TIMEPAC

Towards Innovative Methods
for Energy Performance Assessment and Certification of Buildings

Deliverable 2.3

Creating building renovation passports from data repositories

Transversal Deployment Scenario 3

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Executive Summary

This report summarizes the work done in Task 2.3 “TDS 3- Creating Building Renovation Passports from data repositories”. In a nutshell, TIMEPAC supports the implementation of the Renovation Passport by assessing renovation projects in the partner countries regarding procedures how to make use of data repositories and how to track the implementation of renovation measures. Based on these case studies, conclusions were drawn, and recommendations developed, resulting in a guideline how to proceed and what to consider when developing effective Renovation Passports in an efficient way.

The Renovation Passport has developed in recent years based on European research projects and national activities in some Member States, the latter mainly related to funding schemes. With the amending Directive (EU) 2018/844, the Renovation Passport was included in the Energy Performance of Buildings Directive (EPBD) in a general way, and a technical study was developed by BPIE to investigate examples, methods and feasibility. In the proposed recast of the EPBD, which is still being negotiated at the time of finalising this report, the Renovation Passport is strengthened due to its great potential in achieving the goals of the Renovation Wave. The Renovation Passport is expected to play a key role in meeting the targets of nearly Zero Energy Buildings and, in the medium and long term, in decarbonizing the building stock, also in the context of a future enhanced Energy Performance Certificate. It includes a Renovation Roadmap that lists renovation measures in a sequence that recognizes the full potential of energy and cost savings. However, to ensure success, more knowledge is needed, for example on how to make the process as efficient and effective as possible.

In this respect, TIMEPAC addresses two important aspects, (1) data availability and (2) tracing the evolution of building refurbishment. Specifically, the objective of this task was to create procedures to trace the evolution of building refurbishment using different data sources such as BIM, EPC, energy audit reports, and operational data, among others. To this end, renovation projects were assessed by the consortium partners based on the methodological approach of the BPIE study. Energy modelling and certification tools used in the partner countries and offered by project partner CYPE, were applied to create Renovation Roadmaps that include the different renovation steps and the energy performance achieved in each case. Country contributions were analysed in relation to the following topics: workflow and data; procedures of tracing the evolution of building refurbishment; interlinking the evolution of EPCs with the evolution of BIM models. The findings were processed to a guide for the development of Renovation Passports. This guidance is addressed to professionals involved in the calculation of the EPC and the development of Renovation Roadmaps, as well as to authorities and institutions responsible for providing the legal framework and supporting material for implementation. In addition, target groups are building owners and property managers, and professionals and companies active in building renovation.

Regarding the tracing of building refurbishment evolution, considering workflow and data, and linking it with the evolution of BIM and BEM models, several possibilities have been identified. The feasibility depends on the initial conditions in the respective country or region and the development strategy, and probably also on the building type (residential or non-residential, public or private, large or small). The TIMEPAC proposal for creating Renovation Passports from data repositories and tracking the development of building renovation is well-founded and practically relevant. Thus, it is not only a working tool for TIMEPAC partners, but also a useful input into the discussions on the topic outside the TIMEPAC consortium.

There might be many barriers, ranging from technical challenges to building model ownership and liability questions, but as a partner country noticed: “Training and educational activities will provide stakeholders with new knowledge and motivate them to take energy efficient actions.” Hence, this report feeds into WP3 "Verification Scenarios” to discuss the TIMEPAC approach towards the Renovation Passport with external stakeholders, and into TIMEPAC’s Work Package 4 “EPC Standardisation, Training and Capacity Building”.

1 Introduction

1.1 Purpose and target group

According to the European Commission, the current building sector is the largest consumer of energy in the EU; it is responsible for 40 per cent of energy consumption and 36 per cent of greenhouse gas emissions, but also approximately 75 per cent of the building stock is energy inefficient. Therefore, the European Union intervenes through political actions aimed at the realisation of deep renovation and energy requalification interventions. Proposed policy actions include the European Green Deal[1], the Renovation Wave[2], and the proposed revision of the Energy Performance of Buildings Directive (EPBD)[3], all aimed at achieving the political and environmental targets set for 2050. In this perspective, the Energy Performance Certificate (EPC) represents an essential document to identify the buildings that need to be upgraded, the interventions to be performed, and the best methodology to be applied.

TIMEPAC aims to identify faults in the current energy performance certificates and to improve current energy certification processes by moving from single, static certification to more holistic and dynamic approaches. The aim of Work Package 2 “Transversal Deployment Scenarios” (TDSs) is to deliver and deploy new methods to implement enhanced EPCs schemes, which will be then implemented in the Verification Scenarios to be carried out in WP3. Different partner profiles — certification bodies, software developers, research groups — have been involved in the deployment of these methods, which embrace the technical, scientific, operational, legislative, and standardization levels. WP2 includes five TDSs:

- TDS1 – Generating enhanced EPCs with BIM data.
- TDS2 – Enhancing EPC schemas through operational data integration.
- TDS3 – Creating Building Renovation Passports from data repositories.
- TDS4 – Integration of Smart Readiness Indicators and sustainability indicators in EPC.
- TDS5 – Large scale statistical analysis of EPC databases.

This report covers TDS3 – Creating Building Renovation Passports from data repositories. The objective was to create procedures to trace the evolution of building refurbishment using different data sources such as BIM, EPC, energy audit reports, and operational data among others. For this purpose, case studies were conducted in the partner countries. Energy modelling and certification tools used in the partner countries and offered by project partner CYPE, were applied to create building Renovation Roadmaps. These roadmaps display the different steps in renovation to help owners to plan future renovation investments and to show the evolution of the building in terms of energy performance. Renovation projects were assessed based on the methodological approach of the BPIE study[4] and analysed in relation to the following topics:

- Workflow and data;
- Procedures of tracing the evolution of building refurbishment;
- Interlinking the evolution of EPCs with the evolution of BIM models.

Based on these case studies, conclusions were drawn, and recommendations developed, resulting in findings how to proceed and what to consider when developing effective Renovation Passports in an efficient way. The findings were processed to a guide for the development of Renovation Passports. This guidance is addressed to the following target groups: professionals involved in the calculation

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[1] European Commission 2019.

[2] Communication from the Commission COM/2020/662 final.

[3] European Commission Brussels, 12/15/2021.

[4] Volt and Fabbri 2020.

of the EPC and the development of renovation plans; authorities, administrative units and institutions responsible for providing the legal framework and supporting material for implementation; building owners and property managers; professionals and companies active in building renovation.

1.2 Deliverable structure

This report consists of six main sections. Chapter 1 contains the introduction, including the description of purpose and target groups, contribution of partners, and relations with other project activities. Chapter 2 presents the TIMEPAC vision, which is the basic idea of the project. Chapter 3 describes the current status on the subject of the Renovation Passport which gives an overview of the development, to prepare the ground for the assessment of renovation projects in Chapter 4. Chapter 4 presents the assessment of renovation projects by TIMEPAC partners, contributions by country, including an introductory description of objectives and working guidance. Chapter 5 summarizes the findings of the partner case studies by topic and provides conclusions on options for future action. The thematic summary of country contributions presented in Chapter 5 was used as the basis for developing the guidance presented Chapter 6. In chapter 6, the findings are processed into the guideline for creating Renovation Passports from data repositories and tracing the evolution of building refurbishments.

1.3 Contribution of partners

Project partners in Austria, Croatia, Cyprus, Italy, Slovenia, and Spain assessed several buildings in each country and generated Renovation Roadmaps by using different software tools and data sources including Level 3 BIM architectural models. The focus of analysis was put on the data used, the software, procedures of tracing the evolution of building refurbishment, and how to interlink the evolution of EPCs with the evolution of BIM models. The conclusions drawn based on this analysis were integrated with results from desk research done on other thematically relevant projects, and lessons learnt from the work accomplished in TDS1, TDS2, TDS4, and TDS5. All these elements have been further developed into a set of guidelines on how to implement the Renovation Passport effectively by making use of data repositories. Target groups are the administrative entities and authorities, building owners and property managers as well as professionals and companies active in building renovation.

1.4 Relations to other project activities

This report builds on TDS1 (D2.1) and has cross-connections in particular to TDS2 (D2.2) and TDS4 (D2.4). It is also interlinked with TDS5 (D2.5) via the Renovation Passport requirement to provide financial information. Here a connection can be established to Regulation (EU) 2020/852 on the creation of a framework to facilitate sustainable investment, in short called Taxonomy Regulation[5], which includes a criterion related to the ratio of building performance to the average of the building stock. The results of Task 2.3 summarized in this report are further used in Work Package 3 “Verification Scenarios” for discussion with relevant target groups. The proposed Renovation Passports should enable users (e.g., ESCOs) to assess energy refurbishment scenarios at different timespans and using innovative financial mechanisms, such as energy performance contracting. In WP3.3, municipal renovation plans and related indicators will be discussed. In addition, this report feeds into the training activities planned in Work Package 4 “EPC Standardisation, Training and Capacity Building”.

[5] Regulation (EU) 2020/852 of the European Parliament and of the Council.

2 TIMEPAC vision

The TIMEPAC project supports the implementation of the Renovation Passport by developing new procedures for using data repositories and tracking the implementation of renovation measures. In particular, the objectives of Task 2.3 are as follows:

- To enhance EPCs with information from data repositories
- To interlink the evolution of EPCs with the evolution of BIM models
- To generate Renovation Passports from EPC data combined with BIM models, inspection reports and other relevant data, including operational data

To this end, a series of renovation projects have been assessed by TIMEPAC partners for analysis purposes and as the basis for creating guidelines on how to produce Renovation Passports from data repositories. Resources involved for the analysis of renovation projects were:

- Data: energy bills, energy audits, data from inspection reports, among other
- Tools: CYPE tools and software tools used in the partner countries
- Methods/standards: Method of Buildings Performance Institute Europe (BPIE) for creating a building Renovation Passport[6]

Figure 1 shows a schematic representation of the TIMEPAC vision of how the future of the Renovation Passport based on EPC databases and BIM databases and a connection of the same is envisaged. The idea is that existing building data in BIM databases and EPC databases are used with the addition of other data sources to develop a plan for the stepwise renovation of buildings which is called Renovation Roadmap and is the core element of the Renovation Passport. Mechanisms to update the energy performance status in the BIM database and/or in the EPC database are intended to be used to document and track the status of the implementation of renovation measures. TIMEPAC thus addresses two central challenges, namely data availability for the creation of Renovation Roadmaps and the tracking of renovation measures carried out. The first point is essential for the time- and cost-saving preparation of meaningful and trusted Renovation Roadmaps. The second point is essential to ensure that the Renovation Passport is an effective tool for achieving the goals of the Renovation Wave. Only renovation measures that are actually implemented contribute to energy and greenhouse gas emission savings, and therefore it is necessary to monitor their implementation.

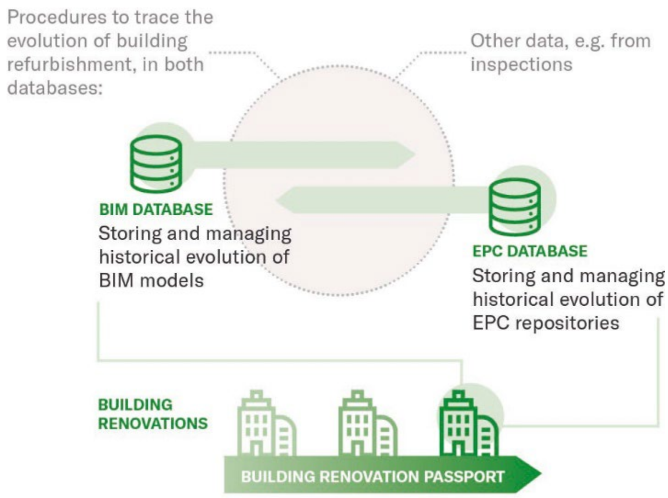

Figure 1. Process of developing a Building Renovation Passport

[6] Volt and Fabbri 2020.

3 Recent developments

This chapter offers a comprehensive perspective on the Renovation Passport, covering its motivation, the process for creating one, an examination of relevant EU initiatives, and the establishment of its legal foundation. It concludes by summarizing the existing challenges associated with Renovation Passport production.

3.1 Motivation for the Renovation Passport

The Renovation Passport is a tool used in the European Union (EU) to promote sustainable and energy-efficient renovations of buildings. The concept of the Renovation Passport has evolved over time, and its development can be traced back to the EU's efforts to reduce carbon emissions and improve energy efficiency.

In 2010, the EU adopted the recast Energy Performance of Buildings Directive (EPBD)[7], which requires member states to set energy performance requirements for new and existing buildings. The EPBD also calls for the development of energy performance certificates (EPCs) to provide information about a building's energy performance[8]. EPCs are supposed to include recommendations how to improve the building performance. However, EPCs are usually based on a standard occupancy pattern, as the main purpose is to provide potential buyers and tenants with information to compare buildings and make informed decisions. The recommendations are often not specific and detailed enough because the user behaviour and the future use plan for the building are unknown. But such an assessment would also be far too time-consuming and expensive, given that the price of an EPC is a few hundred EUR, however, often also less than 100 EUR. Moreover, there is no defined mechanism to track whether the recommendations have been implemented or not.

Both above-described aspects regarding recommendations are essential with a view to improving the energy efficiency of the building stock. Therefore, the European Commission introduced the concept of a Building Renovation Passport in addition to the EPC, based on experiences already available in some Member States and by financing studies to compile information and further develop the concept of BRP. In 2018, the European Commission launched an EPBD amendment[9], which included the voluntary concept of a Renovation Passport, at that time called Building Renovation Passport (BRP). The Renovation Passport is a document that provides a comprehensive overview of a building's energy performance, including its current energy efficiency, potential for improvement, and recommended renovation measures. It is designed to facilitate the renovation process by providing a roadmap for building owners and professionals.

Table 1 shows the main difference between the EPC and the Renovation Passport. In 2020, the European Commission launched the Renovation Wave Strategy[10], which aims to double the renovation rate of buildings in the EU by 2030. The Renovation Passport is expected to play a key role in achieving this goal, as it is a response to the challenge that renovation in one go is often not possible, but step-wise renovation is the usual procedure that needs to be combined with improving the energy performance of the building. The main purpose is to plan the renovation in two steps: first, to achieve the nZEB target (taking the energy efficiency first principle into account) and then to achieve the ZEB target by 2050. Improvement measures are put in the right order and lock-in effects can be avoided.

[7] Directive 2010/31/EU of the European Parliament and of the Council.

[8] These requirements were already introduced by the previously valid Directive 2002/91/EC on the Energy Performance of Buildings

[9] Directive (EU) 2018/844 of the European Parliament and of the Council.

[10] Communication from the Commission COM/2020/662 final.

Table 1. Comparison of EPC and Renovation Passport

	Characteristics of the mandatory EPC	Characteristics of the voluntary Renovation Passport
Building specific	Yes, but not mandatory; for existing buildings: can be based on default values	Yes - because it is important for the economic assessment of improvement measures
User specific and real energy consumption	No – based on a given calculation method and standard user behaviour / standard user profile	Yes – because it is important for the economic assessment of improvement measures
On-site visit	Not mandatory, depends on the regulatory framework and the purpose of the EPC	Yes – because reliable information about the actual condition must be available
Format of recommendations	Can be general; often not specified	Format is specified by the operator of the voluntary scheme
Tracking the implementation of recommendations	Not mandatory; sometimes possible through the EPC database if it allows for versioning of EPCs of a building, and distinct recommendations are represented by individual and defined data fields	Not mandatory; possible if planned by the operator of the scheme; several possibilities, for example through the EPC database

3.2 Method of developing a Renovation Passport

In the EPBD amendment from 2018, article 19a called for the development of a feasibility study regarding Building Renovation Passport which was carried out by the Buildings Performance Institute Europe (BPIE) and it strongly built on voluntary schemes already existing in some Member States. As a result, the method for developing a BRP can be summarised as shown in Figure 2.

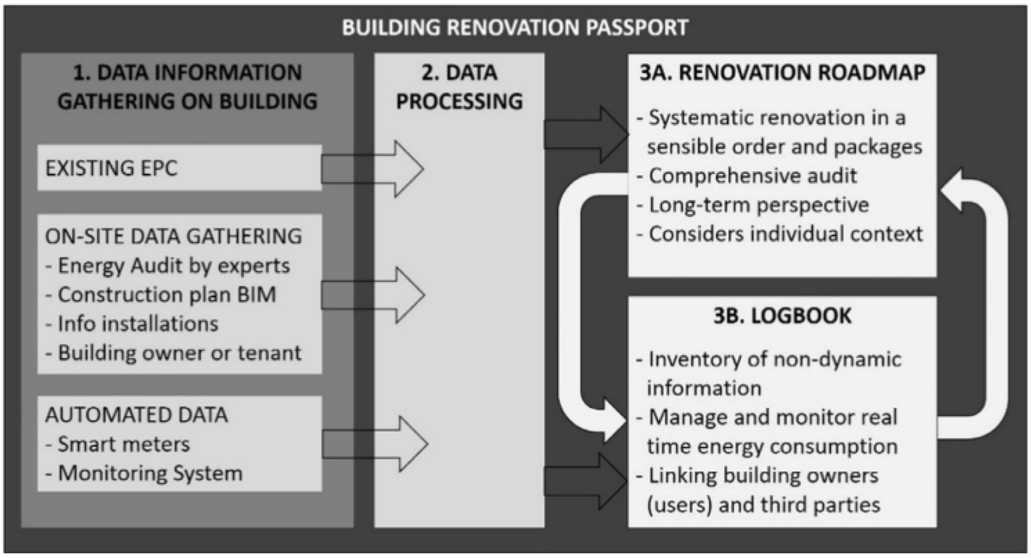

Figure 2. Developing a Building Renovation Passport, based on (Sesana and Salvalai 2018) and (BPIE 2017)

It should be noted that "3B. Logbook" can be represented by an extended EPC database or a BIM database, as is the interpretation in TDS3.

The Renovation Passport has been developed and implemented as part of subsidy schemes in several EU Member States, including France, Germany, and Belgium. Different methodological elements are included in the approaches of the individual countries, and many examples are included in the BPIE technical study on the Renovation Passport[11].

Table 2 shows a selection of these approaches which demonstrate the broad range of possible BRP schemes.

Table 2. Overview of selected BRP approaches

Country	Short description
France	The BRP contains more specific recommendations than the EPC but is also based on default data to keep cost low. https://www.experience-p2e.org/wp-content/uploads/2021/04/210210_Rapport.pdf
Germany	For single family houses; several meetings with the building owner; Renovation Roadmap includes also other adaptations which are not energy-related. (https://www.co2online.de/foerdermittel/individueller-sanierungsfahrplan/#c171241)
Belgium - Walloon region	The Renovation Roadmap is based on a detailed energy audit of the building and the elaboration of specific measures; they are organised in packages, and the whole package must be implemented to get the subsidy. (https://www.walloreno.be/fr/)

In Austria, there is the legal provision which implements the amending Directive (EU) 2018/844 that a building specific renovation concept which is, for example, developed as part of an energy advisory service, can substitute the recommendations in the EPC. The renovation concept is equivalent to the Renovation Roadmap and is intended to enable long-term planning of stepwise refurbishments and the avoidance of lock-in effects. The renovation concept is also used as part of the energy advisory services offered by the regional governments.

3.3 Review of relevant EU projects

Recently, several European Projects were launched dealing with further developing the EPC including aspects of the Renovation Passport. Most of them belong to the so-called “new EPC cluster of projects”. These projects have been reviewed, and selected information on the aspects of the Renovation Passport is presented below. It is noted that the project e-panacea has a deliverable on existing BRP schemes namely the report on the current status of national plans, schemes and initiatives on Building Renovation Passports (https://epanacea.eu/results/).

ALDREN - Alliance for Deep RENovation in Buildings (1/11/2017-30/9/2020)

The ALDREN project provided approaches for step-by-step renovation and rules to take into account the valorisation of energy efficiency, health, and well-being indicators in commercial real estate (i.e., the asset value of the building), in line with the development of a Building Renovation Passport (BRP) for non-residential buildings (especially offices and hotels) as a complementary tool to the Energy Performance Certificate (EPC).

[11] Volt and Fabbri 2020.

The ALDREN BRP core concept consists in the dual element of the Passport: the ALDREN BuildLog and the ALDREN RenoMap, which make the Passport a sort of complementary tool to the EPC with the aim to increase owners' awareness about the current technical energy performance status of their building and support them for its regular daily operation. https://aldren.eu/building-renovation-passport/

IBROAD - Individual Building Renovation Roadmap (1/6/2017-31/12/2020)

The iBRoad project developed an Individual Building Renovation Roadmap for single-family houses. This tool looks at the building as a whole, and provides a customised renovation plan (iBRoad-Plan) over a long-term horizon (15-20 years). The Renovation Roadmap is, at its core, a home-improvement plan which considers the occupant's needs and specific situation and avoids the risk of 'lock-in' future renovation solutions due to a lack of foresight. The Building Renovation Passport is a combination of two concepts, the Renovation Roadmap and the logbook. The Renovation Roadmap delivers a long-term renovation plan for individual buildings through tailored advice to owners and investors, to contribute to the achievement of a long-term vision (e.g. each building should reach nearly-zero energy-level by 2050). The logbook is a repository of building information, going beyond energy performance, and can include features such as design plans, actual energy consumption, maintenance requirements, certificates and legal documents. https://ibroad-project.eu/

QualDeEPC - Enhanced Energy Performance Certification with deep renovation (1/9/2019-31/8/2022)

The objective of the project is to improve the practical implementation of the assessment, issuance, design, and use of EPCs as well as their renovation recommendations, in the participating countries and beyond. With regard to the possibility of introducing a step-by-step renovation, an energy renewal passport could be developed as an integral part of the energy certificate. An energy renewal passport is an electronic or paper document that outlines a long-term and step-by-step roadmap for renewal (with possible steps / steps defined) of a particular building as a result of an EE audit. In this way the energy certificate will enable the owners of buildings, customers, investors, tenants and more, to plan forthcoming activities and necessary financial resources. https://qualdeepc.eu/

X-tendo - eXTENDing the energy performance assessment and certification schemes via a mOdular approach (1/9/2019-31/8/2022)

X-tendo and its toolbox aim to provide public authorities and implementing agencies with improved compliance, reliability, usability and convergence of next-generation energy performance assessment and certification. Cost and time constraints often result in EPCs containing generic, hence not so useful recommendations to the homeowner. The project is exploring cost-effective approaches to deliver tailored renovation recommendations that can enhance the instrument's impact on renovation activities. https://x-tendo.eu

ePANACEA - Smart European Energy Performance Assessment & Certification (1/6/2020-31/5/2023)

The objective is to investigate how the current EPC schemes best establish a link with the Building Renovation Passport (BRP) and the Digital Building Logbook (DBL) to incentivise energy renovations across Europe and stimulate cost-effective deep renovation of buildings. The most preferable option with regard to the potential link of the EPC with the BRP is that the EPC automatically feeds the BRP. ePANACEA comprises the creation of a prototype (the Smart Energy Performance Assessment Platform) making use of 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 an economic viability check. https://epanacea.eu/

D2EPC - Dynamic Digital Energy Performance Certificates (1/9/2020-31/8/2023)

D2EPC proposes a framework that sets its foundations on the smart-readiness level of the buildings and the corresponding data collection infrastructure and management systems. It is fed by operational data and adopts the 'digital twin' concept to advance Building Information Modelling,

calculate a novel set of energy, environmental, financial and human comfort/ wellbeing indicators, and through them the EPC classification of the building in question. There are plans of fully developing building logbooks as part of a "Building Renovation Passport". A new road mapping tool for EPC upgrade will feed into the Relevant Building Renovation Passports.
https://www.d2epc.eu/en

iBroad2EPC (1/9/2021-31/8/2024)

iBRoad2EPC builds on the results of the iBRoad project (2017-2020) which delivered a model for the Building Renovation Passport (BRP), supporting single-family homeowners with personalised advice to facilitate stepwise deep renovation of their buildings. iBRoad2EPC aims to connect the Building Renovation Passport to the Energy Performance Certificate (EPC), and expand, improve and broaden their format and joint scope to consider additional features, e.g., indoor environment and smart technologies, and become applicable also to multi-family and public buildings.
https://ibroad2epc.eu/

3.4 Development of the legal framework

This subchapter provides an overview of the evolution of the Renovation Passport. The concept was introduced with the amending directive (EU) 2018/844 and has been further strengthened in the Commission proposal[12] for the recast EPBD. During preparation of this report the recast EPBD was under negotiation, and for this reason, a short overview of the Council proposal[13] and Parliament proposal[14] is also presented. In a nutshell, the Renovation Passport should provide a solution to the challenge of increasing the building renovation rate, to achieve a zero-emission building stock in the long run.

3.4.1 EPBD 2010/31/EU, amended by Directive (EU) 2018/844

The amending Directive introduced the Building Renovation Passport as part of the long-term renovation strategy in Article 2a and mandated the Commission to carry out a feasibility study in Article 10a:

> **Article 2a - Long-term renovation strategy**
>
> 1. Each Member State shall establish a long-term renovation strategy to support the renovation of the national stock of residential and non-residential buildings, both public and private, into a highly energy efficient and decarbonised building stock by 2050, facilitating the cost-effective transformation of existing buildings into nearly zero-energy buildings. Each long-term renovation strategy shall be submitted in accordance with the applicable planning and reporting obligations and shall encompass:
>
> […] (c) policies and actions to stimulate cost-effective deep renovation of buildings, including staged deep renovation, and to support targeted cost-effective measures and renovation for example by introducing an **optional scheme for Building Renovation Passports**; […]
>
> **Article 19a Feasibility study**
>
> The Commission shall, before 2020, conclude a feasibility study, clarifying the possibilities and timeline to introduce the inspection of stand-alone ventilation systems and an **optional Building Renovation Passport that is complementary to the energy performance certificates, in order to provide a long-term, step-by-step Renovation Roadmap for a specific building based on quality criteria, following an energy audit, and outlining relevant measures and renovations that could improve the energy performance**.

[12] European Commission Brussels, 12/15/2021.

[13] Council of the European Union 10/21/2022.

[14] European Parliament 2/15/2023.

3.4.2 Proposal for EPBD Recast

In the proposal for EPBD recast, the Renovation Passport was strengthened. In the Commission proposal published 15/12/2021, the Renovation Passport is specified in Article 10, paragraph 3:

> 3. The renovation passport **shall comply with the following requirements**:
>
> (a) it shall be issued by a **qualified and certified expert, following an on-site visit**;
>
> (b) it shall comprise a Renovation Roadmap indicating a sequence of renovation steps building upon each other, **with the objective to transform the building into a zero-emission building by 2050 at the latest**;
>
> (c) it shall indicate the **expected benefits** in terms of energy savings, savings on energy bills and operational greenhouse emission reductions as well as wider benefits related to health and comfort and the improved adaptive capacity of the building to climate change; and
>
> (d) it shall contain **information about potential financial and technical support.**

Overall, the Council proposal published 21 October 2022 is nearly in line with the Commission proposal. There is mainly one important addition:

> Member States may decide to allow for the integration of the renovation passport into the energy performance certificate for selected purposes, including in relation to major renovation or to receiving financial support.

The new Article 19 on Databases for energy performance of buildings provides relevant provision regarding data storage, access and use. The Commission's proposal is presented below, with the Council's additions in brackets.

> 1. Each Member State shall set up a national database for energy performance of buildings which allows data to be gathered on the energy performance of the buildings and on the overall energy performance of the national building stock. (Such databases may consist of a set of interconnected databases).
>
> The database shall allow data to be gathered related to energy performance certificates, inspections, the building renovation passport, the smart readiness indicator and the calculated or metered energy consumption of the buildings covered.
>
> 2. The database shall be publicly accessible, in compliance with Union and national data protection rules. Member States shall ensure access to the full energy performance certificate for building owners, tenants and managers, and to financial institutions as regards the buildings in their investment portfolio. For buildings offered for rent or sale, Member States shall ensure access to the full energy performance certificate for prospective tenants or buyers.
>
> 3. Member States shall make publicly available information on the share of buildings in the national building stock covered by energy performance certificates and aggregated or anonymised data on the energy performance of the buildings covered. The public information shall be updated at least twice per year. Member States shall make anonymised or aggregated information available to public and research institutions such as National Statistics Institutes, upon request.
>
> 4. At least once per year, Member States shall ensure the transfer of the information in the national database to the Building Stock Observatory.
>
> 5. The Commission shall, by 30 June 2024, adopt an implementing act with a common template for the transfer of the information to the Building Stock Observatory.
>
> That implementing act shall be adopted in accordance with the examination procedure referred to in Article 30(3).
>
> 6. For the purpose of ensuring coherence and consistency of information, Member States shall ensure that the national database for energy performance of buildings is interoperable and integrated with other administrative databases containing information on buildings, such as the national building cadastre (or land registry) and digital building logbooks.

