CONCERTED ACTION ENERGY PERFORMANCE OF BUILDINGS

(CCT3) Compliance, Capacity and Impact

Status in 2022

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1. Introduction

The CA EPBD Cross-Cutting Team 3 (CCT3) focuses on the compliance, capacity, and impact of the EPBD, in order to document whether policies work or not. It also handles the related topics of data and data quality.

There is a general lack of data on the building stock's energy performance across Europe. It is often possible to access data only on building characteristics or on energy consumption, even though a combination of both sets of data is needed to assess the impact of policies with accurate data and to understand course and impacts. Access to good data or specific surveys and collecting large amounts of building data as a self-standing exercise can be expensive. A more cost-effective way to access building data is to use existing systems and tools that provide building-related data as a by- product – for example, data from certification and inspection of technical systems, as well as smart building technology and smart meters.

Big data is a new way to evaluate the impact of policies, alongside developments in storage capability and the capacity to collect and handle very large sets of data. CCT3 supports activities for increased data quality and seeks to find potential synergies with the Building Stock Observatory and other initiatives.

Work and progress on this cross-cutting team is described in following articles of the Directive 2010/31/EU:

- Article 18 – Independent control systems
- Article 19 – Review
- Article 27 – Penalty systems
- Annex II – Penalty systems for certification and inspection.

There is also good collaboration with other Concerted Actions (CA RES and CA EED) and projects on data and impact assessment.

2. Objectives

CCT3 supports work on data and assessment of impact related to renovation strategies (EPBD Article 2a), new and existing buildings (EPBD Articles 6 and 7), and assessment of impact and collection of data from certification and inspection (EPBD Articles 11-17). The Cross-Cutting Team also supports better data projects as a precondition to the implementation and evaluation of policies (background and multiple articles).

Key topics for CCT3 include:

- Assessment of the impact of articles in the EPBD
- Methodology for impact assessment
- Collection of data and quality of data
- Government capacity and capacity in the different chains of construction business

3. Analysis of Insights

Over the course of the CA EPBD V, the CCT3 team looked into several topics to ensure the articles linked to Compliance, Capacity and Impact in the EPBD have been covered, including:

- How to combine measured and calculated data
- Public access to EPC (Energy Performance Certificate) information – at individual building level
- Energy Service Contracting in Buildings
- Energy poverty – action, definition & mapping – Link to EPBD Article 2a
- Energy renovation of cultural heritage buildings
- Renovation of buildings – impact of fire protection & risk of seismic activity
- Worst-performing buildings – scope, policy and measures (Renovation Wave)
- Linking finance & EPCs for energy renovations with energy savings
- Energy renovation in National Recovery and Resilience Plans
- Energy certification common methodology from A – G (following posters)
- Impact assessments of information activities

The following sections provide the key insights and takeaways from the topics covered.

3.1 How to combine measured and calculated data

Revised Annex I of Directive 2010/31/EU on the Energy Performance of Buildings states that the energy performance of a building shall be determined based on calculated or actual energy use and shall reflect typical energy use for space heating, space cooling, domestic hot water, ventilation, built-in lighting and other technical building systems. The energy performance of a building is expressed by a numeric indicator of primary energy use in kWh/(m^2.year).

Further, revised Article 10 of the EPBD (Financial incentives and market barriers) states that databases for energy performance certificates shall allow data to be gathered based on measured or calculated energy consumption of the buildings covered. As per this article, Member States shall link their financial measures for energy efficiency improvements in the renovation of buildings to the targeted or achieved energy savings, as determined by one or more of the criteria such as the improvement achieved due to such renovation by comparing energy performance certificates issued before and after renovation or the results of another relevant, transparent, and proportionate method that shows the improvement in energy performance.

As the Directive sets out, there are many approaches to collecting data. This section explores the different approaches (measured, calculated and combined) and their accuracies. This includes looking at ways to evaluate and verify the approaches to collecting building stock data, the impact of energy renovations and how different data sources give different energy assessments, as well as ways to verify the accuracy of the EPC.

3.1.1 Measured versus calculated – how much can we trust the EPC?

As per the EPBD, some key expectations of the Energy Performance Certificate include:

- Enabling an evaluation of the building stock
- Identifying the critical buildings that should be first candidates for energy renovation
- Estimating energy consumption of the stock
- Estimating energy consumption of individual buildings

Member States take different approaches to handling these expectations. In most Member Staters, data are collected in a database for analysis. The EPC databases can contain calculated, measured, or combined data.

3.1.2 Proving energy savings from energy renovation projects

Various data sources can be used to calculate how much energy is saved after a renovation measure has been carried out, and these sources may not all give the same answer. The main data sources to work out energy savings post renovation works include:

- The EPC – in most Member States, the Energy Performance Certificate is based on the calculated heating energy (though it is sometimes based on delivered energy). The energy savings are determined by using the calculated energy use before and after refurbishment. This is the most common way to determine whether or not a building should be renovated.

- Another method known as 'design documentation' uses a more holistic approach and has additional inputs such as climatic data, building type and schedules of use.
- Metered data – for public sector buildings, this is a requirement, although for residential buildings, there is limited access due to data protection regulations.
- Monitoring and verification systems that facilitate data collection and calculation of energy savings.

These four approaches and examples of each were presented and discussed during the CA EPBD V. Each method has its pros and cons, levels of accuracy, and degree of simplicity. Based on the case studies, not all methods give the same results and therefore the approach taken to measuring savings should ensure the findings are accurate. Members found that the approach used should be sufficiently detailed to give an accurate answer, but simple enough to engage the user.

3.1.3 Discussion on how to combine measured and calculated data

This Cross-Cutting Team looked at how measured and calculated data can be used together, and the advantages and disadvantages of both.

Calculated data – in some Member States, to find the data needed for an EPC in residential buildings, calculated data is used, based on a standardised usage profile rather than relying on the individual usage which would allow a comparison between different buildings. This means the building profile is pre-defined. This is helpful because, often, measured data are not readily available. The building profile data from the calculated EPC, however, might not give an accurate account of the building's energy use as it does not reflect the user profile and so the results may not align with real use. Since different occupants use energy differently, if user habits are not known it can be difficult to accurately determine savings that could be obtained (e.g., whether it is 18 or 21 degrees inside).

Measured data – on the other hand, energy use in some buildings is calculated using measured data, even though measured data cannot be used to compare buildings. Because it is based on actual energy use, this gives an accurate evaluation of the energy savings of a renovation.

Examples from Member States showed that the data from calculated and measured means differ for several reasons. One potential solution to the gap that is being explored is to establish a platform where the EPC data can be extended with the owner's actual usage patterns – thus giving both calculated and measured data sources.

For non-residential buildings, in cases where a dynamic simulation is used for EPC calculation, it is recommended that the simulation is calibrated with measured data. A weakness is that for new buildings, the consumption will be based on simulated use and that recommended measures are based on the EPC calculation. With this approach, actual energy use would not be used because the reference building would be based on simulations. The outcomes of this topic suggest Member States plan to narrow the gap between the different methods of retrieving data and find a way for actual metered data to be used as an input.

Highlights of 3.1	The main objective was to exchange experiences related to the differences in data provided as input for EPCs and data stemming from other relevant documentation and sources. There was a special focus on exploring the differences in energy consumption data presented in the EPCs representing the theoretical/calculated values compared to the actual or metered data. There is an identified gap between measured and calculated data of energy efficiency in buildings. The data gap is a common characteristic in new, as well as in existing buildings. The way that the data is collected and interpreted is essential for data accuracy and trustworthiness so that it can be used for building initiatives and actions. While experts and researchers are trying to explain the causes and extent of those gaps, it is very important to clarify state-of-the-practice and possible improvements to ensure the best use and accuracy of data.

3.2 Public access to EPC information

Directive 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on energy performance of buildings and Directive 2012/27/EU on energy efficiency stress how important it is for Member States to develop and manage EPC databases. The introductory part of the Directive states that an independent control system, supplemented by an additional database that exceeds the requirements of Directive 2010/31/EU as amended by this Directive, may be used for verification and for production of statistics on regional or national building stocks. These building stock statistics require high quality building data that could be partially generated in energy efficiency databases.

Revised Article 10 (Financial incentives and market barriers) states that databases for EPCs shall allow data to be gathered on the measured or calculated energy consumption of the buildings covered, including at least public buildings, for which an EPC, as referred to in Article 13, has been issued in accordance with Article 12. Furthermore, at least aggregated anonymised data compliant with Union and national data protection requirements shall be made available on request for statistical and research purposes and to the building owner.

The General Data Protection Regulation (GDPR) became applicable from 25 May 2018. GDPR requirements, which apply to all Member States, aim to create more consistent protection of consumer and personal data across the EU. The GDPR requirements include the consent of subjects for data processing, anonymising collected data to protect privacy, and the registration of all personal data requiring consent.

At the same time, the EPBD stresses the importance for EPC databases to be developed and managed by Member States for such purposes, e.g., data validation and stock analysis. Prior to the GDPR becoming applicable, almost all Member States had set up databases to store information on EPCs, assessors, training providers, and so on. However, due to the new Regulation, changes needed to be made. This section discusses the barriers and solutions to ensure compliance with the EPBD regulation respects the GRDP regulation across Member States.

3.2.1 Examples of public EPC databases in Member States

Estonia - EPC database

In Estonia, the internet is seen as a social right and every resident is issued an electronic ID. About 99% of services can be accessed online and Estonians have come to trust e-solutions. This has an impact on their register of buildings known as EHR. Over the last 30 years, the original two separate registries have been combined to one online registry. In 2018, the database had more than 400 GB of data and stored 2.7 million documents. By 2022, all the building and user permits are given out through EHR, including EPCs.

