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Integration of smart building technologies costs and CO2 emissions within the framework of the new EPIQR-web application

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Abstract. The EPIQR method was developed between 1996 and 1998 within the framework of the European research programme JOULE II and with the support of the Swiss Federal Office for Education and Science. In its first versions, the EPIQR software and EPIQR+ that succeeded it, were desktop tools, allowing a precise diagnosis of the state of deterioration of an existing building and the elaboration of renovation scenarios including the different costs of the necessary works. However, deep refurbishment rate is still low. Climatic emergency state declared by most of the Swiss Cantons makes it necessary to search also for other strategies for urgent reduction of CO2 emissions. As part of the PRELUDE project, a web version of this tool has been developed to integrate both smart technologies and energy optimization actions. Some of them can be considered as soft actions, making it possible to develop a soft renovation roadmap for buildings that are not scheduled for renovation in the short term. As examples, the costs of optimization contracts, intelligent heating control, demand-controlled ventilation, abandonment of heat production from fossil fuels, integration of renewable energies into the building, and communities' creation for self-consumption of photovoltaic production have now been modelled. To help the residential building stock fit with the CO2 reduction of 60% by 2030 compliance and the "2000 W society" energy sobriety target by 2050, the EPIQR-WEB database includes the CO2 indirect emissions of each refurbishment action. Hence, this updated version enables the building diagnosis expert to evaluate and optimise deep refurbishment scenarios, from both financial and environmental point of view. Parallel calculation of CO2 indirect emissions with the calculation of refurbishment cost is done without extra time cost for the user. The paper will show the software new functions, the EPIQR-WEB database expansion and how its overall results can be used to meet the European Union Climate Target through a realistic and comprehensive investment plan.

1. Introduction

The cost and financial aspect of refurbishments are often the main obstacle to building's renovation. The lack of clear information between the environmental and energetic requirements of a renovation and the corresponding costs is another issue that slows down building refurbishment, although this is one of the most popular subjects nowadays.

Moreover, reliable tools allowing anyone to understand this relationship through an easy diagnostic should be developed. This is based on this observation linked to the increasing need of having access to informatic instruments from anywhere that the transition from a software platform to a web application for the EPIQR+ method was done. The first PRELUDE development of the EPIQR+ tool therefore corresponded to this transition from a desktop version to an online version, without changing the initial method or the database philosophy. As a reminder, Figure 1 below resumes the building structure and the coding principle of the EPIQR method:

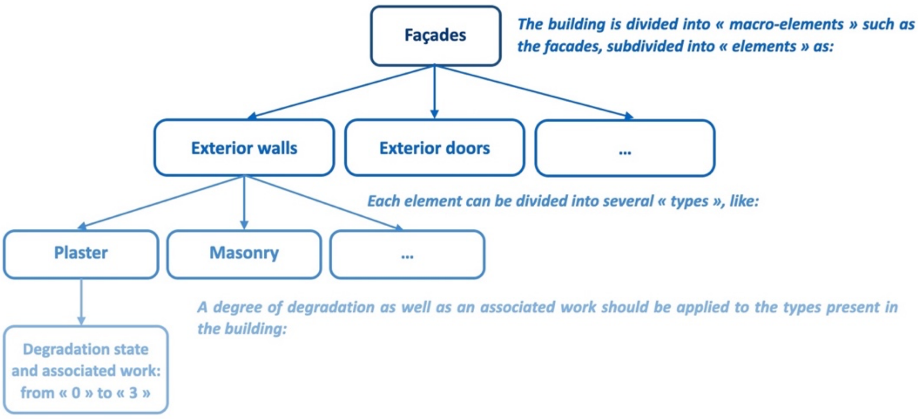

Figure 1: Simplified representation of the building structure and coding principle of the EPIQR method.

Then, in addition to the already existing costs in the EPIQR software, namely the ones linked to the diagnosis of architectural (interior and exterior) and technical elements, a non-exhaustive list of expenses needed to make a residential building smarter were included in the EPIQR web-app and currently based on Swiss reference costs. A validation process of the new interface as well as the integration of other European financial data is currently under development within the PRELUDE project.

Finally, CO2 emissions of each refurbishment or optimization action in the database are actually being calculated and integrated to the new application results.