Article 2 - Definitions includes the following clarifications:

> 18. 'renovation passport' means a document that provides a tailored roadmap for the renovation of a specific building in several steps that will significantly improve its energy performance;

19. 'deep renovation' means a renovation which transforms a building or building unit

(a) before 1 January 2030, into a nearly zero-energy building;

(b) as of 1 January 2030, into a zero-emission building;

20. 'staged deep renovation' means a deep renovation carried out in several steps, following the steps set out in a renovation passport in accordance with Article 10;

37. 'digital building logbook' means a common repository for all relevant building data, including data related to energy performance such as energy performance certificates, renovation passports and smart readiness indicators, which facilitates informed decision making and information sharing within the construction sector, among building owners and occupants, financial institutions and public authorities (public bodies);

The proposal adopted by the European Parliament on 14/03/2023, goes beyond what has been suggested by the European Commission and the Council.

The parliament proposal of Article 10 and relevant paragraphs of the related Article 19 on Databases (difference compared to Commission/Council proposal underlined) as well as the definition of building logbook (difference compared to Commission/Council proposal underlined) are presented as excerpts below.

Article 10 Renovation passport

1. By 31 December 2023, the Commission shall adopt delegated acts in accordance with Article 29 supplementing this Directive by establishing a common European framework for renovation passports, based on the criteria set out in paragraph 3 of this Article.

2. By 31 December 2024, Member States shall introduce a scheme of renovation passports implementing the common framework established in accordance with paragraph 1.

2a. Member States shall ensure that renovation passports are financially supported as part of national building renovation plans in order to not create a barrier, in particular for homeowners who own only the dwelling in which they live. Member States shall ensure that building renovation passports are made available with due financial support for vulnerable households wishing to renovate their buildings in whole or in part.

3. The renovation passport shall comply with all of the following requirements:

(a) it shall be issued in a digital form suitable for printing by a qualified and certified expert, following an on-site visit;

(b) it shall comprise a holistic Renovation Roadmap indicating a maximum number of renovation steps building upon each other in line with the energy efficiency first principle to achieve a deep renovation in line with the objective to transform the building into a zero-emission building by 2050 at the latest, outlining how to achieve minimum energy performance standards, and measures to reduce whole life-cycle greenhouse gas emissions in the renovation process;

(c) it shall indicate the expected benefits in terms of energy savings, savings on energy bills and whole life-cycle greenhouse gas emissions reductions, with an indication of the renovation steps that are to lead to the relevant improvements;

(ca) it shall contain information about a potential connection to an efficient district heating network, the share of individual or collective generation and self-consumption of renewable energy;

(cb) it shall contain information on a range of estimated costs for each recommended renovation step, as well as the estimated costs of a one-step deep renovation as a reference scenario;

(cc) it shall comprise the bill of materials, information on construction products circularity as well as wider benefits related to health, comfort, indoor environmental quality, safety such as fire, electrical, and seismic safety, and the improved adaptive capacity of the building to climate change;

(d) it shall contain information about potential financial and technical support and updated contact details of the nearest one-stop-shop established pursuant to Article 15a;

(da) it shall contain information on any major renovations made to the building, as referred to in Article 8(1), and any retrofitting or replacement of a building element that forms part of the building envelope and has a significant impact on the energy performance of the building envelope, as referred to in Article 8(2).

The renovation passport may contain additional information, taking into consideration the composition of the household and any planned renovations, including those not relating to energy, in accordance with national law and practice.

3a. Member States shall facilitate the integration of renovation passports in the digital building logbook, gathering technical and legal information with essential data for property owners to plan and execute deep and staged deep renovations.

Article 19 Databases for energy performance of buildings

6. For the purpose of ensuring coherence and consistency of information, Member States shall ensure that the national database for energy performance of buildings is interoperable and integrated with other administrative databases containing information on buildings, such as the national building cadastre and digital building logbooks.

6a. By 31 December 2024, the Commission shall, adopt implementing acts to support the efficient functioning of digital building logbooks by establishing a common template for:

(a) a standardised approach for data collection, data management and interoperability and its legal framework;

(b) linking existing databases.

Those implementing acts shall be adopted in accordance with the advisory procedure referred to in Article 30(2).

Article 2 Definitions

37. ‘digital building logbook’ means a common repository for all relevant building data, including data related to energy performance such as energy performance certificates, renovation passports and smart readiness indicators, as well as on the life-cycle GWP and indoor environmental quality, which facilitates informed decision making and information sharing within the construction sector, among building owners and occupants, financial institutions and public authorities

The publication of the EPBD recast is not expected before the end of the year 2023. Therefore, in this task the Commission proposal is taken as a reference for the assessment of renovation projects in Chapter 4, and the discussion of results and development of recommendations in Chapter 5 will also consider aspects of the Parliament proposal.

4 Assessment of renovation projects by TIMEPAC partners

The task of the TIMEPAC partners was to process a certain number of renovation projects to create Renovation Passports using different data sources and tools. The lessons learned were documented on a topic-by-topic basis and then further processed in Chapter 5.

This chapter begins with the description of the objectives and the working guidance for carrying out the work in the partner countries and continues with the presentation of the contributions by country.

4.1 Objectives and working guidance

Up to five buildings were worked on in the partner countries, representing different building types. Energy modelling and certification tools (depending on the country) were used to calculate energy performance and create building Renovation Passports. Central content of the Renovation Passport is the Renovation Roadmap with the different renovation steps included to help owners and property managers plan future renovation investments and show the evolution of the building in terms of energy performance. Depending on the situation in the partner countries, different data sources and tools were used to develop the Renovation Roadmaps.

Specifically, the objectives of the assessment of renovation projects in the participating TIMEPAC countries were:

- To analyse the possibilities of using data repositories for creating a Renovation Roadmap which is defined by a sequence of renovation measures to be implemented in steps and to achieve nZEB (nearly zero-energy building) and ZEB (zero-emission building) targets (definition see Annex 1);
- To formulate distinct renovation measures which can be traced in terms of implementation;
- To identify a possible mechanism on how implementation of renovation measures can be traced, for example by further developing the EPC database, and/or by using a BIM database.

Working guidance for the assessment of renovation projects

The situation in the participating countries varies in terms of the availability of data, the type of data and the type of buildings studied, with the type of buildings also having an impact on data availability. The EPC database environment and the use of BIM is different as well. The voluntary Building Renovation Passport according to amending Directive (EU) 2018/844 is only implemented in Austria and in no other partner country.

Therefore, partners are free to choose and assess renovation projects in a way that provides as much insight as possible in achieving the objectives described above. Regarding the method, Figure 2 in this report serves as orientation and for further information the BPIE feasibility study on voluntary building Renovation Passports[15] can be consulted. With regard to results, the Commission proposal described on page 8 of this report (Article 10, paragraph 3) should be considered.

In so far as possible, each country chapter contains the following information:

1. Tabular description of assessed buildings

- TIMEPAC code, building type, owner, location, short building description, data used.

[15] Volt and Fabbri 2020.

2. Description of the assessment procedure

- Focus of the assessment is to generate distinct renovation measures in the form of a Renovation Roadmap and to analyse options to trace their implementation over time, for example through logging of building changes in the EPC database, and/or through logging of building changes in the BIM.
- The description is complemented by a graphical representation.
- Information is provided on the tool(s) used.
- Information is provided on the type of data used and the data source.

3. Description of assessment results for each assessed building

- Renovation roadmap (measures in the correct sequence) and the timing of renovation measures in tabular or graphic format to avoid possible lock-in effects. The timing of renovation measures is only possible based on recent information about the building status (e.g. roof has not been renovated for the past 30 years and repair is urgently needed – this makes it the first measure in the Renovation Roadmap), or assumptions are being made.
- Indicators as given in the Commission proposal, Article 10, paragraph 3.
- Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets.
- Consider interim targets suggested by the proposed EPBD recast, Article 9 - Minimum energy performance standards.
- Options to trace the implementation of measures / the evolution of the building over time.

4. Conclusions

Conclusions are drawn based on all assessed buildings with regard to:

- Workflow and data, regarding advantages, barriers, etc.
- Procedures of tracing the evolution of building refurbishment
- Interlinking the evolution of EPCs with the evolution of BIM models

4.2 Austria

4.2.1 Tabular characterisation of assessed buildings

Table 3 shows the characteristics of the assessed buildings.

Table 3. Overview of Austrian Case Study buildings

TIMEPAC Code	Building type	Owner	Location	Short building description	Data used
Internal Code from Building List	Residential or type of non-residential	Public, private; single owner or co-ownership	Region and city	Year of construction, gross floor area, implemented improvement measures, Technical Building System (TBS)	Type of data available and used for the Renovation Roadmap
AT-01	Multi-unit residential building	Rented, private building	Salzburg	Constructed in 2016; 2,390 m²; part of an energy efficient settlement; optimised supply concept based on RES and heat recovery; energy consumption is higher than planned due to user behaviour	EPC Technical reports and documentations
AT-07	Dormitory of boarding school	Private	Carinthia	Constructed in 1983; 773 m²; renovation started 2019 due to the age of the building; part of a building complex with independent energy supply (CHP)	EPC Technical reports and documentations
AT-06	Nursery school	Public	Salzburg	Constructed in 1978; 1,402 m²; renovation started 2014 due to the age of the building; extension of floor area and volume; highly efficient building envelope, mechanical ventilation with heat recovery; electricity heating was kept	BIM EPC Technical reports and documentations Interviews with the owner
AT-09	Multi-unit residential building	Co-ownership, private	Lower Austria	Constructed in 1969; 3,077 m²; single measures were	

TIMEPAC Code	Building type	Owner	Location	Short building description	Data used
				implemented now and then; a deep renovation is being planned considering a prefabricated energy efficient façade including TBS elements	
AT-04	Multi-unit residential building	Rented, social housing association	Salzburg	Constructed in 1987; 1,091 m^2; renovation started in 2019 due to the age of the building; extension of floor area and volume; highly energy efficient building envelope and optimised, innovative energy supply concept	

4.2.2 Description of the procedure

The analysis is based on the ETU Tool which is an approved software tool for EPCs in Austria. It contains modules for the creation and assessment of renovation variants, and it also contains a module for creating a Renovation Roadmap in the course of energy advisory services which in some aspects already corresponds to the voluntary Renovation Passport. Focus of the assessment is to generate distinct renovation measures in the form of a Renovation Roadmap and to analyse options to trace their implementation, for example through logging of building changes in the EPC database, or through logging of building changes in the BIM. The case studies selected were partly renovated, and the actually chosen measures are part of the assessment. Thus, the Renovation Roadmaps presented below were therefore created for analysis purposes only, and data gaps in the assessment were filled by assumptions.

Figure 3 shows the procedure applied for assessing the Austrian case studies.

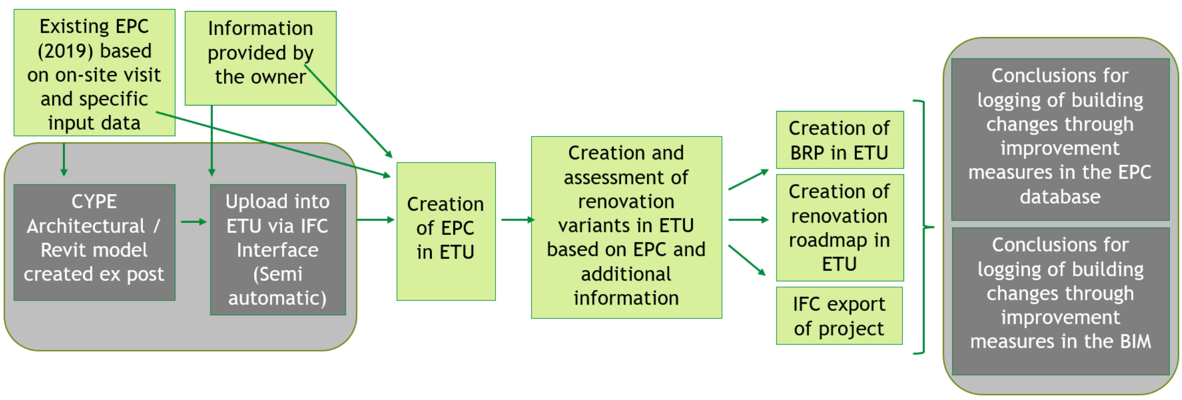

Figure 3. Procedure for assessing the Austrian case studies

Table 4 provides further information about the data used in the process of assessing renovation projects.

Table 4. Data used in the assessment process

Type of data used	Source of information	Comment
Architectural model	Created for TIMEPAC	BIM not yet usual procedure for residential buildings
Energy related building data	EPC, technical reports and documentations received from owners, EPC issuers, designers/engineers	EPC is only accessible for owner and EPC issuer
General building information	Interview with owner	Alternative source of information: facility management company
Renewable energy potential data, district heating / cooling potential data	Interview with owner, GIS, zoning plan / urban development plan	No link between zoning plan and EPC database
Energy consumption (operational data)	Not available for multi-unit residential buildings	Only for individual apartments if users agree

4.2.3 Description of assessment results

For building AT-01, a monitoring study had been carried out in another project that was used for TIMEPAC. It shows that the median heat consumption of the individual flats in 2020 and 2021 is around 76 and 79 kWh/m² useful floor area, respectively, and that ten to ninety per cent of all specific heat consumption is in the range between 35 and around 130 kWh/m² and year. The respective indicator in the EPC is 55 kWh/m². The monitoring showed that the heat generation systems, heat distribution and heat delivery systems functioned according to the state of the art and that it was mainly due to the users who are therefore responsible for the level of heat consumption, which consists of space heating and hot water supply. The range of heat consumption shows that measures addressing user behaviour would be more appropriate than energy efficiency interventions on the building such as introducing a ventilation system with heat recovery. However, information campaigns launched during the above-mentioned project did not change much.

Therefore, an improved level of building automation and control as the basis for real time user feedback on energy consumption for space heating and domestic hot water could be a solution in such a case to improve energy efficiency during building operation. However, such simulations cannot be performed with the ETU software used for creating the building energy model and the renovation variants. Such kind of analysis requires different tools.

For the four remaining buildings the analysis is shown in the Tables 5 to 11, for buildings AT-07, AT-06, AT-09 as a summary of the Renovation Roadmap, for building AT-04 as a summary description. The energy savings of the indicators are shown cumulatively.

With the described measures, both targets will be achieved, nZEB and Zero Emission Building (as defined by the proposed recast EPBD). Cost data are provided where available based on measures already carried out and whenever estimates are possible. Other cost estimates that depend on many factors are not provided, as this would be the case when the renovation is part of a large project and economies of scale can be used.

Table 5. Overview of Austrian Case Study buildings - Renovation Roadmap AT-07

TIMEPAC Code	Renovation roadmap: measures in the correct sequence (final result depends on maintenance and repair plan of facility management)	Timing of measures to avoid possible lock-in effects; considering interactions
AT-07	**(1) Package of measures:** New energy efficient façade (measure 1) and windows (measure 2) **(2) Package of measures:** LED lighting (measure 3), adjusting the heating system (measure 4) **(3) Package of measures:** PV system (measure 5) **(4) Package of measures:** Biogas or another non-fossil fuel instead of LNG for the CHP (measure 6) **(5) Package of measures:** Improve energy efficiency of building envelope (measure 7) including structural shading, mechanical ventilation with heat recovery and cooling function (measure 8)	The building envelope has undergone age-related renovations; energy efficiency has been improved to a good degree based on the cost optimisation principle, but not as best as possible (Step 1, already implemented). This chance comes again in 30 years and should be investigated in combination with a mechanical ventilation system with heat recovery in winter and cooling in summer, and with options for structural shading (Step 5). After improving the energy efficiency of the building envelope, the lighting system is renewed, and internal gains reduced. The heating system is adjusted (Step 2, already implemented). A PV system is installed (Step 3). Steps 2 and 3 are independent from each other. Step 4 is to be taken when a general overhaul of the CHP unit is due and is independent from step 2 and 3.

Table 6. Assessment results based on actual user profile and operational data for AT-07

	Building before renovation	1st Step of renovation	2nd Step of renovation	3rd Step of renovation	4th Step of renovation	5th Step of renovation
Implementation of measures		Measure 1 Measure 2	Measure 3 Measure 4	Measure 5	Measure 6	Measure 7 Measure 8
Total energy consumption (final energy) [kWh/m²]	285	206	144	99	99	82
Heating energy consumption [kWh/m²]	196	118	56	63	63	54
Primary energy consumption (total) [kWh/m²]	440	322	228	146	146	135
CO_2 emissions [kg/m²]	81	57	37	27	11	11
Investment cost [EUR/m²]	-	Not available				
Wider benefits (qualitative)		Reduces LNG consumption and thus increase security of energy supply			Local supply possible	Comfort, health in the hot season

Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets:

With regard to renovation step 1, one could say in retrospect that cost optimisation considerations led to a lock-in effect with regard to further improvement of the building envelope. However, as the building is part of an energy independent settlement which is supplied by a CHP plant, the scope of analysis is wider and not limited to the building. The EPC which was used as a starting point of the analysis refers to a building zone and not to a single building which creates an issue regarding renovation plan for the entire building.

Table 7. Overview of Austrian Case Study buildings - Renovation Roadmap AT-06

TIMEPAC Code	Renovation roadmap: measures in the correct sequence (final result depends on maintenance and repair plan of facility management)	Timing of measures to avoid possible lock-in effects; considering interactions
AT-06	**Building level:** **(1) Package of measures:** Improvement of building envelope including walls, windows, roof (measure 1) Mechanical ventilation with heat recovery (measure 2) **(2) Package of measures:** Photovoltaic system (measure 3) **(3) Package of measures:** Monitoring (measure 4) Improving the control system: adjusting the time programs for heating and mechanical ventilation (measure 5) **(4) Package of measures:** Extension of Photovoltaic system considering grid flexibility services (measure 6)	Improvement of building envelope including walls, windows, and roof, and the mechanical ventilation system with heat recovery is done at once. This package is independent from the installation of the PV system because the PV system is a free-standing plant on the property. In this case, these measures were done in one go (Step 1, already implemented). Monitoring and improving the control system to adjust the time programs for heating and mechanical ventilation follows the measure on the building envelope (Step 2, already implemented). The building uses electric heating, and therefore, the last renovation step suggests the extension of the free-standing PV system, because sufficient space is available. The detail planning needs to consider possible synergies with grid flexibility services.

Table 8. Assessment results based on actual user profile and operational data for AT-06

	Building before renovation	1st Step of renovation	2nd Step of renovation	3rd Step of renovation
Implementation of measures		Measure 1-3	Measure 4-5	Measure 6
Total energy consumption (final energy) [kWh/m^2]	171	59	58	44
Heating energy consumption [kWh/m^2]	149	27	26	18
Primary energy consumption (total)	278	113	111	83

	Building before renovation	1st Step of renovation	2nd Step of renovation	3rd Step of renovation
[kWh/m^2]				
CO_2 emissions [kg/m^2]	39	16	16	12
Investment cost [EUR/m^2]		Total cost of renovation 1,248 €/m^2; energy related cost: 283 €/m^2	3.50 €/m2 (estimated)	Not available
Wider benefits (qualitative)		Comfort and health		Contribution to grid stability

Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets:

In this case, energy-related improvement measures would not have been carried out without the renovation project as such. The cost dimensions illustrate the economic barrier that exists with regard to deep renovation. The building shape was changed during the renovation which means that it is not easy to apply renovation variants to the building model in the energy modelling software. Instead, a new model must be created. In such a case, it is an advantage to have an architectural building model as input into the energy calculation software.

Table 9. Overview of Austrian Case Study buildings - Renovation Roadmap AT-09

TIMEPAC Code	Renovation roadmap: measures in the correct sequence (final result depends on maintenance and repair plan of facility management)	Timing of measures to avoid possible lock-in effects; considering interactions
AT-09	**Building level:** **(1) Package of measures:** Renovation and insulation of roof (measure 1) Installation of PV system on the roof (measure 2) **(2) Package of measures:** North and south façade: Prefabricated Curtain wall, e.g. “GAP façade”, including windows and mechanical ventilation with heat recovery (measure 3) West and east façade: GAP façade with integrated PV panels in the upper third of the façade (measure 4) **(3) Package of measures** (measures 5-8): Reduction of water supply and return temperature of the heating system Low-temperature heat delivery system (panel heating) Individual room control with optimisation function	All measures of Package (1) and Package (2) are implemented prior to Package (3). The Renovation Roadmap must be immediately agreed with the owners to stop individual replacement of windows. Insulation measures must be checked regarding fire safety requirements. When planning the individual measures, the following interactions with other measures must be considered: Insulation of the façade requires a watertight connection to the flat roof.

	Separation of space heating and domestic hot water production **District level:** Decarbonisation of district heating	The renovation of the flat roof must take into account the installation of a PV system. The PV system is installed after the renovation of the flat roof.

Table 10. Assessment results based on actual user profile and operational data for AT-09

	Building before renovation	1st Step of renovation	2nd Step of renovation	3rd Step of renovation
Implementation of measures		Measure 1-2	Measure 3-4	Measure 5-8
Total energy consumption (final energy) [kWh/m²]	282	247	77	63
Heating energy consumption [kWh/m²]	254	222	51	37
Primary energy consumption (total) [kWh/m²]	453	397	125	103
CO_2 emissions [kg/m²]	22	19	13	12
Investment cost [EUR/m²]		Not available		
Wider benefits (qualitative)			Comfort, health	

Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets:

The typical problem of a co-owned building exists, which is that windows belong to the individually owned apartments and thus have been changed over time. The last exchange was around 15 years ago, which means that there will be an opportunity soon to renovate the walls including windows, but owners will have to agree on such a measure. A so-called GAP façade is suggested which is prefabricated including windows and mechanical ventilation systems with heat recovery. The extension of the technical building lifetime is more than 30 years, e.g. due to the materials used for the façade (glass, aluminium); the contracted company disposes of long-term experience thanks to several research projects. The extension of the technical building lifetime has an impact on the building value and thus on financing options.

The recommendations provided in the original EPC of the building (issued 2019, needed for renting apartments) are very general. There were two suggested measures referring to the insulation of the outer walls (external thermal insulation with a composite system) and changing all windows to windows with triple glazing. However, there was no further information on subsequent measures on technical building systems.

Building AT-04 is part of a group of buildings which were all renovated, hence, have a very low heating energy demand. The heating energy demand is so low that the buildings share a common micro heating grid which also supplies domestic hot water. There is a central system for hot water storage for all buildings. Heat is generated from wastewater and waste air via heat pumps. The remaining heat demand is covered by a small biomass boiler. The space on the roofs is used for a photovoltaic system which powers the heat pumps. The energy supply system is operated by an Energy Service Company that is interested in doing it the most energy efficient way. A monitoring and control system for optimization is in place.

In terms of future improvement measures, overheating in summer and the consequences on energy performance must be considered.

Furthermore, grid flexibility was not a topic during development of the renovation concept. This would need discussions between the building owner/facility manager, the ESCO, and the electricity company.

However, such simulations cannot be performed with the ETU software used for creating the building energy model and the renovation variants for the work in TIMEPAC. Such an analysis requires different tools.

Table 11. Assessment results based on actual user profile and operational data for AT-04

	Building before renovation	Building after renovation
Total energy consumption (final energy) [kWh/m^2]	266	43
Heating energy consumption [kWh/m^2]	237	31
Primary energy consumption (total) [kWh/m^2]	309	65
CO_2 emissions [kg/m^2]	65	7
Investment cost: EUR/[m^2]	Part of a large scale project	
Wider benefits (qualitative)		Comfort, energy security

4.2.4 Conclusions

4.2.4.1 Workflow and data

Currently, in the province of Salzburg, Renovation Roadmaps are developed in the course of energy advisory services and in compliance with the transposition[16] of the voluntary Building Renovation Passport according to amending directive (EU) 2018/844.

There is a specific software module called "Energieberater" that can be added to the EPC software tools approved in Austria. It is necessary to do an on-site visit including an interview with the owner. Before that, data are collected through forms, via email or by telephone, including pictures, plans, and energy bills, if available. This method has proven to be very successful in the area of detached single-family and two-family houses where communication takes place directly with the owners. Energy advisory services are regulated by Arge EBA (https://arge-eba.net/), an association which includes all Austrian provinces.

There are certain challenges in the multi-unit residential sector where communication is required with property managers or facility managers responsible for building operations.

Specific challenges related with multi-unit residential buildings

Challenges regarding the uptake of Renovation Roadmap:

- Synchronizing the Renovation Roadmap with property management measures
- Synchronizing the Renovation Roadmap with Austrian Standard ÖN 1300 (Object safety inspections for residential buildings - Regular inspection routines within the scope of visual inspections and non-destructive assessments - Basics and checklists)

Challenges regarding operation data and actual user profiles:

- Occupants of rented flats change and so does their user profile
- Detailed energy consumption of apartments is not easily accessible, but not useful either, considering the item above

Sources of input data including BIM

Currently, there are no data repositories which are generally accessible for the creation of a Renovation Passport. In theory, building owners have access to their building account in the EPC database ZEUS, where they can upload all relevant information and make it accessible to third parties, but in practice this feature is hardly used.

The geometry of a building including the orientation of surfaces and the definition of the reference area for calculating indicators has a great impact on the energy performance assessment result.

Currently, data collection is done from scratch when a new EPC is issued, as the electronic EPC file belongs to the issuer, and the EPC has the status of an expert opinion, meaning that the issuer would not rely on work previously done by another expert due to liability reasons.

A specific EPC is useful, whereas a simplified EPC (calculated based on default values) cannot be used as input into developing the Renovation Roadmap. At least the assessment of plans and an on-site visit including interview with the owner is necessary to generate a reliable data basis for developing the Renovation Roadmap.

The challenge with the plans is that they are usually outdated because changes have been made to the building over time, which can also affect the building's energy performance and the design of renovation measures.

[16] Österreichisches Institut für Bautechnik - OIB 2019.

A well-maintained building model can be used to determine the types and sizes of surfaces as well as materials, helping to avoid errors and manipulations of input data for the EPC calculation. However, for this purpose, the building model might need to be subject to quality check and certification. The question of who will be responsible for maintaining the building model remains open, too.

Calculation tools and data transfer

Hottgenroth ETU Tool was used which allows to develop and assess renovation variants based on a detailed and specific EPC in the same software tool through an additional module which is based on real use and energy consumption data. However, in the current version, the problem of overheating in summer is not adequately addressed, nor is the use of renewable energy systems included to the extent necessary to achieve the envisioned goal of a zero-emission building, including the aspects of grid flexibility services. In these cases, only basic options are available which are needed for the proof of complying with the national and regional transposition of the EPBD. With the software version for non-residential buildings an assessment, of BACS is possible to a certain extent, however, not with the version for residential buildings. In terms of the Renovation Roadmap, this means that additional simulation tools would currently be needed to provide input into the EPC calculation tool. But this also means additional cost for software tools and training efforts for small companies, which is probably unrealistic.

The ETU Tool offers an IFC interface as a test phase, which serves to import architectural models, but there are some problems with correct data transfer. This affects especially material properties which are needed for building physics but also life cycle analysis regarding embodied energy and associated greenhouse gas emissions. This means that currently, material properties will be added in the EPC software and not in the architectural model.

CYPE software including the BIM offering software BIMserver.center was tested. The approach is convincing which is to have a common data environment with the possibility of modelling renovation scenarios and implementing changes to the EPC automatically. However, CYPE software is not among the approved EPC software tools in Austria, in contrast to Spain, Italy, France, and Portugal. Most difficult in the application, however, was the fact that the building services systems implemented in the software are mainly electricity-based, which is suitable for southern countries, but does not cover the Austrian situation.

Provision of information to building owners and property managers

Building owners can use the unique building account that was introduced as part of the EPC database environment ZEUS to upload further information in addition to the automatically uploaded or online generated information (all EPCs, energy advisory protocols, Renovation Roadmaps, subsidy applications over time). They can make this data repository accessible to involved or interested parties.

4.2.4.2 Procedures of tracing the evolution of building refurbishment

The precondition for the following procedure is that a building and its units are uniquely defined, and all documents and data generated for this building are stored in the uniquely assigned place in the database.

The EPC with the attached Renovation Roadmap is uploaded into the unique building data account of the EPC database. The Renovation Roadmap includes the specification of measures which are selected for implementation and subject to financing, supported by a subsidy.

Regarding multi-unit residential buildings, the owner of the multi-unit residential building makes the documents accessible to the facility manager who is in charge of the maintenance and repair plan of the building. In this way, the Renovation Roadmap and implementation of measures become part of the operational procedures.

Implementation of renovation measures results in a new EPC with the updated Renovation Roadmap in the EPC database, which allows for tracing the evolution of building refurbishment.

4.2.4.3 Interlinking the evolution of EPCs with the evolution of BIM models

A procedure for this process has not yet been established. Based on the updated EPC and the updated Renovation Roadmap available in the unique building data account of the EPC database ZEUS, the BIM model could be maintained by the building owner or a specialized company contracted by the building owner. However, due to the loss of information which occurs during data exchange via .ifc files, this procure might not be realistic because the effort for model maintenance might be too high.

4.2.4.4 Other issues

The requirement to consider adaptation to climate change in the development of renovation measures is difficult to implement. For this purpose information from urban development would be needed regarding ventilation corridors, heat islands that prevent overnight cooling, stormwater runoff through infiltration-capable pavements or the creation of rainwater retention basins. Urban development information is also needed concerning allowed height and distance of neighbouring buildings to be able to assess the suitability of renewable energy systems.

It is necessary to extend existing trainings with new elements regarding “wider benefits related to health and comfort and the improved adaptive capacity of the building to climate change”.

