

# Extending the iBRoad Building Renovation Passport II

Report on potential indicators to expand the scope of iBRoad

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### Authors

Iná Maia – TU WIEN

Irma Imamovic – TU WIEN

Lukas Kranzl – TU WIEN

Vivian Dorizas – BPIE

Zsolt Toth – BPIE

Julia Lempik – ifeu

Peter Mellwig – ifeu

### Reviewers

Marianna Papaglastra – Sympraxis Team

Victoria Taranu – BPIE

### Layout

TU WIEN and Sympraxis Team

### Cover illustration

depositphotos.com / agsandrew

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## EXECUTIVE SUMMARY

The main objective of this report is to evaluate available and existing methods to expand the scope of the iBRoad tool within iBRoad2EPC with new indicators or features, considering necessary adjustments and adaptations to the project requirements. The descriptions in this report should form the basis for the IT implementation of potential additional features. Besides a review of existing methods, existing and preferably open-source tools which aim at providing the calculations of these indicators have been investigated. Based on the report [“Experience from other projects – Report on linking Energy Performance Certificates \(EPCs\) with the Building Renovation Passport \(BRP\)”](#), a selection of methods is described in detail to set guidelines on how these can be technically implemented by considering relevant adjustments and adaptations to the project requirements. This is supported by a SWOT and feasibility analysis of each tool concerning its integration in iBRoad2EPC.

The following indicators and features were selected and are further described in this report to provide the basis for IT implementation in future steps of the project:

- **Indoor Environmental Quality (IEQ)** and in particular the CARP methodology spreadsheet tool developed by X-tendo.
- **Smart Readiness Indicator (SRI)** and in particular the existing EC spreadsheet tool for method A.
- **Measured energy performance:** The measured energy performance feature clearly has benefits but it also has some constraints which do not fit in with the basic objective of iBRoad2EPC to provide initial advice at low cost. However, since X-tendo offers a ready-to-use spreadsheet, the implementation of the measured energy consumption is possible by integrating this spreadsheet into the workflow of iBRoad2EPC.
- **Renovation advice** is being developed within the iBRoad2EPC project itself, following the stepwise and deep principles as conceptualised in the iBRoad project and enhanced with EC's and national long-term decarbonisation and climate targets and MEPs. The renovation advice is an integral part of the iBRoad2EPC basic module. It is integrated into the iBRoad2EPC Assistant in the form of country specific databases to support the issuers, including among others: target building standards for specific key dates, foreseeable future obligations or legal requirements, specifications of the recommended renovation measures (e.g., u-values) and recommendations to avoid lock-in situations, depending on the building type and type and sequence of measures. The country specific databases of renovation advice are considered a significant accomplishment of the iBRoad2EPC project.
- **Digital building logbooks:** a key potential for iBRoad2EPC is the possibility of linking it to the logbook developed within the iBRoad project. In parallel, the potential of linking iBRoad2EPC to any Digital Building Logbook proposed by the EC in the future remains and could be investigated accordingly.

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## INTRODUCTION

This report provides guidelines on how to technically implement certain indicators/features to the iBRoad2EPC tool.

The H2020 iBRoad2EPC project builds on the individual building renovation roadmaps which were initially developed in the preceding H2020 iBRoad project (<https://ibroad-project.eu/>) and aims to expand and bridge these with existing Energy Performance Certification (EPC) schemes across Europe. Thus, the main objective of this report is to evaluate available and existing methods to expand the scope of the iBRoad tool within iBRoad2EPC with new indicators, considering necessary adjustments and adaptations to the project requirements. The descriptions in this report should form the basis for the IT implementation of potential additional features into iBRoad2EPC.

Previous work within iBRoad2EPC screened a list of 20 recent European projects and activities dealing with building renovation passports and EPCs with the perspective of collecting indicators and features already developed as part of their work and using the relevant insights, tools, and methods in the iBRoad2EPC project. Relevant input was then assessed based on the following criteria: political relevance, time and effort needed to gather the required data, complexity to integrate within the iBRoad2EPC tool, methodological relevance, and maturity of the proposed methodology. Based on this work, seven projects were clustered along five features potentially relevant to the context of iBRoad2EPC. The projects concerned were: QualDeEPC<sup>1</sup>, U-Cert<sup>2</sup>, X-tendo<sup>3</sup>, SRI study<sup>4</sup>, ALDREN<sup>5</sup>, EPC Recast<sup>6</sup>, iBRoad<sup>7</sup>, as well as the European Commission's (EC) Level(s)<sup>8</sup> framework and the Smart Readiness Indicator study<sup>9</sup>.

The Level(s) framework and the U-Cert, X-tendo, and ALDREN projects elaborated various concepts for assessing IEQ and its integration into the EPCs.

Level(s) contributes to enhancing the dialogue between design, technical and financial actors in new build and renovation projects. This framework proposes indicators that are of interest to iBRoad2EPC.

U-Cert introduces the next generation of user-centred Energy Performance Assessment and Certification Schemes, focusing on EPC data. The project developed indicators as proposed in the iBRoad2EPC project to assess the buildings directly related to the EPC schemes and EPC-related data.

ALDREN is a methodological framework consisting of four stand-alone modules to assess the energy performance, IEQ, financial value of buildings, and two reporting tools (EU Voluntary Certificate, Building Renovation Passport).

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<sup>1</sup> [QualDeEPC - High-quality Energy Performance Assessment and Certification in Europe Accelerating Deep Energy Renovation](#)

<sup>2</sup> [U-Cert Project - User-centred Energy Performance Assessment and Certification](#)

<sup>3</sup> [X-tendo Toolbox](#)

<sup>4</sup> [Smart readiness indicator \(europa.eu\)](#)

<sup>5</sup> [ALDREN | ALLiance for Deep RENovation in buildings](#)

<sup>6</sup> [EPC recast \(epc-recast.eu\)](#)

<sup>7</sup> <https://ibroad-project.eu/>

<sup>8</sup> [Level\(s\) \(europa.eu\)](#)

<sup>9</sup> [https://op.europa.eu/en/publication-detail/-/publication/f9e6d89d-fbb1-11ea-b44f-01aa75ed71a1/language-en?WT.mc\\_id=Searchresult&WT.ria\\_c=37085&WT.ria\\_f=3608&WT.ria\\_ev=search](https://op.europa.eu/en/publication-detail/-/publication/f9e6d89d-fbb1-11ea-b44f-01aa75ed71a1/language-en?WT.mc_id=Searchresult&WT.ria_c=37085&WT.ria_f=3608&WT.ria_ev=search)

Indicators of real measurement-based energy performance are developed in the X-tendo project.

For the SRI, we consider the SRI study [1] carried out for the European Commission as the main source of information. The study describes three methodologies to assess the smart readiness level of a building, namely: the simplified method (method A), the expert SRI assessment (method B), and the in-use smart building performance method (method C). The SRI study also developed the relevant indicators.

Information from the QualDeEPC project is used in relation to renovation advice/recommendations. This Horizon2020-funded project aims to enhance (1) the quality and cross-EU convergence of EPC schemes and (2) the link between EPCs and deep renovation. In the scope of this project, an online tool for comparing EPC recommendations to deep energy renovation recommendations was developed. The project focused on the EPC recommendations and explored different aspects, among others, in two of the iBRoad2EPC countries: Spain and Greece.

Naturally, the iBRoad2EPC's predecessor, the H2020 iBRoad project, is used as the main basis for the integration of the logbook and other features.

Finally, the following indicators and features were selected:

- Indoor Environmental Quality (IEQ)
- Smart Readiness Indicator (SRI)
- Measured energy performance
- Renovation advice
- Digital building logbooks

For more information on this preceding work see the iBRoad2EPC report [“Experience from other projects – Report on linking Energy Performance Certificates \(EPCs\) with the Building Renovation Passport \(BRP\)”](#).

The present report describes the selected features in detail to set guidelines on how these can be technically implemented, by considering relevant adjustments and adaptations to the project requirements. This is supported by a SWOT and feasibility analysis of each tool concerning its integration in iBRoad2EPC. It includes each feature's benefits and market needs, the status quo in implementing countries, a summary of the method, applicability for iBRoad2EPC building types, feasibility aspects and requirements for adaptation and integration in iBRoad2EPC.

## INDOOR ENVIRONMENTAL QUALITY INDICATOR

### Benefits and Market Needs

A plethora of scientific studies [2], [3], [4], [5], [6] shows that indoor environmental quality (IEQ) has a direct effect on health, comfort, wellbeing, and productivity. The recent global pandemic has amplified the importance of IEQ, while the creation of a satisfactory indoor environment is one of the most important benefits and drivers of building renovation. Considering that people spend approximately 90% of their time in indoor environments, building legislation and relevant instruments must ensure adequate IEQ standards in buildings to maintain a healthy indoor environment. The draft report [7] submitted to the European Parliament's Committee on Industry, Research and Energy (ITRE) on the EPBD recast proposal reinforces the importance of IEQ, and it is crucial that the relevant proposed amendments reach the final text of the law.

The main determinants of IEQ are indoor air quality, thermal comfort, lighting, and acoustics. For the time being, these aspects are not covered in most of the existing EPCs. Considering that EPCs are a key source of information on the energy performance of the building stock, they have great potential to become a market tool that can support improvements in energy efficiency and IEQ. The integration of the IEQ assessment in the EPCs through iBRoad2EPC<sup>10</sup> can contribute to reducing health effects generated by unsuitable indoor conditions. The IEQ assessment can further improve the well-being and productivity of building occupants. Considering that energy efficiency and IEQ improvements are interrelated and should be simultaneously achieved, EPCs have the potential to become a compelling market tool to develop demand for energy efficiency in buildings.

In view of integrating IEQ in EPCs, the H2020 X-tendo<sup>11</sup> project developed the IEQ indicator (comfort indicator), which includes an assessment approach for the calculation of Asset (CARP) and Operational (CORP) comfort rating covering all aspects of IEQ. The assessment approach is a robust methodology based on international standards, reliable frameworks, and existing well-grounded methods<sup>12</sup>. The assessment of comfort builds on evidence-based inputs. The asset rating uses checklists, while the operational rating uses measurements, surveys, and checklists for the assessment of all determinants of IEQ. Both ratings are designed for offices, schools and residences.

This section aims to present a summary of the assessment approach of the IEQ indicator as it was developed in the X-tendo project and how it can be used by iBRoad2EPC.

### Status Quo on IEQ in the Implementing Countries

To assess the status quo on IEQ in iBRoad2EPC implementing countries, we classified the status according to the following categories:

- (1) This feature is currently part of the national EPC scheme.
- (2) There are concrete plans to include this feature in the national EPC scheme (expected within the next year).
- (3) There are vague discussions about this feature but no concrete plans.
- (4) Currently, no concrete plans or discussions to include this feature in the national EPC scheme.

The following table shows the results of this assessment.

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<sup>10</sup> The iBRoad2EPC follows a hybrid and modular approach to evolve the specific elements of the proven iBRoad Roadmap to existing EPC schemes. This approach foresees the introduction of new indicators such as indoor environmental quality and smart readiness to improve and expand the usability of EPC schemes.

<sup>11</sup> <https://x-tendo.eu/>

<sup>12</sup> Such as Level(s), ALDREN project: TAIL index

Bulgaria	Greece	Poland	Portugal	Romania	Spain
Currently, no concrete plans or discussions to include this feature in the national EPC scheme	This feature is currently part of the national EPC scheme	Currently, no concrete plans or discussions to include this feature in the national EPC scheme	There are vague discussions about this feature but no concrete plans	There are vague discussions about this feature but no concrete plans	Currently, no concrete plans or discussions to include this feature in the national EPC scheme

Table 1. Status quo on IEQ in the iBRoad2EPC Implementing Countries

So far, only Greece has partially integrated IEQ in their EPCs. The expert issuing the EPC in Greece ticks the relevant boxes of air quality, thermal, lighting, and acoustics comfort, see Figure 1. However, no indication is provided on how these IEQ indicators should be assessed. In Spain, it is not necessary to analyse IEQ to get the EPC. However, in the last section of improvement measures, the EPC issuer may include recommendations about improving comfort, health, and well-being. It is however not common practice to include these recommendations.

Conditions of Comfort and Indoor Environmental Quality			
Thermal comfort	<input type="checkbox"/>	Lighting comfort	<input type="checkbox"/>
Acoustics comfort	<input type="checkbox"/>	Indoor air quality	<input type="checkbox"/>

Figure 1: IEQ as shown in the Greek EPC (translated)

## Summary of the Method and Calculation Formulae

The IEQ indicator developed in X-tendo can be applied to both new and existing buildings. For unoccupied buildings, the Comfort Asset Rating Procedure (CARP) is recommended, while for occupied buildings, the Comfort Operational Rating Procedure (CORP) is available. However, it should be noted that the CARP rating is not limited to unoccupied buildings and can also be used for occupied buildings in case there are restrictions in time and effort required to reach the rating.

The comfort rating procedure is described in detail in the X-tendo user-guide documents: Comfort Asset Rating Procedure (CARP)<sup>13</sup> and Comfort Operational Rating Procedure (CORP)<sup>14</sup> (beta version 1.0). These documents accompany the rating tools (for residences, offices and schools for both CARP and CORP<sup>15</sup>) and Excel spreadsheets, and provide a list of the requirements that need to be assessed to come up with the evaluation of the indoor environmental quality (Figure 2). The guides list the assessment protocol for each parameter with specific criteria of thermal comfort, visual and acoustic comfort and indoor air quality.

<sup>13</sup> [https://x-tendo.eu/wp-content/uploads/2020/01/CARP\\_version1.0\\_final.zip](https://x-tendo.eu/wp-content/uploads/2020/01/CARP_version1.0_final.zip)

<sup>14</sup> [https://x-tendo.eu/wp-content/uploads/2020/01/CORP\\_v1.0\\_final.zip](https://x-tendo.eu/wp-content/uploads/2020/01/CORP_v1.0_final.zip)

<sup>15</sup> <https://x-tendo.eu/toolboxes/comfort/>, under the 'calculation procedures' tab

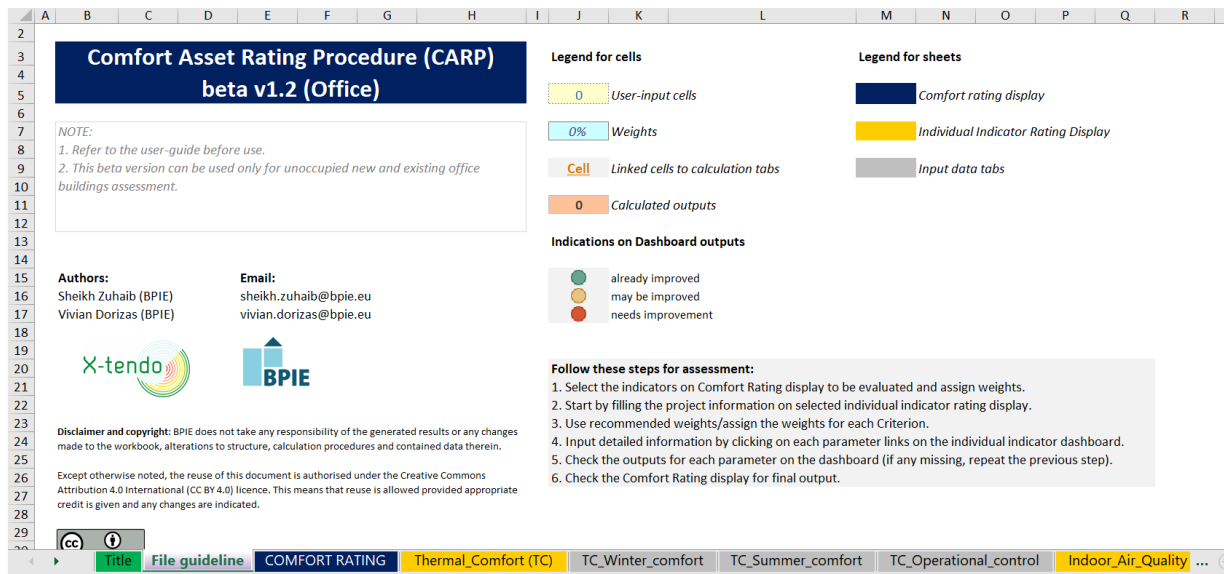


Figure 2: Screenshot of the CARP Excel tool

### Comfort Asset Rating Procedure (CARP)

The Comfort Asset Rating Procedure (CARP) is designed for new, renovated, and existing buildings that are not occupied. Asset rating for comfort can be issued for transactional or business purposes. For the assessment of the indoor environment, the required information can be captured through checklists. The checklists are filled in by the expert issuing the EPC during an on-site visit to inspect the building. The asset rating checklist is given in the Annex of the CARP user guide mentioned above.

### Comfort Operational Rating Procedure (CORP)

For a more detailed evaluation of the IEQ for occupied buildings, the Comfort Operational Rating Procedure (CORP) is recommended. CORP is issued with a longer validity (5 years) in years in comparison to CARP (1 year). Operational rating registers the actual comfort level of occupants throughout a period and provides real information about how comfortable the building is based on its use and operation. The assessment approach for operational rating is more holistic based on the following measurements (objective), surveys (subjective), and checklists.

#### Measurements

On-site measurements are crucial to evaluate the indoor environmental quality objectively. CORP integrates key measurements of temperature, relative humidity, and CO<sub>2</sub> concentrations in the building for the calculation of the comfort rating. The measurements are conducted based on standard protocols<sup>16</sup>.

#### Surveys

Building occupants are the most important source of information regarding IEQ and its effects on their health, comfort, and well-being. A Post Occupancy Evaluation (POE) survey, which is based on standardised questionnaires such as the CBE and BUS surveys, mainly investigates the levels of satisfaction and perception of the indoor environmental quality [8]<sup>17,18</sup>. The main occupier of the building fills in the survey during the EPC assessor's visit onsite. Before handing the survey to the building occupants, the auditor should inform them of the scope of the assessment and the value of

<sup>16</sup> Measurements are conducted by the assessor, obligatory measurements of: temperature, relative humidity, carbon dioxide (ppm)

<sup>17</sup> [https://x-tendo.eu/wp-content/uploads/2020/01/CORP\\_userguide\\_betaversion1.2\\_final.pdf](https://x-tendo.eu/wp-content/uploads/2020/01/CORP_userguide_betaversion1.2_final.pdf)

<sup>18</sup> <https://cbe.berkeley.edu/research/occupant-indoor-survey-and-building-benchmarking/>

IEQ and should highlight the importance of their perception of and satisfaction with the indoor environment. That information is described on the first and introductory pages of the survey.

*Checklists*

Additional important information about the indoor environment is captured through checklists. Checklists are filled in by the expert issuing the EPC during the onsite visit for the building’s inspection and installation of the monitoring equipment.

The combined findings from (objective) measurements, information from checklists, and users’ perceptions (subjective), satisfaction, and preferences, create a clear, comprehensive, and holistic profile of indoor environmental quality.

**Building types and representative spaces**

For the assessment of CORP, a representative space that is usually occupied for a larger period is selected. The representative spaces identified per building typology are the following:

- Residences: Living room
- Schools: Classroom that is frequently occupied at full occupancy around the year (<= 50m<sup>2</sup> or 20-25 students)
- Offices: typical office frequently occupied for a large period of time at full occupancy (25m<sup>2</sup> occupied by 5 people).

**Scoring and Weighting**

All IEQ indicators are assessed in both CARP and CORP methods: (i) thermal comfort, (ii) indoor air quality, (iii) visual comfort, and (iv) acoustic comfort. All four indicators are evaluated independently based on multiple criteria to identify the overall IEQ level. For each criterion, certain parameters must be evaluated (Figure 3). A combined rating covering all IEQ indicators can be estimated, and equal weightage is assumed for all indicators by default. Individual rating of indicators is also an option.

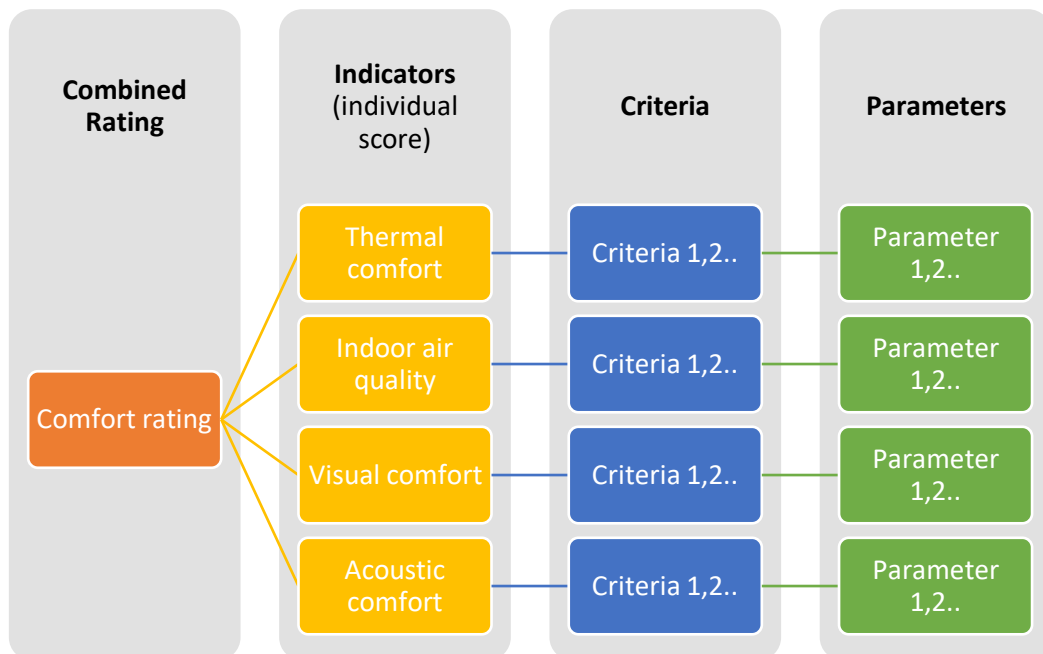


Figure 3: Structure of criteria and parameters for each indicator

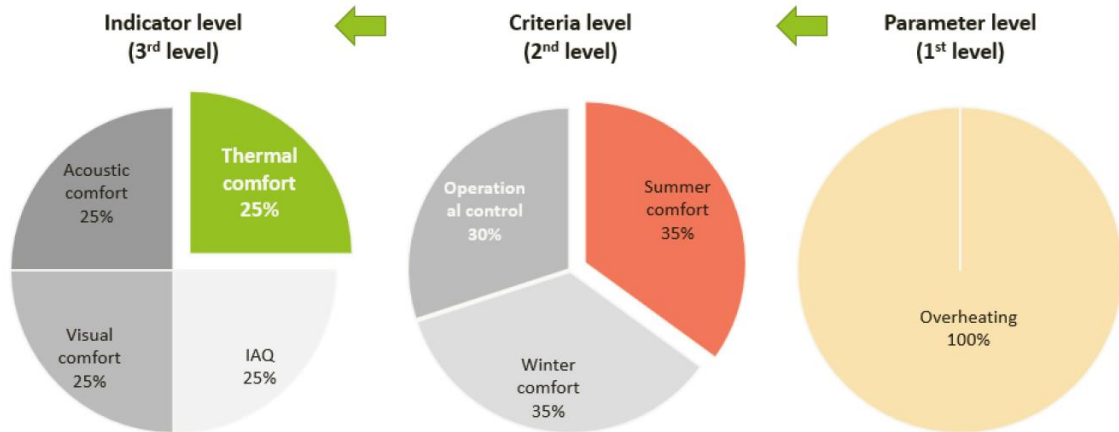


Figure 4: An example of two levels of weightage for the thermal comfort indicator (CARP)

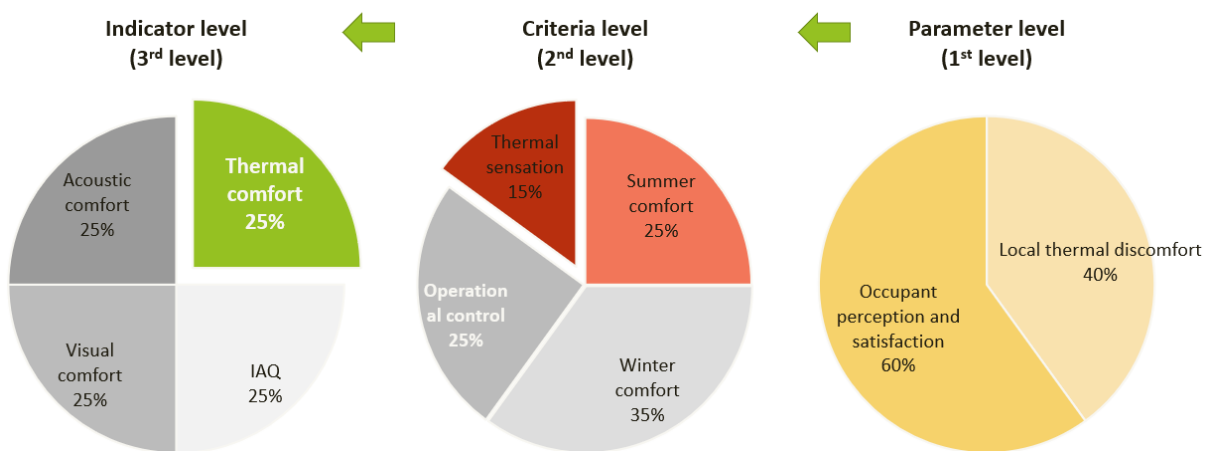


Figure 5: An example of two levels of weightage for the thermal comfort indicator (CORP)

The definitions of the terms used (in the figures above) for the assessment of the IEQ are given below:

- Indicators:** Refer to the four main determinants of the IEQ indicator. Equal or different relative weightage may be assigned to these determinants depending on different aspects, such as region, type of buildings, etc. However, equal weighting is recommended. Each indicator will be evaluated based on several criteria.
- Criteria:** Are aspects that are assessed within each indicator based on existing literature. Criteria will be given different or similar relative weightage based on expert inputs to the tool.
- Parameters:** Are individual factors under the criteria that are used to evaluate the indicator based on the impact on comfort, health, and well-being of the occupants. Relative weightage is assigned to each parameter based on the expert's inputs. Each parameter can achieve a score of 0 (worst) to 10 (best), which is assessed using a checklist. For the scoring of each parameter, individual scales are developed<sup>19</sup>.

