iBRoad2EPC

Integrating Building Renovation Passports
into Energy Performance Certification schemes
for a decarbonised building stock

Experience from other projects

Report on linking Energy Performance Certificates (EPCs) with the Building Renovation Passport (BRP)

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EXECUTIVE SUMMARY

The project iBRoad (individual Building Renovation Roadmaps) developed and tested a method and tool supporting energy assessors in developing individual building renovation roadmaps.

In the context of the project iBRoad2EPC, we considered expanding the scope of iBRoad along various dimensions.

This report aims to provide a summary of research outputs of projects related to next-generation Energy Performance Certificates (EPCs) and deep renovation regarding new features and their calculation methodologies or approaches, analysing them given their potential integration into iBRoad2EPC. For this purpose, this report screens a list of 20 recent European projects and activities dealing with building renovation passports and EPCs with the perspective of making use of relevant insights, tools, and methods for the project iBRoad2EPC. Based on a set of criteria, we selected seven projects and clustered them along five features, i.e., Indoor Environmental Quality, Smart Dimension (Smart Readiness Indicator – SRI), Measured Performance, Renovation Advice, and Digital Building Logbook, potentially relevant in the context of the project iBRoad2EPC.

The task and relevant report were intended as an initial scanning through and quick assessment of relevant features available and their respective methodologies in order to support further discussions early on in the process.

The following key conclusions can be extracted from this work:

- Indoor Environmental Quality is one of the key co-benefits of building renovation. By integrating this relevant feature into iBRoad2EPC, both energy performance and Indoor Environmental Quality (IEQ) can be further enhanced. We propose to integrate the comfort method assessing the IEQ as developed initially in the project X-tendo.
- The smart dimension is a key functionality that future renovation passports and EPCs need to encompass, not only due to the strong focus of the recent legislation. We propose to integrate the method of the European Commission's (EC) SRI study in the iBRoad2EPC framework.
- For the acceptance and relevance of renovation passports and EPCs, it is crucial to reduce the gap between measured and calculated energy performance; introducing the measured performance feature into iBRoad2EPC is deemed beneficial, based on the method developed in the project X-tendo.
- Renovation advice is at the core of the iBRoad and iBRoad2EPC projects, and the development of a method for assisting building assessors and energy advisors in developing customised long-term renovation advice in line with long-term renovation strategies and climate policy targets is necessary. The corresponding tool developed in the project QualdeEPC could be consulted for this purpose.
- Digital building logbooks play a key role in storing building data and making it accessible to building owners, occupants, and potentially other stakeholders like energy assessors, policymakers, professionals, and financing institutions, e.g., via one-stop-shop platforms. iBRoad2EPC should therefore have a clear link to the digital building logbook. For this purpose, we mainly build on the work and concepts developed and tested in the iBRoad project.

More details on the calculation methodologies and information about how and to which extent the relevant features can be integrated in the iBRoad2EPC context are described in the iBRoad2EPC report "*Extending the iBRoad Building Renovation Passport II – Report on potential indicators to expand the scope of iBRoad*".

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INTRODUCTION

The H2020 project iBRoad (2017-2020 - individual Building Renovation Roadmaps) developed, tested, and delivered a model for the Building Renovation Passport (Roadmap + Logbook) supporting single-family homeowners with personalised advice to facilitate deep renovation stepwise. In the context of its successor project, iBRoad2EPC, we consider expanding the scope of iBRoad along various dimensions. Other projects in the past have elaborated numerous methods, tools, guidelines, and analyses in the context of renovation passports, individual building renovation roadmaps, and energy performance certificates. For further activities in the project iBRoad2EPC, it is important to build on these activities and make use of previous developments as far as possible.

This report aims to provide a concise summary of research outputs, methodologies, or proof of concepts of projects related to next-generation EPCs and deep renovation regarding new features (e.g., Indoor Environmental Quality, the smart dimension, measured performance, digital building logbook) and their calculation methodologies or approaches, by analysing them concerning their potential integration into iBRoad2EPC. Even though it would also be interesting to screen the references for financial or cost aspects, this was not the focus of this work. As a result of this project screening, we identify a sub-set of projects and cluster them along certain features, which are described in a bit more detail. Subsequently, the report title selects one method for each of these features, and describes how the relevant method can be adapted for implementation within iBRoad2EPC.

INITIAL SCREENING OF PROJECTS

Initially, we screened 20 projects, mainly projects funded within Horizon 2020 or by the EC as tender studies. According to the knowledge of the authors, this list comprehensively covers recent European Union (EU) projects and activities on the topics of renovation passports and EPCs. **Error! Reference source not found.** shows the overview of all projects which have been screened.

