iBRoad2EPC

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

EPCs – Energy Performance Certificates & LTRSs – Long-Term Renovation Strategies

Summary analysis of Energy Performance Certificates' alignment with national Long-Term Renovation Strategies

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EXECUTIVE SUMMARY

The objective of this report is to understand better the relevance and link of long-term renovation strategies in relation to recommendations being provided in Energy Performance Certificates (EPCs) and Building Renovation Passports (BRPs), to guide the development of iBRoad2EPC. The focus of this analysis is therefore, mainly on the iBRoad2EPC pilot countries BG, ES, GR, PL, PT, and RO, while some results and conclusions are also applicable beyond these.

For this purpose, first, an analysis of the Long-Term Renovation Strategies (LTRS) of selected EU Member States (MS) has been conducted, and information was collected from iBRoad2EPC countries regarding the practice of providing recommendations in EPCs and the role and link of EPCs and BRPs in the long-term renovation strategies. Then, an analysis of selected building stock models used for long-term scenario projections was performed to develop a concept of how results from building stock models might be used to ensure that recommendations provided in EPCs and BRPs can be better aligned with long-term climate and energy policy targets.

The following insights were derived regarding the current state of LTRS and their link with the context of recommendations provided in EPCs (and potentially in the future also in BRPs): (1) Overall, LTRS do not include clear roadmaps towards decarbonisation; (2) currently, EPCs are mentioned in the LTRS mainly as a potential source of information; BRPs are partly mentioned as a strategy for achieving energy and carbon savings in the building sector; (3) recommendations in EPCs in some MS are based on standardised measures, i.e., building assessors choose from a predefined list of measures; (4) recommendations in EPCs (and BRPs, as far as they are already under preparation or being mentioned in LTRS) are not linked to long-term climate and energy policy targets.

The results and discussions in this report might be considered in the following steps of iBRoad2EPC in one or several of the following options: (1) provide guidelines and related training to the EPC assessors in terms of recommendations which are in line with long-term energy policy targets described in LTRS; (2) provide recommendations to the EPBD recast and/or national implementation of the EPBD towards the use of LTRS and long-term climate and policy targets for the framing of consistent recommendations provided in EPCs and BRPs; (3) foresee the uptake of results from building stock models in the framing of recommendations in EPCs and BRPs through a corresponding interface in the iBRoad2EPC tool; (4) contribute to a clear and unambiguous use of the terms BRPs, logbooks or one-stop shops.

LIST OF ABBREVIATIONS

BPIE	Buildings Performance Institute Europe
BRP	Building Renovation Passport
CA EPBD	Concerted Action EPBD
CHP	Combined heat and power system
DHW	Domestic hot water
ECCABS	Energy, Carbon, and Cost Assessment for Building Stocks
ECS	Energy Certification of Buildings System
EEM	Energy Efficiency Mortgage
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
ESCO	Energy Service Company
ESM	Energy-Saving Measures
EU EED	European Energy Efficiency Directive
EU MS	EU Member State
GHG	Greenhouse gas
IAM	Integrated Assessment Model
IFI	International Financial Institution
INECP	Integrated National Energy and Climate Plan
JRC	Joint Research Centre
LTRS	Long-Term Renovation Strategy
MEPS	Minimum Energy Performance Standards
NECP	National Energy and Climate Plan
NPV	Net Present Value
NZEB	Nearly Zero-Energy Building
PEC	Primary Energy Consumption
PV	Photovoltaic

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INTRODUCTION

The EU targets for decarbonising the building stock are ambitious: they do not only aim to reach highly energy efficient buildings but also to achieve climate neutrality by 2050. Therefore, EU Member States (MS) have defined their strategies to accelerate investments in the renovation of residential and non-residential buildings. The national Long-Term Renovation Strategies (LTRS) also provided relevant input to the "European Green Deal[i]", more specifically to the part related to the "Renovation Wave[ii]".

Energy Performance Certificates (EPCs) and Building Renovation Passports (BRPs) are important instruments to support EU buildings' decarbonisation. They are playing an increasingly important role in reducing the gap between policy strategies and targets on the one hand, with building renovation practices on the other. The recommendations in the current EPC schemes are the most important and direct feature of EPCs that connects the current building state with future improvements. However, they currently do not trigger renovation and do not provide information about which energy efficiency and decarbonisation measures should be performed to ensure that improvement measures of individual buildings are in line with long-term climate and energy policy targets. To fill this gap, the iBRoad2EPC project aims to integrate BRP elements into existing EPC schemes.

The objective of this report is to understand better the relevance and link of LTRS in relation to recommendations being provided in EPCs and BRPs, to guide the development of iBRoad2EPC. We expect that by introducing minimum energy performance standards (MEPS) as proposed for the next recast of the EBPD, this could gain even more relevance. The focus of this analysis is therefore, mainly on the iBRoad2EPC pilot countries BG, ES, GR, PL, PT, and RO, while some results and conclusions are also applicable beyond these.

For this purpose, first, an analysis of the LTRS of selected EU MS has been conducted, and information was collected from iBRoad2EPC countries regarding the practice of providing recommendations in EPCs and the role and link of EPCs and BRPs in the LTRS. Then, an analysis of selected building stock models used for long-term scenario projections was performed to develop a concept of how results from building stock models might be used to ensure that recommendations provided in EPCs and BRPs can be better aligned with long-term climate and energy policy targets. This can also be replicable and further expanded in further research, as discussed in chapter 0.

Concerning the structure of this report, chapter 0 describes the status of LTRS in the iBRoad2EPC pilot countries and also provides an overview of LTRS in other countries. Subsequently, chapter 0 documents and discusses the status of recommendations in EPCs and the role of EPCs and BRPs in LTRS. Chapter 4 outlines a possible concept on how to use building stock models to ensure EPC and BRP recommendations consistent with long-term targets. The outlook includes a summary to feed further development steps in the project.

The European Commission's proposal for the Energy Performance of Buildings Directive (EPBD) recast from the year 2021 [1] suggests new requirements for setting up long-term strategies, among which are a mandatory template for the MS, replacing the LTRS with national building renovation plans that will include a more ambitious vision for 2050, and clear links to other planning tools [1]. Though these trends have been at the centre of the current analyses, since the national building renovation plans are not yet developed, they could not be part of this report.

CURRENT STATE OF LTRS IN THE IBROAD2EPC PILOT COUNTRIES AND BEST PRACTICES EXAMPLES

The EU MS are obliged to develop LTRS for their building stocks, according to Article 2a of the EBPD, to set out a trajectory for the decarbonisation of the sector by 2050. The strategies shall, among other elements, include an overview of the building stock and actions to stimulate cost-effective deep renovation of buildings. The LTRS should also include a roadmap to 2050, with clear and measurable milestones for 2030 and 2040[iii]. The purpose of the LTRS is to steer policies, actions, and financial instruments towards the common target of a building stock that is aligned with a net-zero economy by 2050.

The MS submitted their last iteration of the LTRS in 2020. The submitted LTRS are quite diverse in terms of information on existing building stock, existing and planned measures, as well as the 2050 roadmap. While the strategies set out clear visions and intentions, no country provides a clear roadmap for how full decarbonisation will be achieved. Two reports have analysed the LTRS and how well they align with the long-term target, as described below.

The European Commission analysed the legal compliance of 13 LTRS (AT, CY, CZ, DK, EE, FI, FR, DE, IE, LU, NL, ES, SE) [2]. The assessment concluded that all strategies were compliant with the EPBD Art. 2a provisions, whereof 11 strategies were evaluated as 'fully compliant' (including all six requirements of Art 2a-dark green) and four as partially compliant (including at least four requirements). The results of the assessment are summarised in Table 1. The building stock overview is well covered by the majority of MS, while a good overview of the current and planned measures to stimulate cost-effective and deep renovations is covered in all the strategies. However, less than half of the strategies give a clear roadmap to a decarbonised building stock by 2050. Most of the strategies have a high level of ambition, but this is not always supported by comprehensive and realistic policy scenarios [3]. Among iBRoad2EPC implementing countries, Spain was analysed in the report, and its strategy was seen as fully compliant, receiving the highest score of all.

MS	Overview of building stock- Art 2a.1a	Identification of cost-effective approach to renovation - Art.2a.1b	Policies and Actions Art. 2a.1c-f	Expected energy savings and wider benefits - Art.2a.1g	Roadmap and milestones Art.2a.2	Mobilisation of investments; Art.2a.3
Austria	3	3	3	4	4	4
BE Brussels	4	3	4	2	2	4
BE Flanders	4	3	4	4	3	4
Cyprus	4	4	3	3	3	2
Czech Republic	4	3	3	3	4	3
Denmark	3.5	4	4	4	3	4
Estonia	4	4	4	3	2	4
Finland	5	4	4	4	5	4
France	4	4	4	3	4	3
Germany	3.5	4	4	4	3	4
Luxembourg	4	4	4.5	4	3.5	4
Netherlands	3	3	3	3	3	3
Romania	3	4	3	4	4	3
Spain	4	4.5	5	5	4.5	4.5
Sweden	3	3	4	3	2	4

Table 1: Summary evaluation of Member States' compliance with Article 2a EPBD requirements - source: JRC [3]

A review by Buildings Performance Institute Europe (BPIE), analysing 14 LTRS (AT, BE Brussels capital region, BE Flanders, CY, CZ, DK, EE, FI, FR, DE, LU, NL, ES, SE), concluded that most strategies fail to provide sufficient detail to enable an evaluation of whether the supporting policies are adequate to increase the renovation rate of buildings required to meet EU climate goals. The analysis shows that many MS still do not seem to prioritise action in the building sector with the urgency that is needed. Just as the Joint Research Centre's (JRC) analysis showed, the information on the roadmap is one of the lowest-scored elements [4]. The only iBRoad2EPC implementing country included in this study was Spain, which, also in this assessment, scored the highest of all countries.

Clause	Description	Austria	Belgium-Brussels	Belgium-Flanders	Cyprus	Czech Republic	Denmark	Estonia	Finland	France	Germany	Luxembourg	Netherlands	Spain	Sweden	Average
1a	Overview of the national building stock	2	2	4	3	4	4	3	4	4	3	3	3	5	3	3.4
1b	Cost-effective approaches to renovation, including trigger points	1	2	4	3	2	4	2	3	4	3	2	3	4	2	2.8
1c	Policies and actions to stimulate cost-effective deep renovation	2	4	4	3	4	3	1	2	3	4	4	4	5	3	3.3
1d	Policies to target worst performing segments, split-incentives, market failures, alleviation of energy poverty	2	3	4	3	1	3	1	3	3	3	4	3	4	3	2.9
1e	Policies and actions to target all public buildings	3	3	4	2	2	2	1	2	3	2	3	4	4	2	2.6
1f	Smart technologies; well-connected communities; skills education	3	2	3		3	3	1	3	2	3	3	3	3	3	2.6
1g	Expected energy savings and wider benefits	2	0	2	2	2	2	2	2	2	2	2	2	5	2	2.1
2	Roadmap with measures, progress indicators, and indicative milestones	3	2	4	1	1	0	2	5	3	2	2	4	4	3	2.5
3	Mechanisms for mobilising investments	2	3	3	3	2	3	1	3	3	2	3	3	4	3	2.7
5	Consultation	2	0	1	2	0	2	2	4	3	2	2	4	3	3	2.1
6	Implementation details of latest LTRS	0	0	3	0	0	4	0	5	0	1	0	0	5	3	1.5
	Aggregate score	2.0	1.9	3.3	2.2	1.9	2.7	1.5	3.3	2.7	2.5	2.5	3.0	4.2	2.6	

0 missing 1 very superficial 2 incomplete 3 adequate 4 good 5 exemplary

Table 2: Summary evaluation of Member States' compliance with Article 2a EPBD - BPIE 2020

Another BPIE report tries to answer the question of whether the LTRS are in line with the EPBD requirements on decarbonisation and on a path towards total decarbonisation of the building stock by 2050. The analysis just covers seven EU MS (CZ, EE, FI, FR, DE, NL, ES) and one region (Flanders, BE) but clearly shows a gap between the roadmaps to set out the long-term targets. "Half of the analysed strategies (FI, FR, NL, and ES) include an objective at or above 90% greenhouse gas (GHG) emissions reduction, which is in line with the legal requirement of the EPBD article 2a requiring MS to set a long-term 2050 goal of reducing GHG emissions in the EU by 80-95% compared to 1990. However, none of the eight strategies targets 100% decarbonisation of the building stock" [4] [5].