<sup>19</sup> [https://x-tendo.eu/wp-content/uploads/2020/01/CORP\\_userguide\\_betaversion1.2\\_final.pdf](https://x-tendo.eu/wp-content/uploads/2020/01/CORP_userguide_betaversion1.2_final.pdf)

**Comfort Rating Display for CARP and CORP**

Based on the provided inputs, Figure 6 visualises the achieved rating of comfort after assigning weights to each of the indicators (thermal comfort, indoor air quality, visual comfort, and acoustic comfort).



Figure 6: Visualised comfort rating

## SWOT Analysis with Respect to the Integration in iBRoad2EPC

The following table summarises the strengths, weaknesses, opportunities and threats of the introduction of the indoor environmental quality indicator in iBRoad2EPC.

Strengths	Weaknesses	Opportunities	Threats
<ul style="list-style-type: none"> <li>• Builds on good practices adjusted to the needs of the EPC framework and assessment procedure<sup>20,21</sup></li> <li>• Two assessment options are available: (1) asset rating and (2) operational rating</li> <li>• Cost-efficient compared to traditional assessments (costs covering monitoring instruments, training, on-site visits, etc. are kept to the minimum while assuring necessary technical specifications<sup>22</sup>)</li> <li>• Robust, reliable, and trustworthy method for IEQ evaluation (builds on relevant standards such as the EN ISO 15251, EP 16798-1:2019, EN 7730 and also well-developed frameworks and indexes e.g., WELL, LEED, TAIL index, Level(s))</li> </ul>	<ul style="list-style-type: none"> <li>• A few assumptions are made that may affect the accuracy of the outputs (e.g., number of occupants, continuity of conditions)</li> <li>• Measurements necessary for operational rating require more time for the relevant assessment</li> </ul>	<ul style="list-style-type: none"> <li>• Improves the reliability and value of EPCs through the integration of comfort and IEQ</li> </ul>	<ul style="list-style-type: none"> <li>• Potential negative impact on the energy performance rating if an energy-efficient building has poor IEQ</li> <li>• In the case of CORP:               <ul style="list-style-type: none"> <li>○ Owner/users may not be willing to fill in the questionnaire</li> <li>○ Occupant/owner consent is required for the installation of measuring devices and data collection from buildings</li> </ul> </li> </ul>

<sup>20</sup> <https://aldren.eu/>: The TAIL index, developed as part of the ALDREN3 project, provides a rating to describe the quality of the indoor environment of offices and hotels before and after deep renovation.

<sup>21</sup> [https://environment.ec.europa.eu/topics/circular-economy/levels\\_en](https://environment.ec.europa.eu/topics/circular-economy/levels_en): an EU framework for core sustainability indicators for office and residential buildings, also covers indicators of the indoor environment such as indoor air quality, daylight, and thermal and acoustic comfort.

<sup>22</sup> [https://x-tendo.eu/wp-content/uploads/2021/03/X-TENDO\\_MINI\\_2\\_Comfort\\_indicator\\_04.pdf](https://x-tendo.eu/wp-content/uploads/2021/03/X-TENDO_MINI_2_Comfort_indicator_04.pdf)

## Applicability for the iBRoad2EPC Building Types

Both CARP and CORP methodologies apply to new and existing residential buildings (single-family houses, multi-family apartments), schools, and offices, covering both private and public buildings.

### Feasibility Aspects

For the needs of iBRoad2EPC and those interested in a quicker, less expensive, and less time-consuming approach, CARP can also be applied to occupied buildings. In this case, it must be noted that CARP assesses only the capacity of the building to provide a comfortable indoor environment. Information related to the impacts of the building's use and actual operation may not be captured accurately. However, the method still gives an appropriate indication of the IEQ levels.

The Excel spreadsheet for this feature is available from the X-tendo project and could be applied within the project iBRoad2EPC.

### Level of expertise, skills and training Requirements

For the asset rating CARP, which is based primarily on checklists, the assessor should have some fundamental technical skills and intermediate expertise or knowledge of the subject to be able to quickly inspect the interior of the building to identify malfunctions, e.g., on the HVAC systems, presence of mould, etc., and to identify harmful material on the building's structure, such as paints, varnishes adhesives, etc. As concerns soft skills, the operational rating requires effective communication skills to collaborate with the building occupants to fill in the questionnaire and inform them of the benefits of doing so<sup>23</sup>.

For the operational rating CORP, additional intermediate skills are required, such as the ability to use the required monitoring instruments or the ability to execute a quick survey with the building occupants. Technical skills involve setting up and calibrating the monitoring devices, and the ability to monitor, download, analyse, and interpret the monitored data. On required training, assuming that the assessor is an experienced energy expert with basic knowledge (e.g., of HVAC systems), then training would only be required for some IT software skills in relation to the simulation of the thermal conditions. For some Member States, this is already included in their EPC; if not, this training could last for about a full day. The assessor should familiarise themselves with the use of the monitoring devices for all quality checks before the installation on-site.

The EPC expert needs to be familiar with the rating tool before going on-site to make sure the required parameters are sufficiently clear and a plan is created regarding the input parameters to minimise his/her effort and time on site.

### Resources needed

For CORP, the required resources include the monitoring instruments with minimum technical specifications specified in the X-tendo user guide<sup>24</sup>. In terms of effort, measurements necessary for operational rating require more time for the relevant assessment (one week during the summer period and one week of monitoring during the winter period).

For the completion of the checklists in CARP, the assessor will require approximately one to two hours on-site to inspect the building.

## Requirements for Adaptation and Integration within iBRoad2EPC

As presented above, two methodologies (CARP and CORP) are available for the evaluation of IEQ. In cases of time and effort restrictions, CARP is recommended, while for a more detailed analysis of IEQ

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<sup>23</sup> [https://x-tendo.eu/wp-content/uploads/2021/03/X-TENDO\\_MINI\\_2\\_Comfort\\_indicator\\_04.pdf](https://x-tendo.eu/wp-content/uploads/2021/03/X-TENDO_MINI_2_Comfort_indicator_04.pdf)

<sup>24</sup> [https://x-tendo.eu/wp-content/uploads/2020/01/CORP\\_userguide\\_betaversion1.2\\_final.pdf](https://x-tendo.eu/wp-content/uploads/2020/01/CORP_userguide_betaversion1.2_final.pdf)

and if a budget for monitoring equipment and extra time (2 weeks of monitoring, 1 in summer and 1 in winter) is available, then CORP is suggested.

The expert needs to go through the user guidelines provided for the respective method and familiarise her/himself with the Excel tool before going on-site to ensure all required parameters that need to be collected are sufficiently clear.

The Excel spreadsheets of the comfort tool are complete and adjusted to the needs of iBRoad2EPC, and it is recommended to link them directly to iBRoad2EPC to evaluate the IEQ. The only adaptation required is the integration of the climatic zones (including Heating and Cooling Degree Days - HDD, CDD) of the pilot countries in the calculation tool. There is no risk of downgrading the quality or robustness of the method with these adaptations; on the contrary, the addition of further climatic zones makes the tool applicable to an even wider geographical coverage.

## SMART READINESS INDICATOR

### Benefits and Market Needs

The recast Energy Performance of Buildings Directive (EPBD, 2018/844/EU)<sup>25</sup> introduced the Smart Readiness Indicator (SRI), which rates the readiness of buildings to perform three key functionalities:

- to optimise energy efficiency and overall in-use performance
- to adapt their operation to the needs of the occupant
- to adapt to signals from the grid (for example, energy flexibility) [9]

The SRI framework supports technological innovation in the building sector and creates an incentive for smart building technologies integration, which are beneficial for increasing energy efficiency, reducing CO<sub>2</sub> emissions, and improving the comfort and convenience of building occupants. Since the concept of the SRI is rather new, the authors are not aware of any implementation in a certification or EPC framework within Europe.

The concept was introduced in the Directive (2018/844/EU), and it was further developed in the technical study for the European Commission, which investigated the scope, definition, and calculation of the SRI and performed a more detailed assessment of its potential impacts [1]. The study developed describes three SRI assessment methods: the simplified method (method A), the expert SRI assessment (method B), and the in-use smart building performance method (method C).

**Method A** is based on a checklist approach with a limited services list focusing on residential buildings and small non-residential buildings. The method allows both (online) self-assessment and a third-party expert assessment, but only the latter would result in formal certification. It is a quick method that would not take more than one hour. The checklist, including the concrete services listed, is explained in more detail below.

**Method B** is an extension of method A, with a more detailed assessment based on the checklist approach covering a full catalogue of smart services. The method focuses on non-residential buildings and would require an on-site inspection by a qualified third-party expert. It could also potentially allow a self-assessment by a non-independent expert. However, only a qualified third-party expert may issue a formal certification. Due to its complexity, the assessment time could range between half a day and a full day.

**Method C** is a metered/measured method that quantifies the actual performance of in-use buildings. This method assesses the actual performance based on measurement of energy consumption by end-uses, appliances, and behavioural factors. This results in a quantification of savings, flexibility, or comfort improvements that can be delivered as a result of smart technologies. Alternatively, the scope could be broadened beyond the scope of the current SRI to become an assessment of actual performance rather than solely focusing on smart controls.

According to the intention of the EPBD (2018/844/EU) and [1], the SRI is considered to be a potential future evolution of building energy performance certification approaches, in particular of EPCs; in **the scope of the project iBRoad2EPC**, **method A** is considered the most relevant and realistic to be implemented because it is the easiest to implement using the already available spreadsheet. Therefore, the text below will focus on method A and only briefly mention method B. In the sense of IT implementation, the effort to implement method B would be minimal as there would be only additional services offered. Thus, we believe that mentioning method B would be beneficial, as well. In any case, in the context of the project iBRoad2EPC, the assessment needs to be done by an energy expert.

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<sup>25</sup> [https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L\\_.2018.156.01.0075.01.ENG](https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.156.01.0075.01.ENG)

## Status Quo on SRI in the Implementing Countries and other EU Member States

To assess the status quo on SRI in iBRoad2EPC implementing countries, we classified the status according to the following categories:

- (1) This feature is currently part of the national EPC scheme.
- (2) There are concrete plans to include this feature in the national EPC scheme (expected within the next year).
- (3) There are vague discussions about this feature but no concrete plans.
- (4) Currently, no concrete plans or discussions to include this feature in the national EPC scheme.

The following table shows the results of this assessment.

Bulgaria	Greece	Poland	Portugal	Romania	Spain
There are vague discussions about this feature but no concrete plans	Currently, no concrete plans or discussions to include this feature in the national EPC scheme	There are vague discussions about this feature but no concrete plans	There are concrete plans to include this feature in the national EPC scheme	There are vague discussions about this feature but no concrete plans	Currently, no concrete plans or discussions to include this feature in the national EPC scheme

*Table 2. Status quo on SRI in the iBRoad2EPC Implementing Countries*

With the status of August 2022, six EU Member States are currently undergoing an official test phase for the SRI implementation: Finland, Croatia, Austria, Czech Republic, Denmark, and France.

The six implementing countries are not among the countries carrying out an SRI test phase. In Greece, the SRI as an indicator is not mentioned anywhere, but auditors indicate if there are automatic mechanisms on building systems for lighting, hot water use, and heating/cooling. They are also required to rate them for heating/cooling. In Romania, however, SRI has a special box in the annex of the new EPC (under approval), but the calculation procedure is not published. Portugal is expected to include the SRI in the national EPC scheme within the next year.

## Summary of the Method and Calculation Formulae

The technical implementation process of the SRI (focusing on methods A and B) consists of three parts that will be described in detail; (1) necessary data requirements and data collection methods, (2) processing of the collected data to rate the smartness of the various components and services present in the building, and (3) procedures for storing and updating SRI data.

For both methods A and B, to start with the assessment, the user needs to input general building information that includes building type, building usage, building state, and location. Building type has two options, residential and non-residential. In the case of residential buildings, building usage can be single-family house, small multi-family house (ten residential units or less), large multi-family house (more than ten residential units), or other, i.e., student housing, care homes, etc. Building usage for non-residential buildings can be offices, educational buildings, healthcare, or others. The building state can be either renovated or original. Renovated buildings are those that have undergone important energetic upgrades and/or upgrades to the technical building systems since the year of construction. At last, there is the location of the building. Five climate zones are identified, and the appropriate climate zone is determined according to the location of the building<sup>26</sup>.

<sup>26</sup> Northern Europe (Denmark, Finland, Sweden, Norway, Iceland), Western Europe (Austria, Belgium, France, Germany, Ireland, Luxembourg, Netherlands, United Kingdom, Liechtenstein, Switzerland), Southern Europe (Greece, Italy, Malta, Portugal, Spain, Cyprus), North-Eastern Europe (Czech

The following nine domains (Figure 7) are in the scope of assessment: space heating, domestic hot water, space cooling, ventilation, lighting, dynamic building envelope, electricity, electric vehicle charging, and monitoring and control. For each of these services, the user shall be able to select several features.

It is not necessary to assess all domains. The user can omit some services if not relevant or not applicable. However, that should be indicated in the methodology section, where users shall choose options for three fields, (1) preferred weightings, (2) preferred assessment method, and (3) domains present, which will be explained in detail in the following text.

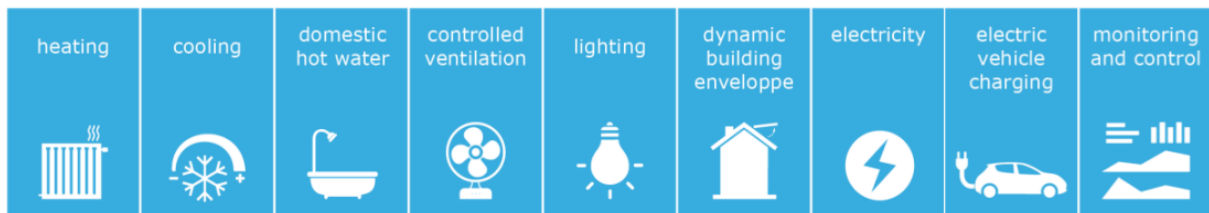


Figure 7: Domains structuring the SRI catalogue [1]

Figure 8 below shows the calculation of the SRI based on the scoring of a building's different services, allocated to certain domains (e.g., heating, ventilation, lighting), which then have a certain impact on different impact criteria (e.g., energy savings, maintenance and fault prediction).

# SRI - CALCULATION METHODOLOGY

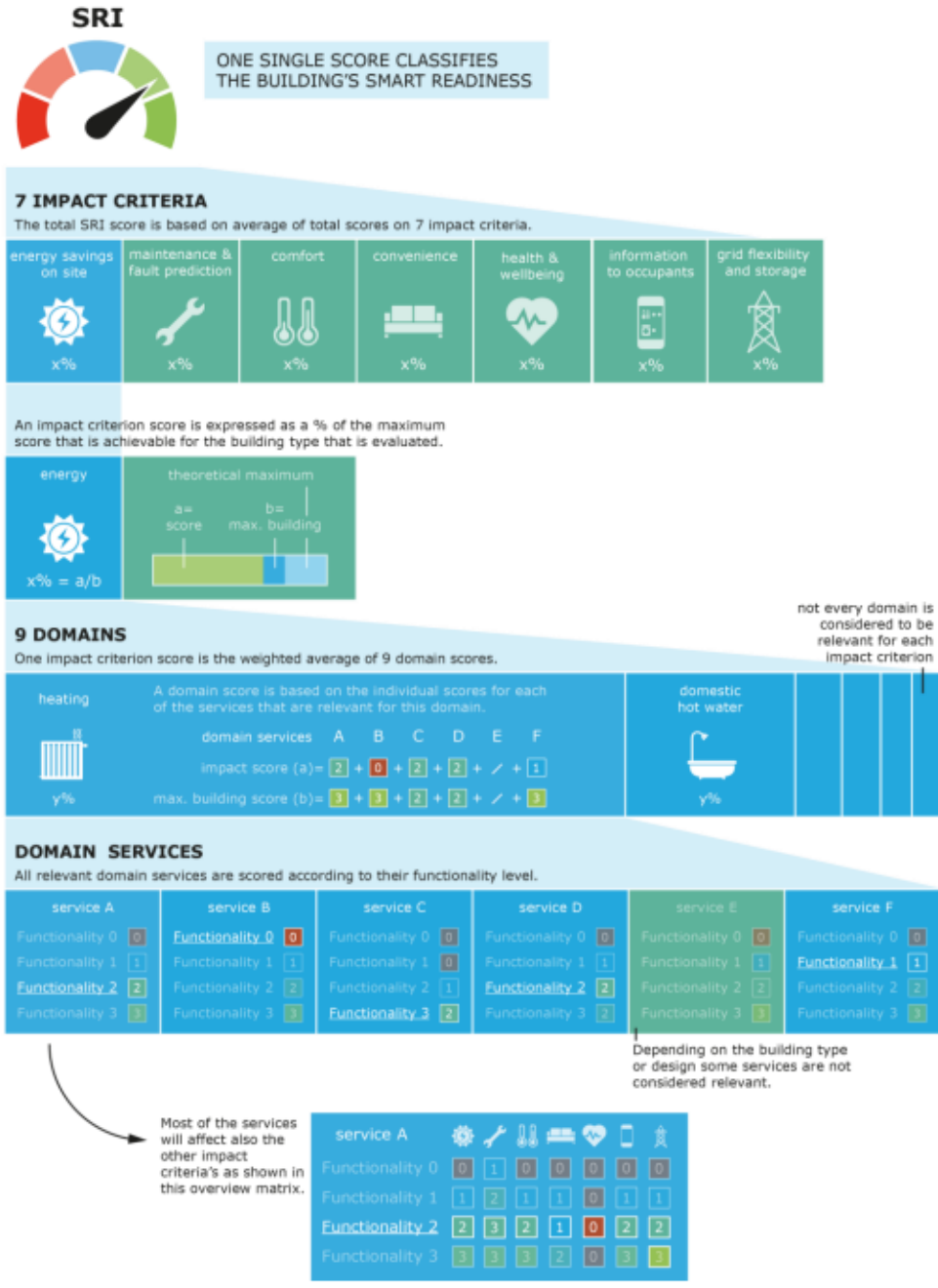


Figure 8: Summary of the calculation method [1]

### Preferred Weightings

The SRI score is based on a weighted sum of seven total impact scores. The seven impact scores are energy savings (1), maintenance and fault protection (2), comfort (3), convenience (4), information to occupants (5), health and wellbeing (6), and energy flexibility and storage (7).

The weighting factors can be attributed to both domains and impact. First, the ordinal scores of the individual services are aggregated to a domain score. Second, the domain scores are aggregated into a single impact score. Three different approaches are envisioned for deriving the domain and service level weighting factors: equal weighting, predicted impact approach, and energy balance approach. Figure 9 shows an overview of the proposed weighting scheme, consisting of fixed weights, equal weights, and energy balance weights, depending on domain and impact. For the aggregation of services to the domain level, equal weighting is assumed, i.e., each service within a domain is equally important. The aggregation of domain scores for a single impact score accounts for the relative importance of the domains concerning the impact criteria (Figure 10).

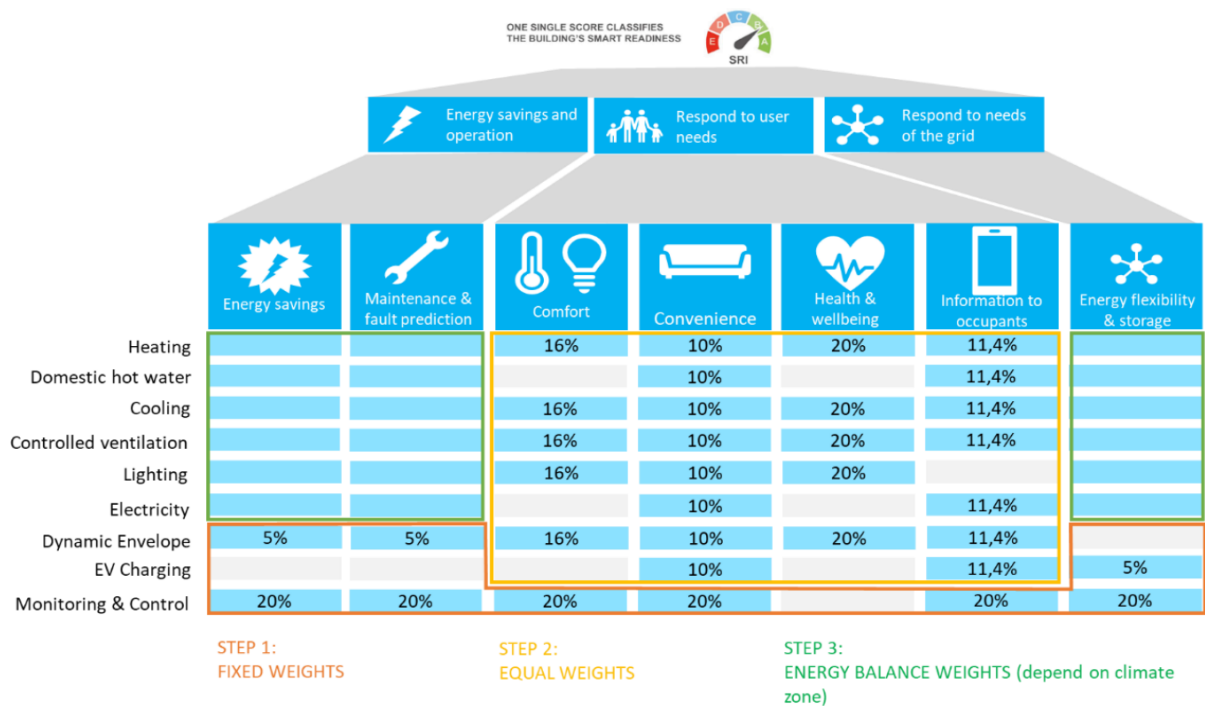


Figure 9: Overview of the weighting scheme [1]

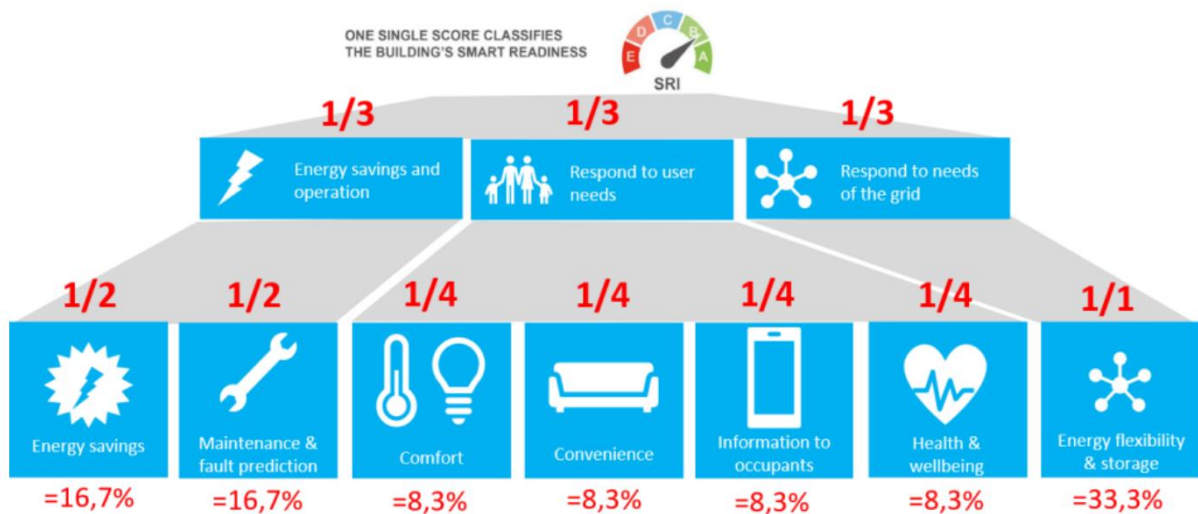


Figure 10: Weighting factors for impact criteria [1]

In the field preferred weightings, the user can choose between two options, default or user-defined. The default weighting is calculated according to the scheme shown in Figure 9. However, a user can set their own weighting factors. In that case, in the tab “building information” under the section “general building information”, the user should set the preferred weighting factors to “user-defined”. Then in the tab “weightings”, the desired weighting factors should be provided. There are two types of weightings:

- Domain weightings: these weighting factors are used to aggregate domain scores (e.g., heating, ventilation, lighting) to impact scores (in the calculation procedure, it must be ensured that the sum is exactly 100%; i.e., the blank fields in Figure 9 would need to be filled in a way that the sum over the columns results in 100%)
- Impact weightings: these weighting factors are used to aggregate the impact scores (e.g., energy savings, maintenance, and fault prediction) to a single SRI score (in the calculation procedure, it must be ensured that the sum is exactly 100%)

### SRI Assessment Method

Options for the preferred assessment method are, A - simplified method contains a list of selected services, B - detailed method contains all services or custom: select the applicable services. In the context of the project iBRoad2EPC, we propose to only use method A, the final implementation of which will be further analysed during the IT implementation process.

