Individual Building
Renovation Roadmaps

The iBRoad tools structure

How to integrate techno-economic assessment, individual building renovation roadmap and logbook components in iBRoad

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EXECUTIVE SUMMARY

The iBRoad project intends to explore, design, develop and demonstrate the concept of individual building renovation roadmaps, outlining a deep step-by-step renovation plan with customised recommendations for individual buildings (the Renovation Roadmap), combined with a repository of building-related information (the Logbook). In this context, iBRoad develops IT solutions which support the implementation of the Renovation Roadmap and Logbook. This requires a set of techno-economic modules for assessing the impact of the proposed renovation steps. Moreover, the data flow between these modules and the data repository needs to be clarified.

This report describes the way in which techno-economic assessment modules can be integrated into the individual building renovation roadmap (iBRoad) concept. Different calculation and assessment approaches are described, as well as the possible data transfer procedures between the modules and the required database structure. The techno-economic assessment in this report concerns mainly the impact of the proposed renovation steps on the energy demand, related CO_2 emissions, share of renewables, etc., on economic indicators and relevant co-benefit aspects (e.g., well-being, health and productivity).

The IT solutions developed in iBRoad are the two iBRoad components Roadmap Assistant and Logbook. The Roadmap Assistant is a tool to assist the energy auditor in the development of the Renovation Roadmap together with the building owner. The data structure used in the Roadmap Assistant and outlined in this report should allow a user-friendly input of the building information, supported by drop-down menus and text fields, and functionalities, e.g., to avoid that a field stays empty. Moreover, the Roadmap Assistant invites the energy auditor to indicate relevant individual co-benefits of the different renovation steps on the roadmap. From the Roadmap Assistant, an optional button should lead the energy auditor to the Cost Calculator, which should help him/her to calculate the total investment costs and possible costs variations over the renovation period. The energy demand and CO_2 emissions can be calculated either by making use of country specific energy demand calculation software or by an open source programme code developed in iBRoad; relevant calculation procedures are presented in this report.

The Logbook is a modular building data repository of all relevant building related information (for example, address, energy demand, energy class etc). Several functionalities for the iBRoad Logbook, i.e., Building data repository, Building diagnosis, Alerts and reminders, and Display of the Renovation Roadmap, are developed, creating an attractive, interactive and dynamic tool.

The mock-ups of the Roadmap Assistant, the Cost Calculator, the Renovation Roadmap and the Logbook present a suggested layout, and provide guidelines for possible IT implementation to be carried out in further steps of the project.

Finally, selected recommendations for a country specific adaptation of some of the iBRoad components, parameters and modules are highlighted in this report. These adaptations may serve as a guidance for further activities in iBRoad regarding IT implementation, in particular also leading to field tests in four pilot countries.

I. INTRODUCTION

This report describes the way in which techno-economic assessment modules can be integrated into the individual building renovation roadmap (iBRoad) concept.

The iBRoad project, funded under the H2020 programme, intends to explore, design, develop and demonstrate the concept of individual building renovation roadmaps, outlining a deep step-by-step renovation plan with customised recommendations for individual buildings (the Renovation Roadmap), combined with a repository of building-related information (the Logbook). The project targets residential buildings, with a focus on single-family and small multi-family houses. iBRoad's implementation will support building owners in step-by-step deep renovation, while avoiding lock-in effects. At the same, the Renovation Roadmap and Logbook are expected to empower energy auditors with knowledge and experience of deep renovation in individual buildings, and to provide public authorities with real-life studies and analyses supporting deep renovation, both for individual buildings and as part of a long-term national strategy, thereby increasing the renovation rate and depth across the EU. The iBRoad approach is an evolution of the EPC and energy audit systems, aiming to become a real driver for renovation. The iBRoad innovative concept and tools will be tested in four pilot countries: Bulgaria, Poland, Portugal and Germany.

The iBRoad concept consists of two customised products:

- The Logbook: a repository where all the building-related information can be stored in an interactive way, allowing the user to get automated information about the building's energy performance and to configure alerts and reminders.
- The Renovation Roadmap: an individual, customised, long-term renovation plan of a specific building, developed by the energy auditor together with the building owner. The Renovation Roadmap displays the energy performance, as well as the cost and co-benefits indicators of the proposed renovation measures in a standardised and user-friendly layout. The Renovation Roadmap is developed through the Roadmap Assistant tool.

Thus, the iBRoad concept helps to increase building owners' awareness about the current energy performance status of the building, and, supported by the energy auditor, to implement the proper renovation measures and to increase the energy performance of the building according to their individual perspectives and needs.

The techno-economic assessment concerns mainly an assessment of the impact of the proposed renovation steps on the energy demand, related CO_2 emissions, share of renewables, etc., on relevant economic indicators, as well as on other aspects (e.g., health and safety) which are considered to be possible co-benefits arising from the applied energy saving measures. For this purpose, different calculation approaches are described, as well as the possible data transfer procedures between modules, and the required database structure. As further activity in the iBRoad project, this general concept will be adapted to the national circumstances in Bulgaria, Poland, Portugal and Germany (for the latter one only the logbook).

The report is structured in five chapters: chapter I is the introduction, whereas chapter II presents the iBRoad concept including possible data sources, modules, mechanisms of data exchange with external tools, and an outline of the required database structure. Chapter III explains and discusses calculation procedures which can possibly be integrated into the iBRoad concept, and in particular for (i) energy demand calculation, (ii) economic assessment and (iii) co-benefits assessment. Chapter IV proposes a possible layout presentation for the Logbook, Renovation Roadmap, Roadmap Assistant and Cost Calculator, in the form of mock-ups. Chapter V highlights selected recommendations for country specific adaptations. Finally, Annexes A to G present other complementary information, as for example, a glossary with main definitions.

II. iBRoad CONCEPT: SPECIFICATIONS AND DATA FLOW

This chapter presents the general iBRoad concept (part I) including its possible internal and external data exchange (part II) and an outline of the required database structure and functionalities (part III). Together with the detailed description of the iBRoad concept, this chapter also highlights which of these aspects are actually going to be implemented within the iBRoad project context.

i. iBRoad concept description

Figure 1: iBRoad Concept – overview illustrates the overall iBRoad concept. The core concept consists of two main customised products: the Logbook and the Renovation Roadmap.

The Logbook is the main repository of all building information, providing additional services in the form of functionalities, comprising e.g., Building Diagnosis, Display the Building Renovation Roadmap, Alerts & Reminders.

The Renovation Roadmap can be presented in a summarised or a detailed form.

There may be different optional data sources feeding into the iBRoad concept (top of Figure 1): building owner, energy auditor, public authorities, energy utility, financial services, EPC, external databases, and others. The Logbook can thereon be linked with other existing or under development external services or databases, e.g., one-stop-shops, energy management systems and others, as showed in the bottom of Figure 1, thereby offering an advanced user experience and overall added value.

The Renovation Roadmap is a customised, individual, long-term building Renovation Roadmap with graphs and detailed information, developed by the energy auditor together with the building owner, using the assistant tool "Roadmap Assistant". The Renovation Roadmap is a plan of renovation measures to be implemented in a specific sequence and time, including relevant indicators, i.e., energy performance, as well as cost and co-benefit indicators, in a standardised and user-friendly layout.

To calculate the energy performance of the building at different stages in time, the energy auditor should use the country specific energy demand software. However, he/she can also use the simplified standardised energy demand calculation procedure delivered as open-source programme code by the iBRoad project (see also chapter III/i).

The grey arrows in Figure 1 represent the possible data flows between the main and secondary components of iBRoad and related services.

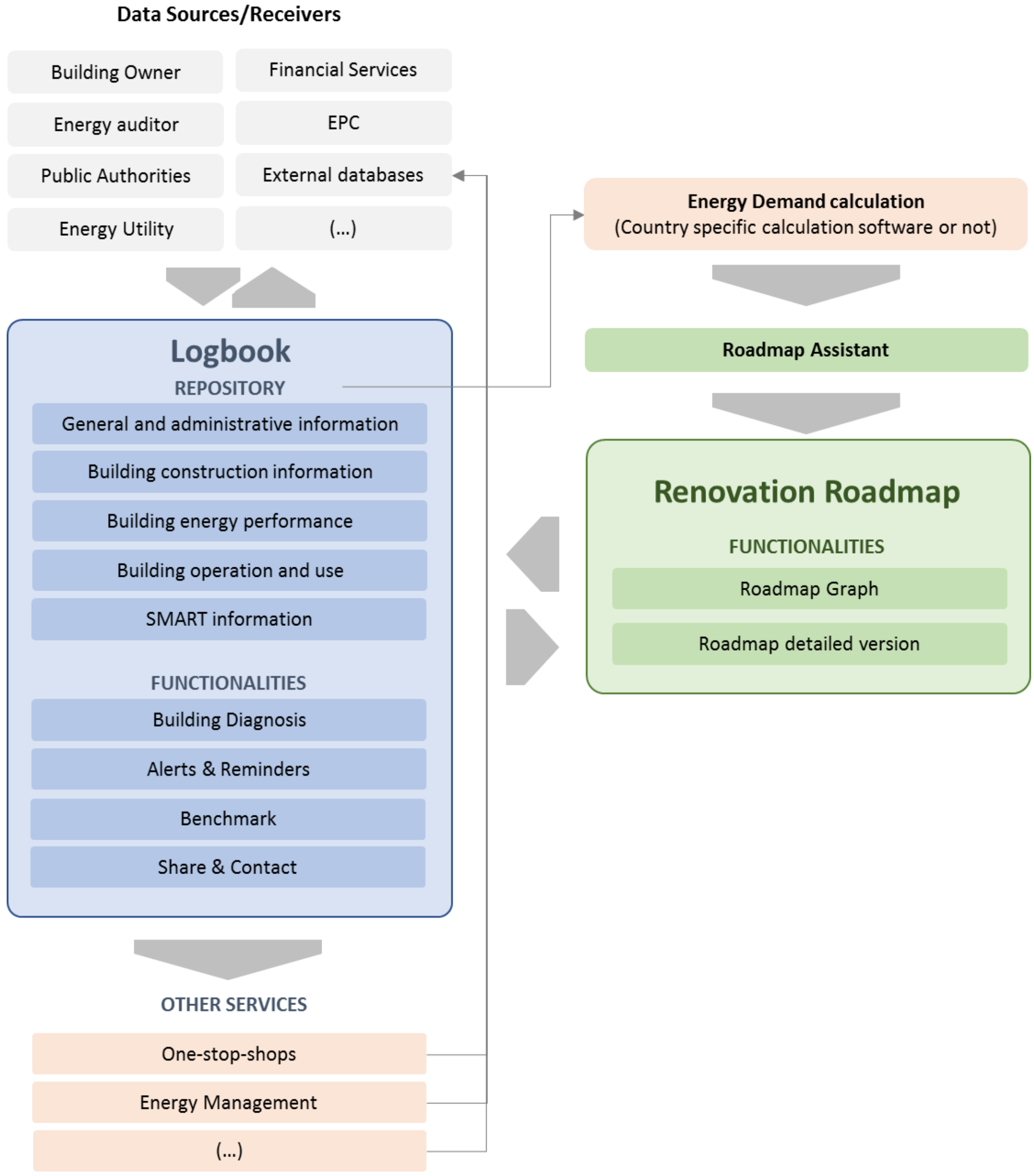

Figure 1: iBRoad Concept – overview

ii. The Logbook and its required database structure

The Logbook is a digital building identity card with its main function being the data repository of all relevant building information (for example, address, energy demand, energy class, etc.). With the implementation of additional functionalities, the Logbook becomes dynamic and therefore more attractive, delivering additional services to its user.

The data repository is divided in five modules (as suggested in the project report "The logbook data quest" (Liborio et al., 2018):

1. General and Administrative Information: general and administrative information related to the building, unit and user characterisation; e.g., building identification number, address, building general features, licenses and plans, climate data, etc.
2. Building Construction Information: technical information and data related to the building construction; e.g., building envelope construction, windows and door types, heating systems and related energy carriers, cooling, lighting and ventilation systems, domestic hot water and renewable energy systems.
3. Building Energy Performance: energy performance information such as calculated energy demand data, environmental indicators, building's thermal performance, comfort level or improvement recommendations based on EPC information or other energy assessments, e.g. energy audits.
4. Building Operation and Use: data and information on how the building is operated (delivered energy use, energy generation and suppliers, etc.), operation profiles (heating, cooling, mechanical ventilation, lighting systems, etc.), inspections and maintenance.
5. Smart Information: smart information related to the building; e.g., smartness indicators, e-mobility and smart district indicators.

These modules are structured in the Logbook in the form of a hybrid structure, which consists of a fixed and a flexible data structure. The fixed part is common to every country. It is the minimum data required for the proper functioning of all functionalities, while the flexible part contains various levels of information, which can be country specific. Detailed information about the Logbook structure is available in *ANNEX H: Logbook hybrid data structure* as well as in the report *"Database structure and programming core of the roadmap and logbook"*[1].

The Logbook functionalities to be implemented within the scope of the iBRoad project are grouped into the following categories: 1) Building Data Repository, 2) Building Diagnosis, 3) Display Renovation Roadmap, 4) Alerts & Reminders. The functionalities are further described in "The iBRoad Concept in practice – Report on suggested elements, content and layout of the iBRoad tools"[2]. Moreover, *ANNEX B: Mapped Fixed Logbook Parameters* and *ANNEX C: Data and parameters required for the iBRoad Logbook functionalities* present a list of identified parameters required for each specific functionality, as well as equations, choice criteria and a detailed description of the Logbook functionalities.

The main user of the Logbook is the building owner, who can grant access to third parties, e.g., the energy auditor (particularly to verify or log building technical information) or a public authority, while keeping other data private or restricted (semi-public upon authorisation to third parties).

iii. Renovation Roadmap

The individual building Renovation Roadmap provides tailored advice to the building owner on how to improve the house by avoiding unwanted lock-in-effects. By supporting staged renovation adapted to the preferences of the individual building owners, the roadmap will allow them to have an overview of the full range of recommended renovation measures and easily identify each renovation step from beginning to end (step-by-step approach).

The Renovation Roadmap consists of two elements:

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[1] This report is also available on the IBRoad project website: https://ibroad-project.eu/

[2] This report is also available on the IBRoad project website: https://ibroad-project.eu/

- A roadmap as illustrative graph, serving as an overview of the results and recommendations of the audit.
- A detailed report, specifying each renovation step.

The Renovation Roadmap follows the guiding principles indicated below:

- Long-term perspective: helps the building owner understand the importance of having a long-term renovation strategy to avoid lock-in effects when implementing individual measures.
- Consideration of individual renovation context: the particular situation (e.g.. financial), as well as needs and wishes of the homeowners are taken into account to provide a tailor-made plan. These include, for example, financial opportunities, living space changes, or family planning (e.g., expecting a baby, or children moving out).
- Attractiveness and motivation: the Renovation Roadmap should be attractive and easily understandable for the users. Building owners are guided throughout the process and receive clear indications so that they can take action without getting lost.
- Timing and Sequencing of actions: frequently, renovations cannot be performed in one go. That is why many buildings are only partially renovated. Early replacement of components may also result in economic losses. Rented stocks can often only be renovated gradually as well. In many cases, the financial situation of the owner allows no extensive refurbishment all at once. The Renovation Roadmap suggests a gradual upgrade following a specific order in which changes should be implemented to avoid lock-in effects.
- Automation: to reduce costs, the Renovation Roadmap should also be a user-friendly tool for the expert (energy auditor) delivering the audit. In the Roadmap Assistant, the energy auditor should work with prefabricated text blocks as much as possible, to make the message clear and directly understandable. Once the audit is concluded, prefabricated blocks of text will also be adjusted with specific property parameters to provide a personalised advice.

The most important data sources to collect information for the development of the Renovation Roadmap are:

a. On-site visit

The auditor visits the building, documents the components of the building (U values of walls, windows, roof, etc., available heating and ventilation, weaknesses of the building, etc.) and talks to the building owner with the help of a checklist, takes photos of the building and inspects it. Here, the validity of potential EPC data is checked as well. Performance measurements will typically not be necessary, because either the real consumption is available, or the building is modelled using the recorded data (U values, etc.). However, some measures of the building characteristics should be done. Special attention should be paid to past renovation measures, in order to suggest proper future renovation steps. The auditor gathers any missing data, discusses and interviews the building owner regarding personal preferences and financial capabilities, and develops an initial rough roadmap together with the building owner.

b. Country specific energy demand calculation software

The auditor uses the country specific energy demand calculation software, if available and generally accepted (national calculation procedures), to:

- calculate the current energy demand of the building and
- propose future measures.

If a country specific energy demand calculation software is not available, the auditor has the possibility to use the Roadmap Assistant, a simplified energy calculation model developed by iBRoad (described in the next chapter).

Based on the current energy demand and the detected weak points of the building, in combination with the wishes and preferences of the building owner, the auditor will produce the Renovation Roadmap.

iv. Calculation Assistants

a. Roadmap Assistant

The Roadmap Assistant is a tool that supports the development of the Renovation Roadmap. The only user of the Roadmap Assistant is the energy auditor. The Roadmap Assistant allows the energy auditor to calculate the energy performance, perform an assessment of the co-benefits of the renovation (the methodology is described in *ANNEX F: Co-benefits assessment in the Renovation Roadmap*) and calculate its cost, using the Cost Calculator. The data input in the Roadmap Assistant is supported by drop-down menus and functionalities to avoid that a field stays empty. Detailed information about the Roadmap Assistant structure is available in the report "*Database structure and programming core of the roadmap and logbook*"[3]. The building owner cannot access the Roadmap Assistant, but can view and/or download and print the Renovation Roadmap through the Logbook.

b. Cost Calculator

From the Roadmap Assistant, an optional button should lead the energy auditor to the Cost Calculator, which should help him/her to calculate the total investment costs and possible costs variations over the renovation period (described in *Chapter III Calculation and assessment modules*). For this calculation, a series of techno-economic data is requested: energy demand, costs of the renovation measures and new technical systems, and other economic data, like energy prices. A database will provide default renovation cost values (iBRoad report "*Quantifying home renovation - Report and database for techno-economic default assessment of renovation measures*"[4]), which can also be overwritten by the user. The same approach will be followed for other economic data, e.g., energy prices, subsidies, annuity, potential CO_2 taxes, where again default values will be suggested, however the energy auditor has the possibility to alter the data.

v. iBRoad possible data flows

The iBRoad concept foresees various data flows, illustrated by the grey arrows in Figure 1: iBRoad Concept – overview, which may in the future take place, either manually or automatically. Possible dataflows are described below.

a. Dataflow between Logbook and data sources

The dataflow between the Logbook and potential data sources can, in an ideal scenario, happen in both directions. Indicatively, information on the buildings' energy performance and energy consumption could be supplied to the Logbook through the EPC database and the energy utility company, respectively, whereas details on available subsidy schemes, craftsmen nearby and current energy

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[3] This report is also available on the IBRoad project website: https://ibroad-project.eu/

[4] This report is also available on the IBRoad project website: https://ibroad-project.eu/

prices, through financial institutions, the local energy agency or municipality, financial institutions, etc. Vice versa, the Logbook could e.g. feed the EPC national registry with data on energy performance, thereby supporting public authorities in mapping and benchmarking the energy performance of the buildings in a specific region, and creating relevant policy schemes. Information could be transferred from one source to the other automatically through a dedicated user interface. Within the iBRoad project, such user interfaces are not realised, and data is entered to the Logbook only manually by the energy auditor.

b. Dataflow between Logbook and External services

In an advanced phase, dataflow between the Logbook and other software or services operated or under development in the market, that are external to the Logbook and the Renovation Roadmap, would also be possible. These could either provide input to, or use inputs coming from, the Logbook and Renovation Roadmap to produce new data and information, and provide more holistic services to a range of stakeholders supporting the energy renovation process. Such possibilities include for example, linking the Logbook with an external energy management system (e.g., electricity consumption from a smart-meter), and allowing the user to have access to their actual and historical energy consumption billing data (e.g., gas, electricity, etc.) in one single web portal or platform.

c. Dataflow between Logbook and Energy Demand Calculation Software

In its advanced version, automatic dataflow between the Logbook and the (national) energy demand calculation software would be very beneficial. This interlinkage would simplify the energy calculation procedure and at the same time serve as a quality check for the data used.