Project and activities	Brief description	Features covered
Levels	Level(s) is a European framework that provides a common language for assessing and reporting on the sustainability performance of buildings.	IEQ, LCA, Embodied energy
QualDeEPC (01.09.2019 - 28.02.2023)	QualDeEPC aims to enhance the quality and cross-EU convergence of Energy Performance Certificate (EPC) schemes and the link between EPCs and deep renovation.	Deep renovation, EPC assessment
U-Cert (01.09.2019 - 30.11.2022)	U-Cert introduces the next generation of user-centered Energy Performance Assessment and Certification Scheme to value buildings holistically and cost-effectively, supported by an EU-wide training and certification process for building professionals.	Smart dimension, actual/measured performance, IEQ
X-tendo (01.09.2019 - 31.08.2022)	X-tendo and its toolbox introduce ten features of the next generation of Energy Performance Certificates to provide public authorities with improved compliance, reliability, usability, and convergence of next-generation energy performance assessment and certification.	IEQ, Smart dimension
SRI study (September 2020)	The Smart Readiness Indicator (SRI) is a common EU scheme for rating the smart readiness of buildings in their capability to perform three key functionalities; to optimise energy efficiency and overall in-use performance, to adapt their operation to the needs of the occupant, and to adapt to signals from the grid (e.g., energy flexibility).	Smart dimension
ePANACEA (01.06.2020 - 31.05.2023)	ePANACEA comprises the creation of a prototype (the Smart Energy Performance Assessment Platform) by using the most advanced techniques in dynamic and automated simulation modelling, big data analysis and machine learning, inverse modelling, or the estimation of potential energy savings and economic viability check.	Smart dimension
INSPIRE (May 2007)	The INSPIRE Directive aims to create an EU spatial data infrastructure for EU environmental policies and policies or activities which may have an impact on the environment.	Smart dimension
DBL study (December 2020)	The study provides the basis for the development of an EU framework for Digital Building Logbooks focusing on three priority actions to spread the use and efficient functioning of Digital Building Logbooks, development of a standardised approach for data collection, data management and interoperability, and its legal framework, development of guidelines for linking existing databases, and launch of public-funded R&I projects to further explore the Digital Building Logbook concept and its implementation.	Digital building logbook
ALDREN (01.11.2017 - 30.09.2020)	ALDREN (ALliance for Deep RENovation in Buildings) targets and supports investments in deep renovation, encouraging key building stakeholders to contribute to the "Renovation Wave", an initiative recently announced in the European Green Deal.	Building renovation passport, EPC assessment

Project and activities	Brief description	Features covered
EPC Recast (01.09.2020 - 31.12.2023)	The objective of the EPC Recast project is to support the work of professional EPC assessors to achieve improved EPC reliability, comparability between building assets, and user-friendliness.	Building renovation passport, EPC assessment
E-DYCE (01.09.2020 - 31.08.2023)	The E-DYCE (Energy flexible DYnamic building CErtification) aims to provide an energy performance labelling methodology that will be closer to building operation conditions and will be able to defend its voluntary status by the benefits it provides.	Total cost of ownership, smart dimension
EPB Center	The EPB Center focuses on the international harmonised set of EPB assessment methods and their implementation at national and regional levels.	Building assessment
EU Commission's EPBD 19a study (May 2020)	The EC-funded study, which is looking into the building renovation passport and its potential in future EU policies, focuses on a review of building renovation passport schemes and related initiatives, an analysis of the relevance, feasibility, and possible scope of measures at the EU level for building renovation passports.	Building renovation passport
D2EPC (01.09.2020 - 31.08.2023)	D2EPC aims to set the grounds for the next generation of dynamic Energy Performance Certificates (EPCs) for buildings, with its foundations set on the smart-readiness level of the buildings and the corresponding data collection infrastructure and management systems.	Smart dimension
BAMB (01.09.2015 - 28.02.2019)	Project BAMB (Buildings as Material Banks) aims to enable a systemic shift where dynamically and flexibly designed buildings can be incorporated into a circular economy.	LCA, Embodied energy, circularity, logbooks
CrossCert (01.09.2021 - 31.08.2024)	CrossCert contributes to the success of the next-generation EPCs (Energy Performance Certificates) by elaborating and testing guidelines and recommendations that achieve improved accuracy and usability of the certificate, people-centric design and satisfactory user experience, and increased homogeneity across Europe.	EPC assessment, overall
EN-Track (01.11.2020 - 31.10.2023)	The goal of EN-TRACK is to create a one-stop shop platform with standardised data related to the energy efficiency performance of the public and private building stock, which will lead to an unambiguous data exchange-based services ecosystem with low transactional costs.	Smart dimension, logbooks, actual/measured performance
EUB SuperHub (01.06.2021 - 31.05.2024)	The EUB SuperHub project will support the evolvement of the certification process in the EU by the development of a scalable methodology to view, assess and monitor the buildings through their lifecycle (embedded energy, costs, etc.).	Level(s), LCA, LCC, Embodied energy
TIMEPAC (01.07.2021 - 30.06.2024)	TIMEPAC helps to improve existing energy certification processes and move from single, static certification to more holistic and dynamic approaches.	SRI, Building renovation passport, large scale analysis
Smartbuilt4eu (01.10.2020 - 31.03.2023)	The SmartBuilt4EU project aims to foster collaboration between stakeholders of the smart building value chain, promote their innovations, and identify R&D gaps and policy recommendations to support the further uptake of smart buildings.	Smart dimension

Table 1: Overview of all the analysed projects

SELECTION OF STUDIES MOST RELEVANT FOR IBROAD2EPC

All projects were evaluated against the following criteria: the political relevance of the feature (in terms of compatibility with the Energy Performance of Buildings Directive (EPBD) and the proposal for recast), time effort to gather the required data, complexity for integrating with the iBRoad2EPC tool, methodological relevance, and maturity of the methodology. Each of the mentioned criteria was rated 0, 1, or 2. The rating is explained in **Error! Reference source not found.**. Rating “1” is in b etween “0” and “2”.

Criteria	0	2
Time effort to gather the required data (additional to the data provided from the EPC)	Very long	Short
Complexity to integrate with the iBRoad2EPC tool	A methodology has to be programmed (IT effort is required)	An already developed spreadsheet can be uploaded to the iBRoad2EPC tool
Methodological relevance	The purpose of the methodology is different from the one of iBRoad2EPC	The purpose of the methodology is compatible with the purpose of iBRoad2EPC
Maturity of the methodology	Only theoretical and not tested	Fully developed
Political relevance (compatibility to EPBD and new proposal)	No direct link with EPBD	Direct link with EPBD

Rating “1” describes projects in between the two extreme ratings “0” and “2”.