2. EPIQR web interface

The following major improvements can be noted:

- Web access,
- Easier navigation in the tool, especially with the merging of the diagnosis and scenarios tabs allowing to directly code the desired interventions in parallel with their respective costs,
- More efficient reporting with a full report directly generated,
- Better design facilitating interactions with the user.
- Addressing the whole Europe with the costs adapted to the local country conditions adapted with the Eurostat country price index.

Hence, new useful data can be added such as the construction date of the building, its rating or protection level in the architectural census and even the visit date and a picture of the whole building.

In addition, the various tabs representing the different stages of the diagnosis have been transferred from the top of the screen to the left of it. This way, reading all the information can be done more naturally, from the left to the right. Also, to be user-friendly, this web-app limits as much as possible the number of clicks or tabs selections needed to enter a parameter or an information.

The user-friendliness of this new application leads to a greater speed of use. Indeed, the web version also helps with the core function of the application, i.e. to provide assistance to the expert making the diagnosis, by improving the global architecture of the application. There is now one tab on the left for the building information inputs, another one underneath to enter all the dimensional coefficients and the two last ones are for creating different renovation scenarios and publishing their results according to the level of information required. Tabs number has been divided by two and the fundamentals data, renovation works and their corresponding costs, can now be assessed together on the same page. Several levels of results can now be chosen, ranging from simple to full reports. Figure 2 below reflects an example of the visual rendering of the evaluation tab:

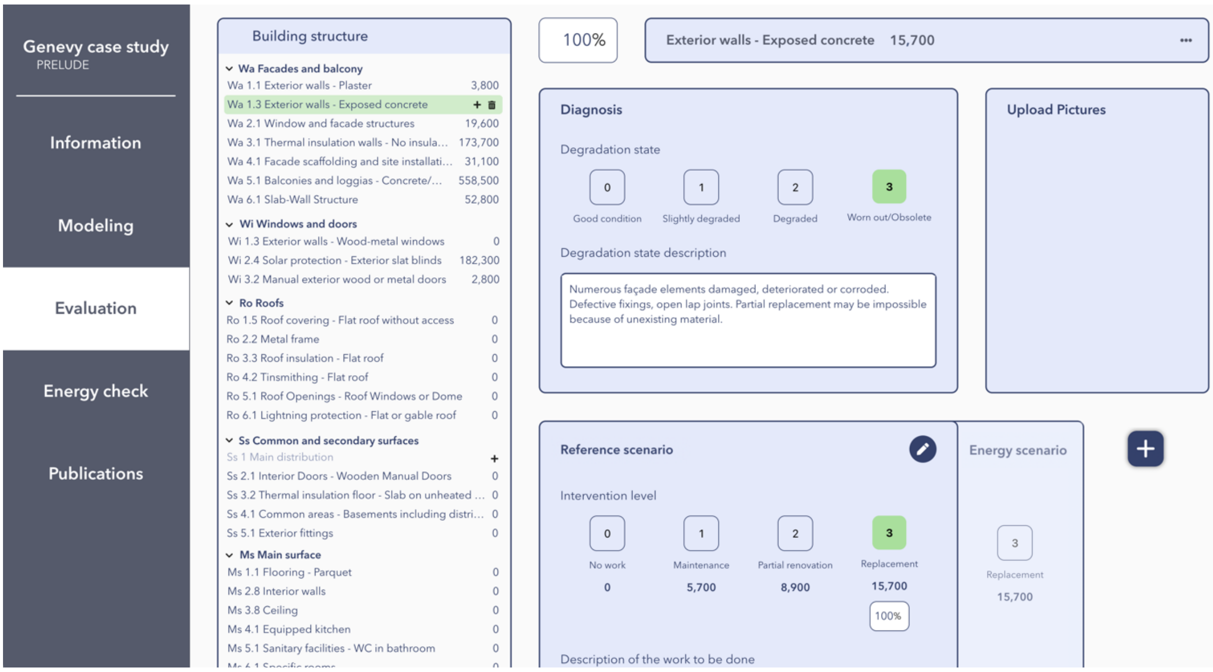

Figure 2: Example of the actual visual rendering of the "Evaluation" tab.

As in the software, some texts can be added to describe in more details the state of the element type and the work to be carried out. Similarly, pictures can also be integrated in the "Evaluation" tab to help the expert and its client understand to which building part the diagnosis is referring to.

The web-application is, for the time being, in French and in English. Translation into other languages could be done later, in the following phases of PRELUDE. Also, the web version of EPIQR is first targeting housing buildings diagnostics. The addition of the remaining building uses present in the software, such as administrative or industrial ones, will be studied afterwards.