In particular, the following topics are important:

- Daylight and heat prevention measures (blinds, structural shading, tinted glass)
- Greening buildings as a microclimatic measure to avoid overheating in summer and how to deal with dry periods
- Short-term heavy rainfall events (drainage systems)

4.3 Croatia

4.3.1 Tabular characterisation of assessed buildings

The table below shows the characteristics of the assessed buildings.

Table 12. Overview of Croatian Case Study buildings

TIMEPAC Code	Building type	Owner	Location	Short building description	Data used
Internal Code from Building List	Residential or type of non-residential	Public, private; single owner or co-ownership	Region and city	Year of construction, net floor area, implemented improvement measures, Technical Building System	Which type of data is available and used for the Renovation Roadmap
HR-01	Non-residential (Office)	Public	Zagreb	Constructed in 1975 and refurbished in 2000; net floor area 2,060 m^2; district heating system for heating and domestic hot water; central cooling system with heat pump and ice bank; central BAS for HVAC and lighting system	EPC BIM model BEM model Energy audit Energy consumption data Information provided by the owner
HR-02	Non-residential (Education)	Public	Osijek	Constructed in 1972; net floor area 1,050 m^2; central heating system with natural gas boiler; no central system for DHW; no central cooling system; no BAS	EPC BIM model Energy audit Energy consumption data Information provided by the owner

4.3.2 Description of procedure

The analysis is based on energy audit reports and KI Expert Plus Tool which is one of the approved software tools for EPCs in Croatia. In addition, a building energy model (BEM) using DesignBuilder tool has been developed for one of the two buildings for additional detailed analysis. Currently, there are no tools for digital and automatic development of Renovation Passports in Croatia. Results obtained from BEM, KI Expert Plus Tool and energy audit reports are aggregated and shown in the next paragraph. They represent the Renovation Passport. In detail, the procedure that has been performed is as follows:

- Energy indicators and energy performance for existing conditions were derived from the EPC and the energy audit report for both buildings. In KI Expert Plus Tool, the standardized building model was developed for both buildings. In addition, for one building (HR-01), a BEM was developed.

- From the energy audit report, energy efficiency measures were taken. In the energy audit report, energy savings were calculated according to real building usage and real consumption. Energy efficiency measures were combined in logical and renovation steps, and recalculated regarding achievable savings and investments.
- For one building (HR-01), the BEM was used as a basis for application of different variants and possibilities of energy efficiency measures. Overall, 720 combinations were calculated with the goal of finding a cos-optimised solution. The solution with optimum costs was then integrated in the energy audit report and the BEM.
- In the KI Expert Plus Tool, the recommended energy efficiency measures were applied on the standardized building model to recalculate EPC ratings that can be achieved after the implementation of energy efficiency measures. Recalculation was done for specific measures, their combinations and for an overall refurbishment.

Table 13 provides more information about the data used in the process.

Table 13. Data used in the assessment process

Type of data used	Source of information	Comment
Architectural model	Created for TIMEPAC	BIM not yet usual procedure in Croatia
Building layout	Dwg received from owner	Dwg is only accessible for owner, designer and Ministry
Energy related building data	EPC received from owner	EPC is only accessible for owner, EPC issuer and Ministry
Detailed building data related to energy	Energy audit report received from owner	Energy audit report is only accessible for owner, auditor and Ministry
Feasibility study for cost optimised solution of energy efficiency measures for building HR-01	Feasibility study received from owner	Feasibility study is only accessible for owner
Detailed energy efficiency savings calculations	Created for IMPULS-MED project	Additional energy efficiency calculations and different scenario calculations
Building Energy Model (BEM)	BEM received from owner	Dynamic BEM or HR-01 and KI Expert Plus building models for both buildings is only accessible for owner
Renewable energy potential data, district heating / cooling potential data	Interview with owner, GIS, zoning plan / urban development plan	No link between zoning plan and EPC database

Energy consumption (operational data)	Energy consumption received from owner	Energy consumption is only accessible for owner and energy distributor

4.3.3 Description of assessment results

The Tables 14 to 16 show the assessment results in terms of Renovation Roadmap as a summary for both analysed buildings.

Table 14. Overview of Croatian Case Study buildings - Renovation Roadmaps

TIMEPAC Code	Renovation roadmap: measures in the correct sequence, the detailed plan depends on the maintenance and repair plan of the facility management	Timing of measures to avoid possible lock-in effects; considering interactions
HR-01	**Building level:** **(1) Package of measures:** Renovation of lighting system – implementation of LED luminaries and advanced control systems Installation of a PV system on the roof **(2) Package of measures:** Thermal insulation of external walls Thermal insulation of the ceiling towards the attic **(3) Package of measures:** Reconstruction of the HVAC system – implementation of a new heat pump for heating and cooling, new VSD pumps and advanced control systems **District level:** Decarbonisation of district heating has not been taken into account – no plans from district heating operator Future decarbonisation of electricity system has not been included in calculation of future CO_2 emissions	All measures of Package (1) and Package (2) are implemented prior to Package (3). When developing the detailed plan, the following aspects must be taken into account: Renovation of lighting system must be done according to relevant standards and codes. Load capacity (statics) of the roof must be checked before installation of the PV system. Insulation measures must be checked regarding fire safety requirements. Underground water capacity and temperature must be checked before installation of the new water to water heat pump.
HR-02	**Building level:** **(1) Package of measures:** Renovation of lighting system – implementation of LED luminaries and advanced control systems **(2) Package of measures:** Thermal insulation of external walls Thermal insulation of the ceiling towards the roof Windows replacement **(3) Package of measures:** Reconstruction of the HVAC system – implementation of new natural gas boiler or heat pump depending on future economic analysis **District level:**	All measures of Package (1) and Package (2) are implemented prior to Package (3). Renovation of lighting system must be done according to relevant standards and codes. Insulation measures must be checked regarding fire safety requirements.

	Future decarbonisation of electricity system has not been included in calculation of future CO_2 emissions	

Table 15. Assessment results based on actual user profile and operational data for HR-01

	Building before renovation	1st Step of renovation	2nd Step of renovation	3rd Step of renovation
Implementation of measures	-	Renovation of lighting system Installation of PV system	Thermal insulation of external walls Thermal insulation of the ceiling towards the attic	Reconstruction of the HVAC system
Total energy consumption (final energy) [kWh/m^2]	156	112	108	27
Heating/cooling energy consumption [kWh/m^2]	107	107	103	22
Primary energy consumption (total) [kWh/m^2]	247	172	166	39
CO_2 emissions [kg/m^2]	44	33	31	5
Investment cost: [EUR/m^2]	-	141.2	69.1	236.5
Wider benefits (qualitative)	-	Better illumination for workers, RES production on location	Better thermal comfort	Better thermal comfort, better indoor air quality

Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets:

With the suggested measures, both targets will be achieved, Nearly Zero Energy (Major Renovation) and Zero Emission Building when applying standardized calculation methods. If the actual user profile and operational data is applied and appliance electricity consumption is taken into account, then Zero Emission Building could not be achieved, unless all of electricity delivered from the grid would be from RES. The EPC is from 2014, but there is an energy audit report from 2022. Energy efficiency measures and calculated values of savings were taken from the newer document (energy audit report). A BIM model used for the building can be the basis for the Renovation Passport but significant model improvements (mainly in technical building systems) must be applied.

Table 16. Assessment results based on actual user profile and operational data for HR-02

	Building before renovation	1st Step of renovation	2nd Step of renovation	3rd Step of renovation
Implementation of measures	-	Renovation of lighting system	Thermal insulation of external walls Thermal insulation of the ceiling towards the roof Windows replacement	Reconstruction of the HVAC system
Total energy consumption (final energy) [kWh/m²]	256	250	58	54
Heating/cooling energy consumption [kWh/m²]	236	236	44	40
Primary energy consumption (total) [kWh/m²]	291	281	70	60
CO_2 emissions [kg/m²]	57	55	13	12
Investment cost: EUR/[m²]	-	45.1	320.2	36.1
Wider benefits (qualitative)	-	Better illumination for children	Better thermal comfort	Better thermal comfort, better indoor air quality

Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets:

With the suggested measures only Nearly Zero Energy (Major Renovation) will be achieved. Zero Emission Building will probably not be achieved in case that no emissions at all are a requirement. The EPC is from 2015, but there are detailed energy efficiency calculations from 2018 done as a part of the IMPULS-MED project. Energy efficiency measures and calculated values of savings were taken from the newer document (IMPULS-MED report). A BIM model used for the building can be the basis for the Renovation Passport but significant model improvements (mainly in technical building systems) must be applied.

4.3.4 Conclusions

Conclusions are drawn based on all assessed buildings regarding workflow and data, regarding advantages, barriers, procedures of tracing the evolution of building refurbishment and interlinking the evolution of EPCs with the evolution of BIM and BEM models. When talking about tracing the evolution of building refurbishment, there are the following future possibilities:

- Through the EPC database
  - Tracking the changes of indicators through versioning the EPC in the database
  - Tracking the changes of recommendations in the EPC
- Trough cadastre
- Tracking the changes in the Renovation Roadmap in connection with the EPC
- Through logging the changes in BIM or BEM: an updated EPC is produced after the BIM has been changed
- Through energy management information system, but only for public buildings.

As far as "Interlinking the evolution of EPCs with the evolution of BIM models" is concerned, it is obvious to propose that the EPC is generated in real time from the BIM database; however, this would fundamentally change the existing EPC scheme, which would not be well accepted by the stakeholders. In addition, there is the question of a BIM model ownership and additional cost of developing BIM models. In case of Croatia, the most obvious solution would be by using the EPC database for tracing the evolution of building refurbishment but there would be the need for extensive database improvements. The most obvious one is the change in EPC identity. The EPC identity is linked to the auditor's identity and not to the building identity from cadastre. This has to be changed if EPC database is to be used also for the Renovation Roadmap or the Renovation Passport.

4.3.4.1 Workflow and data

Specific challenges related with non-residential buildings:

Challenges regarding the uptake of a Renovation Roadmap:

- Synchronizing the Renovation Roadmap with changes in legislation – possible new nZEB definitions, calculation methodology changes, RES integration rules
- Synchronizing the Renovation Roadmap with technological changes and integration of new products and solutions

Challenges regarding operation data and actual user profiles:

- In a dynamic market, different user profiles if the building usage is to be changed or occupants vary

Sources of input data including BIM

The geometry of a building including the orientation of surfaces and the definition of the reference area for calculating indicators has a great impact on the assessment result. Currently, data collection is done from scratch when a new EPC is issued, as the electronic EPC file belongs to the issuer, and the EPC has the status of an expert opinion, meaning that the issuer would not rely on work previously done by another expert. The only exception is if EPC is issued by the same expert or company.

A well-maintained building model (BIM or BEM) can be used to determine the types and sizes of surfaces as well as the materials, including the information about energy systems in buildings, helping to avoid errors and manipulations in the input data for the EPC calculation. However, for this purpose, the complete building model (including energy systems) needs to be subject to quality check and certification. If the BIM model does not include technical systems, then EPC cannot be issued and the auditing part about technical building systems has to be done all over again.

Additionally, the development of a comprehensive BIM model is time consuming and an expert process, meaning increased costs for building owners, which will in large part have negative influence on the real-estate market. BIM could be implemented for new buildings or large-scale refurbishments as a design standard but to be applicable for existing buildings in general, solutions will be needed to keep cost low.

Calculation tools and data transfer

EPC tools do not allow for development and assessment of renovation variants. EPC tools mainly provide energy calculations according to legislation. Calculations for assessing the energy efficiency measures are not implemented in the EPC tools and have to be done externally. Other possible functionalities as thermal comfort or illumination levels are not implemented either. In Croatia, as a part of EPC process, an energy audit has to be produced. Data shown in the energy audit is not the same as in the EPC tool, meaning that an external tool has to be used (mostly Excel), but energy efficiency measures from the energy audit can be used for the creation of the Renovation Roadmap. At this point in time the Renovation Roadmap can be easily implemented in the energy audit which also requires the recommendation of energy efficiency measures. The energy audit is stored in the EPC database together with the EPC.

Provision of information to building owners and property managers

Building owners are provided with a digital (and hard copy) version of EPC and energy audit in pdf format. Other documents are not shared with the building owners.

4.3.4.2 Procedures of tracing the evolution of building refurbishment

Currently, there is no tracing of the evolution of building refurbishment. In the EPC database there is a check box that can be labelled in case of a new EPC that has been calculated because of building refurbishment. There is no link to the previous EPC nor is the previous EPC deleted from the database.

4.3.4.3 Interlinking the evolution of EPCs with the evolution of BIM models

Currently, there is no procedure for this process. Challenges with BIM range from clarifying the ownership of the model to identifying the necessary level of detail, and how to keep costs low.

In Croatia, mechanical and electrical engineers are reluctant in using BIM tools for several reasons, and there are a lot of compatibility issues when using standardized design software.

EPC database and software have the possibility of storing only one version of building calculations, limiting data to the current building state. For different renovation steps separate files have to be produced. There is no linking between EPC database and cadastre.

In conclusion, tracking the evolution of building refurbishment can be done, but it is a demanding process without any clear guidelines.

4.3.4.4 Other issues

Data storage and linking different tools are challenges that have to be addressed for improved EPC process and higher quality of EPCs. Also, cost for producing the EPC have to be retained on minimal level with an increased value for end users. Visual identity has to be modernized with a clear and simple way of presenting calculation results and findings.

4.4 Cyprus

4.4.1 Tabular characterisation of assessed buildings

The overview of BIM models for the analysed buildings is shown in Table 17. CEA offices are the offices of the Cyprus Energy Agency.

Table 17. Overview of analysed buildings in Cyprus

TIMEPAC Code	Building usage	Construction period	Conditioned floor area (m^2)	Data collection resources	Building use
CY-01	Primary school Aglatzia	2007-2013	1,297.98	EPC, Energy audit, Electricity bills, building drawings, smart meters	educational building
CY-02	Primary school Lakatamia	1981-2006	1,760.82		educational building
CY-03	CEA offices Building 1	≤1980	173		offices
CY-04	CEA offices Building 2	≤1980	169		offices
CY-05	Primary school Larnaca (Leivadia)	1981-2006	792.48		educational building

4.4.2 Description of the procedure

Two software programmes were run to test the two methods used for the scenarios. Firstly the three schools were certified by the Ministry of Energy applying the EPC generator software CoreDesigner ECO-engine, and secondly for the CEA buildings the SketchUp Sefaira energy efficient design software was used.

First scenario: The EPC generator software CoreDesigner ECO-engine was used to implement the following improvements:

- Improve the insulation of the walls
- Improve the insulation of the floor
- Improve the lighting of the building
- Improve the glazing systems of the building
- Install a photovoltaic system to cover up the remaining consumption

Second scenario: Using SketchUp Sefaira energy efficient design software for CEA buildings to implement the following improvements:

- Improve the insulation on the walls
- Improve the insulation on the floor
- Improve the lighting systems of the building
- Improve the equipment of the building - General improvement of the BACS systems

Exemplary results of the assessment are presented in Figures 4 to 7 for the two buildings of CEA.

CY-03: The report of results states that the annual energy consumption decreases from 131 kWh/m^2 to 78 kWh/m^2.

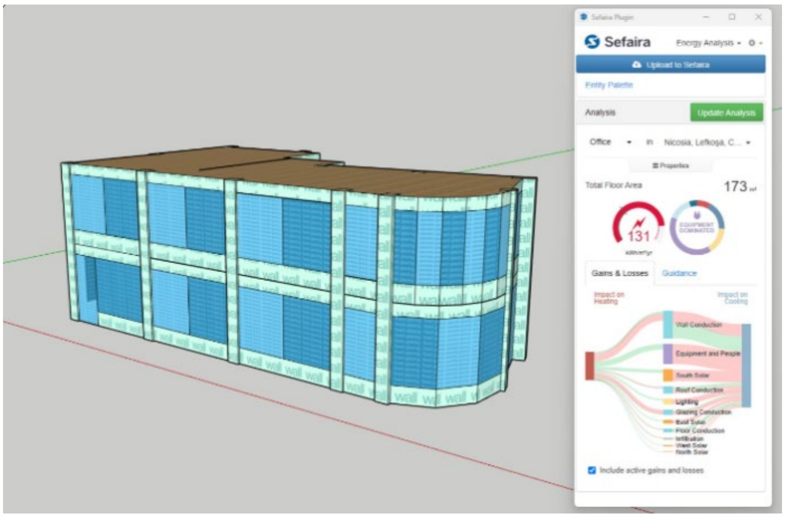

Figure 4. CY-03: Before the improvements

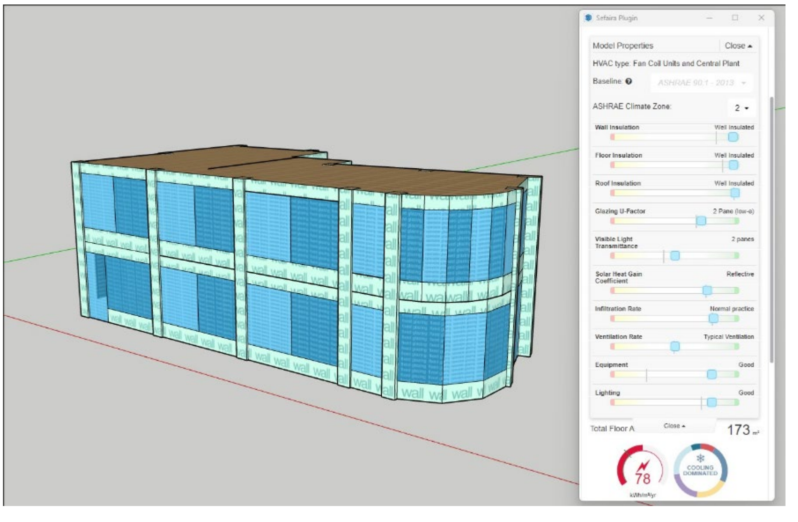

Figure 5. CY-03: After the improvements

CY-04: The report of result states that the annual energy consumption decreases from 122 kWh/m^2 to 73 kWh/m^2.

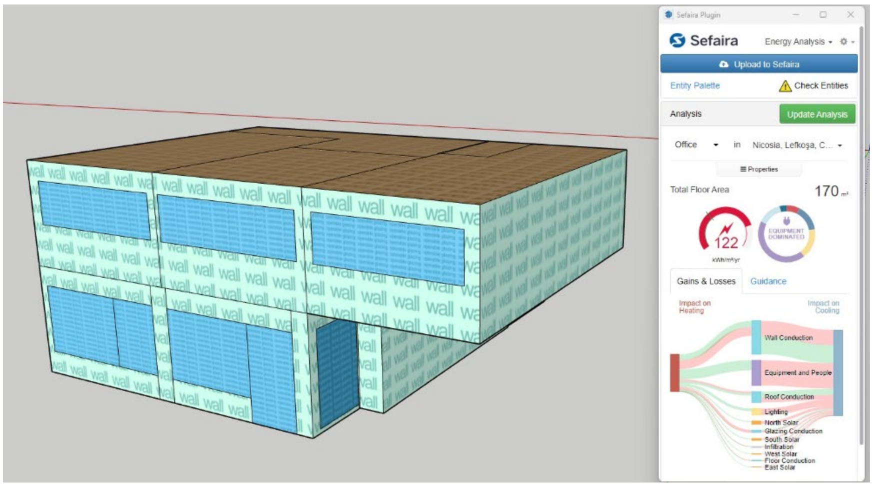

Figure 6. CY-04: Before the improvements

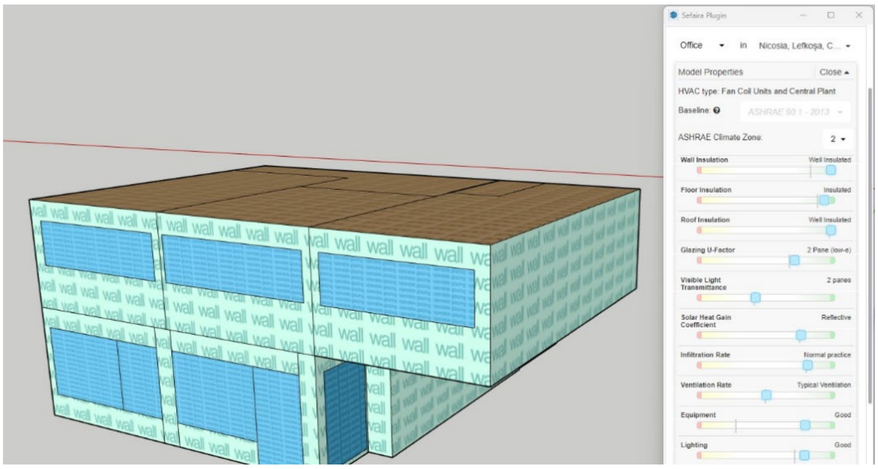

Figure 7. CY-04: After the improvements

4.4.3 Description of the assessment results

The work on the Renovation Passport and the roadmap to improvements resulted in the following observations regarding the process:

1. Detect the specifications of the existing situation: U values of the glazing, insulation of walls and ceiling, appearance of any renewable source of energy etc.
2. Create an EPC based on the existing situation. During the implementation of the EPC, the energy professional must determine the assumptions, the gaps and the disadvantage of the procedure in each case. Generating an EPC in Cyprus is a static procedure which consists of accepting many assumptions. An example could be the input information for any available photovoltaic system. The energy professional must use the covered area of the system as input and not the exact installed power, i.e., the applied data must be calculated in a way the software can receive the correct data, in this case the installed power of the system.
3. The EPC and the energy audit output report will consist of all the parameters and information that will be used from the software to calculate the energy efficiency of the building. Additional output information will also include the suggestions which will improve the efficiency of the building. Those suggestions must be combined with any other available data which are related to the building such as actual measurements of the electricity, the indoor temperature, indoor air flow.

4. The creation of the new EPC must contain a new procedure that will provide a new enhanced certification. The new report needs to be simulated many times to identify the correct renovation scenarios. The new certification has to be holistic and dynamic, and to achieve this, the designer must include information that could affect the building not only in the present but also in the future in the procedure. The use of some important factors shows us that using both methods (EPC generator and energy modelling software), will improve the results. Features such as the actual occupancy of the building, shading factors, orientation and material ageing factors are important.
5. Before the renovation of the building, the owner and all the related energy professionals must consider some of the following important matters:
   - The new equipment must be simulated based on real measurements and not only based on documents and specifications. The interaction of some materials and technologies varies from country to country due to the climate conditions.
   - Before implementing improvements, all political and economic circumstances that may have an impact on the costs and the payback period must be considered.
   - Check the existing and the potential framework and forecast future changes. Some of the renovation changes may be legal or illegal at present, receive a fund in the near future and have difficulties obtaining permission in the future. A notable example is the installation of a photovoltaic system in the past and today. A few years ago, subsidies were much higher than today and the procedures were much simpler and more effective compared to those of today.
   - The proposals developed should be more “user friendly” and include helpful guidelines that can be used by the building´s occupants to improve the energy consumption in the future.
   - It is essential to align the BACS of the construction to eliminate the human factor in terms of the unnecessary use of equipment as much as possible, e.g. lighting consumption could be reduced by using motion sensors.
6. By designing the renovation of the building, it must be considered that it is an investment that not only brings comfort and energy savings but also increases the value of the building. Based on the above, any changes that do not follow these rules must be avoided.
7. After every improvement, it is crucial for the future to keep records. The renovation must include the installation of smart meters for electricity, indoor temperature, and gas or oil consumption. Keeping a cost and consumption history provides a detailed image of the improvement and any additional step that the owner must take.
8. In general, the planning of a building renovation must be based on long-term considerations. The enhanced building always aligns the energy-efficiency with estimated costs and expected energy savings. The main goal is to continuously improve the building and energy consumption.

4.4.4 Conclusions

In conclusion, the energy model method proves to be more accurate and reliable as compared to the EPC generation software. The EPC approach has significant disadvantages due to its reliance on assumptions and inaccuracies, whereas energy modelling offers better results.

To create a positive change in our energy consumption habits, we must raise awareness and motivate society. Educating building owners, designers, and energy professionals about the importance of energy conservation is crucial. By adopting energy-saving practices and changing our mindset we can significantly reduce our impact on the environment, fulfilling the needs of current generations without compromising the needs of future generations.

Currently, Cyprus faces challenges due to the limited data available, and, in addition, the energy modelling procedures are not widely embraced in the country. Furthermore, building owners make minimal efforts to comply with energy-saving regulations. After the initial building permit, there is often no ongoing review of energy efficiency.

Addressing these issues and promoting energy modelling in the construction and energy sectors is essential. Encouraging the use of energy-efficient technologies and regular inspections not only benefits the environment but also saves building owners money in the long run and contributes to a sustainable future. Cooperation with organizations like the Electricity Authority of Cyprus, the only provider of an electricity grid in the country, will be crucial to achieving this positive transformation towards a more energy-conscious society.

4.4.4.1 Workflow and data

Data of the buildings were collected from the following resources:

- Energy Audits done on previous projects.
- Two versions of EPC were created for the three schools.
- Energy models were created for the two Cyprus Energy Agency buildings from the scratch and data were collected from there, using the software mentioned above.

In addition, data were received from:

- Interviews with building managers, building owners and employees, i.e. for heating methods in schools.
- From EPC Reports, Energy Audits (if available), electricity bills, electricity smart meters and temperature and humidity sensors (internal readings).
- External temperatures collected from https://statics.teams.cdn.office.net/evergreen-assets/safelinks/1/atp-safelinks.html

Difficulties in data collection

During data collection, difficulties were encountered in finding the measured data for the indoor hourly temperatures and hourly power consumptions. For example:

- In the case of the school buildings, there were only values for a few weeks.
- In the case of the CEA buildings, there have been values for the electricity consumption for the last three months and for the indoor temperatures for ten months.

It is important to note that the collection of data, analysis and transformation into meaningful and usable data was a time-consuming process. The measurements from most of the meters and sensors were usually collected every minute or at irregular intervals and part of our analysis and transformation procedure was to convert them into hourly readings.

4.4.4.2 Procedures of tracing the evolution of building refurbishment

The lack of public accessibility to EPC and Energy Audit results in Cyprus is a challenge for research and development of new methods and technologies. The data used for the D2.3 deliverable are mainly from energy audits carried out for previous projects and deliverables.

Market research was essential to compare available materials and technologies.

Drawing from past experiences, research has shown that various technologies and materials used in building construction in Cyprus were not well-suited for the country's climate conditions. For example, the sunny weather indicates that installing a small photovoltaic system (around 3kW on average) could meet a house's electricity needs. However, this approach proves to be cost-effective only, lacking effectiveness in terms of thermal comfort and energy efficiency. Instead, a more effective strategy is to focus on improving the insulation of the roof and floor and on improving the glazing. This approach not only contributes to energy savings but also significantly improves thermal comfort. Consequently, the overall energy consumption decreases, giving us the opportunity to use an even smaller photovoltaic system to cover the remaining energy needs. By prioritizing these considerations, designers can create buildings that are more energy-efficient, comfortable, and environmentally friendly.

Before implementation, it is essential to conduct simulations using available software tools and iteratively edit building plans and models to achieve the best results.

Designing with climate change in mind is important. New renovation methods should rather be dynamic than static and consider worst-case climate change scenarios. Weather measures should be guided by these forecasts to ensure long-term sustainability and resilience.

4.4.4.3 Interlinking the evolution of EPCs with the evolution of BIM models

The procedure for issuing the EPC in Cyprus is outdated and needs to be revised. In its calculations it lacks the consideration of essential dynamic conditions, such as occupation patterns, actual internal temperatures, and real electricity consumption. Taking benefits from both procedures and eliminating the disadvantages from each other creates a comprehensive approach that optimizes energy efficiency, cost-effectiveness and thermal comfort in building design. By integrating these improvements, a comprehensive approach can be created that optimizes energy efficiency, cost-effectiveness, and thermal comfort in building design.

4.5 Italy

4.5.1 Tabular characterisation of assessed buildings

Table 18 shows the characteristics of the assessed buildings.

Table 18. Overview of Italian Case Study buildings

TIMEPAC Code	Building type	Owner	Location	Short building description	Data used
Internal Code from Building List	Residential or type of non-residential	Public, private; single owner or co-ownership	Region and city	Year of construction, conditioned floor area, status quo before renovation, Technical Building System	Which type of data is available and used for the Renovation Roadmap
IT-01	Apartment block	Private	Piemonte, Torino	Constructed between 1961 and 1975; conditioned floor area, 5,974 m^2; district heating system for heating and domestic hot water.	BIM model Information provided by other technicians
IT-02	Apartment block	Private	Piemonte, Torino	Constructed between 1901 and 1920; conditioned floor area, 2,018 m^2; district heating system for heating, natural gas boilers for domestic hot water.	BIM model Information provided by other technicians
IT-12	Educational building	Public	Piemonte, Borgofranco d'Ivrea	Constructed between 1961 and 1975; conditioned floor area, 669 m^2; natural gas boiler as generator for heating and domestic hot water.	Information provided by other technicians Energy audit report
IT-13	Educational building	Public	Piemonte, Chieri	Constructed between 1961 and 1975; conditioned floor area, 3,693 m^2; district heating system for heating and domestic hot water.	EPC Information provided by other technicians Energy audit report
IT-15	Educational building	Public	Piemonte, Venaria Reale	Constructed between 1991 and 2005; conditioned floor area, 1,674 m^2; natural gas boiler as generator for heating and domestic hot water.	EPC Information provided by other technicians Energy audit report

4.5.2 Description of the procedure

In Italy, the process of creating an Energy Performance Certificate (EPC) can vary depending on the type of building. For large public buildings, it is common to use a Building Information Modelling (BIM) workflow, which involves starting with an architectural model in IFC format. This model is imported into the EC700 tool, a validated software tool used for generating EPCs in Italy.