Table 2: Rating criteria

The points for each criterion were added up so that every project could score a maximum of ten points. To be selected, the project needed a minimum of seven points. This led to a selection of seven out of 20 projects to be further investigated in the context of the iBRoad2EPC project. The selected projects (see Annex) are described in more detail below, structured by relevant features along which iBRoad is considered to be expanded within the iBRoad2EPC project:

Feature	Projects
Indoor Environmental Quality	X-tendo Level(s) U-Cert ALDREN
Smart dimension	EC SRI study X-tendo
Measured performance	X-tendo ALDREN
Renovation advice	QualDeEPC X-tendo
Digital building logbooks	Tender for the EC iBRoad X-tendo

Table 3: List of selected projects for each feature

The following section provides more information about the selected projects.

X-tendo: The X-tendo project developed ten different innovative features for improving the reliability, usability, and convergence of EPCs: five features on innovative indicators and five features on innovative handling and use of EPC data. Those relevant to iBRoad2EPC are SRI, comfort, smart dimension, outdoor air pollution, and real energy consumption (methodological approaches and spreadsheets available in the X-tendo toolbox). The project was completed in 2022.

Level(s): Level(s) is a common language for building assessment and the basis for reporting activities on buildings, covering IEQ, Life Cycle Assessment (LCA), and embodied energy indicators [1]. Level(s) can enhance dialogue between design, technical and financial actors in new build and renovation projects. Level(s) propose indicators that are also in the interest of iBRoad2EPC. However, there is much more to the Level(s) framework than just a common cross-European methodology of reporting on some indicators that are central to iBRoad2EPC. This is also a tool to inform other (especially financial) mechanisms that the activity on the building is sustainable and, therefore, can apply and expect to receive public funds (next generation, renovation wave, etc.). Furthermore, the project Lifelevels aims at increasing awareness and use of the specified indicators within the framework of Level(s) and thus builds on the Level(s) framework [2].

U-Cert: This project introduces the next generation of user-centred Energy Performance Assessment and Certification Scheme [3]. Indicators used to assess the buildings are the smart dimension and actual/measured performance, which are directly related to the EPC schemes and EPC-related data. Related spreadsheet tools have been elaborated on and are available. The project developed indicators as proposed in the iBRoad2EPC project. The main focus of the project is, however, the EPC data. The project started in 2019 and is expected to be completed in 2022.

ALDREN: This project was funded by Horizon 2020, aiming to explore EPC and passports for non-residential buildings [4]. ALDREN is a methodological framework consisting of four standalone modules to assess energy performance: Indoor Environmental Quality, financial value of buildings, and two reporting tools (EU Voluntary Certificate, Building Renovation Passport). Indicators covered within this project are Building renovation passports, EPC assessment, IEQ, and Costs. Based on the description on the website, the effort seems to be not very time-consuming. The project proposes methods that should be IT implemented into the iBRoad2EPC tools. The project developed indicators as proposed in the iBRoad2EPC project. The project was finalised in 2020.

EPC Recast: House owners' considerations about the usefulness of the EPC are central as owners decide whether to implement energy conservation opportunities provided by the EPC. EPC Recast is a decisive decision-supporting tool for tenants and potential buyers and will provide guidance on cost-optimal building renovation for building owners [5]. Beyond user-friendliness and awareness, EPC Recast develops and consolidates methodologies and tools to support professionals and building certifiers performing EPCs. The project also supports real estate and building owners to invest more in building performance improvement.

QualDeEPC: QualDeEPC is another Horizon 2020-funded project which aims to enhance (1) the quality and cross-EU convergence of Energy Performance Certificate (EPC) schemes and (2) the link between EPCs and deep renovation [6]. QualDeEPC addresses EU-wide convergence of the building assessment and the issuance, design, and use of quality-enhanced EPCs and their recommendations for building renovation. The goal is to make the recommendations consistent with deep energy renovation to have a nearly-zero energy building stock by 2050. The project is expected to finish in early 2023.

Following the structuring of projects along key features as listed above, the following chapters include – for each feature – a brief introduction and summary.

INDOOR ENVIRONMENTAL QUALITY

Indoor Environmental Quality is one of the key co-benefits of building renovation. By integrating a relevant feature into iBRoad2EPC, both energy performance and indoor quality can be further enhanced.

X-tendo Comfort Feature

X-tendo's IEQ features are the Comfort Asset Rating Procedure (CARP) and the Comfort Operational Rating Procedure (CORP).

The Comfort Asset Rating Procedure (CARP) is based on simplified checklists of materials and systems completed by the assessor during an on-site visit. For CARP rating, the assessor should have basic technical and soft skills [7]. CARP is mainly applicable to non-occupied buildings but can also be applied to occupied buildings. In this case, 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 Comfort Operational Rating Procedure (CORP) provides real information on how comfortable the building is at its actual use. The rating is derived based on measurements of carbon dioxide concentrations, temperature, and relative humidity. It also involves a survey of occupants' perceptions of thermal comfort, indoor air quality, visual comfort, and acoustics and checklists that are filled in by the assessor. For CORP rating, the assessor should have intermediate technical and soft skills [8].