To summarize, the EPIQR web-app is based on the existing method but presents a new design and features helping the expert to diagnose the building more easily and quickly and generates results that should be clearer for the clients. It is actually available at the following URL: https://epistimmo.ch/. Note that this version will still be in beta until the official release, implying that the backup of the data is for the time being not guaranteed.

3. Updated cost database

The EPIQR method calculate renovation costs, defined as a one-time investment considering both labor and material costs.

Regarding the second selection criteria, e.g. the use of smart technologies in reducing carbon emissions and improving energy savings in building stock, only elements associated with a corresponding and reliable cost were chosen as pertinent. As expected, the number of data collected, each defined by a new type of technology and its corresponding cost, increases the reliability of the financial element. Thus, to fit with the EPIQR data granularity, only significant costs linked to a smart-technology or equipment installed with sufficient frequency or in other words already on the market were considered.

In total and at the moment, 17 smart actions or building technology integrations have been added to the EPIQR database with their corresponding costs and especially in the "Heating" and "Electricity" macro-elements. They are listed as follows:

1) Abandonment of fossil fuels: installation of an air-water heat pump
2) Abandonment of fossil fuels: creation of a substation and connection to district heating

3) Abandonment of fossil fuels: installation of a wood heating system (wood chips or pellets)
4) Partial abandonment of fossil fuels with 30% of DHW production produced with a heat pump
5) Installation of a heat pump with heat recovery to produce part of the domestic hot water
6) Change of circulation pumps or addition of hydro ejectors
7) Hydraulic balancing
8) Supply and installation of thermostatic valves, purging of the network
9) Remove radiators and replace heating elements, fittings and valves. Filling and bleeding.
10) Implementation of an energy optimization contract with sensors
11) Implementation of an energy optimization contract without sensors
12) Installation of energy meters
13) Implementation of a technical management of the building
14) Installation of presence detectors in the common areas
15) Establishment of a group of self-consumption
16) Addition of storage elements (battery or inertia wheel)
17) Installation of charging stations for electric vehicles

This list is growing as PRELUDE European demo cases are providing more descriptions and installation prices for different smart technology types, most of the costs available in the first version of the web-app come from Swiss projects. Hence, the Swiss cost update factor already in use had to be taken into account and the total cost of each smart technology has been dissected to fit with the EPIQR method structure, i.e. broken down into smaller costs or Building Construction Cost Code (BCC) corresponding to a specific nomenclature including all the construction costs of a project, from its conception to its realization. Every elementary cost corresponding to a specific work is linked to one quantity survey that was measured or counted in a real building, also named the baseline building, and derived from the total expenses for that work. The relation between one specific value measured in the baseline building and its corresponding amount in the diagnosed building depends on dimensional coefficients, that have to be entered in the application by the expert performing the diagnosis. For each building, about ten dimensional coefficients must be inputted (for example: the energy reference surface (ERS) (the sum of all floors area of floors and basements that are included in the thermal envelope and whose use requires heating or air conditioning), the number of dwellings or the windows area, …etc.

Further work will consist in collecting the remaining costs related to the PRELUDE demo-sites monitoring plans, to first verify the already implemented smart-technology costs in the EPIQR database and then confirm the cost-conversion factors between Swiss and other European country currencies at a certain period.

4. CO_2 emissions integration

To help renovated buildings reach the European Union Climate targets of 2030 and 2050, financial and operation direct CO2 emissions is not sufficient. Indirect CO2 emissions linked to each type of work, both those of building fabric, technical installations, but also now with PRELUDE those of new technologies are actually being derived and added to the EPIQR database. New energy technology (electronic control of the building, low current, batteries, inverters) have no negligible CO2 indirect emissions, especially if we consider their short lifespan and frequent replacement. Similarly to the costs structure, to each individual work EPIQR assigns a CO2 indirect emission. These data are drawn from Swiss or European databases (KBOB, ecoinvent). The building dimensional and refurbishment work model calculates with the same user inputs additionally to the refurbishment cost the indirect CO2 emissions. This calculation has absolutely no time cost the EPIQR-WEB user but enables him or her to consider and optimize the total impact of a renovation scenario or renovation roadmap.

PRELUDE case study is used to validate the EPIQR WEB results, comparing the calculated indirect CO2 emissions with those calculated by other software or databases and preliminary results are promising. As soon as the method is validated, it will be easy to calculate the real impact of new technologies and replicate this possibility to diagnosed buildings from the very initial stages of the refurbishment project.