In the iBRoad project, the dataflow between the Logbook and the calculation software is not automated, and the auditor will manually copy data from one to the other.

d. Dataflow between the energy demand calculation software and the Roadmap Assistant

This dataflow takes place from the energy demand calculation software to the Roadmap Assistant, after the new energy demand for each step-by-step renovation measure (and for the complete Renovation Roadmap) has been calculated by the energy auditor.

In the iBRoad project, this dataflow happens manually from the energy demand calculation software to the Roadmap Assistant, by the energy auditor.

e. Dataflow between Roadmap Assistant and Renovation Roadmap

All the information entered in the Roadmap Assistant will be used to develop the Renovation Roadmap.

In the iBRoad project, this dataflow happens automatically by generating the Renovation Roadmap.

f. Dataflow between Logbook and Renovation Roadmap

The dataflow between the Logbook and the Renovation Roadmap may happen in both directions, e.g. from the Logbook to the Renovation Roadmap, by transferring certain building information, or the other way around, by integrating the Renovation Roadmap into the Logbook. Also, after each suggested renovation step has been realised, the new building information, e.g., energy class, energy performance indicators, energy efficiency of building elements (new U-values, new building materials), can be visualised in the Logbook.

In the iBRoad project, the Renovation Roadmap is automatically visualised in the Logbook, and the building information can be manually transferred from the Logbook to the Renovation Roadmap.

III. CALCULATION AND ASSESSMENT MODULES

i. Energy demand calculation

This chapter describes the simplified standardised energy demand model to assess useful, final and primary energy demand of residential buildings. The general calculation procedures and equations are presented in *ANNEX D: Calculation procedures and equations for energy demand for heating, cooling, lighting, ventilation and domestic hot water*. The open-source programme code provided (see iBRoad report "*Simple energy demand calculation tool – open source programme code of techno-economic default assessment of renovation measures*" [5]) allows a simplified and standardised energy demand calculation using the model described below.

In iBRoad, the energy auditor calculates the energy demand using the country specific calculation software. In case this is not possible, the energy demand model presented in this chapter is an alternative to deliver energy performance indicators. This simplified calculation procedure can be realised when all input data necessary is available in the Logbook or manually entered by the energy auditor. Due to its complexity, the energy demand calculation can only be performed by the energy auditor, in order to guarantee the quality of the assessment and to avoid wrong interpretations.

Model description

The model consists of a simplified methodology for an energy demand calculation in a multi-zone model, based on the calculation procedures suggested by the DIN-Standards 18599 and validated simplifications as described by Lichtmeß (2010).

The DIN V 18599 series of standards was developed in a joint working committee of the DIN Standards Committees for Construction (NABau[6]), Heating and Ventilation Technology (NHRS[7]) and Lighting Technology (FNL[8]). It provides a methodology for assessing the energy performance of buildings as required by Article 3 of Directive 2002/91/EC of the European Parliament and of the Council on the Energy Performance of Buildings (EPBD) (Himburg, 2011).

The DIN-Standards describe the energy flows between the building and its surrounding, by considering mutual interactions between building structure, user profile, weather data and technical system. The calculation methodology is appropriate for assessing a monthly-based energy balance calculation: useful, final and primary energy demand, as CO^2 emissions, for heating, cooling, domestic hot water, ventilation and lighting, including the potential use of renewable energy in existing residential buildings.

The model is structured in three distinct parts. The first part refers to the boundary conditions for residential buildings as well as climate data for the reference climate, where input data such as occupancy period, indoor room temperature, internal heat gains, and air change, must be defined. Further information, referring to monthly climate data for intensity of solar radiation and outdoor air temperature, is also necessary.

The second part refers to the definition of the building envelope and the zoning procedure. In this part, input data regarding general building data, building envelope and the technical energy system for each

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[5] This report is also available on the IBRoad project website: https://ibroad-project.eu/

[6] NABau: DIN-Normenausschuss Bauwesen (NABAu), Deutsches Institut für Normung

[7] NHRS: DIN-Normenausschuss Heiz- und Raumlufttechnik sowie deren Sicherheit), Deutsches Institut für Normung

[8] FHL: DIN-Normenausschuss Lichttechnik

zone must be defined. According to the simplified zoning methodology, the building envelope is disaggregated from a whole unit into zone levels, allowing (however not necessarily requiring) a multi-zone calculation procedure.

The third part refers to the calculation procedures. These are structured in a modular approach, where calculation of net, final and primary energy demand, such as CO_2 emission heating, cooling, domestic hot water, ventilation and lighting, are individually described. For the heating and cooling energy demand calculation, input data such as building geometry, envelope quality, indoor/outdoor temperature, artificial lighting and solar heat gains and others have to be defined. This calculation is based on a monthly balance between heat sinks and sources. Heat sources are internal heat gains, solar radiation, heat transmission through the building envelope, and ventilation. Heat sinks are transmissions through the building envelope, ventilation and cold sources. For the domestic hot water energy demand calculation, the input data to be defined include system operation and user profile. The calculation of the energy demand for ventilation considers the energy demand necessary to guarantee indoor air quality and indoor air humidity. Here, the calculation procedures describe the energy demand for ventilation heat sink, with and without a heat exchanger. The procedures also describe the heat sink due to unregular heat and cold entries through the ventilation system or air-heating systems. For the lighting energy demand calculation, input data include window area and position on the wall, daylight hours per day (also depending on the month), constructive elements for sun protection, whereby sensors and/or controlling systems are relevant.

The main model simplifications befall on the technical installations. Identified model limitations include:

1) the use of default values for the generation-expenditure factors and auxiliary energy;
2) use of tabled values for the distribution losses of the heating and domestic hot water systems;
3) simplified modelling of the ventilation system, using a constant volume and heat recovery up to 75%;
4) not considering the energy need for the heat/cold register and related technical losses of the ventilation system, simplified combined heat & power modelling as complementary system to a given heating system; and
5) simplified solar-thermal system with pre-selected collector surface (Garcia, 2017).

ii. Economic-assessment and financial plan

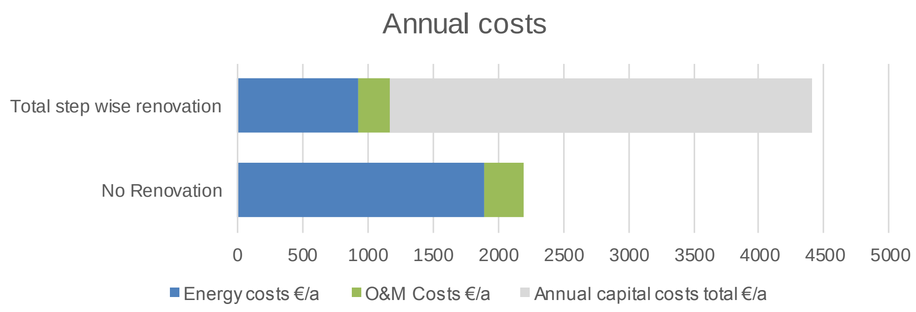
The economic and financial aspects of the renovation measures – together with other important decision-making aspects such as energy savings – play an important role on the decision-making process and the prioritisation of the proposed renovation measures. This chapter presents the study of possible methodological approaches for the economic assessment, as well as its conclusions and suggestions in terms of implementation in the iBRoad project.

Possible options for displaying the costs and results of the economic assessment

The economic assessment module can provide information regarding the total annual costs, as the sum of the energy costs, operation and maintenance costs, and annual capital costs for two options: with the step-by-step deep renovation and without any renovation.

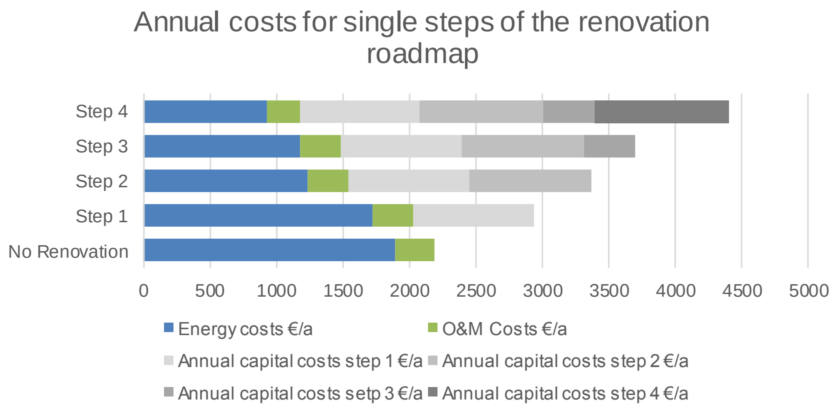
Graph 1 and Graph 2 exemplify the annual costs comparison between a fictitious step-by-step renovation roadmap and no renovation scenario. In Graph 1 it is possible to see that there are no annual capital costs (in grey) in the example of "no renovation", while in the example "total step-by-step renovation" the annual capital costs are significant. On the other hand, the energy costs (in blue) in the example "no renovation" are two times higher than for "total stepwise renovation". This means that,

when renovation measures are completed, the energy costs decrease. Operation and maintenance costs (O&M – in green) will also slightly decrease after renovation.



Graph 1: Annual costs of total step-by-step renovation

Graph 2 illustrates the same thing as does Graph 1, but now disaggregated in the individual renovation steps (given as steps 1 to 4). This graphical representation illustrates the gradual decrease of energy and O&M costs on the one hand, and the increase of the annual capital costs on the other.

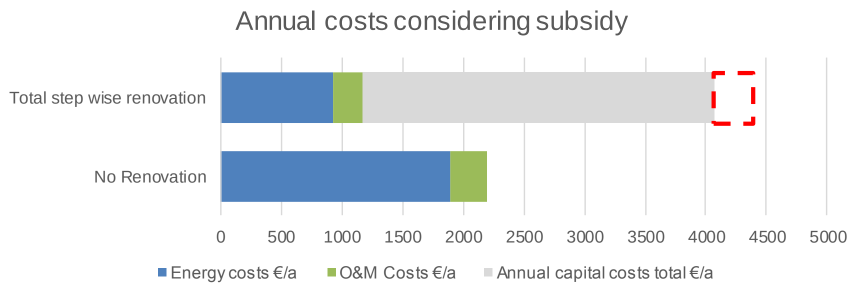


Graph 2: Annual costs for each renovation measures

The objective of the economic assessment is not only to present the cost-effectiveness of the suggested renovation measures, but also to introduce some basic aspects of the complex relation between costs and energy issues to building owners, allowing an intuitive interpretation, especially if taking into account the future perspective. For this, a range of possible variations, considering different influencing parameters, should also be made available to the building owner who has interest in a deeper analysis. These include: 1) subsidies; 2) anyway costs; 3) fuel price uncertainty and 4) climate policy (i.e., CO_2 taxes).

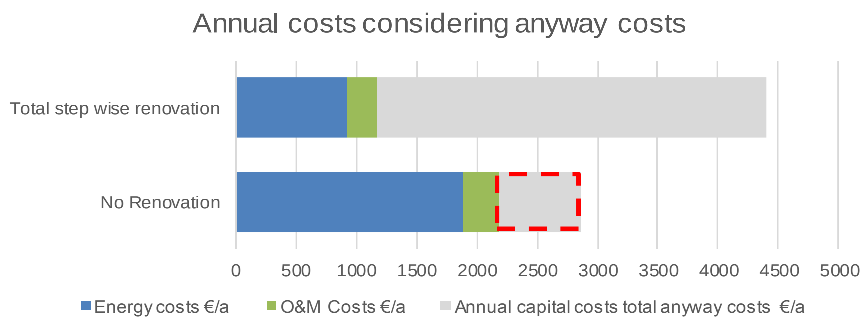
Normally, the *subsidies* offered by the government depend on different conditions, like eligible renovation measures, savings targets, execution by accredited professionals, specific goal adopted by the government, duration, etc. For this, including the economic effects of available subsidies can help encouraging the building owners to realise a step-by-step renovation. For example, Graph 3 illustrates how the availability of a subsidy “x” would represent a possible reduction of the annual costs.

Limitations of this approach would include the energy auditors' access to this kind of information, or, the absence of available subsidies.



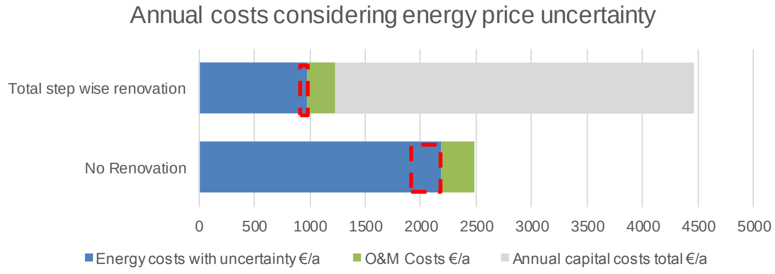
Graph 3: Annual costs of renovation measures, considering subsidy

Another influencing factor are the so-called "*anyway costs*". A house needs to be maintained and improved over its lifetime. Such maintenance costs are called "*anyway costs*". However, relevant measures, e.g., painting external walls or replacing building components with new ones, do not necessarily increase the building's energy performance. The aim of the differentiation between costs for thermal improvements and anyway costs is to showcase that investing in thermal improvement of the building envelope does not translate into much higher renovation costs, as many people believe. For the fictitious example, Graph 4 illustrates that when considering the anyway costs, the annual capital costs of the option without renovation increase. The limitations of this approach include lack of information about disaggregated renovation measure costs and the definition of the different types of costs (not energy efficient or energy efficient improvement).



Graph 4: Annual costs of renovation measures, considering anyway costs

Future development of energy prices and *CO_2 emission reduction policies* are other highly influencing parameters. The prices of gasoline, coal, electricity and other fuels can change rapidly, influenced by national policy decisions and geo-political conjuncture. These trends affect directly building owners' decisions, especially if considering long-term investments. Also, *CO_2 emission reduction policies*, like the *introduction of a CO_2 tax*, impact the economic assessment. The latter economic instrument has been discussed for many years, and some European countries like Denmark or Sweden already implement it. For the fictitious example, Graph 5 illustrates that a change in the future energy prices due to uncertainties or economic instruments like a CO_2 tax would affect the energy costs, in both renovation options, with higher impacts in the "no renovation" example. Limitations in these approaches would be the lack of information about real energy prices and CO_2 trends at national level.



Graph 5: Annual costs of renovation measures, considering energy price uncertainty

The graphical presentation of the economic indicators above could help the building owner to understand the economic effect of the step-by-step Renovation Roadmap, when taking into account different influencing parameters. The owner can make a distinction between energy costs, anyway costs and operational costs. He/she can better understand how these costs change after the step-by-step renovation is completed, as well as how other, partly uncertain factors, e.g. subsidies, energy price fluctuations and climate mitigation policies, influence annual costs.

However, presenting the annual capital costs is not considered to be particularly intuitive for the layman. For this reason, iBRoad provides some selected economic indicators, and a Cost Calculator to assist the energy auditor in determining expected costs of the renovation measures in the Roadmap Assistant. Both are further described below.

Approach suggested for displaying economic data

The following economic indicators are selected to be used in the Renovation Roadmap:

1) Total Investment costs of the measures in each renovation step according to the Renovation Roadmap. The advantage of this approach is that no decision regarding interest rate and depreciation time is required, and users see an intuitive total investment costs value.

2) Total annual running costs, split up into energy carrier costs, and operation and maintenance costs. The advantage of this approach is that the user can see a future perspective of the annual cash flow of his/her costs (energy, as well as operation and maintenance). There are two ways to calculate the running costs: based on the calculated energy demand or on real energy consumption. Here, it is suggested to use the energy consumption. If no information about the real energy consumption is available, the energy consumption can be estimated by applying an energy consumption correction factor to the calculated energy demand. The iBRoad Cost Calculator includes default values for the correction factor, depending on the energy performance of the building, which can be adjusted for country and user specific characteristics by the auditor.

3) Indication about possible uncertainties (e.g., regarding future energy prices). The advantage of this approach is that the user sees future tendencies and possible influences on his/her cash flow.

4) Clear link to co-benefits (see next chapter). Especially in the case where an economic benefit is not possible, this approach has the advantage of helping the user to understand other benefits related to the implementation of the individual Renovation Roadmap.

iv. Co-benefits

The co-benefits are the non-energy improvements of the renovation measures as for example well-being, productivity and health. There are different indicators used to assess the co-benefits: thermal comfort, indoor air quality, acoustics, lighting, aesthetics and others. This chapter aims to define which approach for the co-benefits assessment will be followed in the iBRoad concept. For that, it is structured in two parts. The first part presents the different methodological approaches to assess co-benefits, which were generally explored. The second part of this chapter presents how the co-benefits assessment will be implemented in the iBRoad project.

Exploring assessment approaches to general co-benefits

Further to the obvious energy savings, building renovation can have a positive impact on several other very important factors, including improvement of human health, productivity and well-being, increase of the market value of the house, improved safety, reduced maintenance costs, reduced emissions and waste, etc. These additional positive impacts are the so-called co-benefits.

The main challenge for assessing the co-benefits lies in delivering reliable results, which are in line with peoples' perceptions. Ideally, the main data to assess the co-benefits should be collected through monitoring of activities over a whole year and combined with Post Occupancy Evaluation surveys, capturing occupants' perception.

In theory, in the scope of the iBRoad project, two are the potential data sources, and consequently the methodological approaches to assess the co-benefits.

The first refers to an automated advice to the building owner, based on Logbook data. The second is an assessment carried out by the energy auditor, which is then displayed in the Renovation Roadmap.

In the first approach, the user (building owner, energy auditor, public authorities, etc.) can enter the technical building characteristics into the Logbook. *ANNEX E: Co-benefits assessment in the Logbook* describes the methodology for an assessment based on Logbook data. The idea is that such an assessment could be based upon ranking the building components according to their contribution to certain thermal comfort and indoor air quality standards. This methodological approach would work as automated advices to the building owner.

