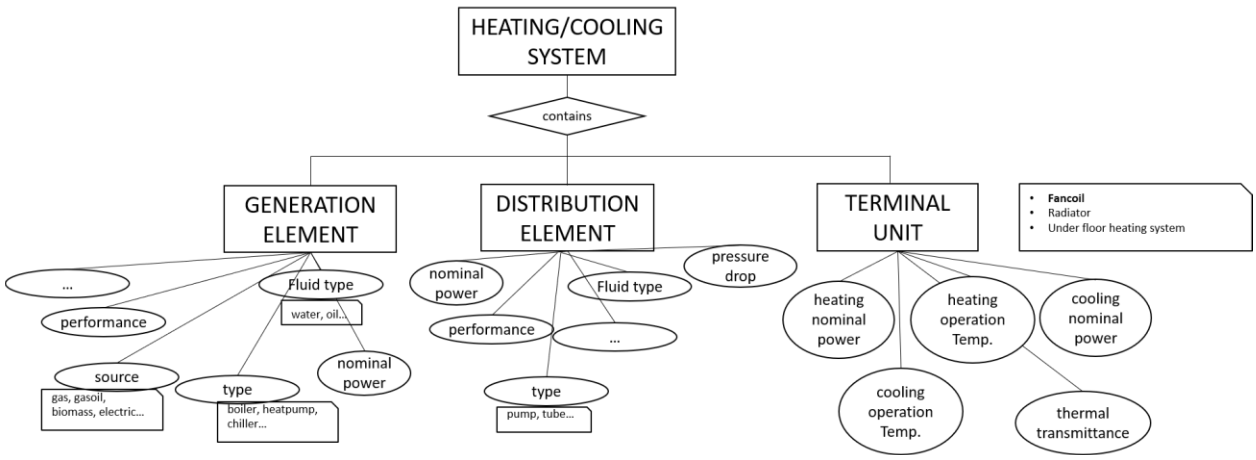

Figure 6 Heating/Cooling systems (Renovation Packages data model)

Figure 7 is devoted to the **PROTECTION AND CONTROL ELEMENTS**, which are in charge of described those systems that are not the ones described until now (e.g. fire protection system), and may contain *SENSORS*, *CONTROLLERS* and/or *ACTUATORS*.

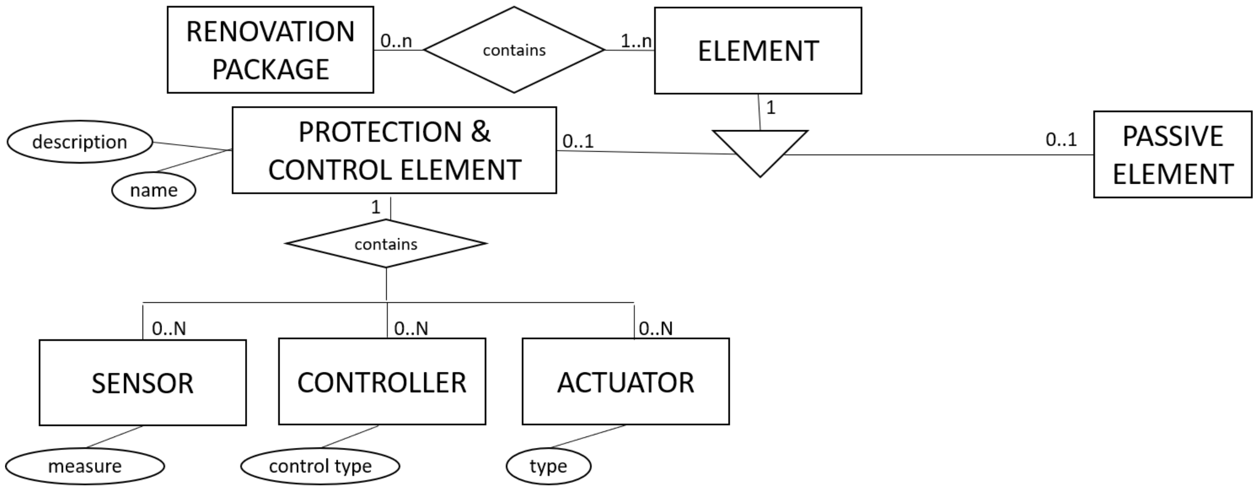

Figure 7: Protection and Control Elements (Renovation Packages data model).

Figure 8 shows the way to describe parameters linked with **LCC** and **LCA** that should be specified for each of the elements that constitutes a renovation package. Besides, information about the quantity of the different materials that make up an element can be described based on the proposed data model. The entities linked to the LCC and LCA parameters (*PRODUCT & CONSTRUCTION STAGE PARAM*, *USE STAGE PARAM*, and *END OF LIFE PARAM*) have been created based on the life cycle stages of a building taken from the CEN/TC 350 standard, EN 15643-2 Sustainability of construction works-Environmental product declarations-Product category rules (explained in detail in Figure 9). In Figure 8 the letters (A), (B), (C) and (D) linked with each stage of the building life cycle have been indicated.

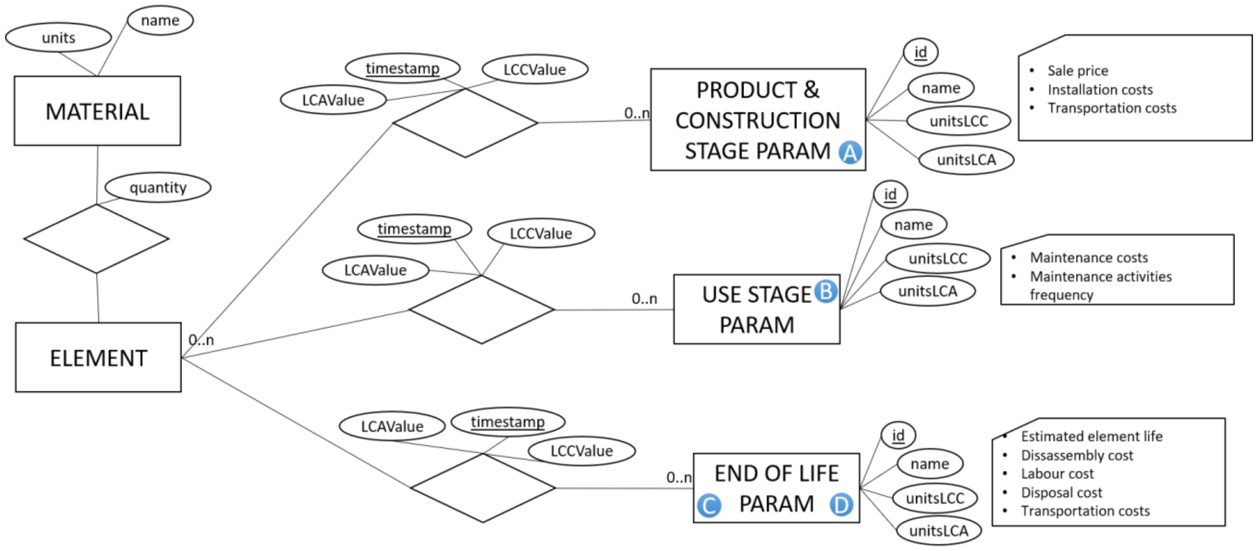

Figure 8: LCC and LCA parameters (Renovation Packages data model)

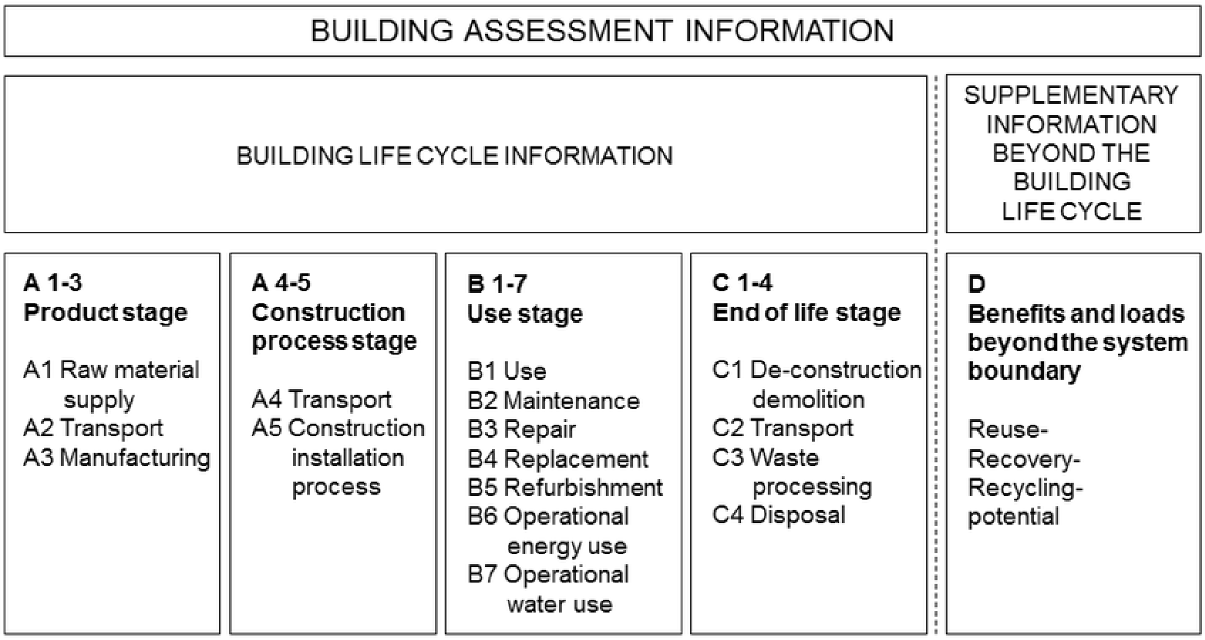

Figure 9: Life cycle stages of a building based on the CEN/TC 350 standard, EN 15643-2 Sustainability of construction works-Environmental product declarations-Product category rules.

Last but not least, Figure 10 shows the last entity of the diagram, focused on allowing for the specification of **co-benefits** and **expected impacts** of an element.

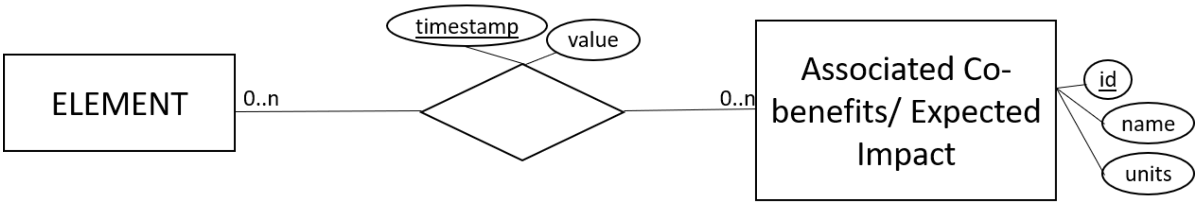

Figure 10: Associated co-benefits and impacts (Renovation Packages data model).

5.2 FEATURES DESCRIPTION AND CHARACTERISATION

This section describes all the features specified for the different entities of the renovation packages data model, defined in section 5.1, in order to better explain the data that should be included on them.

It is important to notice that, probably, more features will come up as the activity of describing each RP is started, so the data model will be updated according to each modification made in the coming months. Those updates will be included in other WP2 - *Renovation Packages Design, Specification & Digitalisation* deliverables of the REHOUSE project.

All the functions of the different entities that compose the data model are described below:

RENOVATION PACKAGE:

- Id (integer): unique identifier linked to each renovation package.
- Name (string): name of the RP.
- Applicability criteria (text): description of the applicability criteria linked to the RP.
- Limitations (text): limitation on the deployment of the RP.

ELEMENT: describes each component which make up a RP.

- IdElement (integer): unique identifier linked to each element.
- Name (string): name of the element.
- Description (text): description of the element.
- Location (string): floor, roof, façade…
- Measure type (string): internal insulation, external insulation, intermediate insulation, thermal storage for heating or cooling, …
- XDimension, YDimension, ZDimension (double): X, Y, Z dimensions of the element.
- Diameter (double): diameter of the element just in case this feature has sense.
- Orientation (string): north, south, east, west, north-east…
- Amount (double): amount of elements of this type included in the RP

PASSIVE ELEMENT:

- IdElement (integer): id of the linked element.
- Total thickness (double): total thickness of the passive element. [m]
- Thermal resistance (double): thermal resistance [(m^2·K)/W].

LAYER:

- IdLayer (integer): auto-numeric identifier assigned to each layer (just for identification issues).
- idElement (integer): identifier of the element to which this layer is referring.
- Name (string): name of the layer.
- Type (string): type of layer.
- Description (text): description of the layer.
- Thickness (double): thickness of this layer [m].
- Density (double): density of the layer [kg/m^3].
- Specific heat (double): specific heat of this layer [J/(kg·K)].
- Thermal conductivity (double): [W/(m·K)].
- Thermal resistance (double): [(m^2·K)/W].
- Water vapor permeability (double): [units].
- Emissivity (double): [units].
- Thermal absorptance (double, [0,1]).
- Solar absorptance (double, [0,1]).
- Visible absorptance (double, [0,1]).
- Roughness (string): Smooth, MediumSmooth, MediumRough, Rough, VeryRough…

OPENING OBJECT:

- IdElement (integer): id of the element linked to this opening object.
- Type (string): window/door…

OTHER OPENINGS:

- IdElement (integer): id of the element linked to this opening object.
- Type (string): cavity…

GLAZING:

- IdOpeningObject (integer): identifier of the opening object to which this glazing is linked.
- Type (string): type of the glazing being described.
- UValue (double): [W/(m^2·K)].
- GValue (double, [0,1]). 1= full transmittance

GLAZING LAYER:

- IdLayer (integer): auto-numeric identifier assigned to each glazing layer.
- idGlazing (integer): id of the glazing to which this glazing layer is linked.
- Attributes to be described.

FRAME:

- IdOpeningObject (integer): identifier of the opening object to which this frame is linked.
- UValue (double): [W/(m^2·K)].
- Material (string): PVC, wood, aluminum…

PANEL:

- IdOpeningObject (integer): identifier of the opening object to which this panel is linked.
- Attributes to be described.

ACTIVE ELEMENT

- idElement (integer): identifier of the element to which this active element is referring
- Description (text)

SOLAR THERMAL SYSTEM

- idElement (integer): identifier of the element to which this solar thermal system is referring
- Nominal power (double): [kW].
- Fluid type (double): water…
- Performance (double): [units].
- Angle (double): [º].

PV SYSTEM

- idElement (integer): identifier of the element to which this PV system is referring
- Performance (double): [units].
- Nominal power (double): [kW].
- Angle (double): [º].
- Inverter efficiency (double): [%].

VENTILATION SYSTEM

- idElement (integer): identifier of the element to which this ventilation system is referring
- Nominal power (double): [kW].
- Type (string): mechanised fans, supply ventilation, balanced ventilation…

STORAGE SYSTEM

- idElement (integer): identifier of the element to which this storage system is referring
- Capacity (double): [kWh, m^3].
- Type (string).
- Nominal power (double): [kW].

THERMAL STORAGE

- idElement (integer): identifier of the element to which this thermal storage is referring
- Thermal conductivity (double): [W/mK].
- Density (double): [kg/m^3]
- Melting temperature (double): [ºC]
- Latent heat (double): [kJ/kg]
- Material (string).

ELECTRICAL STORAGE

- idElement (integer): identifier of the element to which this electrical storage is referring
- Type (string).

HEATING/COOLING SYSTEM

- Attributes to be described

GENERATION ELEMENT

- idElement (integer): identifier of the element to which this generation element is referring.
- Performance (double): [units].
- Fluid type (string): water, oil…
- Source (string): gasoil, biomass, gas, electric…
- Type (string): boiler, heatpump, chiller…
- Nominal power (double): [kW].

DISTRIBUTION ELEMENT

- idElement (integer): identifier of the element to which this distribution element is referring
- Nominal power (double): [kW].
- Performance (double): [units].
- Type (string): pump, tube…
- Fluid type (string).
- Pressure drop (double): [units].

TERMINAL UNIT: it could be a fancoil, a radiator, an underfloor heating system…

- idElement (integer): identifier of the element to which this terminal unit is referring
- Heating nominal power (double): [kW].
- Cooling nominal power (double): [kW].
- Heating operation temperature (double): [ºC].

- Cooling operation temperature (double): [ºC].
- Thermal transmittance (double): [(m^2·K)/W].

PROTECTION AND CONTROL ELEMENT

- idElement (integer): identifier of the element to which this protection and control element is referring
- Name (string).
- Description (text).

SENSOR

- IdSensor (integer): auto-incremental identifier assigned to each sensor.
- idElement (integer): identifier of the element (protection and control element) to which this sensor is referring
- Measure (string): name measure that the sensor is measuring (e.g. temperature, humidity).

CONTROLLER

- IdController (integer): auto-incremental identifier assigned to each controller.
- idElement (integer): identifier of the element (protection and control element) to which this controller is referring to.
- Control type (string).

ACTUATOR:

- IdActuator (integer): auto-incremental identifier assigned to each actuator.
- idElement (integer): identifier of the element (protection and control element) to which this actuator is referring
- Type (string): dimmer, valve…

MATERIAL: each of the material components of an element.

- idElement (integer) identifier of the element to which this material is referring.
- Name (string).
- Units (string): units in which the quantity of this material should be detailed (e.g. m^2, number)
- Quantity (double): number of units of this material that made up the linked element.

PRODUCT & CONSTRUCTION STAGE PARAM: different parameters related to the product and construction stages of the building lifecycle. As most of these parameters are related both to LCC and LCA analysis, unit in both senses can be specified. If one parameter has not sense for LCC (same for LCA), no value will be specified for the units. This explanation is also applicable for the following similar entities (use stage param and end of life param).

- IdParam (integer): auto numeric identifier that identifies to each product and construction stage parameter.
- Name (string): name of the parameter (e.g. sale price, installation cost, transportation cost).
- unitsLCC (string): units in which this parameter is specified when speaking about LCC (no units will be specified if this parameter is not linked to LCC).

- unitsLCA (string): units in which this parameter is specified when speaking about LCA (no units will be specified if this parameter is not linked to LCA).

ELEMENT_PRODANDCONSPARAM

- idElement (integer): identifier of the element to which this parameter values are referring.
- idParam (integer): identifier of the param to which the values are going to be specified.
- Timestamp (timestamp): date-time when the values of the parameter have been calculated.
- LCAValue (double): value of the parameter concerning LCA.
- LCCValue (double): value of the parameter concerning LCC.

USE STAGE PARAM

- IdParam (integer): auto numeric identifier that identifies to each use stage parameter.
- Name (string): name of the parameter (e.g. maintenance cost, maintenance activities frequency).
- unitsLCC (string): units in which this parameter is specified when speaking about LCC (no units will be specified if this parameter is not linked to LCC).
- unitsLCA (string): units in which this parameter is specified when speaking about LCA (no units will be specified if this parameter is not linked to LCA).

ELEMENT_USESTAGEPARAM

- idElement (integer): identifier of the element to which this parameter is referring
- idParam (integer): identifier of the param to which the values are going to be specified.
- Timestamp (timestamp): date-time when the values of the parameter have been calculated.
- LCAValue (double): value of the parameter concerning LCA.
- LCCValue (double): value of the parameter concerning LCC.

END OF LIFE PARAM

- IdParam (integer): auto numeric identifier that identifies to each end of life parameter.
- Name (string): name of the parameter (e.g. estimated end of life, disassembly cost, labor cost, disposal cost, transportation cost…).
- unitsLCC (string): units in which this parameter is specified when speaking about LCC (no units will be specified if this parameter is not linked to LCC).
- unitsLCA (string): units in which this parameter is specified when speaking about LCA (no units will be specified if this parameter is not linked to LCA).

ELEMENT_ENDOFLIFEPARAM

- idElement (integer): identifier of the element to which this parameter is referring
- idParam (integer): identifier of the param to which the values are going to be specified.
- Timestamp (timestamp): date-time when the values of the parameter have been calculated.
- LCAValue (double): value of the parameter concerning LCA.
- LCCValue (double): value of the parameter concerning LCC.

ASSOCIATED CO-BENETIFTS AND EXPECTED IMPACT

- Id (integer): identifier of each described co-benefit or impact
- Name (string): name of the benefit/impact.
- Units (string): units in which this benefit/impact should be specified.

ELEMENT_ COBENEFITSANDIMPACT

- idElement (integer): identifier of the element to which this parameter is referring
- idParam (integer): identifier of the param to which the values are going to be specified.
- Timestamp (timestamp): date-time when the value of the benefit/impact has been calculated.
- Value (double): value of the benefit/impact.

6 VALIDATION OF THE DATA MODEL

As stated before, and after having a first tentative version of the data model, several partners (partners involved in T2.1 and also partners responsible for the RPs) participated in the validation process (Table 8). A table was generated in order to gather the information concerning this validation, meaning checking if the proposed data model was able to contain all the information needed in order to describe each RP. This table was sent to all the partners in order to gather their opinions about the data model and the responses obtained are shown in Table 10.

Table 10: Validation of the RP data model (feedback received from the partners).

QUESTIONS	RP#1	RP#2	RP#3	RP#4	RP#5	RP#6	RP#7	RP#8
Does the T2.1 data model offers the possibility of including information of all the type of elements included in the Renovation Package?	yes	yes	yes	yes	yes	yes	yes	yes
Does the data model include all the features needed in order to describe the Renovation Package from a high-level perspective? (features directly linked with the whole RP (location, orientation, name))	yes	yes	yes	yes	yes	yes	yes	yes
Are the high-level features linked to the "Element" entity enough to describe the elements from a high-level perspective?	yes	yes	no[1] → yes	yes	yes	yes	yes	yes
Is the data model offering the possibility of completely describing the active elements of the renovation package?	yes	yes	yes	yes	yes	yes	yes	yes
Is the data model offering the possibility of completely describing the passive elements of the renovation package?	yes	yes	yes	yes	yes	yes	yes	yes
Is the data model offering the possibility of completely describing the LCC parameters to be specified for the renovation package?	yes	yes	yes	yes	yes	yes	yes	yes
Is the data model offering the possibility of completely describing the LCA parameters to be specified for the renovation package?	yes	yes	yes	yes	yes	yes	yes	yes
Are the features defined by the data model enough to describe the different elements of the renovation package?	yes	yes	yes	yes	yes	yes	yes	yes

[1] In this sense, AMS specified that maybe it would be needed to describe an automatic fire suppression system, so the entity "Protection and Control elements" was added in order to make the data model able to describe those kinds of systems. That way, and as stated in the Table 10, the "no" became a "yes".

7 INTEROPERABILITY REQUIREMENTS

This section describes the interoperability requirements of the data model with existing performance simulation tools, such as INTEMA, VERIFY, OptEEmAL, Energy+ (E+) [17], and TRNSYS [4], as shown in Table 11.

*Table 11: RP structure with the data that can be exporter to different software to perform energy calculations. Note: *Connected to the control ECM.*

DESCRIPTION				OPTEEMAL	INTEMA	VERIFY	E+	TRNSYS
Element	Id			YES	YES	YES	YES	YES
	Name			YES	YES	YES	YES	YES
	Description			YES	YES	YES	NO	NO
	Location (Façade, roof, floor, openings)			YES	YES	YES	NO	YES
	Measure type (Int-Interm-Ext.Insulation, etc.)			YES	YES	YES	YES	NO
	xDimension			YES	YES	YES	YES	NO
	yDimension			YES	YES	YES	YES	NO
	zDimension			YES	YES	YES	YES	NO
	Diameter			YES	YES	YES	YES	NO
	Orientation			YES	YES	YES	YES	NO
		Product & construction Stage Param.	Id	YES	NO	YES	NO	NO
			Name	YES	NO	YES	NO	NO
			unitsLCC	YES	NO	YES	NO	NO
			unitsLCA	YES	NO	YES	NO	NO
		Use Stage Param.	Id	YES	NO	YES	YES	NO
			Name	YES	NO	YES	YES	NO
			unitsLCC	YES	NO	YES	YES	NO
			unitsLCA	YES	NO	YES	YES	NO
		End of life Param.	Id	YES	NO	YES	NO	NO
			Name	YES	NO	YES	NO	NO
			unitsLCC	YES	NO	YES	NO	NO
			unitsLCA	YES	NO	YES	NO	NO
		Associated Co-benefits/ Expected Impact	Id	YES	NO	YES	NO	NO
			Name	YES	NO	YES	NO	NO
			units	NO	NO	YES	NO	NO
Passive element	Total thickness			YES	YES	YES	YES	YES
	Thermal resistance			YES	YES	NO	YES	YES
	Layer	Id		YES	YES	YES	YES	NO
		Name		YES	YES	YES	YES	YES
		Type		YES	YES	YES	YES	YES
		Description		YES	YES	YES	YES	NO
		Thickness		YES	YES	YES	YES	YES
		Density		YES	YES	NO	YES	YES
		Specific heat		YES	YES	NO	YES	YES
		Thermal conductivity		YES	YES	NO	YES	YES
		Thermal resistance		YES	YES	NO	YES	NO
		Water vapor permeability (Sd)		NO	YES	NO	YES	NO
		Emissivity		NO	YES	NO	YES	YES
		Thermal absorptance		YES	YES	NO	YES	NO
		Solar absorptance		YES	YES	NO	YES	YES
		Visible absorptance		YES	YES	NO	YES	NO
		Roughness		YES	YES	NO	YES	NO
	Opening	Other openings	Type (cavity)	YES	YES	YES	YES	NO
		Opening object	Type (window/ door)	YES	YES	YES	YES	YES
			Glazing>type	YES	YES	YES	YES	NO
			Glazing>Uvalue	YES	YES	NO	YES	YES

DESCRIPTION				OPTEEMAL	INTEMA	VERIFY	E+	TRNSYS
			Glazing>Gvalue	YES	YES	NO	YES	YES
			Glazing>GlazingLayer	YES	YES	NO	YES	NO
			Frame>Uvalue	YES	YES	NO	YES	NO
			Frame>material	YES	YES	YES	YES	NO
			Panel	YES	YES	NO	YES	NO
Active element	Solar thermal system	Nominal power		YES	YES	YES	YES	YES
		Performance		YES	YES	YES	YES	YES
		Fluid type		NO	YES	NO	YES	YES
		Angle		NO	YES	YES	YES	YES
	PV system	Nominal power		YES	YES	YES	YES	YES
		Performance		YES	YES	YES	YES	YES
		inverterEfficiency		YES	YES	YES	YES	YES
		Angle		NO	YES	YES	YES	YES
	Heating/ Cooling system	Generation element	Nominal power	YES	YES	YES	YES	YES
			Performance	YES	YES	YES	YES	YES
			Fluid type	YES	YES	NO	YES	YES
			Type (boiler, chiller, etc.)	YES	YES	YES	YES	YES
			Source (gas, biomass, etc.)	YES	YES	YES	YES	NO
		Distribution element	Nominal power	NO	YES	NO	YES	YES
			Performance	NO	YES	NO	YES	YES
			Fluid type	YES	YES	NO	YES	YES
			Type (pump, tube, etc.)	YES	YES	NO	YES	YES
			Pressure drop	NO	YES	NO	NO	NO
		Terminal unit (fan coil, radiator, underfloor heating, etc.)	Heating Nominal power	YES	YES	NO	YES	YES
			Cooling Nominal power	YES	YES	YES	YES	YES
			Heating Operation Temp.	YES*	YES	YES	YES	YES
			Cooling Operation Temp.	YES*	YES	YES	YES	YES
			Thermal transmittance	NO	YES	NO	NO	NO
	Ventilation system	Nominal power		YES	YES	YES	YES	YES
		Type		YES	YES	YES	YES	YES
		Ventilation rate		YES	YES	YES	YES	YES
		HR efficiency		NO	YES	NO	NO	YES
	Storage system	Nominal power		YES	YES	YES	YES	NO
		Type		YES	YES	YES	YES	NO
		capacity		YES	YES	YES	YES	NO
		Thermal storage	Material	NO	YES	YES	NO	NO
			Latent heat	NO	YES	NO	YES	NO
			Melting temperature	NO	YES	NO	NO	NO
			Density	NO	YES	NO	NO	NO
			Thermal conductivity	NO	YES	NO	NO	NO
		Electrical storage		NO	YES	YES	NO	NO
Control element	Sensor	Measure		NO	YES	NO	NO	NO
	Controller	Control type		YES	YES	NO	YES	NO
	Actuator	type		NO	YES	NO	YES	NO

8 DIGITALISATION OF THE DATA MODEL

Initially, the main idea about the digitalisation of the RP data model was to generate XML file/s in order to describe a RP. Using XML files, parsers can be easily developed to read them and obtain the needed parameters for each specific software to be used in the scope of the project. Once the digitalisation activities were started, and taking into consideration the process followed in order to obtain the aforementioned XML files (described below in Section 8.1), the project team decided to also offer the possibility of obtaining the RP information from the data base used to generate the XML files. That way, the interoperability of the RP data model digitalization is bigger considering that two options are offered concerning accessing the information of a RP:

- Through XML files
- Using a database

8.1 DIGITALIZING THE ENTITY-RELATIONSHIP DIAGRAM

As stated before, an entity-relationship diagram was created in order to easy the discussion and creation of the RP data model among all the partners. Taking this into account, and in order to take advantage of this entity-relationship diagram, the following procedure was defined concerning the generation of the XML files that will describe one RP:

I. Creation of the SQL file linked to the aforementioned (and described in section 5.1) entity-relationship diagram.

II. Creation of a database (in this case using MySQL[2]) with the structure contained in the generated SQL file.

III. Population the database with all the information to be provided for the RP that is being described.

IV. Exportation to XML files of the data contained in the database using a kind of database managing tool (in this case, DBeaver[3]) (having the information in separate files rather than everything in one single file makes easy for the user to only use the files they need).

8.2 POPULATING THE DATABASE

The process of inserting in the database all the information that is needed in order to describe a specific RP is easy using a database managing tool (e.g. MySQL Workbench[4], DBeaver).

In this case (in order to test that everything works within the process defined to generate the XML files), DBeaver has been used, and synthetic information has been introduced in the database in order to simulate the real process to be done once all the RP have been completely defined. As it can be shown in Figure 11, the process of populating the database is very easy, and it can be done just filling-in tables with the same structure than the tables to be populated. MySQL Workbench and DBeaver also allow the user to insert information contained in, for example, CSV files.

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[2] https://www.mysql.com/
[3] https://dbeaver.io/
[4] https://www.mysql.com/products/workbench/

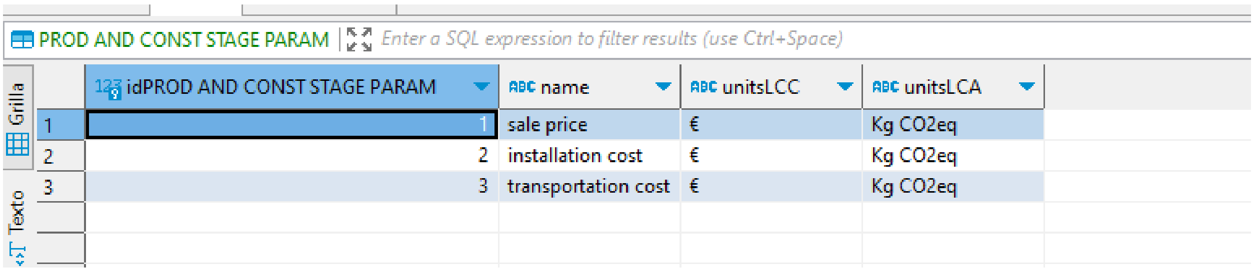

Figure 11: Populating the RP database

8.3 GENERATING THE XML FILES

Once all the information needed in order to describe a specific RP has been introduced in the database, it is time to generate the XML files (if needed because the software tools will obtain the data from the XML files instead of directly from the database). In this case, again DBeaver has been use to connect to the database and extract all the data to XML files.

The process of generating XML files from the information contained in a database is the following one:

I. Select all the tables that must be exported (in this case, all the tables contained in the database).

II. Press the right button and click on "Export data" (see Figure 12). Then select XML[5] from the different formats offered by DBeaver and then specify all the information required by the tool.

III. After selecting the export format, an XML will be created (in the folder specified) for each table of the database.

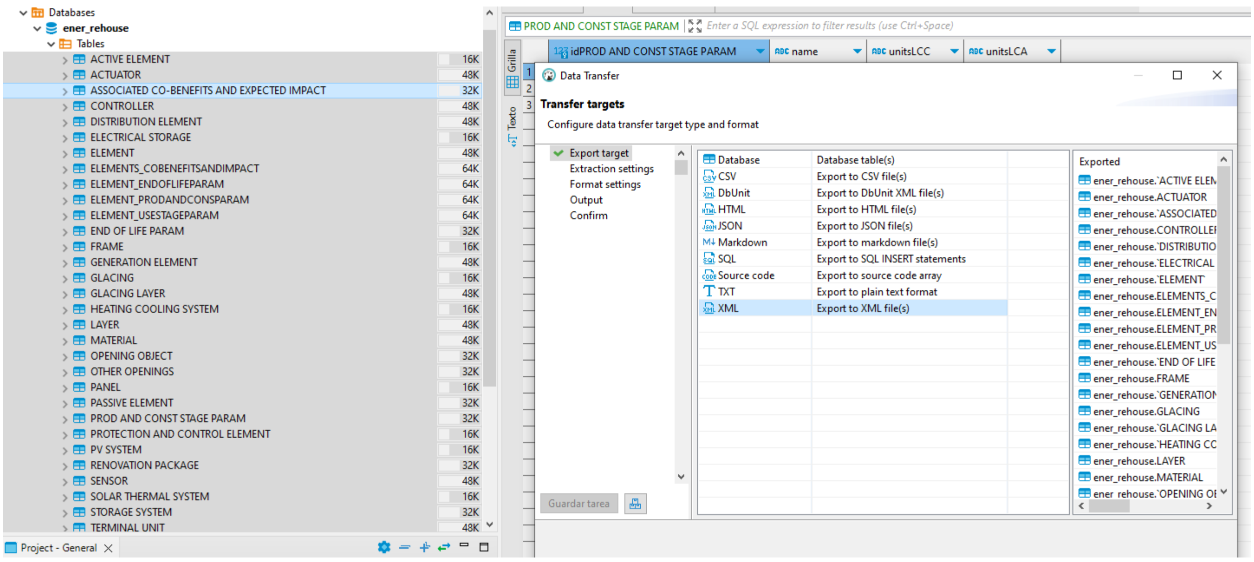

Figure 12: Using DBeaver to generate the XML files

[5] As it can be shown in Figure 12, multiple formats are available for this exportation, so more interoperability reached again because a new user would be able to export the information in another format (if they need to do so).

Using this process, well-formed XML files are obtained without a lot of efforts, so, once the database contains all the information needed, when all the RP have been perfectly defined, creating the XML files will be very easy and fast. Figure 13 shows as an example of an XML file for the table that contains the information about the PRODUCTION AND CONSTRUCTION STAGE PARAMETERS.


```xml
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE PROD_AND_CONST_STAGE_PARAM [
  <!ELEMENT PROD_AND_CONST_STAGE_PARAM (DATA_RECORD*)>
  <!ELEMENT DATA_RECORD (idPROD_AND_CONST_STAGE_PARAM?,name?,unitsLCC?,unitsLCA?)+>
  <!ELEMENT idPROD_AND_CONST_STAGE_PARAM (#PCDATA)>
  <!ELEMENT name (#PCDATA)>
  <!ELEMENT unitsLCC (#PCDATA)>
  <!ELEMENT unitsLCA (#PCDATA)>
]>
<PROD_AND_CONST_STAGE_PARAM>
  <DATA_RECORD>
    <idPROD_AND_CONST_STAGE_PARAM>1</idPROD_AND_CONST_STAGE_PARAM>
    <name>sale price</name>
    <unitsLCC>€</unitsLCC>
    <unitsLCA>Kg CO2eq</unitsLCA>
  </DATA_RECORD>
  <DATA_RECORD>
    <idPROD_AND_CONST_STAGE_PARAM>2</idPROD_AND_CONST_STAGE_PARAM>
    <name>installation cost</name>
    <unitsLCC>€</unitsLCC>
    <unitsLCA>Kg CO2eq</unitsLCA>
  </DATA_RECORD>
  <DATA_RECORD>
    <idPROD_AND_CONST_STAGE_PARAM>3</idPROD_AND_CONST_STAGE_PARAM>
    <name>transportation cost</name>
    <unitsLCC>€</unitsLCC>
    <unitsLCA>Kg CO2eq</unitsLCA>
  </DATA_RECORD>
</PROD_AND_CONST_STAGE_PARAM>
```


Figure 13: XML file for the production and construction stage parameters

9 CONCLUSIONS

This report has included the data model (taxonomy) description characterising the different Renovation Packages in different application areas and with the corresponding co-benefits. The State-of-The-Art about existing taxonomy / data models of other RP or Energy Conservation Measures has been also included in this deliverable. The digitalization of the RP has been developed as part of the task 2.1 of the REHOUSE project, and will be used as a basis for the task 2.2-*Detailed specification of the RP* and task 2.3-*Modelling, Control and improvement of prefab/off-site construction RP*.

As aforementioned, inputs from all the partners have been considered in order to create the RPs data model and, besides, and once the RP data model was available, all the partners in charge of a RP were asked to validate it in order to know if the proposed data model were able to express all the information needed. For most all the partners the data model was covering most of their needs, but slight changes were introduced in the entity-relationship diagram in order to add different concepts proposed by some partners based on their knowledge about their associated RP.

Concerning the digitalisation of the data model, a proof of concept has been developed because the RP are currently being defined, so the detailed information to describe them is not available at this moment. Once all the RP have been detailed, they will be described using the data model, and then, it will be possible to generate the XML files in order to feed the software tools to be used in each of the demo-sites.

As stated before, and although the first idea was to only generate XML files, all the information concerning the RPs description will be available in a database[6] just in case a partner prefers to access a database directly instead of reading XML files.

Finally, it is important to notice that, as aforementioned, the data model has been defined as open and updatable as possible in order to make it easy if needed to modify or update it based on the needs coming from the partners and/or the software tools to be used in each demo-site in the next stages of the project.

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