The EC700 tool includes modules for creating building components, generating graphical representations, characterizing technical building systems, assessing renovation options, and evaluating their economic and energy-related consequences. However, the information contained in the IFC file primarily describes the building's geometry and some details about the envelope elements, such as materials. Additional information, such as data on technical building systems is required to perform an energy evaluation. To obtain such data, information from energy audits, site visits, previous energy analyses, or models needs to be added to the EC700 tool.

On the other hand, for residential buildings, it is less common to have an architectural model or use a BIM workflow. Instead, a more traditional approach is followed, which relies on energy-related building data. This involves collecting data from energy audits conducted during on-site visits or using previous energy calculations. The collected information is then used to create a new energy model or update an existing one within the EC700 tool.

Figure 8 shows the procedure applied for assessing the Italian case studies.

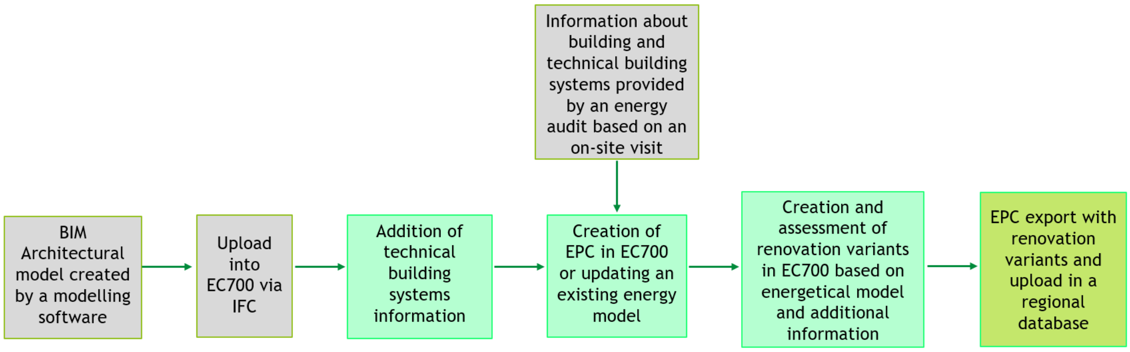

Figure 8. Procedure for assessing the Italian case studies

Tables 19 and 20 provide more information about the data used in the process.

Table 19. Data used in the assessment process of IT-01 and IT-02

Type of data used	Source of information	Comment
Architectural model in BIM environment	Already created	Despite BIM is not yet usual procedure for residential buildings, the cases analysed come from a European project aiming at collecting several items of information of the building through the BIM environment
Energy related building data	Energy model through DesignBuilder	Usually DesignBuilder is not a common tool used for energy assessment, but in this case the dynamic energy model was used for research purposes
General building information	Documents	-

Renewable energy potential data, district heating / cooling potential data	Not available	-
Energy consumption (operational data)	Monitored energy consumption data on hourly basis	Hourly monitoring of energy consumption data is not commonly practiced. Typically, energy consumption data is obtained from utility bills.

Table 20. Data used in the assessment process of IT-12, IT-13 and IT-15

Type of data used	Source of information	Comment
Architectural model	Not present	BIM is not yet a usual procedure
Energy related building data	Energy audit report	Energy audit is not so common. Generally, an on-site visit should be carried out.
General building information	Energy audit report	Alternative source of information: facility management company
Renewable energy potential data, district heating / cooling potential data	Not present	-
Energy consumption (operational data)	Energy audit report; energy consumption data already collected from bills	-

4.5.3 Description of assessment results

The Tables 21 to 30 show the assessment results in terms of Renovation Roadmap as a summary.

Table 21. Overview of Italian Case Study buildings - Renovation Roadmap IT-01

TIMEPAC Code	Renovation Roadmap: measures in the correct sequence, which depend on the maintenance and repair plan of the facility management	Timing of measures to avoid possible lock-in effects; considering interactions
IT-01	**Building level:** **(1) Package of measures:** Measure 1: Renovation and insulation of external walls	Measures in Package (1) should be implemented prior to Package (2) in order to properly size the new generation system.

	Measure 2: Insulation of the flat roof from the internal side with a false ceiling Measure 3: Substitution of the windows **(2) Package of measures:** Measure 4: Emission control enhancement (individual room control)	The Renovation Roadmap must be immediately agreed with the owners to stop individual replacement of windows. Insulation measures must be checked regarding fire safety requirements. When planning individual measures, the following interactions with other measures must be considered: Insulation of the façade requires a watertight connection to the flat roof.

Table 22. Assessment results based on actual user profile and operational data for IT-01

	Building before renovation	1^{st} Step of renovation	2^{nd} Step of renovation
Implementation of measures	-	Measure 1 Measure 2 Measure 3	Measure 4
Overall energy consumption (final energy) [kWh/m^2]	335.1	82.9	62.9
Heating/cooling energy consumption [kWh/m^2]	320.0/0.0	68.0/0.0	48.0/0.0
Primary energy consumption (total) [kWh/m^2]	502.6	125.0	95.0
CO_2 emissions [kg/m^2]	100.5	25.0	19.0
Investment cost [EUR/m^2]	-	205.2	9.6
Wider benefits (qualitative)	-	Reduction of pollutants	Reduction of pollutants

Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets:

With the suggested measures, the target of the Nearly Zero Energy (Major Renovation) will be achieved. Four energy efficiency measures were analysed providing costs and energy improvements useful to determine the economic feasibility of the measures. After the 2^{nd} step of renovation, the building is classified as A1.

Table 23. Overview of Italian Case Study buildings - Renovation Roadmap IT-02

TIMEPAC Code	Renovation Roadmap: measures in the correct sequence, which depend on the maintenance and repair plan of the facility management	Timing of measures to avoid possible lock-in effects; considering interactions
IT-02	**Building level:** **(1) Package of measures:** Measure 1: Renovation and insulation of external walls Measure 2: Insulation of the roof and the floor Measure 3: Substitution of the windows **(2) Package of measures:** Measure 4: Substitution of the natural gas boilers for domestic hot water with air-to-water heat pumps (3) Package of measures: Measure 5: Installation of a PV system on the roof	Measures in Package (1) should be implemented prior to Package (2) in order to properly size the new generation system. All measures of Package (1) and Package (2) are implemented prior to Package (3) in order to follow the principle of "energy efficiency first". The Renovation Roadmap must be immediately agreed with the owners to stop individual replacement of windows. Insulation measures must be checked regarding fire safety requirements. When planning individual measures, the following interactions with other measures must be considered: Insulation of the façade requires a watertight connection to the flat roof.

Table 24. Assessment results based on actual user profile and operational data for IT-02

	Building before renovation	1^{st} Step of renovation	2^{nd} Step of renovation	3^{rd} Step of renovation
Implementation of measures	-	Measure 1 Measure 2 Measure 3	Measure 4	Measure 5
Overall energy consumption (final energy) [kWh/m^2]	98.9	29.5	15.1	16.5
Heating/cooling energy consumption [kWh/m^2]	81.3/0.0	11.8/0.0	11.8/0.0	11.8/0.0
Primary energy consumption (total) [kWh/m^2]	107.1	34.2	24.6	20.0
CO_2 emissions [kg/m^2]	21.4	6.8	4.0	2.5
Investment cost [EUR/m^2]	-	131.7	15.3	29.2
Wider benefits (qualitative)	-	Reduction of pollutants	Reduction of pollutants	Energy security

Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets:

With the suggested measures, the target of the Nearly Zero Energy (Major Renovation) will be achieved. Five energy efficiency measures were analysed providing costs and energy improvements useful to determine the economic feasibility of the measures. After the 3rd step of renovation, the building, is classified as A2.

Table 25. Overview of Italian Case Study buildings - Renovation Roadmap IT-12

TIMEPAC Code	Renovation Roadmap: measures in the correct sequence, which depend on the maintenance and repair plan of the facility management	Timing of measures to avoid possible lock-in effects; considering interactions
IT-12	**Building level:** **(1) Package of measures:** Measure 1: Renovation and insulation of external walls Measure 2: Insulation of the flat roof from the internal side with a false ceiling Measure 3: Substitution of the windows **(2) Package of measures:** Measure 4: Substitution of the natural gas boiler with two air-to-water heat pumps (3) Package of measures: Measure 5: Installation of a PV system on the roof	Measures in Package (1) should be implemented prior to Package (2) in order to properly size the new generation system. All measures of Package (1) and Package (2) are implemented prior to Package (3) in order to follow the principle of “energy efficiency first”. The Renovation Roadmap must be immediately agreed with the owners to stop individual replacement of windows. Insulation measures must be checked regarding fire safety requirements. When planning the individual measures, the following interactions with other measures must be considered: Insulation of the façade requires a watertight connection to the flat roof.

Table 26. Assessment results based on actual user profile and operational data for IT-12

	Building before renovation	1st Step of renovation	2nd Step of renovation	3rd Step of renovation
Implementation of measures	-	Measure 1 Measure 2 Measure 3	Measure 4	Measure 5
Overall energy consumption (final energy) [kWh/m^2]	340.3	174.9	63.7	45.1
Heating/cooling energy consumption [kWh/m^2]	290.5/0.0	124.8/0.0	47.9/0.0	38.7/0.0
Primary energy consumption (total) [kWh/m^2]	359.0	184.1	287.4	202.2
CO_2 emissions [kg/m^2]	71.8	36.8	29.3	20.7

Investment cost [EUR/m^2]	-	264.4	157.8	51.1
Wider benefits (qualitative)	-	Reduction of pollutants	Reduction of pollutants	Energy security

Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets:

With the suggested measures, the target of the Nearly Zero Energy (Major Renovation) will be achieved. Five energy efficiency measures were analysed providing costs and energy improvements useful to determine the economic feasibility of the measures. After the 3rd step of renovation, the building is classified as A4. The primary energy consumption increases in the second step of the renovation measures due to the primary energy conversion factors (in Italy the total primary energy conversion factor is equal to 1.05 for natural gas and 2.42 for electricity), and due to the fact that the thermal energy extracted from the outside environment is accounted as renewable energy in the primary energy calculation.

Table 27. Overview of Italian Case Study buildings - Renovation Roadmap IT-13

TIMEPAC Code	Renovation Roadmap: measures in the correct sequence, which depend on the maintenance and repair plan of the facility management	Timing of measures to avoid possible lock-in effects; considering interactions
IT-13	**Building level:** **(1) Package of measures:** Measure 1: Renovation and insulation of external walls Measure 2: Insulation of the flat roof from the internal side with a false ceiling Measure 3: Substitution of the windows **(2) Package of measures:** Measure 4: Substitution of the control system	Measures in Package (1) should be implemented prior to Package (2) in order to properly size the new generation system. All measures of Package (1) and Package (2) are implemented prior to Package (3) in order to follow the principle of "energy efficiency first". The Renovation Roadmap must be immediately agreed with the owners to stop individual replacement of windows. Insulation measures must be checked regarding fire safety requirements. When planning the individual measures, the following interactions with other measures must be considered: Insulation of the façade requires a watertight connection to the flat roof.

Table 28. Assessment results based on actual user profile and operational data for IT-13

	Building before renovation	1st Step of renovation	2nd Step of renovation
Implementation of measures	-	Measure 1 Measure 2 Measure 3	Measure 4
Overall energy consumption (final energy) [kWh/m^2]	174.8	119.4	85.6
Heating/cooling energy consumption [kWh/m^2]	146.5/0.0	92.2/0.0	58.6/0.0
Primary energy consumption (total) [kWh/m^2]	288.1	204.2	153.2
CO_2 emissions [kg/m^2]	12.2	11.8	11.7
Investment cost [EUR/m^2]	-	98.2	6.8
Wider benefits (qualitative)	-	Reduction of pollutants	Reduction of pollutants

Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets:

With the suggested measures, the target of the Nearly Zero Energy (Major Renovation) will be achieved. Four energy efficiency measures were analysed providing costs and energy improvements useful to determine the economic feasibility of the measures. After the 2nd step of renovation, the building is classified as category B.

Table 29. Overview of Italian Case Study buildings - Renovation Roadmap IT-15

TIMEPAC Code	Renovation Roadmap: measures in the correct sequence, which depend on the maintenance and repair plan of the facility management	Timing of measures to avoid possible lock-in effects; considering interactions
IT-15	**Building level:** **(1) Package of measures:** Measure 1: Renovation and insulation of external walls Measure 2: Insulation of the flat roof from the internal side with a false ceiling Measure 3: Substitution of the windows **(2) Package of measures:**	Measures in Package (1) should be implemented prior to Package (2) in order to properly size the new generation system. All measures of Package (1) and Package (2) are implemented prior to Package (3) in order to follow the principle of “energy efficiency first”. The Renovation Roadmap must be immediately agreed with the owners to stop individual replacement of windows. Insulation measures must be checked regarding fire safety requirements.

	Measure 4: Substitution of the natural gas boiler with two air-to-water heat pumps	When planning individual measures, the following interactions with other measures must be considered: Insulation of the façade requires a watertight connection to the flat roof.

Table 30. Assessment results based on actual user profile and operational data for IT-15

	Building before renovation	1st Step of renovation	2nd Step of renovation
Implementation of measures	-	Measure 1 Measure 2 Measure 3	Measure 4
Overall energy consumption (final energy) [kWh/m^2]	234.2	212.6	120.6
Heating/cooling energy consumption [kWh/m^2]	188.5/0.0	167.0/0.0	81.7/0.0
Primary energy consumption (total) [kWh/m^2]	296.1	273.2	296.8
CO_2 emissions [kg/m^2]	58.3	53.8	55.5
Investment cost [EUR/m^2]	-	226.9	81.3
Wider benefits (qualitative)	-	Reduction of pollutants	Reduction of pollutants

Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets:

With the suggested measures, the target of the Nearly Zero Energy (Major Renovation) will be achieved. The recommendations provided in the original energy audit of the building (issued 2022) are very detailed and suitable to achieve the targets. Four energy efficiency measures were analysed providing costs and energy improvements useful to determine the economic feasibility of the measures. After the 3rd step of renovation, the building is classified as A4. The CO_2 emission slightly increases in the second step of the renovation due to the CO_2 conversion factor (0.21 kg CO_2/kWh for natural gas and 0.46 kg CO_2/kWh for electricity).

General remarks and recommendations

The Renovation Roadmap highlighted above reflects the Energy Efficiency First Principle. Energy efficiency is, indeed, a pillar of the EU Energy Union. The Energy Efficiency First Principle is embedded in the Regulation on Governance of the Energy Union and Climate Action (2018/1999) and in the Energy Efficiency Directive (2018/2002). Article 3 of the Commission's recast proposal sets an obligation for EU countries to ensure that energy efficiency solutions are considered in energy system and non-energy sectors planning, policy and investment decisions.

This obligation is coupled with requirements for EU countries to:

- develop and ensure application of cost-benefit assessment methodologies that allow proper assessment of wider benefits of energy efficiency solutions from the societal perspective
- identify an entity responsible for monitoring of the application of the energy efficiency first principle
- report to the Commission on how it is applied

Energy efficiency is, therefore, a guiding principle that should be always taken into consideration even in the definition of a Building Renovation Passport. It should be the first option in case of lack of different inputs from the end users or in the absence of more detailed information. Nevertheless, there could be several conditions or general aspects that could lead to follow a different approach. The following driving forces could, for instance, affect the assessment:

- The economic dimension of the single measures
- The synergies among measures
- The timing left to reach the zero-emission target.

For the first dimension, it is important to consider what is feasible and realistic from the economic point of view, assuming that the homeowner is keen to implement the most favourable actions in terms of payback or is attracted to catch the opportunities of incentives that are available and that could expire in the future. The sense of urgency of doing some interventions as a first option because the economic and financial conditions are good at present, could lead to a less rational solution compared to a fully-engineering approach (i.e. applying The Energy Efficiency First principle). The installation of a PV system, for instance, is nowadays convenient in most of the cases and it is very likely that it is among the top priorities for end users, given also the incentives available.

Besides, it is always very important to assess potential synergies that can be explored among different measures. Some of them, that we can declare as “follow-up measures”, could thus be anticipated and merged with others, namely the “driving measures”.

Whenever the latter take place, it makes more sense to implement the former. To give an example, we can retrofit the roof that can be combined with the installation of a PV plant.

Finally, it is important to implement a dynamic assessment of the interventions considering the final goal of the Renovation Passport, which is to create a roadmap for a Zero Emission Building. Given the timeframe of 2050, it is also important to assess the technological lifetime of the single measure. Some of them should be replaced after 15 or 20 years, hence it is also important that this is duly taken into account and that measures are planned when their duration is able to impact in the most positive way the overall process or it is not a constraint for the following steps.

In order to overcome all those issues that make an assessment very complex, an option could be to elaborate on more renovation scenarios mixing them in a different way with the foreseen measures. There could be, for instance, an “energy rational” scenario (energy efficiency driven as in the example above) and another one that we could define as an “economically rational” scenario, based on the payback and on available incentives that could shape the choice of end users in a different way.

In addition to the above considerations, it is also important to elaborate on the emission factors that will be used to estimate the carbon impact of the planned measures. To figure out a long-term carbon neutral scenario, it is important that the dynamic evolution of the emission factors is also taken into consideration. This aspect is even more crucial nowadays since most of the thermal use could be shifted to electricity. According to the EU and National Plans, in the future most of the electricity will be largely decarbonized. In the EU-27, the power sector emissions would need to decline at an average annual rate of 6% per year to reach zero emissions by 2035.
Therefore, it is not fully correct to keep the emission factor of electricity fixed to the current data.

Another important point that should be considered when implementing a long-term assessment is related to the evolution of the building site in the surrounding environment due to climate change.

It is very likely that in future the energy consumption for cooling will have much more importance than it has today, even in the domestic sector. Thinking about a Renovation Passport for the zero-emission target should internalize this assumption. Besides, the concept of resiliency should also be taken into account. The climate change will affect the urban context of cities more and more, therefore it is very important that the resilience of buildings is boosted to adapt to the external stress caused by climate change.

4.5.4 Conclusions

4.5.4.1 Workflow and data

Specific challenges related to multi-unit residential buildings

Challenges regarding the uptake of the Renovation Roadmap:

- Synchronizing the Renovation Roadmap with property management measures can indeed lead to challenges when it comes to the replacement of windows in multi-residential buildings in Italy, where the windows are owned by the individual unit owners.
- Synchronizing the Renovation Roadmap with the requirements as outlined in DM 26/06/2015 and in D.Lgs. 199/2021, ensuring that refurbishment activities align with the minimum standards and regulations set by the Italian government. DM 26/06/2015 lays down specific minimum requirements based on the type of building renovation. Major renovations are characterized by a renovation of the building envelope, affecting over 25% of the total thermal envelope area.
  If the renovation measures impact more than 50% of the thermal envelope area and also involve the refurbishment of the technical building system for space heating and/or cooling, it is considered a "1st level major renovation." In this case, certain compulsory actions must be taken, including
    - the arrangement for connection to district heating and cooling networks
    - the installation of systems for the automatic regulation of room temperature in individual rooms or thermal zones
    - the implementation of intelligent measurement systems for energy consumption
    - a heat, cold, and domestic hot water metering system
    - a minimum level of automation for the control, regulation, and management of building technologies and thermal systems (Building Automation and Control Systems - BACS)

  Furthermore, for renovations of buildings with a conditioned floor area exceeding 1000 m^2 and a renovation of the entire building's thermal envelope area, it is mandatory to cover at least 60% of the primary energy used for heating, cooling, and Domestic Hot Water production with renewable energy sources. In this scenario, the installation of a minimum power amount of a Photovoltaic (PV) system in the proximity of the building is also required.

Challenges regarding operation data and actual user profiles:

- Occupants of rented flats change and so does their user profile
- Detailed energy consumption of apartments is not easily accessible, but not useful either, considering the point above

Sources of input data including BIM

The assessment result of an EPC is significantly influenced by the building's geometry, including surface orientation and the definition of the reference area for calculating indicators. Currently, when issuing a new EPC, data collection starts from scratch because the electronic EPC file belongs to the issuer, and there is an expectation that the issuers will conduct their own assessment rather than relying on previous work done by another expert. It is also important to note that the EPC is not sufficient for developing a building Renovation Roadmap. To create a reliable data foundation for the Building Renovation Roadmap, it is necessary to conduct on-site visits.

In some cases, valuable information can be found within the BIM model of a building. While BIM models are not commonly available for residential buildings, they are more frequently used for large public buildings due to legal obligations.

These models typically include information about the building's geometry and envelope materials, but the representation of technical building systems and their mechanical details may not always be present. Additionally, it is important to consider that frequently these models are not regularly updated. Although the architectural BIM model is mandatory for certain public contracts, there is currently no obligation in Italy to maintain and update the model in a specific platform. Consequently, there is a lack of information regarding implemented refurbishments.

Typically, the architectural BIM model and the analytical model used for creating the EPC are developed separately by different professionals, and as a result, there is no direct connection between these two models. Furthermore, in Italy, EPCs for multi-unit residential buildings pertain to individual units rather than to the entire building. Consequently, if implementing a Renovation Passport for the entire building, a new model would need to be created from the scratch. This model would indicate the refurbishment roadmap, which may not align precisely with the refurbishments suggested in the individual EPCs.

Calculation tools and data transfer

Edilclima tool, along with other certified building energy assessment tools in Italy, offers the capability to develop various renovation scenarios and evaluate their energy, environmental, and economic performance. These tools allow for visualizing different refurbishment options and comparing them to the baseline conditions. In a hypothetical scenario, such a tool could also be used to create a Building Renovation Passport by incorporating a timeline for the scenarios.

Currently, the monthly steady-state method, as defined in the UNI/TS 11300 technical standard, is used for energy assessment purposes in Italy and is implemented in each assessment tool. For energy audits, the simple hourly method based on EN ISO 52016-1:2018 can also be utilized to assess thermal energy need for space heating and cooling. However, for primary energy calculations, no hourly method based on European standards has been implemented yet in the Italian territory.

In this context, it is evident that the hourly method offers a more detailed approach as compared to the monthly method. It provides a better estimation of summer energy consumption and addresses the issue of overheating during that season. Additionally, the hourly method allows for a more accurate estimation of energy needs by considering the specific user profile.

Regarding the transfer of data between BIM tools and EPC generation tools, the typical approach involves importing an IFC file from the architectural BIM model into the energy calculation tool. This process ensures that data related to the building's geometry and materials comprising the envelope elements are transferred to the energy model without any loss of information. As mentioned previously, when importing the architectural BIM model into the energy calculation tool, certain information may still be missing. Therefore, an additional input such as data related to technical building systems, needs to be manually inserted into the tool.

Provision of information to building owners and property managers

In Italy owners and building managers can login into the account system of the regional EPC database environment with SSH Certificate-based Authentication or other methods like CIE (Electronic Identity Card) or SPID (Public Digital Identity System).

The information about the progress of the planned updates to the envelope and the plants must be accessible by users and public administration likewise.

In Italy, the information about the state of the building could be associated with the cadastre property titles and fiscal databases. Currently, this is just a hypothesis made by ENEA (National

Agency for New Technologies, Energy and Sustainable Economic Development) to be hopefully implemented during 2024.

Information about the steps of refurbishment needed must be shared with owners of buildings and units to plan actions in the correct time sequence and with the financial resources needed.

4.5.4.2 Procedures of tracing the evolution of building refurbishment

In Italy, there is currently no direct connection between the EPC and the Renovation Roadmap. After the EPC is created, it is typically uploaded into a regional database along with suggested renovation scenarios that could be implemented in the future.

These renovation scenarios include information about the energy and economic assessment of planned building refurbishments. However, there is no comprehensive roadmap outlining the implementation of these scenarios. It is also difficult to determine whether new building renovations will be necessary in the future because there is no centralized location or method to search for updated information within the EPC files. The only available option is to share the documentation with building owners and managers so that they can refer to it when needed in the future.

4.5.4.3 Interlinking the evolution of EPCs with the evolution of BIM models

There is currently no established procedure for addressing the need to update EPC information and make renovation scenarios readily available. However, software companies are actively working on potential workflows for the future.

The problem is clear: EPC information must be updated regularly, and renovation scenarios should be easily accessible. To tackle this issue, the first step is to export and save EPC data using an open format that does not require specific calculation software.

One option is to use the IFC format, which allows the file to be accessed throughout the year without relying on any specialized software. While IFC is an excellent open format, it does not currently support the transfer of all energy information calculated using energy calculation tools. Therefore, additional files are necessary to incorporate such data. Saving them in an .ifc.zip file format can help to maintain an open process.

To complete the process of saving EPC information for the future, a new type of repository or digital platform is needed. This platform would enable experts and public administrators to upload search, and access information and models related to energy data and building refurbishment scenarios. The goal is to create an environment where these resources can be utilized and constantly updated.

A crucial aspect of the platform is its integration with existing databases that contain building-related information, such as the building cadastre and the EPC database. This integration would enable a comprehensive evaluation of building assessments that is continuously updated over time.

Overall, the development of a technological solution involving open file formats such as IFC and .ifc.zip, along with a digital platform for storing and accessing EPC information and renovation scenarios, presents a challenge that requires integration with existing building databases.

4.5.4.4 Other issues

The Renovation Passport should encompass various aspects such as health, comfort, sustainability, and readiness for a smart building. This integration poses significant challenges that can be summarized as follows:

- Updating dynamic information. A robust evaluation system should be established to regularly update and track the dynamic aspects, ensuring the Passport reflects the current state of the building.

- Simplifying the overall assessment. Integrating multiple aspects into a comprehensive assessment requires streamlining the calculation process. This involves developing interoperable tools that can handle all the different components of the assessment while allowing seamless data exchange between them. Standardization of data formats and protocols would be crucial in achieving this simplification.
- Managing multiple professionals and avoiding discrepancies. The calculations and updates for different aspects of the Building Renovation Passport may involve the contributions of various professionals. Coordinating their work and ensuring that there is no overlap or discrepancy in information and results is essential. Establishing clear guidelines, protocols, and communication channels among professionals can help minimize these issues.

Addressing these challenges requires a collaborative and coordinated approach involving stakeholders from various domains. It is crucial to establish efficient workflows, standardized methodologies and effective communication channels to ensure that the Building Renovation Passport will serve as an effective instrument for the purpose of building decarbonisation.

4.6 Slovenia

4.6.1 Tabular characterisation of assessed buildings

Table 31 below shows the characteristics of the five assessed buildings in Slovenia (SI-01, SI-02, SI-03, SI-05 and SI-08).

Table 31. Overview of Slovenian Case Study buildings

TIMEPAC Code	Building type	Owner	Location	Short building description	Data used
Internal Code from Building List	Residential or type of non-residential	Public, private; single owner or co-ownership	Region and city	Year of construction, conditioned floor area, implemented improvement measures, Technical Building System	Which type of data is available and used for the Renovation Roadmap
SI-01	Non-residential (Elementary School)	Public	Komen	Constructed in 1976 and partly renovated in 1994; conditioned floor area 3,174 m^2; installed systems are outdated and energy inefficient; there is no ventilation and cooling systems; newer LED lighting is installed in the building (hallways), while the remaining part has energy-inefficient lighting; an energy accounting system has been introduced to monitor energy consumption in the building. but there is no additional energy consumption measurement besides the official one; delivered energy carriers: electricity and liquefied petrol gas.	EPC BIM model BEM model Energy audit Energy consumption data Information provided by the owner
SI-02	Non-residential (Health centre)	Public	Idrija	Constructed in 1980; in 2019, the building underwent comprehensive energy renovation; conditioned floor area 3,630 m^2; the majority of energy is used for heating the building, while a smaller portion is allocated to lighting, hot water preparation, and cooling; energy management system installed; energy carriers: electricity and district heat.	EPC BIM model Energy audit Energy consumption data Information provided by the owner
SI-03	Non-residential (Offices)	Public	Dobrovo	Constructed in 1956 and completely renovated in 2013; conditioned floor area 605 m^2; ESCO model was applied for the building renovation; energy management system installed; energy carriers: electricity.	EPC BIM and BEM model Energy audit Energy consumption data

					Information provided by the owner
SI-05	Non-residential (Elementary and secondary school)	Public	Koper	Constructed in 1675; the facade was partly renovated in 1970 and the roof was renovated in 1994; conditioned floor area 2,527 m^2; the building is under cultural heritage protection; installed systems are outdated and energy inefficient; there are no ventilation and cooling systems installed in the building; outdated and energy-inefficient lighting is installed without occupancy-based activation; building does not have energy monitoring and reporting systems installed; energy carriers: electricity and extra light fuel oil.	EPC BIM model Energy audit Energy consumption data Information provided by the owner
SI-08	Non-residential (Elementary school)	Public	Nova Gorica	Constructed in 1960; in 2022, the building underwent comprehensive energy renovation; conditioned floor area 3,977 m^2; energy accounting system is installed; energy carriers: electricity, district heating and natural gas (cooking).	EPC BIM model Energy audit Energy consumption data Information provided by the owner

4.6.2 Description of the procedure

The analysis is based on energy audit reports, EPC tools Energija 2010 and PURES 2022, and additionally developed Building Energy Models (BEM) for all buildings using IDA-ICE software. Unfortunately, there are no tools for digital and automatic development of Renovation Passports (RP) for buildings in Slovenia. Results obtained from BEM, EPC tools Energija 2010 and PURES 2022 and energy audit reports are aggregated and shown in the next paragraph and they represent RP for buildings addressed in this report. In detail, the procedure that has been performed is as follows:

- Energy indicators and energy performance for existing conditions were derived from the EPC and energy audit report for all buildings. In Energija 2010 and PURES 2022, the standardized building model was developed for all buildings. BEM models for all addressed buildings were developed, too.
- During organized on-site visits and in discussions with the energy and facility managers a list of energy efficiency measures that have been proposed in energy audits were further discussed and re-evaluated. Special attention was put on the integration of RES and the upgrade of existing monitoring and energy management procedures.
- Based on data from energy audit reports and outcomes from the discussion with the energy and facility managers, an implementation action plan has been created. Energy efficiency measures were combined in logical renovation steps and recalculated regarding achievable savings and investments. In this step BEM models were used to calculate energy savings. Investment costs were estimated based on previous experiences on similar deep renovation

projects, on data from the Slovenian Eco Fund and informative offers submitted by potential technology suppliers.

