ePANACEA
Smart European Energy Performance Assessment & Certification

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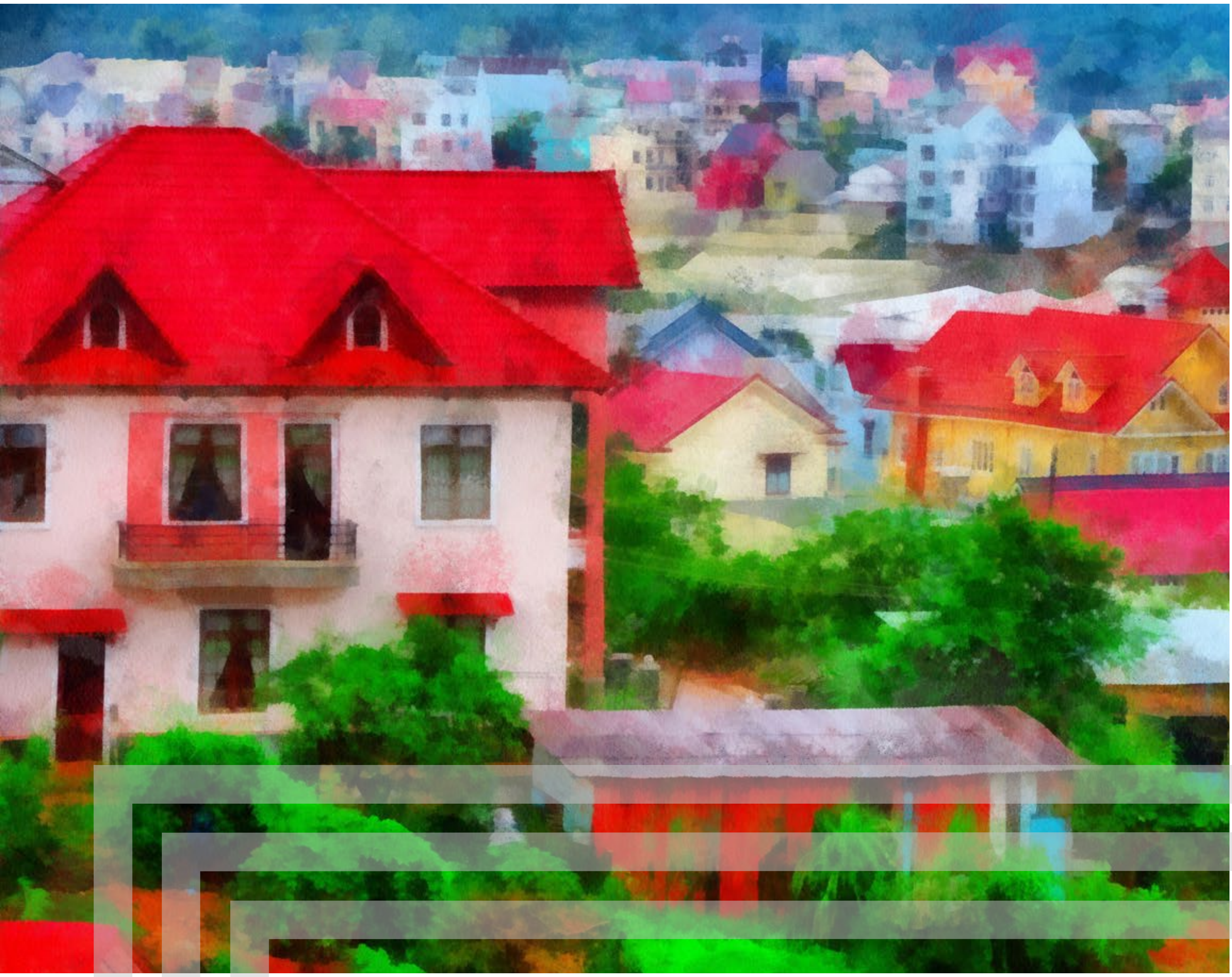

Potential future uptake of new EPC calculation methods

The potential impact of innovative ePANACEA methods on issued Energy Performance Certificates, energy savings, and related investments

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V1	August.2023	TU WIEN	Draft final version for internal review
V1.1	September 2023	TU WIEN	Internal review comments integrated

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ePANACEA PROJECT

After ten years of track record, the current EPC schemes across the EU face several challenges which have led to a not full accomplishment of their initial objectives: lack of accuracy, a gap between theoretical and real consumption patterns, absence of proper protocols for inclusion of smart and novel technologies, little convergence across Europe, lack of trust in the market and very little user awareness related to energy efficiency.

The objective of the ePANACEA project is to develop a holistic methodology for energy performance assessment and certification of buildings that can overcome the above-mentioned challenges. The vision of ePANACEA is to become a relevant instrument in the European energy transition through the building sector.

ePANACEA comprises the creation of a prototype (the Smart Energy Performance Assessment Platform) making use of the most advanced techniques in dynamic and automated simulation modelling, big data analysis and machine learning, inverse modelling, or the estimation of potential energy savings and economic viability check.

A relevant part of the project is to have a fluent dialogue with European policymakers, certification bodies, end-users, and other stakeholders through two types of participatory actions: a feedback loop with policymakers carried out through the so-called Regional Exploitation Boards (REBs) covering EU-27+UK+Norway on the one hand, and dialogue with end-users, established by utilizing specific thematic workshops, on the other.

Thanks to these participatory actions, the acceptance of the ePANACEA approach will be tested and validated to become aligned with and meet the needs of national public bodies, end-users, and other stakeholders.

ePANACEA demonstrated and validated the reliability, accuracy, user-friendliness, and cost-effectiveness of its methodology through 15 case studies in 5 European countries.

EXECUTIVE SUMMARY

The main objective of this working paper is to assess the potential impacts on the EPC issuing by the innovative EPC methods developed during the ePANACEA project. For this purpose, we apply diffusion analysis due to policy setting, EPC tools, and market structure. This report follows two streams of work: (1) discussing the impact of renovation measures on energy demand, CO_2 emissions, related investments, etc., in different scenarios of the EU-building stock and the pilot countries and (2) analysing the potential evolution of EPC uptake and different methods for issuing EPCs, including the methods developed in the ePANACEA project. Based on the end-user acceptance workshops and analysis performed during the project, it is not possible to directly link the impact of different EPC methods and issuing activities to resulting energy savings. Nevertheless, the joint discussion of these two streams allows for drawing relevant conclusions regarding the future role of expanding EPC methods and applying ePANACEA methods, both are presented in this study.

The work carried out also builds on other project activities, such as the report about “Pathways of EPC-related policy framework”, the expert interviews and exchange with “Reginal Board Members” (REB Meetings), and the main conclusion from the new EPCs acceptance test through “End-users workshops”. Finally, scenarios of building stock evolution in Europe until 2025 are also used as a base. The focus countries are Austria (focus Styria), Belgium (focus Flanders), Finland, Germany, Greece, and Spain. The main conclusions are that changing the validity time of EPCs is an important policy measure that can influence the number of issued EPCs. Especially, when associated with EPCs’ energy class, then not only worst performance buildings but all EPC classes would need to be considered for a reduced validity duration. Overall, decarbonisation of the building stock will require significant investments in the building envelope and HVAC systems, leading to potentially high energy savings and in particular savings of fossil fuels and related GHG-emissions. Improved EPCs will play a key role in this transition. The calculation methods developed in ePANACEA have the potential to contribute to a more reliable basis and thus to exploiting the decarbonisation potentials of the building stock.

Chapter 1 introduces the main topics; Chapter 2 presents the different “methods” from the building stock energy demand model (INVERT) to the impact on issued EPC; Chapter 3 presents the defined pathways, according to which the results are calculated and presented in Chapter 4. Finally, conclusions are driven in Chapter 5.

1. INTRODUCTION

The present chapter presents the scope, the context, and the structure of the report. The Energy Performance Certificates (EPCs) were introduced by the Member States of the European Parliament in the Energy Performance of Buildings Directive 2002/91/EC (EPBD) in Article 11. The main objectives of the EPCs as instruments by that time were, firstly, to provide correct information to a prospective building (or building unit) buyer, owner, or tenant about the energy performance of the building and, secondly, to provide practical advice on improving such performance. The main motivation behind this was that increasing transparency and easily accessible information about the building trigger energy renovation of buildings. Consequently, this led to a double effect: reducing the greenhouse gas emissions of the building sector while stimulating the retrofitting sector to compensate for the fall of the market in the building industry at that time.

Although the EPC has been in force for twenty years, the objectives have not been fully accomplished, so it is necessary to design and develop a new generation of EPC that is more reliable, user-friendly, and cost-effective to inspire trust in the market and stimulate investments in energy-efficient buildings.

The ePANACEA project contributes to the next generation of EPCs in different forms, as seen in Figure 1 below. The present report is related to the future impacts of the project outcomes. Then, the next generation of EPC design and future uptake is also affected by the policy setting and choices.

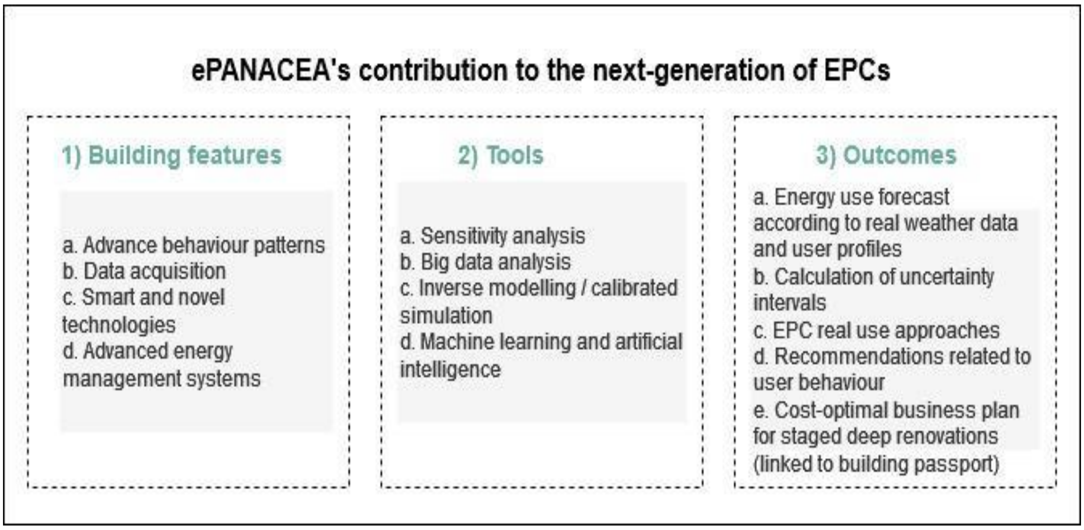

Figure 1: ePANACEA's contribution to the next-generation of EPCs

This work builds on the report about "Pathways of EPC-related policy framework", the expert interviews and exchanges with "Reginal Board Members" (REB Meetings), and the main conclusion from the new EPCs acceptance test through "End-users workshops". Finally, scenarios of building stock evolution in Europe until 2025 are also used as a base. The present work assesses quantitatively the potential impact of innovative EPC using the Method explained below.

The report is structured with the present introduction (Chapter 1), followed by the methods that englobe the building stock modelling and related energy demand and EPC issuing scenarios (Chapter 2), the pathways considered for future EPC development and building stock decarbonisation (Chapter 3), the results for EPCs issued in Austria, Belgium, Finland, Greece and Spain (Chapter 4) and the main conclusions (Chapter 5).

2. METHOD

The approach of this report follows two streams: (1) discussing the impact of renovation measures on energy demand, CO_2 emissions, related investments, etc., in different scenarios of the EU-building stock and the focus countries and (2) analysing the potential evolution of EPC uptake and different methods for issuing EPCs, including the methods developed in the ePANACEA project.

The following chapters explain the method applied, starting with the first stream and then the second one.

2.1. Scenarios of building stock related energy demand

To assess the impact of different scenarios on the reduction of energy demand, change of energy carrier mix, renovation activities, and related costs, we utilize the building stock model Invert/EE-Lab, which is described below.

Invert/EE-Lab is a dynamic bottom-up building stock model that evaluates the effects of different framework conditions (in particular, different settings of economic and regulatory incentives) on the total energy demand, energy carrier mix, CO_2 reductions, and costs for space heating, cooling and hot water preparations in buildings.

The basic idea of the model is to describe the building stock, heating, cooling, and hot water systems on highly disaggregated levels, calculate related energy needs and delivered energy, determine reinvestment cycles and new investment of building components and technologies, and simulate the decisions of various agents (i.e., owner types) in case that an investment decision is due for a specific building segment.

The core of the simulation model is a myopic approach that optimizes the objectives of “agents” under imperfect information conditions and thus represents the decisions concerning building-related investment decisions. It applies a nested logit approach to calculate market shares of heating systems and energy efficiency measures depending on building and investor type.

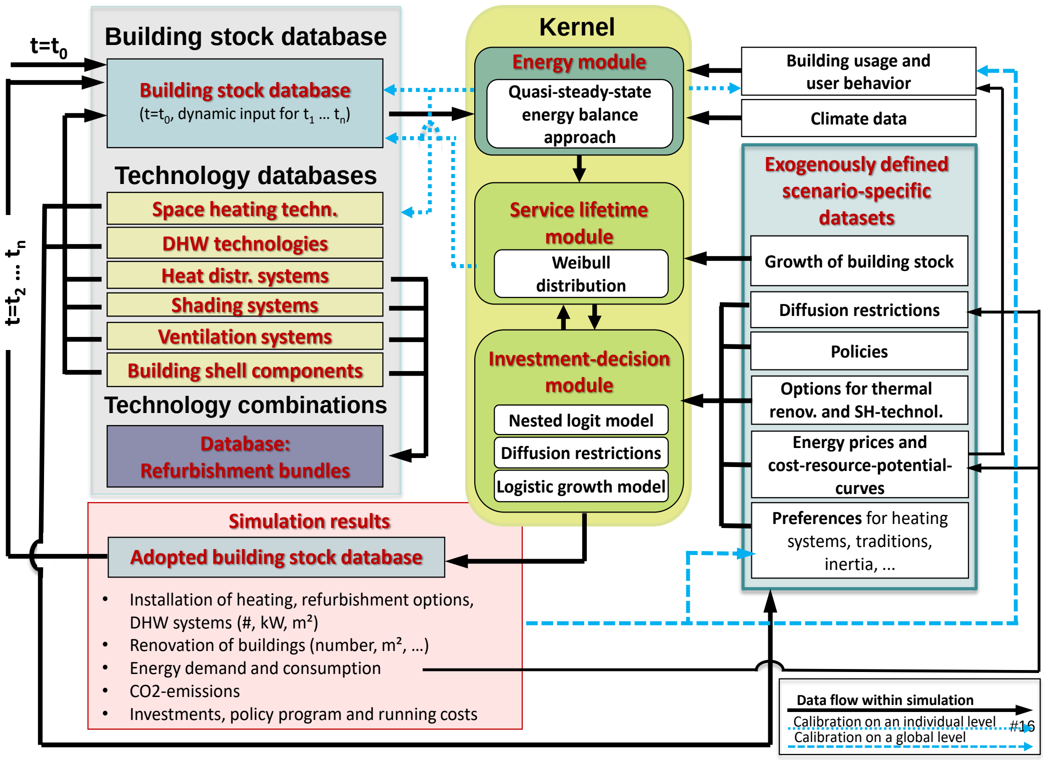

Figure 2: Overview structure of the simulation tool Invert/EE-Lab

The model has been applied in more than 40 projects for various countries and EU-27 (+UK and selected neighbouring countries), as well as for the European Commission, covering residential and non-residential buildings.

More information on the model is available at www.invert.at or in, e.g., (Müller, 2015), (Kranzl et al., 2019), (Hummel et al., 2023).

Standard outputs from the Invert/EE-Lab on an annual basis are:

- Installation of heating and hot water systems by energy carrier and technology (number of buildings, number of dwellings supplied)
- Refurbishment measures by level of refurbishment (number of buildings, number of dwellings)
- Total delivered energy by energy carriers and building categories (GWh)
- Total energy needed by building categories (GWh)
- Policy programme costs, e.g., support volume for investment subsidies (M€)
- Total investment (M€)

To show a certain range of scenarios both on the demand and supply side, we distinguish two dimensions in the scenario specification: (1) the demand dimension, reflected by a high and a low demand scenario, being represented by different renovation rates and depth and (2) the supply dimension, putting certain heating and hot water supply configurations in focus, i.e., one scenario focusing on district heating, one on electrification via heat pumps and one on H2 and e-fuels.[1] All developed scenarios are designed as full decarbonisation scenarios, leading to carbon neutrality by 2050, which, of course, also depends on decarbonisation of electricity and district heating supply, which is not the focus of this study. In addition, we added one scenario with changes in lifestyle considering the uptake of sufficiency measures, e.g., slightly adapted floor area per capita or indoor temperature levels.

2.2. ePANACEA methods linked to EPC issuing scenarios

The methodology of ePANACEA strives to enhance the consistency of energy performance evaluation and building certification throughout the European Union. This effort seeks to bolster confidence in the market and improve user-friendliness by ensuring that the information provided is clear and precise.

ePANACEA develops a methodology consisting of a modular approach applicable to different building typologies and complexity cases. The module englobes three energy performance assessment methods as described below, as shown in Figure 3, together with the responsible project partners:

[1] The scenario logic and method have been developed in the H2020 project "European Climate and Energy Modelling Forum - ECEMF (https://www.ecemf.eu/)". The analysis and presentation of result indicators were adapted for ePANACEA.

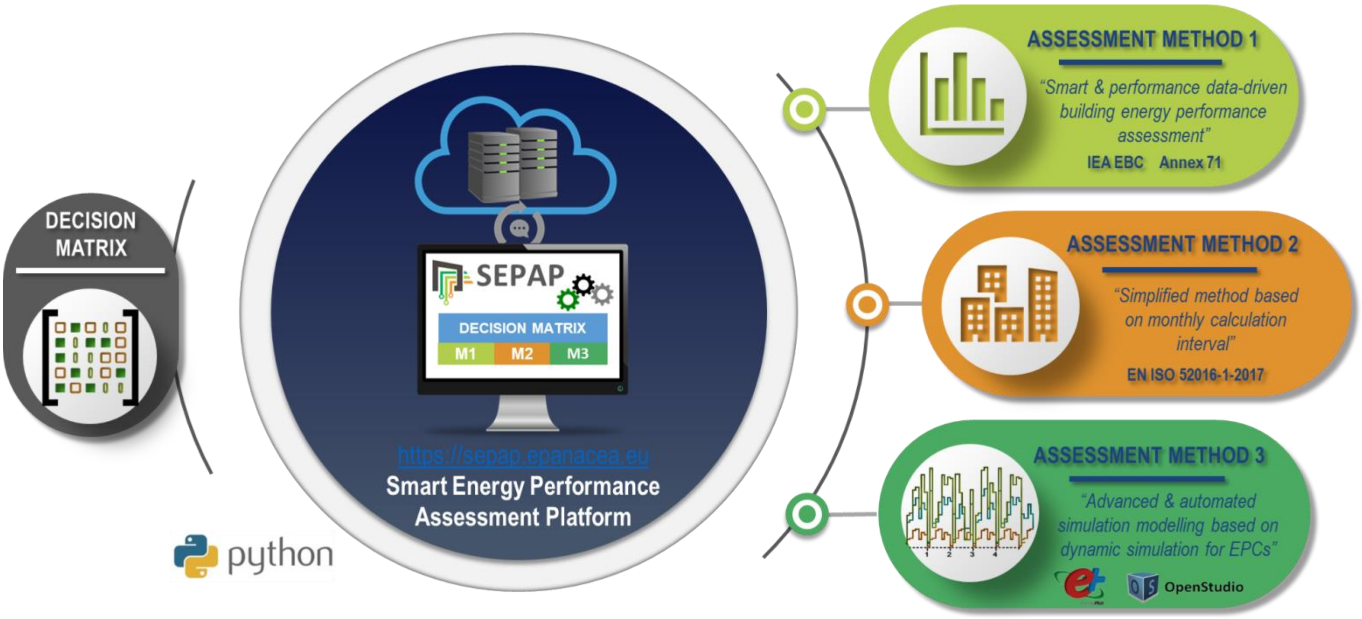

Figure 3: Overview on ePANACEA's three assessment methods. Source:CENER, May 2023

- **Method 1**: Smart & performance data-driven building energy performance assessment, consisting of an inverse energy demand calculation based on measured energy data (based on the IEA EBC Annex 71). This method is explained in detail through an online video tutorial available under the following link: ePANACEA | Method 1 | Youtube Video tutorial.
- **Method 2**: Simplified steady-base monthly calculation method based on ISO 52016 (Energy performance of buildings, energy needs for heating and cooling, internal temperatures, and sensible and latent heat loads). This method is explained in detail through an online video tutorial available under the following link: ePANACEA | Method 2 | Youtube Video tutorial.
- **Method 3**: Advanced & automated simulation modelling (based on thermal-dynamic and calibrated simulations) based on ISO 52017. The generic calculation procedures are based on ISO 52016 and have been ISO 52017 specific for transient hourly and sub-hourly conditions in a single building zone. This method is explained in detail through an online video tutorial available under the following link: ePANACEA | Method 3 | Youtube Video tutorial.

The concept behind the modular methodology's development envisions a progression across three assessment approaches, ranging from simpler to more intricate. This progression is determined by the specific building or assessment needs. For instance, it encompasses advanced energy assessments that fulfil precision and standard criteria, the incorporation of cutting-edge technologies, and the utilization of actual measured data.

Although the methods differ from each other in complexity, the following synergies between them were explored in the project:

- Use of monitoring data
- Data acquisition
- Advanced user behaviour modelling
- Sensitivity analysis
- Semi-automated calibration based on machine-learning techniques
- Inclusion of novel and smart technologies

Figure 4 shows a screenshot of a platform window. Above, are to be seen the different steps of the methodology start for the common input data required in steps 1 to 7, followed by the results generated by each in different steps: step 8 (Method 1), step 9 (Method 2), and step 10 (Method 3).

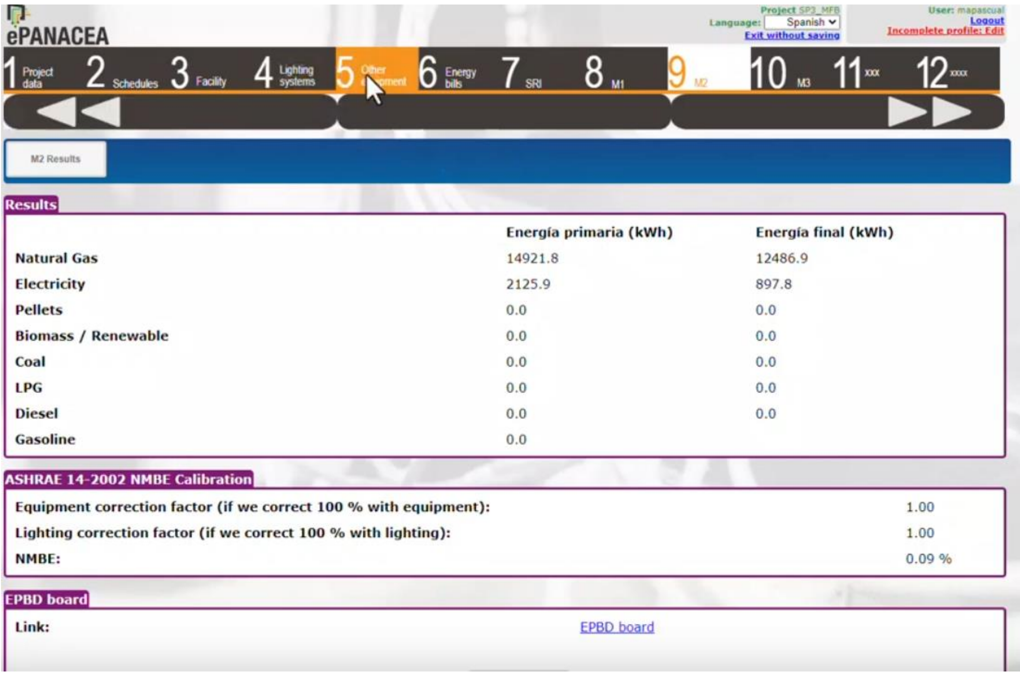

Figure 4: Screenshot of an ePANACEA window, showing the different methodological steps and how the methods are related

2.3. Triggers and occasion of EPC issuing

The methodology used for calculating the number of EPCs is based on the methodology developed in X-tendo and extended to ePANACEA countries. Several general triggering points were identified, due to which EPCs can or need to be issued according to the EPBD and, in particular, in the ePANACEA countries. These triggering points are:

- building sales (if no valid EPC is available) (real estate transaction)
- renting out (if no valid EPC is available)
- new building construction
- major building renovation
- other (e.g., the interest of the building owner in improving the energy performance of the building)

The reference for the above triggering points is drawn from Article 12/1 of the EPBD (2018/844), which states the following "Member States shall ensure that an energy performance certificate is issued for: (a) buildings or building units which are constructed, sold or rented out to a new tenant, and (b) large public buildings". In Article 17 of the proposed recast EPBD, this is extended to "buildings undergoing a major renovation, buildings for which a rental contract is renewed, and all public buildings".

The different EPC calculation methods developed in the ePANACEA project will have a different response to the identified trigger points in each Member State due to factors such as public acceptance, real estate needs, market interests, investments, the state of the EPC system, etc. These trigger points are used for calculating the number of annually issued EPCs until 2030 using the historical data of issued EPCs (2014-2019) for calibration of the approach in five ePANACEA target countries. The number of EPC end-users potentially interested in a certain method was determined by estimating the share of interested end-users per trigger point and method, tenants being interested in triggering point 'change of tenant', homeowners in 'real estate transactions', and method 3, while the triggering points 'new buildings' and 'renovated buildings' are mostly interesting for housing associations. For the 2030 projection, the assumption was that the number of tenants, real estate transactions, and new building constructions follow the same linear trend as in the past ten years.

2.4. Calculating the number of issued EPCs in different scenarios

For each country and considered year, the following equations were applied to estimate the number of annually issued EPCs (E)

$$E = E_{tenant} + E_{sales} + E_{new} + E_{reno} + E_{other}$$

with

E – number of annually issued EPCs

E_{tenant} – number of annually issued EPCs triggered through the change of a tenant

E_{sales} – number of annually issued EPCs triggered through the sale of a property (real estate transaction)

E_{renov} – number of annually issued EPCs triggered through building renovation

E_{other} – number of annually issued EPCs triggered through other occasions, e.g., the need for advice for renovating the building

In the case of rented single-family houses or that in a certain country, an EPC needs to be issued for each apartment of an apartment building, E_{tenant_1} applies:

Under the assumption that $T_{contract} > T_{EPC}$, $E_{tenant\_1} = \frac{n_{tenant}}{T_{contract}}$

Whereas, for apartment buildings in countries where for these buildings only one EPC needs to be issued, E_{tenant_2} applies:

Under the assumption that $T_{contract} > T_{EPC}$, $E_{tenant\_2} = \frac{n_{tenant}}{n_{dwell}(T_{EPC}+\varepsilon)}$

with

$T_{contract}$ – average duration of Tenancy contracts

T_{EPC} – validity period of EPCs

n_{tenant} – total number of rented dwellings and non-residential buildings

$n_{dwelling}$ – the average number of dwellings per building

ε – factor, considering the deviation of changing tenants and the validity of EPCs over time; assumed to be 20% of the validity period of EPCs

For the other trigger points j, the following equation is applied:

$$E_j = \sum_i n_{j,i} \cdot f_{j,i}$$

$n_{j,i}$ – number of trigger points (i.e., number of dwellings and non-residential buildings being sold (excluding new buildings, buildings being constructed, buildings being renovated, or other)) in building category i

$f_{j,i}$ – correction factor, considering, e.g., that some non-residential buildings might not need an EPC or that for apartment buildings in some countries, only one EPC per building needs to be issued

The number of EPC end-users potentially interested in a certain ePANACEA method k (E_k^*) was determined by estimating the share of interested end-users per trigger point j and method k ($s_{j,k}$)[2] in certain ranges. However, method 3 was applied only to the homeowners in owner occupied dwellings, which are represented mainly by the trigger point “real estate transactions”. The main rational for this assumption was that only these homeowners are sufficiently interested in receiving detailed information as available in method 3. Subsequently, the number of potentially interested EPC end-users is estimated by the following equation:

[2] See Table 1

$$E_k^* = \sum_j E_{j,k} \cdot s_{j,k}$$

For the 2030 projection, it was assumed that the number of tenants, real estate transactions, and new building constructions follow the same linear trend as in the past ten years, while all the factors specified above remain the same. For the number of renovated buildings, we assumed a doubling of the number from the period 2015-2019. In addition to the renovated buildings, it is assumed that another 50% of building owners are interested in receiving advice for building renovation (i.e., the trigger point "other"). Overall, a strong increase in building renovation activities, moving towards the targets of the fit-for-55 package is assumed (in consistency with the scenarios presented in chapter 4.2 and related policy targets).

Table 1: Quantitative summary – Relevance of trigger points for each method; assumptions regarding the share of EPC end-users for which the method might be interesting in different trigger points

	Change of tenant	Real estate transaction	New building construction	Building retrofitting (mandatory or not)	Other, in particular, general interest in the potential improvement of building energy performance
Method 1 and 2	20%-40%	20%-40%	80%-100%	40%-60%	40%-60%
Method 3	-	40%-80%	-	-	40%-80%

Table 1 shows the assumed ranges of the share of EPC end-users for which the corresponding method might be interesting. We want to emphasize, that this implies that persons deciding on a certain method understand and know the difference between the methods, which would require a correspondingly clear communication concept.

3. DEFINING FUTURE EPC PATHWAYS

The ePANACEA project focuses on innovative energy performance assessment of buildings. During Regional Board Meetings, workshops with end-users, and bilateral exchange with experts, several challenges and gaps in energy assessment and calculation procedures were identified, which include concerns about the quality of required data, the time and intensity of input data for energy performance calculation, and the use of dynamic or static models, which vary among countries. Harmonizing energy performance indicators is crucial, but there is no common approach currently discussed across all countries regarding dynamic building simulation, calibration methods, measurement data usage, actual building operation data, or the inclusion of energy consumption data.

The validity of EPCs is seen as a trigger for their issuance, and it is considered counterproductive to have a long validity period since, e.g., an old EPC might not be comparable to a new EPC if the rating system was updated. If the validity is extended, there may be no incentive for improving a building's energy performance or updating the EPC. It is recommended that EU Member States allow free updates of EPCs for buildings that achieve a certain level of CO_2 emissions reduction or energy savings through energy efficiency measures. Building owners, particularly of single-family houses, should be able to update the document without incurring additional fees. This approach aims to maintain the EPC as a dynamic document that is regularly updated, as opposed to the current situation where EPCs often remain outdated for extended periods. While the general validity of EPCs in all countries is ten years, a proposal has been made to reduce the validity period, especially for poorly rated buildings (class G), as seen in Spain, where it has been reduced to 5 years.

The ownership status of a building or unit affects the frequency of EPC updates. Dynamic updates are easier for EPCs related to real estate transactions (sale or rental) compared to EPCs for owner-occupied dwellings. Countries with high ownership rates, such as Finland (63%) and Spain (77%), are facing challenges in keeping EPCs up to date. In Finland, where most people live in owner-occupied apartments, decisions on renovations require agreement among all parties involved, potentially preventing/ delaying renovation and causing EPCs to remain outdated for longer periods. Spain, on the other hand, has a higher percentage of people living in multi-family houses (70%), and it is possible to issue EPCs for individual apartments.

Regarding EPC recommendations, they potentially can play a crucial role in achieving building stock decarbonization targets. Currently, recommendations are generally provided in a standardized and generic form across countries. The accuracy of recommendations depends on available building-related information, which is gathered through on-site visits in most implementing countries. However, mandatory on-site visits and complex calculations can impact EPC costs. Balancing accurate and specific recommendations with standardized ones is a trade-off. Three types of recommendations were analysed for future perspectives: policy-tailored (linked to long-term renovation strategies with a focus on carbon emission reduction), end-user-tailored (considering user behaviour), and staged renovation recommendations or building renovation roadmaps (part of building renovation passports). The last type has the highest chance of implementation across all countries. Policy-tailored recommendations are implemented in Flanders, while only end-user-tailored recommendations are provided in Styria (Austria). The availability of incentives, such as accessing incentives in Greece, Austria, and Spain, is often linked to having an EPC as a mandatory document.

Quality assurance and control routines are crucial for ensuring accurate and reliable Energy Performance Certificates (EPCs). These routines involve feedback interactions with energy auditors and EPC issuers to correct any mistakes and prevent their repetition, thus enhancing the reliability of EPCs. All countries implement quality control routines as required by the Energy Performance of Buildings Directive (EPBD), but penalties for non-compliance are not consistently enforced. There is a need to link quality control with expert training to improve the learning process and avoid recurring errors, leading to long-term improvement in the quality and reliability of EPCs.

While studies acknowledge the importance of end-users in building renovation, EPCs have predominantly focused on technical aspects, potentially making them more complex. Therefore, there is a need to develop new indicators and information targeted towards end-users. The ePANACEA project organized workshops to understand end-user's perception and awareness of

EPCs. In many countries where EPCs are mandatory, end-users may accept the EPCs without interacting with or fully understanding them. To address this, increased public communication, campaigns, advertisements, and workshops are essential, with Spain implementing numerous strategies in this direction outlined in the Long-Term Renovation Strategies (LTRS).

An important aspect is exploring possible pathways and dimensions for the future development of EPC schemes, intending to contribute to building stock decarbonization. The decarbonization of the building sector involves various actors, such as building end-users, owners, public authorities, craftsmen, and installers. It is important to define the target group when formulating policy scenarios. External conditions like policy settings and market structures also influence the evolution of EPCs, including the choice between keeping them mandatory or market-regulated.

Currently, EPCs are mandatory for real estate transactions and new buildings, but this approach lacks a market-oriented trigger to drive end-user interest. The market penetration of EPCs can be increased through various scenarios (based on the ePANACEA report "Pathways of EPC related policy framework"):

Scenario A: EPC remains strongly/exclusively underlined on the political framework (status quo)

- EPC remains mandatory for some purposes: for instance, for new buildings and deep renovation
- Regulated under the EPBD
- Active rule of public authorities to stimulate the increase of EPC penetration through incentives, instrument design, dialogue with relevant stakeholders, etc.

Scenario B: EPC remains underlined on the political framework, however with market-driven elements

- Hybrid pathway: policy-based instrument with some market-driven elements
- Scenario B reduces the validity of EPCs for the worst-performing buildings to 5 years, while for other buildings, the validity remains ten years.
- ePANACEA methods 1 and 2 would be suitable methods under scenario B.

Scenario C: EPC issuing is strongly impacted by market-driven elements

- The validity of EPC remains 10 years only if the building has an A or B label, otherwise, the validity is reduced to 5 years (Scenario C.1)
- Scenario C.2 introduces a general validity of EPCs of 5 years and requires EPCs to be updated whenever the validity time is reached, not only in case a triggering point is reached.
- Advanced" EPCs with more functionalities and features (but also higher prices), are introduced (ePANACEA method 3)
    - End-user tailored solutions
    - More complex/accurate calculation methodologies

During the ePANACEA project, workshops were conducted with end-users to discuss their acceptance and perception of Energy Performance Certificates (EPCs). Generally, end-users have a passive attitude towards EPCs because they view them as mandatory documents rather than reliable sources of information. The workshops explored ways to make the layout of the EPC document more user-friendly to enhance acceptance. However, increased acceptance does not necessarily have to lead to behavioural change, such as actively using EPCs to initiate energy efficiency measures or considering them in decision-making regarding the purchase or rental of a property. Thus, it was not possible to derive a quantitative causality between the EPC design, the calculation methodology, and the expected energy savings.[3]

An improved layout and design of EPCs, which is more appealing, understandable etc. is expected to positively influence the uptake of renovation measures. However, at the same time, the influence of the EPC design on the number of issued EPCs would be negligible, except for the trigger point "interest of the building owner in improving the energy performance of the building.

[3] Schweizer-Ries et al. (2010) define acceptance as the positive outcome of an evaluation process that can be accompanied by an intention to act. Often, there is a gap between behavioral intention and actual behavior, also regarding energy issues: e.g., https://www.sciencedirect.com/science/article/abs/pii/S0973082612000701

4. PATHWAYS RESULTS

In this chapter, based on the methods and considerations described above, we show two types of pathways results: first, scenarios for the number of issued EPCs (chapter 4.1), indicating the potential uptake of different ePANACEA methods for calculating energy demand in EPCs; and second, scenarios for the uptake of energy efficiency measures in the building stock of ePANACEA countries and remaining EU-27 Member States (chapter 4.2).

4.1. Scenarios for the number of issued EPCs

In this chapter, we show the results for the number of issued EPCs by triggering point, as explained in the methodology section above. Based on these different trigger points, we derive the potential relevance of different ePANACEA methods. While scenario A serves as a reference baseline scenario, scenario B shows the potential relevance of ePANACEA methods 1 and 2. Scenarios C.1 and C.2 indicate the potential uptake of method 3.

Figure 5 shows the total number of annually issued EPCs by the different trigger points in all ePANACEA countries (Austria, Belgium, Finland, Greece, and Spain) and for different scenarios until 2030: scenario A, scenario B, scenario C.1, and scenario C.2.

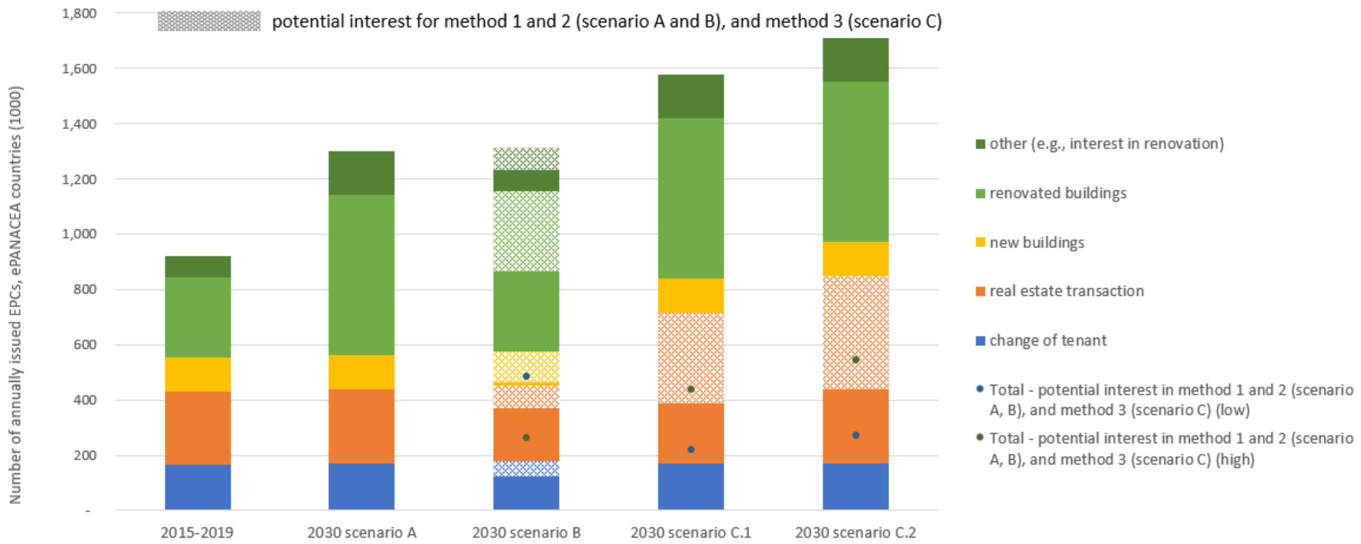

Figure 5: Number of annually issued EPCs by triggering points and the estimated share of potentially interested EPC end-users, a total of ePANACEA countries (Scenario A, B, and C). Historical data 2015-2019, projection until 2030.

In the period 2015-2019, close to a million EPCs were annually issued. The largest part of those results from building renovation, followed by real estate transactions (sell or buy), while EPCs, due to the change of tenant and new building construction, according to our data and the chosen assumptions, have lower numbers. The bar '2030 scenario A' shows projections to 2030, based on the available data from the period 2015-2019, assuming that the validity of EPCs is ten years. There is approximately a 2% increase in the number of issued EPCs for each triggering point. In shaded colours, the figure shows the number of EPC end-users who potentially show special interest in ePANACEA methods 1, 2, and 3 (presented in Chapter 2.2), according to the factors determined in Table 1. The total number of interested EPC end-users for all trigger points (presented in Chapter 2.3) within ePANACEA target countries is estimated to be around 0.25 to 0.50 million in the year 2030, which is indicated by the dots. The bandwidth (low-high) results from two factors: (1) The potential interest of EPC end-users was assigned by categories, each representing a range, such as 20-40% of EPC end-users are estimated to be interested, and

(2) the interest may differ significantly between the buyer and the seller, in particular in case a building does not perform very well (e.g., the building has a low energy class) according to a certain indicator. Thus, for the "lower" case, we assumed the lower value of interest (typically the interest of the seller), whereas, for the "higher" case, we considered a higher value (typically representing the interest of the buyer).

Scenario B reduces the validity of EPCs for the worst-performing buildings to 5 years (this assumption is also in line with the current recast of the EPBD), while for other buildings, the validity remains ten years. According to our calculation, the share of worst-performing buildings is 15-16%, thus, the average validity of EPCs is reduced to roughly nine years. In bar '2030 scenario B', we see a 6.5% increase in the number of EPCs related to the triggering point change of tenant, which is the only difference from scenario A. For the triggering point real-estate transactions, our initial assumption was that the real estate objects take longer than ten years to be sold; therefore, there is no need to issue a new EPC. This means that the shorter validity of EPC would not affect this triggering point. Since for new and renovated buildings, we assume that there are no worst-performing buildings among those, the validity would not affect these EPC issuing.

Scenario C introduces method 3 and further strengthening of EPC-related policies, such as the reduction of the validity of EPCs to 5 years for all buildings except those of EPC labels A and B. According to our calculations, the overall validity is set to be 5.4 years on average. Method 3 is relevant for homeowners, so the method is only applied to the number of EPCs related to triggering point real-estate transactions (sell or buy transaction). In bar '2030 scenario C.1', we see a higher total number of EPCs in ePANACEA countries, close to 1.6 million EPCs. The number of EPCs issued through real estate transactions is 102% higher in Scenario C.1 than in Scenario A.

We introduced scenario C.2, shown in the last bar, to further explore the effect of reduced validity time of EPCs. Scenario C.2 introduces a general validity of EPCs of 5 years and requires EPCs to be updated whenever the validity time is reached, not only in case a triggering point is reached. This scenario increased the overall number of EPCs even further, to around 1.7 million, which is 8.3% more EPCs than in Scenario C.1. The potential interest for method 3, and the number of EPCs triggered by the real-estate transactions increased 24% compared to the Scenario C.1.

Table 2: Estimated number of EPCs for each ePANACEA country based on method 3 for 2030

	Austria	**Belgium**	**Finland**	**Greece**	**Spain**
Real estate transactions Scenario C.1	5,286	27,496	19,169	15,899	96,477
Real estate transactions Scenario C.2	6,103	32,604	21,565	19,405	124,042

4.1.1. Austria

Figure 6 shows the number of annually issued EPCs by the different trigger points in Austria. In the period 2015-2019, close to 50 thousand EPCs were issued annually. The largest part of those results from the change of tenant, followed by new building construction, while real estate transaction and building renovation EPCs have lower numbers according to our data and the chosen assumptions.

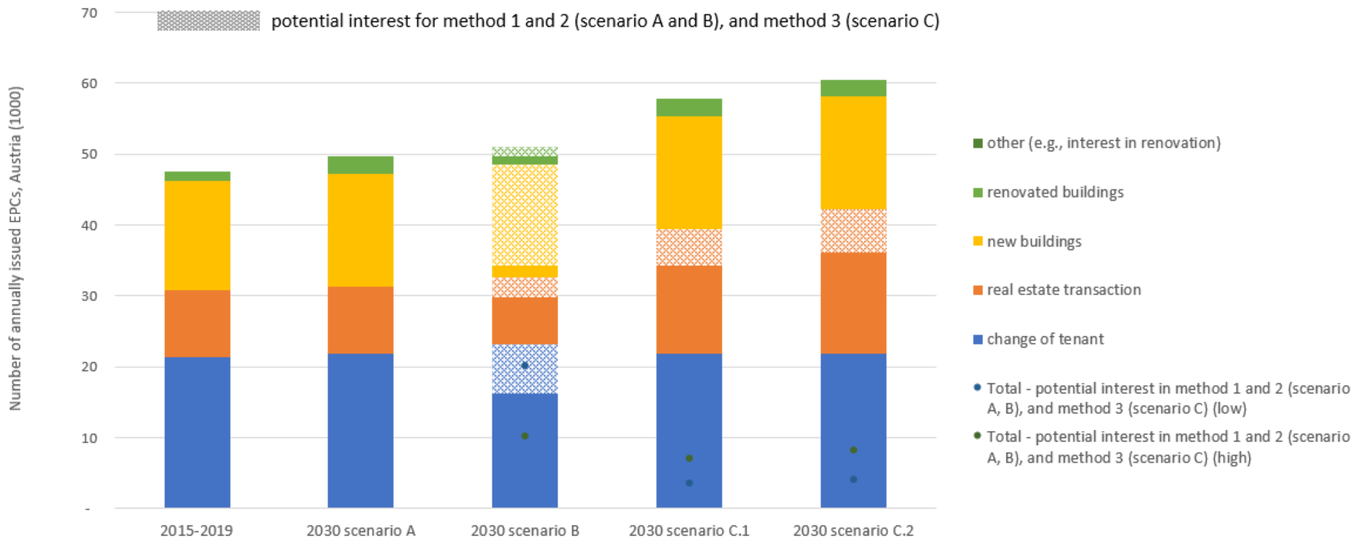

Figure 6: Number of annually issued EPCs by triggering points and the estimated share of potentially interested EPC end-users, a total of Austria (Scenario A, B, and C). Historical data 2015-2019, projection until 2030.

The bar '2030 scenario A' shows projections to 2030, based on the available data from the period 2015-2019, assuming that the validity of EPCs is ten years. There is approximately a 2% increase in the number of issued EPCs for each triggering point. In shaded colours, the figure shows the share of EPC end-users who potentially show special interest in methods 1, 2, and 3, according to the factors determined in Table 1. A high relevance is assumed, in particular, for new building construction, as seen in the bar '2030 scenario B'. The total number of interested EPC end-users for all trigger points within ePANACEA target countries is estimated to be around 10 to 20 thousand in the year 2030, which is indicated by the dots.

In bar '2030 scenario B', we see a 6.1% increase in the number of EPCs related to the triggering point change of tenant, which is the only difference from scenario A.

Scenario C introduces method 3 and further strengthening of EPC-related policies, such as the reduction of the validity of EPCs to 5 years for all buildings except those of EPC labels A and B. According to our calculations, the overall validity is set to be 5.5 years on average. Method 3 is relevant for homeowners, so the method is only applied to the number of EPCs related to triggering point real-estate transactions (buy/sell). In bar '2030 scenario C.1', we see a higher total number of EPCs in Austria, close to 60 thousand EPCs. The number of EPCs issued through real estate transactions is 86% higher in Scenario C.1 than in Scenario A.

We introduced scenario C.2, shown in the last bar, to further explore the effect of reduced validity of EPCs. This time, we set the validity to be five years for all the buildings. This scenario increased the overall number of EPCs even further, to around 60.5 thousand, which is 4.7% more EPCs than in the Scenario C.1. The potential interest for method 3, and the number of EPCs triggered by the real-estate transactions increased 15.4% compared to the Scenario C.1.

4.1.2. Belgium

Figure 7 shows the number of annually issued EPCs by the different trigger points in Belgium. In the period 2015-2019, around 220 thousand EPCs were issued annually. The largest part of those results from real estate transactions, followed by change of tenant, while new building construction and renovation EPCs have lower numbers according to our data and the chosen assumptions. The bar '2030 scenario A' shows projections to 2030, based on the available data from the period 2015-2019, assuming that the validity of EPCs is ten years. There is approximately a 2% increase in the number of issued EPCs for each triggering point.

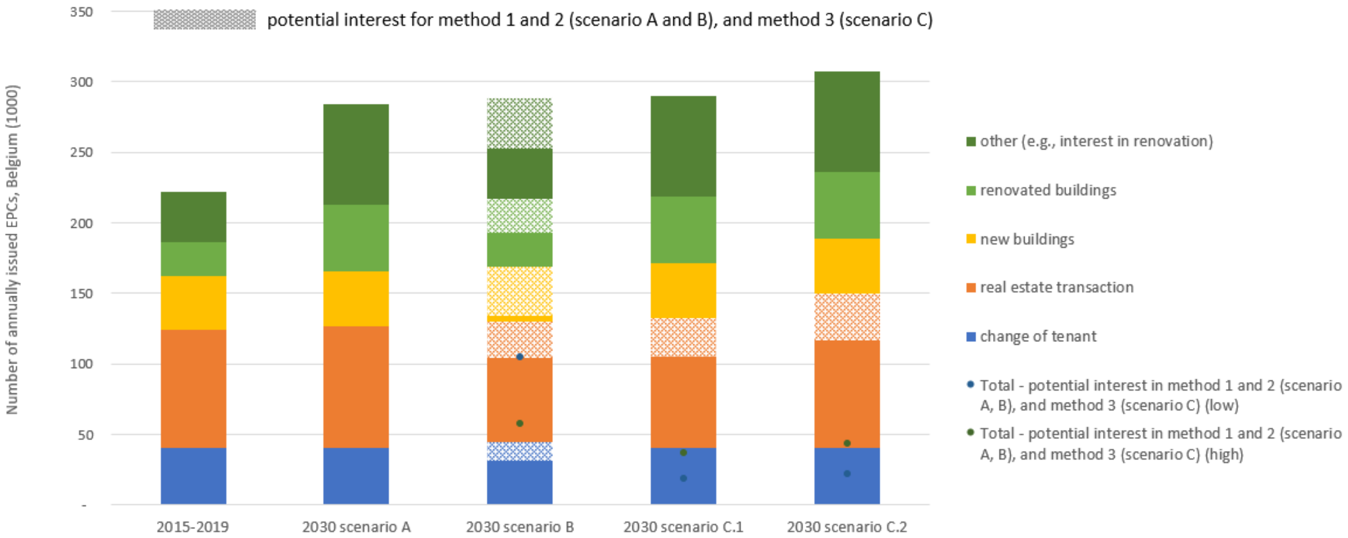

Figure 7: Number of annually issued EPCs by triggering points and the estimated share of potentially interested EPC end-users, a total of Belgium (Scenario A, B, and C). Historical data 2015-2019, projection until 2030.

In shaded colours, the figure shows the share of EPC end-users who potentially show special interest in methods 1, 2, and 3, according to the factors determined in Table 1. A high relevance is assumed, in particular, for new building construction, as seen in the bar '2030 scenario B'. The total number of interested EPC end-users for all trigger points within ePANACEA target countries is estimated to be around 60 to 105 thousand in the year 2030, which is indicated by the dots.

In bar '2030 scenario B', we see a 6.6% increase in the number of EPCs related to the triggering point change of tenant, which is the only difference from scenario A.

Scenario C introduces method 3 and further strengthening of EPC-related policies, such as the reduction of the validity of EPCs to 5 years for all buildings except those of EPC labels A and B. According to our calculations, the overall validity is set to be 5.8 years on average. Method 3 is relevant for homeowners, so the method is only applied to the number of EPCs related to triggering point real-estate transactions (buy/sell). In bar '2030 scenario C.1', we see a higher total number of EPCs in Belgium, around 290 thousand EPCs. The number of EPCs issued through real estate transactions is 7% higher in Scenario C.1 than in Scenario A.

We introduced scenario C.2, shown in the last bar, to further explore the effect of reduced validity of EPCs. This time, we set the validity to be five years for all the buildings. This scenario increased the overall number of EPCs even further, close to 310 thousand, which is 5.9% more EPCs than in the Scenario C.1. The potential interest for method 3, and the number of EPCs triggered by the real-estate transactions increased 18.6% compared to the Scenario C.1.

4.1.3. Finland

Figure 8 shows the number of annually issued EPCs by the different trigger points in Finland. In the period 2015-2019, around 75 thousand EPCs were issued annually. The largest part of those results from real estate transactions (sell/buy), while EPCs, due to the change of tenant, new building construction, and building renovation have lower numbers according to our data and the chosen assumptions. The bar '2030 scenario A' shows projections to 2030, based on the available data from the period 2015-2019, assuming that the validity of EPCs is ten years. There is approximately a 2% increase in the number of issued EPCs for each triggering point.

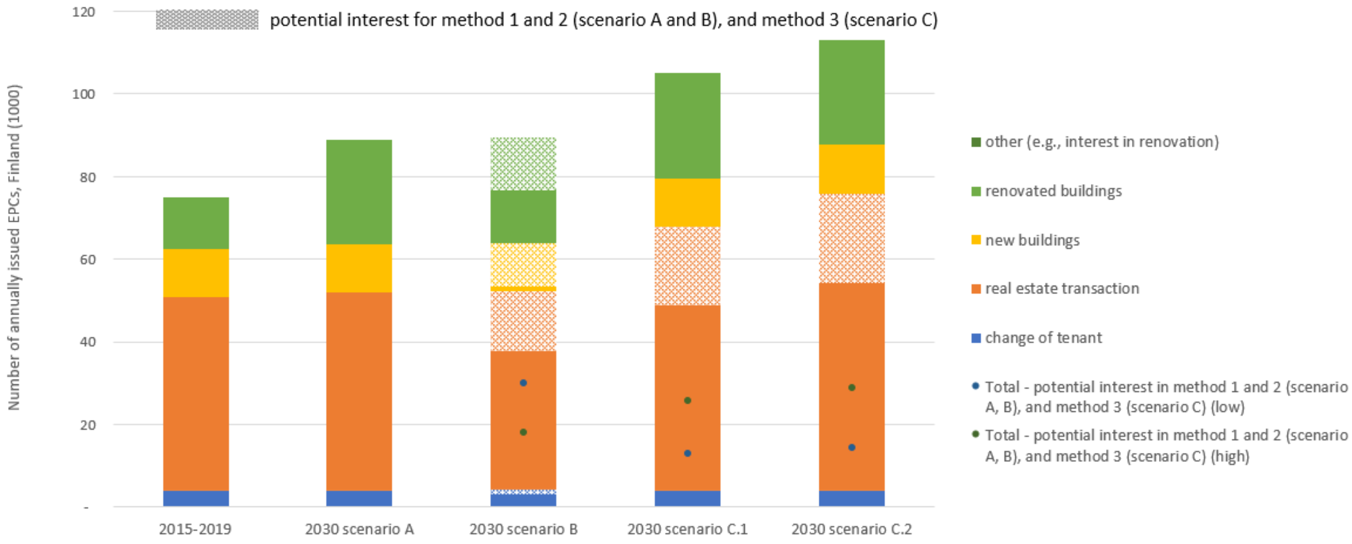

Figure 8: Number of annually issued EPCs by triggering points and the estimated share of potentially interested EPC end-users, a total of Finland (Scenario A, B, and C). Historical data 2015-2019, projection until 2030.

In shaded colours, the figure shows the share of EPC end-users who potentially show special interest in methods 1, 2, and 3, according to the factors determined in Table 1. A high relevance is assumed, in particular, for real estate transactions, as seen in the bar '2030 scenario B'. The total number of interested EPC end-users for all trigger points within ePANACEA target countries is estimated to be around 18 to 30 thousand in the year 2030, which is indicated by the dots.

In bar '2030 scenario B', we see an 8.7% increase in the number of EPCs related to the triggering point change of tenant, which is the only difference from scenario A.

Scenario C introduces method 3 and further strengthening of EPC-related policies, such as the reduction of the validity of EPCs to 5 years for all buildings except those of EPC labels A and B. According to our calculations, the overall validity is set to be 5.5 years on average. Method 3 is relevant for homeowners, so the method is only applied to the number of EPCs related to triggering point real-estate transactions. In bar '2030 scenario C.1', we see a higher total number of EPCs in Finland, around 105 thousand EPCs. The number of EPCs issued through real estate transactions is 33% higher in Scenario C.1 than in Scenario A.

We introduced scenario C.2, shown in the last bar, to further explore the effect of reduced validity of EPCs. This time, we set the validity to be five years for all the buildings. This scenario increased the overall number of EPCs even further, close to 113 thousand, which is 7.6% more EPCs than in the Scenario C.1. The potential interest for method 3, and the number of EPCs triggered by the real-estate transactions increased 12.5% compared to the Scenario C.1.

4.1.4. Greece

Figure 9Figure 8 shows the number of annually issued EPCs by the different trigger points in Greece. In the period 2015-2019, close to 135 thousand EPCs were issued annually. The largest part of those results from change of tenant and real estate transactions, while new building construction and renovation EPCs, have lower numbers according to our data and the chosen assumptions. The bar '2030 scenario A' shows projections to 2030, based on the available data from the period 2015-2019, assuming that the validity of EPCs is ten years. There is approximately a 2% increase in the number of issued EPCs for each triggering point.

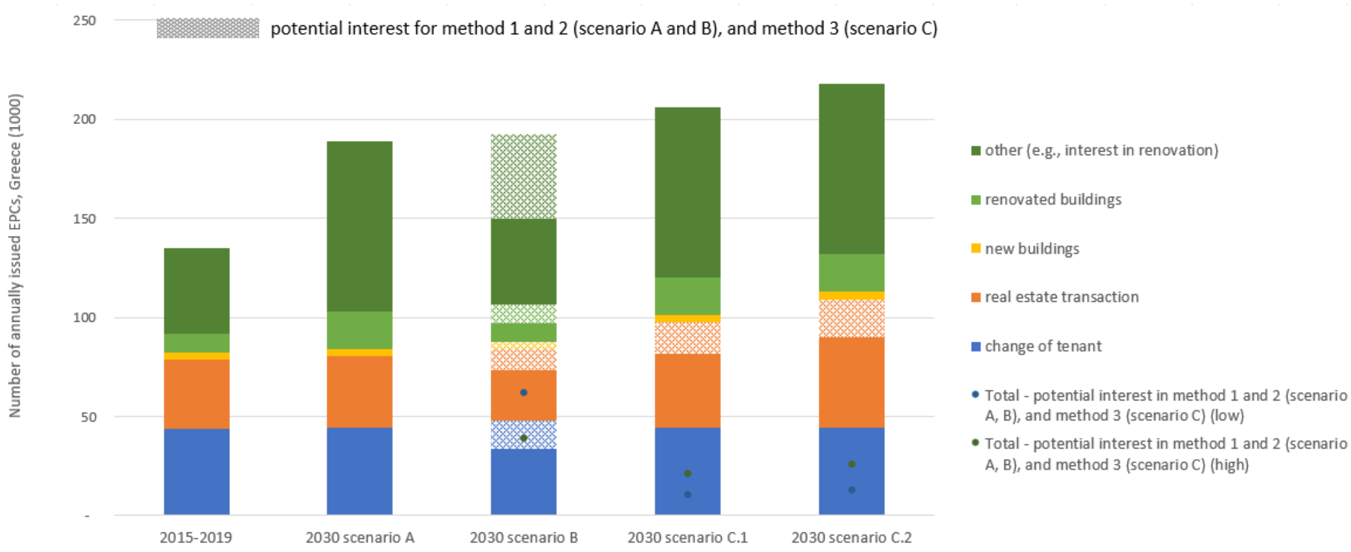

Figure 9: Number of annually issued EPCs by triggering points and the estimated share of potentially interested EPC end-users, a total of Greece (Scenario A, B, and C). Historical data 2015-2019, projection until 2030.

In shaded colours, the figure shows the share of EPC end-users who potentially show special interest in methods 1, 2, and 3, according to the factors determined in Table 1. A high relevance is assumed, in particular, for other triggering points, such as interest in renovation, as seen in the bar '2030 scenario B'. The total number of interested EPC end-users for all trigger points within ePANACEA target countries is estimated to be around 40 to 60 thousand in the year 2030, which is indicated by the dots.

In bar '2030 scenario B', we see an 8.2% increase in the number of EPCs related to the triggering point change of tenant, which is the only difference from scenario A.

Scenario C introduces method 3 and further strengthening of EPC-related policies, such as the reduction of the validity of EPCs to 5 years for all buildings except those of EPC labels A and B. According to our calculations, the overall validity is set to be 5.2 years on average. Method 3 is relevant for homeowners, so the method is only applied to the number of EPCs related to triggering point real-estate transactions. In bar '2030 scenario C.1', we see a higher total number of EPCs in Greece, around 205 thousand EPCs. The number of EPCs issued through real estate transactions is 48% higher in Scenario C.1 than in Scenario A.

We introduced scenario C.2, shown in the last bar, to further explore the effect of reduced validity of EPCs. This time, we set the validity to be five years for all the buildings. This scenario increased the overall number of EPCs even further, close to 218 thousand, which is 5.7% more EPCs than in the Scenario C.1. The potential interest for method 3 and the number of EPCs triggered by the real-estate transactions increased 22% compared to the Scenario C.1.

4.1.5. Spain

Figure 10Figure 9Figure 8 shows the number of annually issued EPCs by the different trigger points in Spain. In the period 2015-2019, around 440 thousand EPCs were issued annually. The largest part of those results from building renovation, while, the change of tenant, real estate transaction, and building renovation EPCs have lower numbers, according to our data and the chosen assumptions. The bar '2030 scenario A' shows projections to 2030, based on the available data from the period 2015-2019, assuming that the validity of EPCs is ten years. There is approximately a 2% increase in the number of issued EPCs for each triggering point.

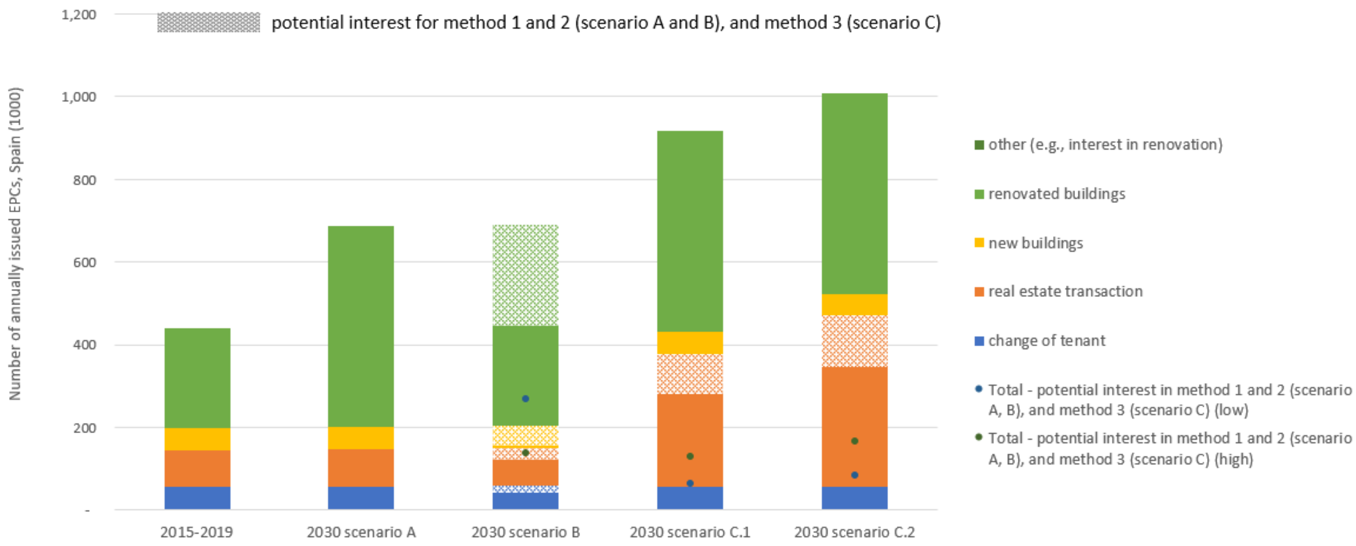

Figure 10: Number of annually issued EPCs by triggering points and the estimated share of potentially interested EPC end-users, a total of Spain (Scenario A, B, and C). Historical data 2015-2019, projection until 2030.

In shaded colours, the figure shows the share of EPC end-users who potentially show special interest in methods 1, 2, and 3, according to the factors determined in Table 1. A high relevance is assumed, in particular, for building renovation, as seen in the bar '2030 scenario B'. The total number of interested EPC end-users for all trigger points within ePANACEA target countries is estimated to be around 136 to 265 thousand in the year 2030, which is indicated by the dots.

In bar '2030 scenario B', we see a 3.6% increase in the number of EPCs related to the triggering point change of tenant, which is the only difference from scenario A. The number of EPCs issued through real estate transactions is 250% higher in Scenario C.1 than in Scenario A.

Scenario C introduces method 3 and further strengthening of EPC-related policies, such as the reduction of the validity of EPCs to 5 years for all buildings except those of EPC labels A and B. According to our calculations, the overall validity is set to be 5.15 years on average. Method 3 is relevant for homeowners, so the method is only applied to the number of EPCs related to triggering point real-estate transactions. In bar '2030 scenario C.1', we see a higher total number of EPCs in Spain, close to 920 thousand EPCs.

We introduced scenario C.2, shown in the last bar, to further explore the effect of reduced validity of EPCs. This time, we set the validity to be five years for all the buildings. This scenario increased the overall number of EPCs even further, around a million, which is 10% more EPCs than in the Scenario C.1. The potential interest for method 3 and the number of EPCs triggered by the real-estate transactions increased 28.6% compared to the Scenario C.1.

4.2. Decarbonising the EU building stock

This chapter shows decarbonisation scenarios of the building stock in EU-27 MS and selected ePANACEA countries. We present the final energy demand by energy carrier, energy savings, investments, and renovation activities. Methods and scenario design are described in Chapter 2 and Chapter 3.

Since all scenarios are designed as decarbonisation scenarios, a broad policy package is required to achieve them, including economic incentives (such as CO_2 prices and/or taxes), regulatory instruments (e.g., minimum energy performance standards for existing buildings such as under discussion in the EPBD recast[4]), training and information, coaching of building owners during the renovation process and – last but not least – improved EPCs. The role of EPCs in this process should be understood as one key element in the overall package of policy instruments that cannot be isolated. Still, the range of scenario results and achieved energy savings give an impression of the ambition level that is required and to which innovative EPC calculation methods such as the one developed within the ePANACEA project contribute. The following figures show the final energy demand by energy carrier in the different scenarios in the base year (2020), for 2030 and 2050 for EU-27 (Figure 11), and for the ePANACEA countries (Figure 12 to Figure 14). All scenarios are characterized by a significant reduction of the final energy demand of about 30% in the moderate efficiency scenario from 2020-2050, more than 35% in high-efficiency scenarios, and more than 40% in the high-efficiency lifestyle scenario. However, subtracting ambient and solar energy, i.e., only considering energy delivered to the buildings, the reduction of energy demand is even higher – around 50% in moderate efficiency scenarios, more than 55% in high-efficiency scenarios, and more than 60% in the high-efficiency-lifestyle scenario. This shows the high relevance of heat pump uptake (and thus the increasing contribution of ambient heat to the energy mix) in all scenarios, not only in the high-electrification case. Also, the share of district heating increases in all scenarios, in the high-district heating scenarios, it increases even up to about one-quarter of final energy demand. The share of gases strongly reduces, even in the H2/e-fuel scenarios, because decarbonised, renewable H2 and e-fuels turn out to be more expensive than other renewable heat supply options. The reduction of biomass in this scenario is mainly driven by exogenous settings regarding the allocation of biomass to different sectors and the assumption that biomass will be used more urgently for decarbonising other sectors rather than for low-temperature heating purposes.

The country charts show differences in the impact of energy-saving measures in the different countries. In particular, FI, ES, and GR result in a lower reduction in final energy demand than the average of EU-27. For FI, this is because of the earlier introduction of stringent building codes and efficiency measures, which leave less room for efficiency improvement compared to other countries. For ES and GR, the comparably mild winters lead to the fact that the energy-saving potentials from building envelope renovation are lower. Having said this, it becomes evident that the potential contribution of ambient heat through heat pumps and solar energy is especially high in these two countries, leading to a potentially even higher reduction of delivered energy in these two countries. The role of district heating is strongly affected by current infrastructure (such as in AT and FI). The cases of ES and GR show that ambitious district heating support policies, in particular spatial energy planning and zoning measures, can reduce the costs of district heating and thus unleash a high potential, even in countries with mild climates (ES, GR), but sufficiently densely populated areas allowing for efficient district heating systems.

[4] Status August 2023

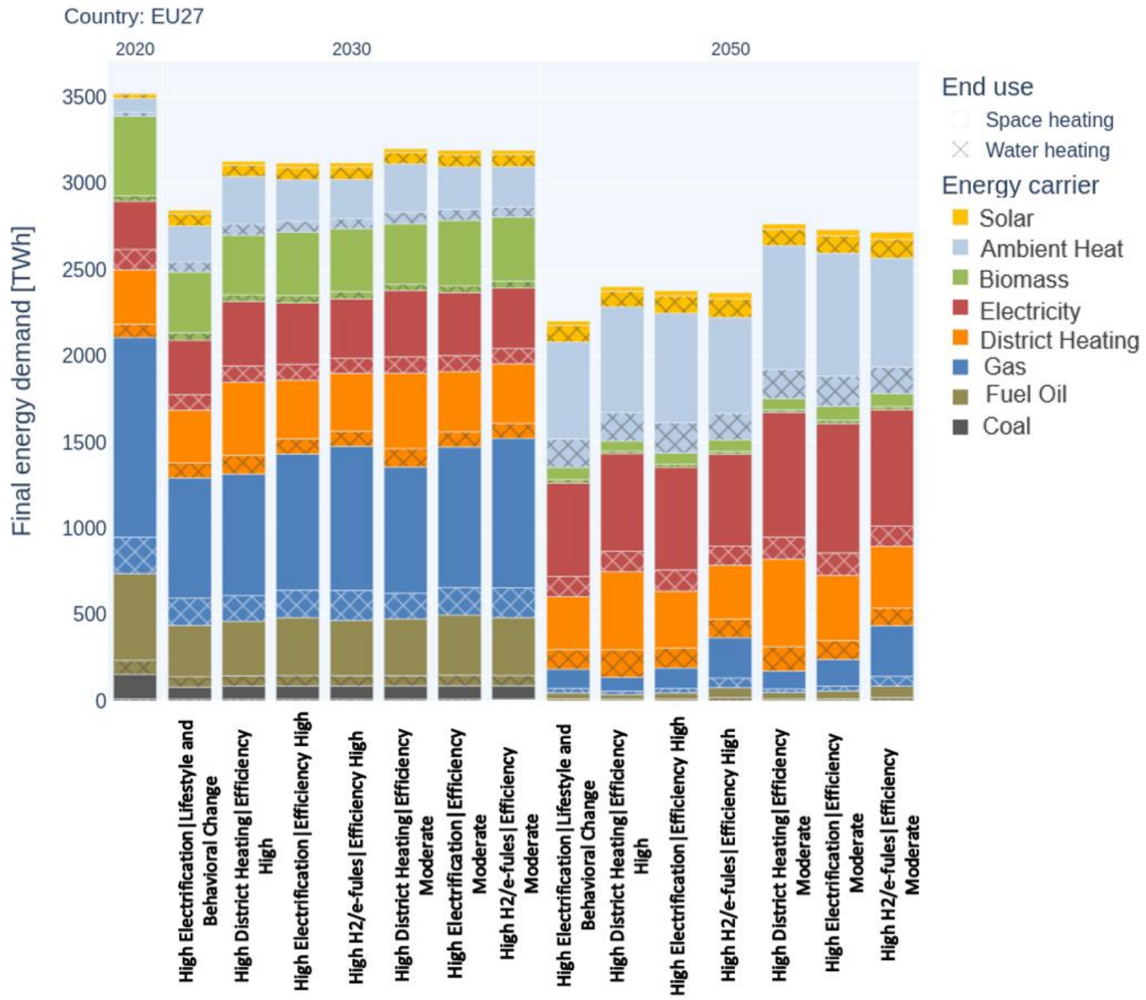

Figure 11: Final energy demand by energy carrier for space and water heating (EU-27)

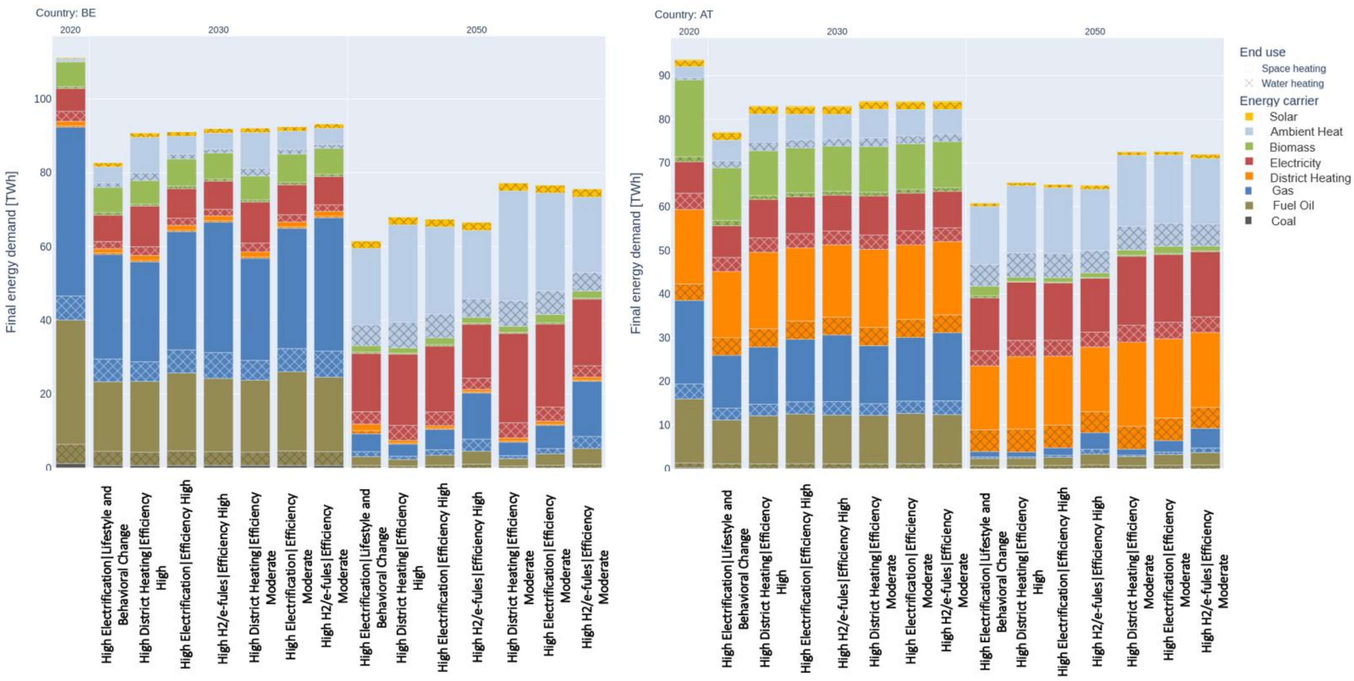

Figure 12: Final energy demand by energy carrier for space and water heating, BE (left) and AT (right)

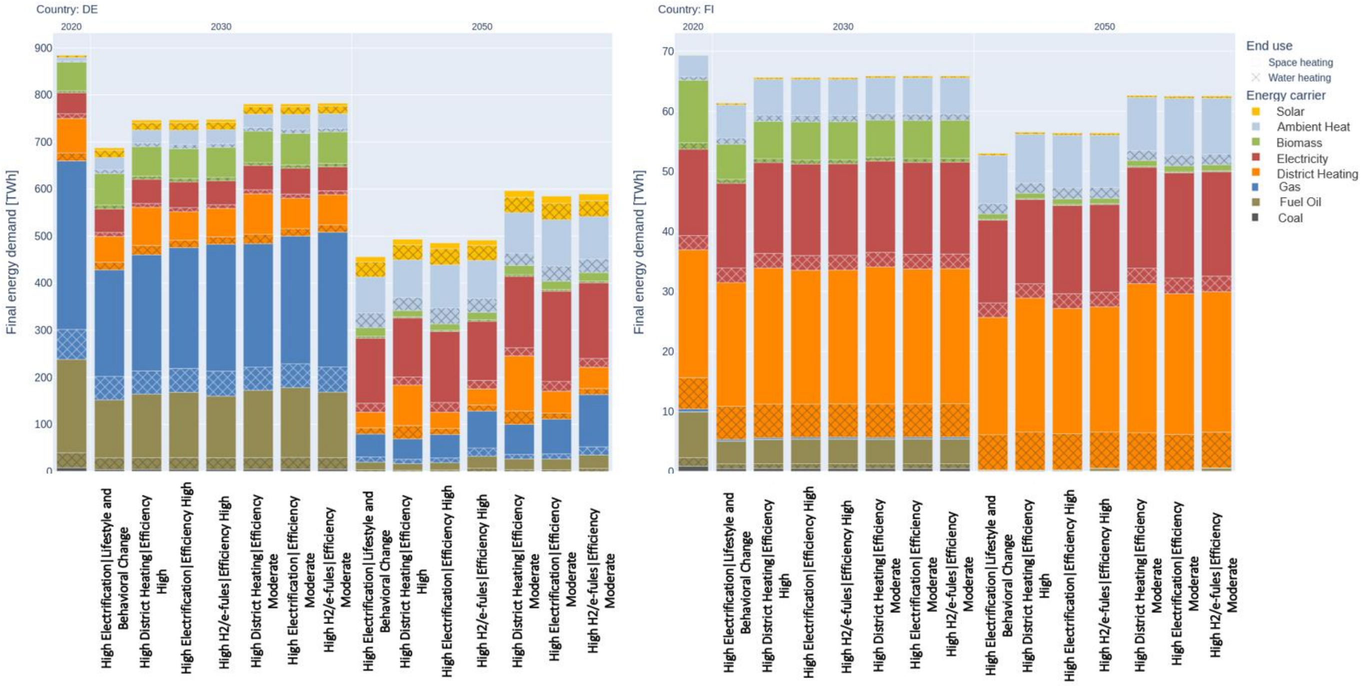

Figure 13: Final energy demand by energy carrier for space and water heating, DE (left) and FI (right)

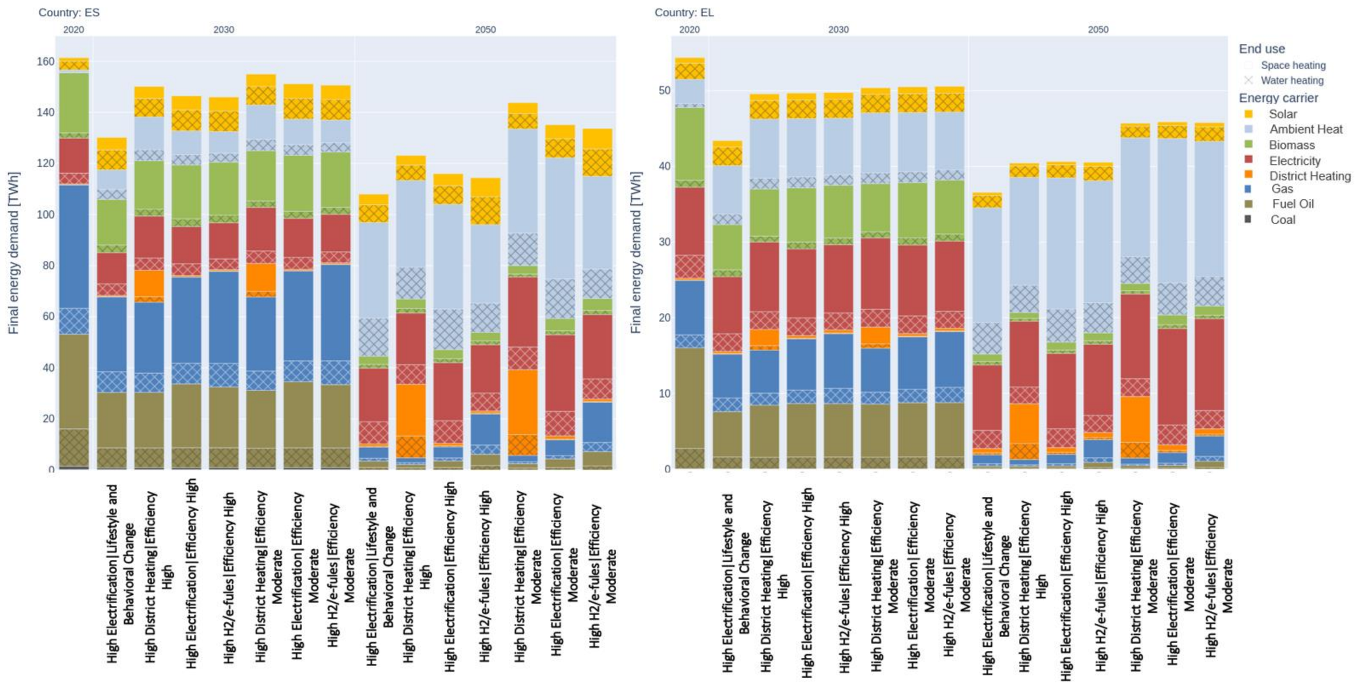

Figure 14: Final energy demand by energy carrier for space and water heating, ES (left) and GR (right)

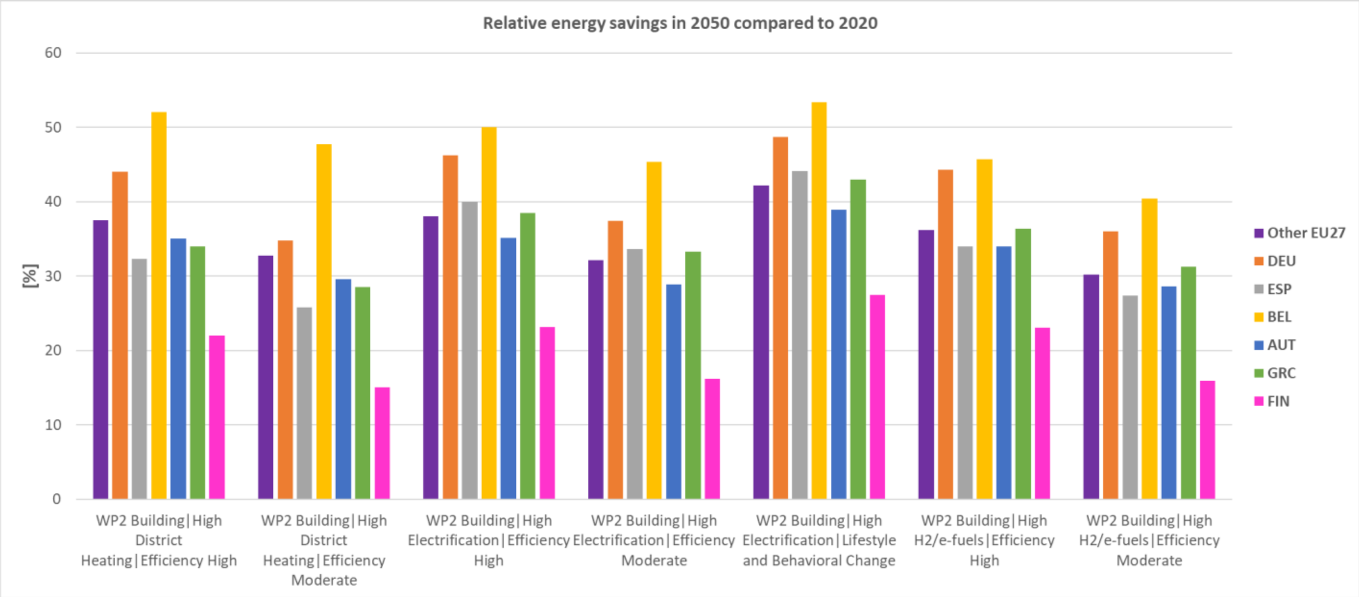

Figure 15: Relative energy savings for space and water heating in residential and commercial buildings in 2050 compared to 2020 for each scenario, EU-27 and ePANACEA countries

The term renovation rate is commonly used to measure the difference in renovation activities. From our modelling results, we derive a renovation rate defined as the rate equivalent of major deep renovation activities measured in the conditioned floor area of renovated buildings divided by the total conditioned floor area of the building stock. This renovation rate is shown in Figure 16. It shows that the equivalent major, deep renovation rate for EU-27 is around or below 1% in the moderate efficiency scenarios and about 1.5% in the high-efficiency scenarios.