Several LTRS provide definitions of "deep renovation" (see Table 3) [6]. However, there is no clear indication that this is also linked to commonly provided recommendations in EPCs and BRPs.

Belgium – Flanders[34]	EPC label A (100 kWh/m²/year)
Belgium – Wallonia[35]	75-100% energy consumption reduction Czechiai
Czechia[36]	EPC label A or B (<107 kWh/m²/year, expected to be reduced to 79 kWh/m²/year as of 2022)[37]
Denmark[38]	60% primary energy consumption reduction
Estonia[39]	EPC label C (<150 kWh/m²/year)[40]
France[41]	Reference to Bâtiment Basse Consommation (BBC) Effinergie Renovation Label (80 kWh/m²/year) and to a scenario of 'rénovation performante' being equal to BBC stepwise renovation
Luxembourg[42]	Reference to renovation quality with EPC A/A to B/B and average 72% energy savings
Spain[43]	Primary energy savings > 60%
Sweden[44]	Level 3 'total energy renovation' = 50% improvement of energy efficiency for residential buildings and 40% for offices

Table 3: Deep renovation definitions in selected national LTRS [6]

The following paragraphs summarise the status of LTRS in the iBRoad2EPC pilot countries in more detail based on the sources listed above as well as some specific information from partners in iBRoad2EPC pilot countries.

Spain

The Spanish LTRS is detailed and ambitious. It provides an analysis of the Spanish building stock (disaggregated according to typology, age, climatic zones, energy consumption, use, and energy label) and a list of policies and actions designed for the decarbonisation of the building sector [5]. The Spanish LTRS covers a detailed analysis of renovation options categorised by building, type, location, and other parameters. Relevant trigger points are considered, such as the timely replacement of boilers and undertaking renovation at the time of improving a building's fire or seismic safety. In Spain, due to the low energy consumption for heating, economic returns of investments in energy efficiency for heating are not considered a sufficient driver for a strong uptake of renovation measures. Thus, energy renovation needs to be combined with other objectives, such as the macroeconomic perspective of the total returns from public investment in building renovation through taxes, healthcare savings, etc., to make it more economically and socially attractive.

Spain plans to create and strengthen administrative structures necessary for the promotion and development of the renovation strategy at the national, regional, and municipal levels.

Public aid programmes will continue, and new actions are established (e.g., the opening of a network of one-stop shops) to be taken into account in the definition of new financing programmes and the reform or continuation of existing ones.

The strategy further covers a detailed analysis of the legislative, economic and physical conditions regarding the building stock and its occupants. It also identifies 1.2 million dwellings (out of 18.7 million primary residence homes) that form the priority market for renovation for the next decade (2021-2030) on which policies are focused. This target would mean a significant increase of 10 times in the renovation rate from 30,000 to 300,000 dwellings per year in 2030. Because of targeting public buildings, the Spanish Government proposes to extend the 3% renovation requirements (in European Energy Efficiency Directive (EU EED) art 5) to all public bodies, including autonomous communities and local entities. A large contribution to the projected energy savings is expected from heating in the residential sector as of 2050; the consumption expected from heating would be less than 55% of the 2020 levels [3].

The Spanish Government will promote citizen awareness of the use and potential of smart meters through the implementation of communication activities on the use of smart meters.

Overall, the strategy proposes a roadmap that addresses all aspects of the market and seeks to utilise a comprehensive and coordinated range of tools from legislative to fiscal as well as education and awareness raising, aiming to raise the renovation activity levels.

The objectives for 2050 for the residential sector are a 37% reduction (compared to 2020) of energy use and a 99.8% reduction of CO_2 emissions compared to 2020 levels, and for the non-residential sector, a 36% reduction in energy use compared to 2020. To achieve this, it is estimated that a total investment of €143 billion is required. See the detailed table in the Annex: LTRS Spain [7].

Romania

Representative buildings of the national building stock were selected following the methodological framework established at the EU level to identify and analyse cost-effective approaches to renovation. The analysis considered three renovation packages: minimum (P1 Package: meet national regulations on the energy performance of buildings, close to an EPC rating of C under the technical regulations in force), average (P2 package, deep renovation to meet future Nearly Zero-Emission Building (NZEB) requirements with minimal use of RES) and maximum (P3 Package, deep renovation or NZEB standard including all renewable options).

The ambition level of the LTRS in Romania is high. The renovation rates will gradually increase from the current 0.5% to 3.39% in 2021-2030, 3.79% in 2031-2040, and 4.33% in 2041-2050, according to the recommended scenario. This is anticipated to bring a reduction of the final consumption by 9% in 2030 (0.83 Mtoe), 24% reduction in GHG emissions (2.34Mton), 65% reduction in final consumption in 2050 (6.14Mtoe), and 80% cumulative reduction in 2021-2050. These targets are quite ambitious considering the current low pro-capita energy consumption (71.5% of the EU-28 average) and the low renovation rate (0.5%) [3] [8].

The main barriers to the transformation of the building stock in Romania are the limited information about the building stock and the lack of understanding of energy-saving potentials. Further market failures are the limited uptake of efficient and smart technologies, the lack of attractive financing products, and insufficient market development (materials, construction, etc.).

The Romanian LTRS mentions, in particular, that the public sector must take the lead to improve energy efficiency by renovating 8.25 million m^2 (26%) of public buildings by 2030.

The vision of the Romanian LTRS is to merge programmes into a single programme with various measures for each market segment aiming at financial mechanisms to support the mobilisation of investments. The greatest part of building renovations was based on EU and International Financial Institution (IFI) financing that covered a significant subsidy share and minimal co-financing. To achieve the 2030 energy efficiency target, the level of investment requires much more financing than what is currently provided by the EU and IFIs. A critical part of the Romanian LTRS is to initiate the swift transition from subsidies to other financial schemes by increasing the co-financing level and developing financing mechanisms [8].

In addition, according to the Romanian Integrated National Energy and Climate plan (INECP), the Primary Energy Consumption (PEC) target is 32.3 Mtoe by 2030 compared to 32.1 Mtoe in 2020. See the detailed table in the Annex: LTRS Romania [8].

Bulgaria

The LTRS of Bulgaria provides a detailed analysis of its building stock disaggregated per building type, year of construction, total floor area, energy efficiency consumption, and ownership.

The Bulgarian LTRS sets a vision for the renovation of the housing stock by 2050, which states:

'Renovation and decarbonisation of the housing stock in Bulgaria by 2050 to ensure high quality of life in a healthy, safe, energy-efficient, modernised, and high-tech living environment based on a set of interrelated factors, such as active consumer involvement in the energy-efficient use of energy, energy generation management and consumption in the building and professional management of housing stock' [9].

The global costs methodology is used to calculate the cost-optimal energy performance. For the strategic planning of the needed investments to renovate the national building stock of Bulgaria, comprising residential and non-residential buildings, the necessary global cost component is the initial investment cost. Criteria for cost-effectiveness involve cost-optimal levels which are considered on energy performance when the projected economic lifecycle of the building is positive. A positive result implies that the economic indicator 'net present value' of the global costs for a particular energy savings measure package is a positive number (NPV>0). Depending on the extent of renovation works carried out to achieve energy savings of more than 60% on average for all categories of buildings with energy use classes E, F, and G, different energy saving measure packages are developed, i.e., light (less than 30%), medium(between 30% and 60%), major (more than 60%) [9].

The milestone for energy savings is 2,917 GWh/year to be achieved by 2030, which corresponds to a reduction of 6.9% in the total consumption of the household and services. These savings are expected to result in a reduction equivalent to 1,307 ktCO_2 GHG emissions. The energy savings for the period 2031-2040 are 6,502 GWh/year, and for the period 2041-2050 are 7,329 GWh/year.

The Bulgarian milestones for the renovation of the residential and non-residential building stock are in line with the scenario and additional policies used in the IECP for the period 2021-2030, with the target to achieve savings in the PEC of 27.89% and the final energy consumption of 31.69%.

The Bulgarian LTRS mentions that by 2050, 60% of the residential housing stock and nearly 17% of the non-residential housing stock will be renovated. The floor area of the renovated buildings will be more than 45% of the total floor area of the entire housing stock in Bulgaria [9].

With regards to policies and measures to contribute to the implementation of energy efficiency projects in public buildings, the energy service companies (ESCO) mechanism has potential. The development of an online platform to provide technical support, information on possible funding sources, monitoring of implemented projects, etc., can boost the uptake of ESCOs.

The dissemination of information on new technological solutions and their applicability in buildings and communities will be enabled through the participation of Bulgaria in the expert working group of the EPBD under the Concerted Action project (CA EPBD). The introduction of an optional scheme to define a readiness indicator of buildings for smart management will be considered, which will be based on the EU calculation methodology taking into account national specificities.

In view of ensuring that sustainable financial investments are available to enable the implementation of the LTRS in Bulgaria, there is a priority in developing the energy efficiency obligations scheme, an instrument to mobilise private investments through energy efficiency.

See detailed information in the Annex: LTRS Bulgaria [9].

Greece

The Greek LTRS presents an extensive overview of its building stock grouped by year of construction, building typology, EPCs classification, and climatic zone.

Only a couple of policy measures are targeting public buildings, among which the 'Electra programme' aims to create a sustainable investment for energy upgrading of the buildings used by public bodies and the upgrading of the role of the energy manager in public buildings.

For the mobilisation of investments, there are a few financing programmes (e.g., 'savings at home', 'Electra', Energy Efficiency National Fund-ETEAP, etc.) for the renovation of buildings in the new programming period. These programmes will be adapting the existing financing model to let beneficiaries increase the current support levels.

The only reference to smart technologies within the Greek LTRS is within the 'savings at home' financing programme. In specific, it mentions that new 'smart' components such as RES systems, batteries, chargers for electric vehicles, and smart lighting systems will be added to strengthen the energy independence of residential buildings.

In view of achieving climate neutrality, buildings will need to achieve a reduction of the final energy consumption of 8% by 2030 compared to 2015, a reduction between 20 to 28% by 2040, and a reduction between 28 to 40% by 2050 compared to 2015, setting a clear roadmap for energy savings in buildings. For buildings and building units, the National Energy and Climate Plans (NECP) aims to achieve energy upgrading between 12-15% in the period 2021-2030 through targeted policy measures.

The Greek LTRS specifies that CO_2 emissions in buildings will be reduced by 100% by 2050 compared to 2005 under the most ambitious scenario. See detailed information in the Annex: LTRS Greece [10].

Poland

The annual savings in energy resulting from thermal modernisation in Poland may reach from 5% in 2013 to 26% in 2030. These thermal modernisation activities will result in an average saving of primary energy from 60 to 109 kWh/(m^2*year). Savings in the final energy may range from 3.8 to 6.8 Mtoe/year [11].

Poland is employing measures to encourage building renovation. The main national institutions supporting investment in the renovation of the building stock are the Bank Gospodarstwa Krajoego (e.g., the thermo-modernisation and Renovation Fund) and the National Fund for Environmental Protection and Water Management (e.g., the Clean Energy programme).

The fast and deep renovation scenario is the most ambitious and economically viable plan and involves deep thermo-modernisation of the building stock. This assumes that by 2027 all buildings with a primary energy ratio greater than 330 kWh/(m^2*year) and by 2035 buildings with a primary energy ratio greater than 230 kWh/(m^2*year) will be renovated. Consequently, this means that in 2045 the primary energy ratio of all buildings will be less than 150 kWh/(m^2*year). Based on this scenario, by 2050, 65% of the buildings will have a primary energy ratio of no more than 50 kWh/(m^2*year), and 24% will have a primary energy ratio between 50 and 90 kWh/(m^2*year). Buildings that cannot be extensively modernised (the remaining 11%) will have a primary energy ratio between 90-150 kWh/(m^2*year). The renovation rate of this scenario is 3%.