- The implementation action plan has been added to the already existing energy audit reports.
- In PURES 2022, the identified and recommended energy efficiency measures were applied on the standardized building model to recalculate EPC ratings that can be achieved after the implementation of energy efficiency measures. Recalculation was done for specific measures, their combinations and for an overall refurbishment.

Table 32 provides more information about the data used in the process.

Table 32. Data used in the assessment process

Type of data used	Source of information	Comment
Energy related building data	EPC retrieved from the official data repository	Complete EPC data is only accessible for the EPC issuer and the Ministry
Building layout	DWG received from owners	DWG is only accessible for owners, designers and the Municipality
Detailed building data related to energy	Energy audit reports received from owners	The energy audit report is only accessible for owners, auditors and the Municipality
Architectural model	Created for TIMEPAC	Only one of the addressed buildings had a BIM model. For creation of BIM models IDA ICE software was used. Creation of the BIM models for the building renovation is not yet common procedure in Slovenia
Building Energy Model	Created for TIMEPAC	Dynamic BEM for all addressed buildings were created. There is no BEM repository and the models are only accessible for owners and designers
Renewable energy potential data, district heating / cooling potential data	Interviews with energy and facility managers, GIS, zoning plan / urban development plan, local sustainable energy and climate plans, national energy and climate plan	No link between zoning plan, sustainable energy and climate plan and EPC data repository
Energy consumption (operational data)	Energy consumption received from the owner and energy managers (obtained through energy accounting system (SI-01, SI-05, SI-08) or energy	Energy consumption is only accessible for owners and energy distributors / traders

	management system(SI-02 and SI-03)	
Implementation costs (materials, equipment, installation and maintenance)	Data from the Eco Fund repository about already implemented deep energy renovation projects from Slovenia. Communication and informative offers from selected technology providers (energy management systems, heat pumps, etc.).	Eco Fund data repository contains information about all already implemented deep energy renovation projects throughout Slovenia but this data is only available to the employees of the Eco Fund.

4.6.3 Description of assessment results

Table 33 shows the assessment results in terms of Renovation Roadmap as a summary for all five analysed buildings.

Table 33. Overview of Slovenian Case Study buildings - Renovation Roadmaps

TIMEPAC Code	Renovation Roadmap: proposed measures are in the correct implementation sequence; the detailed plan depends on the maintenance and repair plan of the facility management	Timing of measures to avoid possible lock-in effects; considering interactions
SI-01	**Building level:** **(1) Package of measures:** Installation of a state-of-the art energy management system Renovation of lighting system – implementation of LED luminaries and advanced control systems in all classrooms Installation of a PV system on the roof **(2) Package of measures:** Thermal insulation of external walls Thermal insulation of the ceiling towards the attic Thermal insulation towards the basement Windows replacement **(3) Package of measures:** Reconstruction of the HVAC system – implementation of new heat pump for heating and cooling, new VSD pumps and advanced control of heating and cooling systems **District level:** Future decarbonisation of power system has been included in calculation of future CO_2 emissions. According to the Slovenian	All measures of Package (1) and Package (2) are implemented prior to Package (3). When developing the detailed plan, the following aspects must be considered: The energy management system must be capable to perform demand side manage functions (peak load management). Renovation of lighting system must be done according to relevant standards and codes. Load capacity (statics) of the roof must be checked before installation of the PV system. Energy permits for the installation of a PV system must be obtained from the local utility. Insulation measures must be checked regarding fire safety requirements. Seismic safety must be checked. Before the installation of the heat pump Local / Municipal Acts

	National Energy and Climate Plan, the power system will be fully decarbonised by 2050.	regarding requirements for the noise reduction must be checked.
SI-02	**Building level:** **(1) Package of measures:** Upgrade of the installed energy management system Installation of a PV system on the roof **(2) Package of measures:** Renovation of lighting system – implementation of LED luminaries and advanced control systems in all rooms **(3) Package of measures:** Installation of the battery system for peak load management, emergency power supply and optimisation of the PV production **District level:** Future decarbonisation of the power system and the local district heating system in Idrija have been included in calculations of future CO_2 emissions. According to the Slovenian National Energy and Climate Plan, the power system and all local district heating systems will be fully decarbonised by 2050.	All measures of Package (1) and Package (2) are implemented prior to Package (3). When developing the detailed plan, the following aspects must be considered: Energy management system must be capable to perform demand side management functions (peak load management). Renovation of the lighting system must be done according to relevant standards and codes. Load capacity (statics) of the roof must be checked before installation of the PV system. Energy permits for the installation of the PV system must be obtained from the local utility.
SI-03	**Building level:** **(1) Package of measures:** Upgrade of the installed energy management system Installation of a PV system on the roof **(2) Package of measures:** Renovation of lighting system – implementation of LED luminaries and advanced control systems in all rooms **(3) Package of measures:** Reconstruction of the HVAC system – advanced control of ventilation, heating and cooling systems (CO_2 based regulation of the ventilation system) Installation of a battery system for peak load management, emergency power supply and optimisation of the PV production **District level:** A future decarbonisation of the power system has been included in calculations of future CO_2 emissions. According to the Slovenian National Energy and Climate Plan, the power system will be fully decarbonised by 2050.	All measures of Package (1) and Package (2) are implemented prior to Package (3). When developing the detailed plan, the following aspects must be considered: The energy management system must be capable to perform demand side management functions (peak load management). Renovation of the lighting system must be done according to relevant standards and codes. Load capacity (statics) of the roof must be checked before installation of the PV system. Energy permits for the installation of a PV system must be obtained from the local utility.

SI-05	**Building level:** **(1) Package of measures:** Installation of a state-of-the-art energy management system Renovation of lighting system – implementation of LED luminaries and advanced control systems in all classrooms **(2) Package of measures:** Installation of a PV system on the roof Thermal insulation of external walls Thermal insulation of the ceiling towards the attic Thermal insulation towards the basement Windows replacement **(3) Package of measures:** Reconstruction of the HVAC system – implementation of a new heat pump for heating and cooling, new VSD pumps and advanced control of heating and cooling systems, modern CO_2 based ventilation Installation of a battery system for peak load management, emergency power supply and optimisation of the PV production **District level:** Future decarbonisation of the power system has been included in calculations of future CO_2 emissions. According to the Slovenian National Energy and Climate Plan, the power system will be fully decarbonised by 2050.	All measures of Package (1) and Package (2) are implemented prior to Package (3). When developing the detailed plan, the following aspects must be considered: The energy management system must be capable to perform demand side management functions (peak load management). Renovation of the lighting system must be done according to relevant standards and codes. PV integration on protected buildings is difficult both, for the presence of heritage values and the differences between the appearance of a PV system and traditional features and materials. The assessment of PV compatibility on protected areas and buildings needs a multidisciplinary team composed by conservators, architects, engineers, landscape designers, heritage, and public authorities. In case of positive evaluation, load capacity (statics) of the roof must be checked before installation of the PV system. Energy permits for the installation of a PV system must be obtained from the local utility. Insulation measures must be checked regarding cultural heritage and fire safety requirements. Seismic safety must be checked. Before the installation of the heat pump, the Local / Municipal Acts regarding requirements for the noise reduction must be checked.
SI-08	**Building level:** **(1) Package of measures:** Installation of the modern energy management system Installation of PV system on the roof **(2) Package of measures:** Installation of a battery system for peak load management, emergency power supply and optimisation of the PV production **District level:** Future decarbonisation of the power system and local district heating system in Nova Gorica has been included in calculations of	All measures of Package (1) and Package (2) are implemented prior to Package (3). When developing the detailed plan, the following aspects must be considered: The energy management system must be capable to perform demand side management functions (peak load management). Load capacity (statics) of the roof must be checked before installation of the PV system. Energy permits for

	future CO_2 emissions. According to the Slovenian National Energy and Climate Plan, the power system and all local district heating systems will be fully decarbonised by 2050.	the installation of a PV system must be obtained from the local utility.

Tables 34 to 38 show the overview of indicators by renovation step and building.

Table 34. Assessment results based on actual user profile and operational data for SI-01

	Building before renovation	1st Step of renovation	2nd Step of renovation	3rd Step of renovation
Implementation of measures	-	Installation of the energy management system Renovation of the lighting system Installation of a PV system	Thermal insulation of external walls Thermal insulation of the ceiling towards the attic and the basement Windows replacement	Reconstruction of the HVAC system
Total energy consumption (final energy) [kWh/m^2]	Liquefied petroleum gas: 83 Electricity: 29	Liquefied petroleum gas: 75 Electricity: 29	Liquefied petroleum gas: 28 Electricity: 29	Electricity: 38
Heating/cooling energy consumption [kWh/m^2]	Liquefied petroleum gas: 83	Liquefied petroleum gas: 75	Liquefied petroleum gas: 28	Electricity: 13
Primary energy consumption (total) [kWh/m^2]	163.8	116.7	63.3	0
CO_2 emissions [kg/m^2]	36.3	21.8	8.1	0
Investment cost [EUR/m^2]	-	120	330	110
Wider benefits (qualitative)		Better energy management, peak load management, grid flexibility,	Better thermal comfort	Better thermal comfort, better indoor air quality

		better illumination for employees and pupils, RES production on location		

Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets:

The renovation scenarios follow the rule of first reducing the energy needs for heating and later on replacing the old heating system. The nominal power of a solar power plant installation is foreseen bigger as the actual needs, since the installation of the heat pump follows later and the plant must cover the needs for the heat pump as well. With the implementation of all proposed measures, both targets will be achieved, a nearly Zero Energy (Major Renovation) as well as a Zero Emission Building when applying standardized calculation methods. When having in mind the national goals (complete decarbonisation of the power system before 2050) and the actual user profile regarding electricity consumption, a Zero Emission Building will also be achieved. Availability of the documentation (two dimensional as .dwg-files), energy audit report, energy bills and the EPC data were very important for the creation of a realistic Renovation Passport. A newly developed BIM model can be used for tracking the progress in view of the set goals.

Table 35. Assessment results based on actual user profile and operational data for SI-02

	Building before renovation	1st Step of renovation	2nd Step of renovation	3rd Step of renovation
Implementation of measures	Energy renovated in 2019 (up-to-date HVAC, energy management, thermal insulation of external walls, etc.)	Upgrade of the energy management system Installation of a PV system	Renovation of the lighting system	Installation of the battery system
Total energy consumption (final energy) [kWh/m²]	District heating: 77 Electricity: 73	District heating: 71 Electricity: 21	District heating: 71 Electricity: 18	District heating: 71 Electricity: 9
Heating/cooling energy consumption [kWh/m²]	District heating: 77	District heating: 71	District heating: 71	District heating: 71
Primary energy consumption (total) [kWh/m²]	274.9	87.5	80.0	0
CO_2 emissions [kg/m²]	57.6	12.8	11.6	0

Investment cost [EUR/m^2]	-	74	43	270
Wider benefits (qualitative)		Better energy management, peak load management, grid flexibility, RES production on location	Better illumination for employees and visitors/users	Better grid flexibility

Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets:

With the implementation of all proposed measures, both targets will be achieved, a Nearly Zero Energy (Major Renovation) and a Zero Emission Building when applying standardized calculation methods. When having in mind the national goals (complete decarbonisation of the power system and all local district heating systems before 2050) and the actual user profile regarding electricity consumption, a Zero Emission Building will also be achieved. Availability of the documentation (two dimensional as .dwg-files), energy audit report, energy bills and the EPC data were very important for the creation of a realistic Renovation Roadmap. A newly developed BIM model can be used for tracking the progress in view of the set goals. A battery system can be also used as an asset that can be offered at the market of auxiliary services.

The ability to analyse the energy balance with the BEM software enables to further exploit the ability of using a storage battery, since peaks of electricity will be stored in the summer, while the actual usage usually follows months later.

Table 36. Assessment results based on actual user profile and operational data for SI-03

	Building before renovation	1st Step of renovation	2nd Step of renovation	3rd Step of renovation
Implementation of measures	Energy system renovated in 2013 (up-to-date heat pump installed, energy management, thermal insulation of external walls, etc.)	Upgrade of the energy management system Installation of a PV system	Renovation of the lighting system	Reconstruction of the HVAC system Installation of the battery system
Total energy consumption (final energy) [kWh/m^2]	Electricity: 38	Electricity: 35	Electricity: 32	Electricity: 30
Heating/cooling energy consumption [kWh/m^2]	Electricity: 26	Electricity: 24	Electricity: 24	Electricity: 22

Primary energy consumption (total) [kWh/m²]	95.0	31.3	23.8	20.8
CO_2 emissions [kg/m²]	15.9	14.7	13.4	0
Investment cost [EUR/m²]	-	91	41	305
Wider benefits (qualitative)		Better energy management, peak load management, grid flexibility, RES production on location	Better illumination for employees and visitors	Better thermal comfort, better indoor air quality, better grid flexibility,

Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets:

With the implementation of all proposed measures, both targets will be achieved, a Nearly Zero Energy (Major Renovation) and Zero Emission Building when applying standardized calculation methods. When having in mind the national goals (complete decarbonisation of the power system before 2050) and the actual user profile regarding electricity consumption, a Zero Emission Building will also be achieved. Availability of the documentation (two dimensional as .dwg-files), energy audit report, energy bills and the EPC data were very important for the creation of a realistic Renovation Roadmap. A newly developed BIM model can be used for tracking the progress in view of the set goals. The battery system can be also used as an asset that can be offered at the market of auxiliary services.

The ability to analyse the energy balance with the BEM software enables to further exploit the ability of using battery storage, since peaks of the electricity will be stored in summer, while the actual usage usually follows months later.

Table 37. Assessment results based on actual user profile and operational data for SI-05

	Building before renovation	1st Step of renovation	2nd Step of renovation	3rd Step of renovation
Implementation of measures	-	Installation of the energy management system Renovation of the lighting system Installation of a PV system	Thermal insulation of external walls Thermal insulation of the ceiling towards the attic and the basement Windows replacement	Reconstruction of the HVAC system Installation of the battery system

Total energy consumption (final energy) [kWh/m^2]	Extra light fuel oil: 87 Electricity: 21	Extra light fuel oil: 79 Electricity: 17	Extra light fuel oil: 31 Electricity: 17	Electricity: 27
Heating/cooling energy consumption [kWh/m^2]	Extra light fuel oil: 87	Extra light fuel oil: 79	Extra light fuel oil: 31	Extra light fuel oil: 10
Primary energy consumption (total) [kWh/m^2]	148.2	117.4	64.6	23.0
CO_2 emissions [kg/m^2]	34.1	31.7	16.1	0
Investment cost [EUR/m^2]	-	130	350	635
Wider benefits (qualitative)		Better energy management, peak load management, grid flexibility, better illumination for employees and pupils, RES production on location	Better thermal comfort	Better thermal comfort, better indoor air quality, better grid flexibility

Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets:

The renovation scenarios follow the rule of first reducing the energy needs for heating and later on replacing the old heating system. The nominal power of the solar power plant installation is foreseen bigger as the actual needs, since the installation of the heat pump follows later and the plant must cover the needs for the heat pump as well.

With the implementation of all proposed measures, both targets will be achieved, a Nearly Zero Energy (Major Renovation) and a Zero Emission Building when applying standardized calculation methods. When having in mind the national goals (complete decarbonisation of the power system before 2050) and the actual user profile regarding electricity consumption, a Zero Emission Building is also achieved. Availability of the documentation (two dimensional as .dwg-files), energy audit report, energy bills and the EPC data were very important for the creation of a realistic Renovation Roadmap. A newly developed BIM model can be used for tracking the progress in view of the set goals. The integration if a PV system on protected buildings is difficult due to both, for the presence of heritage values and the differences between the appearance of a PV system and traditional features and materials. The assessment of PV compatibility on protected areas and buildings needs a multidisciplinary team composed by conservators, architects, engineers, landscape designers, heritage, and public authorities. A battery system can be also used as an asset that can be offered at the market of auxiliary services.

Table 38. Assessment results based on actual user profile and operational data for SI-08

	Building before renovation	1st Step of renovation	2nd Step of renovation
Implementation of measures	Energy renovated in 2022 (up-to-date HVAC, lighting, thermal insulation of external walls, etc.)	Installation of the energy management system Installation of a PV system	Installation of the battery system
Total energy consumption (final energy) [kWh/m^2]	District heating: 42 Electricity: 18	District heating: 38 Electricity: 18	District heating: 38 Electricity: 18
Heating/cooling energy consumption [kWh/m^2]	District heating: 42	District heating: 38	District heating: 38
Primary energy consumption (total) [kWh/m^2]	95.4	86.1	78.2
CO_2 emissions [kg/m^2]	22.3	20.9	0
Investment cost: [EUR/m^2]	-	70	275
Wider benefits (qualitative)		Better energy management, peak load management, grid flexibility, RES production on location	Better grid flexibility

Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets:

With the implementation of all proposed measures, both targets will be achieved, a Nearly Zero Energy (Major Renovation) and a Zero Emission Building when applying standardized calculation methods. When having in mind the national goals (complete decarbonisation of the power system before 2050) and the actual user profile regarding the electricity consumption, a Zero Emission Building will also be achieved. Availability of the documentation (two dimensional as .dwg-files), energy audit report, energy bills and the EPC data were very important for the creation of the realistic Renovation Roadmap. A newly developed BIM model can be used for tracking the progress in view of the set goals. A battery system can be also used as an asset that can be offered at the market of auxiliary services, but with the current prices (2023) the overall investment can be quite high.

The ability to analyse the energy balance with the BEM software enables to further exploit the ability of using the battery storage, since peaks of electricity will be stored in summer, while the actual usage usually follows months later.

4.6.4 Conclusions

In case of the analysis of Slovenian buildings and creation of RPs, it is clear that energy auditing plays a vital role in providing accurate information about possibilities to optimize energy use, reduce costs, mitigate environmental impact, enhance occupant comfort, ensure compliance, and support long-term energy management strategies for buildings. Energy auditing is crucial for buildings due to several reasons. Energy audits help to identify areas of energy waste and inefficiency within a building. Implementing the recommendations from an audit can lead to significant reductions in energy consumption and associated costs, and at the same time improve occupant comfort and satisfaction, leading to a healthier and more productive indoor environment. By understanding current energy usage and potential areas for improvement, building owners can make informed decisions about future investments in energy-efficient technologies and systems. Regarding the tracing of building refurbishment evolution, considering workflow and data, and linking it with the evolution of BIM and BEM models several future possibilities have been identified:

- Energy auditing: Energy audits provide valuable insights into a building's energy performance and can inform about long-term energy management strategies.
- Utilizing the EPC database: Tracking the evolution of refurbishment through the existing EPC database.
- Versioning the EPC in the database: Monitoring changes in indicators by maintaining different versions of the EPC within the database.
- Tracking changes in EPC recommendations: Monitoring modifications to the recommendations provided in the EPC – in connection with the results/recommendation from the energy audit.
- Leveraging the cadastre: Utilizing the cadastre system to trace changes related to building refurbishment.
- Connecting RPs with the EPC: Tracking changes in the Renovation Roadmap in conjunction with the EPC.
- Logging changes in BIM or BEM: Generating an updated EPC when changes are made to the BIM or BEM model.
- Using an energy management system (EMS): Implementing EMS for tracking building refurbishment and verification of achievements.

Regarding the interlinking of EPC evolution with BIM models, it is evident that generating more reliable EPCs from the BIM/BEM models is a logical step forward. However, this would require significant changes to the existing EPC scheme, which may not be well accepted by stakeholders. In addition to this, considerations arise regarding the BIM/BEM model ownership and additional costs associated with developing BIM/BEM models. The main challenge is how to incorporate positive elements of all identified approaches without making the EPC generation process too complex and costly for the end users. The trade-off between extra costs and obtained benefits must be objectively evaluated. In cases when deep renovation is considered, the development of the BIM/BEM model could bring additional benefits for the end-user through better data quality and more accurate energy simulation. In the case of Slovenia, the next step would be a proposal of the enhanced EPC scheme capable of capturing the dynamic components of the building’s long-term renovation process and thus become a driver for renovation and a tool for verification of energy savings. In this context, generation of EPC should move from a simple survey and quick assessment of building towards a detailed on-site energy audit and should include a Renovation Roadmap. An enhanced EPC scheme should support adoption of technologies and practices that reduce energy consumption in buildings and encourage end-users to implement innovative projects which will result in significant energy savings. In this process, the creation of BIM/BEM models is of vital importance. This should be obligatory for all deep renovations with respect to energy with public support.

4.6.4.1 Workflow and data

Specific challenges related to non-residential buildings

Challenges regarding the uptake of the Renovation Passport:

- Synchronizing the Renovation Passport requirements with changes in legislation – possible new nZEB and/or ZEB definitions, changes in the calculation methodology, RES integration rules.
- Synchronizing the RP with technological changes and integration of new products and solutions.

Challenges regarding operational data and actual user profiles:

- Rapid development of information and communication technologies enabled acquisition and storage of huge amount of energy and non-energy related data in buildings. Unfortunately, in many cases this data is used only for the single purpose of process control and not for improvement of energy efficiency in buildings as a whole and a number of opportunities for performance improvement are missed in this way.
- In many cases energy management in the building sector is still a simple collection of energy consumption data for heating, cooling and electricity on a monthly or annual basis.
- A vital part of any building energy management system should include measurements and data acquisition at all levels, from different appliances to systems, depending on the nature of the analysis to be performed.

Sources of input data including BIM

The configuration and geometry of a building, including the orientation of surfaces and the determination of the reference area used for calculating indicators, can significantly impact the outcome of energy performance assessments. At present, when a new EPC is issued, data collection starts from scratch since the electronic EPC file is owned by the former issuer. As the EPC has the status of an expert opinion, the issuer cannot rely on the work done by another expert unless it is issued by the same expert or company.

A well-maintained building model (BIM or BEM) can be employed to accurately determine surface types, sizes, materials, and information about energy systems within the building. This can help prevent errors and manipulations in the input data for EPC calculations. However, to achieve this, the entire building model, including energy systems, must undergo a thorough quality check and certification process. If the BIM/BEM model does not incorporate technical systems, the issuance of the EPC is not possible, requiring a complete re-evaluation of all technical aspects of the building systems. In addition, creating a comprehensive and calibrated BIM/BEM model is time-consuming and requires expertise, resulting in increased costs for the building owners/users. While BIM/BEM could be implemented as a design standard for new buildings or large-scale and deep energy renovations, solutions must be developed to minimize costs for its applicability to existing buildings in general.

Calculation tools and data transfer

The current tools used for generating EPCs in Slovenia lack the capability to develop and assess different renovation options. These tools primarily focus on energy calculations in accordance with legislation, without implementing calculations for evaluating energy efficiency measures. Moreover, important functionalities such as thermal comfort, RES generation potential, sustainability and illumination levels are not incorporated in the EPC tools.

Unfortunately, an energy audit is not a necessary step for generation of an EPC in Slovenia. However, in cases where the EPC results from an energy audit, the identified energy efficiency measures are tailored to the specific building and can be utilized to create a Renovation Roadmap. Currently, integrating the Renovation Roadmap into the energy audit is relatively straightforward and requires the creation of the implementation action plan for all identified energy efficiency measures.

Regarding the provision of information to building owners and property managers, they receive both a digital (PDF) and hard copy (paper) version of the EPC. However, other related documents are not shared with building owners. If an EPC is issued during the energy audit of a building, end users also receive a digital (PDF) and hard copy (paper) version of the energy audit report.

4.6.4.2 Procedures of tracing the evolution of building refurbishment

The existing EPC database does not allow tracing of the evolution of building refurbishments because there is no link to the previous EPC. However, tracing the progress of building refurbishment can be done, but it is a complex process which lacks automation, predefined queries and clear guidelines.

4.6.4.3 Interlinking the evolution of EPCs with the evolution of BIM models

Unfortunately, there is no established procedure for connecting the development of EPCs with the advancement/evolution of BIM/BEM models in Slovenia. Several challenges arise during incorporation in BIM/BEM, ranging from determining model ownership to defining the required level of details and finding cost-effective solutions.

In Slovenia, many certified engineers still show reluctance towards utilizing BIM tools due to various reasons, and the use of standardized design software often leads to compatibility issues. Moreover, the EPC database and software are only capable of storing a single version of building calculations, limiting the available data to the current state of the building. Separate files need to be created for different renovation stages.

4.6.4.4 Other issues

The results confirmed the potential of combining different data sources, methods and modelling tools to discover potentials for energy efficiency improvements. Moreover, the combination of results obtained from energy audits and the parameters hidden in the structure of the BEM provided additional and valuable information for the creator of the RP and helped to properly benchmark the analysed energy management practices. All this has to be addressed in the enhanced EPC and must result in higher reliability of the EPC. Additionally, costs for generating an EPC must reflect the benefits for the end user. Recommendations must be tailored for each specific case and not just in a generic way with no link to the actual situation. The conducted research has clearly revealed that due to the complexity of the proposed TIMEPAC approach, which involves a combination of different methods, models and tools, it must be accompanied by comprehensive trainings and educational activities for all involved stakeholders. Training and educational activities will provide stakeholders with new knowledge and motivate them to take energy efficient actions. The existing EPC has relatively modest visualization possibilities and, in many cases, it is the main reason for a poor understanding of energy consumption data by the end-users. An excellent understanding of energy consumption or an energy awareness is the key prerequisite for timely decisions to reduce energy consumption which means that a visual identity of EPC and RP must reflect real needs of the final users.

4.7 Spain

4.7.1 Tabular characterisation of assessed buildings

Table 39 shows the characteristics of the assessed buildings.

Table 39. Overview of Catalan Case Study buildings

TIMEPAC Code	Building type	Owner	Location	Short building description	Data used
Internal Code from Building List	Residential or type of non-residential	Public, private; single owner or co-ownership	Region and city	Year of construction, gross floor area, status quo before renovation, Technical Building System	Which type of data is available and used for the Renovation Roadmap
ES-03	Non-residential (Nursing home)	Private	Sant Adrià del Besòs (Barcelona)	Constructed in 2020; gross floor area, nearly 6,000 m^2 (source); heat pump for DHW, heating and cooling; mechanical ventilation with heat recovery; central BMS for HVAC and lighting system.	EPC BIM model BEM model Energy consumption data Information provided by the owner
ES-04	Residential building	Private	Barcelona	Constructed in 1984; gross floor area, 708 m^2 (data from cadastre, excluding parking); individual heating and DHW system with natural gas boiler; individual cooling system.	BIM model BEM model Energy consumption data Information provided by the owner
ES-05	Small residential building	Private	Lleida	Constructed in 1933; gross floor area, 360 m^2 (cadastre); individual heating and DHW system with natural gas boiler; individual cooling system.	
ES-09	Residential building	Private	El Prat de Llobregat (Barcelona)	Constructed in 1966; gross floor area, 3,880 m^2 (cadastre); electric boiler for DHW; individual electric heating; individual cooling system.	EPC BIM model BEM model Information provided by the owner
ES-10	Residential building	Public	Barcelona	Constructed in 1900; gross floor area, 1,371 m^2 (cadastre); individual electric boiler for DHW.	EPC BIM model BEM model Information provided by the owner

4.7.2 Description of the procedure

Currently, there are no tools for the digital and automatic development of Renovation Passports in Spain.

The analysis is based on the CYPETHERM Tool which is an approved software tool for EPCs in Spain. The focus of the assessment is to generate distinct renovation measures in the form of a Renovation Roadmap and to analyse options to trace their implementation.

In detail, the procedure that has been performed is as follows:

- Energy indicators and energy performance for existing buildings were derived from the EPC done with the tool CYPETHERM.
- Modelling of the residential buildings ES04 and ES05 were created for WP2. It is not common to have an architectural model or to use a BIM workflow in residential buildings. The standardized building model was developed by the partner CYPE.
- On the other hand the architectural models of the other buildings were already presented in the Catalan register of EPCs. After obtaining permission from the owners, we have consulted the EPC represented in the register.
- The energy efficiency measures have been proposed applying the principle Energy Efficiency First. The measures were combined in logical renovation steps and recalculated with CYPETHERM regarding achievable savings and investments.