Indirect CO_2 emission (typeCO_2) is calculated for all elements types using this formula.

$$typeCO2 = \frac{\sum workCO2}{typeLife} * buildingLife$$

- workCO_2: Indirect CO_2 emission per individual work.
- typeLife: Lifetime per element type.
- buildingLife: Lifetime of building (60 years).

The total indirect CO_2 emission for a building is the sum of all element types indirect CO_2 emissions.

$$buildingCO2 = \sum typeCO2$$

5. Example of diagnosis

The EPIQR method, through its decomposition of the building, guarantees the user to diagnose the whole building without omitting any element. In addition, the presence of images and explanatory texts greatly helps the understanding and uniformity of the data provided.

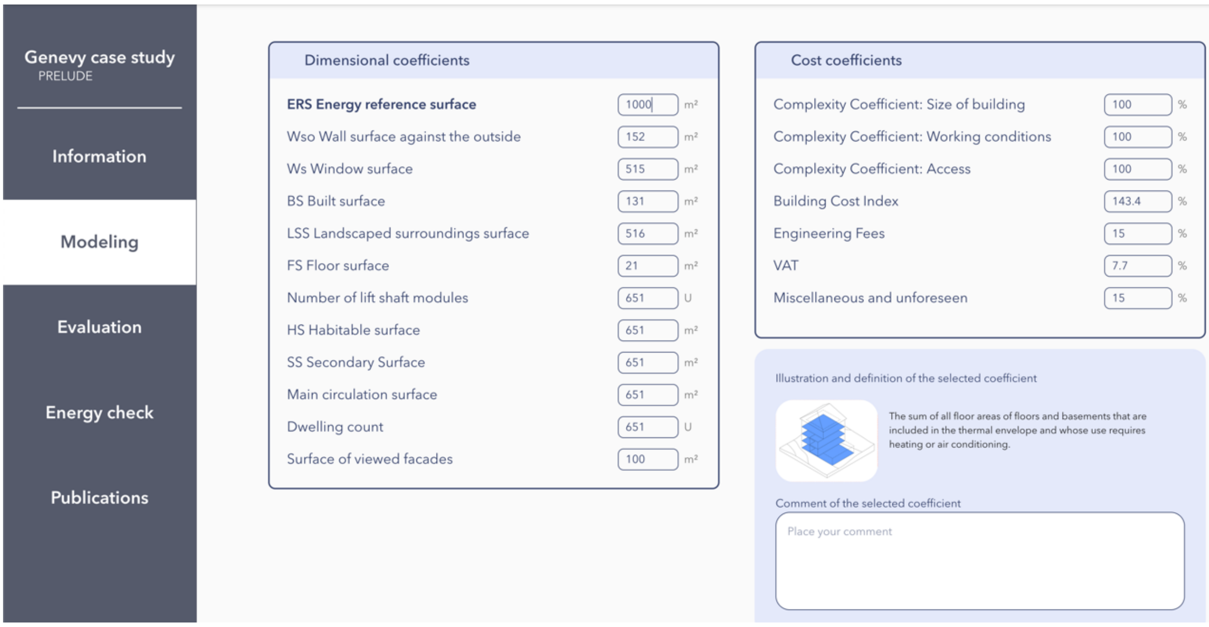

Figure 3 Example of the modelling tab

For example, for a housing building, the user must enter a list of dimensional coefficients, each of which is accompanied by an image and a text describing precisely what value is expected.
The Evaluation tab directly shows the complete structure of the building and encourages the user to question each of the elements. Moreover, each degradation state and necessary works is accompanied by a text helping the user to select the right code and thus to have the correct cost.