Smart technologies and buildings and communities benefiting from good connectivity are supported in Poland, and one of the National Smart Specialisations is smart and energy-efficient construction. EU and national funds are supporting projects related to smart city solutions, smart meters, and other smart building innovations. Legislative work is completed to disseminate smart metering in the electricity and heating systems.

For the period 2014-2019, the key funding area of public and EU funds were public buildings; however, in 2019, due to the introduction of the thermo-modernisation tax credit and the launch of the Clean Air Programme, there was a need to support investments for the thermo-modernisation of single-family houses. Further mobilisation of private funds should be chased in the next years.

The Polish LTRS draft mentions strategic targets for the decarbonisation of the building stock covering a complete please-out of coal for heating by 2050, phase-out of coal in the residential buildings by 2040, and phase-out of natural gas in both residential and non-residential buildings by 2050.

The strategy does not include any target dates or percentage reductions in carbon emissions, nor is there an explicit target for fully decarbonising the building sector [12]. However, it refers to performance indicators for the implementation of the LTRS. Poland sets a target value for CO_2 emissions from fossil fuel combustion in residential, commercial, and stationary sources in agriculture of equal to or less than 35 $MtCO_2$ by 2030 compared to the 2018 baseline of 52 $MtCO_2$. See detailed information in the Annex: LTRS Poland [13].

Portugal

Considering that the current renovation rate of the Portuguese building stock is very low, the LTRS presents several policies and actions aiming to change the current status quo. It further establishes a roadmap of progress indicators and improvement measures as well as indicative milestones for 2030, 2040, and 2050.

Portugal has committed to contributing to climate policy targets by targeting to reduce GHG emissions between 45-55% by 2030, between 65-75% by 2040, and between 85-90% by 2050 compared to 2005 levels [14]. For the residential sector, in specific, the emissions reductions are estimated at 97% and in the services sector at 100% for 2050, with the incorporation of renewable energy in heating and cooling to be 66% and 68% [15]. It is required to reduce PEC by 32.5% to comply with the decarbonisation objectives. The objectives of the Portuguese LTRS for the next three decades, with respect to 2018, are:

- Renovated building area of 363 680 501 m^2 by 2030, 635 637 685 m^2 by 2040, and 747 953 071 m^2 by 2050.
- Primary energy savings of 11% by 2030, 27% by 2040, and 34% by 2050.
- Reduce hours of discomfort by 26% by 2030, 34% by 2040, and 56% by 2050.

The heating energy consumption in the residential sector is expected to be reduced by 26% by 2040 and 50% by 2050, meaning that the increase in comfort does not necessarily imply an increase in the final energy consumption.

The energy consumption per m^2 in the residential buildings is expected to decrease to 20% by 2050, compared to today, by the adoption of high-performance electrical equipment such as LED for lighting [15].

To support public investment in energy efficiency and spur supplementary investment from the private sector several actions are taken, including subsidies for technical assistance covering the costs of EPCs and energy audits when they are not mandatory, credit schemes co-financed by public funds, etc.

To promote smart technologies several policies are introduced. Flexibility mechanisms that focus on technological innovation are launched, the infrastructure of buildings is adapted to accommodate smart technology, and monitoring mechanisms of buildings are implemented [14]. See detailed information in the Annex: LTRS Portugal [14].

CURRENT STATE OF EPC AND BRP RECOMMENDATIONS

European Commission's proposal for EPBD recast in 2021 sets the requirement for the MS to introduce a scheme for renovation passports by the end of 2024 that should be based on a common framework established by the EU by the end of 2023. Renovation passports should be made available to building owners to use voluntarily. The renovation passport is defined as 'a document that provides a tailored roadmap for the renovation of a specific building in several steps that will significantly improve its energy performance'. The EPBD recast further introduces important improvements to the EPC framework requiring the MS to ensure that from 2026 all EPCs have a common template, including indicators on primary energy use, share of renewable energy in energy use, and operational GHG emissions [16].

This chapter looks into the country-specific EPC schemes and aggregates information on how the BRP and EPCs are linked to LTRS of the iBRoad2EPC implementing countries. Moreover, we discuss the status of recommendations in EPCs and the link of EPCs and BRPs to LTRS in iBRoad2EPC pilot countries. Before going into the country-specific details, the following paragraphs provide a summary of the outcomes.

Regarding the overall direction of recommendations provided in EPCs, all pilot countries have the same goals: (1) to improve the thermal quality of the building envelope, (2) to improve the energy efficiency of technical building systems, i.e., heating, cooling, ventilation, domestic hot water (DHW), and lighting, (3) to increase the use of renewable energy resources, and (4) at the same time reduce the CO_2 emissions.

While there are minor differences regarding the focus on certain measures between the pilot countries, the main difference is that for some countries, the recommendations are standardised (Bulgaria, Spain, often also in Romania), while in the remaining countries, the EPC assessors are free to describe and openly formulate the recommendations for improving the building's energy performance.

There was no indication that the recommendations to be provided by assessors in EPCs (be it from a standardised list of measures or more tailor-made) are driven by and linked to long-term targets as described in the LTRS. Also, it was not possible to find a clear regulation or advice to the EPC assessors that drives them to focus on deep renovation measures or a phase-out of fossil fuel-based heating systems.

The findings align with a previous publication of the iBRoad project [17], although focusing more specifically on the role of recommendations in EPCs (with a slightly different country focus).

The following paragraphs describe the situation in each of the iBRoad2EPC pilot countries in more detail.

Spain

Spain has set the following goals in the scope of EPC recommendations:

- Improve the thermal quality of the building envelope, considering the level of architectural protection.
- Improve the energy efficiency of heating, cooling, ventilation, DHW, and lighting technology systems.
- Increase the use of renewable energy sources and reduce CO_2 emissions.

Measures to improve the thermal quality of the building envelope include insulation of the top floor ceiling or roof surface, attachment of external thermal insulation, window replacement, window sealing, insulation of the basement ceiling, minimisation of thermal bridges, and achieving optimal air tightness. Some installations and adjustments should be carried out to improve the energy efficiency of different technology systems, such as installation of heat gains control system, thermostatic valves installation, installation of the free cooling system, adjustment of heat supply system's nominal power, installation of shading systems (internal or external), installation of the mechanical ventilation for heat recovery systems, adjustment of the air volume of the ventilation system, and optimisation of daylight supply. Insulation of heating system pipelines, replacement of the heating system, checking domestic devices efficiency, and insulation of the DHW system pipelines are also some of the measures provided in the recommendations to improve energy efficiency. Finally, to increase the use of renewable energy sources and reduce CO_2 emissions, it is recommended to install a photovoltaic (PV) system, install a solar thermal system, and switch to a biomass boiler.

The above-mentioned recommendations are provided in the form of standardised recommendations. Furthermore, the recommendations should be technically feasible, include estimates of payback periods, include information on the cost-effectiveness of the proposed improvement, assess this cost-effectiveness based on expected energy savings, energy prices, and a preliminary cost forecast, and include information on the actions to be taken to implement the recommendations, which implies a correct description of the actions to be taken.

On actions taken to improve the Spanish EPCs, the Royal Decree sets the requirement to offer the buyers or users of buildings an EPC that covers objective information on the energy performance of a building and minimum performance requirements so that building or unit owners and tenants can compare and evaluate its energy performance. It further regulates the use of the energy performance label, a distinctive symbol throughout the national territory. For buildings that provide public services, this symbol must be prominently displayed.

Further additions to the Spanish decree on the EPCs include:

- The need to use official software to create the certificate;
- The law extends the types of buildings that need EPCs to all buildings with a total useful floor area of more than 250 m^2;
- The worst performing buildings will need to have a certificate every five years (instead of every ten years, as was the case until now).

To further improve the quality of the certificate, a visit to the building by a competent technician is obligatory. There is a further requirement to include improvement measures on the certificates with an estimate of the investment payback period. The improvement measures can cover estimates regarding health, comfort, and well-being. There is a further obligation for individuals and companies to display the energy rating on the sale or rental advertisement. A centralised certificate register is created at the Ministry, aiming to achieve statistical information on the energy rating status of the building stock.

All the technical matters related to the assessment of the energy performance of buildings are compiled in the *technical conditions governing the procedure for assessing energy performance* document.

Regarding BRPs, two unofficial reports have been developed in Spain for the introduction of the BRP:

- *'El reto de la rehabilitación: El Pasaporte Energético y otras propuestas para dinamizar el sector'* (The renovation challenge: The Energy Passport and other suggestions to boost the sector): Based on this report, the BRP would aim to facilitate and fund renovation activities of a residential building of a minimum age over a minimum period of 4 years. The BRP considers improvements on the thermal insulation of the façade, the roof, and the floor, as well as improvements or replacement of the heating, cooling, ventilation, and hot water systems. The BRP represents an agreement between building owners and authorities where 80% of the aid would be subsidised at the end of each phase, while the remaining 20% would be paid after the completion of the project.
- *'PAS-E, Pasaporte del edificio'* (Building Passport): This report covers the steps to be followed to facilitate the deep renovation of buildings. It consists of a roadmap of interventions to be accomplished based on the people's needs, including information on legal, financial, and operational issues [18].

Bulgaria

The recommendations are standardised and linked to the building envelope, technical building systems, and reduction of CO_2 emissions. The recommendations are not linked to deep renovations.

Measures linked to the building envelope include insulation of the top floor ceiling or roof surface, attachment of external thermal insulation, window replacement, window sealing, insulation of the basement ceiling, and minimisation of thermal bridges. The second set of recommendations related to technical building systems includes various sets of measures, such as:

- Insulation of heating system pipelines
- Installation of heat gains control system
- Adjustment of the heat supply system's nominal power
- Hydraulic adjustment
- Thermostatic valves installation
- Optimisation of operation hours
- Replacement of the heating system
- Installation of a free cooling system
- Installation of shading systems (internal or external) – the EPC software is not designed to calculate shading systems differently for summer and winter
- Checking efficiency of domestic devices
- Installation of mechanical ventilation for heat recovery systems
- Adjustment of the air volume of the ventilation system
- Insulation of the DHW system pipelines
- Storage dimensioning
- Optimisation of daylight supply

Installing a PV system, installing a solar thermal system, connecting to the district heating grid, and switching to a biomass boiler are measures to increase the use of renewable energy sources and decrease CO_2 emissions.

The building owner can read more detailed recommendations in the energy audit report, which is an obligatory part of the documentation together with the EPC.

The Bulgarian LTRS only refers to EPCs as the only official source of information regarding the energy performance of buildings.

There is a potential for linking the Energy Efficiency Mortgage (EEM) with the BRP of single-family residences. The BRP can serve as a log of energy efficiency improvements made in a building over time. It will include recommendations and advice for future energy efficiency improvements to ensure a maximum potential to be reached cost-effectively. The passport would allow the data collection on energy efficiency upgrades that can be used by financial, property valuation, and construction sectors, offering a particularly beneficial input for mortgage pricing and bond and debt securitisation. The BRP will further assist real estate valuators in understanding the 'green value' of energy improvements by granting them access to validated information [9].[iv]

Greece

In Greece, the EPC does not include a predefined list of recommendations; the energy inspector is responsible for this and advises openly. Nevertheless, the most common recommendations are related to improving the thermal quality of the building envelope, improving the energy efficiency of technical building systems, and increasing the use of renewable energy sources. For each of these recommendations, there are measures to be carried out.

Measures to improve the thermal quality of the building envelope include insulation of the top floor ceiling or roof surface, attachment of external thermal insulation, window replacement, window sealing, insulation of the basement ceiling, minimisation of thermal bridges, and achieving optimal air tightness. The following installations are recommended to improve the energy efficiency of the technical building systems: thermostatic valves, ceiling fans, shading systems (internal or external), mechanical ventilation for heat recovery systems, and DHW system pipelines. Besides installations, certain adjustments and replacements should be implemented, such as adjustment of the heat supply system's nominal power, hydraulic adjustment, replacement of the heating system, replacement of auxiliary units (pumps, circulators, valves, fans), adjustment of the air volume of the ventilation system, optimisation of daylight supply, replacement of old lamps, and insulation of heating system pipelines. To reduce CO_2 emissions and increase the use of renewable energy sources in addition to prior mentioned measures, installing combined heat and power systems (CHP) and wind turbines is recommended in Greece.