### Domains and Services

In the field, domain present (see Figure 7), there are three options to choose from, 0 - This domain is absent and not mandatory, 1 - This domain is present, 2 - This domain is absent but mandatory.

An example of the option “domain is absent and not mandatory” is: A residential building has no cooling system, and this is not mandatory [10]. In this case, the weighting for this domain is discarded and not considered in the assessment, i.e., it does not have an impact on the building score.

An example of the option “domain is absent but mandatory” is: An office building has no EV charging system, and this is mandatory for new buildings [10]. In this case, the weighting for this domain is discarded, but it is considered in the assessment, i.e., it has an impact on the building score.

To perform the actual assessment, the user should indicate whether the service applies to the building or not (1 - applicable, 0 - not applicable). The list of services for methods A and B, in the corresponding domains, is the following:

#### Heating:

- Heat emission control (methods A and B)
- Emission control for Thermally Activated Building System (TABS) (heating mode) (only method B)
- Storage and shifting of thermal energy (methods A and B)
- Control of distribution pumps in networks (only method B)
- Thermal Energy Storage (TES) for building heating (excluding TABS) (only method B)
- Heat generator control (all except heat pumps) (methods A and B)
- Heat generator control (for heat pumps) (methods A and B)
- Sequencing in case of different heat generators (only method B)
- Report information regarding heating system performance (methods A and B)
- Flexibility and grid interaction (only method B)

#### Domestic hot water:

- Control of DHW storage charging (with direct electric heating or integrated electric heat pump) (methods A and B)
- Control of DHW storage charging (methods A and B)
- Control of DHW storage charging (with solar collector and supplementary heat generation) (only method B)
- Sequencing in case of different DHW generators (only method B)
- Report information regarding domestic hot water performance (methods A and B)

**Cooling:**

- Cooling emission control (methods A and B)
- Emission control for TABS (cooling mode) (only method B)
- Control of distribution network chilled water temperature (supply or return) (only method B)
- Control of distribution pumps in networks (only method B)
- Interlock: avoiding simultaneous heating and cooling in the same room (only method B)
- Control of TES operation (only method B)
- Generator control for cooling (methods A and B)
- Sequencing of different cooling generators (only method B)
- Report information regarding cooling system performance (methods A and B)
- Flexibility and grid interaction (methods A and B)

**Ventilation:**

- Supply airflow control at the room level (methods A and B)
- Airflow or pressure control at the air handler level (only method B)
- Heat recovery control: prevention of overheating (only method B)
- Supply air temperature control at the air handling unit level (only method B)
- Free cooling with a mechanical ventilation system (only method B)
- Reporting information regarding IAQ (methods A and B)

**Lighting:**

- Occupancy control for indoor lighting (methods A and B)
- Control artificial lighting power based on daylight levels (only method B)

**Dynamic building envelope:**

- Window solar shading control (methods A and B)
- Window open/closed control, combined with HVAC system (only method B)
- Reporting information regarding the performance of dynamic building envelope systems (methods A and B)

**Electricity:**

- Reporting information regarding local electricity generation (methods A and B)
- Storage of (locally generated) electricity (methods A and B)
- Optimizing self-consumption of locally generated electricity (only method B)
- Control of combined heat and power plant (CHP) (only method B)
- Support of (micro)grid operation modes (only method B)
- Reporting information regarding energy storage (methods A and B)
- Reporting information regarding electricity consumption (methods A and B)

**Electric vehicle charging:**

- EV Charging Capacity (methods A and B)
- EV Charging Grid balancing (methods A and B)
- EV charging information and connectivity (methods A and B)

**Monitoring and control:**

- Run time management of HVAC systems (only method B)
- Detecting faults of technical building systems and providing support to the diagnosis of these faults (only method B)
- Occupancy detection: connected services (only method B)
- Central reporting of TBS performance and energy use (methods A and B)
- Smart Grid Integration (methods A and B)
- Reporting information regarding demand-side management performance and operation (only method B)
- Override of DSM control (only method B)
- Single platform that allows automated control & coordination between TBS + optimization of energy flow based on occupancy, weather, and grid signals (methods A and B)

For each service to be assessed, the following fields may be completed:

- Main functionality level: functionality level 0 (as non-smart default), functionality level 1, functionality level 2, functionality level 3, and functionality level 4. If this field is left blank or the functionality level is not valid, a warning should be displayed, and no SRI score will be calculated. If the functionality level is valid, the chosen functionality level should turn orange to facilitate visual validation.
  - Share of the functionality level: this field enables testing of partial compliance of a building to the main functionality level. If a user does not wish to test partial compliance, then a default value of 100% shall be used. Otherwise, the percentage of the net surface area of the building that complies with the main functionality level should be indicated.
  - Optional - additional functionality level: if the share of the functionality level is set to less than 100%, then the functionality level that applies to the remaining surface area should be provided.
  - Estimated assessment time: for feedback purposes, the time required to determine the functionality level, including the time needed for visual inspection and/or the time needed to look up technical data, shall be provided.
- Optional - assessor comments: this is the place to provide comments if desired, such as notes, clarifications, difficulties encountered while attempting an assessment, or notification that ordinal scores were altered.

## Results

After the assessment is completed, the results are obtained in five different types, according to the level of detail and granularity that the user would like to see. The figures below mark the cells which are shown in each option in blue:

- Detailed scores: the detailed scores for each domain and each impact criterion, which results in a matrix for nine domains and seven criteria

















	 Energy efficiency	 Maintenance and fault prediction	 Comfort	 Convenience	 Health, well-being and accessibility	 Information to occupants	 Energy flexibility and storage
 Heating	%	%	%	%	%	%	%
 Cooling	%	%	%	%	%	%	%
 Domestic hot water	%	%	%	%	%	%	%
 Ventilation	%	%	%	%	%	%	%
 Lighting	%	%	%	%	%	%	%
 Dynamic building envelope	%	%	%	%	%	%	%
 Electricity	%	%				%	%
 Electric vehicle charging		%		%		%	%
 Monitoring and control	%	%	%	%	%	%	%

Figure 11: Detailed score [10]

- Domain scores: the domain scores for each domain, considering impact weightings

















	 Energy efficiency	 Maintenance and fault prediction	 Comfort	 Convenience	 Health, well-being and accessibility	 Information to occupants	 Energy flexibility and storage	
 Heating	%	%	%	%	%	%	%	%
 Cooling	%	%	%	%	%	%	%	%
 Domestic hot water	%	%	%	%	%	%	%	%
 Ventilation	%	%	%	%	%	%	%	%
 Lighting	%	%	%	%	%	%	%	%
 Dynamic building envelope	%	%	%	%	%	%	%	%
 Electricity	%	%				%	%	%
 Electric vehicle charging		%		%		%	%	%
 Monitoring and control	%	%	%	%	%	%	%	%

Figure 12: Domain score [10]

- Impact scores: the impact scores for each impact criterion, considering domain weightings

















	%	%	%	%	%	%	%	
	 Energy efficiency	 Maintenance and fault prediction	 Comfort	 Convenience	 Health, well-being and accessibility	 Information to occupants	 Energy flexibility and storage	
 Heating	%	%	%	%	%	%	%	%
 Cooling	%	%	%	%	%	%	%	%
 Domestic hot water	%	%	%	%	%	%	%	%
 Ventilation	%	%	%	%	%	%	%	%
 Lighting	%	%	%	%	%	%	%	%
 Dynamic building envelope	%	%	%	%	%	%	%	%
 Electricity	%	%				%	%	%
 Electric vehicle charging		%		%		%	%	%
 Monitoring and control	%	%	%	%	%	%	%	%

Figure 13: Impact score [10]

- Aggregated scores: the aggregated scores for three key functionalities<sup>27</sup>

		%		%				%	
		Optimise energy efficiency and overall in-use performance 1		Adapt its operation to the needs of the occupant 2				Adapt to signals from the grid (energy flexibility) 3	
		%	%	%	%	%	%	%	%
		Energy efficiency	Maintenance and fault prediction	Comfort	Convenience	Health, well-being and accessibility	Information to occupants	Energy flexibility and storage	
	Heating	%	%	%	%	%	%	%	%
	Cooling	%	%	%	%	%	%	%	%
	Domestic hot water	%	%	%	%	%	%	%	%
	Ventilation	%	%	%	%	%	%	%	%
	Lighting	%	%	%	%	%	%	%	%
	Dynamic building envelope	%	%	%	%	%	%	%	%
	Electricity	%	%				%	%	%
	Electric vehicle charging		%		%		%	%	%
	Monitoring and control	%	%	%	%	%	%	%	%

Figure 14: Aggregated score [10]

- Total SRI score: the total SRI score, considering domain weightings and impact weightings (Figure 10)

Overall SRI score (%) + SRI class									
		%		%				%	
		Optimise energy efficiency and overall in-use performance 1		Adapt its operation to the needs of the occupant 2				Adapt to signals from the grid (energy flexibility) 3	
		%	%	%	%	%	%	%	%
		Energy efficiency	Maintenance and fault prediction	Comfort	Convenience	Health, well-being and accessibility	Information to occupants	Energy flexibility and storage	
	Heating	%	%	%	%	%	%	%	%
	Cooling	%	%	%	%	%	%	%	%
	Domestic hot water	%	%	%	%	%	%	%	%
	Ventilation	%	%	%	%	%	%	%	%
	Lighting	%	%	%	%	%	%	%	%
	Dynamic building envelope	%	%	%	%	%	%	%	%
	Electricity	%	%				%	%	%
	Electric vehicle charging		%		%		%	%	%
	Monitoring and control	%	%	%	%	%	%	%	%

Figure 15: Total SRI score [10]

<sup>27</sup> Three key functionalities: to optimise energy efficiency and overall in-use performance, to adapt their operation to the needs of the occupant, to adapt to signals from the grid (for example, energy flexibility)

## Testing Results

Testing of the smart dimensions feature was conducted by X-tendo<sup>28</sup> in Austria, Estonia, Greece, and Romania. The steps for the in-building tests are the same in all countries:

1. Administration/data collection - including the gathering of building data, distribution of tasks, and establishing a testing strategy
2. Assessor evaluation - including on-site visits and the evaluation of the assessor
3. Calculation - including the entry of inputs into the calculation sheets and performing the calculation of the SRI score

In Austria, ten buildings were examined, which consisted of single-family houses and apartments, an office building, and two schools. In Estonia, the SRI feature has been tested on ten different multi-family houses. In Greece four buildings were studied, two office buildings and two apartments. Finally, in Romania, the tested buildings were one single-family house (SFH), one multi-family house (MFH), one office, and one kindergarten/school.

The following figure shows an exemplary result of the testing of the SRI carried out within the X-tendo project [11] in a new single-family house situated in Palermo.

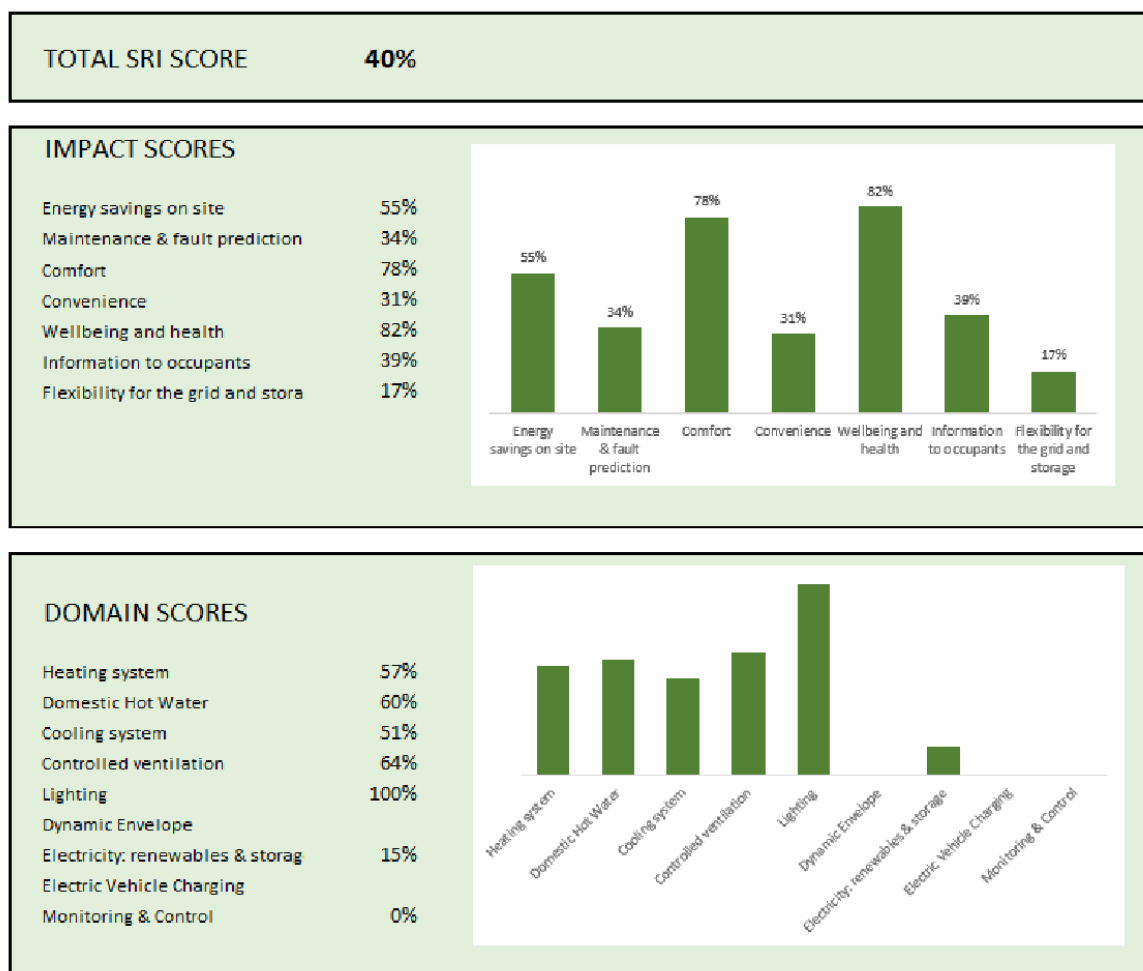


Figure 16: Exemplary test result of the SRI indicator in a new single-family house in Palermo [11]

<sup>28</sup> [https://x-tendo.eu/wp-content/uploads/2020/01/X-tendo\\_deliverable5.2\\_Feature1\\_SmartReadiness\\_Final.pdf](https://x-tendo.eu/wp-content/uploads/2020/01/X-tendo_deliverable5.2_Feature1_SmartReadiness_Final.pdf)

The testing results showed that the overall difficulty of carrying out the calculations is either “somewhat easy” (Greece and Romania) or “neither easy nor difficult” (Austria and Estonia). Austria and Romania found it “neither easy nor difficult” to explain it to assessors or stakeholders, Estonia “somewhat easy”, and Greece “very easy”. The testing partners could perform all steps in the testing process in all buildings.

The feasibility of including the developed methodology in the standard EPC assessment is rated quite differently. Estonia rates it “somewhat unpractical” as the feature might be misunderstood. Greece rates the implementation into the Greek EPC assessment “somewhat practical” with the explanation that “the tool is easy to use and rather easy to complete. Some knowledge about the systems, technologies, and efficiencies is required.” Romania and Austria find the feature “very practical” to be implemented in national EPC assessments in their countries: data was easily collected, the tool was easy to use, and the indicator has sufficient relevance to the users of the EPC. Overall, the testing results within the project X-tendo did not indicate the need for specific adaptations of the methodology as such to national contexts. However, in the course of the ongoing Commission’s SRI testing projects in several countries, additional insights might come up which were not available when this report was written.

### SWOT Analysis with Respect to the Integration of SRI method A in iBRoad2EPC

Strengths	Weaknesses	Opportunities	Threats
<ul style="list-style-type: none"> <li>• Builds on a well-accepted and evaluated approach developed for the EC</li> <li>• Flexible due to the possible choice of different weighting factors</li> <li>• Can be done with limited effort by the building assessors - preparation, data collection, assessor evaluation, and SRI calculation is estimated to be around 2.5 hours per building/apartment [12]</li> <li>• Can be implemented with justifiable IT effort in the tool</li> <li>• Applicability in residential and non-residential buildings</li> </ul>	<ul style="list-style-type: none"> <li>• The aggregated total SRI score is built on a series of inputs and building conditions, which might not be very transparent</li> <li>• The detailed scores are transparent but not easy to communicate</li> </ul>	<ul style="list-style-type: none"> <li>• Strong interest in the SRI and how to improve smart readiness of buildings (at least on the EU-policy level)</li> </ul>	<ul style="list-style-type: none"> <li>• There could be confusion if full consistency with the calculation methodology proposed by the Commission is not ensured.</li> <li>• If MSs take up the SRI in their EPC, consistency of iBRoad2EPC for the national implementation needs to be ensured to avoid confusion</li> </ul>

### SWOT Analysis with Respect to the Integration of SRI method B in iBRoad2EPC

Strengths	Weaknesses	Opportunities	Threats
<ul style="list-style-type: none"> <li>Builds on a well-accepted and evaluated approach developed for the EC</li> <li>Flexible due to the possible choice of different weighting factors</li> <li>Allows detailed assessment, in particular for non-residential buildings</li> <li>Can be implemented with justifiable IT effort in the tool</li> </ul>	<ul style="list-style-type: none"> <li>The aggregated total SRI score is built on a series of inputs and building conditions, which might not be very transparent</li> <li>The detailed scores are transparent but not easy to communicate</li> <li>High effort (half-day to one-day); method B focuses on non-residential buildings only</li> </ul>	<ul style="list-style-type: none"> <li>Strong interest in the SRI and how to improve smart readiness of buildings (at least on the EU-policy level)</li> <li>SRI might be attractive in particular for non-residential buildings. A more detailed approach could increase the depth and quality of information</li> </ul>	<ul style="list-style-type: none"> <li>There could be confusion if full consistency with the calculation methodology proposed by the Commission is not ensured.</li> <li>If MSs take up the SRI in their EPC, consistency of iBRoad2EPC for the national implementation needs to be ensured to avoid confusion</li> <li>Too much effort for method B could put the whole SRI implementation at risk</li> </ul>

### Applicability for the iBRoad2EPC Building Types

In general, the method can be applied to residential and non-residential buildings. In project X-tendo, the method was tested in residential and non-residential buildings. It turned out that specific building typologies such as large-scale non-residential buildings with high energy demand might require the more detailed method B. For residential buildings, the simplified method A would contribute to raising awareness among building owners and help them understand the value of automation in saving energy while increasing comfort. The testing results carried out in X-tendo did not specify huge differences regarding the required time and adaptation needs of the method for residential and non-residential buildings, as long as method A is applied (method B takes significantly longer than method A, about half a day to one day). The same can be concluded for method B; testing does not show differences between various types of buildings. However, the authors of the SRI study explicitly focussed on non-residential buildings for method B, due to the higher effort required.

### Feasibility Aspects

We assess the overall feasibility as high since the Excel spreadsheet is available to be used in the project iBRoad2EPC. Also, the data requirement is limited since the assessment of existing services along the above-described domains is relatively easy to implement. The data as such usually is not collected during a standard EPC issuing process. Still, the information usually can be made quickly and easily available.

According to the testing by X-tendo, all implementing partners agree that the used calculation methods are clearly described, and the required input data is clearly asked for in the spreadsheets. Also, they agree that the user is provided with the fundamental technical knowledge needed to understand the details of the feature through the information in the spreadsheet and the guidelines. There is an agreement that training of assessors is most probably needed. Romanian implementing partner states that “Assessors with strong technical/engineering background may need less training. The others may need a checklist when verifying the presence of specific equipment (sensors, meters, controllers).” Greece agrees that the amount of necessary training depends on the expert’s knowledge and experience, the knowledge required thus refers to the technical systems, technologies, and efficiencies.

The verification of the collected data (e.g., building type, building usage, building state, location) in terms of completeness and correctness should be done by the assessors. There are no additional measures foreseen (e.g., automatic detection of missing or wrong input data in the spreadsheets) to ensure the verification of collected data at the moment of testing the feature in the course of the project. However, the training and certification of assessors should minimise the risk of inserting incorrect or incomplete data. The duration of the training depends on the background and the experience of the assessor, but it should not require more than 2-3 hours. The website of the European Commission on the SRI tool includes materials for the training of assessors<sup>29</sup>.

### Requirements for Adaptation and Integration within iBRoad2EPC

Considering the required time and related resources for carrying out the different methods, we decided to apply method A within iBRoad2EPC. Still, it is important to note that the calculation and assessment of the SRI needs to be done by an energy expert.

To avoid inconsistencies with the SRI tool developed and promoted by the European Commission<sup>29</sup>, we propose to use this Excel spreadsheet tool directly for the purpose of the iBRoad2EPC project. The iBRoad2EPC assistant provides the link to the respective SRI module page where the assessor can download the SRI table. Thus, when applying the SRI within the iBRoad2EPC project, the assessor should fill in the main input data of the SRI Excel spreadsheet directly during the visit to the building. The assessor can upload data from the SRI table to the iBRoad2EPC assistant. This data is then transferred to an iBRoad2EPC layout.

However, as a main additional aspect, for the purpose of iBRoad2EPC, the SRI should be displayed for each renovation step, or at least for those renovation steps which have an implication on the SRI rating. Thus, during the building certification, we propose the following steps:

- (1) Assess the SRI for the current state of the building
- (2) Identify whether a renovation step is expected to result in a change in any of the input variables for the SRI calculation.
- (3) Carry out the SRI calculation for those renovation steps with a possible change of the SRI input variables.

For each step where a change of the SRI may occur, we propose to display the overall SRI rating and the domain scores and impact scores, corresponding to Figure 16 in the iBRoad2EPC framework (to be adapted graphically to the overall iBRoad2EPC format). In particular, the domain scores would be helpful to identify in which domains/areas improvements could be made.

To allow a smooth integration of the SRI calculation within iBRoad2EPC, we propose to expand the list of renovation measures by SRI-related measures. Table 39 in Annex II includes the list of renovation measures foreseen in the iBRoad2EPC, including the SRI-related measures. These renovation measures are displayed to the expert when creating the iBRoad2EPC. The expert can specify them when creating the step-by-step renovation and inform the addressee about the measures that affect the SRI. In addition, the expert receives an overview of the measures for which the SRI must be adjusted.

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<sup>29</sup>[https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator/sri-implementation-tools\\_en](https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/smart-readiness-indicator/sri-implementation-tools_en)

## MEASURED ENERGY PERFORMANCE

### Benefits and Market Needs

The gap between real energy performance and EPC calculated performance can be significant and is a source of confusion for EPC users. Therefore, one of the features covered by X-tendo is the real energy consumption indicator, a method that reflects the actual energy performance of the building under standard conditions of climate and use [13]. The inclusion of real energy use data enables standardization and automation of EPC issuing procedures. The improved accuracy and better link with meter readings and billing information enhance user acceptance. The real energy consumption indicator would also reduce confusion about the energy performance gap. For an illustration of the method, a spreadsheet tool has been developed (the spreadsheet can be downloaded from the X-tendo website<sup>30</sup>). This tool can be used on residential and non-residential buildings. It is necessary to input basic information, such as the actual measured energy consumption that can be gathered by a trained individual, from different sources, e.g., energy bills and may require limited pre-processing to calculate the real energy consumption, as described below. If energy use data is not available, a measurement period of at least 12 months should be factored in to determine the average energy use of the building (according to the specifications explained below in more detail). In this case, the detailed building-level approach or stock model development should be executed by a certified expert, namely an engineer or mathematician/statistician with expert knowledge of building energy performance modelling or statistical modelling. However, since this method is time-consuming, it has not been further elaborated by X-tendo.