Table 40 provides more information about the data used in the process.

Table 40. Data used in the assessment process

Type of data used	Source of information	Comment
Architectural model	Created for TIMEPAC (ES04 and ES05) or received by the owners	BIM is not yet a usual procedure for residential buildings
Building Energy Model (BEM)	Energy model created with CYPETHERM	The BEMs are in the register of EPCs in Catalonia, but they are not public
EPC done with CYPETHERM	They are from the register of EPCs or created for TIMEPAC WP2, in both cases with the permission of the owner	The EPC in PDF is available in the open register. CYPETHERM is a tool used for new buildings more than for existing ones.
Renewable energy potential data, district heating / cooling potential data	Interview with owner, GIS	Information: open database PV potential https://somcomunitatenergetica.cat/
Energy consumption (operational data)	Hourly monitoring is not available	Hourly monitoring of energy consumption data is not commonly practiced. Typically, energy consumption data is obtained from utility bills.

4.7.3 Description of the assessment results

The Tables 41 to 46 show the assessment results in terms of a Renovation Roadmap as a summary for the analysed buildings.

Table 41. Overview of Catalan Case Study buildings - Renovation Roadmaps

TIMEPAC Code	Renovation Roadmap: measures in the correct sequence, the detailed plan depends on the maintenance and repair plan of the facility management	Timing of measures to avoid possible lock-in effects, considering interactions
ES-03	**Building level:** **(1) Package of measures:** Installation of a PV system on the roof: • 100 kWp.	It is a new building with label A in non-renewable primary energy and also in CO_2 emissions. The transmittances of the envelope are low, the facilities are efficient and it includes heat recovery. When developing the detailed plan, the following aspects must be taken into account: Load capacity (statics) of the roof must be checked before installation of the PV system.
ES-04	**Building level:** **(1) Package of measures:** Thermal insulation of external walls: • External Thermal Insulation Composite System (ETICS). Mineral Wood (MW), 10 cm. Conductivity: 0.036 W/m·K. • U_{wall}: 0.23 W/m^{2}K. Thermal insulation of the ceiling towards the roof: • MW, 10 cm. Conductivity: 0.036 W/m·K. • U_{roof}: 0.22 W/m^{2}K. Windows replacement: • Double low-emissivity glass. Wood carpentry. • $U_{windows}$: 2. Sun factor: 0.5. **(2) Package of measures:** Heat pump for DHW, heating and cooling: • COP_{DHW}: 3; $COP_{heating}$: 4; $EER_{cooling}$: 4. • Electric power $_{heat\ pump}$: 6 kW. 7 units, one for each dwelling. Installation or replacement of the heat recovery system for the mechanical ventilation system with high efficiency technologies: • Double-flow heat recovery unit with a 95% efficiency. **(3) Package of measures:** Installation of a PV system on the roof.	All measures of Package (1) and Package (2) are implemented prior to Package (3). When developing the detailed plan, the following aspects must be taken into account: Insulation measures must be checked regarding fire safety requirements. As the insulation is external, it can be applied meanwhile the building is occupied by the owners, and/or during the execution of the package of measures (2). The mechanical ventilation will allow assure the air quality. Heat recovery and free cooling will increase the energy efficiency of the system. Load capacity (statics) of the roof must be checked before installation of the PV system.

ES-05	**Building level:** **(1) Package of measures:** Thermal insulation of external walls: • ETICS. • MW, 10 cm. Conductivity: 0.036 W/m·K. • U_{wall}: 0.23 W/m^{2}K. Thermal insulation of the ceiling towards the roof: • MW, 12 cm. Conductivity: 0.036 W/m·K. U_{roof}: 0.18 W/m^{2}K. Windows replacement: • Triple low-emissivity glass. Wood carpentry. • $U_{windows}$: 1.62 W/m^{2}K. Sun factor: 0.5. **(2) Package of measures:** Heat pump for DHW, heating and cooling: • COP_{DHW}: 3; $COP_{heating}$: 4; $EER_{cooling}$: 4. • Electric power $_{heat\ pump}$: 6 kW. 3 units, one for each dwelling. Installation or replacement of the heat recovery for the mechanical ventilation system with high efficiency technologies: • Double-flow heat recovery unit with a 95% efficiency **(3) Package of measures:** Installation of PV system on the roof.	All measures of Package (1) and Package (2) are implemented prior to Package (3). When developing the detailed plan, the following aspects must be taken into account: When old buildings are refurbished in historical neighbourhoods, it is necessary to check whether the planning regulations allow to act on the outside of the façade (ETICS). In this case, ETICS is allowed, if determined colours are applied. Insulation measures must be checked regarding fire safety requirements. As the insulation is external, it can be applied meanwhile the building is occupied by the owners, and/or during the execution of the package of measures (2). Load capacity (statics) of the roof must be checked before installation of the PV system.
ES-09	**Building level:** **(1) Package of measures:** Heat pump for DHW, heating and cooling: • COP_{DHW}: 3; $COP_{heating}$: 4; $EER_{cooling}$: 4. • Electric power $_{heat\ pump}$: 6 kW, one for each dwelling. Installation or replacement of the heat recovery system for the mechanical ventilation system with high efficiency technologies: • Double-flow heat recovery unit with a 95% efficiency. Installation of a PV system on the roof. **(2) Package of measures:** Thermal insulation of external walls: • ETICS. • MW, 10 cm. Conductivity: 0.036 W/m·K. • U_{wall}: 0.23 W/m^{2}K. Thermal insulation of the ceiling towards the roof: • MW, 12 cm. Conductivity: 0.036 W/m·K. U_{roof}: 0.18 W/m^{2}K. Windows replacement:	All measures of Package (1) and Package (2) are implemented prior to Package (3). When developing the detailed plan, the following aspects must be taken into account: Sometimes the improvements of the facilities must be done before the insulation measures, because of the cost of investment. The payback is often lower in the case of facilities than the insulation measures. Load capacity (statics) of the roof must be checked before installation of the PV system. Insulation measures must be checked regarding fire safety requirements.

	• Triple low-emissivity glass. Wood carpentry. • U $_{windows}$: 1.62. Sun factor: 0.5. Installation or replacement of solar shading devices.	
ES-10	**Building level:** **(1) Package of measures:** Installation or replacement of solar shading devices Heat pump for DHW, heating and cooling: • COP $_{heating}$: 4; EER $_{cooling}$: 4. • Electric power $_{heat\ pump}$: 6 kW one for each dwelling. **(2) Package of measures:** Heat pump for DHW, heating and cooling: • COP $_{DHW}$: 3. • Electric power $_{heat\ pump}$: 6 kW one for each dwelling. Installation or replacement of the heat recovery for the mechanical ventilation system with high efficiency technologies: • Double-flow heat recovery unit with a 95% efficiency. **(3) Package of measures:** Installation of PV system on the roof.	All measures of Package (1) and Package (2) are implemented prior to Package (3). When developing the detailed plan, the following aspects must be taken into account: Load capacity (statics) of the roof must be checked before installation of the PV system.

Table 42. Assessment results based on actual user profile and operational data for ES-03

	Building before renovation	1st Step of renovation
Implementation of measures	-	Installation of PV system and batteries
Total energy consumption (final energy) [kWh/m^2]	45.28	40.81
Heating and cooling energy consumption [kWh/m^2]	10.27	9.24
Primary energy consumption (total) [kWh/m^2]	107.45	40.81
CO_2 emissions [kg/m^2]	18.25	0
Investment cost [EUR/m^2]	-	37.1
Wider benefits (qualitative)		Local RES production and batteries, covering all the consumption. Reduction of primary energy

Table 43. Assessment results based on actual user profile and operational data for ES-04

	Building before renovation	1st Step of renovation	2nd Step of renovation	3rd Step of renovation
Implementation of measures	-	Thermal insulation of external walls Thermal insulation of the ceiling towards the roof Windows replacement	Heat pump for DHW, heating and cooling Installation or replacement of the heat recovery for the mechanical ventilation system with high efficiency technologies	Installation of a PV system on the roof
Total energy consumption (final energy) [kWh/m^2]	101.19	74.78	58.07	58.07
Heating and cooling energy consumption [kWh/m^2]	71.42	41.04	24.05	24.05
Primary energy consumption (total) [kWh/m^2]	144.27	110.04	87.15	71.76
CO_2 emissions [kg/m^2]	27.07	20.24	7.56	3.84
Investment cost [EUR/m^2]	-	130.04	44.96	23.54
Wider benefits (qualitative)		Better thermal comfort	Better thermal comfort, better indoor air quality	RES production on location. Reduction of primary energy

Table 44. Assessment results based on actual user profile and operational data for ES-05

	Building before renovation	1st Step of renovation	2nd Step of renovation	3rd Step of renovation
Implementation of measures	-	Thermal insulation of external walls Thermal insulation of the ceiling towards the roof Windows replacement	Heat pump for DHW, heating and cooling Installation or replacement of the heat recovery for the mechanical ventilation system with high efficiency technologies	Installation of a PV system on the roof
Total energy consumption (final energy) [kWh/m^2]	275.74	108.52	93.90	93.90
Heating and cooling energy consumption [kWh/m^2]	25.97	73.00	56.13	56.13
Primary energy consumption (total) [kWh/m^2]	335.57	131.10	126.35	112.00
CO_2 emissions [kg/m^2]	69.90	22.05	7.85	4.38
Investment cost [EUR/m^2]	-	185.13	147.01	76.97
Wider benefits (qualitative)		Better thermal comfort	Better thermal comfort, better indoor air quality	RES production on location. Reduction of primary energy

Table 45. Assessment results based on actual user profile and operational data for ES-09

	Building before renovation	1st Step of renovation	2nd Step of renovation
Implementation of measures	-	Heat pump for DHW, heating and cooling Installation or replacement of the heat recovery for the mechanical ventilation system with high efficiency technologies Installation of a PV system on the roof	Thermal insulation of external walls Thermal insulation of the ceiling towards the roof Windows replacement Installation or replacement of solar shading
Total energy consumption (final energy) [kWh/m^2]	124.06	77.34	48.12
Heating and cooling energy consumption [kWh/m^2]	66.55	43.65	14.44
Primary energy consumption (total) [kWh/m^2]	269.80	108.72	69.35
CO_2 emissions [kg/m^2]	38.34	7.60	5.14
Investment cost [EUR/m^2]	-	83.62	55.65
Wider benefits (qualitative)	-	Energy savings, Better indoor air quality, RES production on location	Better thermal comfort

Table 46. Assessment results based on actual user profile and operational data for ES-10

	Building before renovation	1st Step of renovation	2nd Step of renovation	3rd Step of renovation
Implementation of measures	-	Installation or replacement of solar shading Heat pump for heating and cooling	Heat pump for DHW Installation or replacement of the heat recovery for the mechanical ventilation system	Installation of a PV system on the roof

	Building before renovation	1st Step of renovation	2nd Step of renovation	3rd Step of renovation
			with high efficiency technologies	
Total energy consumption (final energy) [kWh/m^2]	74.43	73.82	52.04	52.04
Heating energy consumption [kWh/m^2]	39.06	38.46	21.00	21.00
Primary energy consumption (total) [kWh/m^2]	97.70	102.41	68.68	58.43
CO_2 emissions [kg/m^2]	14.74	8.11	4.03	1.55
Investment cost [EUR/m^2]	-	97.80	74.03	19.09
Wider benefits (qualitative)	-	Better thermal comfort, especially during summer	Better thermal comfort, better indoor air quality	RES production on location. Reduction of the primary energy

Comments regarding achieving Nearly Zero Energy / Major Renovation and Zero Emission Building targets:

Energy indicators were calculated with the software CYPETHERM. However, in view of the stakeholder workshops regarding the Renovation Passport, more discussion is needed about how these indicators are calculated and represented. This is especially important for the part of PV systems.

In general, the measures proposed in the first step aim to enhance the building envelope. These measures allow to reduce the energy demand of heating and cooling, applying the principle "Energy Efficiency First". The transmittances proposed in the renovated façades, roofs, windows, etc. fulfil the recommended U values for new buildings from the Technical Code of the Building of Spain (CTE 2019).

In the case of old buildings that are refurbished in historical neighbourhoods, it is important to consult the urban plans and to check if there is a preservation order.

The measures proposed in the second step are related to the facilities. As the energy demand was reduced with the first step of the renovation, the capacity of the heat pumps proposed is lower in order to cover the energy demand of domestic hot water, heating and cooling.

It is important that the mechanical air renovation includes heat recovery, in order to increase energy efficiency.

Renovating the building by improving the building envelope is considered in the first step, as well as the facilities in the second step. These measures will allow achieving a nearly Zero Energy Building.

Although the general recommendation is to improve the building envelope first, sometimes the facilities are also improved first. This fact may be due to the ratio between investment and savings, which is usually more appropriate in the case of installations. Another reason may be for the ease of decision-making, when it comes to a single installation. In the ES09 building the case is considered that the facilities are improved first. In this building, the flats are small, and the individual installations affect the total cost of the measure. Although community facilities are not common in Catalonia, this option could be studied in this building.

In general, the installation of photovoltaic panels is considered in the third step of the renovation. This last step will allow achieving the Zero-Emission Building, as it will be established in the EPBD recast.

It is really important to examine the roof before installing photovoltaic panels, in order to be sure that it is correctly isolated and it can receive the weight of the new installation.

According to the energy prospective of Catalonia (PROENCAT 2050), there will be an electrification of the buildings, spreading the use of heat pumps, and electricity will be 100 % renewable in 2050.

4.7.4 Conclusions

Conclusions are drawn based on all assessed buildings regarding workflow and data, regarding advantages, barriers, procedures of tracing the evolution of building refurbishment and interlinking the evolution of EPCs with the evolution of BIM and BEM models. When talking about tracing the evolution of building refurbishment, there are the following possibilities:

- Through the EPC database.
- Tracking the changes of indicators through versioning the EPC in the database (in the future it will be able to consult it in Catalonia).
- Tracking the changes of recommendations in the EPC (they are not available in the Catalan open data nowadays).
- Through cadastre (it is just connected with the EPC).
- Tracking the changes in the Renovation Roadmap in connection with the EPC (in the future).
- Through logging the changes in BIM or BEM: an updated EPC is produced after the BIM has been changed (although CYPETHERM is an official tool in Spain, it is very little used – 1% of the EPC in Catalonia).
- Through an energy management information system (often it is present in new tertiary buildings).

The energy certification tool most used in buildings or parts of buildings in Catalonia (CE3X, 95% of the EPCs) is very simple - there is no 3D geometry of the building. Its wide application is due to its simplicity, it does not require a lot of training to use it, and therefore, it is in line with the low cost of energy certificates. This tool is not based on BIM.

Nowadays, the EPC certifiers must have a technical degree in architecture or engineering. It is planned that people with other degrees will be able to sign an EPC, after passing a course. This training will include, among others, concepts of energy efficiency of the buildings, and also about the use of the certification tools.

Perhaps, the course will help spreading the use of BIM tools like CYPETHERM. Furthermore, the Renovation Passport and the digital twin can increase the use of BIM tools. It will be more important to have a tool in order to update the different steps of a deep renovation, achieving the Zero-Emission Building.

4.7.4.1 Workflow and data

Specific challenges related with residential buildings

Challenges regarding the uptake of the Renovation Roadmap:

- Synchronisation of the Renovation Roadmap with requirements of Technical Code of the Building (CTE in Spanish). Legislation establishes the quality of the building envelope, technical building systems, and minimum RES requirements. It also defines the nZEB definition and will have to include the ZeroE Building target.
- Synchronisation of the Renovation Roadmap with technological changes and integration of new products and solutions.

Challenges regarding operation data and actual user profiles:

- The occupants of rented dwellings experience a permanent evolution in their user profiles as they may change over time.
- Accessing detailed energy consumption data for apartments is challenging.
- In many cases energy management in the building sector is still a simple collection of energy consumption data for heating, cooling and electricity on a monthly or annual basis. It would be interesting to break down consumption by services.

Sources of input data including BIM

Regarding data repositories in Catalonia, the improvement measures (recommendations) outlined in the EPC are not accessible as open data. Incorporating these measures into the open data framework would significantly aid in facilitating the implementation of the Renovation Passport.

The geometry of a building, encompassing surface orientation and reference area definition significantly influences the assessment results. Some data like the gross area or a rough area and height can be consulted from the Spanish cadastre.

The floor plans of the buildings can be found in the Town Hall Register, the vast majority of measurements, and the information of type of materials and technical building systems, are obtained directly during the visit to the building done by the EPC certifier. In Spain, this visit is compulsory (Royal Decree 390/2021).

Usually, the architectural BIM model and the analytical model, used to create the EPC, are developed independently by different professionals, leading to a lack of a direct link between the two.

Calculation tools and data transfer

CYPETHERM HE Plus is a tool certified by the Spanish government for the energy certification of buildings for any type of building. In addition, it allows verifying the thermal normative, both for energy demand and consumption. This tool allows to calculate the scenarios and to verify improvement measures. It also allows to connect to another tool, CYPETHERM Improvements Plus, to justify which improvement measure to use, from a thermal and economic point of view. Finally, the results can also be used to complete the Building Renovation Passport and incorporate the scenarios into a timeline.

The simplified C3X tool is extensively used in Spain. It enables the inclusion of improvement measures grouped into sets, while also taking into account the cost of energy and billing to calculate the return on investment. Additionally, the program estimates the energy savings achieved through these improvement measures. However, this tool has no link to BIM.

Providing information to building owners and property managers

Building owners are provided with the EPC in pdf. Other documents like the EPC tools are not shared with them.

There are some issues related with the use of the EPC files. Nowadays the EPCs in PDF format are public and available in EPC searcher of Catalonia. However, the EPC file is not available, due to regulations with respect to intellectual property right. If the EPC tool is used for a long period of time, it is possible that the EPC tool is used by different technicians, so access to the programmes must be solved.

4.7.4.2 Procedures of tracing the evolution of building refurbishment

In Catalonia, there is an ICAEN website from which anyone can download any of the EPCs listed in the register. In the future, all the EPCs will be available of each building there, so that it will be possible to see the improvements of a building after renovations.

Among other things, the energy certificate is mandatory for buildings or parts of buildings that are sold or rented out. So, it is therefore possible to produce an EPC of a building unit, e.g. an apartment. The energy measures for deep renovation are useful for the entire building, including the façades, roofs, etc. In the renovation passport scheme, it will be important to consider if this tool is only for a building as a whole, and not for parts of buildings (building units).

4.7.4.3 Interlinking the evolution of EPCs with the evolution of BIM models

Currently, there is no procedure for this process. One possible procedure is to link the building information in the building logbook that would be created. The register of EPCs could also manage the Renovation Passports, as the scope will be similar. There could be a register of the development of buildings: EPCs and Renovation Passports that clearly explain the current, past and future status of the building.

In relation to the building logbook, it will be possible to manage an access restricted to the names of the owners and the technicians involved in the management/design of the building. This way it will be possible to guarantee compliance with personal data protection requirements.

N public buildings have to be designed with BIM models. Maybe it would help to increase the use of tools like CYPETHERM. This tool allows to connect BIM models with the thermal model via a standard IFC file. In this way all hourly energy analysis and the thermal envelope requirements can be calculated, including thermal bridge and interface analysis.

4.7.4.4 Other issues

The Renovation Passport should take a comprehensive and holistic approach. It assesses and implements the necessary measures to transform this building into an adapted property that meets the goal of achieving zero emissions by 2050. In addition, all other requirements for the building should be taken into account, such as structural safety, comfort, accessibility and others.

5 Summary of conclusions from partner contributions

This chapter builds on Chapter 4 and summarizes the findings of the partner case studies by topic including conclusions on options for future action.

5.1.1 Overview of workflow

In the partner countries, the starting point for developing the Renovation Roadmap can be categorized as follows (the situation is different in each country):

- EPC recommendations are not specified but are added as free text in a very general way to the EPC. The recommendations can be substituted by the Renovation Roadmap with specific renovation measures if the targets of major renovation are to be achieved in a stepwise renovation process.
- Specific renovation measures must be included in the recommendations of the EPC if the targets of a major renovation are to be achieved. This can be further developed in terms of sequence and timeline for implementation of measures.
- Energy audits must be done as part of the EPC issuing process, providing an excellent basis for the development of targeted renovation measures.
- Energy audits are not part of the EPC issuing process but are well established in the building sector and thus seen as a recommendable approach towards developing the Renovation Roadmap. If the EPC results from the energy audit, the identified energy efficiency measures are tailored to the specific building and can be utilized to create a Renovation Roadmap which is the action plan for the implementation of all identified energy efficiency measures.
- There is a tradition in developing Renovation Roadmaps for single family houses as part of energy advisory services. This procedure can be adjusted and further developed.

In conclusion, the workflow of creating a Renovation Roadmap will be different, depending on what is the point of departure in a country or region. If possible, the Renovation Roadmap should be linked to the energy audit program, presenting the sequence of actions and a timeline for implementation.

5.1.2 Sources of input data including BIM

The Renovation Passport is closely tied to the EPC in terms of proving how renovation measures will contribute to achieving nZEB and ZEB targets. Therefore, it is logical to start the development of the Renovation Passport from the EPC.

When a new EPC is issued, data collection currently starts from scratch as the electronic EPC file is owned by the previous issuer. As the EPC holds the status of an expert opinion, the issuer cannot rely on the work done by another expert due to liability reasons, unless it is issued by another expert of the same company. Moreover, multiple data collections are a source of error and a potential vulnerability to manipulation of assessment results.

There is agreement that the configuration and geometry of a building, including the orientation of surfaces and the determination of the reference area used for calculating indicators have a strong impact on the outcome of energy performance assessments. The introduction of the architectural model can bring significant improvements in terms of quality assurance and prevention of errors and fraud as it can be employed to accurately determine surface types, sizes, and materials. In addition, a building energy model is necessary (BEM), and information about the location of energy systems within the building. However, to help prevent errors and manipulations in the input data for EPC calculations, the entire building information model, including energy systems, must be well-maintained and subject to a thorough quality check and certification process. If the model does not incorporate technical building systems, the issuance of the EPC is not possible, requiring a complete re-evaluation of the technical aspects of the building systems.

In all partner countries, the results confirmed the potential of combining different data sources, methods and modelling tools in terms of identifying energy efficiency improvements. However, data were collected mainly from building owners instead of retrieving data from existing databases other than the EPC database. Data are scattered and besides the challenge of technical interfaces there are unsolved issued regarding ownership and re-use of data. Thus, it could not be verified that the use of existing data sources results in a more efficient process for the creation of Renovation Passports. Building logbooks that would support the development of Renovation Passports do not yet exist in the partner countries. If they are partially available, such as in the province of Salzburg, then part of the necessary data still has to be collected and released by the building owner, which is not a suitable procedure for the large-scale roll-out of the Renovation Passport. Building logbooks described in recent literature refer to existing data repositories for specific purposes and theoretical concepts which would not pass the reality check due to legal constraints.[17] [18]

A BIM offering software such as on the platform of CYPE, the “BIMserver.center” could offer a solution, but this would mean to transfer the entire work on a building to such a platform to benefit from the exchange and re-use of data between applications. In renovation projects where experts from different companies work together and use their standardized design software, compatibility issues are encountered and, consequently, this results in a loss of information during data exchange.

It is time-consuming and requires expertise to create a comprehensive and calibrated BIM/BEM model, resulting in increased costs for the building owners/users. While BIM/BEM could be implemented as a design standard for new buildings or large-scale and deep energy renovations, solutions must be developed to minimize costs for its applicability to small existing buildings, especially residential buildings.

5.1.3 IT Implementation of data transfer and tools

The tools used in the partner countries can be categorized as follows:

- Simple software programs for the creation of energy performance certificates, which require calculation results from other energy modelling software as input data. All modelling and calculations are done separately. These tools primarily focus on energy calculations in accordance with legislation, without implementing calculations for evaluating energy efficiency measures.
- Calculation software for the creation of the energy model, the monthly energy balance and the energy performance certificate; including the option to create the tailored energy model based on actual use and energy consumption; adding the option to assess renovation scenarios; also including other options, for example cost calculation and calculation of global warming potential of materials.
- BIM offering software that enables data exchange between software applications such as CYPE. With CYPE, it is possible to generate an EPC (for countries where this software is legally authorized) from the architectural model through the process of creating an analytical model which is used for creating the energy model with CYPETHERM EPlus and assess renovation scenarios with CYPE IMPROVEMENT.
- Different software is applied for creating the architectural model and other models: The architectural BIM model and the analytical model used for creating the EPC are developed

[17] Malinovec Pucek et al. 2023.

[18] Dourlens-Quaranta et al. 2021.

separately by different professionals, and as a result, there is no direct connection between the two models.

The consideration of additional indicators in the Renovation Passport, for example related to health, comfort, climate resilience and costs, makes it necessary to use additional tools because also in those cases where the EPC software has extensive calculation properties, not everything is covered. The effort required to create a Renovation Passport increases if data has to be entered again and again. In this respect, the use of BIM will be an approach to keep costs low, or the integrated tools will have to be extended with additional modules.

5.1.4 Tracing the evolution of building refurbishment

Starting from the energy performance certificate, the logical approach would be to use the energy certificate database as a starting point. To do this, energy performance certificates must be versioned, which means that the EPC must be linked to the identity of the building and/or building unit. However, it turned out that this function is mostly not available in the EPC databases of the partner countries and would need to be implemented, or depending on the initial conditions and development strategies, other approaches would need to be taken.

Regarding the tracing of building refurbishment evolution, considering workflow and data, and linking it with the evolution of BIM and BEM models, several possibilities have been identified which are listed below. The feasibility depends on the initial conditions in the respective country or region and the development strategy, and probably also on the building type (residential or non-residential, public or private, large or small).

Possibilities connected to energy management and energy audit:

- Using an energy management system (EMS): Implementing EMS for tracking building refurbishment and verification of achievements.
- Energy auditing: Energy audits provide valuable insights into a building's energy performance and can serve for long-term energy management strategies.

Tracking the evolution of building refurbishment through the existing EPC database:

- Versioning the EPC in the database: Monitoring changes in indicators by maintaining different versions of the EPC within the database.
- Tracking changes in EPC recommendations: Monitoring modifications to the recommendations provided in the EPC (possibly in connection with the recommendation from the energy audit).

Tracking the evolution of building refurbishment through the extended EPC database that allows for upload of Renovation Passports in addition to EPCs:

- Connecting Renovation Passports with the EPC: Tracking changes in the Renovation Roadmap in conjunction with the EPC.

Other options include:

- Leveraging the cadastre: Utilizing the cadastre system to trace changes related to building refurbishment. The information about the state of the building could be associated with the cadastre property titles and fiscal databases.
- Logging changes in BIM or BEM: Generating an updated EPC when changes are made to the BIM or BEM model.

5.1.5 Providing information to target groups

There are the following ways of providing information to target groups (the situation is different in each partner country):

- Building owners and property managers receive a digital (PDF) and hard copy (paper) version of the EPC. If an EPC is issued during the energy audit of a building, end users also receive a digital (PDF) and hard copy (paper) version of the energy audit report. However, other related documents are not shared with building owners.
- Building owners and property managers can login to the EPC database environment into the account system based on a secure authentication and have access to the stored information.
- Building owners and property managers can login to the EPC database environment into the account system based on a secure authentication, have access to the stored information, can upload additional information, and give access to all this information to third parties.

Information about the steps of refurbishment needed must be shared with owners of buildings and units to plan actions in the correct time sequence and with the financial resources needed. The information about the progress of the planned updates to the envelope and the plants must be accessible by both, users and public administration.

It is important to share the documentation with building owners and managers so that they can refer to it when needed in the future. Synchronizing the Renovation Roadmap with property management measures can indeed pose challenges in multi-residential buildings.

5.1.6 Identified challenges

Currently, the development of a Renovation Roadmap is an expensive exercise due to the need for collection of detailed data on the building status which is necessary to come up with feasible suggestions for renovation measures. For several reasons, it would be useful for experts to have access to existing building data. Nevertheless, in reality, there are many barriers, ranging from technical challenges to model ownership and liability questions. In order to make the Renovation Passport a cost-efficient and useful tool, fully functioning building logbooks will be helpful, and so far, in the participating countries, they are not available. In this regard, Article 19 on Databases for energy performance of buildings as outlined in the Parliament proposal for the recast EPBD and as shown below, is especially important.

> **Article 19 Databases for energy performance of buildings**
>
> 6. For the purpose of ensuring coherence and consistency of information, Member States shall ensure that the national database for energy performance of buildings is interoperable and integrated with other administrative databases containing information on buildings, such as the national building cadastre and digital building logbooks.
>
> 6a. By 31 December 2024, the Commission shall, adopt implementing acts to support the efficient functioning of digital building logbooks by establishing a common template for:
>
> (a) a standardised approach for data collection, data management and interoperability and its legal framework;
>
> (b) linking existing databases.
>
> Those implementing acts shall be adopted in accordance with the advisory procedure referred to in Article 30(2).