Greek EPCs are mentioned in the LTRS as a source of information about the national building stock and the energy consumption levels for each building use in the different climatic zones. The Greek LTRS, in the policies and measures to improve the energy efficiency of buildings, further mentions that one of the main measures contributing to building renovation is the regulation on the Energy Performance of Buildings (KENAK), which amongst others, sets out the format of the EPC issued for buildings and the information to be included therein. Along with the energy inspections, EPCs are a tool that provides the real estate market with quality criteria linked to the value of properties and people (owners, tenants, buyers) with measurable data on annual operating costs for heating, cooling, lighting, etc. EPCs constitute a supporting policy measure for the renovation of buildings and energy savings. Based on the NECP, after 31 December 2023, all public authorities' buildings must be classified under energy category B or higher, according to the EPC [10].

There is no reference to the BRP within the Greek LTRS.

Poland

There are no specific goals or measures outlined for building renovation recommendations in Poland, but there are certain technology recommendations. For the overall improvement of energy efficiency, it is recommended to use automatic computerised control systems for all installations. Reversible heat pumps, pulsed gas condensing boilers, cogeneration, trigeneration, polygeneration, district heating, infrared heaters, intelligent control systems for heating and cooling, new more efficient units in split systems, and the use of free-cooling, are recommended technologies to improve heating and cooling systems. For the DHW system, changing the method of hot water preparation (heat pump, solar collectors, condensing boiler with a tank) is recommended. To improve the energy efficiency of lighting systems, users should go with LED technology, systems for optimal use of daylight, and lighting that dynamically changes the colour of light and its intensity depending on the user's needs. The use of mechanical ventilation with heat recovery helps improve the ventilation system. Lastly, the energy efficiency of heat protection should be achieved with the materials and technologies that protect buildings from overheating and/or reduce heat loss.

In support of building renovation in Poland, investments should consider the perspective of phased thermal modernisation to a zero-emission standard by 2050 and gradually increase the scale of deep thermo-modernisation to about 3% over the next years. It may be further necessary to develop tools to enable investment decisions, such as an energy class system based on the energy passport of the building. It is further crucial to support EPCs for buildings and energy audits as a key element in designing thermo-modernisation [19].

To ensure that renovation is not being blocked, regulations on the energy efficiency of buildings should be reviewed and consider the introduction of tools to facilitate investment decisions, such as a system of energy classes based on the concept of the building energy passport that stores information on all thermo-modernisation activities performed and planned for several years, in a single document or electronic database[v]. It is anticipated that this will make it possible to achieve a high standard of energy efficiency and that the application of such tools could control the Polish renovation process [13].

Portugal

Portugal does not have a standardised list of recommendations. Practice is that the energy expert selects recommendations with potential measures from a predefined list based on his own best evaluation of the building situation. The recommendations are related to improving the thermal quality of the building envelope, improving the energy efficiency of technical building systems, increasing the use of renewable energy sources, and improving the implementation of the measures.

The following measures are included in the predefined list of measures for improving the thermal quality of the building envelope:

- insulation of the top floor ceiling or roof surface
- attachment of external thermal insulation
- window replacement
- window sealing
- insulation of the basement ceiling
- minimisation of thermal bridges

The measures for improving the energy efficiency of technical building systems are:

- insulation of heating system pipelines
- installation of heat gains control system
- optimisation of operation hours
- replacement of the heating system
- installation of a free cooling system
- installation of shading systems (internal or external)
- checking the domestic devices' efficiency
- installation of mechanical ventilation for heat recovery systems
- adjustment of the air volume of the ventilation system
- insulation of the DHW system pipelines
- optimisation of daylight supply

Installation of a PV system, solar thermal system, and switching to a biomass boiler are recommended measures for increasing the use of renewable energy sources and reducing CO_2 emissions. The list of measures for improving implementation of the measures includes installing rear ventilation ducts in case of internal insulation, saving construction site facility costs, replacing the windows, and checking orientation, roof inclination, shading, area, and static conditions for PV installations.

Several actions are taking place to stimulate cost-effective deep renovation of buildings:

- EPCs are updated through the introduction of a new version of the energy certificate that is aligned with initiatives such as the improvement of technical methodologies aiming to gain better data.
- There is a gradual implementation of the digital version of the energy certificates aiming to bring together information on the property's energy consumption and the decarbonisation of the building stock.
- The BRP is becoming an optional instrument complementing the energy certificate (in line with iBRoad).
- To more precisely reflect the characteristics of the building (e.g., the situation of energy poverty), the energy certificate should be adapted.
- As part of an annual performance assessment model, investigate the relevance of the impact on energy costs of prolonged excessive annual consumption in relation to the energy certificate estimate.
- Consider the addition of information related to the environmental performance of buildings (e.g., water and material efficiency) in the Energy Certification of Buildings System (ECS) [14].

Romania

The recommendations are often standardised and do not provide detailed information about the costs and benefits of the different potential renovation measures. However, in addition to the overall, high-level overview of recommendations, there is a section in the EPC providing more details on recommended measures. Those measures are insulation of the top floor ceiling or roof surface, attachment of external thermal insulation, window replacement, and basement ceiling insulation. The recommendations for different technical building systems are standardised and are the following:

- insulation of heating system pipelines
- hydraulic adjustment
- thermostatic valves installation
- replacement of the heating system
- installation of shading systems (internal or external)
- installation of mechanical ventilation with heat recovery
- adjustment of the air volume of the ventilation system
- insulation of the DHW system pipelines
- optimisation of daylight supply

The standardised measures for increasing the use of renewable energy sources and reduction of CO_2 emissions are: installing a PV system and installing a solar thermal system.

There is a frequent reference to EPCs within the Romanian LTRS. For the implementation of the LTRS in Romania, a comprehensive database comprising the building stock, EPCs, and information related to energy consumption and renovation programmes must be launched.

The target is that the drafting and collection of Romanian EPCs should be digitalised and accessible online, and energy auditors must have electronic signatures/secure access. The existing database (of the National Institute for Research and Development on Construction, Urban Planning, and Sustainable Territorial Development 'URBAN-INCERC', INSEE) could be merged with the EPC database into a single model. The model shall contain information on energy efficiency renovation, building characteristics, and fuel consumption. A national system for calculation, preparation and online submission of EPCs must be achieved. The database should support online submission, providing the option of implementing compliance checks on submission. The database shall include mandatory reporting requirements on the renovation works carried out, energy savings data for renovation, and energy consumption reduction programmes.

In the context of stimulating cost-effective deep renovation of buildings, the Romanian LTRS mentions that it should be considered whether it is appropriate to implement the BRP in the National legislation. The BRP is part of the Technical Construction Book (Chapter D: 'Documentation on building operation, maintenance, repair, behaviour monitoring in time and post-use'). The BRP may be issued electronically and include information related to each building, such as available financing options for renovations. All this information could be centralised in a digital register available to users. As the central public authority responsible for buildings, the Ministry of Public Works, Development, and Administration may centralise and integrate energy renovation passports with several national-specific IT systems in place.

Technical building regulations need to be revised to stimulate deep renovation, including updates and revisions of energy performance standards. To this end, a deadline will be set for meeting the requirements of deep renovation standards, along with staged renovation plans that can be outlined in the EPC/BRP report (Romanian LTRS).

This step could be considered as a window of opportunity to implement minimum standards for recommendations in EPCs (and future BRPs), ensuring consistency with long-term policy targets.

EPC RECOMMENDATIONS BASED ON BUILDING ENERGY SYSTEM MODELLING

The analysis in the chapters above has shown that recommendations provided in EPCs and BRPs currently are not connected to long-term renovation strategies and climate and policy targets. Thus, a method how to align them would be highly needed. In this chapter we will outline such a method based on building stock models.

Building stock energy modelling is a multi-purpose method for assessing potentials and scenarios for the uptake of building renovation measures, supporting projects at the level of individual buildings (design, control, rating, financial incentives), and building stocks (programme development, policy analysis, research). Building stock modelling can be used to deliver or model future scenarios (as those specified in the LTRS) based on the current state and assuming certain boundary conditions and algorithms affecting the future development. Building stock modelling is used to develop scenarios of future energy demand and technology mix on the level of building archetypes[vi]. These archetypes are representative exemplary building types describing a certain group of buildings with sufficiently similar characteristics, like geometry, U-values of building components, heating systems, etc. Thus, the results for the uptake of renovation measures and technologies might also be used to frame recommendations in EPCs and BRPs. For this purpose, this chapter first introduces some of these building stock models, subsequently dives further into the example of the model Invert, and finally derives conclusions on how related results could be useful in the context of recommendations made in EPCs and BRPs.

The iBRoad2EPC project does not have the resources to apply and implement full scale building stock models. Thus, we leave it to other future projects, activities and research to further explore relevant opportunities.

Building energy system modelling can be a useful instrument in order to derive target building standards – as is done in the Portuguese case. The model should allow quantification and development of future building stocks scenarios, including the achievement of a certain climate or energy policy target (as specified in the LTRS). Possible outcomes from the model are final or useful energy demand, the share of new buildings, the renovation rates and achieved energy efficiency standards, and the demolition of existing buildings. The pathways can represent climate and political targets, market penetration of technologies, renovation rates trends, etc. Furthermore, these models should apply the goals defined by national long-term strategies like the LTRS – as specified in the previous chapters for each pilot country, which can help define ambitious climate targets for individual buildings.

Exemplary Building Stock Models

In the following, a few exemplary building stock models are described in order to set the scene and characterise the range of different models in this field. Although they will not be explicitly used in the further steps of iBRoad2EPC, the intention of this overview is to give an insight about the characteristics of building stock models in order to ensure that the iBRoad2EPC concept to be developed will be applicable to a wide range of such models.

Most of the models are bottom-up, meaning that the full picture and energy demand is composed of a large number of single building archetypes, thus the final result is derived from the aggregation of a large variety of “bottom” building data.

Energy, Carbon, and Cost Assessment for Building Stocks (ECCABS) model is a bottom-up model to evaluate Energy-Saving Measures (ESM) and decarbonisation plans in building stocks [20]. The model is based on a one-dimensional building energy balance, which gives the hourly net energy demand for a number of buildings representative of the building stock. The model generates net and delivered energy results, associated CO_2 emissions, and the costs of implementing different ESM. The results are extended to the entire building stock through weighting factors. The model is developed with the

MATLAB and Simulink tools. The simulation model consists of two elements: (1) a Simulink model, which solves the energy balance for the buildings and delivers the net energy demand; and (2) a code written in MATLAB, which takes the input and output data from the Simulink model and extends the results to the building stock. The model has been applied to the Swedish residential stock represented by sample buildings so that the accuracy of the model has been validated by empirical data. In an exemplary case, the model (Mata et al., 2013) revealed that the energy usage of the Swedish residential sector can be reduced by 55%, and the associated CO_2 emissions can be reduced by 63%, with most of the ESM being cost-effective. Further, it is noted that studies are needed to investigate the model's applicability to countries other than Sweden.

The next exemplary building model is a regional energy system model, developed by Daioglou et al., 2022 [21], who used an updated version of the TIMER energy system model, which forms the energy system component of the IMAGE Integrated Assessment Model (IAM) [22]. TIMER is a recursive dynamic energy system model describing the global energy system, projecting developments in energy supply, conversion, and demand [23]. The model is conducted by exogenous projections of population, GDP, household expenditures, and urbanisation rates. For the residential sector, a bottom-up sub-model (REMG) uses the above drivers to project shifts in household size, floor space, and the final energy demand for five end-use types: cooking, lighting, space heating and cooling, water heating, and appliances. For the referenced study, five different scenarios were prepared, namely *Baseline, Baseline-InsulNew, 2°C, 2°C-InsulNew*, and *2°C-InsulAll*. For the *Baseline* scenario, a revised version of the baseline from the IMAGE 3.2 model was implemented [24]. The *2°C* scenario follows an emission price projection across all GHG emission sources, which results in a cost-effective pathway meeting an emission budget consistent with a 2°C global mean temperature increase. *2°C-InsulNew* and *2°C-InsulAll* are projected as sensitivity cases to isolate and decompose the role of insulation and technology choices. In the first sensitivity case, insulation was limited only to new buildings (*InsulNew*), and in the second, it was allowed on the entire building stock (*InsulAll*). The projections show that in a *2°C* scenario, global heating demand is expected to decrease from current levels by 27% and 66% by 2050 and 2100, respectively. However, cooling demand is expected to increase by 176% and 286%, respectively, due to increasing affluence in warmer regions. However, direct residential emissions are almost eliminated by 2100 by integrating increased envelope efficiency and advanced heating technologies synergistically. The adoption of high-efficiency heating and cooling limits the need for raised insulation and vice versa.

Bianco, Marmori, 2022 presents an analysis of the energy efficiency opportunities in the Italian residential sector. A flexible model called I-REM, applicable to other countries is developed within the scope of that study. The I-REM model has a bottom-up structure. Thus, the consumption processes are modelled, and the study considers space heating and DHW [25]. The model also estimates the different typologies of primary energy used for heating and DHW purposes. Four energy efficiency scenarios are prepared: the *Business As Usual* (BAU) as the reference scenario, the *EU Policy scenario*, the *Advanced Renovation scenario*, and *Advanced Renovation with Heat Pumps scenario*. The *EU Policy scenario* aims at achieving the 2030 EU goal in terms of energy efficiency, which corresponds to a saving of 38.4 TWh. The advanced Renovation scenario tests the possibility of achieving more ambitious targets, and a saving of 76.8 TWh is fixed for 2030. I-REM demonstrates that these ambitious targets are feasible, but more invasive measures, e.g., wall insulation, should be considered and a larger share of buildings retrofitted. Therefore, adequate energy policies can be promoted to support their achievement. To improve this performance, the *Advanced Renovation with Heat Pumps scenario* includes the deployment of heat pumps on top of the other energy efficiency measures. This allows for saving about 100 TWh in 2030 and 120 TWh in 2040. From the developed analysis, the study concluded that a full decarbonisation of the residential building sector could only be achieved if natural gas is substituted with renewable fuel.

Calise et al., 2017 analyses possible decarbonisation scenarios in Italy for the year 2050. The authors aim at providing a profound analysis of the feasibility of Italian decarbonisation targets, presenting different alternative pathways to reduce GHG emissions by at least 80% by 2050. They envisage high electrification of residential buildings and high use of renewable energy. The energy scenarios are evaluated using a software programme, EnergyPLAN, starting from a reference model developed for 2014 [26]. The results show that to decrease GHG emissions and fossil fuel consumption significantly, it is necessary to promote deeper penetration of renewable sources and their integration with other technologies (cogeneration, trigeneration, power-to-heat systems thermal storage, vehicle-to-grid operations). The analysis of the energy scenarios emerged that to achieve the deep decarbonisation goals, a drastic transition is needed. This transition is based on a shift from traditional energy systems, with electricity needs mainly covered by conventional power plants and heating demands mainly covered by individual boilers, to energy systems in which: (i) the electricity needs are covered by solar and wind power; (ii) heat is supplied from heat pumps, CHP plants, and waste-to-heat technologies. The alternative future scenarios show that district heating and district cooling cover around 50% and 40% of the total residential heating and cooling demand, respectively. These actions lead to a CO_2 emissions reduction of over 82% with respect to the 2014 level, a fuel consumption reduction of around 50%, with biomass consumption at the same level as 2014 in line with the EU action plan. In addition to the decarbonisation objectives, the alternative scenarios show a higher economic and environmental sustainability reduction of around 30% in biomass consumption. A substantial decrease in the carbon intensity of energy is required. Renewable sources and substantial electrification of heating services should progressively replace fossil fuel consumption. The success of the DD (degree days) will strongly rely on the development of solar and wind technologies; a significant contribution is also expected from biomass and district heating.

The EUCalc model consists of 15 interconnected modules that reflect the supply and demand sides of activities, materials, energy, and emissions, as well as different interfaces of the energy system with society and the environment [27]. At its core, the modules represent the energy-relevant sectors of agriculture, buildings, power/storage, transport, and manufacturing. These modules respond to the demand for products, activities, and services originated in the lifestyle module and, where relevant, are impacted by changes in climate modelled by the climate module.

The building module uses a bottom-up approach to calculate energy consumption and GHG emissions from the household and service sector. The estimations are based on historical data and projections until 2050. The main outputs of the module are the direct GHG emissions originating from households and services buildings, the energy demand in households and services buildings, the need for construction and renovation of buildings and the number of appliances required, the need for district heating infrastructures, and the total costs of the buildings [27]. The model allows the user to specify in a flexible and easy to use own scenarios.

The PRIMES model has been applied to develop “A European strategic long-term vision for a prosperous, modern, competitive, and climate neutral economy (a clean planet for all)”. It presented nine scenarios, i.e.: baseline, electrification (ELEC), hydrogen (H2), power-to-X (P2X), energy efficiency (EE), circular economy (CIRC), combination (COMBO), 1.5 °C technical (1.5TECH), and 1.5 °C sustainable lifestyle (1.5LIFE) [28]. In the building sector, the ELEC scenario increases the deployment of heat pumps, while the H2 scenario deploys hydrogen for heating. Similarly, P2X is based on the deployment of e-gas for heating. EE focuses on increased renovation rates and depth, and CIRC focuses on sustainable buildings. COMB is a combination of the most cost-efficient options from “well below 2 °C” scenarios with the targeted application, 1.5TECH is the same as COMBO but stronger, and finally, 1.5LIFE is the combination of CIRC and COMBO but stronger. While energy consumption for appliances and lighting in the scenarios are expected to increase from 2005 to 2050 by 25% to more than 40%, (and even 80% in the service sector), the energy consumption for heating and cooling, in particular in the 1.5°C scenarios reduce by more than 60% in the residential sector and by 50-60% in the service sector [28].

Most of the national LTRS also have been developed by some sort of techno-economic bottom-up building stock models as described above. Typically, the potential evolution of certain parts of the building stock is described, analysed and aggregated. Main differences are in the resolution and algorithms for deriving the future developments of the different building archetypes.

The building stock model Invert/EE-Lab is a bottom-up model simulating energy-related investment decision in buildings focusing on space heating, hot water generation, and space cooling. It is based on a highly disaggregated description of the building stocks in the different countries of the EU (+ Norway, Iceland, Switzerland and the UK), including the type of building, age, state of renovation, existing heating systems, user structure as well as regional aspects such as availability of energy infrastructure, e.g., district heating or natural gas on a sub-country level.

The derived model version Invert/Opt can calculate cost-optimal scenarios based on a combination of technology options available in different years, both for heat savings and heat supply, considering diffusion constraints.

In the scope of the project 'Renewable Space Heating under the Revised Renewable Energy Directive' (ENER-2018/494), the following scenarios were developed (all except for baseline under the assumption of full decarbonisation by 2050): baseline, hydrogen, direct-res, electrification, e-fuel, district heating, and best case.

The final energy demand in the baseline scenario reduces from more than 3100 TWh/yr (267 Mtoe/yr) in 2017 by about 40% until 2050. The different decarbonisation scenarios show higher energy savings in the range of 47%. This results from energy savings due to the retrofitting of the building envelope and shifts to more efficient heating systems. Counting delivered energy only, the reduction accounts for more than 70% in the electrification scenario. However, final energy demand in the sense of the renewable energy directive, also for counting RES-HC shares, needs to include solar, ambient, and geothermal energy as well. The highest renovation activities occur in buildings with H2 and e-fuels due to the high variable costs of these energy carriers. The model implements minimum restrictions for the supplied floor area by energy carrier in each MS. While this restriction needs to be fulfilled, the algorithm minimises the use of these energy carriers through the higher use of solar energy and building renovation. Thus, the share of final energy demand on these energy carriers is lower than the supplied heated floor area.

Possible Approaches to Derive Relevant Information from Models for Developing Recommendations in EPCs and BRPs

Figure 1 below presents an example of building stock energy demand analysis. The first picture shows the specific energy needs for heating per gross floor area (kWh/m^{2}year) for different building typologies. They are characterised by the building use and the building construction period – building stock status in the year 2012. Then, the other four graphs show the resulting specific energy needs (and their ranges) according to different renovation depths (specified in the figures below) for the year 2035. The depth of the renovation can be seen through the specific energy needs – renovation package 3 is the most ambitious one. The analysis provides an example of standards for the metrics' (specific) energy needs. Similar approach can be applied to other energy efficiency indicators. Moreover, the graphs show possible target standards and their ranges, which could then be used to generate the EPC recommendations in line with climate strategies.

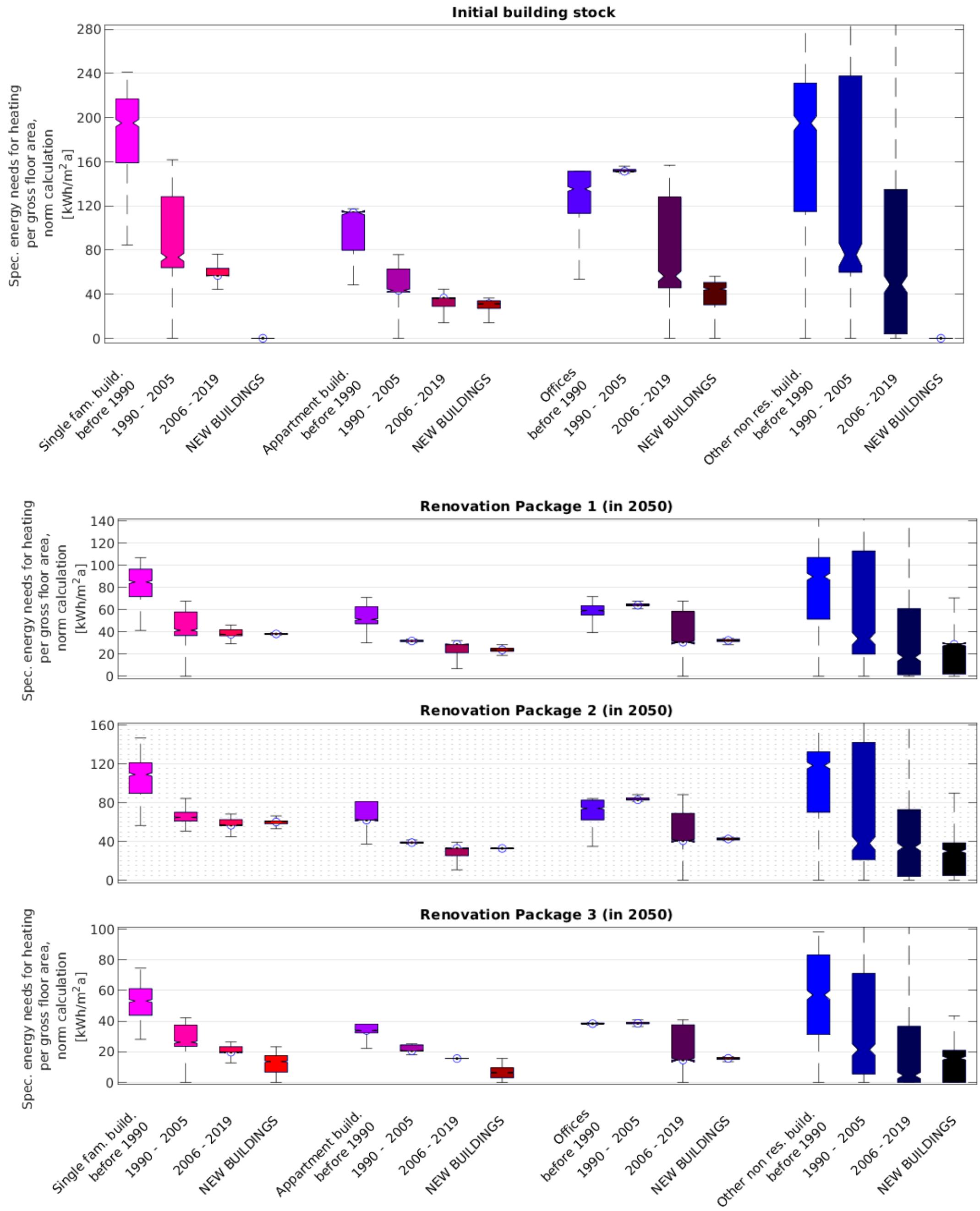

Figure 1: Building stock model analysis: potential impact of renovation packages for the case of the Netherlands. Source: Invert-EE/Lab [29]

For a certain scenario and depending on the settings of this scenario, the model selects a different combination of renovation measures in different building types, which results in certain energy performance of the whole building stock. This result is reflected first of all in the total useful and final energy demand and related CO_2 emissions. However, for a better understanding of the change in the building stock in the decades covered by the scenario, it is also useful – and required – to have a look at more detailed figures on how different parts of the building stock are getting refurbished, demolished or remain unchanged – according to the model assumptions and dynamics. Figures 2, 3, 4 show such an evolution of the building stock for the exemplary case of The Netherlands in a baseline scenario (Figure) and in a decarbonisation scenario (called an alternative scenario, Figure 3). Each step in the curve of the figure represents a certain archetype; for each archetype, different measures are being applied over the whole simulation horizon in the period 2020-2050, resulting in a building stock which – in the case of Figure 3 is in line with long-term climate and energy policy targets.

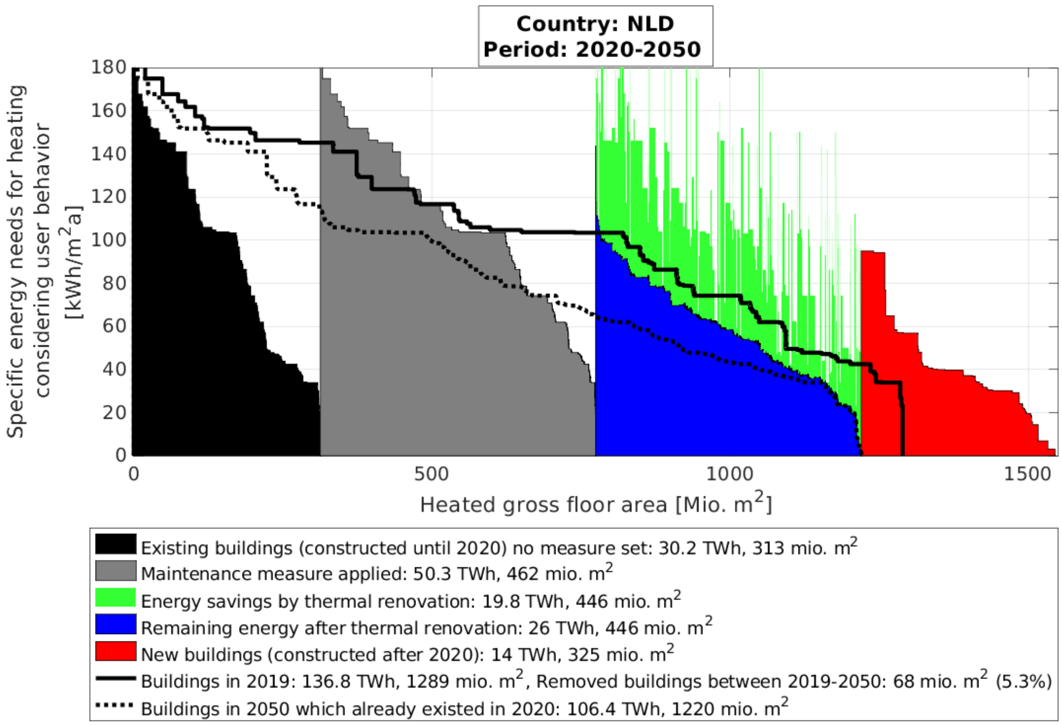

Figure 2. Building stock model analysis: resulting energy needs after uptake of renovation measures across the whole heated gross floor area for the case of the Netherlands. Baseline scenario. Source: Invert-EE/Lab [29]

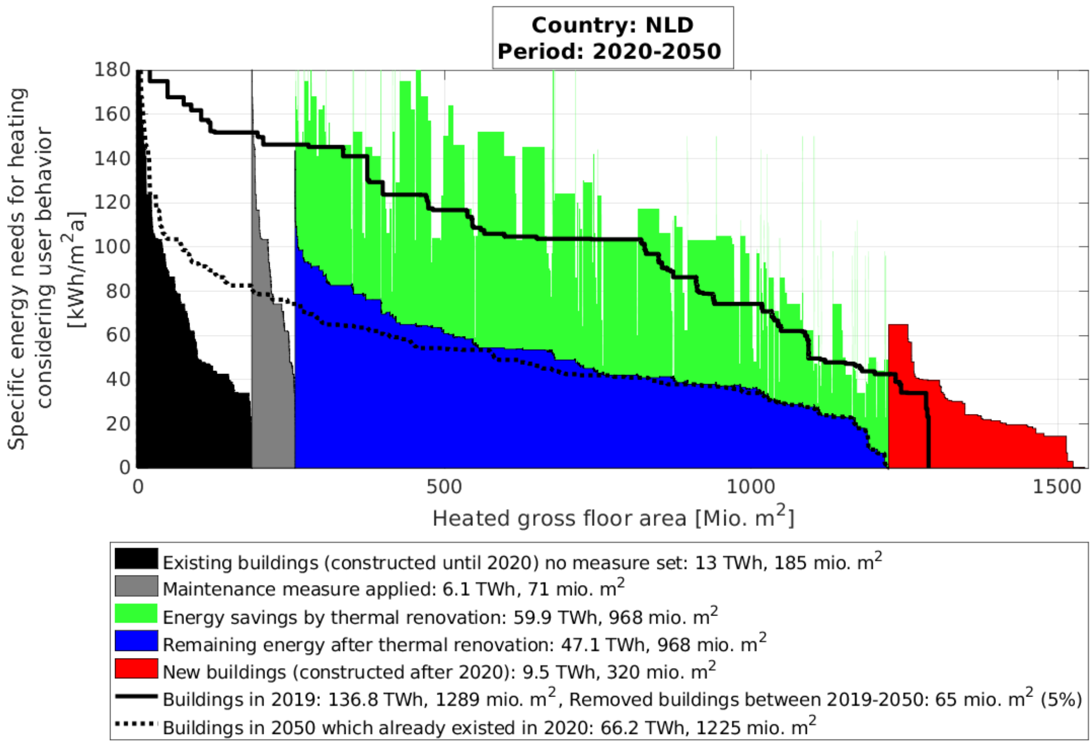

Figure 3 Building stock model analysis: resulting energy needs after uptake of renovation measures across the whole heated gross floor area for the case of the Netherlands. Alternative (decarbonisation) scenario. Source: Invert-EE/Lab [29]

Due to the high level of granularity of most building stock models, it is possible to derive more detailed data for the evolution of specific energy needs or U-values in certain building segments. Figure is an exemplary case that shows U-values for ceiling, exterior walls, windows, and floors for the Netherlands in two different scenarios: the baseline scenario (selected, the exemplary year 2030) is a scenario which – neither in 2030 nor in 2050 achieves climate and policy targets as outlined in the Fit-for-55 package [30]. On the other hand, the alternative 2050 scenario is a scenario in line with carbon neutrality by the year 2050. Due to the high inertia and lifetime of building components, all renovation activities carried out now need to be already in line with the 2050 targets. Thus, if, e.g., the exemplary "alternative 2050" scenario shown below would reflect the targets specified in the LTRS of a country, it would also imply that the U-values indicated in Figure need to be achieved. Thus, recommendations in EPCs should – on average – be in line with these values. This could mean that energy advisors would be asked to justify their recommendations if they are above the mean value (or a certain quantile to be selected) from the distribution of U-values in the target year.

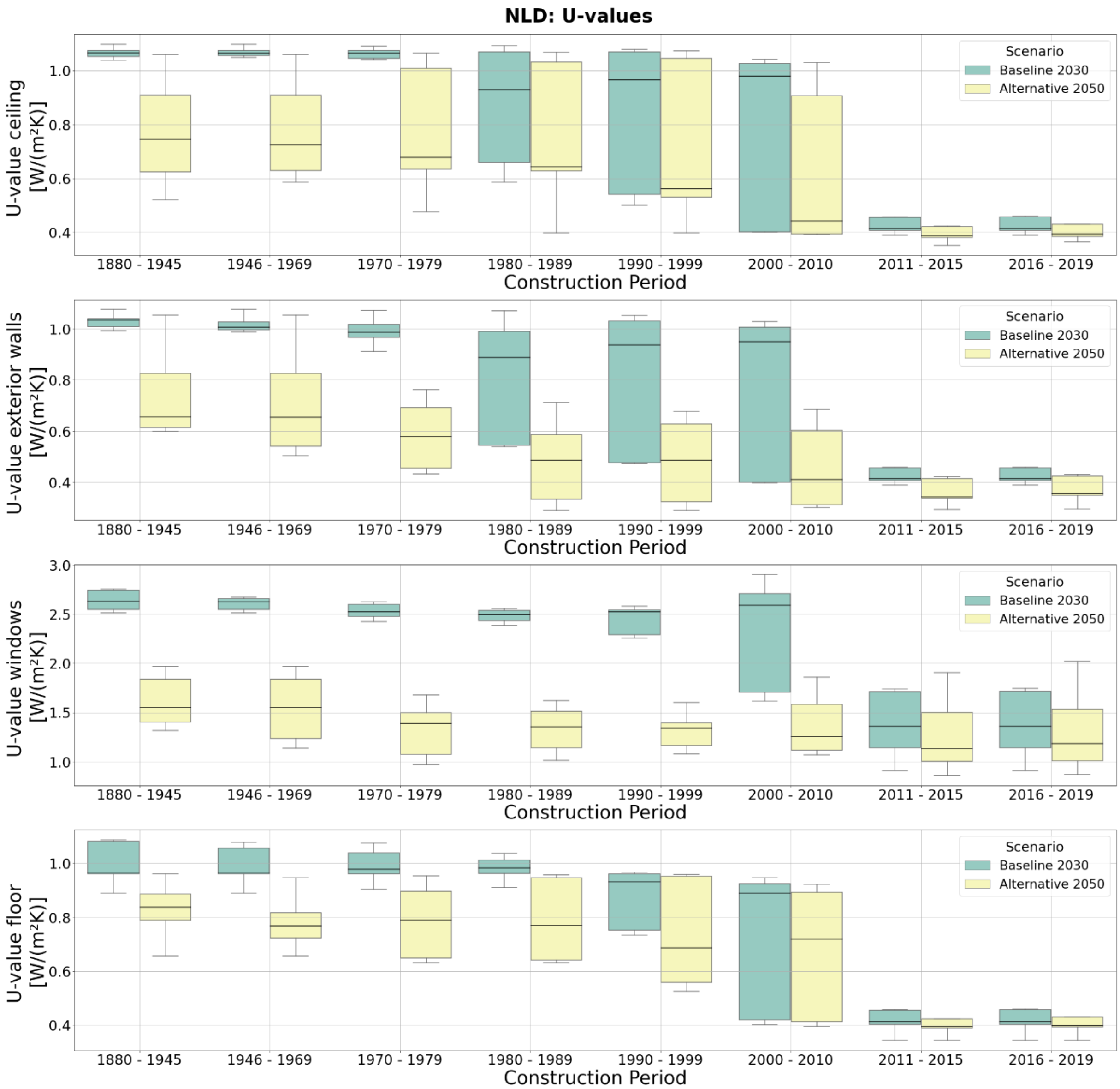

Figure 4. Building stock model analysis: U-values in different building components and construction periods in different, selected scenario years, the Netherlands. Source: Invert-EE/Lab [29]

From the description above, we conclude that an approach to using model-based results for recommendations in EPCs and BRPs could consist of the following steps:

1) Assign the building for which an EPC (or BRP) needs to be issued to certain archetypes used in building stock modelling. The accuracy of this approach will strongly depend on the resolution of the building stock model and how well the building fits to the archetype. Through an iterative improvement of the building stock model considering the data from the EPCs and BRPs, the overall database could be continuously improved.
2) Show the distribution of measures being carried out in a model-based scenario (which is compatible with long term energy and policy targets) for this building archetype. This distribution of measures can be understood as model-based estimations of the targeted measures.
3) Compare the recommended measures and resulting energy performance to the one in the scenario, where the scenario should reflect a future which is in line with long-term climate and energy policy targets, e.g., the ones reflected in the LTRS.
4) An alternative option to step 3: derive certain minimum standards which need to be met, e.g., based on a certain percentile of the building archetypes carrying out a set of measures; this imposes the risk that if the minimum standard is being defined too stringently, EPC assessors often might not be able to comply with it; if the minimum standard is being defined too weakly, EPC assessors might tend to use these standards, which – if applied to the majority of the buildings – would not be sufficient to meet, e.g., decarbonisation targets.
5) Recommendation regarding the choice of the heating system: While the recommendations on the building envelope mostly can be improved in a continuous way (i.e., applying more or less insulation material or more or less efficient windows), the choice of the heating system is discrete, i.e., either one or the other heating system needs to be chosen, with no "continuous" space between, e.g., a heat pump and a biomass boiler. Thus, showing the distribution of heating systems choice in the model-based (decarbonisation) scenario and comparing it to the recommended heating system might provide an indication of the consistency of this recommendation with long-term targets.