Measured space heating, space cooling, domestic hot water, and other energy needs shall be entered separately per energy carrier, while non-EPC-related energy usage, e.g., the energy consumption of appliances (plug loads), cooking, mechanical escalators, and elevators, should be excluded. The output is a real-energy performance indicator representing the building's yearly specific primary energy use. In addition, the output provides annual CO<sub>2</sub> emissions and, if desired, the renewable energy ratio, based on the existing heating system and applied energy carriers. The measured energy use is corrected to enable inter-building comparison, such that it represents standard conditions of climate and use. The correction procedure takes by default the following aspects into account: size of the building unit (useful/reference floor area), external weather conditions (heating and cooling degree days method), and energy carrier (primary energy factors, as being used in national EPC calculations).

### Status Quo of Measured Energy Performance in the Implementing Countries

To assess the status quo of Measured Energy Performance in iBRoad2EPC implementing countries, we classified the status according to the following categories:

- (1) This feature is currently part of the national EPC scheme.
- (2) There are concrete plans to include this feature in the national EPC scheme (expected within the next year).
- (3) There are vague discussions about this feature but no concrete plans.
- (4) Currently, no concrete plans or discussions to include this feature in the national EPC scheme.

The following table shows the results of this assessment.

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<sup>30</sup> <https://x-tendo.eu/toolboxes/real-energy-consumption/>

Bulgaria	Greece	Poland	Portugal	Romania	Spain
This feature is currently part of the national EPC scheme	This feature is currently part of the national EPC scheme	Currently, no concrete plans to include this feature in the national EPC scheme (expected within the next year)	Currently, no concrete plans or discussions to include this feature in the national EPC scheme	Currently, no concrete plans or discussions to include this feature in the national EPC scheme	Currently, no concrete plans or discussions to include this feature in the national EPC scheme

Table 3. Status quo of Measured Energy Performance in the iBRoad2EPC Implementing Countries

In Greece, measured energy performance is used in primary and final energy consumption, CO<sub>2</sub> emissions, and energy class. To get an EPC in Spain, it is not necessary to measure the energy consumption. However, in the last section of improvement measures, if the EPC issuer wants to make a deeper economic analysis of the savings, these must be based on real consumption or historical data.

### Summary of the Method and Calculation Formulae

The tool offers three different methodological options to determine the energy performance. The options relate to a specific correction approach (whether to apply or not a correction for solar irradiation, domestic hot water or indoor environmental conditions, or a combination of them) or to the calculation method itself.

The following options are available in the method:

- Optional module A: correction for solar irradiation: “Apply correction for solar irradiation?” (yes/no):
  - If “no” is selected, monthly values for solar irradiation on a horizontal plane for the standard (reference) year  $I_{sol\_STD}$  serve to translate the solar energy data for the period not equal to one year to a period of one year. (See Annex III for formulae)
  - If “yes” is selected, the solar energy data obtained in a period with actual solar irradiation is corrected to represent solar energy data of one year with standard (reference) solar irradiation. Thus, it requires additional input by Member States (MS) of monthly solar irradiation values on a horizontal plane  $I_{sol\_hor}$  of recent years.
- Optional module B: correction for domestic hot water: “Apply correction for domestic hot water energy?” (yes/no)
  - If “no” is selected, no further info is needed related to this optional module.
  - If “yes” is selected, the following question is asked:
    - “Total system efficiency of domestic hot water is known?” (yes/no):
      - If “yes” is selected, the following question is asked:
        - “Total system efficiency of domestic hot water is a fixed average value or from a linear model?” (fixed value/linear model):
          - If “fixed value” is selected, the requested input is a fixed input value for the system efficiency of the domestic hot water system [-].
          - In case “linear model” is selected, the requested input is the following:
            - Linear model coefficient a [-]
            - Linear model coefficient b [-]

These coefficients determine the linear relationship between the net energy use for domestic hot water  $Q_{net\_STD\_DHW}$  and the total system efficiency for domestic hot water  $Eta_{sys\_DHW}$  described by the following equation:  $Eta_{sys\_DHW} = a \times Q_{net\_DHW} + b$ , with a and b representing the linear model coefficients mentioned above. (See Annex III for formulae)

- Optional module: correction for indoor environmental conditions: “Apply correction for indoor temperature in heating season?” (yes/no):
  - If “yes” is selected, the energy delivered for application space heating for each of the energy carriers associated with the application space heating is corrected by a factor as a function of the indoor air temperature [ $^{\circ}\text{C}$ ].
  - If “no” is selected, no correction for indoor environmental conditions deviating from standard indoor environmental conditions is applied.

The input data has two categories, input that is requested on the level of the building unit that is to be assessed and input that is requested on the level of the Member State.

The first category is primarily administrative data which consists of information describing the building and its use and monitoring data. An example of such data is gas use for space heating in case there is only one heat generator that only provides thermal energy for space heating. This data shall be accompanied by the corresponding start and end date of the monitoring period. In some cases, this data needs pre-processing to obtain the requested input parameter. For example, the final energy use per energy carrier for space heating in case one or more of the production systems are hybrid ones providing different end-uses, e.g., hot water and space heating. This data shall also be accompanied by the corresponding start and end date of the monitoring period. In this case, submetering is required, which allows the division of the final energy delivered to various applications.

The data for the second category is, e.g., data of the heating degree days or a model valid for the regional context describing the average number of building users as a function of the size of the building or other determining parameter(s).

Table 40 of Annex III in this report includes a list of all input parameters with their abbreviation, unit, name, type, and the entity that has to provide it [14]. The entity can be either “MS” or “P”, where “MS” means a Member State’s national or regional implementation body, while “P” is an EPC Practitioner. In the case of “MS”, the Member State would propose default values which can (or need to be) taken. In the case of “P”, it is up to the EPC Practitioner (assessor), to decide on a certain value.

### Calculation Method

The calculation process consists of five steps executed consecutively:

1. Calculation of the correction factors and standard inputs
2. Calculation of the standard energy required to be delivered
3. Calculation of the standard energy available by energy carriers of type 1<sup>31</sup>
4. Calculation of the standard energy delivered and exported
5. Calculation of the energy performance indicators

For a proper IT implementation, it is necessary to understand each of the five steps in the calculation process.

#### *Calculation of the correction factors and standard inputs*

In the first step, the correction factors are calculated by correcting the energy data from measurements to represent the energy of the actual building under standard conditions of use and climate. Correction to standard outdoor climatic conditions is applied to outdoor climatic conditions during the heating season (HDD), outdoor climatic conditions during the cooling season (CDD), and

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<sup>31</sup> All energy carriers delivered from on-site are considered energy carriers of type 1, while all energy carriers delivered from a distance and those delivered from nearby are classified as energy carriers of type 2.

solar irradiation (these are included in the input parameters). On the other hand, correction to standard use is applied to domestic hot water energy use and indoor temperature during the heating season.

The heating degree-days method is used on energy data for space heating only. It is used to extrapolate or interpolate energy data for the monitoring period differing from one year or to convert the energy data to a value typical for a year under standard outdoor climatic conditions (reference year with standard heating season). The cooling degree-days method is applied in the same way, with the difference that energy data are used for space cooling only.

Solar irradiation is considered if the question “Apply correction for solar irradiation?” is answered “Yes”. It is then applied only to the energy data for the electrical energy from on-site (PV) and solar thermal energy delivered from on-site. In this case, the correction factor  $f_{I\_sol\_1\_year}$  is calculated according to the formulae provided in Annex III.

If the question “Apply correction for solar irradiation?” is answered with “No”, then only the factor  $f_{I\_sol\_1\_year\_STD}$  is calculated with the same equation for  $f_{I\_sol\_1\_year}$ ; however, this time using standard values (reference year).

The parameters for domestic hot water are calculated only if the answer to the question “Apply correction for DHW energy?” is “Yes”, and this is only applied to energy data used for domestic hot water. The standard net energy use for domestic hot water  $Q_{STD\_net\_DHW}$  [kWh/year] is calculated, differentiating between “Residential” and “Non-residential” building types.

The standard net energy use for domestic hot water  $Q_{STD\_net\_DHW}$  is used if “Yes” is selected for the question “Total system efficiency of DHW is known?”. The correction factor for domestic hot water energy use  $f_{DHW}$  is then calculated (according to the equations in Annex III).

Correction factor  $f_{DHW}$  is used if “No” is selected for “Total system efficiency of DHW is known?”.

In case the question “Apply correction for indoor temperature?” is answered with “Yes”, then the correction of indoor temperature during the heating season is considered and only concerning energy data for space heating. In this case, the correction factor  $f_{T\_i}$  is calculated.

#### *Calculation of the standard energy required to be delivered*

The total amount of energy needed to be delivered to the building under the standard use and climate parameters is calculated for each application. In this step, the type of energy carriers is not differentiated, only the total final energy required to be delivered under conditions of standard use and climate is considered.

Firstly, two calculations are performed:

- the total energy required to be delivered per application  $i$  for standard use and climate  $Q_{req\_STD\_i\_tot}$
- the relative shares of energy carriers of type 2 in the total energy required to be delivered by energy carriers of type 2 per application  $i$  for standard use and climate  $S_{req\_STD\_i\_cr2}$

This is applied to energy used for space heating, domestic hot water, space cooling, and others.

The energy required to be delivered to application  $i$  for standard use and climate  $Q_{req\_STD\_i\_cr}$  [kWh/year] is calculated per application for every energy carrier separately (see Annex III).

#### *Calculation of the standard energy available by energy carriers of type 1*

The standard energy made available by energy carriers of type 1 is determined for each application. This can be viewed as the maximum amount of energy from energy carriers of type 1 that can be provided to satisfy the total required standard energy or part of it for the respective application. All energy carriers delivered from on-site are considered energy carriers of type 1, while all energy carriers delivered from a distance and those delivered from nearby are classified as energy carriers of type 2.

In this step, two calculations are also performed:

- the total energy available by energy carriers of type 1 per application  $i$  for standard climate  $Q_{ava\_STD\_i\_cr1}$
- the relative shares of energy available by energy carriers of type 1 in the total energy available by energy carriers of type 1 per application  $i$  for standard climate  $S_{ava\_STD\_i\_cr1}$  [-]

This is applied to energy used for space heating, domestic hot water, space cooling, other, and exportation.

#### *Calculation of the standard energy delivered and exported*

This phase involves calculating the standard energy that type 2 carriers deliver. According to the fixed quantity of energy made accessible by energy carriers of type 1, the calculation includes distributing the entire amount of energy that must be delivered for each application (the result of step 1) among the energy carriers connected to that application (the result of step 3). Any remaining standard energy given is divided across the energy carrier's standard energy exported to determine the standard energy exported for each energy carrier. For each application, these calculations are carried out independently for energy carriers of type 1 and type 2 in three steps:

- Calculation of the standard energy delivered and exported by energy carriers of type 2 per application
- Calculation of the standard energy delivered and exported by energy carriers of type 1 per application
- Calculation of the total standard energy delivered and exported

#### *Calculation of the standard energy delivered and exported by energy carriers of type 2 per application*

The standard energy delivered and exported by energy carriers of type 2 per application is calculated in four steps:

1. Calculation of the total standard energy delivered by energy carriers of type 2 per application
2. Calculation of the standard energy delivered by energy carriers of type 2 per application and energy carrier
3. Calculation of standard energy delivered for electrical energy production of energy carrier fuel for CHP
4. Calculation of the standard electrical energy produced by CHP

In the first step, the total standard energy given by energy carriers of type 2 is determined by subtracting the total standard energy needed for each application from the total standard energy made available by energy carriers of type 1. The result is then divided over the type 2 energy carriers related to the relevant application by the shares determined in step 1 (relative shares of the required energy by energy carriers of type 2). The last two steps are only executed if CHP is present (non-zero input values for energy delivered by energy carrier Fuel for CHP). In that case, the energy delivered for electrical energy production is rescaled to match the original ratio of thermal energy output to the electrical energy output of the CHP.

#### *Calculation of the standard energy delivered and exported by energy carriers of type 1 per application*

The total standard energy delivered by energy carriers of type 1 per application is calculated separately for each application, e.g., space heating, domestic hot water, space cooling, and others, and per energy carrier of type 2. The total is divided over the energy carriers associated with the respective application according to the relative shares of the standard energy available for the respective application. Any remainder of the standard energy available is added to the standard exported electrical energy of the respective energy carrier, while any remainder in standard energy available of the energy carrier solar thermal or environment is considered unused and is neglected in the calculation method.

The calculation of standard energy exported by energy carriers of type 1 is done in two steps, calculation of standard energy exported by energy carriers of type 1 per energy carrier and calculation of the total standard energy exported (all energy carriers with exportation). Any remainder of electrical energy delivered by energy carriers of type 1 (electrical energy from on-site, produced by

PV or other) is added to the exported energy, while any remainder of thermal energy delivered by energy carriers of type 1 (solar thermal energy delivered from on-site or environment energy delivered from on-site) is considered as unused and neglected in the further calculation.

#### *Calculation of the total standard energy delivered and exported*

The total standard energy delivered to all applications is calculated per energy carrier, and the total standard energy exported is calculated as the sum of the exported electrical energy of the associated energy carriers.

#### *Calculation of the energy performance indicators*

In the final step, the energy performance indicators are calculated based on the weighted energy balance equations following EN 52000-1: 2017. The indicators are calculated according to EN 52000-1 (default choices) by considering exported on-site produced electrical energy (“-Exported on-site produced electrical energy”).

For the non-renewable energy performance  $E_{Pnren}$ , the output is extended, and it is differentiated between the following production sites, exported on-site produced electrical energy (1), self-used on-site produced electrical energy only (2), and No on-site produced electrical energy (3).

“Exported on-site produced electrical energy” considers both self-used on-site produced electrical energy and exported on-site produced electrical energy.

“Self-used on-site produced electrical energy only” is the same as “Exported on-site produced electrical energy” but exported electrical energy is set to zero.

“No on-site produced electrical energy” is the same as “Exported on-site produced electrical energy” but exported electrical energy is set to zero, and electrical energy produced by CHP, PV (or Other) and used on-site for applications S, DHW, C, and OTH is added to the electrical energy (delivered from distant) to the respective applications.

The renewable energy ratio RER [-] is calculated according to EN ISO 52000-1: 2017 using the following equation:

$$RER = E_{Pren\_RER} / E_{Ptot}$$

The renewable primary energy  $E_{Pren\_RER}$  is calculated excluding perimeter distance, while the total primary energy  $E_{Ptot}$  is calculated including perimeter distance.

After all the calculation steps are performed the tool provides output which contains the following information:

- Specific annual final standard energy delivered and exported total per application  $Q_{STD\_i\_tot}$  [kWh/(m<sup>2</sup>·year)]
- Specific annual final standard energy delivered and exported total per energy carrier  $Q_{STD\_tot\_cr}$  [kWh/(m<sup>2</sup>·year)]
- Non-renewable energy performance  $E_{Pnren}$  [kWh<sub>prim,nren</sub>/(m<sup>2</sup>·year)] for the following cases:
  - No on-site produced electrical energy
  - Self-used on-site produced electrical energy only
  - Exported electrical energy
- Total energy performance  $E_{Ptot}$  [kWh<sub>prim,tot</sub>/(m<sup>2</sup>·year)]
- Renewable energy ratio RER [kWh<sub>prim,ren</sub>/kWh<sub>prim,tot</sub>]
- CO<sub>2</sub> equivalent emission [kg<sub>co2,eq</sub>/(m<sup>2</sup>·year)]
- Produced electrical energy on-site, self-used  $E_{pr\_self}$  [kWh<sub>prim</sub>/(m<sup>2</sup>·year)]
- Produced electrical energy on-site, exported  $E_{pr\_export}$  [kWh<sub>prim</sub>/(m<sup>2</sup>·year)]
- Produced electrical energy on-site, total  $E_{pr\_tot}$  [kWh<sub>prim</sub>/(m<sup>2</sup>·year)]

Since some of these outputs are typically already included in an EPC (or the renovation passport as previously developed in the project iBRoad), careful consideration of the potential overlap of these output indicators with other indicators needs to be done.

Some input information is repeated in the output:

- Default corrections applied to the final measured energy delivered and exported
- Optional corrections applied to the final measured energy delivered and exported
- Selected input for the options of the optional correction methods

Some general information is included also in the output:

- Default corrections
- Building type
- Building subtype
- Building useful floor area
- Location
- Year of construction
- Year of renovation
- Number of units in a multifamily house
- Building address
- Building identifier
- EPC Practitioner identifier

## Testing Results

This feature was tested in Austria, Estonia, Italy, and Romania. All tests of this feature were in-building tests with the following steps, which were the same in all countries:

1. Administration / data collection
2. Monitoring
3. Assessor evaluation

The perception of how easy or difficult it was to implement this feature varies remarkably between the different implementing partners. While Romania found it “very difficult”, Austria and Estonia “somewhat easy”, and Italy “neither easy nor difficult”. This is similar to the question of how easy or difficult it was to explain the feature to the EPC assessors. Here, the answers even vary between “very difficult” and “very easy”.

The implementation of the different steps in the testing procedure (data collection, monitoring, assessor evaluation) was possible for all implementing partners. Austrian implementing partner mentioned that detailed measurement for complex heating systems (like a pellet boiler combined with solar thermal collectors) was not possible to do in the course of the X-tendo project and the related testing activities.

The reported challenges in implementing the test cases concerned the gathering of the necessary data and were similar in the different countries: metering of energy consumption for different purposes within the buildings or apartments was not available. Thus, the allocation of the energy consumption values found in the energy carrier bills to the different purposes had to be done based on information from users and assumptions/assessor experience. In the Italian cases, for example, the split between energy consumption for space heating and domestic hot water consumption was done based on the summer baseline method.

## SWOT Analysis with Respect to the Integration in iBRoad2EPC

Strengths	Weaknesses	Opportunities	Threats
<ul style="list-style-type: none"> <li>Builds on a well-accepted and evaluated approach from another H2020 project</li> <li>Can potentially create more trust in demand indicators and renovation advice since they are closer to real energy consumption values</li> <li>More options are available, depending on data availability and the required level of accuracy</li> </ul>	<ul style="list-style-type: none"> <li>The high effort of the method to gather/measure data on the energy-use level: administration and data collection took between 20 and 120 minutes (depending on the country) per building; for the energy data collection and allocation to different use purposes, reported time was also between 20 and 120 minutes; the calculation with the tool took between 10 and 240 minutes per building. The total time per building is between 50 and 480 minutes [15]</li> <li>Probably high effort to implement in the iBRoad2EPC tool (but depends on the different options of the iBRoad2EPC concept<sup>32</sup>)</li> <li>Sub-metering is currently often not available</li> </ul>	<ul style="list-style-type: none"> <li>European legislation supports the use of ‘metered’ energy consumption alongside calculated energy consumption for the calculation of the energy performance of buildings</li> <li>If sub-meter measuring devices are introduced more widely, the indicator can become much more relevant</li> </ul>	<ul style="list-style-type: none"> <li>GDPR limits and restricts the application and use of the real energy consumption feature</li> </ul>

### Applicability for the iBRoad2EPC Building Types

The method can be applied to residential and non-residential buildings. However, in non-residential buildings, the probability of having more detailed measurements available might be higher.

### Feasibility Aspects

Overall, we assess the efforts to implement this indicator as high and also the effort to provide the related measurements is high. An Excel spreadsheet is available from the X-tendo project and would be ready for use within iBRoad2EPC. However, the implementation of the process is expected to require substantial effort.

<sup>32</sup> See iBRoad2EPC report “Conceptualising iBRoad2EPC – How Energy Performance Certificates (EPCs) can be upgraded with Building Renovation Passport (BRP) elements” <https://ibroad2epc.eu/results/>

This is also supported by testing conducted by X-tendo<sup>33</sup>, as the implementing partners in Romania, Austria and Italy rate the overall feasibility of implementing the feature in the national EPC schemes as “somewhat unpractical”. This is mainly argued with the mentioned challenges related to the data collection needed in the spreadsheets. Measuring energy (carrier) consumption for different purposes within buildings or apartments is rarely done today, for which the allocation of the data found in energy (carrier) bills is estimated to be complex and time-consuming. This estimation is still easier in case only a split between space heating and domestic hot water must be found, e.g., in the case of district heating or natural gas. In case electricity is used for space heating and/or hot water generation the complexity is remarkably higher. X-tendo Italian implementing partner further mentions that official data for heating degree days (HDD), cooling degree days (CDD), and solar radiation is not available for each location in Italy. For the test, these data had to be collected, and for implementation of this feature into the national EPC schemes, official data need to be generated and provided.

### Availability of Data in the EPC Issuing Process

A key bottleneck of the method is the availability of sub-meter measurements of end-uses. Although it would be relevant to increase awareness regarding this information and thus better understand consumption patterns, we consider this as a key barrier.

## Requirements for Adaptation and Integration within iBRoad2EPC

The X-tendo measured energy performance feature clearly has both benefits and constraints.

Energy consumption is an important parameter for describing the initial state of a building. It is particularly relevant for the level of energy costs and thus for the potential savings through renovation measures.

On the other hand, the real energy consumption after future renovation measures can only be estimated but not calculated. This makes the indicator not well suited for a long-term renovation strategy such as iBRoad2EPC. In addition, the difference between energy consumption and demand is usually highest in unrenovated buildings. In a renovation strategy, the difference will become smaller with each step. Future legal requirements for buildings will always refer to the calculated demand and not to the consumption. The energy demand will therefore have the greatest significance in the strategy.

To compare the energy consumption of a building with the calculated energy demand, the meter readings or energy calculations of all energy sources recorded in the EPC must be available for a certain period. This is only possible if corresponding individual meters are installed. This is not always the case, especially for electrical appliances. Ideally, the calculation should be carried out for a period of several years to ensure greater accuracy. This consumption data must have been recorded or collected by the building owners and be available at the time of the on-site visit. For energy sources that are not grid-bound but are stocked (e.g., heating oil), the remaining quantity that is still in the storage tank when refilling must be considered. All energy quantities must be converted from the source unit (e.g., cubic metres, litres, tonnes) into kilowatt hours. These preconditions for the use of the consumption tool cause a relatively high processing effort and therefore do not fit in with the basic objective of iBRoad2EPC to provide initial advice at low cost.

However, since X-tendo offers a ready-made spreadsheet available to use within the iBRoad2EPC tool, the implementation of the measured energy consumption is possible by integrating this spreadsheet into the workflow of iBRoad2EPC.

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<sup>33</sup> [https://x-tendo.eu/wp-content/uploads/2020/01/X-tendo\\_deliverable5.2\\_Feature4\\_RealEnergyConsumption\\_Final.pdf](https://x-tendo.eu/wp-content/uploads/2020/01/X-tendo_deliverable5.2_Feature4_RealEnergyConsumption_Final.pdf)

## RENOVATION ADVICE

### Benefits and Market Needs

EPC schemes foresee recommendations on how to improve the energy performance of a building. However, the quality and ambition level of recommendations often strongly depend on the assessor, which leads to a frequent use of standardised, not very specific and tailor-made recommendations provided in EPCs. Moreover, the building owner cannot assess to which extent the recommendations provided are sufficient to achieve a certain envisaged target, e.g., to make a building future-proof and in line with long-term climate and energy policy targets. A comprehensive renovation advice could try to overcome these gaps.

The development of an online tool called the Master tool, was envisaged in the scope of the QualDeEPC project for comparing EPC recommendations to deep energy renovation recommendations [16]. This online tool addresses the needs of end-users, i.e., building owners, to receive an estimation of their dwelling's or building unit's energy efficiency performance at the building's elements and technical systems level. With this tool, the building owners can simulate their dwellings by entering the main characteristics of the building from the predefined lists. Additionally, the user can obtain recommendations for improving the energy efficiency of their home for the walls, roof, floor, windows, shading, heating, cooling, DHW, and RES, and see the results and the indicative cost of the potential renovation activities. These recommendations could be compared to those of an EPC or could be used to prepare a discussion with an energy consultant or EPC issuer.

While there are various tools available to assess the impact of various renovation levels, the ambition level and compliance with long-term decarbonisation targets often is not so clear. Thus, the aim of the tool is also to give guidance and support regarding the proposed ambition level of the renovation process. At the same time, it should be emphasised that the tool does not explicitly refer to the process of staged renovation as it is being done within iBRoad2EPC.