The link with databases in the area of energy management is especially important due to the connection with operational data and actual user profiles. Rapid development of information and communication technologies enabled acquisition and storage of huge amount of energy and non-energy related data in buildings. Unfortunately, in many cases this data is used only for the single purpose of process control and not for improvement of energy efficiency for the entire building, and opportunities for performance improvement are missed. Often, energy management in the building sector is still a simple collection of energy consumption data for heating, cooling and electricity on a monthly or annual basis. A vital part of any building energy management system should be measurements and data acquisition at all levels, from the different appliances to systems, depending on the nature of the analysis to be performed.

BIM models can provide valuable information. While BIM models are not commonly available for residential buildings in all partner countries, they are more frequently used for large public buildings due to legal obligations in some countries. These models typically include information about the building's geometry and envelope materials, but the representation of technical building systems and their mechanical details may not always be present. Additionally, it is important to consider that these models are often not regularly updated. For example, although the architectural BIM model is mandatory for certain public contracts in some partner countries, there is currently no obligation to maintain and update the model in a specific platform. Consequently, there is a lack of information regarding implemented refurbishments.

There are two types of challenges identified regarding the long period of the Renovation Passport. First, how to synchronize the renovation measures with changes in legislation, for example possible new nZEB and/or ZEB definitions, calculation methodology changes, and integration rules for renewable energy sources. The second one is how to synchronize the Renovation Passport with technological changes and integration of new products and solutions.

Regarding the interlinking of EPC evolution with BIM models, it is evident that generating more reliable EPCs and Renovation Passports from the BIM/BEM models is a logical step forward. However, this would require significant changes to the existing EPC scheme, which may not be well accepted by stakeholders. There is a trade-off between extra costs and obtained benefits, and a justification for additional costs is needed. In cases where large scale deep renovation is considered, the development of the BIM/BEM model could bring additional benefits for the end-user through better data quality and more accurate energy simulation.

In countries such as Italy or Spain, where EPCs are issued at the level of the building unit (e.g. apartment in a multi-unit residential building) and not for the building as a whole, a new model would need to be created from scratch if the Renovation Passport relates with the building. This model would indicate the refurbishment roadmap for the building, which may not align precisely with the refurbishments suggested in the individual EPCs. In countries such as Austria, where the EPC is issued at the building level, issues arise regarding energy consumption data and actual user profiles at apartment level.

Building owners and property managers do not always understand the need for the long-term perspective, because the ZEB target in 2050 is still far away. However, in case of an emergency such as a boiler breakdown, the Renovation Passport will provide valuable guidance in which heating system to invest in order to achieve the long-term ZEB target.

In this regard, the link with the district level (urban plan, spatial energy plan) is important which adds even more complexity to the concept of a Renovation Passport. It means that the building logbook needs to be connected to municipal urban planning.

The conducted research has clearly revealed that the proposed TIMEPAC approach responds to the needs of future developments outlined by the proposed EPBD recast. However, it involves a combination of different methods, models and tools, and therefore the process must be accompanied by comprehensive trainings and educational activities for the involved stakeholders.

6 Guideline for creating Renovation Passports from data repositories

The thematic summary of country contributions presented in Chapter 5 was used as the basis for developing the guidance presented in this chapter. Therefore, the TIMEPAC proposal for creating Renovation Passports from data sets and tracking the development of building renovation is well-founded and practically relevant. Thus, it is not only a working tool for TIMEPAC partners, but also a useful input into the discussions on the topic outside the TIMEPAC consortium.

All figures in this chapter were developed by the lead partner SERA within the scope of this task.

6.1 Purpose of the guideline

This guideline is part of Task 2.3 "TDS 3- Creating Building Renovation Passports from data repositories", and is designed to be useful as a stand-alone document, as well. It can easily be translated into national languages for discussion with stakeholders and further use in designing and applying Renovation Passport schemes.

6.2 Features of the TIMEPAC Renovation Passport

In a nutshell, the Renovation Passport should complement the energy performance certificate and provide a solution to the challenge of increasing the building renovation rate, and to achieve a Zero-Emission building stock in the long run. It is based on a Renovation Roadmap displaying building specific renovation measures to be implemented in a given sequence and timeframe.

Approaches to the Renovation Passport have been developed and implemented as part of subsidy schemes in several EU member states. In 2018, the concept was introduced into the legal framework of the Energy Performance of Buildings Directive 2010/31/EU (EPBD) with the amending directive (EU) 2018/844. It has been further strengthened in the Commission proposal for the recast EPBD, expected to be fully negotiated by the end of the year 2023 or at the beginning of 2024.

Differences between EPC and Renovation Passport

Table 47 shows the main differences between the Energy Performance Certificate and the Renovation Passport.

Table 47. Comparison of Energy Performance Certificate and Renovation Passport

	Characteristics of the mandatory Energy Performance Certificate	Characteristics of the voluntary Renovation Passport
Building specific	Yes – but not mandatory; for existing buildings: can be based on default values	Yes – because it is important for the economic assessment of improvement measures
User specific	No – based on standard user behaviour/standard user profile	Yes – because it is important for the economic assessment of improvement measures
Real energy consumption	No – based on a given calculation method to determine energy demand	Yes – based on operational data, because it is important for the

	Characteristics of the mandatory Energy Performance Certificate	Characteristics of the voluntary Renovation Passport
		economic assessment of improvement measures
On-site visit	Not mandatory, depends on the regulatory framework and the purpose of the EPC	Yes – because reliable information about the actual condition must be available
Format of recommendations	Can be general; data fields often not sufficiently specified	Format is specified by the operator of the voluntary scheme Stepwise implementation of specific renovation measures in a given sequence
Tracking the implementation of recommendations	Not mandatory; often not possible	Not mandatory; possible if planned by the operator of the scheme
Method of tracking the implementation of renovation measures	Possible through the EPC database if it allows for versioning of EPCs of a building, and distinct recommendations are represented by individual and defined data fields	Several possibilities, for example through the EPC database

The TIMEPAC Renovation Passport, with its claim to track the implementation of renovation measures, links the EPC to the architectural and engineering work of actual renovation planning and implementation, as shown in Figure 9.

Process of creating a Renovation Passport

The process is as follows:

1. The analysis of existing building data from data repositories, including the existing EPC if available, reduces the effort for data collection, and serves to prepare the on-site visit.
2. The on-site visit is needed to determine the actual status of the building and to collect missing information.
3. This information basis is used to develop the Renovation Roadmap with the sequence of renovation measures to be implemented. Achievement of Nearly-Zero Energy (nZEB) and Zero Emission Building (ZEB) targets is verified by EPC calculations.
4. Measures to be implemented in the first step are selected and financing is secured.
5. Detailed planning is done, and renovation works are performed.
6. The EPC for the renovated building is issued and the Renovation Roadmap is updated.

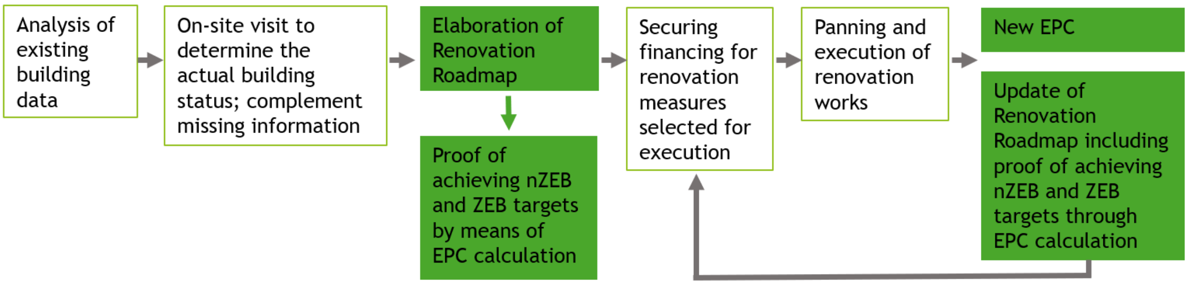

Figure 9. Overview of workflow of TIMEPAC Renovation Passport (SERA 2023)

Currently, the EPC can only be issued to verify the achievement of nZEB targets, as zero emission targets still need to be defined in detail by the recast EPBD expected by end of 2023.

The link between EPC and Renovation Passport is displayed in more detail in the Figures 10 and 11.

The indicators listed are exemplary and not exhaustive.

Figure 10 shows in a schematic presentation that the EPC (created conventionally or using BIM) serves as a starting point in terms of building data and energy performance. Renovation Roadmaps are drawn up taking into account additional data such as from on-site visits and energy bills.

The individual renovation steps, which follow one another, each end with an EPC and thus the determination of the energy performance achieved.

Figure 11 shows that when the measures of a renovation stage are implemented, an update of the EPC is made. This gives the previous EPC the status "outdated", and the current EPC provides the input into the updated Renovation Roadmap.

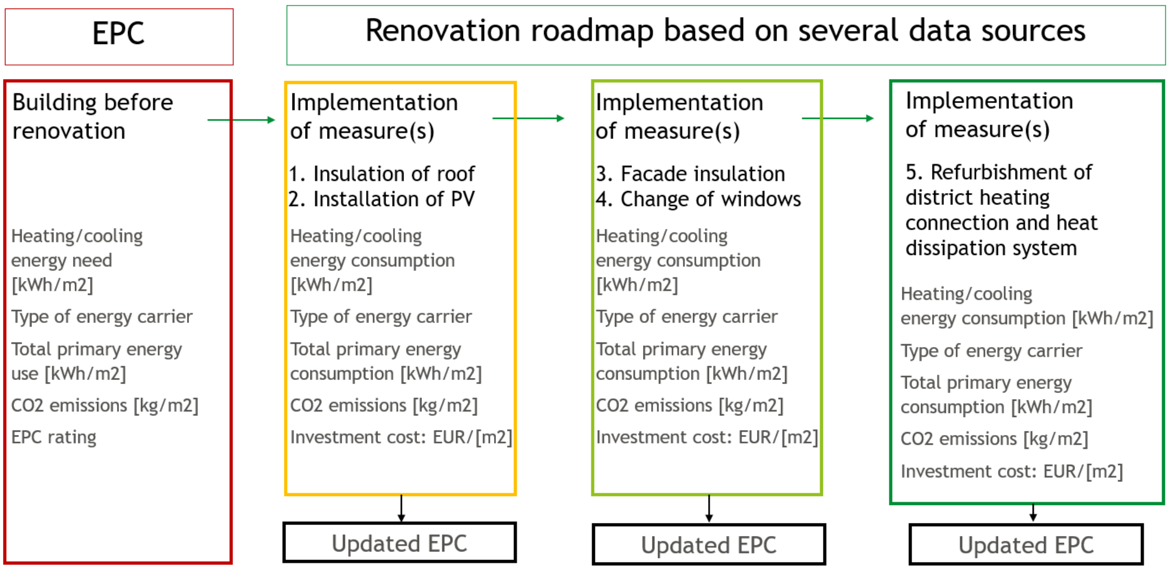

Figure 10. Overview of relation between EPC and Renovation Roadmap (a) (SERA 2023)

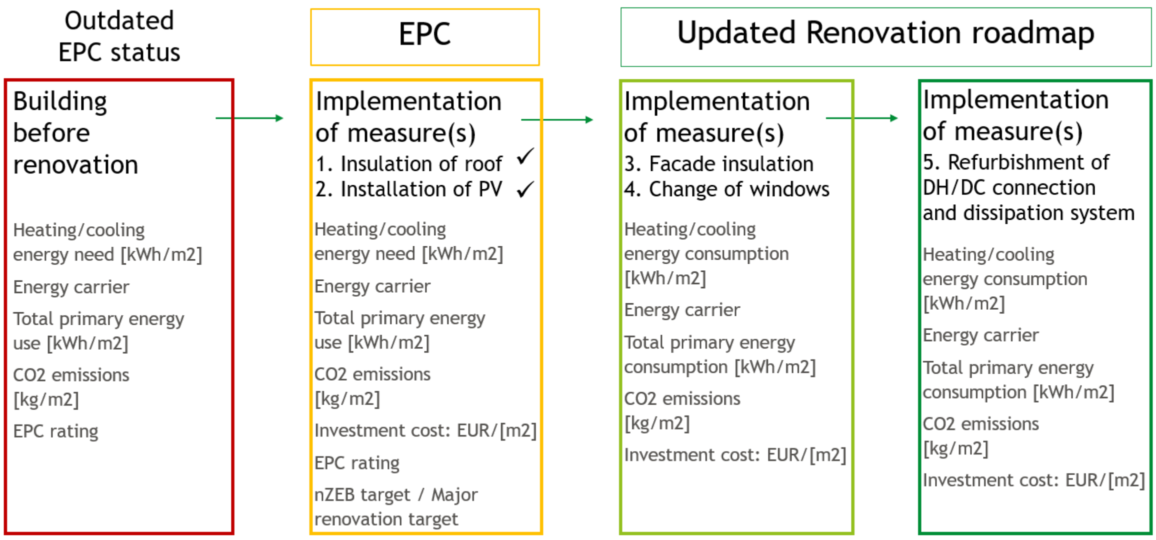

Figure 11. Overview of relation between EPC and Renovation Roadmap (b) (SERA 2023)

<u>Validity of the Renovation Passport</u>

The validity of the Renovation Passport must be limited in the sense that the first package of renovation measures or the first selected renovation measure must be implemented within a given time, for example five years.

This is important as legal changes occur over time, and the Renovation Passport needs to be synchronized with changes for example in nZEB[19] and/or ZEB[20] definitions, calculation methodology, or integration rules for renewable energy sources.

Secondly, such a limitation of validity is also a way how to synchronize the Renovation Passport with technological changes and integration of new products and solutions.

Thus, the process outlined in the figures above, based on updating the Renovation Roadmap after each step has been implemented, ensures that technological and regulatory changes are properly addressed. If there is no update of EPC and Renovation Roadmap within the given deadline, an alert could be activated in the database and the status of the Renovation Roadmap could be changed to "invalid", meaning that the entire process starting from data analysis and on-site visit would start from scratch.

6.3 Creating Renovation Passports from data repositories

6.3.1 Overview of the workflow

The Renovation Passport is closely tied to the EPC and it can draw valuable insights from it during its development. Furthermore, upon implementing a measure from the Renovation Roadmap, a new EPC must be issued as proof of compliance with nZEB and ZEB targets. Therefore, a link with the EPC calculation software package can be useful to save time and effort for entering data into different tools. However, this depends on which kind of EPC software tools are actually used in a country or region.

[19] nZEB nearly Zero Energy Building, definition according to EPBD

[20] ZEB Zero Emission Building, definition according to Commission proposal for recast EPBD

There are basically two ways to establish this link between EPC and Renovation Passport, depending on the situation in each country:

- The EPC calculation software, which includes energy modelling and is already linked to material databases, is to be further developed to meet the requirements of the Renovation Passport.
- The EPC calculation software remains a simple tool for proving compliance with legal requirements, but indicators for real energy consumption, health, comfort, life cycle cost, and climate change adaptation are calculated with other tools.

Figure 12 shows the elements of the Renovation Passport in terms of processes and data repositories or data sources that can provide input into developing a Renovation Passport or are even necessary to perform this task well.

As shown in the process described in Figure 12, the wealth of information that can be generated about a building but is scattered in different places. The concept of a building logbook represents an approach to store all information about a building in one place, and the use of a standardized building logbook would be a major step forward in terms of increasing the efficiency of data provision for developing the Renovation Roadmap.

In addition to building data that could be stored in the building logbook, information is needed about urban plans, spatial energy plans and other information which is important for achieving zero-emission targets through increasing renewable energy use. This information can be stored in one place called Municipal information system. However, often, this is not available, or not yet easily accessible, and thus needs special attention when elaborating the Renovation Passport schemes.

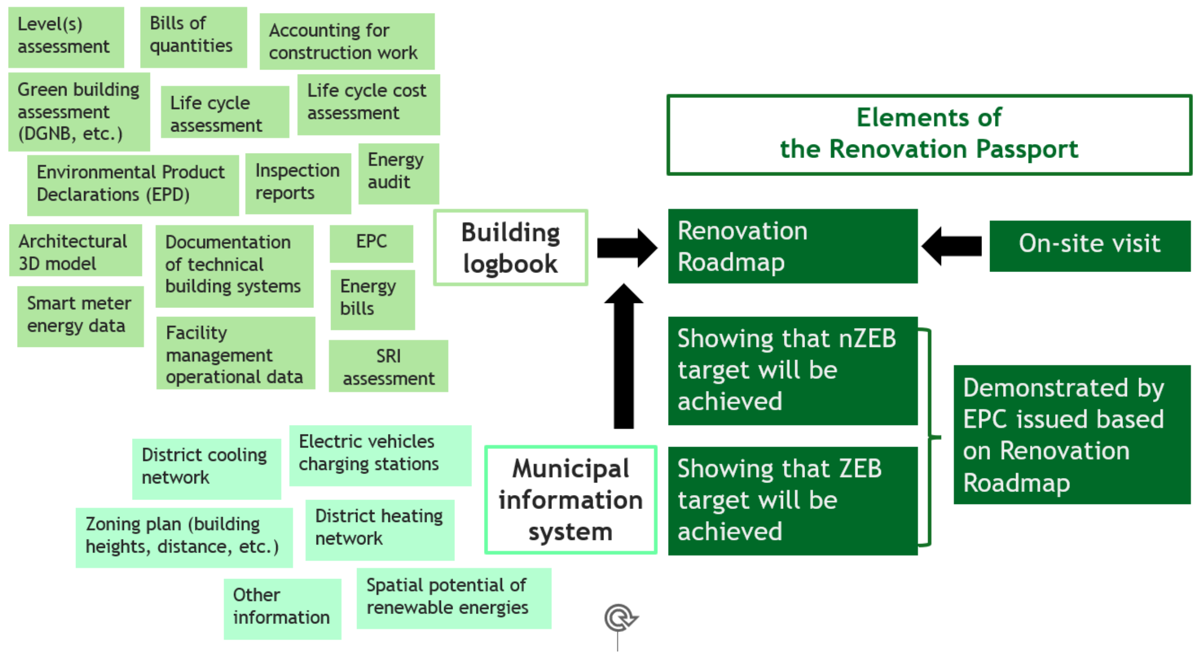

Figure 12. Overview of data and processes for the Renovation Passport (SERA 2023)

6.3.2 Specific aspects of data repositories including BIM

Building data that is already available can be used for analysis, provides a source of input data into developing the Renovation Passport. It can be used to prepare the site visit and the collection of remaining information. As shown in the process described in Figure 12, the wealth of information that can be generated about a building but is scattered in different places. The concept of a building logbook represents an approach to store all information about a building in one place.

The concept of a building logbook can be put into practice through the following exemplary approaches:

- The EPC database environment: all EPCs, Renovation Passports and subsidy applications for a building are stored in the related specific account. In addition, the building owner can upload additional information, and give access to this information to third parties (example Province of Salzburg, Austria).
- A BIM offering software: Level 3 BIM provides a possibility to store data at the same place and with the option of ensuring up-to-date information. Especially regarding renovations, there is an added value, namely the fact that the architectural model allows to show changes of area and volume that can occur as part of a renovation project (example CYPE BIMserver.center).

Creating an architectural model necessitates an initial investment of effort. Later, the use of the architectural model offers several advantages:

- It can bring significant improvements in terms of quality assurance and prevention of errors and fraud as it can be employed to accurately determine surface types, sizes, and materials used to calculate various indicators including those used for proving compliance with regulatory requirements.
- It avoids multiple data collections which are a source of error and a potential vulnerability to manipulation of assessment results.
- It can provide a solution when it comes to produce an EPC for the entire building and EPCs for the individual building units at the same time.

In addition, a building energy model (BEM) is necessary which contains information about the location of energy systems within the building.

Table 48 shows a comparison of the two logbook approaches.

Table 48. Comparison of logbook approaches

	EPC database environment	BIM offering software
Data exchange and sharing	Data exchange in defined formats in the form of retrieving and providing files.	Data sharing and re-use of data in several software tools at the same time.
Ownership and re-use of data	Arrangements for re-use of designs, calculations, etc. are necessary (e.g. inclusion in tenders and contracts).	Is regulated by the terms of use.
Ensuring up-to-date information	Is checked by the expert in case of an occasion.	The entire building information model, including energy systems, is always maintained. The sovereignty over the data must be clearly assigned to a person.
Liability	Processes are repeated: EPC holds the status of an expert opinion, the issuer cannot rely on the work done by another expert due to liability	Repetition of processes is avoided, for example: the entire building information model is

	EPC database environment	BIM offering software
	reasons, unless it is issued by another expert of the same company. Also, experts use different tools.	subject to a thorough quality check and certification process.
Connection with other databases	Each building (and building unit) must have a unique identity that allows to retrieve building specific information from other databases. Legal challenges need to be solved.	Information is incorporated during creation and maintenance of building models.

Considering that several EPC calculation tools are available on the market in some countries and that thinking about the implementation of a building logbook is still at an early stage, a product-independent approach using data repositories for the creation of Renovation Passports would encompass the following considerations:

- The first step is to export and save EPC data using an open format that does not require specific calculation software.
- One option is to use the IFC format, which allows the file to be accessed without relying on specialized software. However, IFC does not support the transfer of all energy related information calculated using energy calculation tools. Therefore, additional files are necessary to incorporate such data, and saving them in an .ifc.zip file format can help maintain an open process.
- To complete the process of saving EPC information for the future, a new type of repository or digital platform is needed. This platform would enable experts and public administrators to upload, search, and access information and models related to energy data and building refurbishment scenarios. The goal is to create an environment where these resources can be utilized and constantly updated.
- A crucial aspect of the platform is its integration with existing databases that contain building-related information, such as the building cadastre and the EPC database. This integration would allow for a comprehensive evaluation of building assessments that is continuously updated over time.

6.3.3 Procedures of tracing the evolution of building refurbishment

In the recitals of the proposed EPBD recast (Commission proposal 15/12/2021), reference is made to the EPC databases Member States have to set up which shall also allow to gather data related to building Renovation Passports and smart readiness indicators. In addition, it is planned to extend the current independent control system (according to article 18 EPBD) for EPCs to include Renovation Passports and smart readiness indicators. Reference is also made to monitoring and enforcement of a buildings policy which is key to ensure that it makes real progress on the ground, in particular with regard to the improvement of the existing building stock.

This advocates for a mechanism to trace the implementation of renovation measures with a procedure which is tied to the EPC database. An example is shown in Figure 13, as implemented by the province of Salzburg. Essentially, the recommendations in the EPC are replaced by the specific Renovation Passport. The implementation of a measure is linked to the updating of the EPC and to the updating of the Renovation Passport. Thus, by means of comparisons, the measures and the indicators can be tracked.

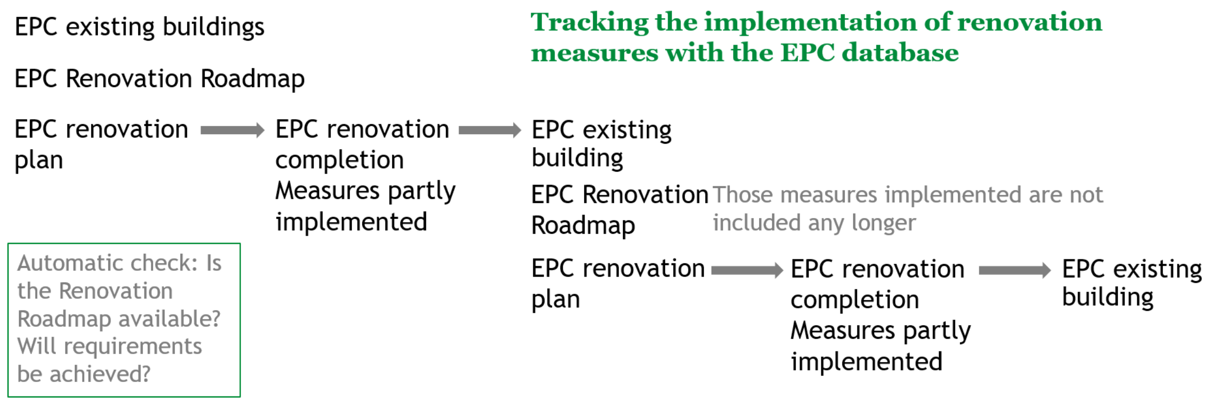

Figure 13. Integrating Renovation Passports into the EPC database and the independent control system (SERA 2023)

This process can be enhanced by integrating a BIM-based workflow, enabling the implementation of changes to the building model in alignment with the Renovation Roadmap and the generation of a new EPC seamlessly (Figure 14).

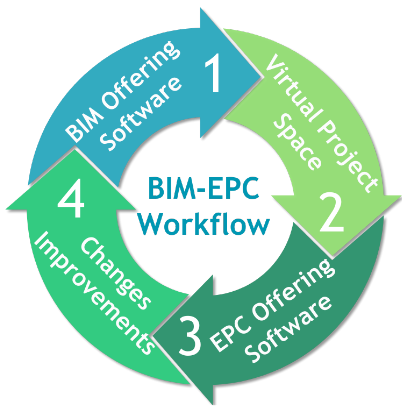

Figure 14. A BIM based workflow to generate the Renovation Passport in connection with the EPC (SERA 2023)

Nonetheless, a prerequisite for this is the inclusion of EPC certification software within the corresponding software package. Additionally, it's worth noting that the BIM-based workflow can serve as an independent method for logging changes to the building, irrespective of the EPC database.

Another possibility of tracing the evolution of building refurbishment is connected to energy audits and energy management systems. Energy audit reports contain recommendations how to improve the building’s energy performance which can be further developed to form a Renovation Roadmap. If an energy management system is in place, it can be used for tracking building refurbishment and verifying achievements.

6.4 The perspective of policy makers and administration

6.4.1 Key issues for implementing the Renovation Passport

The following aspects need to be considered to ensure an effective Renovation Passport:

- **Keep cost of the Renovation Passport low:** This can be achieved through making use of data repositories. Professionals will use the data to be prepared for the on-site-visit. In this way, the site-visit will be most effective.

- **Easy access to energy consumption data (operational data) for professionals:** Advantage should be taken from the smart meter roll-out, and professionals should be granted access to smart meter data based on their license.
- **Ensure latest information on the building status:** This information is based on tracking the implementation of renovation measures and is needed by ESCOs, real estate valuers, and for the national renovation plans.
- **Enable the spatial reference of the information:** A link to regional/municipal plans with information about spatial renewable energy potentials and details of the urban plans is especially important with a view to achieving the zero-emission target.
- **Include financial information and a reference to the Taxonomy Regulation:** Financial information should include a life cycle cost analysis and a statement how the renovation project would be rated against the criteria of sustainable investment according to Taxonomy Regulation.
- **Extend the independent control system according to Article 18 EPBD from the EPC to the Renovation Passport:** Indicators refer to square meter and cubic meter which means that the determination of floor area and volume is a source of errors regarding the reliability of indicators. Quality checked Level 3 BIM architectural models could be used by the independent control system to check the reference area and the reference volume used for calculating the indicators.
- **Make the Renovation Passport accessible for further renovation planning:** It needs to be clear that the Renovation Passport does not substitute technical and construction planning, but offers the building owner and/or the facility manager an orientation to start such a process.

6.4.2 Detailed information on key issues

The following tables provide further information on the key aspects briefly described in the previous section. The information is structured as follows:

- **TIMEPAC scenario:** the envisaged situation, as a result of the analysis carried out in the TIMEPAC project.
- **Challenges that need to be addressed:** difficulties encountered during the analysis carried out in the TIMEPAC project.
- **Possible solutions:** approaches analysed and tested in the TIMEPAC project.

More information about each aspect is provided in the Tables 49 to 55 below.

Table 49. Keep cost of Renovation Passport low through making use of data repositories

TIMEPAC scenario	Challenges to be addressed	Possible solutions
Keep cost of Renovation Passport low through making use of data repositories	Data are generated by experts; due to liability reasons, experts usually do not build on the work of other experts, even if data is accessible, which is often not the case. Building related data can be generated in different legal contexts, for example: energy audits under the EED and the respective national body which	Level 3 BIM: Promote the use of architectural and TBS models of the building. The models would contain information about materials and the respective LCA data. BIM models contain information that is otherwise split between different sources: 2D plans, structural engineering description, technical building services description, building physics parameters of materials,

TIMEPAC scenario	Challenges to be addressed	Possible solutions
	can be different from the body responsible for the building law and the transposition of the EPBD; inspection of heating and cooling systems under the clean air act and not under the building law, and the respective databases with the reports are managed by different departments of the administration; etc. If data is accessible, it is not available in the required form. Lack of data hinders renovations at neighbourhood level that would allow to reduce costs due to economies of scale.	results of material life cycle assessments. Data format: Develop a common data format for recording and storing operational data. Data accessibility: Provide a platform where building specific data can be stored and shared by the building owner (building logbook). Ideally, these data should have undergone a quality check. Ideally, the building owner does not need to upload the data but can retrieve them automatically from other databases.