The comfort indicator can be applied to any building type. The developed approach was tested in residential, school, and office buildings in Greece, Romania, Austria, and Portugal. The key findings from the testing are [9]:

- CARP was easier to implement in comparison to CORP
- CARP can also be used as a design tool for buildings
- CARP and CORP have similar final comfort ratings[1], and CORP was found to be lower than CARP [8] (meaning worst comfort)

The X-tendo comfort feature is very relevant for iBRoad2EPC as it offers a reliable approach to evaluating the comfort levels in buildings. The way the feature is developed gives the option for a more detailed and quicker yet robust evaluation of the indoor environmental quality while considering time and cost restrictions. Costs are kept to the minimum while assuring necessary effectiveness and technical specifications. In addition, the comfort rating is simple and, as it is visualised, can be easily communicated, making it particularly user-friendly. The methodology builds on relevant EU standards, and all indicators are developed in a way which ensures the high quality of the evaluation process.

For the needs of iBRoad2EPC, where a quick, less expensive, and time-consuming approach is necessary, the CARP method can be adopted. The method assesses the capacity of the building to provide a comfortable indoor environment. In terms of required effort, an assessor having basic technical knowledge will need up to two hours on-site to inspect the building and fill in the checklists.

Level(s)

The Level(s) common framework is based on six macro-objectives that address key sustainability aspects over the building life cycle. One of these six macro-objectives is 'healthy and comfortable spaces', defined as the design of buildings that are comfortable, attractive, and productive to live and work in and which protect human health. It includes the following four indicators:

- Indoor air quality, i.e., the indoor air for specific parameters and pollutants

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[1] Final comfort rating revers to the overall rating of comfort based on the individual ratings estimated for each of the indicators of thermal comfort, indoor air quality, visual and acoustic comfort

- Time outside of thermal comfort range
- Lighting and visual comfort, i.e., the quality of artificial and natural light and associated visual comfort
- Acoustics and protection against noise, i.e., the capacity of the building fabric to insulate occupiers from internal and external sources of noise

The initial focus areas for this macro-objective are indoor air quality and thermal comfort. For indoor air quality, two composite indicators are provided, with each requiring the consideration of multiple parameters related to the quality of the indoor air in the useful internal spaces of a building. In the case of thermal comfort, an assessment is needed of the time out of thermal comfort range of a building's useful internal space during an average year. Since there are many possible aspects of this macro-objective, and the mentioned indicators only reflect two of them, initial guidance is also provided on performance assessment for two other aspects that may be considered for potential future indicator development. These are lighting and visual comfort, and acoustic performance of the building fabric.

Each indicator has either one, two, or three levels that can be applied at each stage of a building´s life cycle. Level 1 is about early-stage qualitative assessments and reporting on the concepts that the indicator will cover. It provides a simple structure that can be presented to clients to prioritise attention on sustainability aspects. Level 2 is a quantitative assessment of the designed performance, which allows comparison between different design options and construction monitoring according to standardised units and methods. Level 3 is monitoring and surveying activity both on the construction site and the completed building and its first occupants. This level helps the entire team understand actual building performance and identify lessons learned from the design to inform and improve future projects. Indoor air quality and thermal comfort are elaborated on all three levels, while for lighting and visual comfort, and for acoustic performance, users can only choose level 1 (qualitative assessments and reporting on the concepts).

U-Cert

In U-Cert, IEQ indicators cover parameters such as room temperature, airflow, air velocities, CO_2 levels, and heating, ventilation, and air conditioning (HVAC) system noise [10]. In new buildings and large-scale renovations, a minimal amount of additional access to design documentation and enhanced assessor competency would be required. For example, one of the most frequent concerns about the indoor environment in contemporary non-residential buildings is draught; therefore, additional design information concerning air distribution and air quality is required. Nevertheless, the design criteria for the indoor environment parameters must be stated in the building's design documentation. The evaluation effort of IEQ for certification is justifiable if all calculation and simulation reports that demonstrate compliance with the design criteria are provided with the design documentation. On the other hand, the design documentation for existing buildings typically provides limited information, and in some cases, it may not even be available. The IEQ assessment would then need to be conducted on-site.

ALDREN

In the scope of the ALDREN project, an index is created for rating IEQ in buildings that are currently occupied and undergoing Deep Energy Renovation (DER). The project also developed a mechanism for estimating IEQ when DER was being designed in offices and hotels. The first is known as ALDREN-TAIL, or just TAIL, while the second is known as predicTAIL. In all situations, TAIL identifies the four IEQ components –thermal environment (T), acoustic environment (A), indoor air quality (I), and luminous (visual) environment (L) – as well as the overall environmental quality [11].

Twelve IEQ-related parameters make up the TAIL index. Four ranges are defined for each parameter, indicating the four quality levels that correspond to those in the standard EN16798-1. One of the four colours is used to indicate each of the four quality levels of the 12 parameters and four IEQ components that make up the ALDREN-TAIL index: green denotes a high-quality level, yellow a medium-quality level, orange a moderate-quality level, and red a low-quality level.

Quality levels of green, yellow, orange, and red reflect the total IEQ level and are marked with Roman numbers I, II, III, and IV. Before and after energy restoration, the twelve parameters are calculated using measurements in buildings, observations (just visible mould), or models (only daylight factor). The lowest quality is used to define both the quality level of each TAIL component and the overall IEQ level to encourage improvement and avoid compromising any of the key IEQ components.

Since the TAIL index should provide a high IEQ following an energy renovation, it must also be possible for building owners or investors to determine the potential effects of various renovation measures on IEQ. The predicTAIL index was developed with this objective in mind. The IEQ parameters, quality levels, and calculation methodology used in TAIL are also used in PredicTAIL, which is solely based on modelling. PredicTAIL is first modelled as a baseline before refurbishment, and then it is modelled for several renovation approaches. PredicTAIL after and PredicTAIL before energy remodelling can be compared to determine the optimal renovation plan. PredicTAIL is not a TAIL verification tool; rather, it is a supplementary tool for decision-making. Both ought to be utilised separately.