While the iBRoad tool already foresees the assessment of various renovation steps through the assessor to establish an individual building renovation roadmap to trigger deep renovations the QualDeEPC tool aims to support homeowners in assessing the renovation measures regarding their ambition levels and is therefore interesting for iBRoad2EPC.

### Status Quo of Renovation Advice/Recommendations in the Implementing Countries

To assess the status quo of Renovation Advice/Recommendations (in the sense of the description in this chapter) in iBRoad2EPC implementing countries, we classified the status according to the following categories:

- (1) This feature is currently part of the national EPC scheme.
- (2) There are concrete plans to include this feature in the national EPC scheme (expected within the next year).
- (3) There are vague discussions about this feature but no concrete plans.
- (4) Currently, no concrete plans or discussions to include this feature in the national EPC scheme.

The following table shows the results of this assessment.

Bulgaria	Greece	Poland	Portugal	Romania	Spain
Currently, no concrete plans or discussions to include this feature in the national EPC scheme	Currently, no concrete plans or discussions to include this feature in the national EPC scheme	Currently, no concrete plans or discussions to include this feature in the national EPC scheme	There are concrete plans to include this feature in the national EPC scheme	There are concrete plans to include this feature in the national EPC scheme	This feature is currently part of the national EPC scheme

*Table 4. Status quo of Renovation Advice/Recommendations (according to the description in this chapter) in the iBRoad2EPC Implementing Countries*

In Greece, renovation recommendations are required and measured only when participating in the national energy efficiency scheme but are not part of the EPC.

In Spain, on the other hand, the EPC has to include recommendations, among others:

- Measures to improve the building envelope, taking into consideration the level of architectural protection
- Measures to improve the building's installations or to reduce thermal losses in the heat transfer
- Measures to incorporate automation and control systems
- The most appropriate time sequence for carrying out the proposed measures

In Spain, the recommendations:

- Should be technically feasible
- Should include estimates of payback periods
- Should include information on the cost-effectiveness of the proposed improvement, assessing this cost-effectiveness based on expected energy savings, energy prices, and a preliminary cost forecast
- Should include information on the actions to be taken to implement the recommendations, which implies a correct description of the actions to be taken

The new Spanish EPC has to include recommendations with payback periods or cost-effectiveness analysis which is an upgrade compared to the more standardised recommendations and with less information from the previous certification scheme. However, these recommendations are not linked to long-term decarbonisation goals or similar plans.

In Portugal and Romania, the feature is expected to be included in the respective national EPC scheme within the next year.

## Summary of the Method and Calculation Formulae

The QualDeEPC tool allows homeowners to simulate their dwellings by entering the necessary characteristics of their building, typology, geographical area, floor area, characteristics of the building shell and heating/cooling systems, etc., in only 14 steps explained in the following text. The tool provides a list of possible building typologies as listed in Table 5.

Type	Vicinity
1-storey single house	Detached
2-storey single house	Detached
3-storey single house	Detached
Flat in multifamily building	In touch with the ground
Flat in multifamily building	Intermediate floor
Flat in multifamily building	Upper floor
2-storey single house	Terraced
Multifamily building	Whole building
Multifamily building attached in both side elevations - Terraced	Whole building - Terraced
Multifamily building attached on one side - Corner	Whole building

*Table 5: Building types as the QualDeEPC tool*

After the building type is selected, the climatic conditions are determined by entering the geographical area where the building is located. The selection comprises data from representative cities from QualDeEPC partner countries. The user should also indicate whether the building is located at an altitude higher than 500 meters. Additionally, the floor area of the house shall be given, either by entering the exact floor area or by choosing one of the following options: < 100 m<sup>2</sup>, between 100 and 150 m<sup>2</sup>, between 150 and 200 m<sup>2</sup>, or above 200 m<sup>2</sup>.

The third step is to provide information about the building envelope and technical systems installed. Ten categories are available:

1. Walls
2. Roof
3. Floor
4. Windows
5. Shading
6. Heating systems
7. Cooling systems
8. Mechanical ventilation
9. Domestic hot water (DHW)
10. Renewable energy sources (RES)

For each of these ten categories, the user can choose further options as included in the tables in Annex IV.

In the case of the RES system selection, the software (Master tool) considers the total floor area of the building unit, calculates the demand and the dimensioning of the system, and finally, the heat or electricity produced.

After the user enters all inputs, the software calculates the current energy situation of the house/building in energy consumption figures and energy categories. It provides the yearly final energy consumption for heating, cooling, and hot water production. Then, the user can apply energy-

efficient solutions for many building systems. A recommendation list is offered to the user, which they can use according to the energy measure. The complete list of renovation recommendations considered in the QualDeEPC tool is given in Table 6.

Recommendations	
Roof insulation	Roof with exceptional thermal insulation properties
Window replacement	Window with enhanced insulation properties that fulfil nZEB requirements
Installation of shading	Fixed horizontal/vertical shading devices, Venetian shutters, or awning to decrease cooling needs
External wall insulation	Wall with enhanced thermal insulation properties which fulfils nZEB requirements
Replacement/modernization of the heating system	Energy-efficient devices, i.e., heat pumps, condensing boilers with A energy category label
Replacement/modernization of the cooling system	Use of efficient cooling systems (A energy label), geothermal heat pump, reversible inverter air-air heat pump, etc.
Utilization of renewable energy sources	Use of solar collectors, biomass boilers, and PVs for heating and electricity production purposes
Energy-efficient DHW production	Use of solar thermal collectors or energy category A heat pumps

*Table 6: List of renovation recommendations considered in the QualDeEPC tool*

Finally, the comparison results between the current and energy-improved cases are given. There is a message stating one of the three possible contents:

- “Deep energy renovation criteria have been reached”
- “Deep energy renovation of the house/building will be achieved when fully implementing the recommendations”
- “Deep energy renovation of the house/building will not be achieved when fully implementing the recommendations”

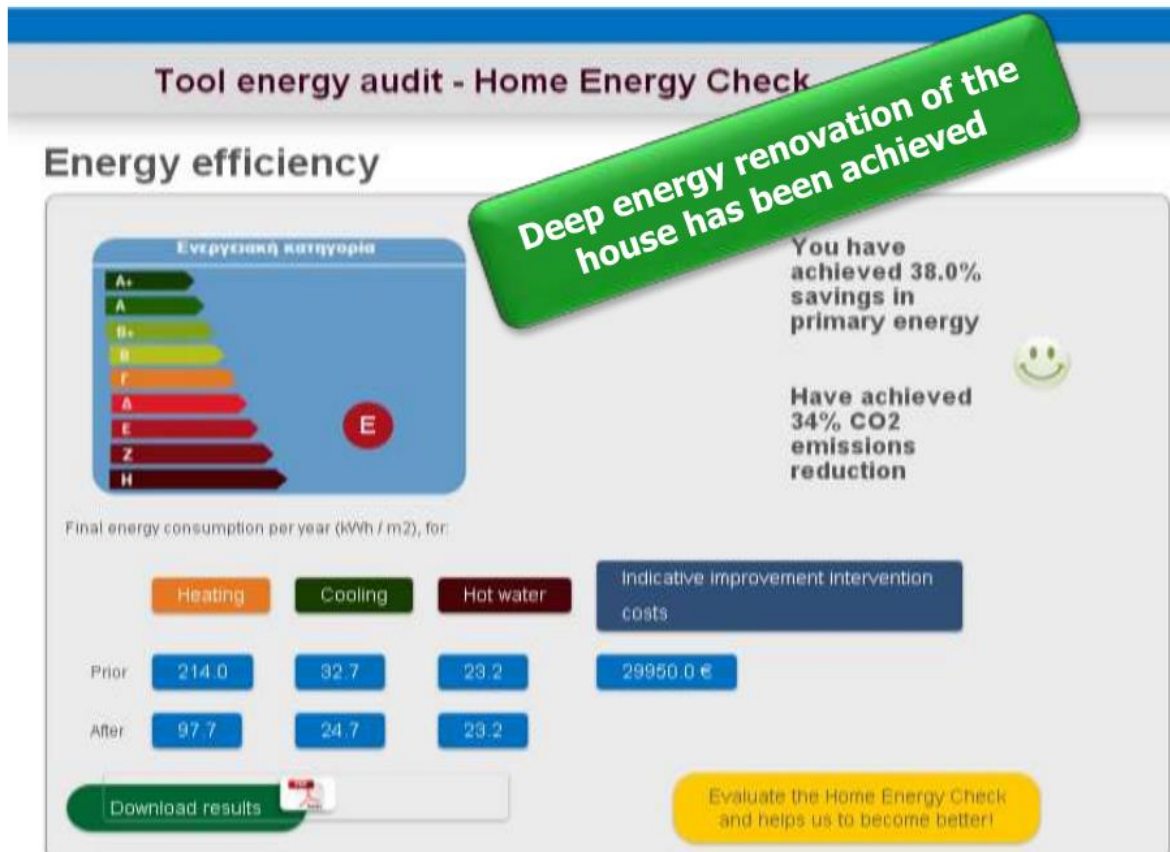


Figure 17: Comparison of the results

Additionally, the new energy class of the house is given together with the achieved energy conservation (in %), the CO<sub>2</sub> emissions reduction (in %), and an estimation of the cost for the improvement measures tested.

As soon as data input is completed, a .xlm file is produced. The software is used again to test the selected energy improvements, and all results are shown on the last screen of the tool (Figure 18).

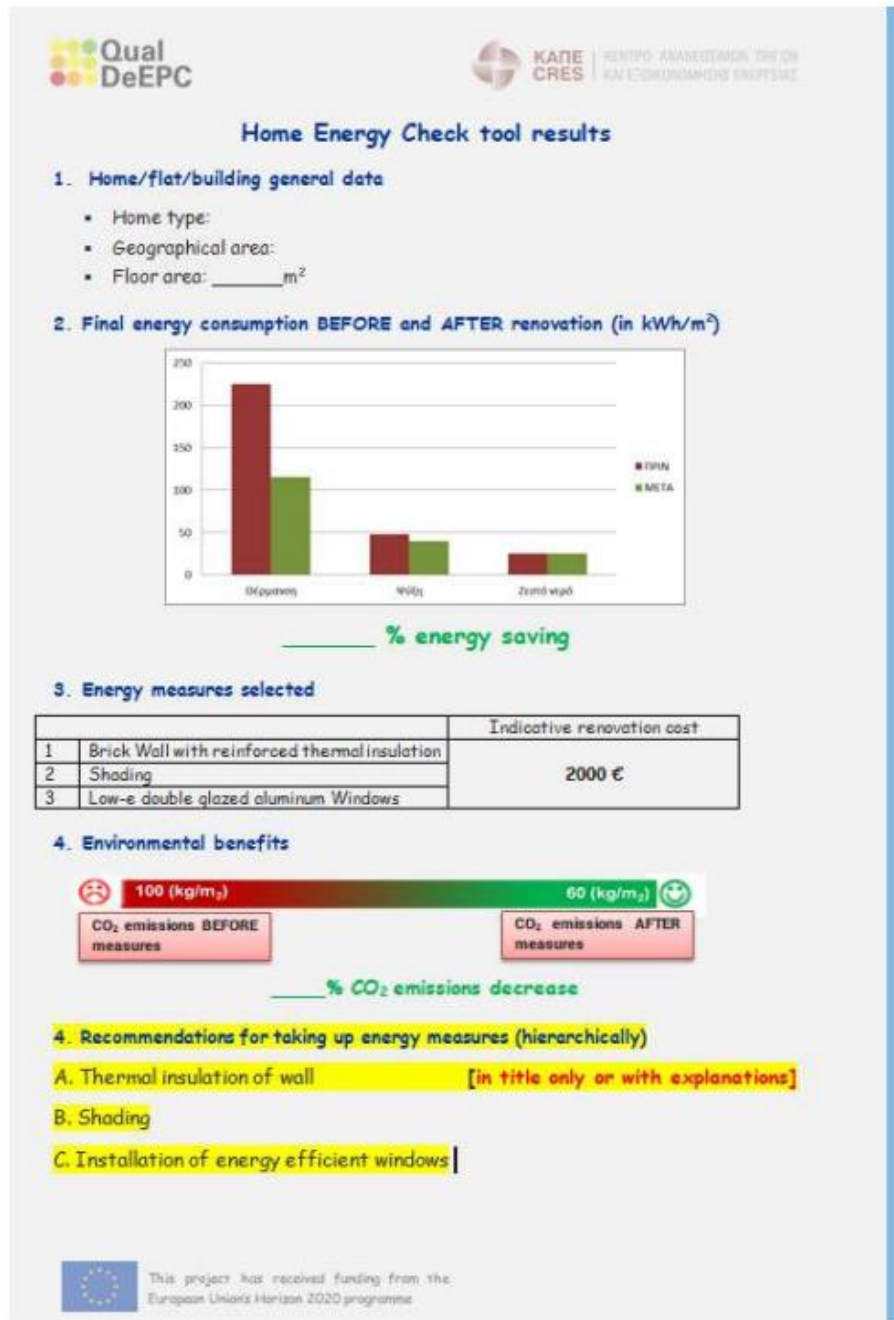


Figure 18: Tool results report layout [16]

Recommendations given are related to which energy efficiency technology should take place first and in what order. The prioritisation of recommendations is based on the following pillars:

**Pillar I: The commonly accepted engineering scientific approach**

1st: improve the performance of the envelope components to reduce the energy demand of the building.

2nd: improve the efficiency of the Technical Systems, the dimensioning of which will be based on the “reduced energy demand”, after implementation of Step 1.

3rd: install renewable energy technologies, which are meant to cover a percentage of the energy demand resulting after the implementation of Steps 1 and 2.

## Pillar II: Implementation of energy retrofit measures toward Deep Renovation

When considering the improvement of the envelope performance, attention should be paid to the order of measures to be implemented to avoid either lock-in effects or damages to previously implemented technologies/materials.

In the end, the tool shall advise the user to obtain professional energy advice to understand better the options for improving the energy efficiency of their home, benefits, and costs. It is possible to use the Greek Home Energy Check tool<sup>34</sup> on which QualDeEPC's Master tool is based.

## SWOT Analysis with Respect to the Integration in iBRoad2EPC

Strengths	Weaknesses	Opportunities	Threats
<ul style="list-style-type: none"> <li>• Builds on a well-accepted and evaluated approach developed in another H2020 project</li> <li>• Easily understandable assessment of the impact of renovation measures, which could be used in addition to a detailed calculation from the assessor</li> <li>• May increase the understandability and acceptance of renovation advice</li> <li>• Flexible regarding the choice of different renovation measures</li> </ul>	<ul style="list-style-type: none"> <li>• Needs an active action of the end-user to play around with the proposed measures</li> <li>• The calculation is simplified and may lead to different results compared to a detailed assessment</li> <li>• The assessment is done by the end user and therefore does not guarantee quality</li> <li>• Recommendations are not aligned with envisaged targets, i.e., to make a building future-proof and in line with long-term climate and energy policy targets.</li> <li>• The IT implementation in the iBRoad2EPC tool is expected to require significant effort</li> <li>• Main applicability for residential buildings</li> <li>• Does not make use of and may not be aligned with official software programmes for the calculation</li> </ul>	<ul style="list-style-type: none"> <li>• Interested users may find it attractive to analyse the impact of different renovation measures on their own, creating an increased market dynamic</li> <li>• Together with the logbook and potential digital one-stop-shops linked to the logbook, the renovation advice tool may facilitate the uptake of renovation measures</li> </ul>	<ul style="list-style-type: none"> <li>• Due to the different calculation measures in the detailed assessment tool and this renovation advice tool, users might be confused</li> <li>• The simplified assessment may lead to over- or underestimation of savings, which might lead to a lack of trust in the tool</li> <li>• Potential risk for lock-ins and misinvestments or not reaching policy targets</li> </ul>

<sup>34</sup> <http://www.cres.gr/energyhubforall/HEC.html>

## Applicability for the iBRoad2EPC Building Types

The tool is expected to be mainly relevant to residential buildings.

### Feasibility Aspects

The integration of the renovation advice module (Excel spreadsheet) of the project QualDeEPC overall could be feasible.

However, IT implementation would require a significant amount of additional resources, to build a specific user interface to allow the end-user (i.e., building owner or occupant) to modify renovation steps and parameters.

In addition, there are two important points to take into consideration:

(1) iBRoad2EPC builds on a detailed assessment performed by a qualified assessor using official software calculation programmes available on the national markets. The QualDeEPC Master tool on the other hand is a self-assessment tool aimed for use by the building owners. The integration of the QualDeEPC renovation advice module into iBRoad2EPC could potentially jeopardise the level of quality and trust in iBRoad2EPC, particularly where the results of the simplified QualDeEPC deviate from the detailed assessment.

(2) iBRoad2EPC's predecessor, the iBRoad, already provides a comparison of results between the current and the targeted (energy-improved) status and includes a concrete and tailor-made plan of renovation measures to be implemented in a specific sequence to reach deep renovation levels, considering measures to avoid lock-ins. iBRoad2EPC by default is intended to utilise or build further upon the iBRoad framework.

### Availability of Data in the EPC Issuing Process

The data required for running the renovation advice module of the project QualDeEPC overall is available from EPC issuing processes in many countries as far as on-site visits are carried out. In particular, if a building logbook is available, related information on building components and materials is expected to be available. Default data from the QualDeEPC tool might also help.

## Requirements for Adaptation and Integration within iBRoad2EPC

Where QualDeEPC's renovation recommendations are automatically generated from the building information directly by the building user, iBRoad2EPC builds on the principle of a renovation strategy being drawn up by a qualified energy expert during an obligatory on-site visit. Thus, the weakness and risk of the QualDeEPC tool of having the assessment done by the building owner which may lead to misconception, errors and deviations to the calculation with the official EPC software is directly addressed by iBRoad2EPC. The recommendations derived from the latter one are tailored to the specific building by the issuer to develop the strategy. Ideally, they draw up the strategy together with the building owners. The expertise of the issuers ensures a high quality of the recommendations.

As already explained above, the integration of the QualDeEPC tool does not fit the principles, and objectives of iBRoad2EPC. While the tool is an interesting way to allow building users to become more involved in the comparison of different packages of renovation measures and their impact on energy savings and economic comparison, it can only be a complement rather than a key feature of iBRoad2EPC.

In this respect, integration of the QualDeEPC tool will not be part of the iBRoad2EPC project. The question "How to link iBRoad2EPC and QualDeEPC?" could potentially be considered in the context of future follow-up projects which might have a stronger focus on user awareness, involvement and participation. In such a process, the following questions would need to be addressed:

- What specific adjustments should be made to the QualDeEPC master tool to cover the needs and requirements of integrating it into the existing iBRoad2EPC tool?

- Following the specific adjustments, is there a risk of downgrading the quality and robustness of the method? How can these risks be minimised?
- Are there country-specific requirements that should be considered for adaptation?

Instead, extensive renovation advice and related data are being developed within the iBRoad2EPC project itself, foreseen as an integral part of the basic module. The iBRoad2EPC Assistant tool is foreseen to support the issuers with content that is added automatically: target building standards for specific key dates, foreseeable future obligations or legal requirements as well as the key dates themselves are defined at the country level and hosted in a database. The specifications of the recommended renovation measures (e.g., u-values) are derived from the long-term renovation strategies of the countries and are added automatically when issuers select a measure. Issuers can edit the specifications, if required. Once the issuers have defined the strategy for an individual building, recommendations to avoid lock-in situations are inserted automatically. They are selected from a database depending on the type and sequence of measures. The extensive databases for the iBRoad2EPC Assistant tool are being developed by iBRoad2EPC partner ifeu together with the iBRoad2EPC pilot country partners, following the stepwise and deep principles as set in the iBRoad project and enhanced with EC's and national long-term decarbonisation and climate targets and MEPS.

As explained, QualDeEPC's automatic recommendations are not integrated into iBRoad2EPC. The QualDeEPC recommendation tool can nevertheless exist in parallel to iBRoad2EPC in the consultancy market. Building owners can use it to obtain initial information independently of the issuing of an EPC or from professional consultants.

## DIGITAL BUILDING LOGBOOK

### Benefits and Market Needs

Policymakers and value chain stakeholders continue to cite building data - its availability, reliability, and storage - as one of the most challenging aspects of energy efficiency renovation and building stock decarbonisation. Yet, relevant information and data are generated at every lifecycle stage by different stakeholders for different purposes (i.e., urban planning, building design, construction, operation and maintenance, renovation, financing, etc.). A significant issue is that data and information management, as well as the subsequent transfer and evaluation, are mostly inadequate.

If information is available at all, that is, if it has not already been lost or mislaid, it is often no longer useful being outdated, unsuitably formatted, or has an unclear context or data collection methodology. Moreover, there is little whole-life data thinking. Only limited information flows from one life cycle stage to the next or covers only partial data (e.g., operational energy). Often none or only a part of the information generated throughout the building lifecycle is available to stakeholders on the data and information demand side (i.e., building owners, tenants, investors, financing institutions, or building managers). Data that may not be needed immediately, but may have use at a later stage, is not retained due to the absence of a storage facility and lack of interoperability between the databases.<sup>35</sup>

Building logbooks are repositories or containers, that collect and facilitate different types of building-related data and information. Logbooks are aimed to become the central digital data repositories for building-related data in the future built environment. For that aim to become a reality, the following criteria need to be fulfilled: (i) import data from various data sources, as automated as possible, (ii) interpret, complete, and process that data, including assessing the data quality and proposing corrections of data conflicts or perceived errors, (iii) allow intuitive data governance for the data owner and (iv) link to functionalities /services based on building data that can access the data in the logbook in a secure way when given access by the building owner. These criteria serve as an orientation point for linking logbooks to EPC databases, renovation roadmaps, and one-stop shops.

Logbooks and existing data sources should be integrated through an online platform and will be a critical factor for the success of iBRoad2EPC and building renovation roadmaps. Data integration can verify the provenance of data inputs, while integration with the building logbooks - several of which are currently under development and production - can ensure that renovation advice and roadmaps are relevant and practical for building owners. Stakeholder engagement over the use of data and access by third parties will be a relevant aspect. Mapping logbook-related benefits, costs, drivers, and potential challenges, mapping of information flows, i.e., who needs what data, when, from what sources, and in what form are key questions to answer while assessing the feasibility of linking logbooks with iBRoad2EPC.

Given the scope of iBRoad2EPC, the focus of the logbook is on enhancing data and information created through EPC certification and leveraging logbooks as a rich source of information to create bespoke renovation roadmaps. In addition, the logbook can store records of historical works in a building so that building owners, energy auditors and future renovation contractors have knowledge of previous interventions and the materials used. Equally, by establishing connections to logbooks, the iBRoad2EPC could become a live and dynamic digital document, capturing not only inputs as they change over time, with enough historical data to establish a baseline for the property's performance,

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<sup>35</sup> A stakeholder survey focusing on the main challenges in relation to sectoral data capture and management, the Work Area on Building Data, Information and Measurement within the UNEP-hosted Global Alliance for Buildings and Construction (GlobalABC) clearly identified the absence of an adequate data storage option as the most prominent barrier to enable market participants' "data house". See [here](#).

but also in real-time (e.g., through smart meters) providing relevant, comprehensive and reliable information about actual performance.

The iBRoad project already developed an Individual Building Renovation Roadmap that is combined with a Digital Building Logbook (the iBRoad logbook or iBRoad-Log). The iBRoad logbook is intended to store information and specific data about buildings throughout time from a number of sources<sup>36</sup>. The information is stored in a unique digital file for each individual building.

### Status Quo of Digital Building Logbook in the Implementing Countries

To assess the status quo of Digital Building Logbooks in iBRoad2EPC implementing countries, we classified the status according to the following categories:

- (1) This feature is currently part of the national EPC scheme.
- (2) There are concrete plans to include this feature in the national EPC scheme (expected within the next year).
- (3) There are vague discussions about this feature but no concrete plans.
- (4) Currently, no concrete plans or discussions to include this feature in the national EPC scheme.

The following table shows the results of this assessment.

Bulgaria	Greece	Poland	Portugal	Romania	Spain
Currently, no concrete plans or discussions to include this feature in the national EPC scheme	This feature is currently part of the national EPC scheme	There are vague discussions about this feature but no concrete plans	This feature is currently part of the national EPC scheme	There are vague discussions about this feature but no concrete plans	Currently, no concrete plans or discussions to include this feature in the national EPC scheme

*Table 7. Status quo of Digital Building Logbooks in the iBRoad2EPC Implementing Countries*

In Greece, the Digital Building ID scheme is in place, but the information is accessible only to engineers and is used for legal due diligence ahead of property transactions.

The National Digital Building registry is to be developed in Romania as a distinct action as part of the National Recovery and Resilience Plan (NRRP). The deadline for the development of a functional system is December 31, 2024, but the work has not yet effectively kicked off.