The heating system replacement rate is similar in all scenarios and varies between 2-3 % per year.

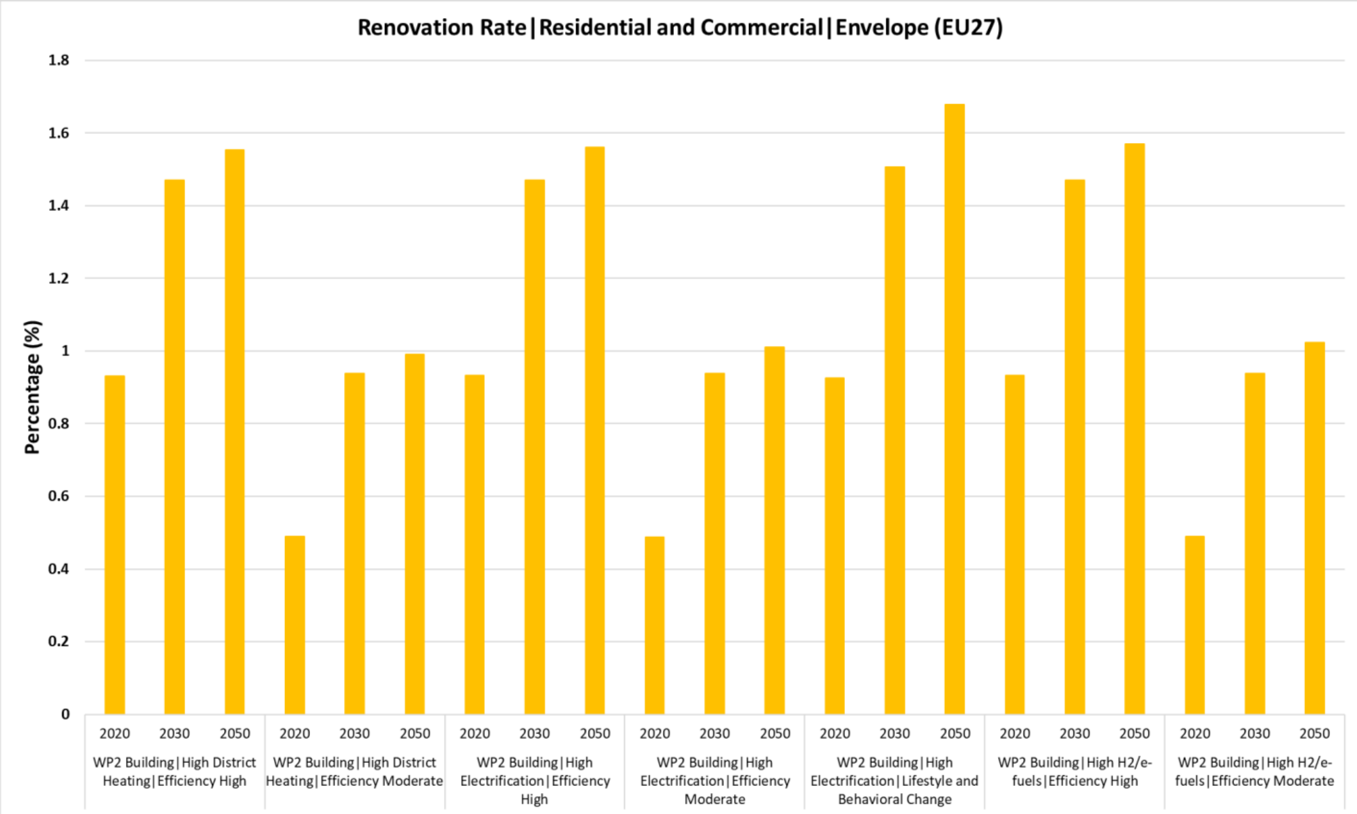

Figure 16: Renovation rate (defined as major renovation equivalent) of building envelope in residential and commercial sector for each scenario

The Annex provides tables with renovated floor area per MS and scenario. These values were used to create a basis for the number of renovated buildings and the number of EPCs issued because of the triggering point “renovation” (see chapter 4.1). Figure 17 displays the investments in building envelope renovation measures, for residential and commercial sector. In order to achieve the decarbonisation scenarios shown above, high efficiency scenarios correspond to an investment need of about 100 bn Euro per year in the ePANACEA countries.

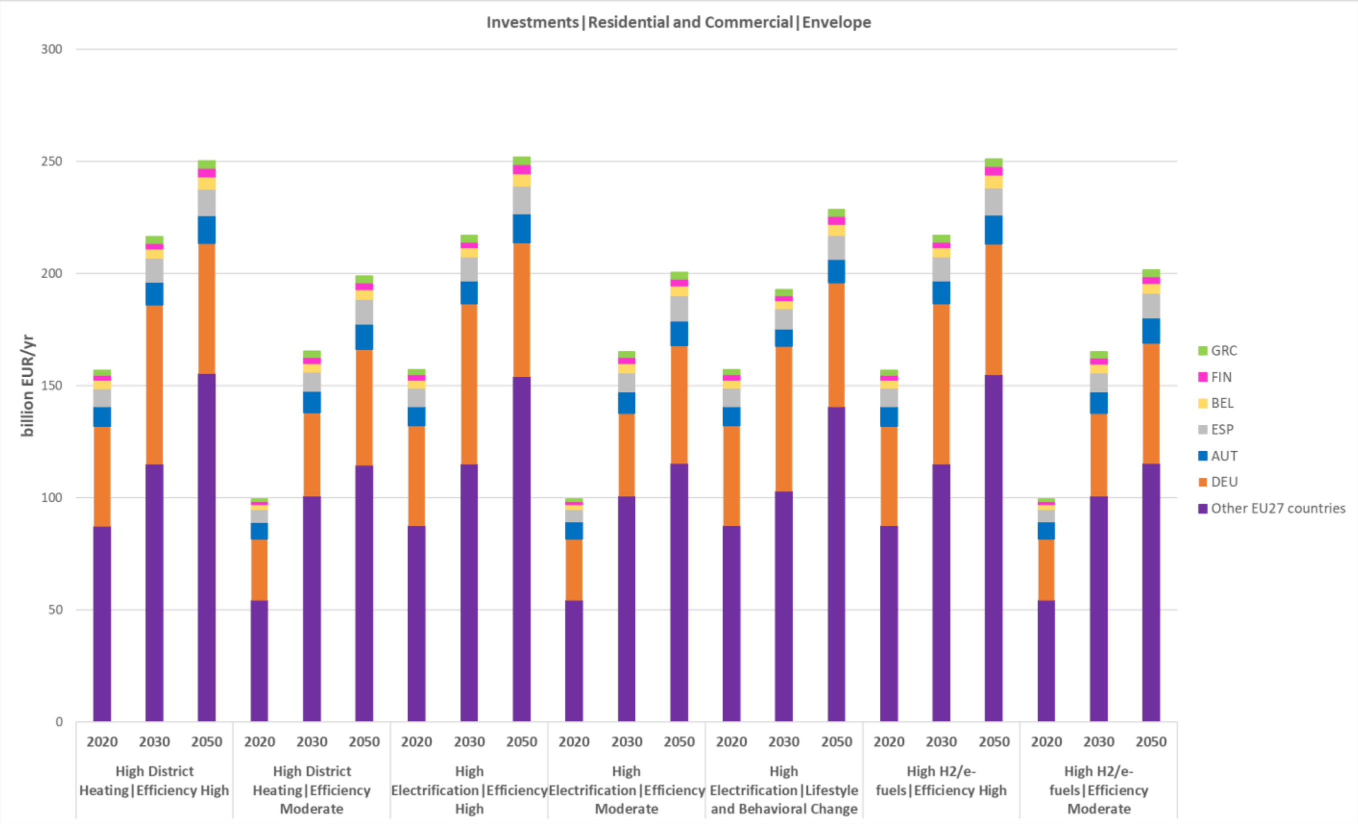

Figure 17: Investments in building envelope renovation measures for the residential and commercial sector

5. CONCLUSIONS AND NEXT STEPS

According to the set pathways, the different scenarios allowed quantifying the impact on the number of issued EPCs according to different trigger points (new buildings, real estate transaction, change of tenant, renovated buildings, and others) for Austria, Belgium, Finland, Greece, and Spain (including their sum). The pathways also consider the potential relevance of the ePANACEA methods 1, 2, and 3 by distinguishing and linking potentially interested end-users to the methods. We consider that due to the calculation complexity in each method and, consequently, the effort required by the energy auditor, EPC costs are affected. Therefore, the results reflect the prior assumption that methods 1 and 2 would be especially relevant for change of tenant, renovation, and new buildings (where very detailed and specific energy performance calculations are not necessary, and a good estimation is sufficient), while method 3 for real estate transition (defined as buy and sell transactions) where very detailed and specific energy performance calculations would be necessary. The set pathway also considers relevant changes in the policy context, for example, change of EPCs validity according to the buildings' energy class. Furthermore, the results reflect the current characteristic of country-specific building stocks (represented by the parameters ownership structure and buildings' energy class).

Scenario A projected the issuing of EPC for the triggering points similar to current circumstances until 20230. Scenario B distinguishes the aspect of end-users interested in ePANACEA methods 1 and 2 represented by the shaded areas and reduces the validity of EPCs for the worst-performing buildings (EPC classes F and G) to 5 years (this assumption is also in line with the current[5] discussion on the recast of the EPBD), while for other buildings, the validity remains ten years. In general, none of the five countries show a significant difference in the number of issued EPCs. Thus, it can be concluded that it is expected that the reduction of the validity of EPCs only for EPC classes F and G would have a limited impact on the number of issued EPCs.

Scenario C focuses on end-users' interest in ePANACEA method 3, reflected by the trigger point real estate transaction. Here, two policy scenarios were considered: (C.1) the reduction of the validity of EPCs to 5 years for all buildings except those of EPC labels A and B, and (C.2) the reduction of the validity of EPCs to 5 years for all buildings (energy class independent). In all countries, scenarios C.1 and C.2 have a higher number of issued EPCs than scenarios A and B. However, the share of issued EPCs per trigger point depends on countries' ownership status and share of energy classes. Countries with a higher share of owner-occupied buildings will have a higher impact from the validity time reduction. The same goes for countries with a higher share of EPCs with classes F and G, as they will have more EPCs issued (represented, especially by the difference between scenarios B and C). For some countries, e.g., Spain, we see an exceptionally high increase of EPCs in Scenario C compared to Scenario A and B due to the low share of rented dwellings. When collecting the data, it was observed a gap between the number of existing buildings (and dwellings) and the number of issued EPCs shows a potential to increase the number of issued EPCs to ideally cover the whole building stock. Then, calibrations were performed to shorten this gap. Scenario C represents this potential as well.

We can conclude that changing the validity time of EPCs alone does not necessarily lead to a large number of newly issued EPCs (and leads to the related potential investments and potential behavioural change). Limiting the validity to buildings' energy class (F and G) may also not highly impact the number of issued EPCs. A stronger impact is observed when expanding EPC issuing policies to all building labels, as shown in Scenario C.2. There, we see a significantly higher number of issued EPCs than in other scenarios where the validity is only reduced for certain energy labels. Not forgetting that country-specific impacts will depend on the ownership structures and homeowner's affordability and interest to investing in deep renovation measures and national EPC issuing prices. Other projects activities could prove that increasing end-users' acceptance and interest in EPCs would consequently generate an increase in EPC issuing practices. Table 3 summarises the country-specific pathways presented in the results for Austria, Belgium, Greece, Finland, and Spain.

[5] Status August 2023

Table 3: Summary of country specific pathway results until 20230 for number of issued EPCs

	Austria	Belgium	Finland	Greece	Spain
2015-2019 Issued	47,511	221,831	75,124	134,800	441,086
2015-2019 Largest part	1- tenant 2- new building construction	1- real estate transaction (sell/buy) 2- change of tenant	1- real estate transactions	1-change tenant 2-real estate transactions	1-building renovation
EPC issuing due to real estate transaction, 2030 C.1	17,621	91,653	63,896	52,998	321,591
Share of EPCs issued due to real estate transaction, 2030, C.1. compared to EPCs issued 2015-2019	~37%	~41%	~85%	~39%	~73%
Increase of scenario B compared to A	6.1%	6.6%	8.7%	8.2%	3.6%
Increase of scenario C.1 compared to A	86%	7%	33%	48%	250%
Increase of scenario C.2 compared to C.1	15.4%	18.6%	12.5%	22%	28.6%

Overall, decarbonisation of the building stock will require significant investments in the building envelope and HVAC systems, leading to potentially high energy savings and, in particular, savings of fossil fuels and related GHG emissions. Stringent policy instruments are required to achieve these targets. Improved EPCs will play a key role in this respect, not only for providing more reliable and trustful information to building owners, occupants, and potential buyers but also for creating a relevant basis for regulatory policy instruments such as minimum energy performance standards for existing buildings, as proposed in the EPBD recast[6]. The calculation methods developed in ePANACEA have the potential to contribute to such a more reliable basis and thus exploit the decarbonisation potentials of the building stock.

[6] Status August 2023.

FIGURES

TABLES

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ANNEX

Table 4: Renovated floor area of residential and commercial buildings (Envelope)

Scenario	Region	Renovated Floor Area of Residential and Commercial Buildings - Envelope [Mm2] 2030	2050
High District Heating|Efficiency High	AUT	0.969	1.280
High District Heating|Efficiency Moderate	AUT	0.787	1.060
High Electrification|Efficiency High	AUT	0.979	1.346
High Electrification|Efficiency Moderate	AUT	0.780	0.989
High Electrification|Lifestyle and Behavioral Change	AUT	0.950	1.292
High H2/e-fuels|Efficiency High	AUT	0.979	1.332
High H2/e-fuels|Efficiency Moderate	AUT	0.787	1.028
High District Heating|Efficiency High	BEL	1.441	1.392
High District Heating|Efficiency Moderate	BEL	1.173	1.115
High Electrification|Efficiency High	BEL	1.440	1.436
High Electrification|Efficiency Moderate	BEL	1.174	1.081
High Electrification|Lifestyle and Behavioral Change	BEL	1.421	1.433
High H2/e-fuels|Efficiency High	BEL	1.445	1.477
High H2/e-fuels|Efficiency Moderate	BEL	1.170	1.118
High District Heating|Efficiency High	DEU	14.311	10.036
High District Heating|Efficiency Moderate	DEU	6.472	8.379
High Electrification|Efficiency High	DEU	14.388	10.377
High Electrification|Efficiency Moderate	DEU	6.435	8.642
High Electrification|Lifestyle and Behavioral Change	DEU	14.157	10.465
High H2/e-fuels|Efficiency High	DEU	14.406	10.107
High H2/e-fuels|Efficiency Moderate	DEU	6.406	8.819
High District Heating|Efficiency High	ESP	3.896	3.395
High District Heating|Efficiency Moderate	ESP	2.312	3.251
High Electrification|Efficiency High	ESP	3.900	3.684
High Electrification|Efficiency Moderate	ESP	2.291	3.324
High Electrification|Lifestyle and Behavioral Change	ESP	3.857	3.591
High H2/e-fuels|Efficiency High	ESP	3.906	3.589
High H2/e-fuels|Efficiency Moderate	ESP	2.319	3.158
High District Heating|Efficiency High	FIN	0.349	0.570
High District Heating|Efficiency Moderate	FIN	0.263	0.280
High Electrification|Efficiency High	FIN	0.350	0.582
High Electrification|Efficiency Moderate	FIN	0.263	0.283
High Electrification|Lifestyle and Behavioral Change	FIN	0.343	0.553
High H2/e-fuels|Efficiency High	FIN	0.353	0.576
High H2/e-fuels|Efficiency Moderate	FIN	0.263	0.281
High District Heating|Efficiency High	GRC	1.512	1.362
High District Heating|Efficiency Moderate	GRC	1.049	1.050
High Electrification|Efficiency High	GRC	1.508	1.373
High Electrification|Efficiency Moderate	GRC	1.049	1.082
High Electrification|Lifestyle and Behavioral Change	GRC	1.479	1.367
High H2/e-fuels|Efficiency High	GRC	1.513	1.340
High H2/e-fuels|Efficiency Moderate	GRC	1.048	1.079
High District Heating|Efficiency High	Other EU-27	34.019	33.715
High District Heating|Efficiency Moderate	Other EU-27	24.570	23.574

High Electrification|Efficiency High	Other EU-27	34.013	33.547
High Electrification|Efficiency Moderate	Other EU-27	24.574	23.685
High Electrification|Lifestyle and Behavioral Change	Other EU-27	33.411	33.556
High H2/e-fuels|Efficiency High	Other EU-27	34.001	33.900
High H2/e-fuels|Efficiency Moderate	Other EU-27	24.587	23.601

Table 5: Renovated floor area of residential and commercial buildings (Heating systems)

		Renovated Floor Area of Residential and Commercial Buildings - Heating Systems [Mm2]	
Scenario	**Region**	**2030**	**2050**
High District Heating|Efficiency High	AUT	2.235	1.587
High District Heating|Efficiency Moderate	AUT	2.231	1.517
High Electrification|Efficiency High	AUT	2.233	1.585
High Electrification|Efficiency Moderate	AUT	2.229	1.373
High Electrification|Lifestyle and Behavioral Change	AUT	2.230	1.574
High H2/e-fuels|Efficiency High	AUT	2.225	1.719
High H2/e-fuels|Efficiency Moderate	AUT	2.225	1.727
High District Heating|Efficiency High	BEL	3.759	1.889
High District Heating|Efficiency Moderate	BEL	3.752	1.963
High Electrification|Efficiency High	BEL	3.752	1.902
High Electrification|Efficiency Moderate	BEL	3.757	1.979
High Electrification|Lifestyle and Behavioral Change	BEL	3.756	1.917
High H2/e-fuels|Efficiency High	BEL	3.756	2.088
High H2/e-fuels|Efficiency Moderate	BEL	3.756	2.097
High District Heating|Efficiency High	DEU	23.868	14.811
High District Heating|Efficiency Moderate	DEU	23.922	13.828
High Electrification|Efficiency High	DEU	23.887	15.464
High Electrification|Efficiency Moderate	DEU	23.855	14.996
High Electrification|Lifestyle and Behavioral Change	DEU	23.865	13.614
High H2/e-fuels|Efficiency High	DEU	23.944	15.277
High H2/e-fuels|Efficiency Moderate	DEU	23.856	16.484
High District Heating|Efficiency High	ESP	7.764	5.028
High District Heating|Efficiency Moderate	ESP	7.772	5.006
High Electrification|Efficiency High	ESP	7.765	5.215
High Electrification|Efficiency Moderate	ESP	7.771	4.885
High Electrification|Lifestyle and Behavioral Change	ESP	7.756	5.081
High H2/e-fuels|Efficiency High	ESP	7.758	5.459
High H2/e-fuels|Efficiency Moderate	ESP	7.770	5.365
High District Heating|Efficiency High	FIN	1.342	0.878
High District Heating|Efficiency Moderate	FIN	1.340	0.902
High Electrification|Efficiency High	FIN	1.342	0.885
High Electrification|Efficiency Moderate	FIN	1.339	0.909
High Electrification|Lifestyle and Behavioral Change	FIN	1.341	0.873
High H2/e-fuels|Efficiency High	FIN	1.340	0.928
High H2/e-fuels|Efficiency Moderate	FIN	1.340	0.921
High District Heating|Efficiency High	GRC	3.075	1.714
High District Heating|Efficiency Moderate	GRC	3.077	1.725
High Electrification|Efficiency High	GRC	3.072	1.803
High Electrification|Efficiency Moderate	GRC	3.073	1.808

High Electrification|Lifestyle and Behavioral Change	GRC	3.067	1.777
High H2/e-fuels|Efficiency High	GRC	3.073	1.871
High H2/e-fuels|Efficiency Moderate	GRC	3.076	1.876
High District Heating|Efficiency High	Other EU-27	77.606	42.933
High District Heating|Efficiency Moderate	Other EU-27	77.600	43.967
High Electrification|Efficiency High	Other EU-27	77.540	45.245
High Electrification|Efficiency Moderate	Other EU-27	77.507	44.535
High Electrification|Lifestyle and Behavioral Change	Other EU-27	77.654	43.912
High H2/e-fuels|Efficiency High	Other EU-27	77.654	45.397
High H2/e-fuels|Efficiency Moderate	Other EU-27	77.530	45.190

Table 6: Renovated floor area of residential buildings (Envelope)

		Renovated Floor Area of Residential Buildings - Envelope [Mm2]	
Scenario	**Region**	**2030**	**2050**
High District Heating|Efficiency High	AUT	0.792	0.999
High District Heating|Efficiency Moderate	AUT	0.674	0.905
High Electrification|Efficiency High	AUT	0.800	1.042
High Electrification|Efficiency Moderate	AUT	0.669	0.853
High Electrification|Lifestyle and Behavioral Change	AUT	0.780	1.013
High H2/e-fuels|Efficiency High	AUT	0.800	1.026
High H2/e-fuels|Efficiency Moderate	AUT	0.674	0.877
High District Heating|Efficiency High	BEL	0.761	0.902
High District Heating|Efficiency Moderate	BEL	0.666	0.698
High Electrification|Efficiency High	BEL	0.759	0.925
High Electrification|Efficiency Moderate	BEL	0.667	0.681
High Electrification|Lifestyle and Behavioral Change	BEL	0.747	0.923
High H2/e-fuels|Efficiency High	BEL	0.764	0.944
High H2/e-fuels|Efficiency Moderate	BEL	0.664	0.698
High District Heating|Efficiency High	DEU	10.014	6.920
High District Heating|Efficiency Moderate	DEU	4.241	5.719
High Electrification|Efficiency High	DEU	10.070	7.173
High Electrification|Efficiency Moderate	DEU	4.214	5.911
High Electrification|Lifestyle and Behavioral Change	DEU	9.899	6.949
High H2/e-fuels|Efficiency High	DEU	10.092	6.958
High H2/e-fuels|Efficiency Moderate	DEU	4.191	6.012
High District Heating|Efficiency High	ESP	2.635	2.549
High District Heating|Efficiency Moderate	ESP	1.608	2.304
High Electrification|Efficiency High	ESP	2.641	2.706
High Electrification|Efficiency Moderate	ESP	1.588	2.345
High Electrification|Lifestyle and Behavioral Change	ESP	2.627	2.645
High H2/e-fuels|Efficiency High	ESP	2.643	2.622
High H2/e-fuels|Efficiency Moderate	ESP	1.611	2.224
High District Heating|Efficiency High	FIN	0.158	0.327
High District Heating|Efficiency Moderate	FIN	0.115	0.141
High Electrification|Efficiency High	FIN	0.158	0.333

High Electrification|Efficiency Moderate	FIN	0.115	0.143
High Electrification|Lifestyle and Behavioral Change	FIN	0.154	0.323
High H2/e-fuels|Efficiency High	FIN	0.159	0.330
High H2/e-fuels|Efficiency Moderate	FIN	0.115	0.142
High District Heating|Efficiency High	GRC	0.618	0.671
High District Heating|Efficiency Moderate	GRC	0.485	0.497
High Electrification|Efficiency High	GRC	0.615	0.676
High Electrification|Efficiency Moderate	GRC	0.484	0.518
High Electrification|Lifestyle and Behavioral Change	GRC	0.601	0.695
High H2/e-fuels|Efficiency High	GRC	0.618	0.654
High H2/e-fuels|Efficiency Moderate	GRC	0.485	0.512
High District Heating|Efficiency High	Other EU-27	23.623	23.718
High District Heating|Efficiency Moderate	Other EU-27	17.337	16.381
High Electrification|Efficiency High	Other EU-27	23.621	23.655
High Electrification|Efficiency Moderate	Other EU-27	17.341	16.472
High Electrification|Lifestyle and Behavioral Change	Other EU-27	23.184	23.669
High H2/e-fuels|Efficiency High	Other EU-27	23.598	23.853
High H2/e-fuels|Efficiency Moderate	Other EU-27	17.354	16.370

Table 7: Renovated floor area of residential buildings (Heating systems)

		Renovated Floor Area of Residential Buildings – Heating Systems [Mm2]	
Scenario	**Region**	**2030**	**2050**
High District Heating|Efficiency High	AUT	1.717	1.183
High District Heating|Efficiency Moderate	AUT	1.714	1.146
High Electrification|Efficiency High	AUT	1.716	1.186
High Electrification|Efficiency Moderate	AUT	1.713	1.048
High Electrification|Lifestyle and Behavioral Change	AUT	1.714	1.181
High H2/e-fuels|Efficiency High	AUT	1.711	1.285
High H2/e-fuels|Efficiency Moderate	AUT	1.709	1.288
High District Heating|Efficiency High	BEL	2.547	1.309
High District Heating|Efficiency Moderate	BEL	2.542	1.358
High Electrification|Efficiency High	BEL	2.540	1.305
High Electrification|Efficiency Moderate	BEL	2.546	1.357
High Electrification|Lifestyle and Behavioral Change	BEL	2.546	1.324
High H2/e-fuels|Efficiency High	BEL	2.543	1.435
High H2/e-fuels|Efficiency Moderate	BEL	2.544	1.439
High District Heating|Efficiency High	DEU	15.988	10.374
High District Heating|Efficiency Moderate	DEU	16.028	9.662
High Electrification|Efficiency High	DEU	15.992	10.776
High Electrification|Efficiency Moderate	DEU	15.983	10.456
High Electrification|Lifestyle and Behavioral Change	DEU	15.985	9.548
High H2/e-fuels|Efficiency High	DEU	16.054	10.612
High H2/e-fuels|Efficiency Moderate	DEU	15.977	11.596

High District Heating|Efficiency High	ESP	5.408	3.705
High District Heating|Efficiency Moderate	ESP	5.414	3.692
High Electrification|Efficiency High	ESP	5.405	3.847
High Electrification|Efficiency Moderate	ESP	5.411	3.574
High Electrification|Lifestyle and Behavioral Change	ESP	5.405	3.791
High H2/e-fuels|Efficiency High	ESP	5.401	4.115
High H2/e-fuels|Efficiency Moderate	ESP	5.415	4.058
High District Heating|Efficiency High	FIN	0.926	0.603
High District Heating|Efficiency Moderate	FIN	0.925	0.617
High Electrification|Efficiency High	FIN	0.926	0.608
High Electrification|Efficiency Moderate	FIN	0.925	0.622
High Electrification|Lifestyle and Behavioral Change	FIN	0.926	0.606
High H2/e-fuels|Efficiency High	FIN	0.925	0.637
High H2/e-fuels|Efficiency Moderate	FIN	0.924	0.633
High District Heating|Efficiency High	GRC	1.646	0.862
High District Heating|Efficiency Moderate	GRC	1.647	0.870
High Electrification|Efficiency High	GRC	1.643	0.915
High Electrification|Efficiency Moderate	GRC	1.644	0.915
High Electrification|Lifestyle and Behavioral Change	GRC	1.648	0.915
High H2/e-fuels|Efficiency High	GRC	1.644	0.983
High H2/e-fuels|Efficiency Moderate	GRC	1.647	0.984
High District Heating|Efficiency High	Other EU-27	56.254	31.034
High District Heating|Efficiency Moderate	Other EU-27	56.248	31.810
High Electrification|Efficiency High	Other EU-27	56.213	32.715
High Electrification|Efficiency Moderate	Other EU-27	56.171	32.150
High Electrification|Lifestyle and Behavioral Change	Other EU-27	56.347	31.997
High H2/e-fuels|Efficiency High	Other EU-27	56.301	32.540
High H2/e-fuels|Efficiency Moderate	Other EU-27	56.202	32.351