However, there are also major concerns regarding the complexity and feasibility of the co-benefits' assessment based on building status quo data. E.g., this assessment would need to link building data with climate and behavioural data, using quite complex algorithms, which entail considerable uncertainties. Such an approach ranges beyond the scope of iBRoad.

In the second option, the energy auditors carry out an assessment based on on-site visits and their expertise regarding the different dimensions of the co-benefits. This approach guarantees stronger consistency with the Renovation Roadmap and thus a higher relevance of the information delivered to the building owners. A limitation of this approach lies in the time, complexity and resources necessary for carrying out possible additional measurements during the on-site visit. *ANNEX F: Co-benefits assessment in the Renovation Roadmap* explores different methodological approaches to assess the co-benefits: 1) general assessment of a certain renovation step with a simple scheme applying three classes; 2) assessing the different comfort aspects with points; 3) evaluation according to thermal comfort standard; 4) indicative evaluation of the individual co-benefits indicator; and 5) assessing the real estate value benefit. These approaches aim to assess thermal comfort, indoor air quality, lighting and others (approaches 1 to 4), and real state value (approach 5).

After analysing the advantages and disadvantages of these approaches, the approach chosen to be implemented in iBRoad is the *"indicative evaluation of the individual co-benefits indicator"* (described in the next paragraph). This approach allows the energy auditor to assess specific aspects of co-benefits

improvement due to each renovation step, and display them in the Renovation Roadmap. iBRoad supports the energy auditor in this assessment through guidance provided in the Roadmap Assistant and related Handbooks (developed in further steps of the project).

Delivering results on co-benefits both in the Logbook (resulting from an automatic assessment based on Logbook data) and in the Renovation Roadmap (resulting from the auditors' indication), would potentially have led to considerable inconsistencies, misunderstanding and even confusion and misleading messages to the building owner. For this reason, the co-benefits' results in iBRoad are only included in the Renovation Roadmap (not in the Logbook); see paragraphs below.

Indicative evaluation of the individual co-benefits indicator

The energy auditor evaluates individually different co-benefits indicators for each proposed renovation step: aesthetics, health, acoustic comfort, security, thermal comfort, indoor air quality, and lighting, using the Roadmap Assistant. Each co-benefit is displayed through a dedicated icon and symbol, normally coloured in light grey. When a specific renovation step leads to a certain improvement of the co-benefit, the auditor can change the colour of the icon into blue. Thus, in the ongoing renovation process, the positive impact on co-benefits is represented by an increased number of blue icons (see example in Figure 2).

Relevant Handbooks will help the auditor make the choice whether a specific icon should be coloured blue or not.

Figure 2: Co-benefits indicators

IV. LAYOUT PRESENTATION

The previous chapters described the iBRoad concept, including the data flows, calculation modules, functionalities and other aspects of the different components. This chapter will focus on the layouts, and how the components will be visualised for the iBRoad users. For this, mock-ups of the Roadmap Assistant, Cost Calculator, Renovation Roadmap and Logbook are presented.

i. Roadmap Assistant

The Roadmap Assistant is a very easy and intuitive web tool, with which energy auditors can develop the Renovation Roadmap. Starting by a Welcome page, the user can surf through the platform, and enter the data requested or make a selection from a drop-drown menu.

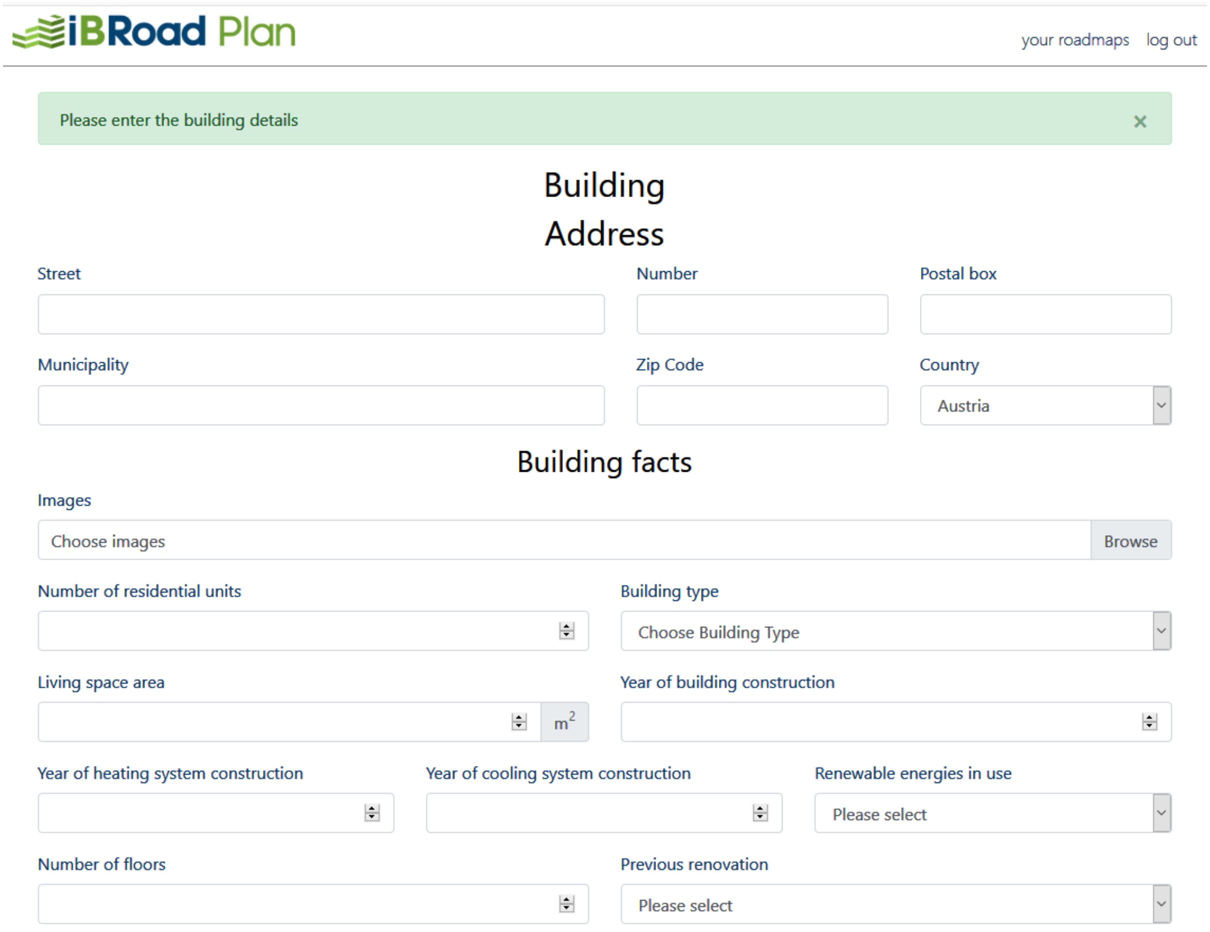


Figure 3: Roadmap Assistant page Building information

The Roadmap Assistant includes some prefabricated text blocks to make the message clear and understandable (see Figure 4):

In Use Advice

Click on the advice to prefill it into the next empty advice field.

Reduce room temperature: Every degree less room temperature saves around 6 % of heating energy. Usually 20 to 22 C° is sufficient in living rooms, 18 to 20 C° in the kitchen, 23 C° in the bathroom and 16 to 18 C° in the bedroom.

Short and intensive ventilation: Tilted windows hardly provide fresh air, but they cool walls and rooms down. Correct intensive ventilation should be provided 2 to 3 times a day for about 4 to 5 minutes, with open windows and doors in all rooms. This ensures the necessary air exchange.

Keep radiators free: Prevent furniture, curtains and curtains in front of radiators so the heat can spread evenly throughout the room.

Keep blinds and curtains closed: Keep blinds and curtains closed at night to prevent heat from escaping on cold nights.

Automatic regulation: Programmable thermostats ensure more comfort and less consumption. This allows rooms to be heated to the right temperature at the right time. 10% savings are possible.

Vent radiators: If radiators chortle and do not warm up properly even though the thermostat is fully turned on, there is air in the radiator which wastes unnecessary energy. By regular venting you save heating costs and consume less CO_2.

Clean the radiator: Dust has an insulating effect and reduces the efficiency of the radiator.

Figure 4: Roadmap Assistant prefabricated text blocks for user advice

The step-by-step Renovation Roadmap consists of single renovation steps. For each step, the energy auditor enters the information related to the energy performance, economic information, and additional benefits (Figure 5, Figure 6 and Figure 7):

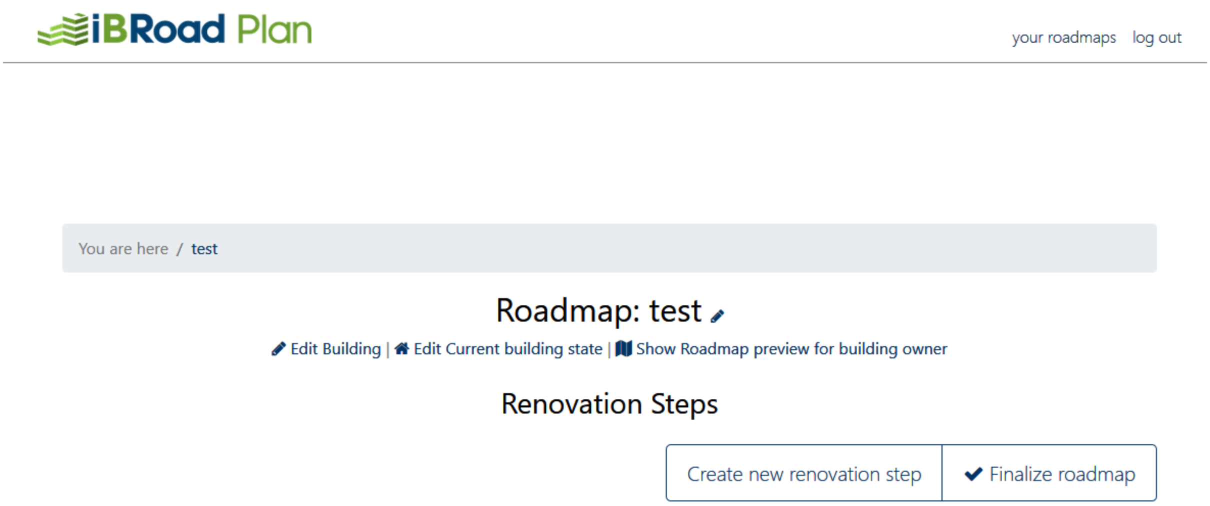


Figure 5: Roadmap Assistant page creating a renovation step

Figure 6: Roadmap Assistant page entering energy performance of each renovation step

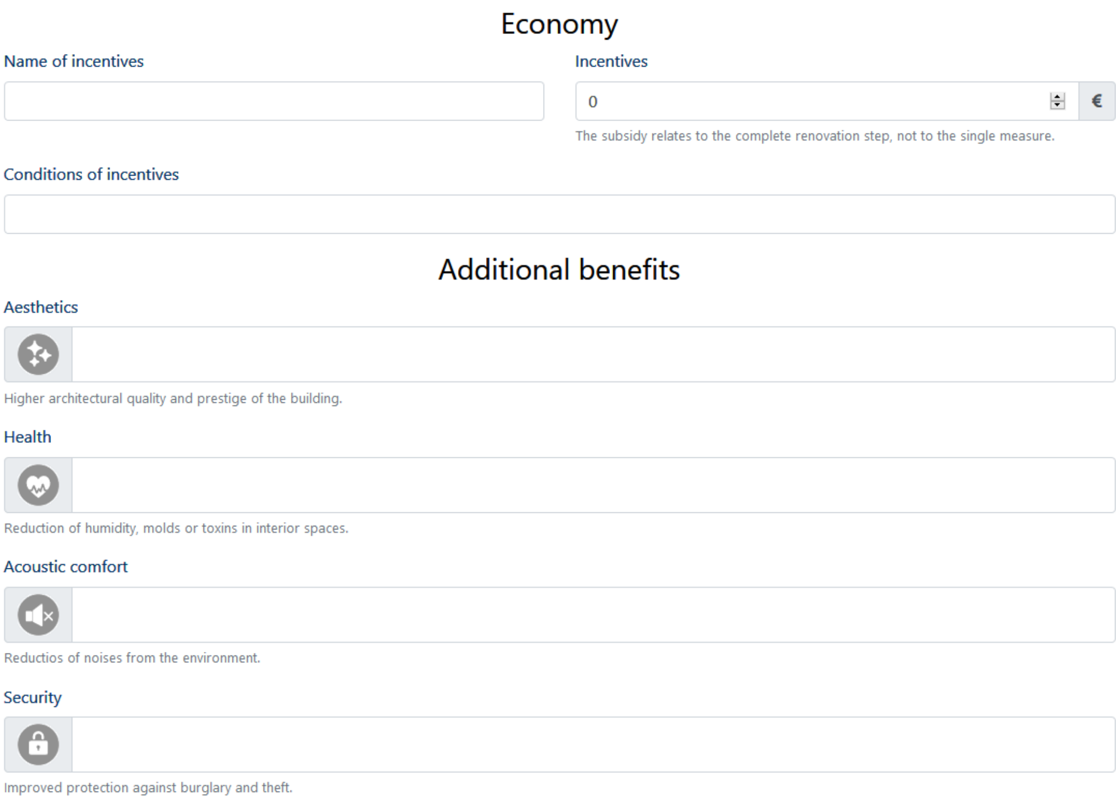


Figure 7: Roadmap Assistant page entering economic and additional benefits of each renovation step

ii. Cost Calculator

The Cost Calculator is accessible when entering the detail of a renovation step in the Roadmap Assistant. The calculation approach is divided in three main steps: first, the input data is entered by the energy auditor in the empty fields (Figure 8), then the tool runs the calculation after the user clicks on the bottom "calculate" and finally, the output parameters are displayed (Figure 9).

The page where the input parameters are required is presented in Figure 8. The energy auditor manually enters the data in the empty fields, whereas some data can also be imported from the general database with default values[9].

- Calculation page: input parameters
  - Renovation measure (from roadmap assistant)
  - Reference Area of renovation measure (Roof, Wall, Floor, Window and others) (enter the data)
  - Reference Load of the heating/cooling system
  - Total investment cost for each renovation step (also from the roadmap assistant or calculated from D3.2)
  - Energy demand after each step taking into account optionally energy consumption factor (also from the roadmap assistant)
  - Energy demand for all measures in the roadmap taking into account optionally energy consumption factor (also from the roadmap assistant)
  - Efficiency of the heating/cooling system (enter or from D3.2)
  - Main energy source heating/cooling (from the roadmap assistant)
  - Energy price source heating/cooling (enter or from D3.2)
  - O&M cost (enter or from D3.2)
  - CO2 Tax (enter or from 3.2)

Calculate

Figure 8: Graphical presentation mock-up of the Cost Calculator– Input parameters and calculation command

When the calculation finishes, the results page opens automatically. The calculation output parameters are presented in Figure 9.

- Calculation page: outputs
  - Total investment costs (for each step and for the roadmap) – min, middle, max
  - Anyway costs (for each step and for the roadmap)
  - Extra costs due to energy related renovation measures (excluding the anyway costs) for each step and for the roadmap
  - Energy costs (each step and for the roadmap)
  - Energy costs variation for each step (due to energy prices)
  - Energy costs variation for all renovation (due to energy prices)
  - O&M costs

Figure 9: Mock-up of the Cost Calculator Output parameters

[9] Explained in detail in the iBRoad project report "*Quantifying home renovation – report and default database for techno economic default assessment of renovation measures*", available on the web-site: https://ibroad-project.eu/

iii. Renovation Roadmap

The Individual Building Renovation Roadmap is visualised in a digital form, including an overview (Figure 10) of the renovation steps in a specific sequence and timing, the energy label achieved after each renovation step, as well as the energy performance, comfort and other co-benefits and cost indicators for each renovation step. By clicking on a specific renovation step, the user gets the detailed technical information about this step (illustrated in Figure 11).

Figure 10: Renovation Roadmap - summarised overview.

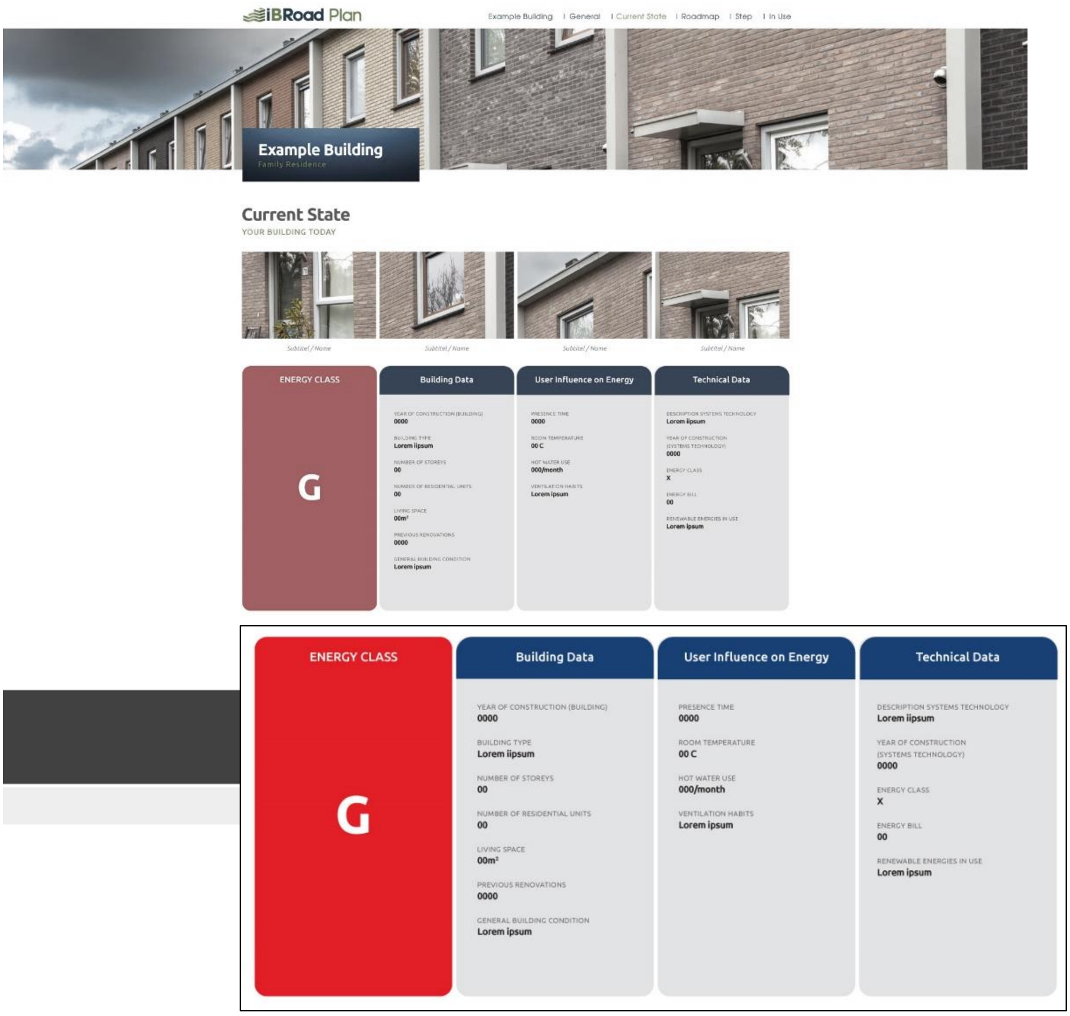


Figure 11: Renovation Roadmap - detailed overview.

iv. Logbook

Figure 12 shows the suggested layout presentation of the Logbook.