Table 50. Easy access to energy consumption data (operational data) for professionals

TIMEPAC scenario	Challenges to be addressed	Possible solutions
Easy access to energy consumption data (operational data) for professionals	For residential buildings access to energy consumption data can be difficult, especially in multi-unit residential buildings and for more than one billing period. Monthly payments to energy providers do not reflect the true energy consumption which is disclosed in the annual balance.	Smart meter data: Advantage should be taken from the smart meter roll-out. Each building/building unit is equipped (or will be equipped soon) with a smart electricity meter and a smart meter for grid-bound energy sources such as gas, district heating and district cooling. There is the possibility to opt out from the smart meter scheme, but this is the exemption. The business-as-usual procedure should be based on the use of smart meter data. Professionals should be granted access to smart meter data based on their professional license. Energy bills: In addition, energy bills provide useful information, and they are the only source of information for non-grid-bound energy sources such as solid biomass. A copy of the energy bill should be transferred automatically to the building logbook.

Table 51. Ensure latest information on the building status

TIMEPAC scenario	Challenges to be addressed	Possible solutions
Ensure latest information on the building status	The actual building status is unknown. The EPC has a validity of 5 to 10 years, and during this period, changes may have occurred. This leads to challenges in various areas: In the building renovation plan that will substitute the long-term renovation strategy according to proposed EPBD recast, the renovation rate must be reported. Real estate valuers need up-to-date information about the building for their assessment and thus will appreciate such information. ESCOs are also interested in the actual status of buildings in a certain area, to decide if further investigation could be worthwhile.	A process of tracking the implementation of measures presented in the Renovation Passport ensures that the latest information about the building status is available. It is also important to make some selected information publicly accessible for further use.
		Possible options for tracking the implementation of renovation measures are: • through the extended EPC database including Renovation Passports • trough energy audits and energy management systems (the building specific; result would need to be transferred to the building logbook) • through logging changes to the building in building information models (building specific and available in the building logbook)
		To make selected information from the database publicly accessible: A data processing step is needed to connect buildings to a Geographical Information System and display selected data on a map.

Table 52. Enable the spatial reference of the information

TIMEPAC scenario	Challenges to be addressed	Possible solutions
Enable the spatial reference of the information	As far as the integration of renewable energy systems into the Renovation Roadmap is concerned, information about potentials and possible obstacles is difficult to	Municipal/regional spatial information repository: A link should be established with regional/municipal plans to provide information about spatial renewable energy potentials and details of the urban plans which could hinder the exploitation of renewable energy.

	access and sometimes not even available.	This is especially important with a view to achieving the zero-emission target.

Table 53. Include financial information and a reference to the Taxonomy Regulation

TIMEPAC scenario	Challenges to be addressed	Possible solutions
Include financial information and a reference to the Taxonomy Regulation	Economic profitability calculations are not suitable to consider the investor user dilemma regarding energy efficiency and renewable energy measures. Life cycle cost analysis can provide a solution to this challenge. However, per definition, life cycle cost analysis can refer to different physical and temporal system boundaries, and thus, results from different calculations are hardly comparable. Financing organisations need easily understandable information on the extent to which a project is compliant with the Taxonomy Regulation or not.	Life cycle cost analysis: For the Renovation Passport, the parameters for the life cycle analysis must be specified so that the results are comparable. But even then, this cost estimate only offers a rough orientation due to the long period under consideration and the rapidly changing economic environment. It must be clear that no liability can arise in this respect for the experts involved. Compliance with the criteria of the Taxonomy Regulation: Regarding financing, it is suggested to include a statement in the Renovation Passport on how the renovation project would be rated against the criteria of sustainable investment according to Taxonomy Regulation.

Table 54. Extend the independent control system according to Article 18 EPBD from the EPC to the Renovation Passport

TIMEPAC scenario	Challenges to be addressed	Possible solutions
Extend the independent control system according to Article 18 EPBD from the EPC to the Renovation Passport	In the course of a building renovation, the volume and the net floor area of a building can change, for example because an additional floor is added. Indicators refer to square meter and cubic meter which means that the determination of floor area and volume is a source of errors regarding the reliability of indicators.	Check of renovation measures, timeline, energy savings, area and volume: Often, the independent control system is a stepwise system which is based on an automatic plausibility check implemented during or after upload of the EPC into the database. Checks need to include the renovation measures suggested in the Renovation Passport and could focus on estimated savings and the implementation timeline. Quality checked Level 3 BIM architectural models could be used by the independent control system to check the reference area and the reference volume used for calculating the indicators.

Table 55. Make the Renovation Passport accessible for further renovation planning

TIMEPAC scenario	Challenges to be addressed	Possible solutions
Make the Renovation Passport accessible for further renovation planning	It is not always clear that the Renovation Passport does not substitute technical and construction planning, but provides orientation to the building owner and/or the facility manager to start such a process. It is important that the Renovation Passport includes information about crucial energy-related aspects which need to be considered when starting detailed technical and construction planning.	Start of renovation planning based on the Renovation Passport: It must be ensured that the building owner and the facility manager take note of the Renovation Passport. If general measures are planned for the buildings, it must be clear that the Renovation Passport will be consulted so that the corresponding energy upgrading will also take place. The first step is to upload the Renovation Passport into the building logbook which the owner and the facility manager have access to. Ideally, however, a link can be established between the Renovation Passport and the facility management software used for property management.

The Tables 56 and 57 refer to the requirements for the Renovation Passport as outlined in Article 10 of the proposals for EPBD recast and provide suggestions on how authorities could address these requirements, and/or which aspects are important to consider.

Table 56. Requirements which most likely will apply (based on the Commission proposal for the recast EBPD)

Requirements the Renovation Passport shall comply with (according to Article 10 Commission proposal for EPBD recast)	Recommendations on how these requirements can be addressed by the authority
It shall be issued by a qualified and certified expert, following an on-site visit	Specialised professionals such as energy auditors, EPC assessors, and energy advisors should be entitled to develop Renovation Passports after having passed an additional training.
It shall comprise a Renovation Roadmap indicating a sequence of renovation steps building upon each other, with the objective to transform the building into a zero-emission building by 2050 at the latest	The Renovation Roadmap must be building specific and provides orientation for the building owner what needs to be done to upgrade the building according to the standard. The Renovation Roadmap is the basis for a detailed technical renovation and construction planning. Renovation measures must be planned applying the principle of energy efficiency first, whenever possible. The Renovation Roadmap is the basis for access to affordable finance which includes the cost for

Requirements the Renovation Passport shall comply with (according to Article 10 Commission proposal for EPBD recast)	Recommendations on how these requirements can be addressed by the authority
	detailed technical renovation and construction planning. A municipal information system is established (zoning plan, spatial energy information, etc.) to ensure transformation into zero-emission buildings.
It shall indicate the expected benefits in terms of energy savings, savings on energy bills and operational greenhouse emission reductions as well as wider benefits related to health and comfort and the improved adaptive capacity of the building to climate change	The information to be included on wider benefits might require the use of additional tools. The information to be included on the improved adaptive capacity of the building to climate change might require an assessment that includes information from the municipal plan (e.g. heat islands, green spaces, urban ventilation corridors, share of soil capable of rainwater infiltration).
It shall contain information about potential financial and technical support	The measures outlined in the Renovation Roadmap should be eligible for funding if the packages of measures and the sequence are adhered to. Funding covers both, detailed design and implementation of renovation measures, i.e., costs for planners/engineers, materials, and labour are eligible.

Table 57. Additional possible requirements (based on the Parliament proposal for the recast EBPD)

Additional possible requirements for the Renovation Passport (according to the Parliament proposal)	Comments and recommendations for the authority
Issued in a digital form suitable for printing	Upload via XML from the software to the Database is recommended. In this way, an important step is made to extend the Independent Control System to the Renovation Passport as required by the Commission proposal for recast.
Renovation steps building upon each other in line with the Energy Efficiency First principle	This is an essential principle, but not easy to control and enforce. It needs to be addressed in trainings and funding schemes.
Outlining measures to reduce whole life-cycle greenhouse gas emissions in the renovation process	The scope needs to be defined: is it only related to materials and building operation, or is construction site logistics (transport of materials, machines, and workers for renovation) also included? The databases of the embedded energy (and emissions) of the materials should be consistent and

Additional possible requirements for the Renovation Passport (according to the Parliament proposal)	Comments and recommendations for the authority
	common in the European Union, in order to be able to compare the results of life-cycle greenhouse gas emissions of different buildings.
Expected benefits in terms of whole life-cycle greenhouse gas emissions reductions	Whole life-cycle greenhouse gas emissions reductions can gain importance in connection with national carbon tax schemes and the extension of emission trading to non-ETS sectors such as the building sector.
Information about a potential connection to an efficient district heating network, the share of individual or collective generation and self-consumption of renewable energy	Access to spatial information regarding district networks, renewable energy potentials, and municipal urban plans is required. Regarding solar technologies, it is essential to have information regarding possible urban changes in terms of new buildings to be constructed in the neighbourhood, and the possibility of adding storeys to buildings in the neighbourhood.
Information on a range of estimated costs for each recommended renovation step, as well as the estimated costs of a one-step deep renovation as a reference scenario	The reference scenario of a one-step deep renovation scenario should not be mandatory. In many cases, when a staged renovation is envisaged, a one-step renovation is simply not an option for practical reasons such as building components technical and/or economic lifetime, and financing.
Information on bill of materials, information on construction products circularity as well as wider benefits related to health, comfort, indoor environmental quality, safety such as fire, electrical, and seismic safety	Material and product databases contain results of life cycle assessments. Environmental Product Declarations (EPD) can be used to extract the relevant information. Attention needs to be paid to the fact that EPDs can be generic or product specific. It is recommended to check the planned renovation measures regarding implications on fire safety (insulation, installation of PV systems) and other aspects. However, this requires detailed technical and construction planning that is beyond the scope of a Renovation Passport. It must be clear that the Renovation Passport does not substitute technical and construction planning.
Information on any major renovations made to the building, and any retrofitting or replacement of a building element that forms part of the building envelope with significant impact on the energy performance.	The development of a Renovation Passport must be based on an on-site visit. It is necessary to assess the status quo, as the energy performance certificate and energy audit reports, if available, may be outdated, as well as the architectural drawings and the documentation of the technical building systems, because changes have been made to the building.

Additional possible requirements for the Renovation Passport (according to the Parliament proposal)	Comments and recommendations for the authority
The Renovation Passport may contain additional information, taking into consideration the composition of the household and any planned renovations, including those not relating to energy, in accordance with national law and practice.	This is an essential aspect, because renovation measures such as changes to the building envelope or the heating system are not always carried out exclusively to improve energy efficiency.
Member States shall facilitate the integration of Renovation Passports in the digital building logbook, gathering technical and legal information with essential data for property owners to plan and execute deep and staged deep renovations.	Attention needs to be paid to Copyright law/act and Intellectual Property Rights of designs, reports and data collections. Guidance is needed who owns which data and who can re-use data under which conditions; e.g. contractual agreements that data, designs, reports are uploaded to the building logbook and can also be shared with others by the building owner.

6.4.3 The role of municipalities

Apart from overriding federal and/or state building regulations, municipalities enact ordinances based on local, topographical, and demographic conditions. Here, the holistic approach to interfaces between energy performance certificates and 3D models of a building for renovation can be embedded very well. TIMEPAC supports the municipalities in filling the gaps.

- In the municipalities, original plans of the building stock are usually available, but rarely digitised. They also contain all the information about the various grid owners (natural gas, district heating, district cooling, and electricity). These must be collected by a specialist planner before renovation and the actual condition of the building, which is provided with a notice from the responsible municipality, must be determined.
- These original plans have to be reconciled with the current condition of the building and the owner's ideas under building law. For the authorities, an official submission plan, previously 2D, is explicitly important, as it shows, for example, the taxable area. Thus, the holistic approach of TIMEPAC therefore also helps here in the municipalities, as it breaks down these areas quickly and reliably.

A forward-looking example that has already been implemented in Vienna is the EU-funded "BRISE Vienna" project, in which a BAM - a building application model - is submitted digitally to the authority, which makes a statement in advance on the 3D model. The Artificial Intelligence in the background quickly examines the legal specifications, and residents can use virtual reality to check out the future building. The advantages are a 50% reduction in processing time for the authority and the citizens. More information is available at https://digitales.wien.gv.at/projekt/brisevienna/

6.5 The perspective of building professionals

6.5.1 Key points concerning workflow and corresponding tools

The following key points concerning the workflow and the corresponding tools are important in the process of generating a TIMEPAC Renovation Passport and consequently more renovations.

The TIMEPAC Renovation Passport, with its claim to track the implementation of renovation measures, links the EPC to the architectural and engineering work of actual renovation planning and implementation.

In this context, it is noted that each architectural or planning office works with different software providers, drawing software with their updates and various operating systems. Each of them also offers the possibility of a 3D model to work with different components involved in the project.

The following important points need to be considered when establishing the ideal workflow:

- In terms of developing the TIMEPAC **Renovation Passport** including the long-term Renovation Roadmap and the possibility of tracking the implementation of renovation measures, a specific model with a BIM offering software must be created in which all the data relevant to the project participants, such as the attributes of the materials, are listed. The compatibility of the files plays a major role here which can be ensured by compatible software products.
- In terms of **actual planning and implementation of renovation measures**, in many cases, an official submission plan for the renovation project is required by the authority which has to comply with certain requirements.
- In terms of **issuing the EPC**, the official software approved in a country must be applied.
- Ideally, the **BIM offering software and the included software packages** can perform the three functionalities as described above.
- In any case, a coordinator who manages the data and recreates it in case of changes due to the implementation of renovation measures is of great importance. This is a new role, the one of the **TIMEPAC manager**.

Larger offices have one or more BIM experts. SMEs still save the costs, as it does not (yet) seem economically viable to use BIM except for large-volume construction projects, which tend to be industrial and commercial buildings. The same applies to the creation of the Energy Performance Certificate, either it is created in the office or outsourced.

The implementation of the TIMEPAC Renovation Passport can be the starting point to combine several small offices into a network, using the same BIM offering software and the corresponding software packages.

In summary, the possibility of all data being collected in one place should be more widely used by professional designers. This would be to their advantage to be able to perform the life cycle assessment of a building, which is required not only for the improved TIMEPAC EPC and Renovation Passport, but also for green building rating systems and determination of compliance with the Taxonomy Regulation.

6.5.2 Software providers, plug-ins, and EPC software

It is important to note that using different software providers results in loss of information each time data is transferred. Although the .ifc exchange format enables product-independent cooperation, information losses cannot be avoided at present and are particularly problematic for material properties, which play a decisive role for the extended TIMEPAC EPC and the Renovation Passport.

Figure 15 shows a brief overview of the market of software providers concerning 3D software, BIM, energy modelling and LCA assessment software, as well as EPC providers, using the example of Austria. It is evident that collaboration between different companies on the Renovation Passport will be challenging due to the different software that is used.

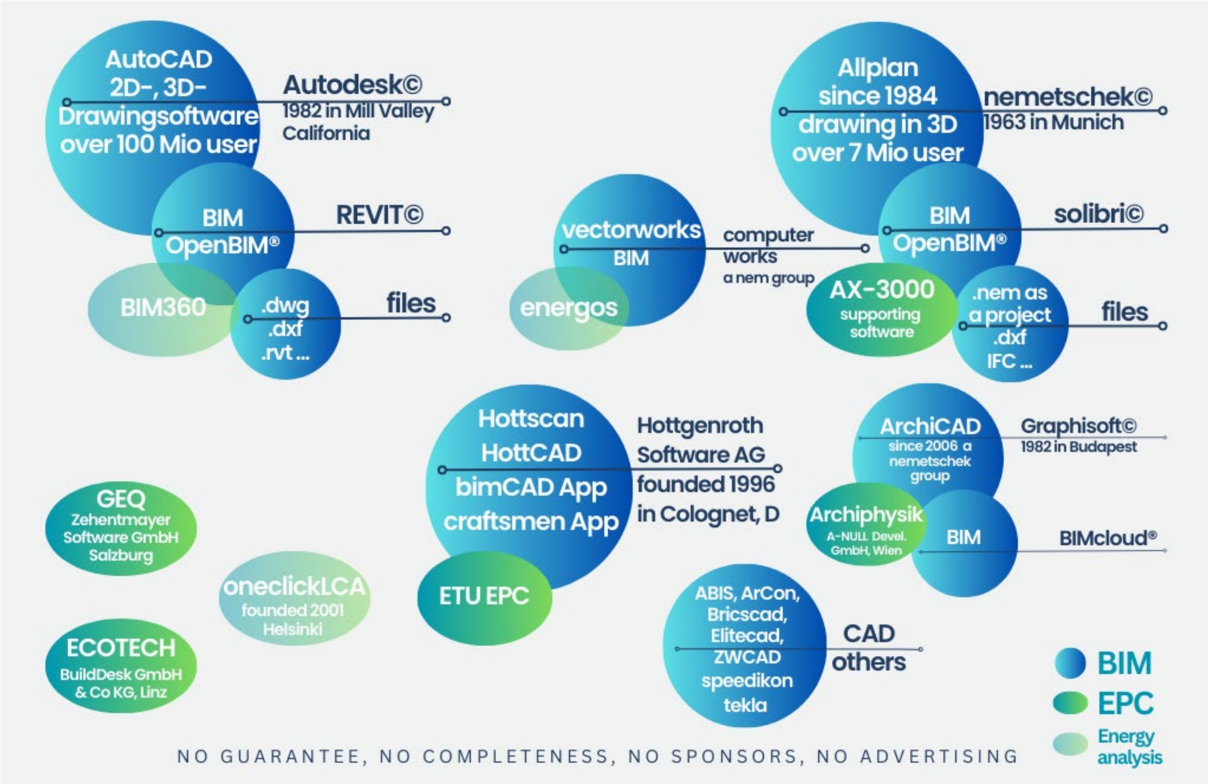

Figure 15. A brief overview of software providers with focus on Austria (SERA 2023)

6.5.3 Workflow with the software tools of CYPE

CYPE Ingenieros offers software solutions for engineering and construction with its headquarters in Alicante (Spain). With 171 applications, they cover the entire range of design, analysis, regulation, reports, and graphical results (plans and 3D models). The individual applications have small amounts of data, only 12 MB each.

Furthermore, they created a collaborative tool, the so-called *BIMserver.center*. This virtual platform connects these modules via OpenBIM® in the cloud as a holistic solution. In accordance with EN ISO 19650, it manages all information and stores all data throughout the life cycle of a construction project. It is a place where experts can work on the project in a team, make it public in the sense of OpenBIM® or not (Figure 16).

The specialist planner is able to upload a building, feed it into the various modules offered and also work on it there. BIM experts have the possibility, if there is a change, to change it directly here.

- CYPE facilitates many things: implement all changes without importing all new models. The workflow with CYPE connects the individual models, adds supplements in parallel and uses only the tools needed for this purpose.
- Three options are available to start a project:
    1. You prefer 2D drawings for the project, so you use the IFC Builder.
    2. The planner applies the tool CYPE Architecture or optionally another one.
    3. The Open BIM Construction Systems, if you want to define the construction elements before the energy model.
- Then the tool Open BIM Analytical Model follows. If you work with an IFC-file then the IFC Uploader will be beneficial. To create an analytical model, the OpenBIM Analytical Model is used and easily guides to the CYPETHERM EPlus.
- CYPETHERM EPlus is the energy modelling tool and generates the EPC.

- If you want to compare some models or make changes within them, e.g. through renovation measures, the tool CYPETHERM Improvements Plus is available.

It is important to know that the tools for official Energy Performance Certificates according to legal provisions are only available for the countries Spain, Portugal, Italy, and France. In these countries, the EPC can be generated from CYPETHERM EPlus. Thus, these countries benefit from the seamless and complete data transfer between tools without loss of information. Changes to the architectural model due to renovation measures will be reflected automatically in the EPC.

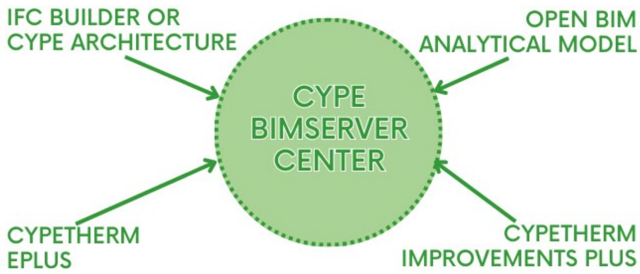

Figure 16. Overview of the relevant software tools of CYPE (SERA 2023)

6.6 The perspective of building owners and property managers

6.6.1 Single-family houses

Building owners have to face a multitude of possibilities to adapt their living space to the respective demands. Depending on the stage of life of the owner or on the year of construction of the living space, there are different reasons arise why renovations are relevant.

- The space requirements no longer cover family needs
- Material fatigue appears on an object and causes creeping damages to the building structure
- Roof renovation
- Outdated drainage and heating pipes
- High energy consumption

The simple installation of a photovoltaic system and the replacement of the heating system at great expense do not make a building energy efficient. The life cycle assessment of the building comes into focus.

It is not easy for the owners to figure out the extent of renovation in terms of time or technical possibilities. The holistic approach of the BIM based TIMEPAC Renovation Passport helps to generate a virtual 3D model to which everyone has access with all data sovereignty, which is stored with the Energy Performance Certificate or with specific data on the building structure and can be modified depending on the renovation status.

These processes capture temporal developments on buildings along with the complicated renovation route. With a virtual twin, created from a BIM-offering software and its plug-ins, an enhanced energy certificate is created that potentiates the number of renovations in existing buildings.

Challenges in this area are the high financial costs of redevelopment. These costs are not only justified by the fact that building-relevant data is stored for future generations, who have faster access to the structure of the building. In addition, the real estate industry is taking up the term `stranded asset´. This means that existing properties are devalued due to high CO_2 emissions to such an extent that they are difficult or even impossible to sell on the real estate market - they become stranded. It also means that energy-inefficient buildings lose significant value. Building refurbishments to zero-emission standard not only bring comfort for the occupants - but they are also worthwhile in the long run.

6.6.2 Apartment buildings

In the case of apartment buildings, renovation is either to be carried out on condominiums, rental flats or the building complex itself. These are managed by building managers, whose focus is the maintenance and upkeep of the same. The holistic approach of the BIM-based TIMEPAC Renovation Passport provides a fast, cost-effective and supportive method to assist property managers. This results in the following:

- Combine several building complexes in ONE refurbishment campaign to reduce costs.
- First advantage: Contractors such as façade builders, heating engineers, plumbers, receive large orders for an entire area. If you only refer to a single building with a single order, it is uneconomical. Many things are not renovated for this reason due to the high expenditure of time and the low return.
- Second advantage: The one-stop-shop of the TIMEPAC Renovation Passport provides a project-controlling unit that coordinates all participants, property managers, architects, executing companies, based on the intelligent 3D model. During the renovation process, everyone involved has access to the 3D model, which, with rapidly advancing digitalisation, can also be read with data glasses and modified on-site in the near future. Even if something unforeseen happens on the construction site, the collaborative BIM image of the building is analysed and reflects the changes to the building or building services in real time. It saves costs and is stored for subsequent planners and generations, and later changes.

Good examples for such group building renovations exist, for example in Hepokulla, a suburb of Turku in Finland. This is a joint project of seven housing companies carrying out extensive renovation work on 26 apartment buildings. These include façade and pipe renovations, implementing geothermal energy, recovery from exhaust air and provisions for solar power. Both the pipes and the facades were nearing the end of their useful life, and the mortgage lending value of the flats would not have been sufficient to cover the square metre cost of the refurbishment of around € 1,200. With the help of an external valuer, it was possible to show that the value of the flats would increase to a sufficient level if the whole area were uniformly refurbished.[21] So, the term "stranded asset" also plays a significant role here.

6.6.3 Non-residential buildings

For non-residential buildings, the same applies as for those already mentioned, but there are differences in data protection rules. In general, non-residential buildings benefit from the holistic approach of the BIM based TIMEPAC approach. The interlink of the improved Energy Performance Certificate with the ever-evolving 3D models in the appropriate application framework and usage space helps to unfold the great renovation potential on the one hand and to facilitate the documentation of changes within it on the other hand.

- The virtual model of a building object contains all data regarding energy consumption and life cycle information. These are managed in designated data repositories.
- Changes to the building resulting from refurbishment are updated as required.

The ownership structure of non-residential buildings must be considered. In the case of administrative and state institution buildings there are seldom - if any - requirements for data

[21] Kaisa Salminen, Renovation project Hepokulla, Rakennuslehti – in “Construction Industry Magazine”, 28.02.2022

protection with respect to the collected and deposited data of the object. In the private sector, dealing with it is essential.

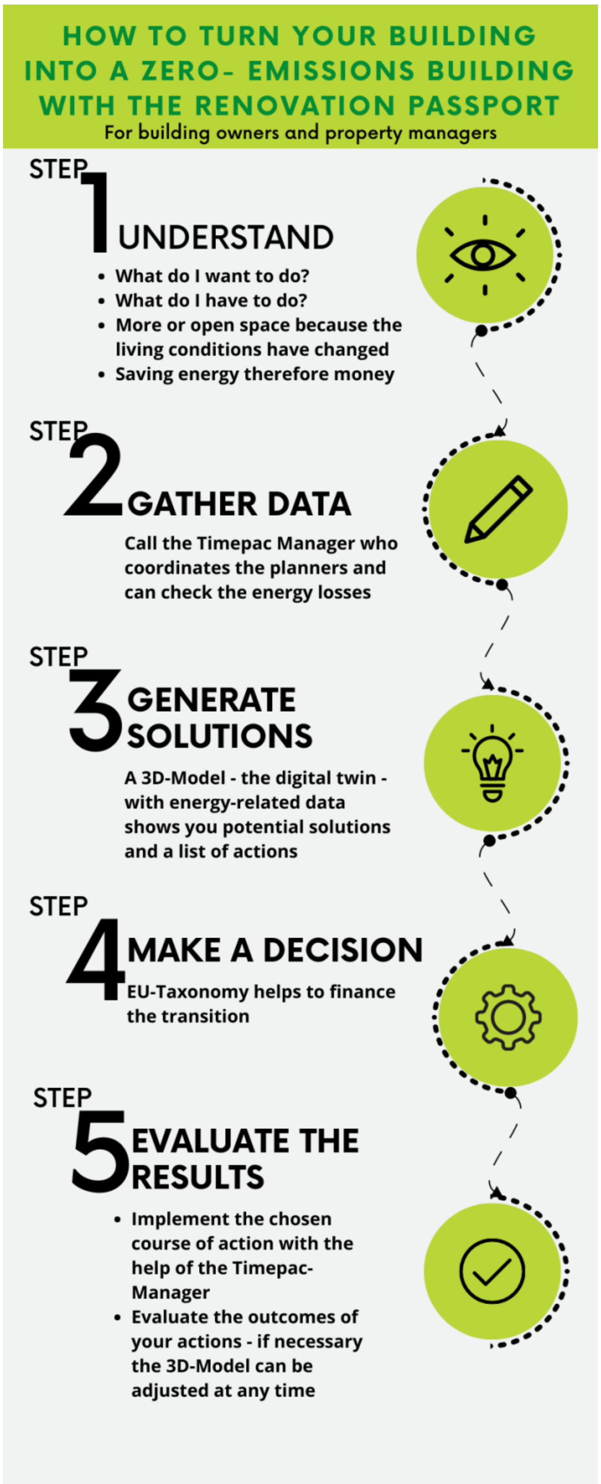

Figure 17. How to turn your building in a zero-emission building with the TIMEPAC Renovation Passport (SERA 2023)

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Annex A – Definitions of nearly Zero-Energy Building and Zero-Emission Building

Article 2 - Definitions

EPBD recast - Commission proposal

'zero-emission building' means a building with a very high energy performance, as determined in accordance with Annex I, where the very low amount of energy still required is fully covered by energy from renewable sources generated on-site, from a renewable energy community within the meaning of Directive (EU) 2018/2001 [amended RED] or from a district heating and cooling system, in accordance with the requirements set out in Annex III;

'nearly zero-energy building' means a building with a very high energy performance, as determined in accordance with Annex I, which cannot be lower than the 2023 cost-optimal level reported by Member States in accordance with Article 6(2) and where the nearly zero or very low amount of energy required is covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby;

EPBD recast - Council proposal

'zero-emission building' means a building with a very high energy performance, as determined in accordance with Annex I, requiring zero or a very low amount of energy, producing zero on-site carbon emissions from fossil fuels and producing zero or a very low amount of operational greenhouse gas emissions, in accordance with the requirements set out in Article 9b.

'nearly zero-energy building' means a building with a very high energy performance, as determined in accordance with Annex I, which cannot be lower than the 2023 cost-optimal level reported by Member States in accordance with Article 6(2) and where the nearly zero or very low amount of energy required is covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby;

EPBD recast - Parliament proposal

'zero-emission building' means a building with a very high energy performance, as determined in accordance with Annexes I and III, which contributes to the optimization of the energy system through demand-side flexibility, where any very low residual amount of energy still required is fully covered by energy from:

(a) renewable sources generated or stored on-site;

(b) renewable sources generated nearby off-site and delivered through the grid in accordance with Directive (EU) 2018/2001 [amended RED];

(c) a renewable energy community within the meaning of Directive (EU) 2018/2001 [amended RED]; or

(d) renewable energy and waste heat from an efficient district heating and cooling system within the meaning of Directive (EU) .../.... [recast EED], in accordance with the requirements set out in Annex III;

'nearly zero-energy building' means a building with a very high energy performance, as determined in accordance with Annex I, which cannot be lower than the 2023 cost-optimal level reported by Member States in accordance with Article 6(2) and where the nearly zero or very low amount of energy required is covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby;