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Advancing energy renovations through digitalisation: A critical review of EU policies and instruments

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A B S T R A C T

This paper provides a holistic overview of the evolution of policies towards digitalising energy renovation processes in the European Union (EU). Since the European Green Deal initiative in 2019, EU policies have been increasingly addressing the digitalisation of the building industry to enable evidence-based decisions when tackling environmental challenges. To better understand the development(s) since, this paper integrates a structured policy analysis approach and critically reviews 31 EU policy documents on digitalisation and/or energy renovation. The analysis identified a growing number of policy instruments aimed at supporting a robust use of data, to, among others, improve decision-making and information sharing throughout the energy renovation process. These include Energy Performance Certificate, Building Renovation Passport, Smart Readiness Indicators, Level(s), Digital Building Logbook, Digital Product Passport, Digital Twin, Building Information Modelling, and Digital Permitting. While each of these nine instruments can independently facilitate decision-making on sustainable and/or smart renovations, they also project a significant degree of complementarity between each other. To that, this paper presents the Digital Energy Renovation Framework, which comprehensively synthesises the (inter)relationships between the proposed policy instruments with respect to facilitating energy renovation processes. A key finding is that the integration between the Building Renovation Passport and a data-rich Digital Building Logbook is fundamental to maximise the impact on decision-making throughout the renovation process. To achieve this, ensuring coherence and interoperability of data throughout the renovation value chain is crucial, with the standardisation of data formats and protocols being essential for effective data gathering and processing across these instruments.

1. Introduction

1.1. The need to advance energy renovation in the EU

In the European Union (EU), approximately 97 % of the existing building stock is regarded as energy inefficient, with only 11 % undergoing some form of renovation annually [1]. However, a substantial share of these renovations fails to address energy efficiency sufficiently, leading to energy-focused upgrades being described as "virtually absent" [2]. Given that the majority of today's building stock is projected to be in use in 2050, decarbonising the existing building stock through energy performance improvements is essential to achieve the EU's target of climate neutrality by 2050 [2]. To meet this goal, the annual energy renovation rate must be increased [1].

Energy renovations encompass a range of strategies designed to reduce a building's energy demand. These can include basic measures, such as upgrading insulation, sealing air leaks, and replacing windows, as well as more advanced interventions like retrofitting heating, ventilation, and air conditioning (HVAC) systems. Among many approaches, deep renovation seeks to capture a building's full energy-saving potential through comprehensive upgrades carried out in one or a number of steps [3]. The European Commission considers this approach highly effective as it can deliver energy savings of over 60 % [2]. While it is seen as an effective solution to accelerate the renovation rates, its widespread implementation remains a challenge [4–6], mainly due to the high costs and significant disruptions involved, as well as its time-intensive nature [7].

1.2. EU policy frameworks for energy renovation

Energy efficiency policies for buildings have been a central element of environmental and energy strategies in the EU for decades, starting

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with the 2002 Energy Performance of Buildings Directive (EPBD) to unlock cost-effective savings, followed by the 2011 Energy Efficiency Action Plan [8]. The EPBD, in particular, has played a key role in shaping EU policies aimed at enhancing energy efficiency in buildings, by requiring Member States to establish progressively higher standards for buildings undergoing renovations [8]. For instance, its shift from specific requirements, such as the use of U-values for building walls, to performance-based standards has made possible the incorporation of cost-optimal concepts in building regulations and the implementation of net-zero energy targets for new buildings [8].

Currently, the revised EPBD [9] enacted in April 2024 and the Energy Efficiency Directive (EED) [10] enacted in 2023 are the most comprehensive and enabling frameworks that shape renovation practices in the EU. The former provides a framework for Member States to increase the renovation rates of particularly the worst performing buildings, while the latter is directed to improving efficiency across the full energy chain in the EU, from energy generation, transmission and distribution, to end-use.

The proposal to revise the EPBD and EED is initiated with the Renovation Wave [2], which recommends more concrete regulatory, financing and enabling measures to promote energy renovations that reflect the increased need for climate and social action following the COVID-19 pandemic. These recommendations provide the basis for both the EPBD and EED to introduce EU-level policies that are aimed to create a stable environment for decision making, including the digitalisation of the building industry [2,9,10]. On the latter, both directives call for the robust use of digitised data from several policy instruments to improve decision making and information sharing throughout the entire renovation process. These include the Energy Performance Certificate (EPC), Building Renovation Passport (BRP), Smart Readiness Indicators (SRI) as well as Level(s) Indicator 1.2 on Lifecycle Global Warming Potential, which measures the contributions of a building to the environment across its lifecycle. The EPBD further emphasises on the integration of these instruments in a common repository for building data, namely the Digital Building Logbook (DBL). Table 1 lists these instruments and provides a summary of their purposes.

1.3. Addressing data-related challenges with digitalisation

However, significant challenges persist in achieving effective information sharing and data integration across the construction value chain [17]. Although data required by the instruments listed in Table 1 are generated by various stakeholders throughout the building lifecycle [14–16], the lack of standardisation [18] and difficulties in retrieving data from its source [16] often result in recurring cycles of data loss and inefficiencies in collection processes. These issues are identified in literature to be caused by the fragmentation of the construction value chain [19,20], the absence of a cohesive approach to data management [16,21] and data governance [22], as well as the uncertainties surrounding stakeholder roles [15] and data requirements [21]. Such asymmetries in data management further complicate efforts to define parameters and develop indicators that can provide reliable information to users [18].

Table 1
Overview of policy instruments mentioned in the EPBD and EED.

Instrument	Acronym	Purpose	Reference
Energy Performance Certificate	EPC	To provide tenants and buyers with reliable information on the energy performance of the building.	[11]
Building Renovation Passport	BRP	A user-friendly document that outlines the long-term, step-by-step renovation roadmap for homeowners to easily plan deep renovations.	[12]
Smart Readiness Indicator	SRI	To assess how smart a building is in terms of adapting its operation to the needs of the occupants, particularly concerning indoor environmental quality.	[13]
Level(s)	–	A European framework of core indicators of sustainability that assesses and reports on the sustainability of a building.	[2]
Digital Building Logbook	DBL	A repository for building data that serves to standardise data collection processes and support the generation, storage, and management of reliable, high-quality building information.	[14–16]

The EPBD and EED consider the integration of these instruments crucial to bridge information silos across the building industry. Nevertheless, questions remain as to whether these gaps have been thoroughly analysed and effectively addressed. While several measures, such as *Shaping Europe's digital future* [23], *A European Strategy for Data* [24], *Powering a climate-neutral economy: An EU Strategy for Energy System Integration* [25], the *Digital Europe Programme* [26] and the *Digital Decade Policy Programme 2030* [27], have been taken at the EU level to highlight the urgency of adopting interoperable practices, many of these initiatives remain superficial and fail to specifically address the building industry. Regardless, these policy frameworks and action plans collectively underscore the increasing focus on the digital transition of the EU. This, in turn, reflects a broader shift towards the (rapid) digitalisation of the building industry, including energy renovation processes, which is becoming increasingly anticipated across the EU [9].

In line with these developments, it is necessary to critically analyse the existing policies to challenge the underlying assumptions about the integrated use of the proposed policy instruments to identify potential avenues for future development. A starting point involves examining both the individual contributions of and the interrelationships between the instruments, particularly in the context of energy renovations. In this regard, several academic studies have made significant contributions, including the exploration of definitions and typologies of various instruments [12,20,28], the integrated use of the EPC, BRP and/or the DBL [19,29–31] to provide more tailored renovation advice, as well as the combined use of the EPC, BRP and Level(s) when assessing the energy performance of the building [5]. However, despite these efforts, a comprehensive synthesis of all available policy instruments remains absent in the literature. This gap underscores an imbalance in their development and emphasises the need for a more integrated and holistic approach to ensure the seamless incorporation of the available instruments into cohesive energy renovation strategies, ultimately advancing the goals of sustainability and efficiency. From a policy perspective, the call for integration reflects a broader need to move beyond fragmented initiatives towards a unified framework capable of supporting comprehensive, long-term renovation goals that align with both current and emerging energy performance standards.

This paper therefore aims to address this research gap by analysing EU policies on the intersection between digitalisation and energy renovation, presenting a comprehensive framework that synthesises the relationships between the proposed policy instruments, with respect to facilitating energy renovations. The central research question is: *What are the key policy instruments introduced at the EU level that support the digitalisation of energy renovation processes, and how can they support each other to accelerate the transition?* In this paper, digitalisation is explored through how digitised building data can be used by the available policy instruments to support decision-making for energy renovation, and how the integration of the instruments can maximise the impact. To respond to the question, *Section 2* first elaborates on the research design and methods adopted for this study. *Section 3* then presents the key findings of this paper, which are as follows: (1) an overview of EU policy frameworks on digitalisation and/or energy renovation, (2) an analysis of the available instruments and their contributions to energy renovation, and (3) the Digital Energy Renovation Framework. *Section 4* subsequently reflects on the policy achievements, challenges and implications, and the paper ultimately closes with a conclusion on research contributions in *Section 5*.

2. Materials and methods

This study employs a qualitative research design to explore the intersection of digitalisation and energy renovation within the context of EU policy. The research design integrates a structured policy analysis approach that consists of three stages, namely data collection, analysis, and presentation, to ensure a comprehensive examination of relevant policy frameworks and ongoing EU-funded projects. The scope of the analysis is limited to EU policies for and within the built environment, with a specific focus on energy renovation. Each research stage is described in detail in the following subsections.

2.1. Data collection

A deep search was conducted between May and September 2024 to first identify all relevant policy documents from two sources: (1) EUR-Lex,[1] which is the official online platform for all EU legal documents, and (2) the Publications Office of the European Union,[2] which is the official publishing body for a wider range of EU-issued documents including legal documents, such as reports, data and procurement notices. The EUR-Lex platform is considered as the main source as it provides the most comprehensive access and is updated daily.

The scope of search was restricted to all documents published from 2019 to present. This follows the European Green Deal [32] initiative, which sets out policy initiatives to transform the EU into a resource efficient and competitive economy that is climate neutral in 2050. As part of its efforts to mainstream sustainability in all EU policies, it stressed on the need for accessible and interoperable data as well as data-driven innovations to enable evidence-based decisions and maximise the capacity thereof when addressing environmental challenges. This has led to the proposal of several policy frameworks and action plans to conceptualise various instruments that aim to support a wider, robust use of data to, among others, accelerate energy renovations in the EU.

Using the key words *digit**, *data* and *building renovat** and the snowballing procedure [33], the search resulted in 14 policy documents. These include one *Regulation*, two *Directives*, one *Decision*, seven *Communications* and three *Reports*. In addition, key takeaways from relevant (ongoing) EU-funded projects are also considered. These projects are anchored on the policy frameworks and action plans of the EU, suggesting that the findings may shape the policy discourses in the future. An initial search on CORDIS,[3] a platform that provides information about EU-funded research and innovation, was conducted between June and September 2024. Using the keywords *digit**, *data* and *building renovat** and coupled with the snowballing procedure [33], the search resulted in 21[4] relevant EU-funded projects. 11 projects were eliminated following the initial analysis due to either the lack (or absence) of published deliverables or irrelevance to energy renovation, resulting in nine EU-funded projects (see Appendix A). From carefully screening the projects, 17 practitioner reports were selected for in-depth analysis.

[1] For more information, see https://eur-lex.europa.eu/homepage.html?lang=en.

[2] For more information, see https://op.europa.eu/en/.

[3] For more information, see https://cordis.europa.eu/.

[4] In alphabetical order: ALDREN; BEreel!; BIM4EEB; BIM4Ren; BUILDCHAIN; CHRONICLE; D^2EPC; Demo-BLog; DigiPLACE; ePANACEA; EPBDwise; EUB SuperHub; iBRoad; iBRoad2EPC; openDBL; Platform CB'23; PROBONO; Renocally; SmartLivingEPC; Smart^2; X-tendo.

2.2. Data analysis

An analytical framework was developed to code the identified documents. The framework followed three main steps. Step one involves the sorting of all identified policy documents into two primary categories —digitalisation and energy renovation— and the identification of overlaps in between, as can be seen in Fig. 1. The aim is to provide an overview of how the policies on both categories have developed overtime and potentially enhanced their synergy. A deductive approach was applied in this step when coding the documents.

Step two then aims to understand how digitalisation and energy renovation are being addressed at the EU policy level. Here, the inductive approach was applied to identify the discrete components embedded in the policy documents. These codes were then aggregated into four secondary categories: *Barrier identification*, *Long-term goals*, *Strategies* and *Policy instruments.* This step helped to identify not only the gaps and overlaps between the policy frameworks and initiatives, but also how they can complement each other to diversify the roles of the instruments identified. Step three ultimately analyses how these instruments are envisioned to individually address both the digital and green transition goals of the EU.

2.3. Data presentation

With the combined findings in *Section 2.2*, a comprehensive framework that synthesises the visible and potential interrelationships between all identified instruments with respect to facilitating energy renovations is mapped. Subsequently, the strengths and gaps in the current policy framework are identified to highlight future areas of research.

3. Results

3.1. Policy development on digitalisation and energy renovation in the EU

This subsection provides a chronology of EU policy frameworks, action plans and the Commission-issued reports on digitalisation and/or energy renovation published since the European Green Deal [32] initiative in 2019. As illustrated in Fig. 2, a total of 14 relevant documents were identified, and among them are one *Regulation*, two *Directives*, one *Decision*, seven *Communications* and three *Reports*. These terms represent the different types of policy documents at the EU level and encompass different meanings and legal obligations. For instance, while *Regulations* are fully binding and directly applicable in all EU Member States [34], *Directives* must be transposed by Member States into national laws [35] and *Decisions* are only binding on the addressee (s) [36]. In contrast, *Communications* and *Reports* are not legally binding but may provide directions for future policy development. To illustrate, *Communications* report on matters such as policy evaluations, descriptions of action plans and programmes, outlines of impending policies and arrangements regarding details of current policies [37]. Similarly, *Reports* are European Commission-issued documents that report and assess on current policies [37].

Two key observations can be made. First, the mapping demonstrates that the energy renovation category is a subset of the digitalisation category (see also Fig. 1). This not only indicates that every policy framework on energy renovation proposed since 2019 has been explicitly addressing digitalisation, but also implies that the digitalisation of the energy renovation processes in the EU is already ongoing.

The second observation concerns the types of policy documents in accordance with the years published. It can be observed that the year 2020 sees the largest volume of publications with a total of one Report and eight action plans and strategies presented across five *Communications*. On the other hand, between 2021 and 2024, while there is a significant decrease in volume, there is an increased focus on the publication of legally binding frameworks; one *Regulation*, two *Directives*

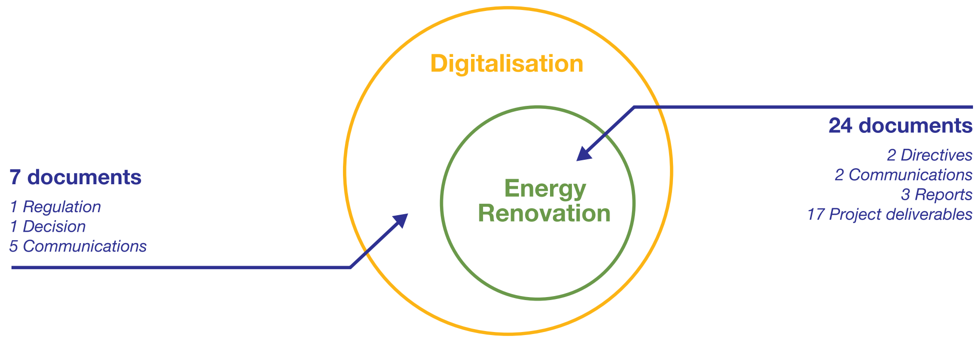

Fig. 1. Categorisation of the identified policy documents.

and one *Decision*. Between the same years, two proposals to revise existing policy frameworks, a proposal for a new framework, and two sector-specific reports were published. This flow of events can be deduced as natural steps in policymaking and implementation; the European Green Deal instigated the development of various action plans and strategies, calling for the need to amend existing and/or introduce new regulatory frameworks, supported by sector-specific studies.

3.2. Policy instruments as enablers of energy renovation

Our analysis identified five policy instruments that directly contribute to the digitalisation of energy renovation processes. These include the Energy Performance Certificate (EPC), Building Renovation Passport (BRP), Smart Readiness Indicators (SRI), Level(s) and the Digital Building Logbook (DBL). These instruments are enabled by both the EPBD and the EED, implying that their development, implementation and standardisation are viewed as priority actions at the EU level. Nevertheless, other non-regulatory frameworks that support the EPBD and EED have explored the capacities additional instruments, though not explicitly in the context of energy renovation. These include the Digital Product Passport (DPP), Digital Twin, Building Information Modelling (BIM) and Digital Permitting. These instruments are identified as valuable data sources that can support and enhance the quality of energy renovation processes.

3.2.1. Energy performance Certificate (EPC)

The EPC provides information on the energy performance of a building or a building unit that is calculated based on the methodology described in Article 4 of the EPBD [9]. It is aimed to enhance transparency of the performance of the building stock [2]. For instance, at the building level, it informs building owners about the share of renewables and energy costs of their building. At the district, regional, Member State and/or the EU level(s), it can help key stakeholders identify the worst-performing buildings in urgent need of energy renovation and address them accordingly.

The EPBD mandates the issuance of an EPC for buildings when they are constructed, have undergone a major renovation, and at point(s) of sale and lease. The EPBD thus considers it as an opportunity to inform building owners of the necessary renovation interventions. Consequently, the EPC also includes recommendations for building owners to improve the energy performance and indoor environmental quality, as well as to reduce the operational gas emissions for all buildings below the energy performance class A [9]. Such recommendations may range from small-scaled renovation interventions to the building elements, to large-scale interventions to the building envelope or the technical systems.

It is important that the recommendations are both technically and economically feasible [9]. On the technical feasibility, information such as the remaining lifespan of building equipment, the possibility for the existing building and its equipment to operate at more energy saving settings, and the alternatives for replacements to existing systems that are aligned with the climate targets are key. On the economic feasibility, its ability to measure the cost-effectiveness of quality renovation is fundamental [38]. In general, the EPC should be able to facilitate the evaluation of post-renovation improvements relative to the investment made [2], estimate the range of payback periods [9], and provide information on the available financial incentives [38]. Furthermore, as a mean to address the underlying issue that surrounds the low quality of the EPC [2,38], the EPBD highlights that the generated EPC must be recognised by either the Member State or the designated legal body.

The EPC is therefore envisioned to be the primary source of information for all certified buildings [38]. While varying systems to collect EPC data have already been (voluntarily) established in most Member States [38], there is a need for more stringent provisions on the availability and accessibility of EPC data [2]. As a result, a national database for the energy performance of buildings that includes all issued EPCs, the data necessary for the calculation of the energy performance [9], and an inventory of all public buildings that do not reach the nearly zero-energy buildings level [10] has become a requirement in Member States.

In line with this requirement, a uniform, machine-readable data format for the EPC [2] is necessary to ensure optimum data exchange and interoperability between stakeholders of interest [39]. To that, several measures have been taken: the issuance of a digital EPC with the provision of a paper version upon request [9] and the proposal to harmonise and strengthen the EPC indicators [39].

3.2.2. Building renovation Passport (BRP)

The EPBD defines a BRP as a tailored roadmap for the deep renovation of a building to significantly improve its energy performance. The goal of the BRP is to increase renovation rate and depth [38] by creating better conditions for staged renovations [2]. Consequently, the roadmap is to be delivered in the maximum number of steps to support building owners and investors when assessing the type(s), scope, sequence and quality of renovation interventions that are best aligned to their capacities and convenience [38].

The BRP can be viewed as an evolution of the EPC as they both facilitate building owners with tailored recommendations to improve the energy performance of their buildings [40,41]. In fact, several studies emphasise that the (calculated) energy performance achieved by the recommendations in the BRP should be based on and/or demonstrated by the EPC [41–43]. Nevertheless, while the EPC provides a static overview of the energy performance of a building at a given time [44], the BRP is more dynamic in nature. For instance, if a recommendation on the use of gas changes shortly after the BRP is issued, the BRP can incorporate and address the change relatively quickly [45]. In addition, unlike the EPC, the BRP explicitly takes user behaviour, such as consumption patterns, into account, to best facilitate renovation activities that are most necessary for the building and its occupants [41]. These added qualities of the BRP can not only address the gap in the EPC in triggering renovation [46], but also help eliminate the risk of building

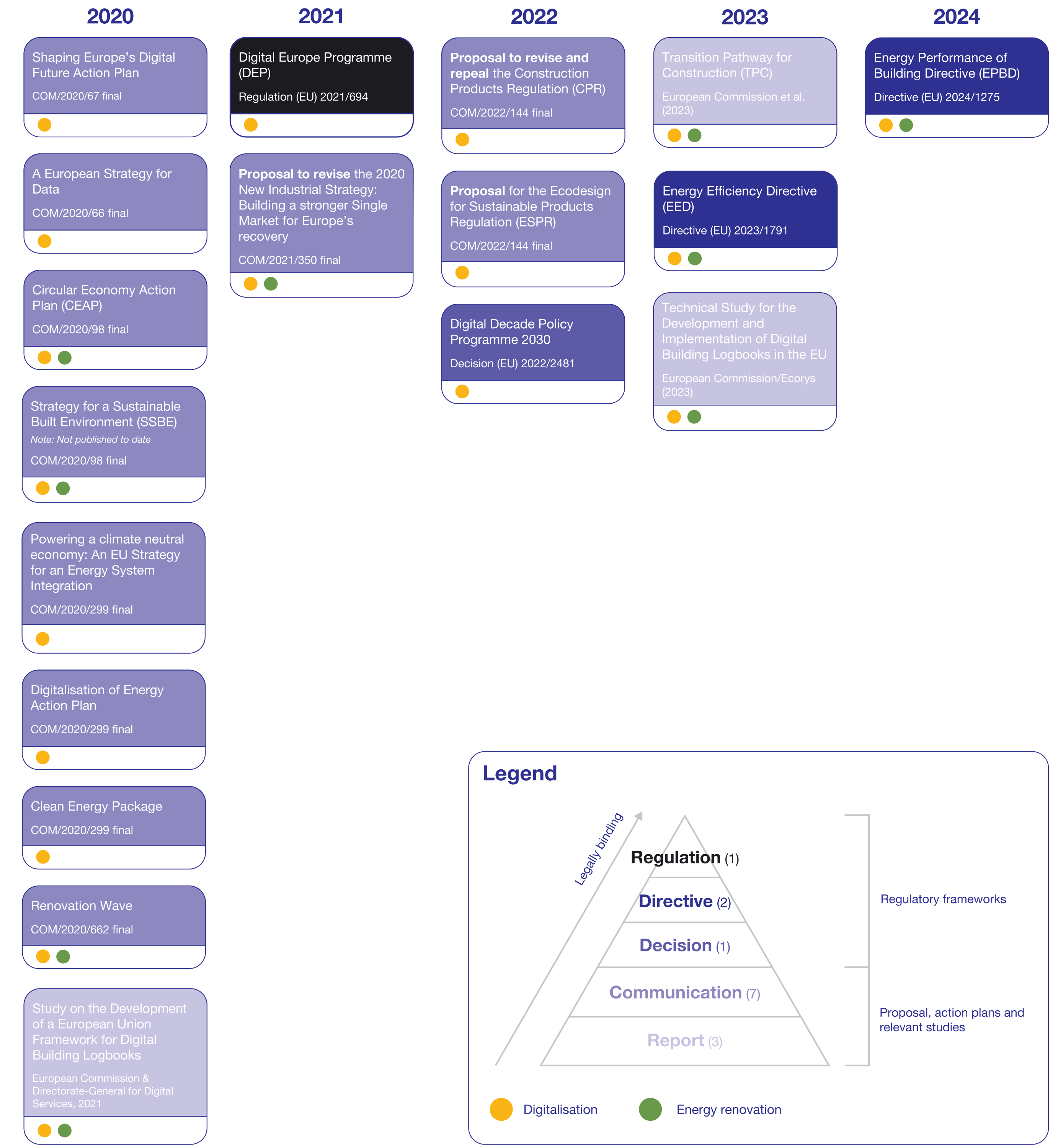

Fig. 2. A timeline of EU policy documents on digitalisation and/or energy renovation (Own illustration).

owners 'locking-out' future renovation recommendations due to the current lack of foresight [47]. To ensure the synergy between both instruments, the EPBD elaborates that the BRP should be issued jointly with the EPC in Member States that require the BRP, and the BRP shall substitute the EPC on the recommendations.

To ensure that the BRP is implemented at the ideal scale, relevant policies are introduced at the EU level [38]. For instance, the BRP must be issued in a digital format by a certified expert following an on-site visit, in accordance with the minimum requirements in Annex VIII in the EPBD [9]. The EPBD also requires Member States to provide a digital tool with which the BRP can be prepared and updated by the relevant stakeholders, and to upload all issued BRPs to the national database for the energy performance of building as introduced in *Section 3.2.1*. Similarly, the EED calls for Member States to generate BRPs for public buildings and initiate the relevant renovation interventions to achieve the nearly zero-energy building level by 2040.

3.2.3. Smart Readiness indicators (SRI)

The SRI is a set of indicators to assess the smart capabilities of a building and its equipment to adapt their operations to the needs of the occupants, while simultaneously improve the energy efficiency and overall performance of the building [9,48]. The SRI focuses largely on two aspects: (1) the readiness to facilitate efficient operation and maintenance of a building and its equipment to improve indoor environmental quality, and (2) the flexibility to shift loads and communicate with the energy grid [38].

The Renovation Wave [2] considers the SRI as an opportunity to stimulate digitally friendly renovations as it allows for more comprehensive and integrated renovation interventions. This can contribute to eliminating barriers such as uncertainties on energy related benefits by end-users and difficulties in measuring, monetising benefits and mobilising financing. Subsequently, the European Commission indicated its plan to establish a common EU scheme that defines the SRI and provides a standardised calculation methodology [9]. Areas to be explored include the features to enhance energy savings, benchmarking and flexibility, as well as improved functionalities and capacities by means of creating more interconnected and intelligent devices. This is expected to be highly relevant as the smart readiness assessment should consider the possible existence of all digital technologies available in the building [49], such as a Digital Twin of the building (see further in *Section 3.2.6*), smart meters, building automation and control systems, and self-regulating devices, and achieve data interoperability between them.

Similar to the BRP, while the SRI can be implemented as a standalone instrument, a good degree of complementarity exists with the EPC [50] as it presents opportunities for the EPC to integrate dynamic information [48]. The integration of the SRI methodology within EPC can thus contribute to improving the quality and reliability of the recommendations provided by the EPC. Naturally, this added value can be extended to the BRP as well.

3.2.4. Level(s)

Level(s) is a common European framework of indicators and metrics that assesses and reports on the sustainability of buildings, spanning across a wide range of themes including energy, material and water use, quality and value of buildings, health, comfort, resilience to climate change and life-cycle cost [2]. It is particularly viewed to be useful when promoting more efficient use of resources in both new and renovated buildings, and reduce their overall environmental impacts throughout their full lifecycle [38]. Correspondingly, the Circular Economy Action Plan [51] considers Level(s) as an instrument to integrate lifecycle assessment in public procurement and the EU Sustainable Finance Framework when evaluating the aptness of setting carbon reduction targets, and when assessing the potential of carbon storage.

The most emphasised Level(s) indicator in recent years is Indicator 1.2, the Lifecycle Global Warming Potential (GWP), which quantifies the GWP contributions of a building across its lifecycle [9]. For instance, the EPBD mandates the disclosure of the Lifecycle GWP in the EPC for all new buildings and the estimated value in existing building renovated to level A + . Similarly, the EED suggests that where a national calculation tool for the Lifecycle GWP does not exist, the use of available tools is possible if they meet the minimum criteria as indicated in the Level(s) common Union framework.

3.2.5. Digital building Logbook (DBL)

The idea of a DBL was first introduced in the Strategy for a Sustainable Built Environment [51] as an instrument, along with Level(s), to ensure coherence across policy areas including climate, energy and resource efficiency and digitalisation. The Renovation Wave [2] later conceptualised the DBL as a repository for all data and information on a building to facilitate information sharing between stakeholders across the construction value chain. More specifically, the DBL is envisioned to integrate all building related data from the EPC, BRP, SRI and Level(s) to ensure compatibility and integration of data throughout the renovation process. Over time, its scope has expanded to also encompass the processing of stored data, facilitating effective decision-making and streamlined information exchange within the construction sector [9].

The *Study on the Development of a European Union Framework* [38] was the first initiative to properly explore the integration of the DBL with external data sources. As an instrument for information sharing, the operations of the DBL rely on data interoperability. Data interoperability refers to the capability of systems to exchange and make use of information [52]. The DBL is consequently designed to systematically bring together any types of existing data source, as either a physical repository, a digital gateway, or both, as depicted in Fig. 3:

1. The DBL as a physical repository into which building related information and data, including technical plans, HVAC guides, inspection reports and Building Information Modelling (BIM) data (see further in *Section 3.2.6*), can be individually inputted and stored. This enables the easy retrieval of building information and data at moments of need.
2. The DBL as a digital gateway to which external data and information can be linked via a unique building ID. This not only indicates that information can be collated from various public and private sources, but also ensures that the information available in the DBL can be updated automatically when data is updated at the source. Examples can range from (real-time) building monitoring sources, building automation and control systems and Digital Twins (see further in *Section 3.2.6*), to national and regional databases as well as EU policy instruments including the EPC, BRP, SRI and Level(s).
3. Hybrid versions which are a combination of the above two approaches.

As such, the DBL can help ensure the availability and accessibility to structured, granular performance and maintenance data for a variety of purposes to a broader range of stakeholders [38], and contribute to the development of interoperable building-related datasets [39]. For instance, such a repository can be beneficial not only to keep track of aspects related to the produced and/or assessed EPC, BRP, SRI and Level (s), but also when collecting the data required for future updates, including those that concern the impact of the renovation intervention upon execution [53].

Specifically on energy renovation, the integration of the BRP and DBL is observed to be prioritised at the EU level; they are viewed to be deeply interlinked [53,54] and can be considered as a single digital tool for energy renovation [2]. This is because the leverage there is to holistically stimulate energy renovation is directly proportional to the amount of quality information available [55,56]. In consequence, the EPBD requires that, where the DBL is available, the BRP should be linked to and/or stored in it. In line with that, recent studies have also explored how the BRP can be integrated in the DBL interface as a functionality to achieve optimum use of all available data [38,49].

3.2.6. Supporting instruments as data sources

As mentioned previously, the analysis identified supporting instruments that are potentially beneficial for energy renovations. They are the Digital Product Passport (DPP), Digital Twin, Building Information Modelling and Digital Permitting.

The Digital Product Passport (DPP) tracks and provides information on the origin, durability, composition, journey, possibilities for reuse, repair and dismantling, and end-of life handling of a product [24,51]. It is envisioned to address two primary goals: (1) to stimulate the large-scale reuse of data to facilitate the collection, sharing, processing and analysing of data relevant to enabling the European Green Deal initiative [24], and (2) to mobilise the potential of digitalising product information to enable circular value creation in the EU [51]. Scaling into the building industry, the DPP can help improve standardisation and sharing of data on construction materials [38], increasing transparency along the construction supply chain whilst incentivising the reuse of