SMART DIMENSION

The EPBD revision of 2018 placed a strong emphasis on the potential of smart technology in the building sector and introduced the concept of a Smart Readiness Indicator (SRI) [12].

The ‘smartness’ of a building is defined as its capacity to detect, comprehend, communicate, and actively react in an effective way to changing conditions concerning

- the operation of technical building systems
- the external environment (including energy grids)
- demands from building occupants

The SRI rates the smart readiness of buildings (or building units) in their ability to perform three key functionalities:

- optimise energy efficiency and overall in-use performance
- adapt their operation to the needs of the occupant
- adapt to signals from the grid (e.g., energy flexibility)

The SRI is intended to raise awareness about the benefits of smart buildings, including energy efficiency, an optimised mix of various energy sources, user occupancy experience, and grid flexibility. In addition, its implementation is expected to stimulate investments in smart building technologies and support the uptake of technology innovation in the building sector. The SRI methodology applies to all types of buildings – residential and non-residential, existing and new – regardless of their size.

SRI study

The official SRI methodology was developed by the EC, and the final report on the technical support for the development of a smart readiness indicator for buildings was finalised by VITO [13]. The study covers smart dimension indicators. There are two possible methodologies, a simplified and a detailed one. In this report we propose that iBRoad2EPC could focus on a simplified version. Nevertheless, both versions are rather time-consuming. Spreadsheets are available online.

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_2 emissions, and improving the comfort and convenience of building occupants.

X-tendo

SRI is selected as one of the X-tendo features to increase the visibility and uptake of smart technologies in the European building stock and link them to the current EPC schemes [14]. Two parallel methodologies have been developed and tested so far to speed up SRI evaluation capabilities. These methodologies vary in the amount of information required and the skills needed by the assessor to quantify the level of smartness. In contrast to other quantification schemes used in existing EPCs, the X-tendo SRI calculation is intended to follow the same general methodology across all Member States.

The testing of the SRI methodology in X-tendo helps to evaluate the viability of collecting data relevant for both EPC and SRI schemes and to quantify the eventual savings in costs and time. In addition, the process includes the systematic collection of qualitative data from SRI assessors and building owners/managers on their view of the new process/indicator.

MEASURED PERFORMANCE

EPCs currently rely primarily on calculated energy demand. For EPC users and other stakeholders, the discrepancy between real energy performance and EPC calculated performance can be large and is frequently a source of confusion (e.g., public authorities, energy managers, financing bodies, and energy suppliers). Investigating how and to what extent measured data of energy use may be linked to the EPC-derived indicators, or perhaps replace them in the current EPC methodology, is crucial to overcoming this obstacle and boosting trust in EPC.

Real energy use data is also necessary for the automation of the processes and the streamlining of on-site inspections. The increased accuracy and better connection between meter readings and billing data enhance user acceptance. Energy performance improvement measures can be better tailored to the specific building, augmenting the quality of renovation advice, which could boost market confidence and encourage additional investments in building energy renovations.

X-tendo

The X-tendo tool for measured performance can be used on residential and non-residential buildings. It is necessary to input basic information that can be gathered from different sources, e.g., energy bills, and may require limited pre-processing to calculate the real energy consumption [15]. 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. The evaluation method is based on the operational EPC rating method and has optional modules to enable reliable inter-building comparison. 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 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_2 emissions and, if desired, the renewable energy ratio. 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).

The methodology has three options to choose from, which differ in the correction approach.

ePANACEA

In the scope of the ePANACEA project, a prototype for the Smart Energy Performance Assessment Platform is developed, which uses the most advanced techniques in dynamic and automated simulation modelling, big data analysis and machine learning, inverse modelling, or the estimation of potential energy savings and economic viability check to overcome, among others, EPC lack of accuracy and the gap between theoretical and real consumption patterns [16].

ALDREN

One of the key attributes adopted by ALDREN is the idea of energy performance verification. An energy performance verification framework allows comparison between actual (measured) performance and simulated (predicted) performance. It includes a “Design for Performance” protocol that sets out and tracks the actions required during the deep renovation process [17]. It also comprises a “Performance Verification Tool” (PVT) to compare predicted and actual performance at different levels of granularity.

The process proposed for ensuring the target energy performance of a deep retrofit is achieved and verified using measured data has the following key steps [17]:

- Calculate energy performance for existing buildings under standard conditions
- Calculate energy performance for existing building under actual conditions
- Measure existing building energy use, compare with predicted energy use and calibrate the model to match measurements
- Use a calibrated model to agree on a list of building improvements for fabric, plant, controls, etc.

- Calculate energy performance under actual conditions
- During the first year of operation, compare measured vs. calculated energy under actual conditions at monthly and sub-meter resolution
- Calculate “verified” energy performance under standard conditions for the upgraded building

The ambition for verification of the energy performance suggests an expectation that metered values will be close to the simulated targets; however, there are some challenges. The first challenge is the inadequacies of the models. Commonly used models required for regulatory compliance and EPCs are unlikely to accurately predict energy use by sub-meter. Moreover, there is inefficient building operation. Many (if not most) air-conditioned office buildings suffer from multiple imperfections in the way they are operated and controlled. Finally, we have indoor environmental quality. Control settings in a real building may not match the specifications assumed in the model.