In Spain, there is an Existing Building Book (LEE) which is not in digital format but presents a repository of information related to the building, not only energy performance (EPC, among others) but also accessibility, structural safety, fire safety, etc.

### Summary of the Method of the iBRoad-Log

The core data feeding the iBRoad logbook is currently gathered during on-site visits by the experts issuing the EPC but the tool is built with the intention to make automated data transfer possible through various sources (smart meters, public EPC databases, energy management systems, etc.). The type of information stored in the logbook and its functionalities range from energy consumption and production to equipment maintenance, as well as insurance, property plans and obligations, energy bills, smart meter data and links to available financing options for renovation projects (e.g., green loans, incentives, tax credits). The following diagram shows how the core data available feeds the logbook and the renovation roadmap.

<sup>36</sup> <https://ibroad-project.eu/news/the-ibroad-concept-in-practice/>

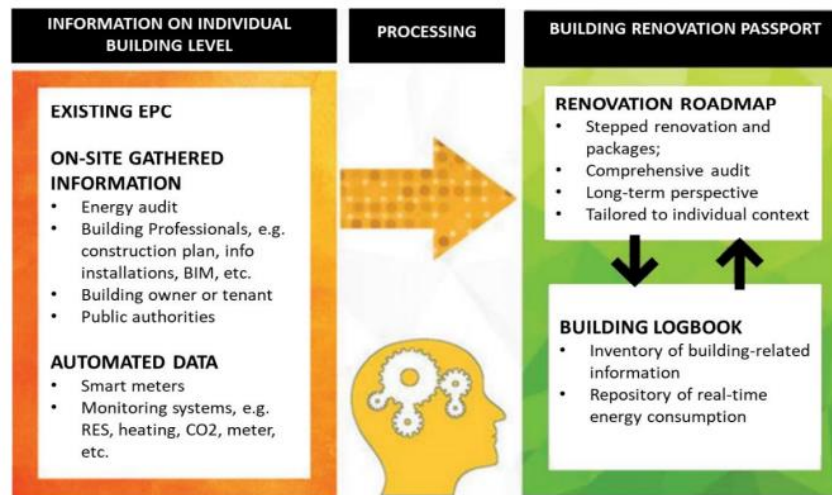


Figure 19: The core ingredients of the iBRoad logbook and renovation roadmap

The iBRoad-Log builds on a modular approach that can provide several functionalities to the building user (or the participating stakeholders):

**Repository of building information** that will serve as a base for other functions such as:

- Property identification (legal and fiscal aspects)
- Building plans and urban licences
- Relevant statistical information about the building (e.g.: from Census)
- Registration of previous renovation works
- Record of the building construction features
- Record of energy consumption & production
- Smartness information

**An interactive and dynamic tool** giving access to the building user on building information, promoting awareness and incentivising him/her to take the following actions:

- Monitor and compare energy consumption (real versus forecasted)
- Monitor energy generation from renewable energy sources
- Receive automated renovation advice (e.g., improvement of the building envelope if the thermal performance is above/below a certain threshold)
- Receive automatic notifications in case of unusual consumption patterns
- Receive alerts and guidance concerning maintenance aspects
- Receive information about the building improvement potential and benefits that may arise from the recommendation's implementation, linking the iBRoad-Log to the iBRoad-Plan
- Benchmark with surrounding buildings

**Link to third parties** to support the decision-making process and enrich the information available to the building user and other entities that may provide support to the implementation of a building's renovation roadmap:

- Public Authorities (to provide the available information about the building or existing incentives, tax reductions, etc.)
- Market actors (that may participate in a marketplace of qualified building professionals like installers)
- Financial services to find specific information like loans, subsidies for energy efficiency, etc.<sup>37</sup>

The iBRoad-Log has been successfully tested in Bulgaria, Poland, Portugal, Germany and Ireland.

### Data Template

The systematic collection and maintenance of data and information is the backbone of the logbook. The main purpose of the logbook data template is to provide a common set of data entry points that need to be gathered and stored. Adhering to a common standardised data template can remove the need for the additional mapping, accessing, and transformation work that is currently required when collecting building information from various sources.

### Functionalities & Benefits

The iBRoad logbook structure is based on a core/fixed component and a flexible component allowing for certain flexibility to serve both national/regional needs but also to integrate into a wider European approach. The fixed structure represents the common European approach detailed in 3 levels of information while the flexible one gives support to the national/regional approach and will embrace the remaining data required to complete the logbook<sup>38</sup>.

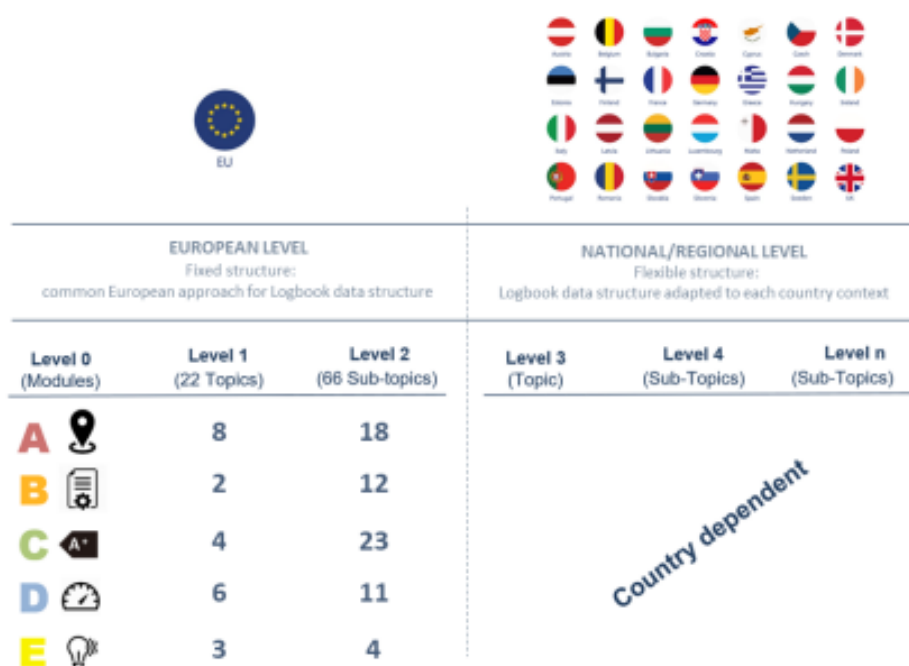


Figure 20: Data structure at the European and National level of the iBRoad-Log

<sup>37</sup> <https://ibroad-project.eu/news/the-ibroad-concept-in-practice/>

<sup>38</sup> <https://ibroad-project.eu/news/the-logbook-data-quest/>

The iBRoad logbook includes five areas of knowledge that accommodate the necessary general information to support the concept of a Building Renovation Passport. These areas, designated as ‘modules’ aim at facilitating the aggregation of information and the use of the database among different stakeholders, making a clear distinction between the topics related to administrative data on one side, or the EPC and SMART data on the other side<sup>39</sup>. The modules are:

1. General administrative information
2. Building construction information
3. Building Energy Performance
4. Building Operation and Use
5. SMART information

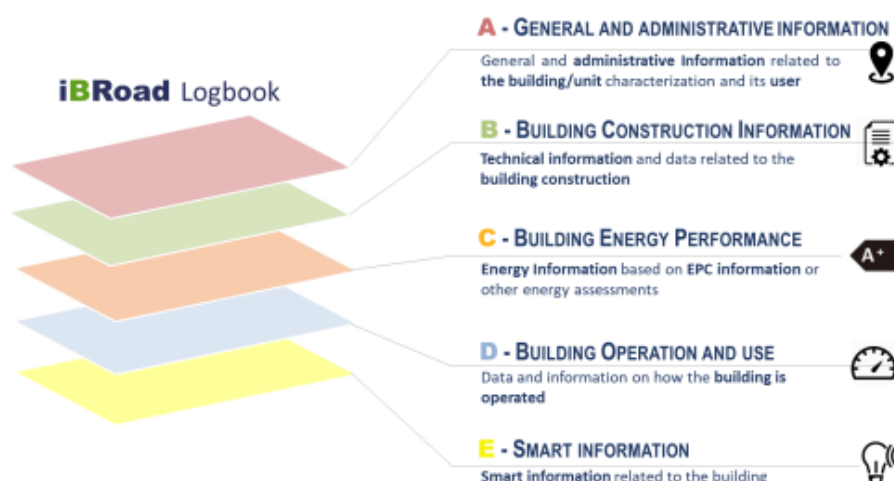


Figure 21: iBRoad logbook modules

The iBRoad logbook can be further enhanced with additional functionalities, act as a digital one-stop-shop portal, bring together building sector stakeholders, overcome value chain fragmentation and enable streamlined and integrated renovation journeys.

The benefits of logbooks have been widely documented<sup>40</sup>. The direct and indirect benefits are not limited to energy efficiency improvements; therefore, these will need to be mapped and clearly articulated to all stakeholders to get the buy-in of all market actors involved.

### Data Governance & Ownership

Data governance refers to the process, organisation, and standards implemented to ensure the effective and efficient storage of and access to data. The development and proper implementation of logbooks require settling a series of legal and technical questions around GDPR, IP rights, data ownership, access, storage, privacy, and security, issues which have been widely discussed in the context of iBRoad and must be further decided based on the configuration of the entity setting up the logbook in each Member State.

Finding the best arrangement for data privacy and security can, however, be difficult: EU data protection provisions are constantly being modernised and updated, and data-gathering technology is developing fast - this brings new data-gathering opportunities but also challenges. There must be

<sup>39</sup> <https://ibroad-project.eu/news/the-logbook-data-quest/>

<sup>40</sup> [GABC Building Passport Practical Guideline](#)

active collaboration between the built environment value chain, operators, IT companies, public authorities, and the public to ensure the security of the data in the logbook.

### SWOT Analysis with Respect to the Integration in iBRoad2EPC

Strengths	Weaknesses	Opportunities	Threats
<ul style="list-style-type: none"> <li>• Significantly enlarge the scope of end-user benefits connected to iBRoad2EPC, including shorter on-site audits; time and cost savings related to the development of the renovation roadmap; renovation advice; aggregate demand and links to one-stop-shops; optimise the renovation for whole-life carbon savings.</li> <li>• Include links to retrofit supply chains (trusted and qualified local service providers) and funding options (both public and private).</li> <li>• Provide additional information and advice to engage and educate homeowners on regulations and policies, the benefits of decarbonisation measures, funding and grants options, and information relating to property and appliance maintenance.</li> </ul>	<ul style="list-style-type: none"> <li>• The integration of iBRoad2EPC with logbooks presupposes the existence of an existing and fully operational logbook that is also accessible to a wider set of stakeholders as well features an open platform that facilitates easy connection of plug-in modules.</li> <li>• Potential costs caused by additional administrative and software requirements and the need for third-party services.</li> </ul>	<ul style="list-style-type: none"> <li>• Opportunity to enrich and standardise data collection and analysis, enabling coherent insights about individual buildings and building stock.</li> <li>• Raise awareness and engage homeowners as well as create market demand for renovations.</li> </ul>	<ul style="list-style-type: none"> <li>• Risks around privacy and data protection if the iBRoad2EPC data is connected to an open-ended logbook platform.</li> <li>• Potential stakeholder perception of additional administrative burden without a benefit for themselves if there is no incentive to keep and manage the data.</li> </ul>

### Applicability for the iBRoad2EPC Building Types

The iBRoad-Logbook is successfully tested for single-family houses and, with small adaptations, can cover all other building typologies. Small residential units do not require the same level of sophistication and data granularity as large commercial or public buildings.

## Feasibility Aspects

A main feasibility advantage of linking iBRoad2EPC to the existing iBRoad logbook is that the two tools already follow technically compatible paths. In this respect, similar to the iBRoad building renovation roadmap being linked to the iBRoad logbook, it will also be possible to have iBRoad2EPC integrated as another of the iBRoad logbook's functionalities or modules, accessible through the logbook portal. Other relevant functionalities could include building diagnosis and pre-emptive maintenance, benchmarks, alerts, reminders, and third-party renovation services (contractors and financing). Additionally, it is considered feasible to allow automated data feed from one to the other through further development of APIs. Depending on the above, iBRoad2EPC could also practically become the bridge between current EPC schemes and the full iBRoad building renovation roadmap and logbook.

## Requirements for Adaptation and Integration within iBRoad2EPC

Within this project, the logbook developed within the project iBRoad will be linked to the iBRoad2EPC assistant.

The logbook implementation is rather flexible, however in view of integrating the iBRoad-Log within iBRoad2EPC, specific aspects may need to be considered and certain adjustments may need to take place. The questions in need to be answered involve:

- Would the smart information module remain within the logbook or will that stand as a separate SRI module outside the logbook?
- Will the flexible structure 'remain flexible' to allow each Member State to adapt the logbook implementation to the data collection procedure specific to their region (including terminologies, existing data etc.)?
- Will the classification under the fixed structure maintain the same number of detail levels (Figure 20)?
- Is there a regulatory context allowing the deployment of the logbook concept to be replicated?
- The viability of all technical aspects should be determined<sup>41</sup>

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<sup>41</sup> <https://ibroad-project.eu/news/how-can-member-states-implement-ibroad/>

## OUTLOOK AND CONCLUSIONS

This document provides a suggestion for possible expansion of the iBRoad tool (as initially developed in the previous project iBRoad) in the project iBRoad2EPC, with new indicators or features, and corresponding guidelines and technical information for eventual implementation. Moreover, we discuss the strengths, weaknesses, opportunities, and threats of these possible additional indicators.

Five potential indicators are described and discussed:

- Indoor Environmental Quality Indicator: We decided to select the CARP methodology developed by X-tendo and apply the relevant spreadsheet tool for the purpose of the project iBRoad2EPC.
- Smart Readiness Indicator: We decided to apply the existing EC spreadsheet tool and selected method A for the purpose of this project.
- Measured energy performance indicator: We decided to apply the existing X-tendo spreadsheet tool for the purpose of this project and to integrate this spreadsheet tool in the workflow of iBRoad2EPC.
- Renovation advice: The existing QualDeEPC Master tool is an interesting way to allow the end-user to become more involved in the comparison of different packages of renovation measures and their impact on energy savings and economic comparison. However, considering the scope of the iBRoad2EPC project requiring an energy expert to provide the renovation advice, we consider the added value of the QualDeEPC Master tool not sufficient to justify the required effort for integration. Instead, Renovation Advice and related specifications in iBRoad2EPC are decided to be developed as an integral part of the iBRoad2EPC basic module, following the stepwise and deep principles as developed in the iBRoad project and enhanced with EC's and national long-term decarbonisation and climate targets and MEPS, following close liaison with national iBRoad2EPC partners. In follow-up projects, which might focus stronger on user awareness, involvement and participation, QualDeEPC's method could be considered a valuable add-on to the iBRoad2EPC tool.
- Digital Building Logbooks: A key potential for iBRoad2EPC is the possibility of linking it to the logbook developed within the iBRoad project. In this respect, we described the concept of the iBRoad logbook and how the link with iBRoad2EPC could be realised. We also discussed what needs to be considered and which questions need to be resolved when linking the logbook to iBRoad2EPC. Furthermore, the potential of linking iBRoad2EPC to any Digital Building Logbook proposed by the EC in the future is considered possible and could be investigated accordingly.

For the X-tendo IEQ and measured energy performance features, the EC SRI feature, and the iBRoad logbook feature, we provided concrete suggestions on how the implementation in the iBRoad2EPC framework could be done. Renovation advice is developed within the iBRoad2EPC project itself, following the stepwise and deep renovation principles as set in the iBRoad project and enhanced with EC's and national long-term decarbonisation and climate targets and MEPS. The advice is integrated into the iBRoad2EPC Assistant in the form of country specific databases to support the issuers, including among others: target building standards for specific key dates, foreseeable future obligations or legal requirements, specifications of the recommended renovation measures (e.g., u-values) and recommendations to avoid lock-in situations, depending on the building type and type and sequence of measures. The country specific databases of renovation advice form a significant accomplishment of the iBRoad2EPC project.

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## ANNEX I. INDOOR ENVIRONMENTAL QUALITY

### X-tendo's Operational Rating Survey, CORP Method of the Environmental Indoor Quality

Thermal comfort [Thermal\_comfort (TC)]

CRITERION 3: Thermal sensation [TC\_Survey]

Parameter 3.1: Local thermal discomfort

How often do you experience the following in your space?					
Cold walls in winter	One or more times a day	One or more times a week	One or more times over a month	Less often	Never
Warm/Cold floor in winter					
Common condensation on windows (humidity)					
Draughts from windows/ doors/ attic (air movement)					
Temperature differences among office rooms					
Temperature differences while standing and sitting					
Direct sunlight indoors in winter					
Convectors used in winter					

Table 8: Local thermal discomfort occupant survey for office buildings (to be completed by the occupant)

How often do you experience the following in your space?					
Cold walls in winter	One or more times a day	One or more times a week	One or more times over a month	Less often	Never
Warm/Cold floor in winter					
Common condensation on windows (humidity)					
Draughts from windows/ doors/ attic (air movement)					
Temperature differences among rooms					
Temperature differences while standing and sitting					
Direct sunlight indoors in winter					
Convectors used in winter					

Table 9: Local thermal discomfort occupant survey for school buildings (to be completed by the occupant)

## Indoor Air Quality [Indoor\_Air\_Quality (IAQ)]

## CRITERION 1: Contaminants [TC\_Survey]

## Parameter 1.4: Indoor contaminant sources [IAQ\_Checklist]

Drying on radiators	Daily	3-4 times a week	1-2 times a week	Bi-weekly	Once a month/Never
Use hot water kettle					
Use printer/copying machine					
Use cleaning disinfectants					
Light candles/incense					
Use of air fresheners					
Smoking					

Table 10: Survey for indoor contaminant sources in office buildings (to be completed by occupant)

Eating activities (lunch, food breaks etc.)	Daily	3-4 times a week	1-2 times a week	Bi-weekly	Once a month/Never
Use teaching products (chalk, paints, art supplies etc.)					
Use printer/copying machine					
Use cleaning disinfectants					
Furnishings made of wood, plywood, fibre board					
Use of air fresheners					
Outdoor traffic intensity (vehicle emissions)					

Table 11: Survey for indoor contaminant sources in classrooms (to be completed by teacher)

## Visual Comfort [Visual\_Comfort (VC)]

## CRITERION 2: Occupant perception and satisfaction [VC\_Survey]

## Parameter 2.1: Artificial and natural light perception and satisfaction

How do you perceive the artificial lighting quality in your room?					
Very poor		Poor	Acceptable	Good	Very good
How do you perceive the daylight quality in your room?					
In summer	Very poor	Poor	Acceptable	Good	Very good
In winter	Very poor	Poor	Acceptable	Good	Very good
How satisfied are you with the artificial lighting in your room?					
Very dissatisfied		Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
How satisfied are you with the daylight quality in your room?					
Very dissatisfied		Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very Satisfied

Table 12: Survey for natural and artificial light perception and satisfaction (office buildings)

How do you perceive the artificial lighting quality in your classroom?					
Very poor		Poor	Acceptable	Good	Very good
How do you perceive the daylight quality in your classroom?					
In summer	Very poor	Poor	Acceptable	Good	Very good
In winter	Very poor	Poor	Acceptable	Good	Very good
How satisfied are you with the artificial lighting in your classroom?					
Very dissatisfied		Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
How satisfied are you with the daylight quality in your classroom?					
Very dissatisfied		Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very Satisfied

Table 13: Survey for natural and artificial light perception and satisfaction (school buildings)

## Parameter 2.2: Glare perception and satisfaction

How would you describe the glare in your normal work area? The question refers to all year- round conditions.				
Too much	Much	Moderate	Little	None
Does artificial (e.g. reflections in computer screen for offices) or natural light ever cause glare strong enough to bother you?				
Frequent	Sometimes	Occasional	Rare	Never
How satisfied are you with the visual comfort of the lighting in terms of glare, reflections and contrast?				
Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
Overall, does the lighting quality enhance or interferes with your comfort?				
Much interference	Some interference	Neither interferes nor enhances	Some enhancement	Much enhancement

Table 14: Survey for glare perception and satisfaction (office buildings)

How would you describe the glare in your normal work area? The question refers to all year-round conditions.				
Too much	Much	Moderate	Little	None
Does artificial (e.g. reflections on whiteboard) or natural light ever cause glare strong enough to bother you?				
Frequent	Sometimes	Occasional	Rare	Never
How satisfied are you with the visual comfort of the lighting in terms of glare, reflections and contrast in your classroom?				
Very dissatisfied	Dissatisfied	Neither satisfied nor dissatisfied	Satisfied	Very satisfied
Overall, does the lighting quality enhance or interferes with your comfort?				
Much interference	Some interference	Neither interferes nor enhances	Some enhancement	Much enhancement

Table 15: Survey for glare perception and satisfaction (school buildings)

## Acoustic Comfort [Acoustic\_Comfort (AC)]

## CRITERION 1: Noise levels

## Parameter 1.1: Indoor noise [AC\_Checklist]

Sound absorbing materials used in walls, floor, roof			
Not used	Used in 1 of the areas	Used in 2 of the areas	Used in all areas
Noise producing appliances in the room (e.g. printer, refrigerator, freezer, kettle etc.)			
No	Yes		
Is the room completely separated by doors, partitions etc. from other spaces?			
No	Yes		
Access to HVAC systems to adjust airflows			
No	Yes		
Does the HVC system have an adequate silencing system installed against noise from fans, ducts, machine vibrators etc.?			
No	Yes		

Table 16: Sound operational control checklist (office buildings)

Sound absorbing materials used in walls, floor, roof			
Not used	Used in 1 of the areas	Used in 2 of the areas	Used in all areas
Noise producing appliances in the classroom (e.g. printer, copier etc.)			
No	Yes		
Is the room completely separated by doors, partitions etc. from other spaces?			
No	Yes		
Access to HVAC systems to adjust airflows			
No	Yes		
Does the HVC system have an adequate silencing system installed against noise from fans, ducts, machine vibrators etc.?			
No	Yes		

Table 17: Sound operational control checklist (school buildings)

## CRITERION 2: Occupant perception and satisfaction

## Parameter 2.1: Noise perception and satisfaction [AC\_Survey]

How do you perceive the acoustic environment in your room?				
Very poor	Poor	Sufficient	Good	Very good
How satisfied are you with the overall noise level in the room?				
Very satisfied	Slightly dissatisfied	Neither satisfied nor dissatisfied	Slightly satisfied	Very satisfied
How satisfied are you with the internal sound transmission to the room from adjacent rooms?				
Very satisfied	Slightly dissatisfied	Neither satisfied nor dissatisfied	Slightly satisfied	Very satisfied
Have you experienced problems with noise inside your room, e.g. the ventilation system, HVAC, technical installation?				
Frequently	Sometimes	Occasional	Rare	Never
How satisfied are you with the outdoor noise level during the winter?				
Very satisfied	Slightly dissatisfied	Neither satisfied nor dissatisfied	Slightly satisfied	Very satisfied
How satisfied are you with the outdoor noise level during the summer?				
Very satisfied	Slightly dissatisfied	Neither satisfied nor dissatisfied	Slightly satisfied	Very satisfied

Table 18: Survey for noise perception and satisfaction (office buildings)

How do you perceive the acoustic environment in your classroom?				
Very poor	Poor	Sufficient	Good	Very good
How satisfied are you with the overall noise level in the classroom?				
Very satisfied	Slightly dissatisfied	Neither satisfied nor dissatisfied	Slightly satisfied	Very satisfied
How satisfied are you with the internal sound transmission to the classroom from adjacent rooms?				
Very satisfied	Slightly dissatisfied	Neither satisfied nor dissatisfied	Slightly satisfied	Very satisfied
Have you experienced problems with noise inside your classroom, e.g. the ventilation system, HVAC, technical installation?				
Frequently	Sometimes	Occasional	Rare	Never
How satisfied are you with the outdoor noise level during the winter?				
Very satisfied	Slightly dissatisfied	Neither satisfied nor dissatisfied	Slightly satisfied	Very satisfied
How satisfied are you with the outdoor noise level during the summer?				
Very satisfied	Slightly dissatisfied	Neither satisfied nor dissatisfied	Slightly satisfied	Very satisfied

Table 19: Survey for noise perception and satisfaction (school buildings)

## X-tendo's Asset Rating Checklist, CARP method of the Environmental Indoor Quality

Thermos tats	No thermos tat	Central thermostat (non-programmable)	Individual room control (non-programmable)	Central thermostat (programmable)	Individual room control (programmable)	Wi-Fi thermostat	Smart thermostat (self-learning)
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Table 20: Checklist for thermostats

Solar shading	No shading/No direct solar gain	Curtains (manual)	Curtains (automatic)	Internal blinds (manual)	Internal blinds (automatic)	External blinds (manual)/ fixed external shading	External blinds (automatic)
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Table 21: Checklist for solar gain

Operable windows	No windows	Fixed windows	Top hung/ Double hung windows	Sliding windows	Pivoted windows	Casement/tilt and turn windows
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Table 22: Checklist of operable control of windows

Natural ventilation boost	No natural ventilation	Trickle ventilation	One sided window ventilation	Cross-ventilation (windows on opposite sides)	Passive stack ventilation (ventilation from roof and windows)
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Table 23: Checklist for natural ventilation boost

Mechanical ventilation boost	Mechanical ventilation without boost	Ceiling/portable fans	High occupancy fresh air boost	Warm air/damp air boost present	Occupancy and warm/damp air boost present
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Table 24: Checklist of mechanical ventilation boost

Automatic ventilation control	No	Yes	
Automatic windows and ventilators	Operator controlled	Programmable	Sensor controlled
Automatic ventilation control	without demand control	with demand control	

Table 25: Checklist for automatic ventilation control

Mould	Larger areas with visible mould ( $\geq 2500\text{cm}^2$ )	Damage with moderate area visible mould ( $< 2500\text{cm}^2$ )	Moderate area visible mould ( $< 2500\text{cm}^2$ )	Damage with minor area visible mould ( $< 400\text{cm}^2$ )	Minor area visible mould ( $< 400\text{cm}^2$ )	No visible mould
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Table 26: Checklist for mould inspection

Cooking stove	Solid fuel	Gas	Modular cook top (gas and electric)	Electrical coil cook top	Electric smooth cook top	Induction
Heating stove	Solid fuel	Gas	Electric			
Unvented stove	Yes	No				
Fireplace (operational)	Yes	No				
Portable heater	Yes	No				

Table 27: Checklist for indoor contaminant sources (residential)

Category (Residential/School/Office)	Corresponding CO <sub>2</sub> concentration above outdoors in PPM for non-adapted persons*	Corresponding air flow rate <sup>#</sup> (l/s per person) - $A_f$	Corresponding ventilation rate (ach)
I	$\leq 550$	$\geq 10$	$V_r = \frac{A_f \times N \times 3.6}{V}$
II	$\leq 800$	$\geq 7$	
III	$\leq 1350$	$\geq 4$	
IV	$\geq 1350$	$\leq 4$	
NOTE: <sup>#</sup> when major contribution to emissions is by people			V= Volume of the room A <sub>f</sub> = Air flow rate N= No. of persons

Table 28: Corresponding air flow rates to CO<sub>2</sub> concentration

Kitchen hood/exhaust	No	Yes	Manual switch	Automatic with manual override
Bathroom exhaust	No	Yes	Manual switch	Automatic with manual override
Toilet exhaust	No	Yes		
Utility exhaust	No	Yes		

Table 29: Checklist for exhausts (only residential)

ID	East (m <sup>2</sup> )	West (m <sup>2</sup> )	North (m <sup>2</sup> )	South (m <sup>2</sup> )
Window 1				
Window 2				
Window 3				
Window 4				
Window 5				
Window 6				
Window 7				
Window 8				
Window 9				
Window 10				
Total area				

Table 30: Table to enter window areas per orientation

Categories	Window to Floor Area Ratio (WFR) Residential	Window to Floor Area Ratio (WFR) Office and School
I	>20 and ≤30%*	>35 and ≤50%*
II	>10 and ≤20%	>20 and ≤35%
III	≥5 and ≤10%	≥10 and ≤20%
IV	<5%	<10%

Note: To avoid over lit spaces in buildings a maximum value is defined.

Table 31: Window to floor area ratio (WFR) classification for South, West and East facing facades (for all building types) [17]

Category	Residences (Lux)	Schools (Lux)	Offices (Lux)
I	250 ≤ Illuminance < 500	500 ≤ Illuminance < 750	750 ≤ Illuminance < 1000
II	150 ≤ Illuminance < 250	300 ≤ Illuminance < 500	500 ≤ Illuminance < 750
III	50 ≤ Illuminance < 150	no criteria	300 ≤ Illuminance < 500
IV	Illuminance < 50	Illuminance < 300	Illuminance < 300

Table 32: Illuminance classification (adapted from [18])

Incandescent light bulbs installed		Fluorescent/LED lamps		Lumens (lm)	Total Lumens (lm)
Count	Watt	Count	Watt		
	25		6.23	375	
	40		10	600	
	60		15	900	
	75		18.75	1125	
	100		25	1500	
	150		37.5	2250	
	200		50	3000	

Table 33: Checklist for the assessment of artificial lighting illuminance (to be completed by assessor) [19]

Availability of shading for lighting or glare control (for south facing windows)						
	None	Adjustable work or activity area	interior window shading e.g. shades, curtains, internal blinds)	Tinted/reflective/fritted glazing	external shading systems (e.g. external blinds, awning)	Variable opacity glazing e.g. electrochromic glass etc.
Availability of devices to control artificial lighting and glare						
	None	Adjustable work or activity area	Task lighting	Adjustable lighting controls	Filter and diffusers	

Table 34: Checklist for shading (for all building types)

Walls	Rock-wool and Glass-wool- type sound absorbing materials etc.
Floors	Carpet, tatami matting etc.
Ceiling:	Rockwool glass-wool, gypsum board type sound absorbent ceiling material etc.

Table 35: Examples of sound absorbing materials for walls, floors and ceiling [18]

Sound absorbing materials used in walls, floor, roof			
Not used	Used in 1 of the areas	Used in 2 of the areas	Used in all areas
Noise producing appliances in the room (e.g. refrigerator, freezer etc.)			
No		Yes	
Is the room completely separated by doors, partitions etc. from other spaces?			
No		Yes	
Access to HVAC systems to adjust airflows			
No		Yes	
Does the HVAC system have an adequate silencing system installed against noise from fans, ducts, machine vibrations etc.?			
No		Yes	

Table 36: Indoor noise checklist (for all building types)

Please describe the noise sources that are in vicinity					
Airport	Railway/ construction-demolition works/industrial activity	Heavy traffic (main streets, highways)	Urban area (low traffic)	Quiet rural area	
Please describe the building’s construction (in relation to noise)					
Single glazing, no thermal insulation	Single glazing, thermal insulation	Single glazing, thermal insulation, sound-proofing insulation	Double glazing, no thermal insulation	Double glazing, thermal insulation	Double glazing, thermal and sound proofing insulation

Table 37: Checklist for outdoor noise levels (for all building types)

Openable windows towards silent side	
Yes	No
Flexibility to close internal doors	
Yes	No

Table 38: Checklist for noise adjustment (all building types)

## ANNEX II. SMART READINESS INDICATOR

Measure	Measure_2	Specification of the measure	Description of measure
Air tightness	Improve the air permeability of the envelope		Installation or removal and replacement of the internal layer, plus air stop band in correspondence of the connection element, plus air stop element where the building plant crosses the building element, plus sealing electric box and tube.
External Wall	External insulation (EIFS System)	15 cm of insulation ( $U = 0,2 \text{ W}/(\text{m}^2\text{K})$ )	The external wall is insulated with an "Exterior Insulation Finishing System (EIFS)". EIFS is a lightweight synthetic wall cladding that includes foam plastic insulation and thin synthetic coatings.
External Wall	External insulation (ventilated façade)		Thermal insulation will be protected by a new external layer attached, through a substructure, to the existing structure or building façade. Between the insulation and the external layer there will be a highly ventilated air chamber which will protect the building from solar radiation.
External Wall	Filling air chamber with thermal insulation		Thermal insulation will be installed into the existing air chamber. The thickness of the thermal insulation will depend on the air chamber thickness.
External Wall	Internal insulation		Addition of thermal insulation, vapor barrier and a new inner plaster layer on the internal surface of the wall. The larger the insulation thickness, the greater the reduction in the useful floor area in the building.
External Wall	Replace internal insulation		Remove the inner skin of the cavity wall and then create a new skin, separated by an air chamber from the external skin, and composed by thermal insulation, brick masonry and plaster inside.
Floor	Insulation in the inner of the floor		Removal of the existing layers over the concrete slab. Installation of the thermal insulation and, over the insulation a concrete screed, a vapour barrier and finally the finishing layer/s.
Floor	Insulation on the basement ceiling	10 cm of insulation ( $U = 0,26 \text{ W}/(\text{m}^2\text{K})$ )	Insulation of the cellar ceiling from below.

Roof	Roof insulation	20 cm of insulation ( $U = 0,15 \text{ W}/(\text{m}^2\text{K})$ )	Insulation of the roof surface together with the renewal of the roof tiles. The new insulation will be installed on top of the slab/framework.
Roof	Insulation of the top storey ceiling		Installation of a thermal insulation layer inside the false ceiling of the last conditioned storey of the building.
Roof	Insulation of a pitched roof		Insulation for gable roofs, as with many other thermal insulations for pitched roofs, is possible both as above-rafter and as between-rafter and below-rafter insulation.
Roof	Insulation of a flat roof		When choosing the right insulation for your flat roof, it depends on whether the roof is to be used or not. In most cases, and if the roof is to be used, you decide on internal insulation if the outer roof skin is still intact. If the flat roof is to be completely renovated or if no special use is planned, external insulation can be installed at a later date. The insulation can be applied to the flat roof as an inverted roof, whereby a new waterproofing layer is then applied to the old roof, as well as a new layer of insulation boards.
Solar shading	Drop-arm awnings installation		Drop-arm awnings offer the ideal solution for providing shade for windows and balconies only in summer periods.
Solar shading	Internal window blinds		External sun protection is not always possible. Sometimes there is no other way, in which case the summer heat protection must be installed inside. However, the heat is then already in the room. The effect of the sun protection is then considerably less. In this case, interior awnings and blinds can be used.
Solar shading	External window blinds or shades		It is best if the summer thermal protection can be installed outside. This can be external window blinds or shades, roller shutter or external awning. External sun protection is much more efficient than internal sun protection. Roller shutters or awnings in front of the window are therefore the first choice for summer heat protection.

Solar shading	Automation of solar shading devices	Motorized operation with automatic control based on sensor data	Automatic solar shading devices help you to enjoy the summer without any worries: When the sun shines, your solar shading devices extends automatically; when the wind or a storm comes up, it retracts again.
Solar shading	Sun protection film		External sun protection is not always possible. Sometimes there is no other way, in which case the summer heat protection must be installed inside. However, the heat is then already in the room. The effect of the sun protection is then considerably less. In this case, sun protection films can be applied to the outside of the window surfaces.
Window	Replacement of the windows	Triple glazing, highly efficient windows ( $U_w = 0,8 \text{ W}/(\text{m}^2\text{K})$ ).	Replacement of all windows that are older than 10 years.
Window	Window glazing substitution		Windows glazing substitution, keeping the actual frames.
Window	Window open/closed control, combined with HVAC system	Manual operation or only fixed windows	Centralized coordination of operable windows, e.g., to control free natural night cooling
Door	Replacement of the door	Maximum U-value = $1,0 \text{ W}/(\text{m}^2\text{K})$ .	Replacement of the old external doors by highly insulated and air-tight doors.
Dynamic building envelope	Reporting information regarding performance of dynamic building envelope system	Position of each product and fault detection	Position of each product, fault detection, predictive maintenance, real-time and historical sensor data (wind, lux, temperature...)
Auxiliary systems	Change pumps		Remove old pumps and install new equipment with high efficiency rate.
Auxiliary systems	Change fans		Remove old fans and install new equipment with high efficiency rate.
Electric vehicle charging	EV charging capacity	Ducting (or simple power plug) available	>50% of parking spaces has recharging point
Electric vehicle charging	EV charging grid balancing	1-way / 2-way controlled charging	2-way controlled charging (e.g., including desired departure time and grid signals for optimization)
Electric vehicle charging	EV charging information and connectivity	Reporting information on EV charging status to occupant	Reporting information on EV charging status to occupant AND automatic identification and authorization of the driver to the charging station (ISO 15118 compliant)
Cooling	Installation of a chiller		Installation of a chiller that cools the drawn-in air.

Cooling	Installation of an absorption chiller		Installation of an absorption chiller connected to thermal solar collectors (solar cooling).
Cooling	Substitution of the cooling system		Substitution of the heating/cooling system by a heat pump (Air to Air technology).
Cooling	Cooling emission control	Central automatic control / Individual room control	Individual room control with communication and occupancy detection
Cooling	Emission control for Thermally Activated Building System (heating mode)	(Advanced) Central automatic control	Advanced central automatic control with intermittent operation and/or room temperature feedback control
Cooling	Control of distribution network chilled water temperature (supply or return)	Constant temperature control	Demand based control
Cooling	Control of distribution pumps in network	On/off control / Multi-stage control	Variable speed pump control (external demand signal)
Cooling	Interlock: avoiding simultaneous heating and cooling in the same room	Partial interlock	Total interlock (control system ensures no simultaneous heating and cooling can take place)
Cooling	Control of Thermal Energy Storage operation	Continuous or time-scheduled or load prediction-based storage operation	Cold storage capable of flexible control through grid signals (e.g., DMS)
Cooling	Generator control for cooling	On/off control of cooling production	Variable control of cooling production capacity depending on the load AND external signals from grid
Cooling	Sequencing of different cooling generators	Priorities only based on running time	Sequencing based on dynamic priority list, including external signals from grid
Cooling	Report information regarding cooling system performance	Central or remote reporting of current performance KPIs	Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection
Cooling	Flexibility and grid interaction	Scheduled operation of cooling system	Optimized control of cooling system based on local predictions and grid signals (e.g., through model predictive control)

Domestic hot water (DHW)	Installation of a new hot water boiler		In domestic hot water boiler drinking water is heated in a water heater. There are different types of water boilers and how they work. Examples are instantaneous water heaters, directly or indirectly heated hot water tanks, solar thermal system, biomass boiler or a heat pump. Replace your old water boiler with a new efficient one.
Domestic hot water (DHW)	Centralise the domestic hot water supply		By centralising your hot water production, only one common device is needed in the entire house. The "system losses" are only incurred by one unit and the energy efficiency is increased. The central hot water supply has the advantage that energy-efficient and climate-friendly systems can be used (solar thermal, CHP wood pellet, etc.), which cannot be implemented for a single flat
Domestic hot water (DHW)	Control of DHW storage charging (with direct electric heating or integrated electric heat pump)	Automatic control on/off	Automatic control on/off and scheduled charging enable and multi-sensor storage management
Domestic hot water (DHW)	Control of DHW storage charging	HW storage vessels available	Automatic charging control based on local availability of renewables or information from electricity grid (DR, DSM)
Domestic hot water (DHW)	Control of DHW storage charging (with solar collector and supplementary heat generation)	Manual selected control of solar energy or heat generation	Automatic control of solar storage charge and supplementary storage charge, demand-oriented supply and return temperature control and multi-sensor storage management
Domestic hot water (DHW)	Sequencing in case of different DHW generators	Priorities only based on running time	Control according to dynamic priority list (based on current AND predicted load, energy efficiency, carbon emissions, capacity of generators AND external signals from grid)
Domestic hot water (DHW)	Report information regarding DHW performance	Indication of actual values	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection
Heating	Centralise the heat supply		If you switch to a central heating system, the investment costs are lower overall. Another advantage of a central heating system over a gas heating system is that the heating is located outside the living space.

			The conversion of gas floor heating systems is technically possible without exception. The most significant challenges in converting apartment buildings are the construction of a central boiler room, the installation of a heat distribution network and the connection of the individual flats to the newly constructed heat distribution network.
Heating	Substitution of the distribution system with a floor heating system		Floor heating provides cosy warmth because it emits its heat over a large area. With this heating system, the heated air rises evenly throughout the room and cools down again. The air circulation is very low. Therefore, hardly any dust is stirred up. This is why floor heating systems are very suitable for people who are allergic to house dust. When you install them, you have to remove the existing floor.
Heating	Substitution of the distribution system with new radiators		Replacing radiators after modernising a heating system or renovating an energy system makes sense. The old radiators are usually no longer suitable for the heating requirements of the renewed heating system and have differently dimensioned heating surfaces as well as a different water requirement. Replacing radiators also makes sense if you use a heat pump or solar thermal system that requires lower flow temperatures.
Heating	Optimization distribution system		No matter which heating system, the correct setting of the heating system is essential. With hydraulic balancing, the system is pre-set so that each radiator receives exactly the amount of water to bring the room to the desired temperature. The heating load is precisely calculated for each individual room, enabling particularly more efficient and cost-saving operation.
Heating	Improve distribution system		Insulate your heating, hot water and circulation pipes, especially in unheated rooms. This will prevent heat loss.
Heating	Substitution of the heating		Remove your old heating system and install a new gas boiler.

	system by a gas boiler		
Heating	Substitution of the heating system by a biomass system		An alternative to fossil fuels are renewable resources in the form of logs and wood pellets or wood chips for larger buildings (biomass). They are particularly suitable in buildings where high flow temperatures are necessary. The reason for this is insufficient insulation of the building envelope or radiators or heating surfaces that are too small. Replace the existing heating system with a biomass heating system.
Heating	Substitution of the heating system by a heat pump	The heat pump should feature a coefficient of performance (COP) of at least 4.0.	Install a heat pump. There are two common types of heat pumps: With ground-source heat pumps, a liquid is pumped through pipes laid in the ground and is heated by the temperature of the soil.
Heating	Substitution of the heating system to an existing district heating		Remove your old heating system and connect to a district heating. The big advantage: homeowners do not need their own heating system, and by integrating waste heat or renewable energies, a lot of emissions can be saved regionally. Check in advance whether a district heating is available in your area.
Heating	Substitution of the heating system by a cogeneration system		Install a cogeneration system. Unlike most energy generation systems, combined heat and power (CHP) units produce electricity and heat in one system through the principle of combined heat and power (CHP). Electricity is generated by burning fuel. The resulting heat is reused by storing it and using it for heating and warming.
Heating	Heat emission control	Central automatic control / Individual room control	Individual room control with communication and occupancy detection
Heating	Emission control for Thermally Activated Building System (heating mode)	(Advanced) Central automatic control	Advanced central automatic control with intermittent operation and/or room temperature feedback control
Heating	Storage and shifting of thermal energy	HW storage vessels available	HW storage vessels controlled based on external signals (from Building Automation Control System or grid)

Heating	Control of distribution pumps in network	On/off control / Multi-stage control	Variable speed pump control (external demand signal)
Heating	Thermal Energy Storage for building heating (excluding Thermally Activated Building System)	Continuous or time-scheduled or load prediction-based storage operation	Heat storage capable of flexible control through grid signals (e.g., DSM)
Heating	Heat generator control (all except heat pumps)	Constant temperature control	Variable temperature control depending on the load (e.g., depending on supply water temperature set point)
Heating	Heat generator control (for heat pumps)	On/off control of heat generator	Variable control of heat generator capacity depending on the load AND external signals from grid
Heating	Sequencing in case of different heat generators	Priorities only based on running time	Control according to dynamic priority list (based on current AND predicted load, energy efficiency, carbon emissions, capacity of generators AND external signals from grid)
Heating	Report information regarding heating system performance	Central or remote reporting of current performance KPIs	Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection
Heating	Flexibility and grid interaction	Scheduled operation of heating system	Optimized control of heating system based on local predictions and grid signals (e.g., through model predictive control)
Lighting	Install LED lamps		Removal of the old lamps and installation of new LED lamps.
Lighting	Occupancy control for indoor lightning	Manual on/off switch / Automatic detection	Automatic detection (manual on/dimmed or auto off)
Lighting	Control artificial lightning power based on daylight levels	Manual/automatic	Automatic dimming including scene-based light control (during time intervals, dynamic and adapted lightning scenes are set, e.g., in terms of illuminance level, different correlated colour temperature
Renewable energy sources	Installation of a photovoltaic system		The generation of electrical energy by means of solar energy is called photovoltaics (PV). Solar cells convert incident sunlight directly into electricity.

Renewable energy sources	Installation of a solar thermal system		A solar thermal system converts solar energy into heat. This heat is used to heat drinking water or for heating. For this purpose, so-called solar collectors are mounted on the roof of the house and connected to the heating system in the basement. As a rule, a solar thermal system does not completely cover the demand for heating energy, but is combined with a conventional heating system.
Electricity	Reporting information regarding local electricity generation	Current generation data available	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection
Electricity	Storage of (locally generated) electricity	On site storage of energy	On site storage of energy (e.g., electric battery or thermal storage) with controller optimising the use of locally generated electricity and possibility to feed back into the grid
Electricity	Optimizing self-consumption of locally generated electricity	Scheduling electricity consumption	Automated management of local electricity consumption based on current and predicted energy needs and renewable energy availability
Electricity	Control of combined heat and power plant		CHP runtime control influenced by the fluctuating availability of RES and grid signals; dynamic charging and runtime control to optimise self-consumption of renewables
Electricity	Support of (micro)grid operation modes		Automated management of (building-level) electricity consumption and supply, with potential to continue limited off-grid operation (island mode)
Electricity	Reporting information regarding energy storage	Current state of charge data available	Performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection
Electricity	Reporting information regarding electricity consumption	Reporting on current electricity consumption on building level	Real-time feedback or benchmarking on appliance level with automated personalized recommendations
Ventilation	Install a mechanical ventilation with heat recovery	Heat recovery rate at least 0.95.	Buildings with mechanical ventilation are more comfortable if they have options to regulate the mechanical ventilation in conditions when the occupancy is high or there is too much damp air inside.