The Logbook is personalised, and therefore the Welcome Page, includes the username, home address, last access data and an uploaded photo of his/her house.

The Welcome Page allows access to the following Logbook sections:

- Building Logbook Data
- Building Diagnosis
- Your iBRoad
- Alerts & Reminders

On the left side of the Welcome Page, the user can upload a photo of the house and get quick access to the individual Logbook sections.

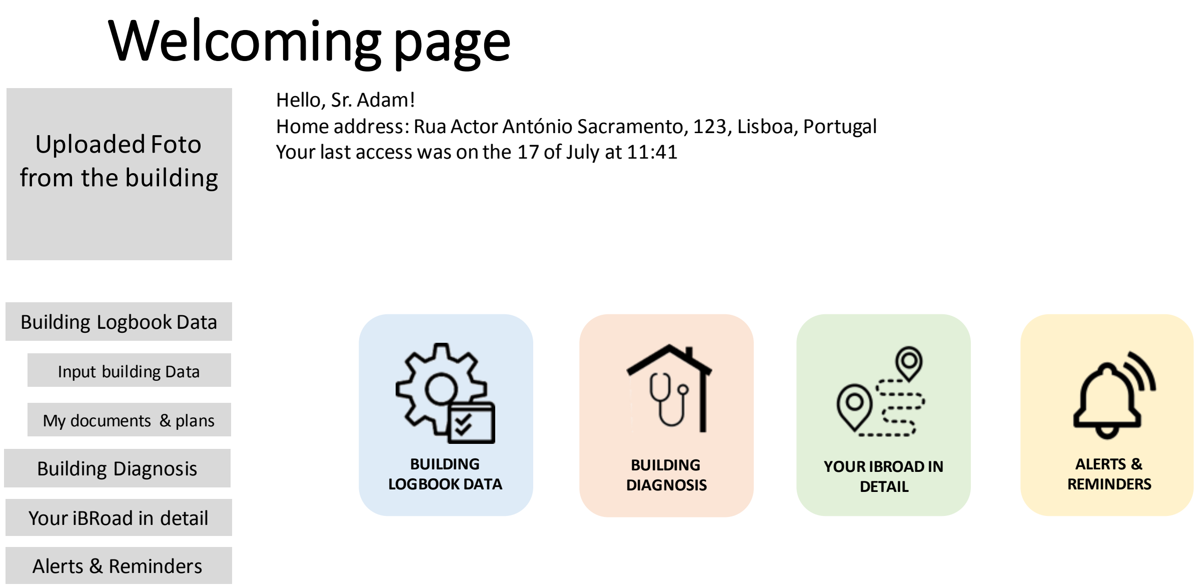


Figure 12: Mock-up of the Logbook "Welcome Page"

Building Logbook Data

The section "Building Logbook Data", foremostly comprises the Logbook data repository, which is structured around the five modules (also mentioned above), namely: General and Administrative information, Building Construction Information, Building Energy Performance, Building Operation and Use, and Smart information (Figure 13).

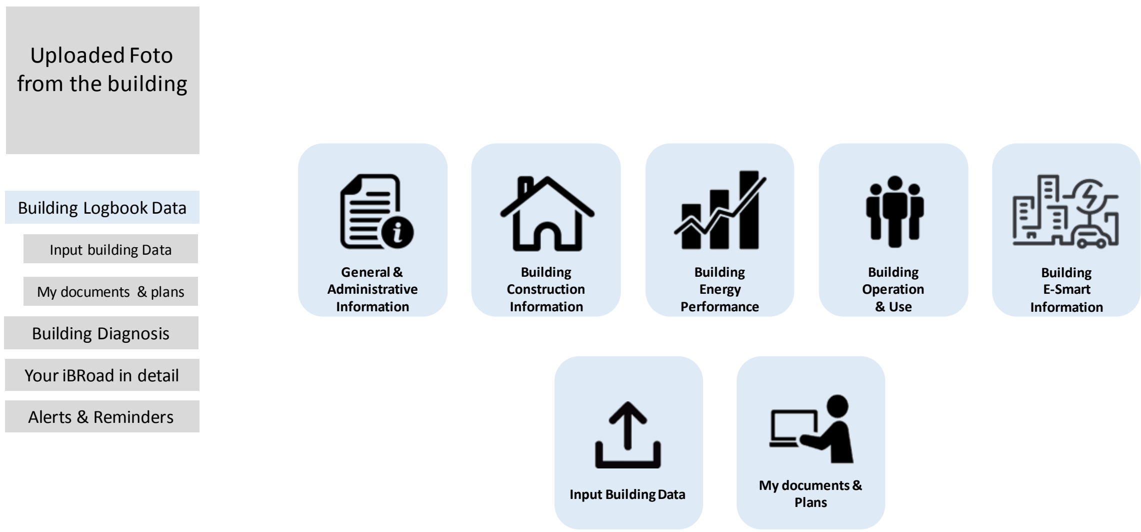


Figure 13: Mock-up of the Logbook "Building Logbook Data Page"

The section further includes the following pages:

- *Input building information* (Figure 14): through this page, the user can enter or alter any relevant Logbook data (building information).

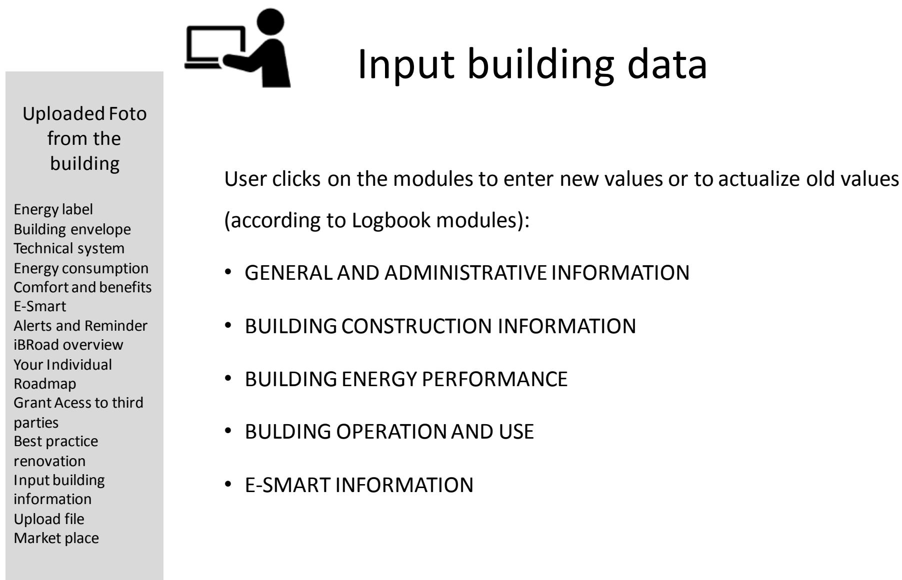


Figure 14: Graphical presentation mock-up of the Logbook Input building data

- *My documents and plans* (Figure 15): in this page, the user can upload and file additional documents, e.g. building plans, contracts, invoices, photographs, energy bills, technical offers, guarantees, etc., in various formats (e.g. word, excel, jpeg, pdf, etc.)

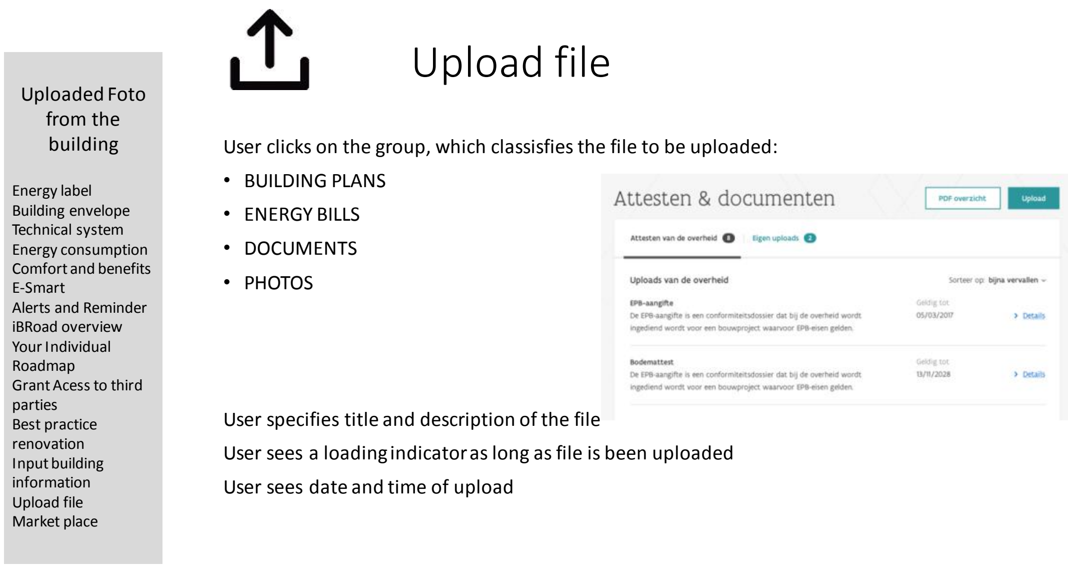


Figure 15: Graphical presentation mock-up of the Logbook Upload files

Building diagnosis

The Building Diagnosis includes the following pages:

- *Energy label* (Figure 16): in this page, the user sees the actual Energy Label of the building, rated according to the national EPC classification. A notification on available subsidies and incentives for renovation serves as trigger for action, particularly in the case of a low energy rating.

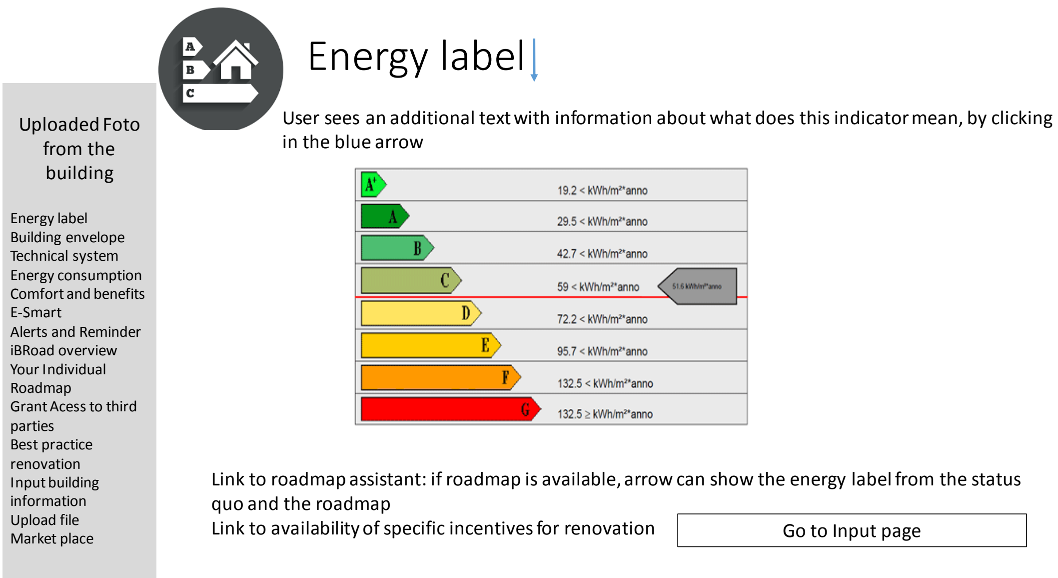


Figure 16: Mock-up of the Logbook page Energy Label

- *Building envelope* (Figure 17): in this page, the user sees the actual status quo (rating) of the various building elements, coloured according to a country specific energy efficiency scale, and accompanied by related description and/or advice.

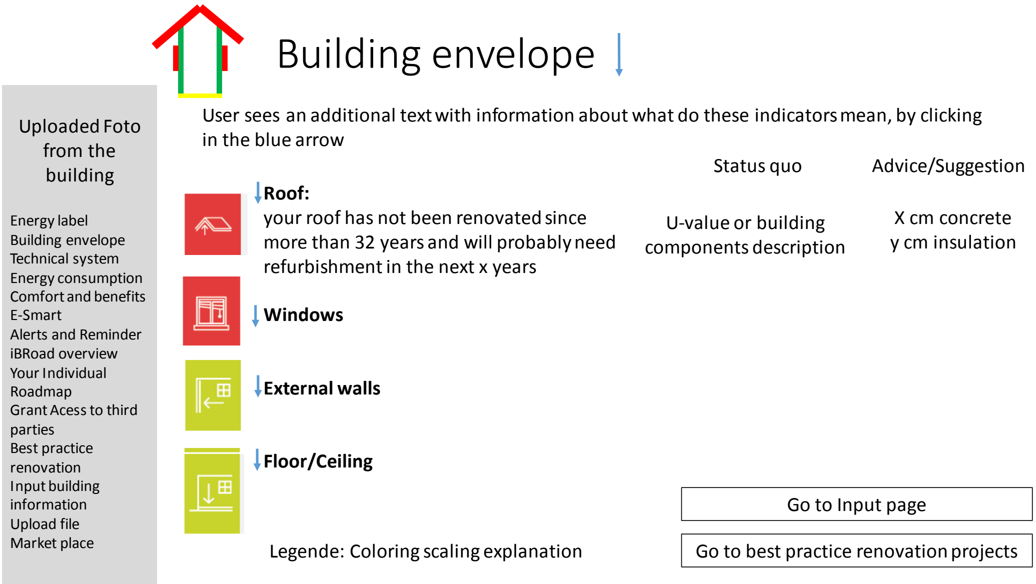


Figure 17: Mock-up of the Logbook page Building Envelope

- *Technical Systems* (Figure 18): in this page, the user sees the actual status quo of the technical building systems (heating, cooling, ventilation, domestic hot water, lighting, renewable energy and heat distribution), coloured according to an energy efficiency scale (country specific). In addition, a text message indicates the equipment's life time, and includes possible suggestions related to equipment maintenance and/or replacement. Finally, automated advices and suggestions about technological possibilities may also be shown.

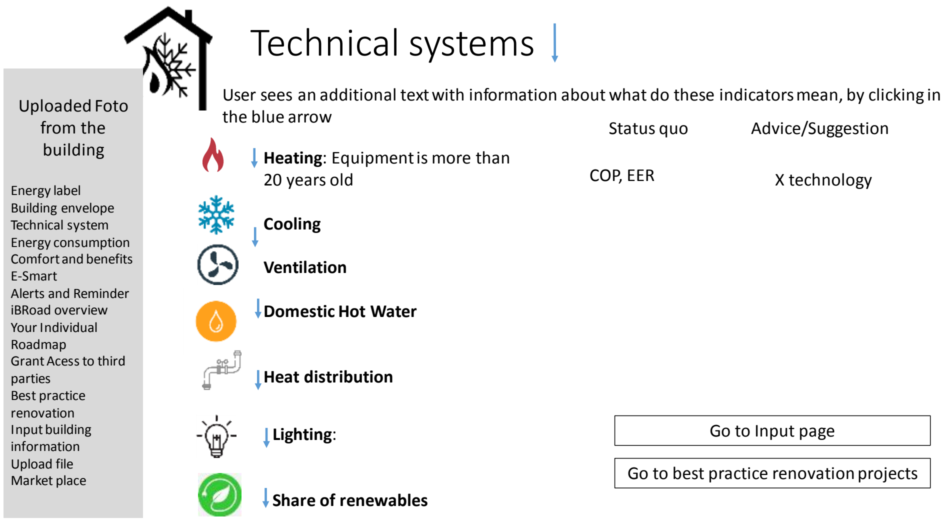


Figure 18: Mock-up of the Logbook page Technical Systems

Your iBRoad

This section includes the following pages:

- *Your iBRoad Overview* (Figure 19): in this page, the user sees and may print the summarised overview of the Renovation Roadmap developed using the Roadmap Assistant (as described before).

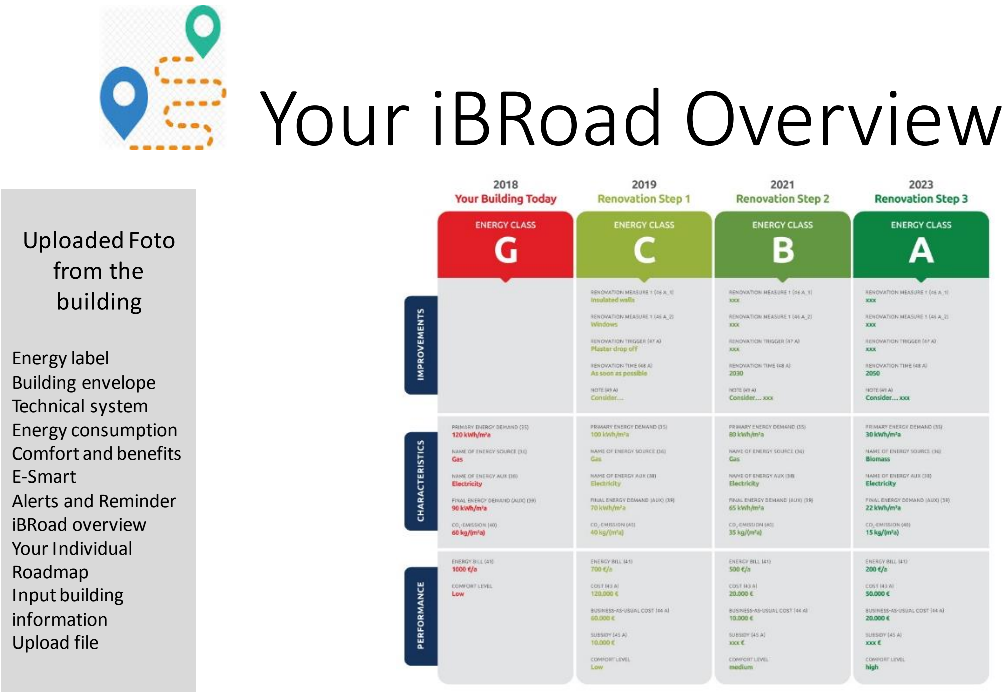


Figure 19: Mock up of the Logbook page Your iBRoad Overview

- Your iBRoad in detail (Figure 20): this is the page through which the user has access to the detailed Renovation Roadmap of his/her building.