The ALDREN's energy performance verification protocol proposes three elements to help overcome mentioned challenges:

- Dynamic thermal simulation of building design and HVAC system: During the design stages, simulation of the building and its HVAC system and controls, with a time step of one hour or less, should be undertaken to predict heating and cooling demands.
- Independent design review (IDR): An IDR should be undertaken by an independent and experienced energy efficiency professional.
- Continual alignment of actual building with the simulation model: At the start of the design stage, a control plan should be agreed upon, which specifies which parties will be able to control the HVAC (landlord, tenants, hotel guests, etc.). By the end of the final design stage, a simple description of the controls which implement the control plan should be articulated in plain English in a Description of Operations (DesOps).

RENOVATION ADVICE

The energy performance assessment and certification schemes offer an objective estimate of a building's energy efficiency under normal use and cover some of the indicators necessary to assess compliance with long-term renovation strategies required by the EPBD. However, there are several challenges to overcome to increase market confidence and incite investments in energy-efficient buildings, one of those being the quality of the renovation recommendations. Often, EPCs contain standardised and generic recommendations resulting from time and cost restrictions, which only add limited value to homeowners or buyers. Most importantly, EPC current recommendations do not foresee for deep renovation to be achieved through multiple steps over time, which is common practice all over the EU.

Currently, the EPCs recommendations in most European countries are oriented toward the minimum legal requirements. The actions recommended are often low-cost options but not necessarily the most cost-effective ones, while actions that are not low-cost but could be cost-effective in the longer term may not be recommended at all. Additionally, deep renovations require detailed recommendations and measures to avoid lock-ins.

QualDeEPC

The relevant indicators in the scope of QualDeEPC are deep renovation and EPC assessment. Deep renovation and EPCs are both important topics mentioned in the EPBD revision. An online tool for comparing EPC recommendations to deep energy renovation recommendations might be an interesting aspect to analyse. It seems that the same parameters as in the EPC are required. The project also focuses on the development of a Master tool, which compares EPC recommendations to deep energy renovation recommendations. The tool is rather complex, and a serious IT effort is required. The project is widely focused on the EPC recommendations and explored many different aspects under others in two of the iBRoad2EPC countries, Spain and Greece. The project is expected to be completed in 2022.

X-tendo

The aim of the X-tendo feature "Enhanced Recommendations" is to improve the current state of generic recommendations, which often only provide limited value to homeowners or buyers. The enhanced recommendations methodology develops a method to automatically generate useful EPC recommendations, extending the recommendations currently provided in EPC schemes [18]. Although the proposed recommendations will improve the status quo, they cannot fully replace professional advice. Additionally, the methodology suggests an approach to align the EPC recommendations with the national long-term renovation strategies.

The approach is based on the following:

- Enhancing actual recommendations by automatically generating building-specific recommendations
- Demonstrating how the EPC provision process may be extended to incorporate the costs of proposed measures, allowing for the cost-effectiveness of the recommended measures to be determined
- Setting targeted values for recommendations to guarantee that they align with the long-term national renovation and climate strategies for the building stock

The methodology can be divided into three parts, (1) providing measure-by-measure recommendations, (2) assessing the whole building impact of all recommendations, and (3) providing an economic assessment.

LOGBOOK

Digital building logbooks play a key role in storing building data and making it accessible to building owners, occupants, and potentially other stakeholders like energy assessors, policymakers, professionals, and financing institutions, e.g., via one-stop-shop platforms.

Tender for the EC

The EC's "Study on the development of a European Union framework for digital building logbooks" [19] sets out the conceptual definition of logbooks and the pathway for the EU to incentivise the rollout of logbooks across Europe. The work explains the scope and role of the building logbook concept as a more systematic and coherent approach to building-related data and information management, including the type of information collected and stored, their sources, and the functionalities and tools applicable to potential users. The study also provides relevant insights into the key issues concerning the technical and legal aspects of data governance with the intent for the EU to ensure a minimum of harmonisation and standardisation.

The EU Digital Building Logbook (DBL) study builds on thorough stakeholder consultation, interviews with experts, and a detailed analysis of 40 existing building logbook initiatives across Europe and beyond. It identified gaps and recommendations for the progressive implementation of logbooks and the digitisation of building-related data. The list of priority actions includes (1) development of a standardised approach for data collection, data management, and interoperability with its legal framework; (2) development of guidelines for linking existing databases; and (3) launch of public-funded R&I projects to explore the concept and its implementation further.

The EU definition of DBL is comprehensive and covers the entire lifecycle as well as the widest range of potential benefits and uses. As such, it is not restricted to the operation, maintenance, and building renovation and offers a one-stop shop gateway to all information related to the building. Equally, its uses and functionalities are not limited to energy efficiency improvements or renovation roadmaps but span across, e.g., finance, circularity, whole life carbon mitigation, etc.

The EU DBL initiative is relevant for iBRoad2EPC as it may be able (1) to inform data exchange and interoperability between different data sources; (2) to suggest innovative proposals regarding the DBL features, functionalities, and user-friendliness/user interface. In return, iBRoad2EPC could ensure the compatibility of next-generation EPCs with building logbooks and thus feed the follow-up (ongoing) work on technical guidelines to deploy DBLs in the EU Member States.

iBRoad

The Horizon 2020 iBRoad project (2017-2020) worked on eliminating barriers to staged deep renovation by providing proof of concept of the Building Renovation Passport through the development of an individual building renovation roadmap (iBRoad Roadmap) combined with a digital building logbook (iBRoad Logbook). The iBRoad Logbook is a digital repository where all building-related information is stored and continuously updated.