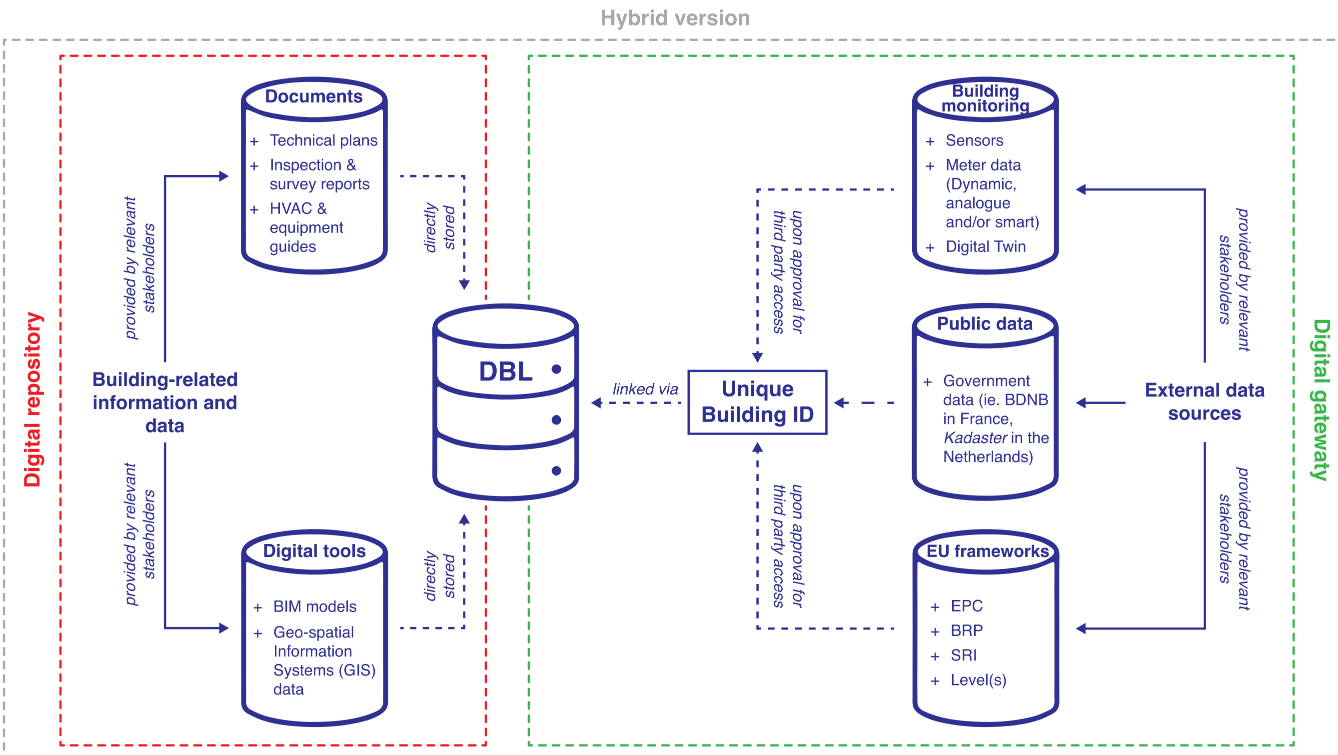

Fig. 3. The ways in which building data can be stored in and/or linked to the DBL (Own illustration).

products [57]. The DPP also contributes to the development of building-related datasets [39], and can feed the DBL with detailed information on the materials and products in a building [52]. This can be particularly useful when considering ways to extend the service life of building parts and/or assess their end-of-life possibilities during renovation processes [38].

A Digital Twin of a building provides real-time information on the performance of the building to help identify and predict potential failures in building systems, prevent severe pitfalls and optimise processes [2,58]. The Renovation Wave [2] recognises the Digital Twin as an instrument to support digitalisation in the building industry. This is because it can accelerate administrative procedures and the execution of physical works by means of efficiently recording the progression of works and the use of materials, further stimulating cost savings across the construction value chain [2]. As was also discussed in *Sections 3.2.3 and 3.2.5*, the Digital Twin provides opportunities to generate large pools of real-time data on the performance of the building, identifying the instrument as a valuable data source to support decision-making in renovation processes. Considering the positive impact this can yield to both the digital and green transition of the building industry, the use and development of the Digital Twin can be further promoted through the increased use of the SRI in building assessment schemes [48].

The foundation of a building's Digital Twin is a comprehensive Building Information Modelling (BIM), which generates and manages data on the physical characteristics of a building in its virtual form [52,59]. BIM often provides more granular information about a building and/or its environment when compared to a DBL [52], and a BIM-based Digital Twin has the extended capacity to identify energy behaviour patterns and report on cases of unusual patterns in consumption [59]. As such, the use of BIM has been increasingly widespread by construction companies in recent years [39] for its benefits in improving transparency as well as reducing costs and resources [2]. In line with that, the Renovation Wave [2] recognises the opportunity for the EU to promote the use of BIM in public procurement for construction and provide a supporting methodology to conduct cost-benefit analysis in public tenders. This way, BIM can be perceived as an instrument to address the digitalisation goal of the EU for its use in achieving standardisation in both data collection and processing across industries and vertical markets [24]. Naturally, such developments in BIM can result in a valuable data source for the DBL to increase the quality of the BRP [52].

Lastly, to support a data-driven building industry and incentivise the use of instruments, the digitalisation of building permit processes is likewise necessary [39]. In response, the Renovation Wave calls for the need to develop a common EU framework for digital permitting [2]. Though not yet an established instrument, starting points include the introduction of BIM in public procurement and ensuring its compatibility with the DBL [39]. How this will specifically impact the digitalisation of energy renovation processes must be further explored.

3.3. *Digital energy renovation framework*

Section 3.2 concludes that all nine identified policy instruments can independently contribute to facilitating informed decision making on sustainable and/or smart building renovations. The section also deduces that a good degree of complementary and interdependency exists between the instruments. Building on the findings, this section maps the instruments and presents the Digital Energy Renovation Framework. The framework, as illustrated in Fig. 4, provides an infrastructure of the (inter)relationships between all instruments studied, and illustrates how their synthesis can improve the quality of energy renovation processes. The framework proves that a holistic approach to developing the instruments is fundamental to ensure that the efforts towards achieving the digital and green transition of the EU can complement each other and yield better results.

3.3.1. *Priority instruments for energy renovation*

In the context of digitalising energy renovation processes, the framework suggests that two instruments can be prioritised; an accurate BRP that is supported by a data rich DBL, achieved through the integration of the identified instruments. The analysis made clear that an