Ventilation	Improvement of the natural ventilation		Especially during summers, the thermal comfort conditions are driven by natural ventilation possibilities inside the buildings. Therefore, cross-ventilation (windows on opposite sides) or passive stack ventilation (ventilation from roof and windows) can be used in the order to assess the effectiveness to boost the natural ventilation in the building spaces.
Ventilation	Supply air flow control at the room level	Clock control	Local demand control based on the air quality sensors (CO <sub>2</sub> , VOC...) with local flow from/to the zone regulated by dampers
Ventilation	Air flow or pressure control at the air handler level	On/off time control / Multi-stage control	Automatic flow or pressure control with pressure reset: Load dependent supplies of air flow for the demand of all connected rooms (for variable air volume systems with VFD)
Ventilation	Heat recovery control: prevention of overheating	Modulate or bypass heat recovery based on sensors in air exhaust	Modulate or bypass heat recovery based on multiple room temperature sensors or predictive control
Ventilation	Supply air temperature control at the air handling unit level	Constant/variable set point	Variable set point with load dependant compensation. A control loop enables to control the supply of air temperature. The setpoint is defined as a function of the loads in the room
Ventilation	Free cooling with mechanical ventilation system	Night cooling / Free cooling	H,x-directed control: the amount of outside air and recirculation air are modulated during all periods of time to minimize the mount of mechanical cooling. Calculation is performed on the basis of temperatures and humidity (enthalpy)
Ventilation	Reporting information regarding IAQ	Air quality sensors and real-time autonomous monitoring	Real-time monitoring and historical information of IAQ available to occupants + warning on maintenance needs or occupant actions (e.g., window opening)
Monitoring and control	Run time management of the HVAC system	Manual setting	Heating and cooling plant on/off control based on predictive control or grid signals
Monitoring and control	Detecting faults of technical building systems and providing support to the		With central indication of detected faults and alarms for all relevant technical building systems, including diagnosing functions

	diagnosis of these faults		
Monitoring and control	Occupancy detection: connected services	Occupancy detection for individual functions	Centralised occupant detection which feeds into several technical building systems such as lightning and heating
Monitoring and control	Central reporting of technical building systems performance and energy use	Central or remote reporting of real-time energy use per energy carrier	Central or remote reporting of real-time energy use per energy carrier, combining technical building systems of all main domains in one interface
Monitoring and control	Smart grid integration	Demand side management for technical building systems	Coordinated demand side management of multiple technical building systems
Monitoring and control	Reporting information regarding demand side management performance and operation		Reporting information on current, historical and predicted DSM status, including managed energy flows
Monitoring and control	Override of DSM control		Scheduled override of DSM control and reactivation with optimised control
Monitoring and control	Single platform that allows automated control and coordination between technical building systems + optimization of energy flow based on occupancy, weather, and grid signals		Single platform that allows automated control and coordination between technical building systems + optimisation of energy flow based on occupancy, weather, and grid signals

Table 39: List of measures from iBRoad2EPC data base, including SRI related measures (marked as italic fonts)

## ANNEX III. REAL ENERGY CONSUMPTION INDICATOR (MEASURED ENERGY PERFORMANCE)

Abbreviation	Unit	Name	Type	Entity
f_Pnren	$kWh_{prim}/kWh_{fin}$	Conversion factor to non-renewable primary energy	Value per energy carrier	MS
f_Pren	$kWh_{prim}/kWh_{fin}$	Conversion factor to renewable primary energy	Value per energy carrier	MS
f_Ptot	$kWh_{prim}/kWh_{fin}$	Conversion factor to total primary energy	Value per energy carrier	MS
K_CO2	$g/kWh_{fin}$	Conversion factor to CO <sub>2</sub> equivalent emissions	Value per energy carrier	MS
k_exp	-	Factor to control which part of exported energy is included in the EP of the building	Value	MS
-	-	Climate zone	Text (multiple climate zones possible)	MS
HDD	-	Heating degree-days	Value per month per year and per month for the standard year	MS
CDD	-	Cooling degree-days	Value per month per year and per month for the standard year	MS
I_sol_hor	$kWh/m^2$	Solar irradiation on a horizontal plane	Value per month per year and per month for the standard year	MS
T_i_STD_H	°C	Standard indoor temperature (standard use) during the heating season	Value per subtype of building	MS
Δ_T_gains_H	°C	Temperature offset for heat gains in heating	Value per subtype of building	MS

		season (standard year)		
T_e_repres_H	°C	Representative outdoor temperature during the heating season (standard year)	Value per climate zone	MS
A_STD_p	m <sup>2</sup> /person	Standard area per building user	Value per subtype of building	MS
Q_STD_net_DHW_A	kWh/(m <sup>2</sup> ·year)	Annual standard net energy use for DHW per unit of useful floor area	Value per subtype of building	MS
x	-	Coefficient x for calculation of residential reference DHW use	Value	MS
y	-	Coefficient y for calculation of residential reference DHW use	Value	MS
T_dhw	°C	Specified mixed DHW delivery temperature	Value	MS
T_cw	°C	Specified cold water delivery temperature	Value	MS
-	-	Apply correction for indoor temperature in heating season (optional)?	Selection list (Yes/No)	MS
-	-	Apply correction for DHW energy (optional)?	Selection list (Yes/No)	MS
-	-	Total system efficiency of DHW is known?	Selection list (Yes/No)	MS/P
-	-	Total system efficiency of DHW is a fixed average value or from a linear model?	Selection list	MS/P
-	-	Building name	Text	P

-	-	Building identifier	Value	P
-	-	Building address	Text	P
-	-	Building year of construction	Text	P
-	-	Building year of renovation	Text	P
-	-	Building picture	Picture	P
-	-	EPC Practitioner name	Text	P
-	-	EPC Practitioner identifier	Value	P
-	-	EPC Practitioner address	Text	P
-	-	EPC Practitioner signature	Signature	P
-	-	Country	Selection list	P
-	-	Region	Selection list	P
-	-	Type of building	Selection list	P
-	-	Subtype of building	Selection list	P
n	-	Number of residential units in MFH	Value	P
A <sub>use</sub>	m <sup>2</sup>	Building useful floor area	Value	P
Q <sub>act_i_cr</sub>	kWh	Actual energy delivered (or exported) per energy carrier and per application for monitoring period per energy carrier	Value	P
-	-	Monitoring period start date	Date (possible per energy carrier)	P
-	-	Monitoring period end date	Date (possible per energy carrier)	P
-	-	Energy carrier type (in case of energy carrier)	Selection list	P

		Fuel or Fuel for CHP)		
-	-	Energy carrier subtype (in case of energy carrier Fuel or Fuel for CHP)	Selection list	P
-	-	Technology (in case of energy carrier electrical energy from on-site)	Selection list	P
n_act_p	-	Actual number of building users	Value	P
Eta_DHW	-	Total system efficiency for DHW	Value	P
a	-	Linear model coefficient a	Value	P
b	-	Linear model coefficient b	Value	P
T_i_act_H	°C	Linear model coefficient b	Value	P

Table 40: List of all input parameters to determine X-tendo's real energy consumption indicator [14]

## Real Energy Consumption Indicator – Calculation Method (Formulae)

### *Calculation of the correction factors and standard inputs*

The correction factor  $f_{I\_sol\_1\_year}$  is calculated using following equation:

$$f_{I\_sol\_1\_year} = I_{sol\_1\_year} / I_{sol\_monper},$$

where:

- $I_{sol\_1\_year}$  is the sum of  $I_{sol\_hor}$  of the most recent twelve months included in the monitoring period
- $I_{sol\_monper}$  is the sum of  $I_{sol\_hor}$  of all the months included in the monitoring period

The correction factor  $f_{I\_sol\_STD}$  is calculated using the equation below:

$$f_{I\_sol\_STD} = I_{sol\_STD} / I_{sol\_1\_year},$$

where:

$I_{sol\_STD}$  is the value for  $I_{sol\_hor}$  for the standard year.

$$f_{I\_sol\_1\_year\_STD} = I_{sol\_1\_year\_STD} / I_{sol\_monper\_STD}$$

where:

- $I_{sol\_1\_year\_STD}$  is  $I_{sol\_STD}$  of one standard (reference) year
- $I_{sol\_monper\_STD}$  is the sum of  $I_{sol\_STD}$  of all the months included in the monitoring period

The factor  $f_{I\_sol\_STD}$  is not applied in this case.

The standard net energy use for domestic hot water  $Q_{STD\_net\_DHW}$  [kWh/year] is calculated in the following way:

If the building type is “Residential”, then:

$$Q_{STD\_net\_DHW} = V_{STD\_DHW} \times \rho \times c_p \times (T_{dhw} - T_{cw})$$

where:

- $V_{STD\_DHW}$  is calculated according to formula (B.5) of Annex B of standard EN 12831-3: 2017 [CEN; 2017g], in which the habitable area is taken as equal to the useful floor area
- $\rho = 994 \text{ kg/m}^3$  (average density of water at conditions representative for water in the DHW system)
- $c_p = 0,00116 \text{ kWh/(kg.K)}$  (the average thermal capacity of water at conditions representative for water in the DHW system)

If the building type is “Non-residential”, then:

$$Q_{STD\_net\_DHW} = Q_{STD\_net\_DHW\_p} \times n_{std\_p}$$

where:

- $Q_{STD\_net\_DHW\_p} = A_{std\_p} \times Q_{STD\_net\_DHW\_A}$
- $n_{std\_p} = A_{use} / A_{std\_p}$

The correction factor for domestic hot water energy use  $f_{DHW}$  is calculated using the equation below:

$$f_{DHW} = n_{std\_p} / n_{act\_p}$$

where:

$$n_{std\_p} = A_{use} / A_{std\_p}$$

The correction factor  $f_{T\_i}$  is calculated using the following equation:

$$f_{T\_i} = (T_{i\_STD\_H} - DT_{gains} - T_{e\_repres\_H}) / (T_{i\_act\_H} - DT_{gains} - T_{e\_repres\_H})$$

#### *Calculation of the standard energy required to be delivered*

Space heating:

$$Q_{req\_STD\_H\_cr} = Q_{act\_H\_cr} \times f_{HDD\_1\_year} \times f_{HDD\_STD} \times f_{T\_i}$$

Domestic hot water:

The preliminary calculation for one year of not standard use of the total energy required for DHW and the shares of contribution to the energy required for DHW per energy carrier is calculated with the following equation:

$$Q_{req\_1\_year\_DHW\_cr} = Q_{act\_DHW\_cr} \times f_t$$

$$\text{if } Q_{req\_1\_year\_DHW\_tot} = 0, \text{ then } S_{req\_1\_year\_DHW\_cr} = 0$$

Otherwise:

$$S_{req\_1\_year\_DHW\_cr} = Q_{req\_1\_year\_DHW\_cr} / Q_{req\_1\_year\_DHW\_tot}$$

where,

$$Q_{req\_1\_year\_DHW\_tot} = \text{sum}(Q_{req\_1\_year\_DHW\_cr})$$

If “Apply correction for domestic hot water energy (optional)?” is “No”, then

$$Q_{req\_STD\_DHW\_cr} = Q_{req\_1\_year\_DHW\_cr}$$

f “Apply correction for domestic hot water energy (optional)?” is “Yes”, then

If “Total system efficiency of DHW is known?” is “Yes”, then

$$Q_{req\_STD\_DHW\_cr} = Q_{STD\_net\_DHW\_cr} / \text{Eta}_{DHW\_tot}$$

where,

$$Q_{STD\_net\_DHW\_cr} = S_{req\_DHW\_cr} \times Q_{STD\_net\_DHW\_tot}$$

where,

$S_{req\_DHW\_cr} = S_{req\_1\_year\_DHW\_cr} / Q_{STD\_net\_DHW\_tot}$  is calculated in step 1.

if “Total system efficiency of DHW is known?” is “No”, then

$Q_{req\_STD\_DHW\_cr} = Q_{req\_1\_year\_DHW\_cr} \times f_{DHW}$   $f_{DHW}$  is calculated in step 1.

Space cooling:

$$Q_{req\_STD\_C\_cr} = Q_{act\_C\_cr} \times f_{CDD\_1\_year} \times f_{CDD\_STD}$$

Other:

$$Q_{req\_STD\_OTH\_cr} = Q_{act\_OTH\_cr} \times f_t$$

$Q_{act\_i\_cr}$  [kWh] is the input value of application  $i$  for energy carrier  $cr$  corresponding to the monitoring period between the start date and end date. The calculation of the energy required to be delivered per application and per energy carrier is done on the energy carriers of type 1 and type 2.

The total energy required to be delivered to application  $i$  for standard use and climate  $Q_{req\_STD\_i\_tot}$  [kWh/year] is calculated per each application:

Space heating:  $Q_{req\_STD\_H\_tot} = \text{Sum}_i(Q_{req\_STD\_H\_cr})$

Domestic hot water:  $Q_{req\_STD\_DHW\_tot} = \text{Sum}_i(Q_{req\_STD\_DHW\_cr})$

Space cooling:  $Q_{req\_STD\_C\_tot} = \text{Sum}_i(Q_{req\_STD\_C\_cr})$

Other:  $Q_{req\_STD\_OTH\_tot} = \text{Sum}_i(Q_{req\_STD\_OTH\_cr})$

These calculations also include energy carriers of type 1 and type 2.

The relative shares of the energy required to be delivered for standard use and climate by energy carriers of type 2 per application  $i$   $S_{req\_STD\_i\_cr2}$  [-] are calculated as following:

Space heating: if  $Q_{req\_STD\_H\_tot2} = 0$ ;  $S_{req\_STD\_H\_cr2} = 0$

Otherwise:  $S_{req\_STD\_H\_cr2} = Q_{req\_STD\_H\_cr2} / Q_{req\_STD\_H\_tot2}$

where:  $Q_{req\_STD\_H\_tot2} = \text{Sum}_i(Q_{req\_STD\_H\_cr2})$

This is done analogically for each application.

#### *Calculation of the standard energy available by energy carriers of type 1*

The available energy by energy carriers of type 1 per application  $i$  for standard climate  $Q_{ava\_STD\_i\_cr1}$  [kWh/year] for energy carriers PV energy delivered from on-site and solar thermal energy delivered from on-site, are calculated per application using the following equations:

Space heating:  $Q_{ava\_STD\_H\_cr1} = Q_{act\_H\_cr1} \times f_{I\_sol\_1\_year} \times f_{I\_sol\_STD}$

Domestic hot water:  $Q_{ava\_STD\_DHW\_cr1} = Q_{act\_DHW\_cr1} \times f_{I\_sol\_1\_year} \times f_{I\_sol\_STD}$

Space cooling:  $Q_{ava\_STD\_C\_cr1} = Q_{act\_C\_cr1} \times f_{I\_sol\_1\_year} \times f_{I\_sol\_STD}$

Other:  $Q_{ava\_STD\_OTH\_cr1} = Q_{act\_OTH\_cr1} \times f_{I\_sol\_1\_year} \times f_{I\_sol\_STD}$

Exportation:  $Q_{ava\_STD\_EXP\_cr1} = Q_{act\_EXP\_cr1} \times f_{I\_sol\_1\_year} \times f_{I\_sol\_STD}$

The exportation is not considered for Solar thermal energy delivered from on-site.

For energy carrier Wind electrical energy delivered from on-site and Environment energy delivered from on-site, the equations are the following:

Space heating:  $Q_{ava\_STD\_H\_cr1} = Q_{act\_H\_cr1} \times f_t$

Domestic hot water:  $Q_{ava\_STD\_DHW\_cr1} = Q_{act\_DHW\_cr1} \times f_t$

Space cooling:  $Q_{ava\_STD\_C\_cr1} = Q_{act\_C\_cr1} \times f_t$

Other:  $Q_{ava\_STD\_OTH\_cr1} = Q_{act\_OTH\_cr1} \times f_t$

Exportation:  $Q_{ava\_STD\_EXP\_cr1} = Q_{act\_EXP\_cr1} \times f_t$

The exportation is not considered for Environment energy delivered from on-site.

The total energy available by energy carriers of type 1 per application for standard climate  $Q_{ava\_STD\_i\_tot1}$  is equal to the sum of the energy available to application  $i$  by all energy carriers of type 1 for standard climate:

Space heating:  $Q_{ava\_STD\_H\_tot1} = \text{Sum}_i(Q_{ava\_STD\_H\_cr1})$

$Q_{ava\_STD\_i\_tot1}$  for other energy carriers is calculated analogically to the equations above.

The relative shares of the available energy by energy carriers of type 1 per application  $i$  for standard climate  $S_{ava\_STD\_i\_cr1}$  [-] are also calculated per application:

Space heating: if  $Q_{ava\_STD\_H\_tot1} = 0$ ;  $S_{ava\_STD\_H\_cr1} = 0$

Otherwise:  $S_{\text{ava\_STD\_H\_cr1}} = Q_{\text{ava\_STD\_H\_cr1}} / Q_{\text{ava\_STD\_H\_tot1}}$

$S_{\text{ava\_STD\_i\_cr1}}$  for other energy carriers is calculated analogically to the equations above.

*Calculation of the standard energy delivered and exported by energy carriers of type 2 per application*

The calculation of the total standard energy delivered by type 2 energy carriers per application  $Q_{\text{del\_STD\_i\_tot2}}$  [kWh/year] is done separately for each application, space heating, domestic hot water, space cooling, and other using the following equation:

Space heating:  $Q_{\text{del\_STD\_H\_tot2}} = \text{MAX}(0; Q_{\text{req\_STD\_H\_tot}} - Q_{\text{ava\_STD\_H\_tot1}})$

This is done in the same way for other energy applications.

The calculation of the standard energy delivered by energy carriers of type 2 per application and per energy carrier is done by distributing the total standard energy delivered by energy carriers of type 2 per application  $Q_{\text{del\_STD\_i\_tot2}}$  according to the shares equal to the relative shares of the required energy to be delivered for standard use and climate by energy carriers of type 2 per application  $i$   $S_{\text{req\_STD\_H\_cr2}}$  (the result of step 2).

Space heating:  $Q_{\text{del\_STD\_H\_cr2}} = S_{\text{del\_STD\_H\_cr2}} \times Q_{\text{del\_STD\_H\_tot2}}$

where,

$S_{\text{del\_STD\_H\_cr2}} = S_{\text{req\_STD\_H\_cr2}}$

This is done in the same way for other energy applications.

The standard energy delivered for electrical energy production is rescaled to meet the original ratio of fuel associated with electrical energy output to fuel associated with the thermal energy output of the CHP system(s).

$Q_{\text{del\_STD\_ELE\_FuelCHP}} = Q_{\text{del\_STD\_TH\_FuelCHP}} \times R_{\text{ele/th}}$

where,

$Q_{\text{del\_STD\_TH\_FuelCHP}} = Q_{\text{del\_STD\_H\_FuelCHP}} + Q_{\text{del\_STD\_DHW\_FuelCHP}} + Q_{\text{del\_STD\_C\_FuelCHP}} + Q_{\text{del\_STD\_OTH\_FuelCHP}}$

$R_{\text{ele/th}} = Q_{\text{act\_ELE\_FuelCHP}} / Q_{\text{act\_TH\_FuelCHP}}$

where,

$Q_{\text{act\_TH\_FuelCHP}} = Q_{\text{act\_H\_FuelCHP}} + Q_{\text{act\_DHW\_FuelCHP}} + Q_{\text{act\_C\_FuelCHP}} + Q_{\text{act\_OTH\_FuelCHP}}$

FuelCHP is an energy carrier of type fuel for CHP.

The electrical energy produced by CHP is also rescaled in equal relative share. The total standard electrical energy produced by CHP  $Q_{\text{del\_STD\_tot\_EleCHP}}$  is calculated with the following equation:

$Q_{\text{del\_STD\_tot\_EleCHP}} = Q_{\text{del\_STD\_ELE\_FuelCHP}} \times Q_{\text{act\_TOT\_EleCHP}} / Q_{\text{act\_ELE\_FuelCHP}}$

where,

$Q_{\text{act\_tot\_EleCHP}} = Q_{\text{act\_H\_EleCHP}} + Q_{\text{act\_DHW\_EleCHP}} + Q_{\text{act\_C\_EleCHP}} + Q_{\text{act\_OTH\_EleCHP}} + Q_{\text{act\_EXP\_EleCHP}}$

The standard electrical energy produced by CHP and exported is calculated using the equation below:

$Q_{\text{del\_STD\_EXP\_EleCHP}} = Q_{\text{del\_STD\_TOT\_EleCHP}} - (Q_{\text{del\_STD\_H\_EleCHP}} + Q_{\text{del\_STD\_DHW\_EleCHP}} + Q_{\text{del\_STD\_C\_EleCHP}} + Q_{\text{del\_STD\_OTH\_EleCHP}})$

EleCHP is an energy carrier of type electrical energy produced by CHP.

*Calculation of the standard energy delivered and exported by energy carriers of type 1 per application*

The total standard energy delivered by energy carriers of type 1 of application  $i$   $Q_{del\_STD\_i\_tot1}$  is calculated separately for each application for space heating, domestic hot water, space cooling, and other and per energy carrier of type 2:

Space heating:  $Q_{del\_STD\_H\_tot1} = \text{MIN}(Q_{req\_STD\_H\_tot} ; Q_{ava\_STD\_H\_tot1})$

This is done in the same way for other energy applications.

The standard energy delivered by energy carriers of type 1 per application and per energy carrier is calculated in the following way:

Space heating:  $Q_{del\_STD\_H\_cr1} = S_{del\_STD\_H\_cr1} \times Q_{del\_STD\_H\_tot1}$

where,  $S_{del\_STD\_H\_cr1} = S_{ava\_STD\_H\_cr1}$

This is done in the same way for other energy applications.

## ANNEX IV. RENOVATION ADVICE

Information options available in the QualDeEPC project about the building envelope and technical systems installed - in order to determine the renovation advice - are presented in the tables 41-50 below.<sup>42</sup>

Construction type	U-value
Stone wall	4.25 W/(m <sup>2</sup> K)
Brick wall without thermal insulation	2.5 W/(m <sup>2</sup> K)
Brick wall with thermal insulation	0.7 W/(m <sup>2</sup> K)
Brick wall with reinforced thermal insulation	0.6, 0.5, 0.45 and 0.4 W/(m <sup>2</sup> K) according to the climatic zone where the building is located
Timber wall	n/a
Light concrete wall	n/a
Reinforced concrete panels	n/a
Any wall with “high” thermal insulation properties	[e.g., U=0,2 W/(m <sup>2</sup> K)]
Other type (i.e., exceptional thermal insulation properties, reinforced concrete, waterproof coating with exposed face brick)	1.80

Table 41: Walls (exemplary values for the case of Greece)

Construction type	U-value
Uninsulated Pitched roof	4.25 W/(m <sup>2</sup> K)
Pitched roof with insulation	0.5 W/(m <sup>2</sup> K)
Pitched roof with reinforced insulation	0.5, 0.45, 0.4 and 0.35 W/(m <sup>2</sup> K) according to the climatic zone
Flat roof without insulation	3.05 W/(m <sup>2</sup> K)
Flat roof with typical insulation	0.5, 0.45, 0.4 and 0.35 W/(m <sup>2</sup> K) according to the climatic zone
Flat roof with reinforced insulation	U=0,2 W/(m <sup>2</sup> K)
Other type (i.e., exceptional thermal insulation properties)	n/a

Table 42: Roof (exemplary values for the case of Greece)

<sup>42</sup> The values in the tables below are exemplary values taken from the QualDeEPC tool for the case of Greece.

Construction type	U-value
Floor in contact with the ground without insulation	3.1 W/(m <sup>2</sup> K)
Floor in contact with the ground with insulation	3, 1.9, 0.8 and 0.8 W/(m <sup>2</sup> K), according to the climatic zone
Floor in contact with the ground with reinforced insulation	1.2, 0.9, 0.75 and 0.7 W/(m <sup>2</sup> K), according to the climatic zone
Floor in contact with the ground with reinforced insulation	2.00
Ground floor in contact with unheated basement with insulation	0.80

Table 43: Floors (exemplary values for the case of Greece)

Construction type	U-value
Wooden frame single glazed windows	5 W/(m <sup>2</sup> K)
Wooden frame double glazed windows	2.9 W/(m <sup>2</sup> K)
Wooden frame double glazed low-e (low-emissivity) windows	2.1 W/(m <sup>2</sup> K)
Aluminium frame single glazed windows	6 W/(m <sup>2</sup> K)
Aluminium frame single glazed windows	3.7 W/(m <sup>2</sup> K)
Aluminium frame with double low-e glazing	3 W/(m <sup>2</sup> K)
Aluminium frame with thermal break and double glazing	2.9 W/(m <sup>2</sup> K)
Aluminium frame with thermal break and double low-e glazing	2.3 W/(m <sup>2</sup> K)
Synthetic frame single glazed windows	5.0 W/(m <sup>2</sup> K)
Synthetic frame double glazed windows	3.0 W/(m <sup>2</sup> K)
Aluminium frame double glazed equipped with thick argon or krypton thermal break and low-e glass	1.5 W/(m <sup>2</sup> K)
Synthetic or wooden frame double glazed with thick argon or krypton thermal break and low-e glass	1.2 W/(m <sup>2</sup> K)
Other window type with very low U-value (e.g., triple glazed, vacuum gap)	U < 0.9 W/(m <sup>2</sup> K)

Table 44: Windows (exemplary values for the case of Greece)

Shading type	Value
Shading not present	Shading coefficients: $F_{hor}=0.91$ , $F_{on}=0.93$ , $F_{fin}=0.46$
Shading present (shading covering 30% of the facade)	0.2/0.3 according to the orientation of the building component Shading coefficients: $F_{hor}=0.86$ , $F_{on}=0.73$ , $F_{fin}=0.28$
Shading present (shading covering 70% of the facade)	Shading coefficients: $F_{hor}=0.91$ , $F_{on}=0.93$ , $F_{fin}=0.46$

Table 45: Shading (exemplary values for the case of Greece)

Heating system type	Efficiency
Conventional fuel oil boiler	0.84
Condensing fuel oil boiler	0.97
Conventional gas boiler	0.90
Condensing gas boiler	0.97
Conventional air conditioning unit - (old technology)	2.00
Air conditioning unit (with inverter)	3.20
Local electrical units	1.00
Biomass boiler	0.95
Biomass pellet boiler	0.95
Geothermal heat pump	4.80
Air-to-water heat pump	n/a
Air-to-air heat pump	n/a
Exhaust air heat pump	n/a
Stove	0.57
District heating	0.98
Small-scale CHP unit	0.75

Table 46: Heating system (exemplary values for the case of Greece)

Cooling system type	Efficiency
No cooling system	-
Local air conditioning units - (old tech)	2.2
Local air conditioning units - (with inverter)	3.3
AC units with inverter driven technology (VRF/VRV)	3.5
Geothermal heat pump	4
District cooling system	n/a
Central cooling system	3.5

*Table 47: Cooling system (exemplary values for the case of Greece)*

System type	Mechanical Ventilation
Heating system	Y/N
Cooling system	Y/N

*Table 48: Mechanical ventilation (exemplary values for the case of Greece)*

Hot water system type	Efficiency
Boiler	0.88, 0.9/0.97 according to the boiler type
Electrical resistance heater (instantaneous)	1
Electrical resistance storage heater	n/a
Boiler and solar collector	0.88, 0.9, 0.97 according to the boiler type (flat solar collector)
Electrical resistance storage heater and solar collector	1 (flat solar collector)
Geothermal heat pump	n/a
Domestic hot water heat pump	n/a
Domestic hot water heat pump	n/a
District heating	0.98

*Table 49: Domestic hot water (exemplary values for the case of Greece)*

RES type	Description
Solar Thermal collector (for DHW)	0.5
Geothermal Heat Pump (for space heating & DHW)	4.8
Biomass boiler (for space heating & DHW)	1
Solar photovoltaic (monocrystalline efficiency 16%)	efficiency 16%
Solar thermal collector for space heating	0.9
Solar photovoltaic (Polycrystalline and thin film PVs)	efficiency 19%

*Table 50: Renewable energy sources (exemplary values for the case of Greece)*



# iBRoad2EPC

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