The initially proposed five modules of the iBRoad logbook were [20]:

A. General and administrative information
B. Building construction information
C. Building Energy Performance
D. Building Operation and Use
E. SMART information

The iBRoad logbook is however designed to allow an evolution of the type of information stored as well as of its functionalities and could contain, among others, building performance, energy use and sustainability, equipment maintenance, insurance overview, property plans and obligations, smart meter data and links to available financing options. Data collection could also be expanded to enable circularity in the construction sector, traceability of materials and chemicals, transparency of environmental quality (indoor, and surroundings), reflect the building's smart readiness and be linked with various renovation services, like one-stop shops.

The possibility for data exchange between the EPC and the iBRoad Logbook would enable the logbook to store predefined EPC data and allow better management of the building, improved market information, and transparency, creation of innovative services and business models, as well as more effective policymaking.

The logbook structure developed in the iBRoad project is based on a core/fixed section and a flexible section to allow for certain flexibility to adapt to national/regional needs while serving EU harmonisation across Member States. This approach has been tested and positively evaluated in four pilot countries, i.e., Bulgaria, Germany, Poland, and Portugal [21] followed by an external exploitation action in Ireland [22].

The iBRoad Logbook is thereby considered to be in line with the definition and requirements proposed in the relevant EC study and is ready for further expansion in the context of the iBRoad2EPC project.

X-tendo

The X-tendo building logbook feature also closely follows the EU definition of DBL. The conceptual framework and methodology have been designed according to the core components of the logbook: (1) data templates and access, (2) functionalities and benefits, and (3) data governance. Given the scope of X-tendo, the focus of the logbook features is on enhancing data and information created through EPC certification and making these a source of information for additional stakeholders and uses. Implementing partners developed and tested some of these logbook elements according to their needs and market realities:

- Portugal: added functionalities (Buildings Dashboard and Consumption Monitoring) to the one-stop-shop portal casA+
- Greece: design of a Logbook Messaging Protocol that describes the process of data exchange with the EPC database, as well as the development of a prototype of a logbook software system
- Estonia: development of a functionality to estimate renovation costs and financial planning based on already existing logbook data of renovated buildings

The X-tendo logbook data template is based on a detailed country-specific scoping and review of the EPC data points that are relevant and reliable enough to be included in or linked to the logbook. The X-tendo logbook uses the EPC database as a starting point and can be expanded until it covers all relevant building information. The X-tendo logbook could potentially offer additional insights into questions relevant to iBRoad2EPC, such as:

- What type of data and data sources are to be considered?
- What is the rationale behind the data collected?
- What is the data flow?
- How to link the databases to the building logbook?
- How are the data stored in the building logbook?

CONCLUSION

This report screens a list of 20 recent European projects and activities dealing with building renovation passports and EPCs with the perspective of using the relevant insights, tools, and methods for the iBRoad2EPC project. Based on a set of criteria, we selected seven projects and clustered them along five features potentially relevant to the context of iBRoad2EPC. We briefly summarised the projects for each of these features. In parallel, we consider it important to have further developments in iBRoad2EPC complementary and consistent with the Level(s) framework.

Indoor Environmental Quality is one of the key co-benefits of building renovation. By integrating this co-benefit into the context of building renovation passports and EPCs, the visibility of this co-benefit can be enhanced. Out of the screened projects, we suggest the X-tendo CARP feature for further consideration of being integrated into iBRoad2EPC.

The **smart dimension** is a key functionality that future building renovation passports and EPCs need to encompass, not only due to the strong focus of the recent legislation. The proposed projects featuring smart dimensions were the EC's SRI study and X-tendo. The technical SRI study investigates the scope, definition, and SRI calculation and performs a more detailed assessment of its potential impacts. X-tendo, on the other hand, evaluates potential pathways to integrate the SRI assessment as an integrated part of the EPC.

Measured performance: For the acceptance and relevance of building renovation passports and EPCs, it is crucial to reduce the gap between measured and calculated energy performance. This feature was investigated through three projects, X-tendo, ePANACEA, and ALDREN. The ePANACEA methodology is currently under development, which was the main reason for not choosing it for further consideration. X-tendo's measured performance feature, formulae, and methodology options are well explained and tested. The project provides a spreadsheet for the measured performance feature, which makes implementation clear and straightforward.

Renovation advice is at the core of the iBRoad and iBRoad2EPC projects by developing a method for assisting building assessors and energy advisors in developing customised deep renovation advice for stepwise implementation. When it comes to renovation advice, we analysed X-tendo and QualDeEPC. Both projects propose a similar approach, but QualDeEPC provides a more general, universal approach that is more applicable and relevant to iBRoad2EPC. X-tendo proposes two calculation methods that might be harder to implement. Furthermore, QualDeEPC has already developed an accessible online tool, ready to use, which can be tested first-hand.

Digital building logbooks play a key role in storing building data and making it accessible to building owners, occupants, and potentially other stakeholders like energy assessors, policymakers, professionals, and financing institutions, e.g., via one-stop-shop platforms. The EC's "Study on the development of a European Union framework for digital building logbooks" sets out the conceptual definition of logbooks and the pathway for the EU to incentivise the rollout of logbooks across Europe. The in iBRoad developed and tested advanced iBRoad-Logbook is in line with the definition proposed by the EC study and is designed to fulfil all the prerequisites for further expansion as well as for establishing a direct link with the EPC. The results of the X-tendo study on the logbook are assessed to provide a further overview of possibilities to be implemented in the iBRoad-Logbook.

Overall, based on a broad screening of available studies, projects, and reports, this report sets the scene for the further development of enhanced methods and tools within the iBRoad2EPC project. Further details on the technical adaptation and development will follow in separate reports.

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ANNEX

Project	Indicator covered	Description	Political relevance of indicator (rating)	Political relevance (explanation)	Time effort to gather the required data (rating)	Time effort (explanation)	Complexity to integrate with the iBROAD2EPC tool (rating)	Complexity (explanation)	Methodological relevance (rating)	Methodological relevance (explanation)	Maturity of methodology (rating)	Maturity of methodology (explanation)	Total score
Levels	IEQ, LCA, Embodied energy	Level(s), A common language for building assessment	2	Level(s) methodology is mentioned in the EPBD proposal and most likely will be included when WLC and LCA are being required through regulation or encouraged through their provisions.	0	Between 2017 and 2019, the Level(s) indicators were tested by more than 130 projects (both residential and non-residential, in new built and renovation) in 21 EU member states. Level(s) can enhance a dialogue between design, technical and financial actors in new build and renovation projects. The language must be adapted to be applied to the iBRoad2EPC and actual renovation projects. Collecting the additional data will take, at least 2 hours,	2	The iBRoad2EPC solutions must be adapted to integrate these wider indicators (only considering the lifecycle elements of Level(s)).	2	Levels proposes indicators which are also in interest of iBRoad2EPC.	2		8

Project	Indicator covered	Description	Political relevance of indicator (rating)	Political relevance (explanation)	Time effort to gather the required data (rating)	Time effort (explanation)	Complexity to integrate with the iBROAD2EPC tool (rating)	Complexity (explanation)	Methodological relevance (rating)	Methodological relevance (explanation)	Maturity of methodology (rating)	Maturity of methodology (explanation)	Total score
						especially in the countries without public LCA/EPD databases.							
QualDeEPC	Deep renovation, EPC assessment	The Horizon2020 funded project QualDeEPC aims to enhance (1) the quality and cross-EU convergence of Energy Performance Certificate (EPC) schemes, and (2) the link between EPCs and deep renovation.	2	Deep renovation and EPCs are both very important topic mentioned in the EPBD Revision.	2	Online tool for comparing EPC recommendations to deep energy renovation recommendations might be an interesting aspect to analyse. It seems that the same parameters as in the EPC are required.	0	Master2 Tool	2	The project is very much focused on the EPC recommendations, and explored many different aspects under others in two of the iBROAD2EPC countries: Spain and Greece.	2	The project is almost 3 years old.	8
U-Cert	Smart dimension, actual/measured performance	Introduce a next generation of user-centred Energy Performance Assessment and Certification Scheme.	2	Indicators to assess the buildings directly related to the EPC schemes and EPC related data.	2	Project focused on EPC data.	2	Spreadsheets for energy and SRI	2	The project developed indicators as proposed in the iBROAD2EPC project.	2	The project is almost 3 years old.	10
X-tendo	IEQ, Smart Dimension	Features: Comfort, Outdoor air pollution, Real energy consumption (methodological approaches and spread-sheets available	2	The project developed 10 different innovative features.	2	IEQ may be relevant. A simplified version for the SRI was developed, however is was agreed that it will not be used. SRI methodology	2	Spreads sheets are available: - SRI: website EU commission -IEQ: X-tendo website.	2	The project developed indicators as proposed in the iBROAD2EPC project.	2	The project is almost 3 years old.	10

Project	Indicator covered	Description	Political relevance of indicator (rating)	Political relevance (explanation)	Time effort to gather the required data (rating)	Time effort (explanation)	Complexity to integrate with the iBROAD2EPC tool (rating)	Complexity (explanation)	Methodological relevance (rating)	Methodological relevance (explanation)	Maturity of methodology (rating)	Maturity of methodology (explanation)	Total score
		in the X-tendo toolbox).				is the same as the suggested by the commission.							
SRI study	Smart Dimension	Final report on the technical support to the development of a smart readiness indicator for buildings emp/MJ0320335ENN.en.pdf.	2	Official SRI methodology developed by the EU Commission.	0	There are two possible methodologies simplified and detailed.	2	Spread sheets are online available date: 22 September 2020.	2	The project developed indicators as proposed in the iBROAD2EPC project.	2		8
ALDREN	Building passport, EPC assessment, IEQ,Costs	H2020 project exploring EPC and passport for non-residential buildings.	2	ALDREN is a methodological framework consisting of 4 standalone MODULES to assess the energy performance, Indoor Environmental Quality, and financial value of buildings, and 2 reporting TOOLS (EU Voluntary Certificate, Building Renovation Passport).	2	Based on the description from the website, the effort seems not very time consuming.	0	The project proposes methods that should be IT implemented into the iBROAD2EPC tools.	2	The project developed indicators as proposed in the iBROAD2EPC project.	2	Project has been finalised.	8

Project	Indicator covered	Description	Political relevance of indicator (rating)	Political relevance (explanation)	Time effort to gather the required data (rating)	Time effort (explanation)	Complexity to integrate with the iBROAD2EPC tool (rating)	Complexity (explanation)	Methodological relevance (rating)	Methodological relevance (explanation)	Maturity of methodology (rating)	Maturity of methodology (explanation)	Total score
EPC Recast	Building passport, EPC assessment	By enhancing EPCs usability, reliability, and comparability, and by linking them to renovation roadmaps and building digital notebooks, EPC RECAST can achieve unprecedented user-friendliness and user awareness of building performance.	2	Sister project - Innovation Actions (IA) that started in 2020 (Call H2020_LC-SC3-EE-5-2018-2019).	2	Not sure - less information on the website (should be quick due to the fact that machine readable files will be used).	1	Not sure-Blue planet has to evaluate the IT implementation between iBROAD2EPC tools and IFC files.	2	The project has a bit different propose than iBROAD2EPC as it focuses on existing and proven technology components. The project will develop an interoperable modelling and calculation toolbox.	0	Project has not been finalised.	7

iBRoad2EPC

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