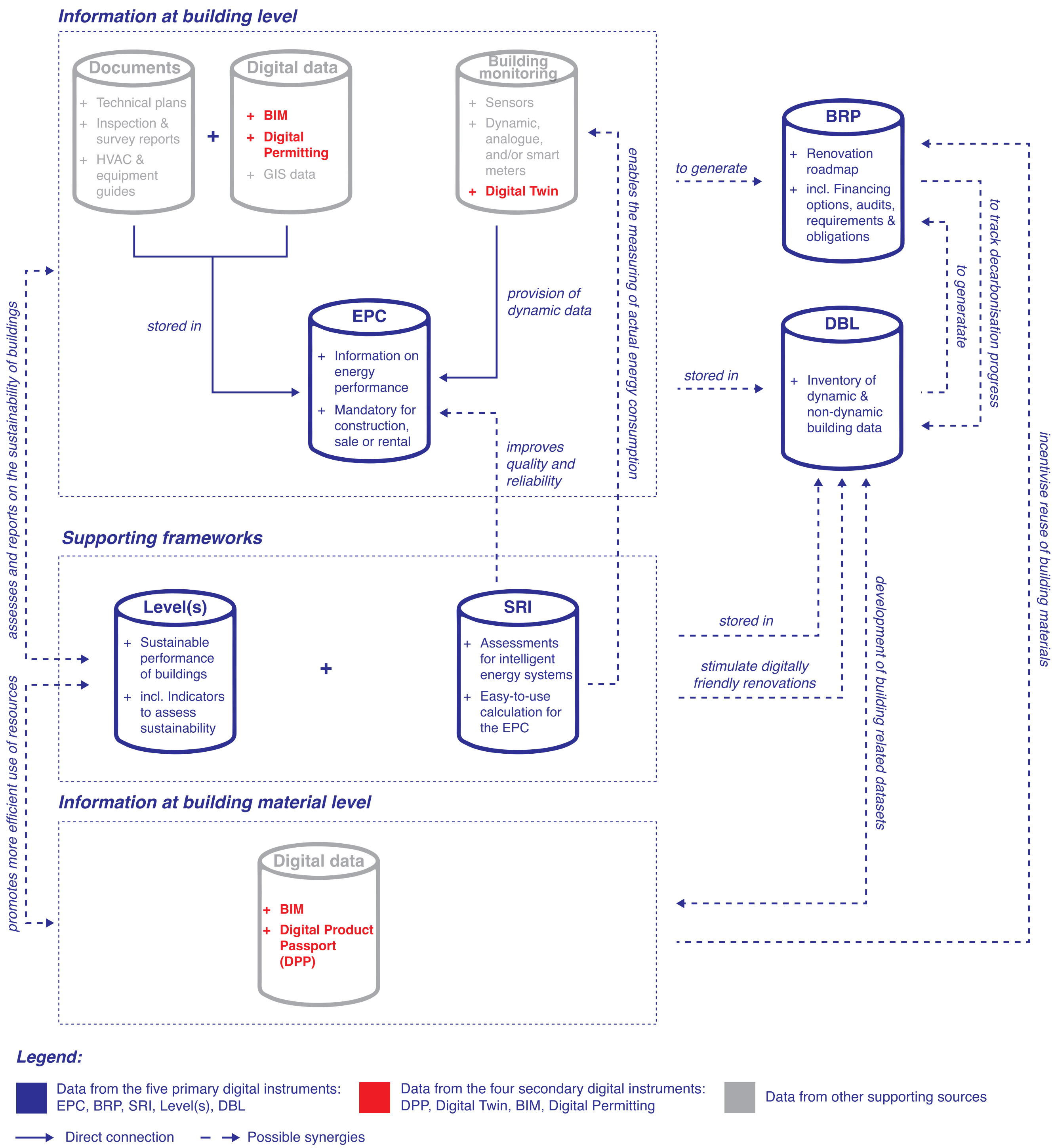

Fig. 4. The proposed Digital Energy Renovation Framework (Own illustration).

immense volume of quality data is required for the BRP to design efficient and effective renovation processes. Nevertheless, the EU considers that the value of data lies in its use and innovative reuse, and the challenges that surround the reusability of data is largely two-part: (1) the differences in data holders and target users between instruments, and (2) the disparities in the nature of data involved [24]. There is thus a strong need to implement standardised formats and protocols for gathering and processing data from different sources to achieve coherence and interoperability across the building industry. Here, the DBL can be deduced as a viable solution. This is because the function of the common repository is to strategically structure and organise all available data and information on a building, which can be done with the presence of homogeneity or consensus on the data formats a DBL can support or use to represent the stored data [50,52,60]. Such use of the instrument is of increasing significance with the development of technologies, including the Digital Twin, which will contribute to the generation and collection of an even larger amount of heterogeneous data. With all data present and processed in the DBL, it can increase opportunities for data exchange between a greater number of stakeholders across the renovation value chain, making way for enhanced cross-sector and cross-border collaborations [26].

As an example, data from the identified instruments can be integrated in the DBL to allow the BRP to recommend renovation interventions that are more effective based on risk assessments and mitigations of increased accuracy [59], and more tailored with the relevant financial and legal support provided [49]. In addition, these data can also remain available and accessible in the DBL to support a wider variety of functionalities that can further support building decarbonisation, including the monitoring and estimation of environmental impacts of the building over its lifetime [38].

3.3.2. Long-term goals for the BRP and DBL

With the adoption of the EPBD in 2024, the long-term goals for the BRP and DBL have likewise been established. By December 2026, Member States are required to establish a national building renovation plan which details, among others, a roadmap, with the intermediate 2030 and 2040 targets, to decarbonise the existing stock by 2050, and an overview of the supporting strategies, including policies and financial measures [9]. To generate this plan, data and information on the national building stock is needed. Correspondingly, Member States are also required to also establish a national database for the energy performance of buildings (see also *Section 3.2*), from which data related to the EPC, BRP, SRI, building inspections, as well as the calculated and/or metered energy consumption of buildings can be retrieved. Much of these data overlap with those collected by DBL (see Fig. 4), which is why the integration and interoperability between the DBL and the database is stressed. Once the national roadmap is available, the BRP can align its recommendations to ensure that the national targets are reflected in its recommendations as well. Fig. 5 provides an illustration on the relationship between the BRP, DBL and the long-term national obligations of Member States.

3.3.3. Identification of new barriers in recent developments

From analysing recent developments in the relevant EU-funded projects (see Appendix A), three barriers to digitalising energy renovation processes are identified. The first barrier concerns the availability and quality of data at its source, predominantly the EPC [43,50]. The analysis revealed that many of the existing BRP schemes developed in line with the projects studied are highly dependent on the EPC. However, it was also identified that the implementation and maturity levels of the EPC vary significantly between Member States in terms of scope and the information available [40]. For instance, a study conducted by the iBRoad2EPC project identified that while the EPC recommendations are based on standardised measures in Bulgaria, Spain and Romania, the recommendations in Spain, Greece, Poland and Portugal are highly dependent on the perspectives of the EPC assessors [46]. In addition, the study further revealed that, in all cases, there is no evidence suggesting that the recommendations provided by the EPC schemes are aligned with, or driven by the long-term targets outlined in the national building renovation plans of the Member States [46]. The degree of misalignment between the data schemes and the national renovation goals must thus be carefully studied to ensure that all efforts are directed to enabling a larger uptake of renovation initiatives across the EU.

Another barrier concerns the technical challenges associated with the integration of multiple external data sources. It was identified in the BEreel! project that the integration of an increased number of datasets often results in added challenges to achieve data interoperability [60]. As was earlier discussed in *Section 1.3*, a lot of heterogeneous data sources data is generated by various stakeholders throughout the building lifecycle to address a variety of goals, purposes and users [14–16]. Naturally, this may lead to differences in the data language, collection and processing methods, as well as the degree of accuracy between datasets and data sources. Such a lack of data standardisation [18] builds on the complexities for instruments such as the DBL and BRP to provide an interoperable interface that accommodates as many available datasets as possible. Consequently, this calls for the need to enforce the standardisation between data protocols and frameworks not just across the building renovation value chain, but across the building industry, to better enable the available instruments.

The third barrier concerns the high costs to develop and implement the instruments [41,43,60]. According to a study conducted by the EPBD.wise project, BRPs can differ in the level of detail they provide [41]. For instance, some BRP schemes may offer somewhat detailed recommendations in an 'ideal' sequence, while others may include

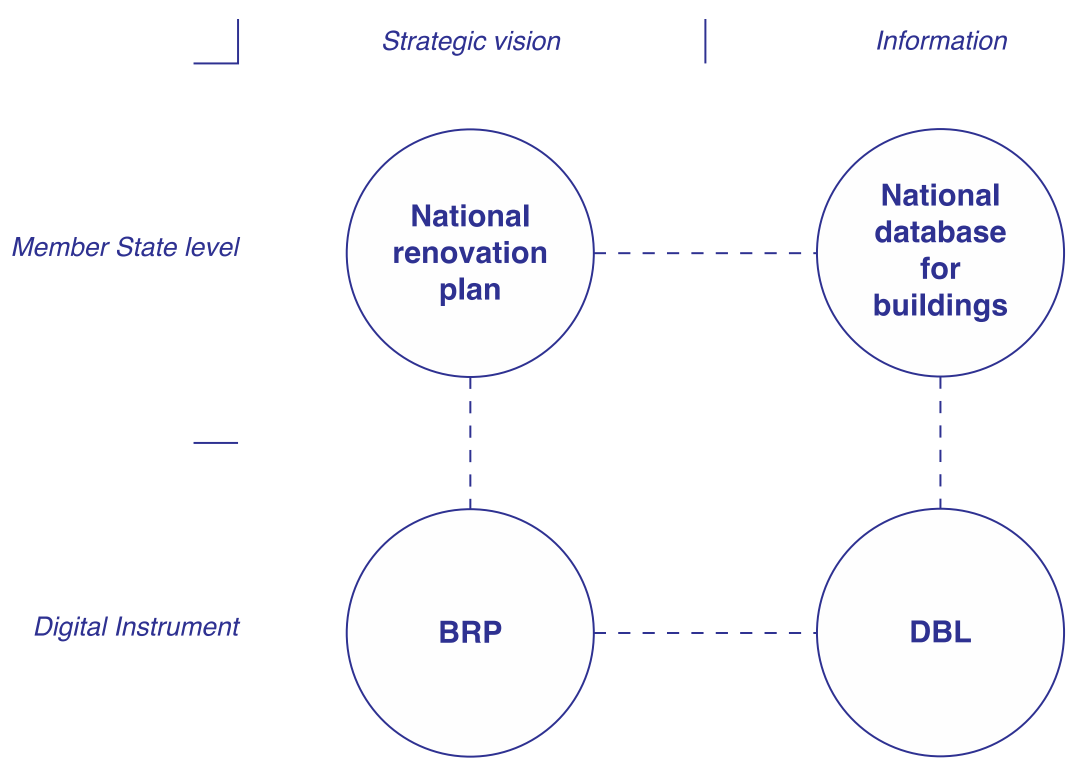

Fig. 5. Long-term goals for the BRP and the DBL in accordance with the EPBD (Own illustration).

specific requirements for implementing measures, such as guidelines for window and wall connections. The difference in the level of detail affects not only the successful execution of the recommended renovation measures, but also the cost of developing and implementing the BRP [41]. Furthermore, the transition from the proposed roadmap to the actual renovation plan —which serves as the basis for tendering and commissioning the renovation work— can likewise lead to added costs [41].