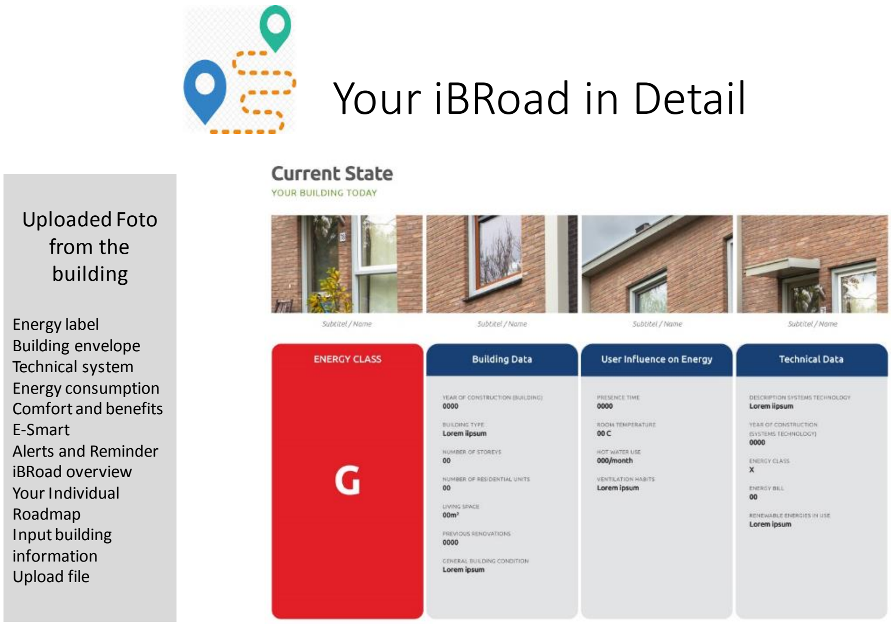


Figure 20: Mock up of the Logbook page Your iBRoad in Detail

Alerts & Reminders

In this section, the user configures, among the following possibilities, which alerts and reminders he/she wants to receive:

- Notifications on Energy performance
- Alerts on Refurbishment needed
- Alerts on Maintenance needed
- Available financing

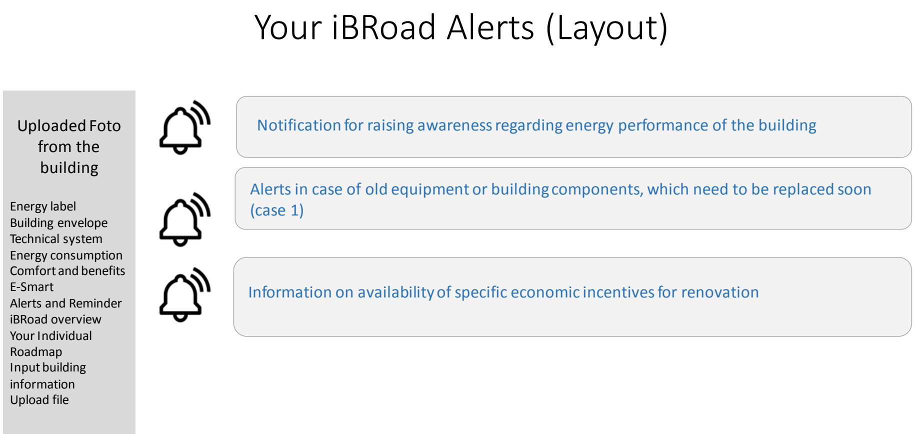


Figure 21: Mock-up of the Logbook page Your iBRoad Alerts

V. RECOMMENDATIONS FOR COUNTRY SPECIFIC ADAPTATION

The iBRoad components, as described in this report, have been developed without considering details of country specific characteristics, in order to allow replicability across various countries. For implementation in a certain country or region, certain adaptations are required. This chapter highlights some selected recommendations, which are essential for a country specific adaptation of some of the iBRoad components (Logbook, Renovation Roadmap and Roadmap Assistant). By these adaptations, the concepts described above will take into account national conditions on, e.g., data availability, national standards for demand calculation, EPC, cost data, climatic data, etc.

- *Logbook fixed parameters* (chapter II.): some indicators, as for example, energy class or useful heating demand or primary energy demand should be specifically defined for each country, because they could be related to national energy policies and EPCs' schemes.
- *Logbook flexible parameters* (chapter II.): The flexible parameters, which are not obligatory for the functioning of the Logbook functionalities should be chosen according to the specific availability of building information and requirements of each pilot country.
- *Energy demand calculation* (chapter III.i): the model up to now includes default values for a building in Germany. Therefore, data such as climate, occupants' behaviour, primary energy factors and others, need to be adapted.
- *Economic assessment* (chapter III.ii): the default database presented in the project report "*Quantifying home renovation – report and default database for techno economic default assessment of renovation measures*" offers a method to calculate the renovation measure costs, including generic values. However, these values should be country specific, together with other economic data (as for example, energy prices).

These adaptations will serve as guidance on further activities of the iBRoad-project, in particular regarding the IT implementation, and adaptation for the four pilot countries: Bulgaria, Germany, Poland and Portugal.

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ANNEX A: iBRoad CONCEPT GLOSSARY

iBRoad Concept Glossary	
Logbook	The logbook is the main repository of all building related information, including aspects such as actual energy consumption, energy performance, maintenance requirements, design plans. The iBroad logbook can only be edit/used by building owner who can grant access to other parties.
Logbook functionalities	The logbook is mainly a repository for building information but functions can also include automated alerts, benchmark function, simplified renovation advice, facilitation market places etc.
Logbook modules	The iBRoad logbook is build upon a number of modules (not exclusively related to the building), which can comprise energy performance, renovation advice, the housing quality (such as stability, humidity, safety), data on the environment, sustainability, water, installations and building permits.
Roadmap	The iBRoad roadmap is at its core a home-improvement plan which considers the occupants' needs and specific situations (e.g. age, financial situation, composition and expected evolution of the household, etc.) and avoids the risk of 'locking-out' future renovation solutions due to a lack of foresight.
Roadmap assistant	The iBRoad roadmap assistant is the corresponding software tool which assists in the production of the roadmap documents. The roadmap assistant is used by the auditor only, not by the building owner, as it requires expert knowledge.
iBRoad data ownership	The iBRoad logbook and roadmap are both property of the building owner,who can grant access to third parties
End-user	The end-user of the iBRoad is the building owner
Logbook access	The building owner can grant access to different parties (auditors, public authorities, financial institutions, utilities etc.) to view, input and edit data in the logbook.
Roadmap input	Based on a detailed energy audit, and taking the specific wishes and preferences of the building owner into account, the auditor uses the roadmap assistant to outline renovation packages, including financing advice/information on support schemes and things to consider in the renovation steps etc.
Co-benefits	The benefits that are not related to energy-savings and costs, including e.g. better health, wellbeing and comfort, but also impact on the buildings' market value and others.
Thermal comfort	Thermal comfort describes the occupants satisfaction with the indoor temperature, including not only the ambient temperature but also on the perceived air quality.
Indoor Environmental Quality	Indoor environmental quality refers to the quality of a building's environment, including aspects such as air quality, temperature, biophilia, light, damp condition, acoustics.
Renovation steps	The renovation roadmap sets out a long-term transformation of the building to a energy efficient building. The roadmap includes a set number of renovation steps (each includes one or a limited number of measures), which should be take in a certain order.
iBRoad	Individual Building Renovation Roadmap is defined as a document - in electronic or paper format - outlining a long-term (up to 10 or 20 years) step-by-step renovation roadmap for a specific building. The expected benefits in terms of reduced heating bills, comfort improvement and CO2 reduction are a constitutive part of the concept and are explained in a user-friendly way. The renovation roadmap can be combined with a repository of building-related information (logbook) on aspects such as the energy consumption and production, executed maintenance and building plans, providing several functionalities to the building owner which could go beyond the energy performance.
iBRoad project	The iBRoad project is a 3-year project funded by the Horizon 2020 European programme, aimed at exploring, designing, developing and demonstrating the concept of individual Building Renovation Roadmaps.

ANNEX B: MAPPED FIXED LOGBOOK PARAMETERS

						Building information (5 Logbook Modules)	Document depository (documents and plans upload)	your iBRoad Overview	your iBRoad in Detail	building energy performance	envelope energy perfomance	**equipment energy performance**	Notification on energy performance	Alerts on refurbishment needed	Alerts on maintenance needed	Available financing
						1.1	1.2	2.1	2.2	3.1	3.2	3.3	4.1	4.2	4.3	4.4
						should be country spefic defined		the same as in the Roadmap Assistant		energy class and %of Renewables (or to be country specific defined: need, final and/or primary energy demand; CO2 emissions)	u-values (country specific, for example window label; equipmend label)	energy efficiency/ energy sources	u-values; material type; equipment type or material properties	u-value/ material properties (material type and thermal capacity)/ renovation year	energy source/ type of equipment /age of technical system	u-values/type of technical system/age of technical system/building construction year/renovation year
Module	**L1**	**L2**	**L3**	**L4**	**Type**	x										
A- General Information and Admnistrative	Building	Building General Features	Construction year			x										x
A- General Information and Admnistrative	Building	Building General Features	Total net floor area			x										
B - Building Construction Information	Envelope	Walls	Wall type n	Structural material type	free text	x							x			
B - Building Construction Information	Envelope	Walls	Wall type n	Structural material thickness	float number	x							x			
B - Building Construction Information	Envelope	Walls	Wall type n	Structural material thermal conductivity	float number	x							x			
B - Building Construction Information	Envelope	Walls	Wall type n	Insulation type	free text	x							x			
B - Building Construction Information	Envelope	Walls	Wall type n	Insulation thickness	float number	x							x			
B - Building Construction Information	Envelope	Walls	Wall type n	Insulation thermal conductivity	float number	x							x			
B - Building Construction Information	Envelope	Walls	Wall type n	Overall wall thermal U-value	float number	x					x		x	x		x
B - Building Construction Information	Envelope	Walls	Wall type n	Renovation year	number	x								x		x
B - Building Construction Information	Envelope	Walls	Wall type n	Cost of renovation	float number	x								x		x
B - Building Construction Information	Envelope	Walls	Wall type n	Contractor info	free text	x								x		x
B - Building Construction Information	Envelope	Walls	Wall type n	Source of financing	free text	x								x		x
B - Building Construction Information	Envelope	Roof	Roof type n	Description of the constructive solution	free text	x										x
B - Building Construction Information	Envelope	Roof	Roof type n	Surface area north orientation	float number	x										x
B - Building Construction Information	Envelope	Roof	Roof type n	Structural material type	free text	x							x			
B - Building Construction Information	Envelope	Roof	Roof type n	Structural material thickness	float number	x							x			
B - Building Construction Information	Envelope	Roof	Roof type n	Structural material thermal conductivity	float number	x							x			
B - Building Construction Information	Envelope	Roof	Roof type n	Insulation type	free text	x							x			
B - Building Construction Information	Envelope	Roof	Roof type n	Insulation thickness	float number	x							x			
B - Building Construction Information	Envelope	Roof	Roof type n	Insulation thermal conductivity	float number	x							x			
B - Building Construction Information	Envelope	Roof	Roof type n	Overall roof thermal U-value	float number	x					x		x	x		x
B - Building Construction Information	Envelope	Roof	Roof type n	Renovation year	number	x								x		x

						Building information (5 Logbook Modules)	Document depository (documents and plans upload)	your iBRoad Overview	your iBRoad in Detail	building energy performance	envelope energy perfomance	**equipment energy performance**	Notification on energy performance	Alerts on refurbishment needed	Alerts on maintenance needed	Available financing
						1.1	1.2	2.1	2.2	3.1	3.2	3.3	4.1	4.2	4.3	4.4
						should be country spefic defined		the same as in the Roadmap Assistant		energy class and %of Renewables (or to be country specific defined: need, final and/or primary energy demand; CO2 emissions)	u-values (country specific, for example window label; equipmend label)	energy efficiency/ energy sources	u-values; material type; equipment type or material properties	u-value/ material properties (material type and thermal capacity)/ renovation year	energy source/ type of equipment /age of technical system	u-values/type of technical system/age of technical system/buildig construction year/renovation year
B - Building Construction Information	Envelope	Roof	Roof type n	Cost of renovation	float number	x								x		
B - Building Construction Information	Envelope	Roof	Roof type n	Contractor info	free text	x								x		
B - Building Construction Information	Envelope	Roof	Roof type n	Source of financing	free text	x								x		
B - Building Construction Information	Envelope	Floor	Floor type n	Structural material type	free text	x							x			
B - Building Construction Information	Envelope	Floor	Floor type n	Structural material thickness	float number	x							x			
B - Building Construction Information	Envelope	Floor	Floor type n	Structural material thermal conductivity	float number	x							x			
B - Building Construction Information	Envelope	Floor	Floor type n	Insulation type	free text	x							x			
B - Building Construction Information	Envelope	Floor	Floor type n	Insulation thickness	float number	x							x			
B - Building Construction Information	Envelope	Floor	Floor type n	Insulation thermal conductivity	float number	x							x			
B - Building Construction Information	Envelope	Floor	Floor type n	Insulation density	float number	x							x			
B - Building Construction Information	Envelope	Floor	Floor type n	Overall thermal U-value	float number	x					x		x	x		x
B - Building Construction Information	Envelope	Floor	Floor type n	Renovation year	number	x								x		x
B - Building Construction Information	Envelope	Floor	Floor type n	Cost of renovation	float number	x								x		
B - Building Construction Information	Envelope	Floor	Floor type n	Contractor info	free text	x								x		
B - Building Construction Information	Envelope	Floor	Floor type n	Source of financing	free text	x								x		
B - Building Construction Information	Envelope	Thermal bridges	Flat thermal bridge type n	Insulation type	free text	x							x			
B - Building Construction Information	Envelope	Thermal bridges	Flat thermal bridge type n	Overall flat thermal bridge U-value	float number	x					x		x	x		x
B - Building Construction Information	Envelope	Thermal bridges	Flat thermal bridge type n	Renovation year	number	x								x		x
B - Building Construction Information	Envelope	Thermal bridges	Flat thermal bridge type n	Cost of renovation	float number	x								x		
B - Building Construction Information	Envelope	Thermal bridges	Flat thermal bridge type n	Contractor info	free text	x								x		
B - Building Construction Information	Envelope	Thermal bridges	Flat thermal bridge type n	Source of financing	free text	x								x		
B - Building Construction Information	Envelope	Thermal bridges	Linear thermal bridge type	Renovation year	number	x										x
B - Building Construction Information	Envelope	Door	Door type n	Door U-value	float number	x					x		x	x		x
B - Building Construction Information	Envelope	Door	Door type n	Renovation year	number	x								x		x
B - Building Construction Information	Envelope	Door	Door type n	Cost of renovation	float number	x								x		

						Building information (5 Logbook Modules)	Document depository (documents and plans upload)	your iBRoad Overview	your iBRoad in Detail	building energy performance	envelope energy perfomance	**equipment energy performance**	Notification on energy performance	Alerts on refurbishment needed	Alerts on maintenance needed	Available financing
						1.1	1.2	2.1	2.2	3.1	3.2	3.3	4.1	4.2	4.3	4.4
						should be country spefic defined		the same as in the Roadmap Assistant		energy class and %of Renewables (or to be country specific defined: need, final and/or primary energy demand; CO2 emissions)	u-values (country specific, for example window label; equipmend label)	energy efficiency/ energy sources	u-values; material type; equipment type or material properties	u-value/ material properties (material type and thermal capacity)/ renovation year	energy source/ type of equipment /age of technical system	u-values/type of technical system/age of technical system/building construction year/renovation year
B - Building Construction Information	Envelope	Window	Window type n	Window type	options	x							x			
B - Building Construction Information	Envelope	Window	Window type n	Window frame U-value	float number	x					x		x	x		x
B - Building Construction Information	Envelope	Window	Window type n	Window glazing type	options	x							x			
B - Building Construction Information	Envelope	Window	Window type n	Window glazing U-value	float number	x					x		x	x		x
B - Building Construction Information	Envelope	Window	Window type n	Window SHGC	float number	x								x		
B - Building Construction Information	Envelope	Window	Window type n	Window thermal U-value	float number	x					x		x	x		x
B - Building Construction Information	Envelope	Window	Window type n	Window Energy label	free text	x					x		x	x		
B - Building Construction Information	Envelope	Window	Window type n	Solar protection type	free text	x					x		x	x		
B - Building Construction Information	Envelope	Window	Window type n	Solar protection location	options	x					f		x	x		
B - Building Construction Information	Envelope	Window	Window type n	Daylight factor	float number	x								x		
B - Building Construction Information	Envelope	Window	Window type n	Renovation year	number	x								x		x
B - Building Construction Information	Technical Building syster	Ventilation system	Ventilation system type n	Heat recovery efficiency	float number	x						x				
B - Building Construction Information	Technical Building syster	Ventilation system	Ventilation system type n	Renovation year	number	x								x		x
B - Building Construction Information	Technical Building syster	Ventilation system	Ventilation system type n	Equipment age	number										x	x
B - Building Construction Information	Technical Building syster	Heating system	Heat system type n	Energy source	options	x						x	x		x	
B - Building Construction Information	Technical Building syster	Heating system	Heat system type n	Type of equipment	options	x							x		x	x
B - Building Construction Information	Technical Building syster	Heating system	Heat system type n	Nominal efficiency	float number	x						x	x		x	x
B - Building Construction Information	Technical Building syster	Heating system	Heat system type n	Nominal thermal power	float number	x						x	x		x	x
B - Building Construction Information	Technical Building syster	Heating system	Heat system type n	Number of units installed	number	x										x
B - Building Construction Information	Technical Building syster	Heating system	Heat system type n	Renovation year	number	x									x	x
B - Building Construction Information	Technical Building syster	Heating system	Heat system type n	Equipment age	number										x	x
B - Building Construction Information	Technical Building syster	Cooling system	Cool system type n	Energy source	options	x						x	x		x	
B - Building Construction Information	Technical Building syster	Cooling system	Cool system type n	Type of equipment	options	x							x		x	x
B - Building Construction Information	Technical Building syster	Cooling system	Cool system type n	Nominal efficiency	float number	x						x	x		x	x
B - Building Construction Information	Technical Building syster	Cooling system	Cool system type n	Nominal thermal power	float number	x						x	x		x	x

ANNEX C: DATA AND PARAMETERS REQUIRED FOR THE iBRoad LOGBOOK FUNCTIONALITIES

This ANNEX specifies the necessary data and parameters required for the functionalities that will be implemented in iBRoad's IT framework: 1) building data repository, 2) building diagnosis, 3) display Renovation Roadmap, 4) alerts and reminders, including how the user is intended to travel through the tool to receive this information (exemplary user stories for the IT implementation), defining also which equations and criteria are necessary.

a. Building Logbook Data Repository

The Logbook's main functionality is the storage of the building related data, also called Building Logbook Data Repository. This data storage happens in a hybrid structure form, which consists of a fixed and a flexible data structure. The fixed part is common to every country. It is the minimum data required for the proper functioning of all functionalities, while the flexible part contains various levels of information, which can be country specific.

a.1 View Logbook data repository

This is the main functionality of the Logbook and allows users to visualise the stored building information in a user-friendly form.

The user can access the Logbook, and surf through the different modules and data and see which functionalities are available.

a.2 Input data

This functionality should allow users to enter, store and access the building information structured in the five modules described above.

The user enters the building data, e.g. building address, house number and house owner information

Exemplary user story for IT implementation: building owner enters data such as building address in the Logbook section "input building data, module "general administrative information"[10]

a.3 Upload of documents (plans, documents etc)

This functionality should help the user to organise and save relevant files, like plans, licence documents, bills, etc., in different formats (pdf, jpeg, etc.). The user will be able to upload, store and download documentation. No further processing of the information in these documents will be possible (for example, from uploaded plans, no areas will be automatically calculated).

For example, the user accesses the "Upload material" section to upload plans, pictures, licences and permitting documents; he/she saves and stores them and downloads them at later stage.

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[10] As a guidance for the IT implementation in the further work of the project, each functionality will include exemplary user stories.

b. Building Diagnosis

b.1 Building energy performance

This functionality should facilitate understanding about the current building status, by displaying a country specific energy performance indicator in a colour coding form (ideally corresponding to the colour code of the national EPC).

For implementation in the pilot countries, the corresponding project partners should define the relevant energy indicator (e.g., primary energy, EPC energy class, or any other national energy performance indicator), the classification (according to the EPC classification or other country specific criteria), and the colour code rating (see below).

For example, the user sees a representative figure of the house with a colour code rating for specific components (roof, floor against ground, windows and external walls), e.g., house envelope icon coloured in red for a building class G (Figure 22).

Necessary parameters: possible parameters could be primary energy, CO_2 emissions, building heat losses and energy label (or class).

For IT implementation, the information on the energy label needs to be translated in a corresponding colour, according to a country-specific defined colour-code-rating (example: energy class as building performance indicator, with 9 level ranking):

e.g. energy label = x

if, x = “A++”, then display “A++” in “light blue”, according to the colour code rating below:

A++	A+	A	B	C	D	E	F	G

b.2 Envelope energy performance

This functionality should facilitate understanding about the current building status by displaying building elements in a colour associated with their energy efficiency. For each pilot country, the scale (less efficient to more efficient, according to national building codes and technological standards), scaling system and/or colour code needs to be defined.

For example, the user sees a representative figure with building elements such as roof, external walls, floor, window, coloured according to the energy efficiency of the building element (Figure 22).

Figure 22: Graphical representation of features “building energy performance” and “envelope energy performance”

Link with other functionalities: alerts when building elements need to be replaced.

User story for IT implementation: the building owner and/or energy auditor access the Logbook module 'building construction information' and can see the building elements coloured according to their energy efficiency performance.

Main parameters: U-values for each building element[11]

Other optional parameters: g-Value for glazing, building material labels (if available in the country)

Equations for IT implementation of the main parameters:

Weighting the U-values of each building element according to different building element types. The example below refers to external walls; however, it should be implemented for all building elements - roof, floor and windows correspondingly.

$$U_{wall,mean} = \frac{\mathrm{A}_{\mathrm{wall,type\ 1}} * U_{\mathrm{wall,type\ 1}} + \mathrm{A}_{\mathrm{wall,type\ 2}} * U_{\mathrm{wall,type\ 2}} + \cdots + \mathrm{A}_{\mathrm{wall,type\ n}} * U_{\mathrm{wall,type\ n}}}{\mathrm{A}_{\mathrm{wall,type\ 1}} + \mathrm{A}_{\mathrm{wall,type\ 2}} + \cdots + \mathrm{A}_{\mathrm{wall,type\ n}}}$$

U_{wall} = U-Value of the external wall, according to each wall Type [W/K * m²]

A_{wall} = external wall surface [m²]

We suggest to classify the U-values according to three energy efficiency levels (low, middle and high)[12] and display them according to the table below. Here, threshold values should be defined for each pilot country:

U-values	Low	Middle	High
Walls total			
Roof total			
Floor total			
Window total			

Figure 23: Suggested colour presentation of U-values

e.g. a = $U_{wall,\ mean}$

if, a =< X_{wall}, then display external wall in “green”,

if X<a =<Y_{wall}, then display external wall in “yellow”

if a > Z_{wall}, then display external wall in “red”

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[11] The logbook could store more comprehensive information about the wall layers too, for example, thickness, density, and conductivity of each wall layer, so that the information about the U-value and the thermal mass can be provided too.

[12] These are exemplary threshold values, which should be defined at country specific level.

b.3 Equipment energy performance

This functionality should facilitate the understanding about the current building status by displaying building equipment in a colour associated with the related energy performance. The threshold values (less efficient to more efficient, according to national building codes and technological standards), scaling system, and/or colour code need to be defined for each pilot country.

For example, the user sees a representative figure with heating and cooling systems coloured according to the energy performance of the technical systems. We propose to combine the efficiency with the share of renewables used by the equipment (see below).

Example: low energy efficient heating system

Link with other functionalities: alerts when equipment need to be replaced.

User story for IT implementation: the building owner and/or energy auditor sees in the Logbook module 'building construction information' the equipment's colouring according to the energy efficiency performance.

Main necessary parameters: equipment's efficiency and used energy carrier (linked to a classification whether this energy source is renewable or not or to which share)

Other possible parameters: equipment's energy class labels (if available)

The representative colour for the energy efficiency derives from a combination of two indicators: equipment's efficiency (separately analysed for the building services space heating, cooling, domestic hot water and mechanical ventilation) and energy source. E.g.. the equipment's efficiency level may be classified in three levels (low, middle and high[i]), while the energy source can be labelled as renewable or not if a certain minimum share of renewables is achieved (see Figure 24). Also here, more steps of renewable shares would be possible.

For IT implementation, the following table would need to be implemented (while the number of efficiency classes and the number of renewable-share classes might be adapted for each pilot country):

		Energy source	
		renewable	not renewable
Energy efficiency (EE or COP)	low		
	mid		
	high		

Figure 24: Choice criteria for functionality "Equipment energy performance"

e.g. for a biomass boiler with low energy efficiency, display "yellow", or for a gas boiler with medium energy efficiency, display "orange".

c. Display Renovation Roadmap

c.1 Summary of the building Renovation Roadmap

This functionality should display a summary of the building Renovation Roadmap. If no Renovation Roadmap is available, the user sees a message such as: "Please develop a customised Renovation

Roadmap with the help of an energy auditor next to you", including a link to corresponding certified energy auditors when possible.

The user selects the Logbook section "Individual Building Renovation Roadmap" and sees the overview of the building renovation plan with the step-by-step Renovation Roadmap (including information like total investment, energy savings and others).

Exemplary user story for IT implementation: After the building owner and/or energy auditor selects the Logbook section "Individual Building Renovation Roadmap", the Logbook visualises the summary of the "Individual Renovation Roadmap" developed with the energy auditor (Figure 10).

Necessary parameters: no Logbook parameters needed for this functionality.

c.2 Details of the building Renovation Roadmap

This functionality displays the details of the building Renovation Roadmap and allows the user to see the detailed information about his/her individual building Renovation Roadmap developed by the energy auditor.

Exemplary user story for IT implementation: the building owner and/or energy auditor selects the Logbook section "Individual Building Renovation Roadmap" and visualises the roadmap details such as renovation measures developed by the energy auditor. By clicking on each step, a new window opens with detailed information about the renovation measures, including economic data on this proposed renovation step (Figure 11).

Necessary parameters: no Logbook parameters needed for this functionality.

d. Alerts and Reminders

d.1 Notification on energy performance

This functionality increases user's awareness about the building status by showing alerts, which can be chosen by the building owner.

For example, if the window has a low efficiency, the user receives an alert with the message "your window has low energy efficiency".

If there is no individual building Renovation Roadmap, then it should also be recommended to develop a Renovation Roadmap or to ask for advice from an energy auditor.

User story for IT implementation: Building owner selects the Logbook section "Building Diagnosis – Building envelope" and gets alerts regarding actual building elements and equipment.

Main parameters: Age of installations, efficiency of installations, last time of repair/maintenance, energy labels, U-values, energy source and energy efficiency.

Other possible parameters: type of materials, g-values, material labels, renewable energy generation.

d.2 Alerts on refurbishment needed

This functionality should indicate to the user that a building element is reaching its end of life, and consequently, it should be replaced. For this functionality, there are two information sources: a) if the information is available in the Logbook, then the alert is sent automatically; b) if the information is not available, the user selects the date of the latest building renovation or equipment replacement from a list made available in the Logbook. Based on this information, in case the equipment has exceeded its expected lifetime, the functionality produces again the corresponding alert.

For example: if the window is older than a certain threshold-value, the user gets an alert; e.g., "Your window is 17 years old. Typically, windows need to be replaced after 15-20 years."

User story for IT implementation (if the information is available in the Logbook): the building owner selects the Logbook section "Building Construction Information" and gets alerts regarding actual technical system age.

Main parameters: renovation year, building year.

Other optional parameters: U-values, material properties (material type and thermal capacity).

Equations for IT implementation:

- if (actual year - year of renovation) > expected life time of the building element, then an alert appears;
- if not, no alert appears.

d.3 Alerts on maintenance needed

This functionality should indicate the user that the installed equipment needs to undergo regular maintenance. For this functionality, there are two information sources: a) if the information is available in the Logbook, then the alert is sent automatically. If the information is not available, the user selects from a list the date of the latest equipment maintenance or replacement. Based on this information, the functionality produces the corresponding alert, in case that the equipment has exceeded the expected maintenance time.

For example: if the heating equipment is older than a certain threshold-value (depending on the type of heating system), the user gets an alert.

Other functionalities that could be linked: Awareness of actual building status by displaying colour scheme according to equipment's energy efficiency and building diagnosis.

User story for IT implementation (if the information is available in the Logbook): Building owner selects the Logbook section "Building Construction Information" and receives an alert on required equipment maintenance.

Main parameters: type of equipment, year of maintenance.

Other possible parameters: energy source, age of technical system.

Equations for IT implementation:

- if (actual year - year of last maintenance) > maintenance period of the equipment, then an alert appears;
- if not, no alert appears

d.4 Available financing

This functionality should indicate to the user, whether public incentives, e.g., in the form of investment subsidies, are available for the selected renovation measure, if possible, accompanied by the amount of the related incentive.

For example, for a certain renovation measure occurring in the Renovation Roadmap, the user receives an alert on specific economic incentives available, including a link to other related internet websites from where she/he can get further information.

User story for IT implementation: the building owner selects a certain measure from the Renovation Roadmap. For this measure she/he sees in the Logbook section “Building diagnosis” – “Energy label” the link to access the governmental website.

The parameters necessary for this functionality depend on the exact design of the support or financing scheme and which criteria are being used. They may involve: U-vales, type of technical system, age of technical system, building construction year, renovation year and energy label, assignment of measure to a certain class of renovation measures, for which, e.g., subsidies are available.

ANNEX D: CALCULATION PROCEDURES AND EQUATIONS FOR ENERGY DEMAND FOR HEATING, COOLING, LIGHTING, VENTILATION AND DOMESTIC HOT WATER

This Annex presents the basic calculation procedures and equations for energy demand for heating, cooling, lighting, ventilation and domestic hot water.

a. Monthly balance procedure for the calculation of the energy need for heating

The energy need demand for heating is determined as the daily mean for each month. The sum of all heat sources and losses are balanced, taking also into consideration the utilisation factor. The equation describes the energy need demand for heating (DIN V 18599-2, 2011)

$Q_{h,n} = Q_{sink} - \eta * Q_{source} - \Delta Q_c$ Equation 1

$Q_{sink} = Q_T + Q_V$ Equation 2

$Q_{source} = Q_s + Q_{Isource}$ Equation 3

The monthly utilisation factor depends on the relation between heat sources and heat losses in the building zone (Equation 4):

$\eta = \frac{1-\gamma^a}{1-\gamma^{a+1}}$, when $\gamma \neq 1$, and Equation 4

$\eta = \frac{a}{a+1}$ when $\gamma = 1$

$\gamma = \frac{Q_{source}}{Q_{sink}}$

where,

$Q_{h,n}$= monthly energy need demand for heating	[kWh]
$Q_{c,n}$= monthly energy need demand for cooling (equation shown below)	[kWh]
η= $Utilization\ factor$	[-]
a=time constant for each zone	[-]
ΔQ_c= $Stored\ heat\ during\ time\ of\ reduced\ operation$	[kWh]
Q_T=$Transmission\ sinks$	[kWh]
Q_V=$Ventilation$ losses	[kWh]
Q_S=$Solar\ gains$	[kWh]
$Q_{ISource}$=$Internal\ heat\ sources$	[kWh]
γ = relation between heat losses and gains	

Equation 5 describes the calculation of output generator energy demand, taking into account energy need demand, heat transfer, distribution and storage losses for heating (DIN V 18599-5, 2011):

$Q_{h,outg} = Q_{h,n} + Q_{h,t} + Q_{h,d} + Q_{h,s}$ Equation 5

where,

$Q_{h,outg}$= output generator energy need demand for heating [kWh]

$Q_{h,t}$ = heat losses due to heat transfer to the surrounding [kWh]

$Q_{h,d}$ = heat losses from the heating distribution system [kWh]

$Q_{h,s}$ = heat losses from the heating storage system [kWh]

Finally, the equations below describe the final energy demand for heating (DIN V 18599-5, 2011):

$Q_{h,f} = (Q_{h,outg} + Q_{h,gen}) * f_{gen,PM} - Q_{h,reg}$ Equation 6

$Q_{h,reg} = Q_{h,sol} + Q_{h,in}$ Equation 7

where,

$Q_{h,f}$= monthly final energy demand for heating [kWh]

$Q_{h,gen}$= monthly heat loss from the generation system due to heat transfer to the surrounding [kWh]

$Q_{h,reg}$= renewable energy source [kWh]

$Q_{h,sol}$= monthly solar heat [kWh]

$Q_{h,in}$= ambient heat [kWh]

$f_{gen,PM}$ = correction factor [-]

b. Monthly balance procedure for the calculation of the energy need for cooling

The cooling demand is determined by the fraction of "heat gains not usable for heating purposes". In non-cooled buildings, this fraction causes an indoor temperature increase, which is normally dissipated with natural ventilation (by opening the windows). In mechanically cooled buildings, this part of the heat gains represents exactly the amount of heat, which must be removed by the cooling system.

The equation describes the energy need demand for cooling (DIN V 18599-2, 2011):

$Q_{c,n} = (1 - \eta) * Q_{source}$ Equation 8

where,

$Q_{c,n}$= monthly energy need demand for cooling [kWh]

The following equation describes the calculation of output generator energy demand, taking into account energy need demand, heat transfer, distribution and storage losses for cooling (DIN V 18599-6, 2011):

$Q_{c,outg} = Q_{c,n} * f_{c,part} * f_{c,limit} + Q_{c,t} + Q_{c,d} + Q_{c,s}$ Equation 9

where

$Q_{c,outg}$= output generator energy need demand for cooling [kWh]

$Q_{c,t}$ = heat losses due to heat transfer to the surrounding [kWh]

$Q_{c,d}$ = heat loss from the cooling distribution system [kWh]

$Q_{c,s}$ = heat loss from the cooling storage system [kWh]

$f_{c,part}$ = partial cooling factor[13] [-]

$f_{c,limit}$ = pre cooling factor[14] [-]

Finally, the equations below define the final energy demand for cooling (DIN V 18599-6, 2011):

$$Q_{c,f} = Q_{c,reg} + Q_{c,nreg} - (Q_{c,outg} + Q_{c,g})$$ Equation 10

where,

$Q_{c,f}$= monthly final energy demand for cooling [kWh]

$Q_{c,reg}$= regenerative recooled energy from generator [kWh]

$Q_{c,nreg}$= not regenerative recooled energy from generator [kWh]

$Q_{c,g}$= heat losses for cooling energy generation [kWh]

c. Monthly balance procedure for lighting energy demand

The energy demand for lighting is calculated by the multiplication between the specific electrical rating and effective operation hours of the artificial lighting system, taking into account the daylight, user presence and control systems.

The final energy demand for lighting ($Q_{l,f}$) for N zones of the building, which are divided in J calculation areas, is described in the equation below (DIN V 18599-4, 2011):

$$Q_{l,f} = \sum_{n=1}^{N} F_{t,n} * \sum_{j=1}^{J} Q_{l,f,n,j}$$ Equation 11

The final energy demand for lighting from a calculation area j is

$$Q_{l,f,n,j} = p_j * [A_{DL,j} \left(t_{eff,day,DL,j} + t_{eff,night,DL,j}\right) + A_{AL,j} \left(t_{eff,day,AL,j} + t_{eff,night,AL,j}\right)]$$ Equation 12

The total calculation area is:

$$A_j = A_{DL,j} + A_{AL,j}$$ Equation 13

where:

$Q_{l,f}$ = Final energy demand for lighting [kWh]

N=Number of zones [-]

J=Number of lighting areas [-]

---

[13] As the building is not cooled the whole time, this factor adjusts the energy need demand for cooling according to a partial use.

[14] As the cooling system delivers part of the energy demand for cooling, this factor adjusts the energy need demand for cooling according to what is delivered by the cooling system.

$Ft, = Operation\ factor\ for\ lighting\ of\ the\ zone$, according to building use [-]

pj= the specific electrical rating of area j, $[W/m2]$

A_j= $Area\ of\ the$ j lighting areas $[m2]$

$A_{DL,j}$ = part of $area$ j $supplied\ with\ daylight$ $[m2]$

$A_{AL,j}$ = part of $area$ j $supplied\ with\ artificial\ light$ $[m2]$

$t_{eff,day,DL,j}$=$effective\ operation\ time\ in\ area$ j $supplied\ with\ daylight$ at day time $[h]$

$t_{eff,night,DL,j}$=$effective\ operation\ time\ in\ area$ j $supplied\ with$ day$light$ at night time $[h]$

$t_{eff,day,AL,j}$=$effective\ operation\ time\ in\ area$ j $supplied\ with$ artificial $light$ at day time $[h]$

$t_{eff,night,AL,j}$=$effective\ operation\ time\ in\ area$ j $supplied\ with$ artificial $light$ at night time $[h]$

d. Monthly balance procedure for ventilation energy demand

The energy demand from the ventilation system generator is described in the equation below (DIN V 18599-6, 2011):

$Q_{v,\mathrm{outg}} = Q_{h,n} + Q_{v,t} + Q_{v,d} + Q_{v,s}$ Equation 14

where

$Q_{v,\mathrm{outg}}$ = output generator energy demand for ventilation [kWh]

$Q_{v,t}$ = heat loss due to heat transfer to the surrounding [kWh]

$Q_{v,d}$ = heat loss from the ventilation distribution system [kWh]

$Q_{v,s}$ = heat loss from the ventilation storage system [kWh]

Finally, the equation below defines the final energy demand for ventilation (DIN V 18599-6, 2011):

$Q_{v,f} = Q_{v,outg} + Q_{v,g} - Q_{v,reg}$ Equation 15

where,

$Q_{v,f}$ = monthly final energy demand for ventilation [kWh]

$Q_{v,reg}$ = from renewable generator or from heat recovery [kWh]

$Q_{v,g}$ = heat losses for ventilation energy generation [kWh]

e. Monthly balance procedure for the calculation of the energy for domestic hot water

The calculation of the energy demand for domestic hot water is based on the boundary conditions and reference values. The equation below defines the calculation for daily energy need demand for domestic hot water (DIN V 18599-8, 2011):

$Q_{w,day} = q_{w.day} * Reference$ Equation 16

The monthly energy need demand for domestic hot water is:

$Q_{w,n} = Q_{w,day} * d_{op,mth}$ Equation 17

$d_{op,mth} = \frac{d_{op,a}}{365} * d_{mth}$ Equation 18

where,

$q_{w.day}$ = reference value for daily energy need demand for domestic hot water [kWh/reference]

Reference = reference value for use (for example: person, bed, sitting places)

$Q_{w,n}$ = monthly energy need demand for domestic hot water [kWh]

$Q_{w,day}$= daily energy need demand for domestic hot water [kWh/d]

d_{mth} = nummer of day (in month) [d]

$d_{op,mth}$ = monthly operation hours [d]

$d_{op,a}$ = yearly operation hours

[d/a]

The next equation describes the calculation of total generated energy demand, taking into account energy need demand, heat transfer, distribution and storage losses for domestic hot water system:

$Q_{w,outg} = Q_{w,n} + Q_{w,t} + Q_{w,d} + Q_{w,s}$ Equation 19

where,

$Q_{w,outg}$= output generator energy need demand for domestic hot water [kWh]

$Q_{w,n}$ = monthly energy need demand for domestic hot water [kWh]

$Q_{w,t}$ = heat loss due to heat transfer to the surrounding [kWh]

$Q_{w,d}$ = heat loss from the domestic hot water distribution system [kWh]

$Q_{w,s}$ = heat loss from the domestic hot water storage system [kWh]

Finally, the equation below describes the calculation of the final energy demand for domestic hot water:

$Q_{w,f} = Q_{w,outg} + Q_{w,gen} - Q_{w,reg}$ Equation 20

$Q_{w,reg} = Q_{w,sol} + Q_{w,in}$ Equation 21

where,

$Q_{w,f}$= final energy demand for domestic hot water [kWh]

$Q_{w,g}$= total generated energy need demand for domestic hot water [kWh]

$Q_{w,gen}$= monthly heat loss due to heat transfer to the surrounding (equipment room) [kWh]

$Q_{w,reg}$= renewable energy [kWh]

$Q_{w,sol}$= monthly solar heat [kWh]

$Q_{w,in}$= ambient energy [kWh]

f. Calculation of the primary energy demand

The equation below describes the calculation of the primary energy demand (DIN V 18599-1, 2011):

$$Q_{p,HS} = \sum_j (Q_{f,j} * f_{p,j})$$ Equation 22

where,

$Q_{p,HS}$= primary energy demand based on the calorific value [kWh]

$Q_{f,j}$= final energy demand for the energy carrier j [kWh]

$f_{p,j}$= primary energy factor for the energy carrier j [-]

g. Calculation of the CO_2 equivalent emissions

The CO_2 equivalent emissions should be associated with the final energy demand of the building multiplied by the CO_2 equivalent emissions factor, expressed in kg CO_2 equivalent per kWh (ISO 52000, 2017).

ANNEX E: CO-BENEFITS ASSESSMENT IN THE LOGBOOK

Annex E presents the explored methodological approaches for the Logbook assessment of the renovation co-benefits., even though these are not going to be implemented in the context of the iBRoad project.

a. Thermal-Comfort assessment

ASHRAE 55 Standard for Thermal Environmental Conditions for Human Occupancy defines thermal comfort as "a condition of mind that expresses satisfaction with the thermal environment". However, because there are variations of both physiologically and psychologically comfort perception from person to person, it is difficult to satisfy everyone in a space (ASHRAE 55, 2017).

There are two models to assess thermal comfort. The first model is the classic steady-state model developed by Fanger, which aims to predict the mean thermal sensation of a group of people and their respective percentage of dissatisfaction with the thermal environment, expressed through the indices Predicted Mean Vote - Predicted Percentage Dissatisfied (PMV–PPD). The second model is the adaptive model, which is based on the adaptive principle "if a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort". Here, the user is considered to be related actively (and not passively) with the thermal environment (Rupp et al., 2015), adapting her/himself in order to achieve a comfort sensation (for example, by taking off or putting on a sweater while working in a room).

Besides calculating of the thermal comfort indicators, thermal comfort can also be assessed through measurements and real data analysis based on parameters like indoor temperature and air humidity – usually not done in residential buildings-, and by carrying out surveys with building's users, in order to analyse people's satisfaction. This is the most common practice, as it particularly does not request high investments.

The main challenge of assessing thermal comfort is to deliver reliable results, which are in line with people's perception. Ideally, the thermal comfort assessment should be based on monitored data covering all 4 seasons, combined with Post Occupancy Evaluation surveys capturing occupants' perception. However, energy auditors time is often limited for carrying out longer or more frequent measurements during the on-site visit. Thus, it would increase the auditor's cost, if more measurements should take place.

Taking into account the limitation of time and frequency of the on-site visits, and consequently, certain limitation on available building information, this chapter presents below a methodological approach of quantitative analysis to assess Thermal-Comfort based on data available in the Logbook. The Logbook stores, among others, the technical characteristics of the buildings, which were basically the main input data for the quantitative analysis.

We propose that the assessment is done though a quantitative analysis of the building information. The key idea is to rank the building elements and components according to their contribution to certain comfort standards. As suggestion, the parameters entered in the Logbook are automatically classified in five scales ranging from "very good", through "good", "acceptable" and "bad", to "very bad". The classification can also be done in accordance with national building codes, building best practices and available technology. Error! Reference source not found. shows the structure, the suggested building components and elements and the parameters related to them. Further work should give more depth on understanding how the suggested parameters really influence the comfort standards. Moreover, the values showed in the table below are merely illustrative.

Multiple benefit	Building element/ component/ characteristic	Building parameter	Unit	Very good	Good	Acceptable	Bad	Very bad	Comments
Summer comfort	Window	g-Value	-	<0.3	<0.4	<0.5	<0.6	<0.7	Can be country specificly adapted
	Shading	Shading system	-	Light colored external sun protection	Dark colored sun protection	Internal sun protection	Sun protection films	Non	
	Shading	Controlling	-	Automatic Radiation	Automatic User controll	Manual	Non	Non	
	Cooling system	Cooling system	-	Passive cooling	Fan coil unit with very good energy efficiency	Window ventilation with big window area and/or ceiling fans	Window ventilation with small window area	Non	
	... And others								
Winter comfort	Window	U-value	W/m2K	<0.9	<01.1	<2	<3	<5	Can be country specificly adapted
	Walls	U-value	W/m2K	<0.15	<0.30	<0.5	<0.8	<1	
	Roof	U-value	W/m2K	<0.15	<0.30	<0.5	<0.8	<1	
	Heating system	heat ttransfer system	-	Underfloor heating, smart	Underfloor heating (non-smart), radiators up to 55°C, smart	radiators up to 55°C	radiators hotter than 55°C	Ovens	
	Airtightness	Airtightness	h−1	<0.5	<1.5	<2	<2.5	<3	
	... And others								

Table 1: Simplified, exemplary qualitative comfort analysis (dummy data)

Winter comfort practices aim at maintaining the indoor air temperature within acceptable and recommended ranges and avoiding heat losses from the building. Because of that, the quality assessment will take into account the U-values of building elements (external walls, roofs and windows) and the kind of the heat transfer system, which means the technology used to transfer the generated heat to the room (through radiation, convection or conduction - (Ede, 1967)). In terms of comfort, radiation-based heating transfer systems are more adequate than convective systems (for example, fan coils units). Therefore, depending on the heating transfer mechanisms between the room and building element and/or heating system, the operative temperature will be affected, influencing the thermal comfort perception.

Summer comfort faces the opposite challenges. During summer, heat gains from the surroundings have to be avoided, to keep indoor air temperature within acceptable and recommended ranges and to avoid overheating. For this, the quality assessment will take into account the following parameters: g-values of the windows, sun protection measures as shading system and controlling strategies for shading system, ventilation system and cooling system.

The values as well as technology presented in the level of criteria can and should be adapted according to country specific norms (building codes), technical standards (ISO Standards) and best practices (successful projects), to be in line with the climatic, regional and cultural context of the pilot countries.

b. Indoor air quality

The indoor air quality (IAQ) affects directly health and well-being of the building users, therefore one indicator to address indoor air quality will also be presented the iBRoad project. Most single-family houses are naturally ventilated, which means that indoor air quality has a significant relation with user's behaviour of opening the windows. One alternative to assuring good indoor air quality, and reducing user behaviour influences, is the installation of controlled mechanical ventilation in residential buildings.

Buildings should be constructed in a way which allows the building user to have good indoor air quality. For this, ASHRAE Standard 62.1[15] for Ventilation and Acceptable Indoor Air Quality in Low-Rise Residential Buildings suggests the indicator *minimum area of operable window area in naturally ventilated spaces*.

For mechanically ventilated houses, ASHARE Standard 62.1 suggests the indicator *minimum air change rate* according to the mechanical ventilation system dimension. This rate should vary according to the number of persons in the house and the size of the house (ASHRAE 62.2, 2016) (ASHRAE 62.2, 2017).

The assessment of indoor air quality should define whether the minimum requirement is achieved or not. For this, suggested indicators should be stored in the Logbook: *minimum area of operable window area in naturally ventilated spaces* (for naturally ventilated buildings) and *minimum air change rate* (for mechanical ventilated buildings). Nevertheless, additional parameters referring to appliance devices, indoor furniture and their material quality could also be part of the Logbook, in order to enable further Indoor Air Quality assessment.

[15] Basing on the ASHRAE is only a suggestion, European norms as EN 15251 or EN 16798-1 can be used as well.

ANNEX F: CO-BENEFITS ASSESSMENT IN THE RENOVATION ROADMAP

This Annex presents five possible different methodological approaches to assess the co-benefits (i.e. thermal comfort, healthy housing, indoor air quality, aesthetic, security and lighting) in the Renovation Roadmap, including their advantages and disadvantages: 1) general assessment of a certain renovation step with a simple scheme applying three classes; 2) assessing the different comfort aspects with points; 3) evaluation according to Thermal Comfort Standard; 4) evaluation of the individual aspects of comfort; and 5) assessing the real estate value benefit.

a. General assessment of a certain renovation step with a simple scheme applying three classes

The auditor decides for each renovation step, which benefit class the building should be sorted in. The classes can be "good, medium, bad" or "green, yellow, red" or similar categories. As a decision support, the auditors receive a table with criteria in the handbook. The co-benefits aspects are described in the table in words for the three categories. The auditor can decide for each aspect which category it fits to and eventually count the good, medium and bad ratings. The building will only be rated the best class, if at least all but one aspect are rated best and the one exception is rated second best. The building will be rated the worst class, if the single aspects are predominantly rated worst. For all other cases, the building will be rated medium. This scheme can easily be adapted to other aspects or other requirements for the classes.

Advantages:

- Easy to implement
- This scheme can easily be adapted to other aspects or other requirements for the classes
- No accuracy is suggested on a subject that is difficult to quantify
- Easy for building owners to understand

Disadvantages:

- Auditor must define the class on his own – no automated system
- Explanation / manual required for auditor

b. Assessing the different comfort aspects with points

The auditor rates the different comfort aspects with points. Similar schemes are the German Evaluation Scheme for Sustainable Buildings (BNB) or LEED (Leadership in Energy and Environmental Design). The specific number of points should reflect the importance and weight of a single aspect compared to others. Once a scheme like this is derived and evaluated, it allows a quick and clear rating of quality aspects.

Advantages:

- Unambiguous evaluation
- Any number of comfort aspects can be considered and weighed against each other

Disadvantage:

- Point system must first be created and evaluated – requires extreme effort

c. Evaluation according to Thermal Comfort Standard

The auditor calculates thermal comfort using the general database for thermal comfort indicator PMV/PPD, as suggested in the approach below.

Advantages:

- Calculation method available
- Unambiguous evaluation

Disadvantages:

- Other aspects of comfort are not considered
- Strong simplification or simulation required
- Complex and time-consuming methodology to define the PMV/PPD matrix

In the scope of the iBRoad project, a general database for thermal comfort indicator PMV/PPD classification could be developed. This table should help the energy auditors to assess the thermal comfort based on the PMV/PPD.

In the first step, building input data, as for example, building elements' quality, HVAC systems and occupancy profile (thermal simulation input data) of different reference buildings will be defined as well as three different energy efficiency building standards, for example case 1 is low energy efficient envelope, case 2 middle and case 3 high.

Using an hourly based dynamic building simulation software (for example, EnergyPlus), the thermal comfort related parameters (air temperature, mean radiant temperature, air speed and air humidity) will then be calculated (thermal simulation output data).

In the second step, these parameters will serve as input data for the Comfort Assessment (illustrated as the overlapping area in Figure 25), together with other thermal comfort parameters (metabolic rates and clothing level), to deliver the PMV/PPD indicators for different building conditions.

Figure 25 summarises the method described above.

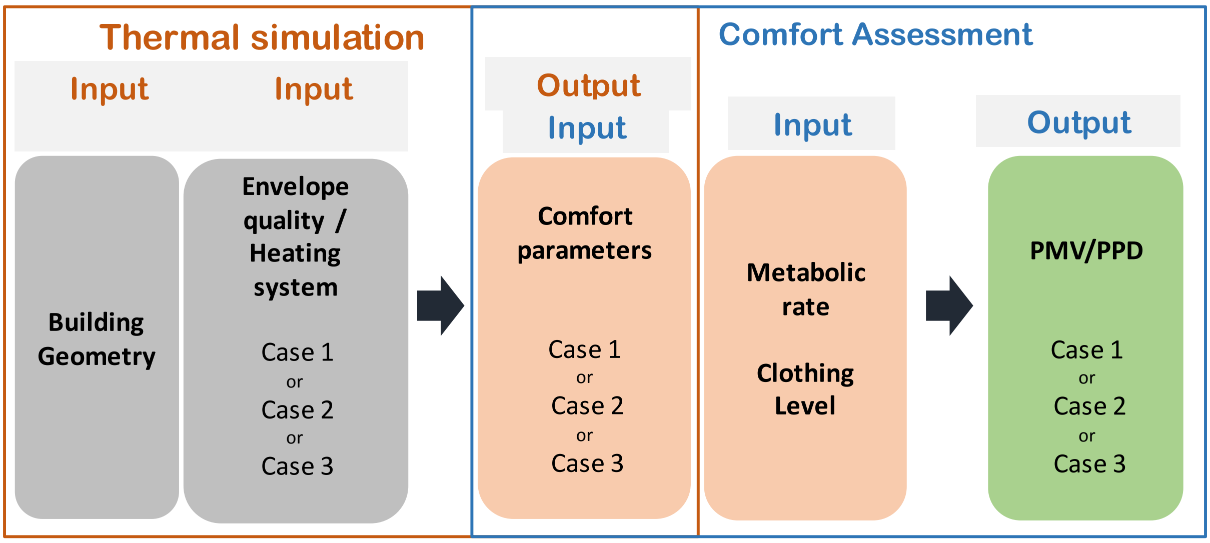

Figure 25: Method for defining Thermal Comfort indicator

An example of a methodological approach to assess comfort is the CBE Thermal Comfort online tool (CBE Tool). This tool was developed by the Center for the Build Environment of the University of California, Berkeley to assess thermal comfort based on the PMV-PPD Methodology (Fanger model as described above). Entering the six thermal comfort parameters: air and mean radiant temperature, air speed, humidity, metabolic rate and clothing level, a chart indicates the PMV-PPD rates and its compliance with the ASHRAE Standard 55-2017 or EN 15251 (Thermal Environmental Conditions for Human Occupancy) (Hoyt et al., 2017).

Figure 26 shows how the Thermal Comfort assessment using the CBE Tool is done. On the left side the user enters the thermal comfort related input parameters. On the top on the right side, the user selects the form (ASHRAE-55 or EN-15221) or other functionality. Also on the right side, the results of the PMV/PPD indicators are shown, together with a graphical form (psychometric Chart (air-temperature).

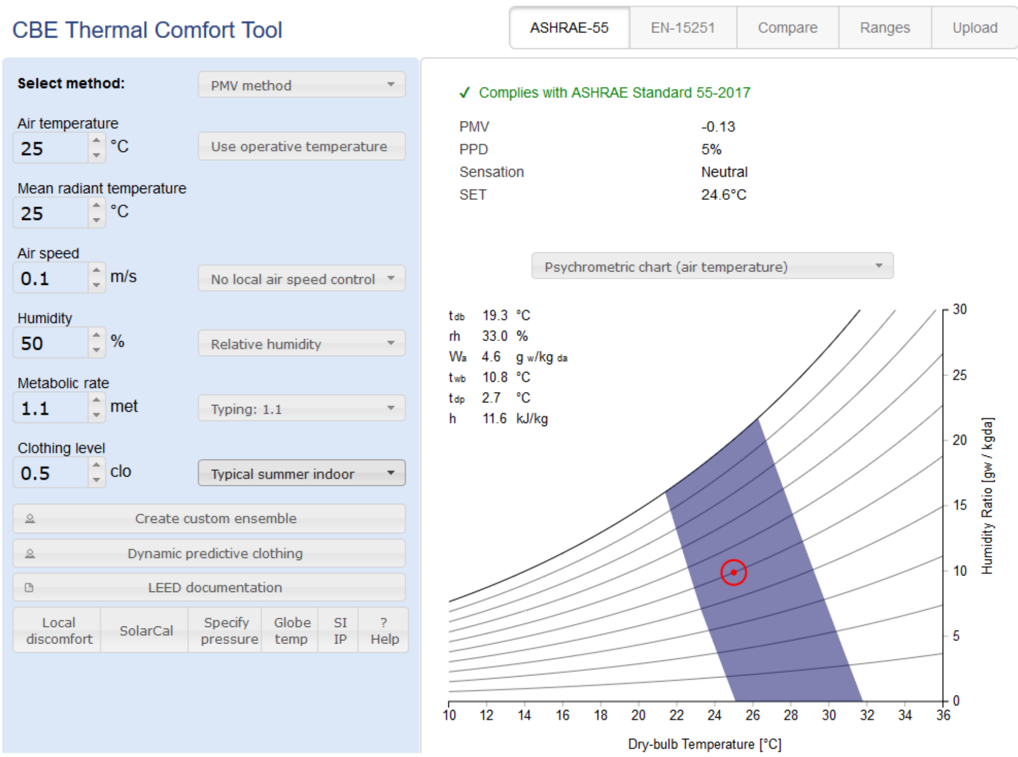

Figure 26: Thermal Comfort assessment with CBE thermal comfort tool

To calibrate the results of the method to predicting the thermal comfort based on the building standards, both occupants' surveys and measurements during the on-site visit can be applied by the energy auditor. Building characteristics like indoor temperature, air speed and humidity can be easily and rapidly measured on-site with equipment as anemometer, hygrometer and thermometer.

d. Real estate value benefit

The aim of the real estate value benefit indicator is to help the building owner to quantify the impact of the energy performance improvement on the market value of the house.

The new real estate market value (after renovation) is defined by applying a real estate value surplus factor for each one-letter energy performance improvement to the actual real estate value. E.g., in the

context of the EU Founded Project ZEBRA 2020, the economic impact of energy improvement measures on the housing market was analysed, by developing a methodology to assess the dwelling price increase due to energy performance measure and applying this methodology to 12 EU countries. The energy performance improvement was determined as one-letter improvement according to the EPC rating, which is country specific, and varies normally between A (very good) and G (very bad). In this case, one letter improvement means, for example, the upgrade from energy class D to C.

Figure 27 shows the results as presented in the corresponding ZEBRA report (Bointner et al., 2016).

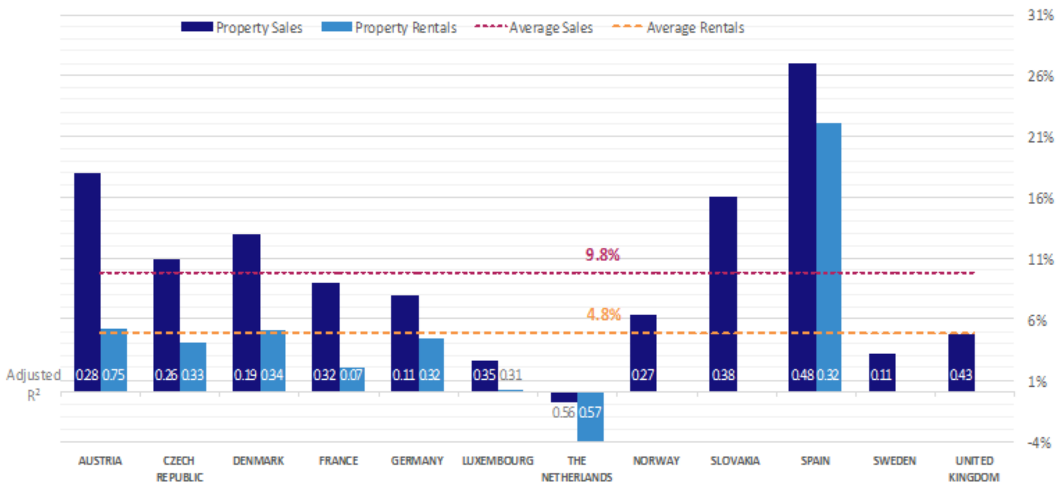

Figure 27: Real estate value benefits (Source: ZEBRA 2020)

These results present the percentage of added value in sales and rentals of properties due to any one-letter EPC rating improvement, for each of the analysed markets. Also, it indicates an average of 9.8% added value increase in the sales properties and an average of 4.8% in the rental properties.

In the scope of the ZEBRA 2020 project, general and country specific surplus factors were determined; however, these should be revised with a literature review, as for example from the Project Revalue[16], in course of the country specific implementation of the iBRoad components in the next steps of the iBRoad project.

[16] EU funded project REVALUE, which aims to incorporate energy efficiency into stock valuation. Project internet site: http://revalue-project.eu/

ANNEX G: OTHER POSSIBLE LOGBOOK SECTIONS

In this Annex we present the mock-ups of other possible Logbook Modules, in addition to those described in the main part of this report. The key idea and approaches to these functionalities were considered during the iBRoad project, however their development and implementation falls out of the project's context.

- *Energy consumption:* in this page, the user sees the historical development of the energy consumption (electrical energy, heating and water), based on energy bills

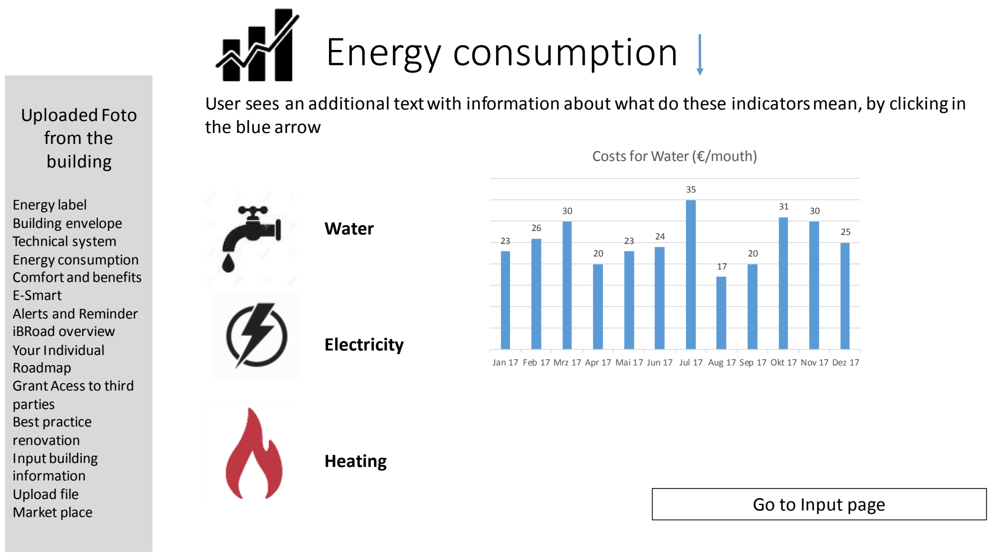

Figure 28: Mock-up of the Logbook page Energy Consumption

- *Comfort and Benefits (similar approach to Building Envelope's page):* in this page, the user sees the actual status quo of comfort, indoor air quality and real state value.

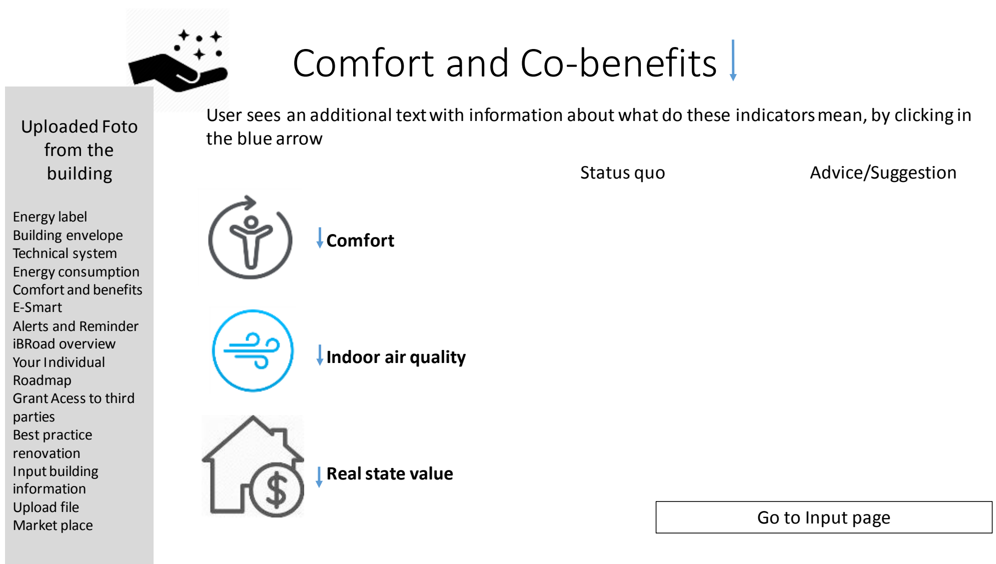

Figure 29: Mock-up of the Logbook page Comfort and Co- Benefits

- *E-Smart (similar approach to energy consumption):* in this page, the user sees the historical development of the energy generation (solar energy production) and other indicators, like e-mobility and smart district.

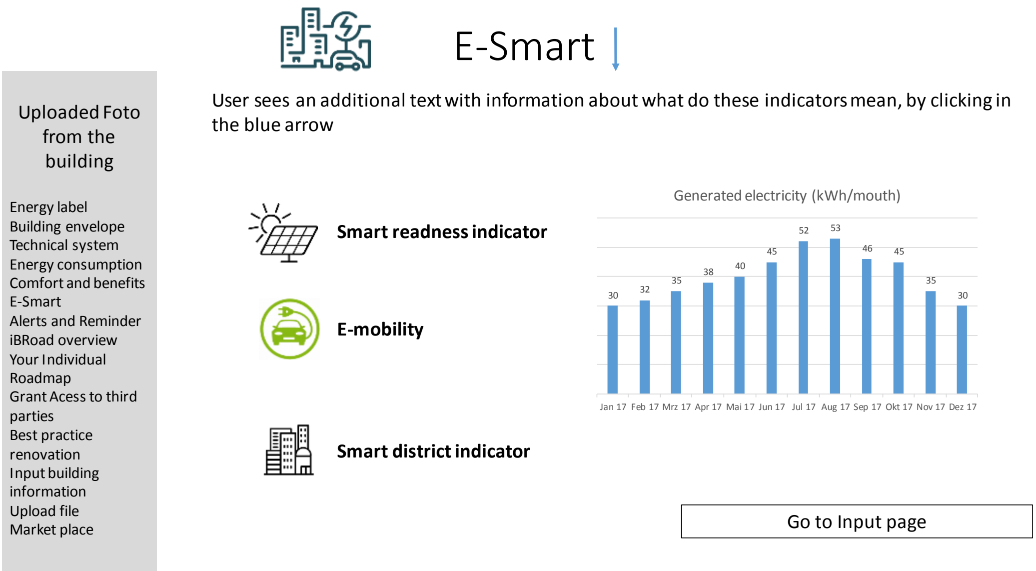

Figure 30: Mock-up of the Logbook page E-Smart

- *Grant Access to third parties:* in this page, the user configures the access to be granted to third parties, as energy auditors, public authorities and others.

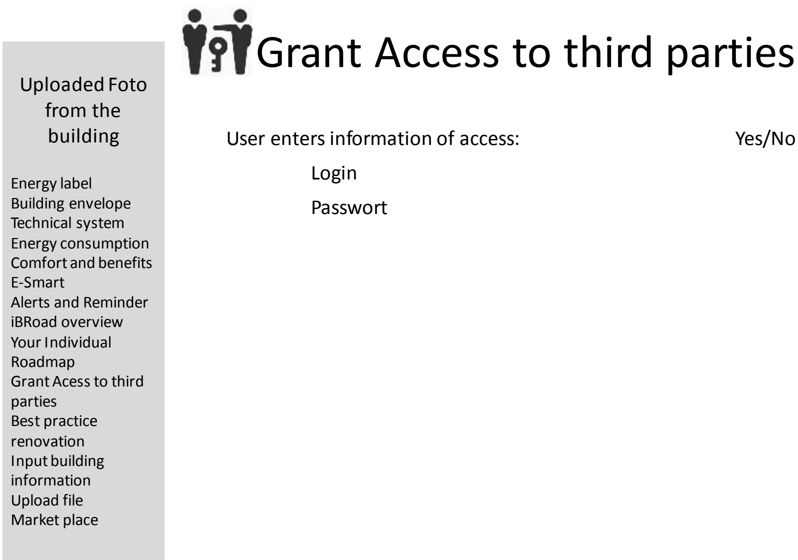

Figure 31: Mock-up of the Logbook page Grant Access to third parties

ANNEX H: LOGBOOK HYBRID DATA STRUCTURE

A detailed and well-thought-out concept for the Logbook structure has been elaborated and is summarised in Figure 32. It consists of both a fixed part (levels 0, 1 and 2), which lists all topics every national (or regional) Logbook should contain, and a flexible part (levels 3 and higher), which is country or region specific. This document explains how this concept can be implemented in an IT system.

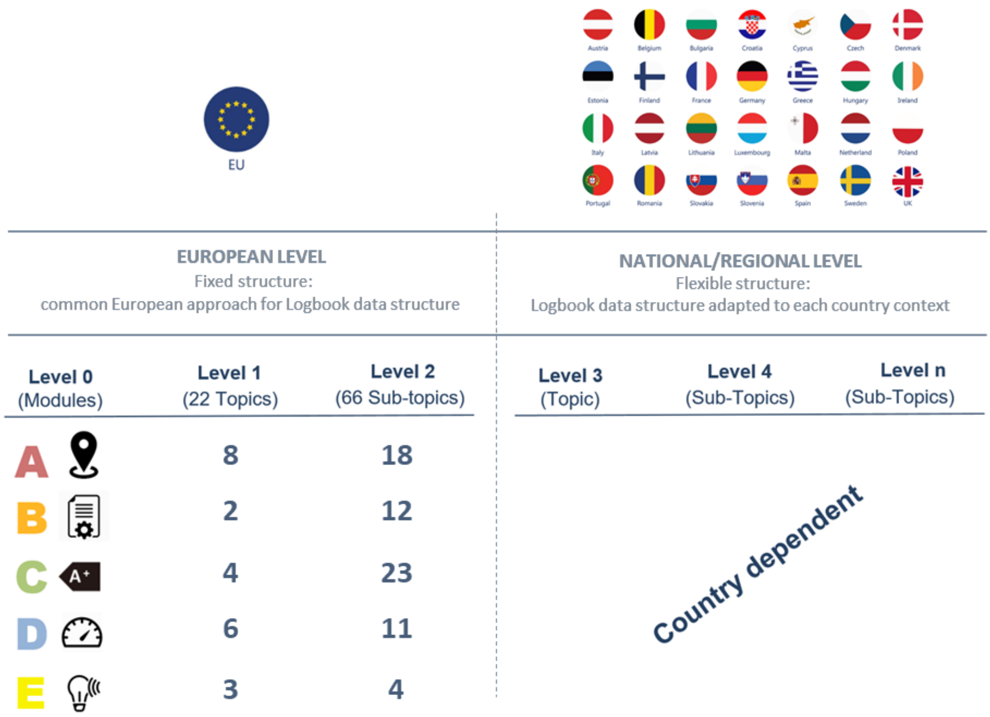

Figure 32: Original Logbook data structure concept (source: "iBRoad - The logbook data quest" report)

Flexible data structure

In order to understand the challenges involved in implementing the Logbook structure in a database, let's consider an example. Table 1 shows how it is proposed to store information about a building's age in a Logbook for Portugal. Since everything up to level 2 is fixed (and hence always present), table 1 shows that every country or region is required to store information about the sub-topic "Building", belonging to topic "Building general features", which is part of module "A. General and administrative information". For Portugal, the choice was made to include (among other items) information about the building's age (level 3), split into two fields (level 4): year of construction and year of renovation.

Level 0	Level 1	Level 2	Level 3	Level 4
A. General and Administrative information	…			
	4. Building general features	1. Building	…	
			3. Building age	1. Construction year
				2. Year of renovation

Table 2: Example - building's age in a Logbook for a Portuguese case.

In a relational database (by far the most common type), data is organised in (usually multiple) tables consisting of columns and rows. Roughly speaking, the database structure consists of a description of all tables and their columns (column names and data types). In virtually all cases, the database structure is fixed (i.e., the tables and columns are defined in advance), the data itself is then placed in the rows of the tables by the application.

If we would design a database specifically for Portugal, the information in Table 1 would lead us to create, e.g., a table called "Buildings"[17], containing columns "year of construction" and "year of renovation"[18] (among others). For each building stored in the Logbook, we would add one row to the "Buildings"-table, with the construction and renovation years stored in the relevant columns.

The iBRoad Logbook should not only work for Portugal, however, but for any country or region wishing to implement it. Due to the flexibility built into the Logbook concept we cannot define the database columns as described above, since each country/region should be able to choose its own columns (because all parameters at level 3 and higher are country specific). This is the first major challenge: how to combine the inherently fixed and predefined structure of a relational database with the need for high country/region specificity in determining what data to store?

We decided to introduce flexibility using JSON-fields[19]. In the unmodified proposal shown above, this would work as follows: all level 2 sub-topics become database columns. Inside these columns, we put

[17] In order to avoid any confusion, please note that this name is not related to the level 2 parameter "Buildings" in the example, it simply is the table in which we store all building-related information.

[18] Note that only the nodes at the highest level for each row in a table such as Table 1 would result in a database column.

19 JSON is a commonly used human-readable data interchange format.

all parameters belonging to the relevant sub-topic in a country specific JSON data structure. If we take the example of Table 1, we would create a column called “building” (named after its level 2 sub-topic). For each row (i.e., for each building in the Logbook), the contents of that column would be a JSON-structure containing the parameters to be stored under this sub-topic for that country / region. For Portugal, the relevant part of the JSON (i.e., only the part related to building age) would look something like this for a specific building:

```
{
   "Building age":{
      "Construction year":1967,
      "Renovation year":2003
   }
}
```

Another country might choose different parameters for the same sub-topic, resulting in the following JSON content, for instance:

```
{
   "Age of the building":{
      "Date of completion":"1967/5/23",
      "Renovations":{
        "Technical Building Systems": 2003,
        "Structure": 1998
      }
   }
}
```

The structure of the JSON for each sub-topic is described in a configuration file (one file for each country or region). This description does not influence the data structure, but is needed for the user interface, since it determines which information a user must or can enter.

In the last few years, most relational database systems (including PostgreSQL, the database system selected for iBRoad) have added native support for JSON columns, which implies that database queries can also operate on keys within JSON fields.

Hybrid Data Structure

The above described proposal offers a lot of flexibility, but this flexibility comes at a price. Since most data items are contained in JSON columns, the data is largely unstructured, and the Logbook application does not really “understand” what data is being stored, or how to use it. This lack of structure makes it difficult to implement Logbook features, which depend on the data entered by the user.

We will consider colour coding as an example to illustrate this. Suppose we want to colour-code certain elements in the user interface based on (among others) the year of construction of the building. Of

course, this means the application must be able to extract it from the entered data. For the first JSON listing shown above, we could get this data as follows:

```
"Building" (JSON-column) -> "Building age"
                                -> "Construction year"
```

For the second listing, it would be:

```
"Building" (JSON-column) -> "Age of building"
                                -> "Date of completion"
                                -> Operation: Extract year from date
```

The problem is that it is not clear in advance how to extract this value: it depends on the choice of parameters made by the country, it might require one or more operations or transformations (in this example, extracting the year from a date is a simple illustration of this), it might not even be present if the country chose not to include it.

A similar example is a (simplified) energy demand calculation, which would require U-values for all walls (and of course many other parameters). The level 2 parameter "Walls" is present in the original iBRoad logbook concept, so every country is required to store information about walls, but since all higher levels are country specific, there is no general way of knowing what countries will choose to store, or how to extract the needed U-values from that.

This is the second challenge: how do we combine Logbook features that depend on data with the need for a flexible data structure? Unfortunately, adding more structure to the data seems to be the only workable solution. This is why we chose to make the "boundary" between what is fixed (normally everything up to level 2) and what is flexible (normally levels 3 and up) subject dependent. This allows imposing more structure when necessary (and only then) by selectively increasing the number of "fixed" levels. For walls, for example, we could require everything up to level 4 to be fixed, and place the parameters we strictly need to know for calculations at that level. Any additional information about walls (which can be country specific) can be placed at level 5 (or higher). Of course, this only makes sense for parameters for which we can objectively assume that they will be present and meaningful regardless of the country (such as U-values of walls, years of construction of a building, etc.).

This is what we call the "hybrid" data structure: it is not as flexible as the above described flexible data structure, but there are still a lot of possibilities for adding country/region specific information, so it is not fixed either.

Note that, due to the fact that the number of fixed levels will probably often be increased for entities of which we may have many, such as wall types (the user can define as many wall types as necessary), roof types, floor types, etc., the resulting database structure of the hybrid structure is fundamentally different (and more complicated) than for the fully flexible data structure.

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