Moreover, it is believed that the approach proposed here can also be replicable and further expanded in further research. In particular, the question how concretely - with sufficient accuracy – buildings can be assigned to certain building archetypes remains an important question which can and should be further investigated, potentially also by machine learning methods.

CONCLUSIONS AND RELEVANCE FOR IBROAD2EPC

The following insights were derived regarding the current state of LTRS and their link with the context of recommendations provided in EPCs (and potentially in the future also in BRPs).

- It turned out that LTRS only partially include clear roadmaps towards decarbonisation. Only half of the analysed LTRS go up to a decarbonisation target of more than 90%, but none of them towards complete decarbonisation by 2050.
- Currently, EPCs are mentioned in the LTRS mainly as a potential source of information. BRPs are partly mentioned as a strategy for achieving energy and carbon savings in the building sector.
- Recommendations in EPCs in some MS are based on standardised measures, i.e., building assessors choose from a predefined list of measures.
- Recommendations in EPCs (and BRPs, as far as they are already under preparation or being mentioned in LTRS) are not linked to long-term climate and energy policy targets. E.g., there is, in general, no clear recommendation to mandatorily foresee a phase-out of fossil fuels when providing building retrofitting recommendations.

The results and discussions in this report might be considered in the following steps of iBRoad2EPC in one or several of the following options:

- Including relevant and future-proof recommendations for building renovation in EPCs is key. In the context of our analysis in this report and in the further steps of iBRoad2EPC, these recommendations (1) need to reach full decarbonisation and (2) to consider staged renovation and an ideal sequence and coordination of renovation steps. The question how recommendations in EPCs should refer to BRPs needs to be discussed which refers to the role and objective of both instruments.
- Provide recommendations to the EPBD recast and/or national implementation of the EPBD towards the use of LTRS for the framing of recommendations in EPCs and BRPs. In particular, it needs to be guaranteed that LTRS (or national building renovation plans, according to the proposal of the revised EBPD), EPCs, BRPs, MEPS and digital building logbooks are designed in a consistent, integrated way, forming a coherent policy package. It needs to be avoided that recommendations provided in EPCs and BRPs deliver different signals to end-users than those specified in LTRS or as required in MEPS.
- Provide guidelines and related training to the EPC assessors in terms of recommendations which are in line with long-term energy policy targets described in LTRS. Often, there are no clear guidelines about the target states of buildings that need to be achieved after the recommended measures. By providing evidence from models which are consistent with long-term decarbonisation scenarios, such targets could be derived, and assessors could/should be informed and guided in this direction. We expect that by introducing minimum energy performance standards (MEPS) as proposed for the next recast of the EBPD, this could gain even more relevance.
- Foresee the uptake of results from building stock models in the framing of recommendations in EPCs and BRPs (see chapter 0) through a corresponding interface in the iBRoad2EPC tool.
- The terminology of BRPs used in some MS's LTRS is not fully consistent to the understanding of BRPs in the project iBRoad2EPC. In particular, it seems that sometimes BRPs are confused with functionalities of the building logbook or one-stop shops. We believe that a clear, unambiguous definition and use of these terms can avoid confusion. Thus, the project iBRoad2EPC intends to contribute to such a clear, unambiguous definition.

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ANNEX: LTRS SPAIN

Questions	Indicators	Answer column	Answer column
Which are the targets for the building stock?	Does the LTRS specify a long-term target?	Yes	
	If yes, what is the target for?	kWh/y	CO_2 (tCO_2eq/y)
	2030 target (tertiary)	1.14788E+11	
	2040 target (tertiary)	9.17030E+10	
	2050 target (tertiary)	8.44630E+10	
	2030 target (residential)	1.46025E+11	10,725
	2040 target (residential)	1.24172E+11	4,854
	2050 target (residential)	1.08264E+11	201
	Is there a specific target for:	Yes/No	If yes, what is the target and metric?
	Energy efficiency	Yes	Residential+tertiary 2030: 26.394+17.069 GWh 2040: 48.247+40.155 GWh 2050: 64.154+47.395 GWh
	Energy consumption (includes EPBD uses: heating+DHW)		Residential: (fossil/electric/RES) 2030: 47.465/64.403/34.157 GWh 2040: 21.995/78.561/23.627 GWh 2050: 0/88.110/20.155 GWh Terciary: (fossil/electric/RES) 2030: 37.572/72.201/5.016 GWh 2040: 8.385/76.987/6.331 GWh 2050: 0/77.306/7.157 GWh

	share of heating technologies	Yes	Page 257. Page 307: graphic with 10 different energy sources for 2020, 2030, 2040 and 2050
	share of cooling technologies	No	
	share of DHW technologies	Yes	Page 265: table with the share of 9 different DHW systems in 2030 Page 308: graphic with 10 different energy sources for 2020, 2030, 2040 and 2050
	share of lighting technologies	Yes, for tertiary	Page 317
	share of ventilation technologies	No	
	heat protection	Yes	Dwellings with energy renovation: 2021-2030: 1,2 million 2031-2040: 3,5 million 2041-2050: 2,4 million
	Are there targets already defined for	Yes/No	If yes, what is the target and metric?
Type of buildings	Single-family buildings	Yes	Energy renovation: 2021-2030: 410.356 dwellings 2031-2050: 2.017.450 dwellings
	Multi-family buildings	Yes	Energy renovation: total (≤ 3 floors + > 3 floors) 2021-2030: 789.723 (147.926 + 641.797) dwellings 2031-2050: 3.883.988 (728.401 + 3.155.587) dwellings
	Non-residential buildings	Yes	Terciary: (fossil/electric/RES) 2030: 37.572/72.201/5.016 GWh 2040: 8.385/76.987/6.331 GWh

			2050: 0/77.306/7.157 GWh
	other	No	
Ownership types	owner occupied	No	Only diagnosis: no target
	publicly rented	No	
	privatly rented	No	
	condominium	No	
Location	urban	No	Only diagnosis: no target
	rural	No	Only diagnosis: no target
	suburban	No	
	Existing district heating	No	
	climate zone	No	Only diagnosis: no target
Year of construction	<1900	Yes	2021-30: 34.471 renov. 2031-50: 169.396 renov.
	1901-40	Yes	2021-30: 60.975 renov. 2031-50: 299.519 renov.
	1941-60	Yes	2021-30: 156.548 renov. 2031-50: 769.651 renov.
	1961-80	Yes	2021-30: 555.369 renov. 2031-50: 2.731.328 renov.
	1981-2007	Yes	2021-30: 392.716 renov. 2031-50: 1.931.544 renov.
	2008-20	Yes	0 renovations (already energy efficient)
	>2021	Yes	0 renovations (already energy efficient)

Restrictions	share of buildings with monumental protection	No	
	insulation restrictions	No	
Specific long-term requirements for building components	walls	Yes (indicative, only an hypothesis)	0,5-0,83 W/m2·K
	roofs	Yes (indicative, only an hypothesis)	0,44-0,51 W/m2·K
	cellars	Yes (indicative, only an hypothesis)	0,55-1,39 W/m2·K
	windows	Yes (indicative, only an hypothesis)	1,81-3,37 W/,2·K
	doors	No	

ANNEX: LTRS ROMANIA

Questions	Indicators	Answer column	
Which are the targets for the building stock?	Does the LTRS specify a long-term target?	Yes	
	If yes, what is the target for?	kWh - reduction	CO_2 (tons) - saved
	2030 target	9,673,667,031	2,340,137
	2040 target	38,627,890,714	4,912,056
	2050 target	71,420,018,379	7,850,831
	Is there specific target for:	Yes/No	If yes, what is the target and metric?
	Energy efficiency	Yes	2030: -8.7% compared with 2020
	share of heating technologies	No	
	share of cooling technologies	No	
	share of DHW technologies	No	
	share of lighting technologies	No	
	share of ventilation technologies	No	
	heat protection	No	
	Are there targets already defined for	Yes/No	If yes, what is the target and metric?
Type of buildings	Single-family buildings	Yes	19.95 Mm2 renovated
	Multi-family buildings	Yes	65.66 Mm2 renovated
	Non-residential buildings	Yes	9.74 Mm2 renovated
	other	No	
Ownership types	owner occupied	No	
	publicly rented	No	
	privatly rented	No	
	condominium	No	
Location	urban	No	split only for SFH
	rural	No	split only for SFH

	suburban	No	
	Existing district heating	No	
	climate zone	No	
Year of construction	<1945	No	
	1945-1960	No	
	1960-1975	No	
	1975-1990	No	
	1990-2010	No	
	after 2010	No	mostly built before 2000 to be included
Restrictions	share of buildings with monumental protection	No	excluded from obligations
	insulation restrictions	No	excluded from obligations
Specific long-term requirements for building components	walls	No	minimum EP requirements under revision
	roofs	No	minimum EP requirements under revision
	cellars	No	minimum EP requirements under revision
	windows	No	minimum EP requirements under revision
	doors	No	minimum EP requirements under revision
	other?	No	minimum EP requirements under revision

ANNEX: LTRS BULGARIA

Questions	Indicators	Answer coloum	
Which are the targets for the building stock?	Does the LTRS specify a long-term target?	Yes	
	If yes, what is the target for?	kWh	CO_2
	2030 target	2917 GWh	1306435 tCO_2
	2040 target	6502 GWh	2891610 tCO_2
	2050 target	7329 GWh	3274453 tCO_2
	Is there specific target for:	Yes/No	If yes, what is the target and metric?
	Energy efficiency	No	
	share of heating technologies	No	
	share of cooling technologies	No	
	share of DHW technologies	No	
	share of lighting technologies	No	
	share of ventilation technologies	No	
	heat protection	No	
	Are there targets already defined for:	Yes/No	If yes, what is the target and metric?
Type of buildings	Single-family buildings	combined with MFB	
	Multi-family buildings	combined with SFB	Residential buildings - 2030 : 2477 GWh; 2040 : 5694 GWh; 2050 : 6294 GWh
	Non-residential buildings	Yes	2030 : 440 GWh; 2040 : 508 GWh; 2050 : 1035 GWh
	other	No	
Ownership types	owner occupied	No	
	publicly rented	No	

	privatly rented	No	
	condominium	No	
Location	urban	No	
	rural	No	
	suburban	No	
	Existing district heating	No	
	climate zone	No	
Year of construction	<1945	No	
	1945-1960	No	
	1960-1975	No	
	1975-1990	No	
	1990-2010	No	
	after 2010	No	
Restrictions	share of buildings with monumental protection	No	
	insulation restrictions		
Specific long-term requirements for building components	walls	No	only referance: 0,28 W/m2K
	roofs	No	only referance depending on the type: 0,25 - 0,30 W/m2K
	cellars	No	only referance depending on the type: 0,40 - 0,50 W/m2K
	windows	No	only referance depending on the structure and type of the frame: 1,4 - 1,9 W/m2K
	doors	No	only referance: 2,20 W/m2K
	other?	No	

ANNEX: LTRS GREECE

Questions	Indicators	Answer coloumn		
Which are the targets for the building stock?	Does the LTRS specify a long-term target?	Yes		
	If yes, what is the target for?	kWh	CO_2	Percentage
	2030 target			1. Energy upgrade of 12-15% of the existing housing stock. 2. 8% reduction of the total final energy consumption related to reference year 2015 (This target id defined at the NECP)
	2040 target			
	2050 target			1. Energy upgrade of the rest of the existing housing stock. 2. 40% reduction of the total final energy consumption related to reference year 2015 (2021-2050 roadmap of the LTRS report (Gazette 974/B/2021)
	Is there specific target for:	Yes/No	If yes, what is the target and metric?	
	Energy efficiency	Yes	energy upgrade of 600.000 housing units until 2050	

	share of heating technologies	Yes	21% of the final energy demand for heating at the residential sector must be provided via heat pumps until 2040 and 50% until 2050	
	share of cooling technologies	No		
	share of DHW technologies	Yes	86% of the final energy demand for DHW at the residential sector must be produced via solar systems until 2040 and 92% until 2050	
	share of lighting technologies	No		
	share of ventilation technologies	No		
	heat protection	No		
	Are there targets already defined for:	Yes/No	If yes, what is the target and metric?	
Type of buildings	Single-family buildings	Yes	The envelope of 23% of the residential building stock must be energy upgrated until 2030, 36%-42% until 2040 and 45%-49% until 2050	
	Multi-family buildings			
	Non-residential buildings	Yes	The envelope of 9% of the tertiary building stock must be energy upgrated until 2030, 14%-16% until 2040 and 19%-20% until 2050	
	Buildings housing public authorities	Yes	Since 01.07.2020 all new buildings	

			constructed have to be of Energy Class A.	
			All public buildings acquired after 01.01.2022 have to be energy class B and from 01.01.2026 NZEB.	
			All public buildings leased after 01.01.2023 have to be energy class B and from 01.01.2026 NZEB.	
	other			
Ownership types	owner occupied	No		
	publicly rented	No		
	privatly rented	No		
	condominium	No		
Location	urban	No		
	rural	No		
	suburban	No		
	Existing district heating	No		
	climate zone	No		
Year of construction	<1945	No		
	1945-1960	No		
	1960-1975	No		
	1975-1990	No		
	1990-2010	No		
	after 2010	No		
Restrictions	share of buildings with monumental protection			
	insulation restrictions	Yes	Only internal insulation is	
	walls	Yes		

Specific long-term requirements for building components	roofs	Yes	permitted under very strict presuppositions	
	cellars	Yes		
	windows	Yes	Repalcement of openings is permitted only after approval by the authorised momumental protection services and under very strict limitations	
	doors	Yes		
	other?		Replacement of existing electrical and mechanical installations and replacement by energy efficient is permitted under limitations and after approval by the authorised momumental protection services	

ANNEX: LTRS POLAND

Questions	Indicators	Yes	No
Which are the targets for the building stock?	Does the LTRS specify a long-term target?	Yes	
	If yes, what is the target for?	kWh	CO_2
	2030 target	11% of building stock will be brought to passive standard (50 [kWh/(m2*year)]), 9% to energy efficient standard (50-90 [kWh/(m2*year)]), 26% will be in 90-150 [kWh/(m2*year)] category, 39% will be in 150-230 [kWh/(m2*year)] category and 25% will be in 230-330 [kWh/(m2*year)] category	
	2040 target	40% of building stock will be brought to passive standard (50 [kWh/(m2*year)]), 17% to energy efficient standard (50-90 [kWh/(m2*year)]), 30% will be in 90-150 [kWh/(m2*year)] category and 18% will be in 150-230 [kWh/(m2*year)] category	

	2050 target	66% of building stock will be brought to passive standard (50 [kWh/(m2*year)]), 21% to energy efficient standard (50-90 [kWh/(m2*year)]), rest will fall into 90-150 [kWh/(m2*year)] category	
	Is there specific target for:	Yes/No	If yes, what is the target and metric? *
*No specific goal or measure, only technology recommendations	Energy efficiency	No	Using automatic computerized control systems for all installations
	share of heating technologies	No	Reversible heat pumps, pulsed gas condensing boilers, cogeneration, trigeneration, polygeneration, district heating, infrared heaters, intelligent control systems for heating and cooling
	share of cooling technologies	No	The use of new more efficient units in split systems and the use of freecooling.
	share of DHW technologies	No	Changing the method of hot water preparation (heat pump, solar collectors, condensing boiler with condensing boiler with a tank)

	share of lighting technologies	No	Use of LED technology, systems for optimal use of daylight, lighting that dynamically changes the color of light and its intensity depending on the needs of the user depending on the user's needs,
	share of ventilation technologies	No	Use of mechanical ventilation with heat recovery
	heat protection	No	Materials and technologies that protect buildings from overheating and/or reduce heat loss.
Are there targets already defined for	...	Yes/No	If yes, what is the target and metric?
Type of buildings	Single-family buildings	Yes	up to 50 [kWh/(m2*year)] in 2050
	Multi-family buildings	Yes	up to 50 [kWh/(m2*year)] in 2050
	Non-residential buildings	Yes	up to 50 [kWh/(m2*year)] in 2050
	other	Yes	up to 50 [kWh/(m2*year)] in 2050
Ownership types	owner occupied	No	
	publicly rented	No	
	privatly rented	No	
	condominium	No	
Location	urban	No	
	rural	No	
	suburban	No	
	Existing district heating	No	
	climate zone	No	

Year of construction	<1945	No	
	1945-1960	No	
	1960-1975	No	
	1975-1990	No	
	1990-2010	No	
	after 2010	No	
Restrictions	share of buildings with monumental protection	No	
	insulation restrictions		
Specific long-term requirements for building components	walls	"Materials with increased parameters, in particular: construction, insulation, materials with improved resistance to ageing processes, vapour-permeable, low embedded embedded energy, high fire resistance, low emissivity, thermo-reflective and manufactured from plant raw materials and technologies of their manufacturing."	
	roofs		
	cellars		
	windows		
	doors		
	other?		

ANNEX: LTRS PORTUGAL

Questions	Indicators	Yes	No		
	Does the LTRS specify a long-term target?	X			
	If yes, what is the target for?	kWh	CO_2	Other	
Which are the targets for the building stock?	2030 target	44,674,779,753	6,403,264	11% primary energy saving 11% Local Renewable Production 68% Total Renewable Production (Local + Supply) 15% CO_2 emissions reduction 365176455 m2 of renovated buildings 69% renovated buildings 26% disconfort hours reduction 82 €/m2 of investment 89 €/m2 of savings	
	2040 target	36,962,974,472	4,018,992	27% primary energy saving 30% Local Renewable Production 75% Total Renewable Production (Local + Supply) 47% CO_2 emissions reduction 637133639 m2 of renovated buildings 99% renovated buildings 34% disconfort hours reduction 164 €/m2 of investment 192 €/m2 of savings	

	2050 target	33,006,754,934	1,784,651	34% primary energy saving 62% Local Renewable Production 98% Total Renewable Production (Local + Supply) 76% CO_2 emissions reduction 747953071 m2 of renovated buildings 100% renovated buildings 56% disconfort hours reduction 256 €/m2 of investment 283 €/m2 of savings	
	Is there specific target for:	Yes/No	If yes, what is the target and metric?		
	Energy efficiency	Yes	The PT LTRS is based on a building energy model. Therefore it was set different assumptions to achieve the final targets, dependent on the building typology (type of building, age, climatic zone)		
	share of heating technologies	Yes	The PT LTRS is based on a building energy model. Therefore it was set different assumptions to achieve the final targets, dependent on		

			the building typology (type of building, age, climatic zone)		
	share of cooling technologies	Yes	The PT LTRS is based on a building energy model. Therefore it was set different assumptions to achieve the final targets, dependent on the building typology (type of building, age, climatic zone)		
	share of DHW technologies	Yes	The PT LTRS is based on a building energy model. Therefore it was set different assumptions to achieve the final targets, dependent on the building typology (type of building, age, climatic zone)		
	share of lighting technologies	Yes	The PT LTRS is based on a building energy model. Therefore it was set different assumptions to achieve the final targets, dependent on the building typology (type of building,		

			age, climatic zone)		
	share of ventilation technologies				
	heat protection				
Are there targets already defined for	…	Yes/No	If yes, what is the target and metric?		
Type of buildings	Single-family buildings	Yes	Targets are defined for residential buildings (2030): 15% primary energy saving 10% Local Renewable Production 57% Total Renewable Production (Local + Supply) 16% CO_2 emissions reduction 299524729 m2 of renovated buildings 70% renovated buildings 26% disconfort hours reduction 82 €/m2 of investment 88 €/m2 of savings	Targets are defined for residential buildings (2040): 37% primary energy saving 35% Local Renewable Production 62% Total Renewable Production (Local + Supply) 56% CO_2 emissions reduction 513059967 m2 of renovated buildings 100% renovated buildings 34% disconfort hours reduction 165 €/m2 of investment 191 €/m2 of savings	Targets are defined for residential buildings (2050): 40% primary energy saving 71% Local Renewable Production 98% Total Renewable Production (Local + Supply) 84% CO_2 emissions reduction 514265282 m2 of renovated buildings 100% renovated buildings 56% disconfort hours reduction 258 €/m2 of investment 279 €/m2 of savings
	Multi-family buildings	Yes	check above		

	Non-residential buildings	Yes	Targets are defined for non-residential buildings (2030): 7% primary energy saving 11% Local Renewable Production 78% Total Renewable Production (Local + Supply) 15% CO_2 emissions reduction 65651726 m2 of renovated buildings 28% renovated buildings 81 €/m2 of investment 137 €/m2 of savings	Targets are defined for non-residential buildings (2040): 15% primary energy saving 25% Local Renewable Production 87% Total Renewable Production (Local + Supply) 37% CO_2 emissions reduction 124073673 m2 of renovated buildings 53% renovated buildings 145 €/m2 of investment 240 €/m2 of savings	Targets are defined for non-residential buildings (2050): 28% primary energy saving 54% Local Renewable Production 97% Total Renewable Production (Local + Supply) 68% CO_2 emissions reduction 233687788 m2 of renovated buildings 100% renovated buildings 155 €/m2 of investment 447 €/m2 of savings
	other	No			
Ownership types	owner occupied	No			
	publicly rented	No			
	privatly rented	No			
	condominium	No			
Location	urban	No			
	rural	No			
	suburban	No			
	Existing district heating	No			
	climate zone	Yes	The PT LTRS is based on a building energy model. Therefore it was set different assumptions to achieve the final targets,		
Year of construction	<1945	Yes			
	1945-1960	Yes			
	1960-1975	Yes			
	1975-1990	Yes			
	1990-2010	Yes			
	after 2010	Yes			

			dependent on the building typology (type of building, age, climatic zone)		
Restrictions	share of buildings with monumental protection	No			
	insulation restrictions	Yes	Based on PT thermal regulation, depends on the climatic zone where the building is built. See below		
Specific long-term requirements for building components	walls	Yes	Based on PT thermal regulation, depends on the climatic zone where the building is built. (I1 - Uvalue = 0.50; I2 - Uvalue = 0.40; I3 - Uvalue= 0.35)		
	cellars	No			
	roofs	No	Based on PT thermal regulation, depends on the climatic zone where the building is built. (I1 - Uvalue = 0.40; I2 - Uvalue = 0.35; I3 - Uvalue= 0.3)		
	windows	Yes	Based on PT thermal regulation, depends on the climatic		

			zone where the building is built (I1 - Uvalue = 2.80; I2 - Uvalue = 2.40; I3 - Uvalue= 2.20)		
	doors	No			
	other?				

[i] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en
[ii] https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/renovation-wave_en#:~:text=The%20Renovation%20Wave%20initiative%20builds,and%20climate%20plans%20(NECPs).
[iii] https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficient-buildings/long-term-renovation-strategies_en
[iv] While the Bulgarian LTRS lists these potential benefits and features under the BRP, the authors of this report understand the logging of efficiency improvement and data collection to be used, e.g,. by financial and construction sectors, mainly as a feature typically covered by building logbooks – and partly one-stop-shops.
[v] While the LTRS of Poland lists these potential benefits and features under the BRP, the authors of this report understand the logging of efficiency improvement mainly as a feature typically covered by building logbooks.
[vi] The term "building archetype" is commonly used in building stock modelling for representative buildings describing typical patterns of buildings usually defined through their geometry, energetic performance, use, type of HVAC system and more. By this categorisation, typical patterns of decarbonisation can also be derived for these building archetypes.

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