Another key aspect of consideration on the barrier of high costs is that the efforts to digitalise the energy renovation process must simultaneously promote social inclusivity [27]. For instance, Regulation 2021/694 [26] requires that cross-sector and/or cross-border data interoperability is achieved and promoted through ways that are most effective and most responsive to end-users. Similarly, studies conducted by the ALDREN, X-tendo and ePANACEA projects recognise user-friendliness as an important driver for the uptake of new instruments and their features [44,48–50]. However, the BEreel! project have identified vulnerable groups such as older citizens have been observed to perceive instruments as high thresholds [43]. This necessitates the collaboration between a larger number of stakeholders to map solutions that can further eliminate potential legal and administrative barriers for the end-users [40], suggesting an increase in costs. These combined imply the need to explore ways to finance and/or incentivise the development of instruments [47], so that opportunities for more innovative, user-friendly solutions can be maximised.

4. Discussion

4.1. Policy achievements

The findings of this article suggest that the development of policies with regards to the digitalisation of energy renovation processes in the EU have yielded positive contributions, specifically in the efforts to achieve data standardisation, interoperability and reusability. This subsection outlines the four main achievements: (1) the establishment of a 'top-down' approach to the use of building data, (2) expanded scope and more ambitious target at the EU level, (3) targeted improvements of the policy instruments, and (4) expanded scale for decision making at urban level.

4.1.1. Establishment of a 'top-down' approach to the use of building data

The increasing role of policies in both the digital and green transition of the EU can be observed. Earlier policy documents identified existing (global) barriers to the digital transition of the EU and recognised the need to address them (see Fig. 2). Sector-specific explorations were subsequently conducted to understand how the identified barriers particularly correlate with those of the green transition of the building industry. These steps combined have led to the gradual concretisation of policy frameworks around the use of data in facilitating and promoting energy renovation in the EU, including improved strategies for data standardisation, interoperability and reusability. Among those frameworks, several have been established to be legally binding in the form of *Regulations*, *Directives* and *Decisions*, upon which Member States are required to take the necessary actions at national and/or regional levels [34–36]. While most of these developments take time to be properly implemented, such a top-down approach can be expected to have increased the urgency for Member States to take the necessary actions towards achieving the 2050 climate goals.

4.1.2. Expanded scope and more ambitious target at the EU level

At the EU level, the efforts towards the digital and green transition are observed to have expanded in scope to address more ambitious targets. Clearly, the growing environmental concerns have led to stronger demands for a stable environment for decision making, one of which is the digitalisation of the building industry. The European Green Deal initiative [32] reflects this need, and every policy framework and action plan on energy renovation proposed since has been explicitly embedding digitalisation (see Figs. 1 and 2). This has led to the refining of the existing EPC and BIM schemes, and the introduction of new policy instruments, namely the BRP, SRI, Level(s), DBL, DPP, Digital Twin and Digital Permitting.

In line with the goal to achieve data reusability [24], the scope of the supporting policy frameworks has likewise evolved from addressing individual instruments to the integration of many (see Fig. 4). Predominantly, the widespread use of the DBL has been identified as a key driver that can assist the implementation of standardised formats and protocols to achieve coherence when processing data from different sources. This role of the DBL is of high significance as an increased availability of quality data is deduced to be a prerequisite for informed decision making in sustainable and smart building renovations. To further ensure harmony across all identified instruments, future frameworks should prioritise to eliminate data fragmentation and support both cross-sector and cross-border collaboration in data management [26].

4.1.3. Targeted improvements of policy instruments

Parallel to the increasingly ambitious goals at the EU level, the frameworks for the individual instruments identified in this paper have correspondingly evolved through diversified and detailed revisions. For instance, the analysis deduced that the development of digital technologies for building systems, such as the Digital Twin, smart meters, building automation and control systems, and self-regulating devices, will lead to the collection of vast amounts of dynamic data that can be integrated in the EPC and/or BRP to improve the quality and reliability of their recommendations for renovation interventions [48]. Simultaneously, this creates an opportunity for the SRI to provide a standardised calculation methodology for the EPC [9]. Ensuring that these targeted developments are carried out bilaterally is thus fundamental to achieve data standardisation and interoperability across the industry.

4.1.4. Expanded scale for decision-making at urban level

In line with the development of the individual instruments and their corresponding policy frameworks, the establishment of the national database for the energy performance of buildings in Member States (see *Section 3.3.2*) can help expand the possibilities of data driven decision-making processes to the urban scale. The database is set to store data on the national building stock, including the EPC, BRP, SRI, building inspections, as well as the calculated and/or metered energy consumption of buildings, for Member States to record and assess the energy performance of buildings at national level [9]. The information that can be drawn from the database can be used by local stakeholders such as policymakers to set more practical goals and strategies [50,59].

4.2. Policy challenges and implications

Despite the continuous efforts to improve the feasibility of digitalising energy renovation processes at the EU level, several challenges remain to be addressed. This subsection outlines three main challenges and elaborates on the corresponding policy implications: (1) implementation in Member States, (2) underlying (regional) discrepancies in the data quality, and (3) high costs for development and implementation.

4.2.1. Implementation in Member States

While a *Regulation*, *Directive* and *Decision* are all legally binding and form part of the secondary law of the EU, it is important to note that their influence over the Member States is not guaranteed in their entirety. Unlike a *Regulation* which is directly applicable in and can be invoked before national courts of all Member States [34], a *Directive* must be transposed into national and/or regional laws, often within two years of adoption, for it to take effect in Member States [35]. Similarly, a *Decision* does not have to be of general application; it can be directed to a specific addressee, implying that while it may be adopted at the EU level, it can either be adopted as a legislative or a non-legislative act at the Member State level [36].

These differences are particularly important for this paper as the primary policy instruments identified —the EPC, BRP, SRI, Level(s) and DBL— are enabled by the EPBD and EED, both of which are *Directives*. This means that the time taken to transpose the frameworks of the individual instruments into national and/or regional schemes and, at the same time, meet the common EU standards, depend highly on the (digital) readiness of the Member States to implement them. Here, factors of influence identified in this article include the availability of quality digital data and databases (see further in *Section 4.2.2*) and the financial support to develop the instruments (see further in *Section 4.2.3*). In response, more efforts must be made at the EU level to assist Member States in the development of the prerequisite conditions, such as the national database for energy performance of buildings [9], for the holistic implementation of all proposed instruments.

4.2.2. Underlying (regional) discrepancies in data quality

This paper identifies the availability and quality of digital data and databases as influencing factors that can hinder the policy instruments from achieving a common EU standard. An example discussed thereof is the EPC. The EPC widely considered as the primary source for information on the performance of buildings [38] and many of the existing BRP schemes are highly dependent on the information it provides [40,43,53]. While various data collection systems have already been established in most Member States [38], the question of whether the quality of data meets the Member State and/or EU standards remains unresolved [40]. Considering that the EPC is the longest existing and most established among all instruments studied in this paper, similar discrepancies in the quality of data provided by the other instruments can likewise be expected for the near future. Hence, there is a need to enforce more stringent minimum requirements in the protocols and frameworks for all proposed instruments to ensure that the overall quality of data is met within and between Member States.

4.2.3. High costs for development and implementation

Another barrier to the development and implementation of the instruments is the high costs involved [43,60]. For instance, a lot of resources are required to create an accurate BRP and ensure its effective implementation, including the integration of data from the instruments identified in this paper (see Fig. 4), the collaboration of stakeholders along the building renovation value chain [40,55,59] and aspects that concern the user experience of the tool [43,44,48–50,60]. It is thus crucial that future policies embody ways to finance and/or incentivise the development of the instruments as an essential aspect, also considering that they are not well addressed in the current policy frameworks. As a starting point, this paper suggests that the assessment of these costs is included in the national renovation building plan [9], as it can also contribute to marking the digitalisation of energy renovation processes as a national agenda in Member States. As a mean to further drive Member States to take action, EU policies can simultaneously explore opportunities to propose a framework for action, with focus placed on the lowest performing buildings as priority subjects.

5. Conclusion

This paper critically reviews the development of EU policies towards digitalising energy renovation processes since the launch of the European Green Deal [32] initiative in 2019. From analysing 31 policy documents, the following key conclusion can be made: the digitalisation of the energy renovation processes in the EU is already ongoing. In its efforts, this paper identified nine policy instruments that have shown to contribute to a wider, more robust use of building data to support and enhance the quality of energy renovation processes. They are the Energy Performance Certificate (EPC), Building Renovation Passport (BRP), Smart Readiness Indicators (SRI), Level(s), Digital Building Logbook (DBL), Digital Product Passport (DPP), Digital Twin, Building Information Modelling (BIM) and Digital Permitting.

The paper also presents the Digital Energy Renovation Framework, which synthesises the (inter)relationships between the identified policy instruments with respect to facilitating energy renovation processes. The framework proves that while all nine instruments can operate as standalone instruments for informed decision-making on sustainable and/or smart building renovations, a good degree of complementarity exists between them. The impact on the renovation process and the intervention itself can thus be maximised when they are used together, primarily with an accurate BRP that is supported by a data rich DBL, achieved through the integration of the identified instruments. For this, achieving coherence in and interoperability of data across the building renovation value chain is fundamental, for which the standardisation of formats and protocols for gathering and processing data between the instruments is key.

Although EU policies have seen vast improvements and achievements, several challenges must still be addressed: (1) implementation in Member States, (2) underlying (regional) discrepancies in the data quality, and (3) high costs for development and implementation. In response, this paper proposes the following corresponding policy implications: (1) assisting Member States in the development of the prerequisite conditions including the establishment of the national database for energy performance of buildings, (2) enforcing more stringent minimum requirements in the protocols and frameworks for all proposed instruments, and (3) embodying ways to finance and/or incentivise the development of the instruments as an essential aspect in future policies.

5.1. Scientific contribution

While digitalisation has been considered as the fundamental enabler of circular economy [17,21,22], its relevance to energy transition is not yet widely addressed in literature. A plausible reason here could be that circular economy is a largely accepted concept from all relevant industries including manufacturing, which considers data, automation and digitalisation as most important, triggering large-scale research as a result. This paper can therefore be seen as a unique initiative to expand research towards digitalising energy transition in the built environment, providing a starting point with the EU policy perspective.

For instance, in practice, this paper establishes the agenda of the EU which can serve as a comprehensive basis for Member States to design and optimise their national and/or regional schemes. The discourses that result from this transposition phase can, in turn, be brought back to the EU level for necessary revisions. Similarly, this paper was also able to identify directions for future development in research through challenging the underlying assumptions about the integrated use of the available instruments. Not only is there an imbalance in research between the available instruments, but it is also important to note that innovations in digital technologies are often fast paced. Therefore, there is a need to regularly and systematically evaluate the available instruments in line with the digital and green transition goals of the EU. To that, the proposed Digital Energy Renovation Framework can help identify areas of attention to ensure their holistic development.

5.2. Research limitations

Additional research on the impact of EU policies in Member States must be conducted to further understand the extent to which the policies have an impact on decision-making at various scales. In particular, the barriers to enable the various instruments in practice, including the underlying (regional) discrepancies in data quality and the corresponding data needs, as well as their economic feasibilities must be studied. This involves the critical analyses of how the instruments are positioned in different Member States and the availability of the necessary data and resources, as well as a comparative review of the resulting national frameworks. Similarly, further work is likewise required to assess the measurable impact of the instruments on energy renovation. This is particularly crucial when identifying the data requirements for the BRP and DBL to be able to propose more accurate and effective energy renovation strategies. From analysing the selected EU-funded projects (see Appendix A), it was deduced that there are various ways in which the BRP and DBL are being developed and implemented to address different markets, purposes and (national) goals. There is thus a need to study the similarities and differences between the existing examples to expand knowledge on how building data can be used (and reused) in the context of energy renovation. Such efforts can provide the foundation for a common, digitally enabled framework for energy transition at both Member State and EU levels.

CRediT authorship contribution statement

Sun-Ah Hwang: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sultan Çetin:** Writing – review & editing, Writing – original draft, Validation, Supervision, Methodology, Conceptualization. **Henk Visscher:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Ad Straub:** Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

Table 2
Overview of the EU-funded projects selected for practice review in order of project commencement.

Project acronym	Project name	Duration	Goal		Project deliverable reviewed
iBRoad	Individual Building Renovation Roadmaps	Jun 2017 –Dec 2020 (Completed)	A consumer-tailored project aimed to demonstrate the concept of an individual building renovation roadmap tool that generates a step-by-step plan with customised recommendations for each building.	HORIZON 2020 research and innovation programme	[40,42,47,53,54]
ALDREN	ALliance for Deep RENovation in buildings (ALDREN) Implementing the European Common Voluntary Certification Scheme, as back-bone along the whole deep renovation process	Nov 2017 – Sept 2020 (Completed)	Targets and supports investments in deep renovation to achieve higher renovation rates and better renovation quality. The project demonstrated (1) four standalone modules to assess energy performance, indoor environmental quality and the financial value of buildings and (2) the implementation of two reporting tools, namely an EU voluntary certificate and a BRP.	HORIZON 2020 research and innovation programme	[44]
BEreel!	Belgium Renovates for Energy Efficient Living!	Jan 2018 – Dec 2024	Adopts a multi-structural approach to accelerate the renovation rate of the residential building stock in Belgium, one of which is the development of a Flemish BRP, the *Woningpas*.	LIFE programme	[43,45,55,60]
X-tendo	Extending the energy performance assessment and certification schemes via a modular approach	Sept 2019 – Aug 2022 (Completed)	To explore additional features that can be attached to the existing EPC scheme to inspire the next generation of the instrument.	HORIZON 2020 research and innovation programme	[50]
ePANACEA	Smart European Energy Performance AssessmeNt And CErtificAtion	Jun 2020 – Oct 2023 (Completed)	To develop the 'Smart Energy Performance Assessment Platform' which encompasses a holistic methodology for the energy performance assessment and certification of buildings.	HORIZON 2020 research and innovation programme	[48,49]
D^2EPC	Dynamic Digital Energy Performance Certificates	Sep 2020 – Aug 2023 (Completed)	To develop a next-generation EPC model that is anchored on the smart-readiness level of buildings and the corresponding data collection infrastructure and management systems.	HORIZON 2020 research and innovation programme	[59]
iBRoad2EPC	Integrating Building Renovation Passports into Energy Performance Certification schemes for a decarbonised building stock	Sep 2021 – Aug 2024 (Completed)	To explore energy performance assessment schemes and certification practices with the aim to promote and demonstrate the integration of BRP elements into EPC schemes.	HORIZON 2020 research and innovation programme	[46]
Renocally	Effective implementation of the EPBD in line with short-term and long-term policy requirements	Feb 2023 – Jan 2025	To enhance the competences of municipalities in three EU Member States to reach the Fit-for-55 compliance and climate targets.	European Climate Initiative (EUKI)	[41]
EPBD.wise	Municipal Renovation Action Plans	Oct 2023 – June 2026	To provide direct support to local authorities in six EU Member States to implement the EPBD.	LIFE programme	[56]

Data availability

No data was used for the research described in the article.

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