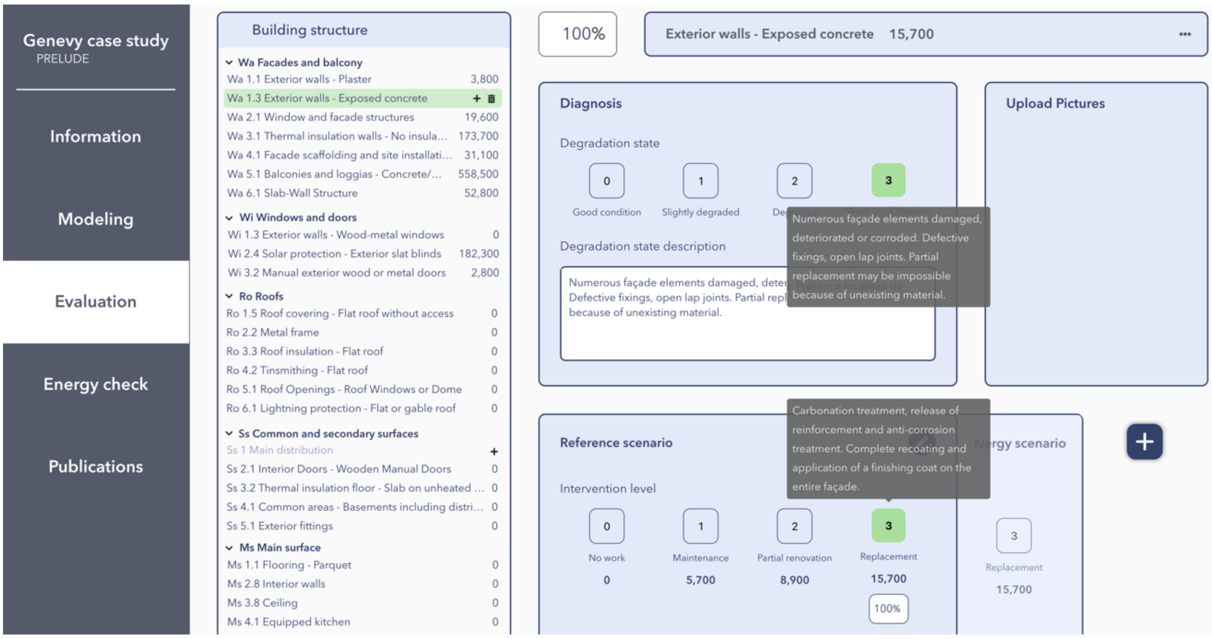

Figure 4 Evaluation tab with the building structure and descriptive texts

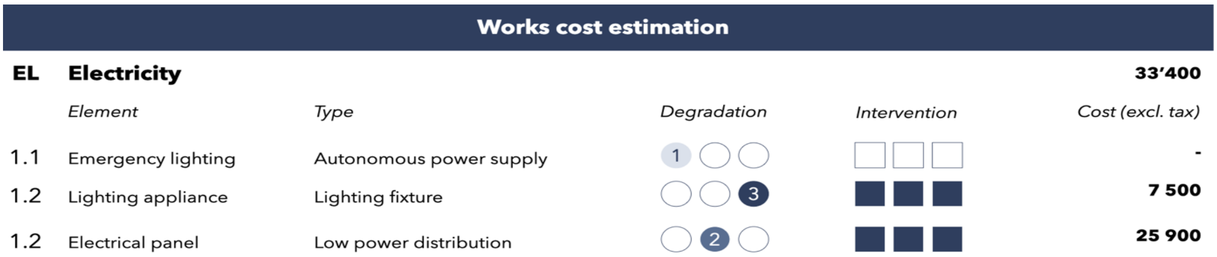

Figure 5: Example of EPIQR output (elements of the "Electricity" group).

6. Conclusion

The EPIQR diagnosis method is addressed to any person or organization involved in the renovation of buildings and helps owners in their decision-making scheme, by comparing different renovation scenarios with their corresponding costs, energy savings and CO2 emissions. The corresponding web-app, whose beta version is now available for residential buildings, was born out of the growing need to have access to IT tools or data from anywhere. Through the modernization of its graphical interface and the implementation of new functionalities, it also allows the expert to diagnose more easily and quickly and to have clearer results for the clients.

In addition to the already existing costs in the EPIQR+ database, namely the ones linked to the diagnosis of architectural (interior and exterior) and technical elements, a non-exhaustive list of expenses needed to make a building smarter have been included in the EPIQR web-app, hence participating in the development of the third renovation strategy set by the European Union through the "Energy Performance of Buildings Directive". 17 new actions corresponding to the implementation of smart systems were added or updated. They have been selected both for their conformity with the EPIQR method and for their market representation.

Future work will concern in priority the continuity of the development of the EPIQR web-app through, among other things, the diagnosis of other building types as well as the verification of the new costs and CO2 emissions with in particular the data available from the PRELUDE project. EPIQR assessments of test buildings are needed to validate the new interface and its overall costs in different European location.

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