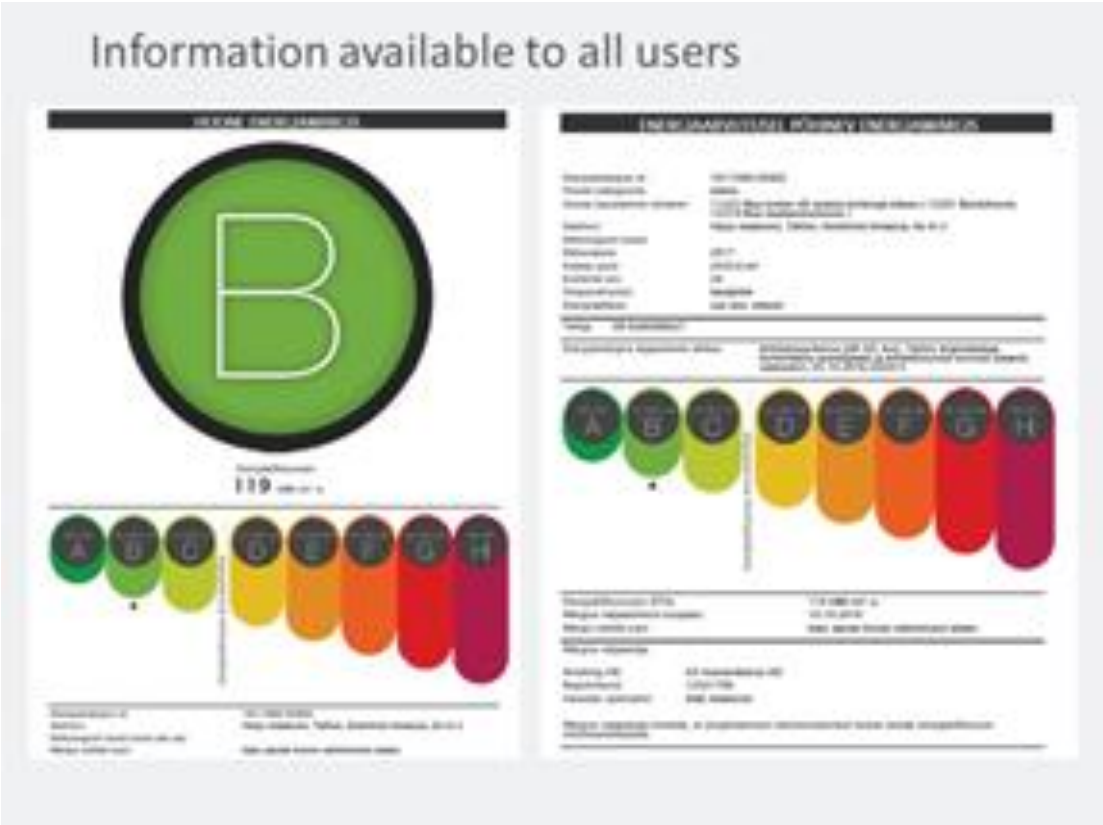

Figure 1. Estonian EPC database.

The EPC database is integrated with the EHR and allows a completely paperless assessment process. EPCs must be input into the database to become legally valid. All the data contained within it is publicly accessible. Every assessor knows that their work can be seen by anyone, which has been found to provide an incentive to carry out high quality work and has improved the overall quality of assessments and reports. This has also made quality control easier as fewer errors are made.

In Estonia, there are two types of EPC – calculated and measured. The calculated EPC is based on standard usage patterns and is used to show compliance with minimum energy performance requirements. This type of EPC is valid for two years after the building permit is issued. After two years, the calculated EPC becomes invalid, and a measured EPC must be issued. This EPC is based on actual energy consumption and gives information about energy efficiency improvement measures. The new EPC (based on measured data) is valid for 10 years. Every EPC is digitally signed by a certified expert before being uploaded to the database. The database includes all information in an easily accessible format including the label and energy use, the EPC input data, and the metered energy for the measured EPCs. This data can be downloaded as a bulk file, though addresses of individual buildings are hidden for privacy reasons. Although residents have the right to ask to be removed, they seem to trust the system and no requests for removal have been made.

Croatia – EPC database and GDPR

In Croatia, GDPR affects the national EPC database and since September 2017, the IEC (Informatic system of Energy Certification) has served as the database for the issuance, storage, and quality control of EPCs. It is made up of five registers: Persons authorised for energy certification; Issued energy certificates and energy audits of buildings; Reports on regular inspections of heating and cooling systems; Persons authorised for the control of energy certificates; and Legal persons with approval for conducting training programmes.

Additionally, there are four types of users; Administrator – representative of the Ministry; User – natural or legal person authorised for energy certification; Legal person with approval to perform training programmes; and Legal persons authorised to perform control of the issued EPCs.

Access to the IEC is controlled through a central system known as NIAS to identify who should have access and at which level. Some data can be seen by the public – for example, excerpts showing lists of persons authorised for energy certification controllers and trainers.

Slovenia – EPC database data available on demand

In Slovenia, the EPC is seen as an official public document, the same as a passport or an ID card. As in Estonia, an EPC must be registered to the national registry by an authorised expert for it to become valid. The registry is controlled by the government and is part of a central system. The database allows the public to access the registry of licensed experts, organisations that can issue EPCs, and calculated and measured data for EPCs that have been issued. Generally, only high-level data is shown but, upon request, more detailed information can be given. This is usually granted for research and statistical purposes.

An important piece of information that is hidden is the name of the owner. It is possible to cross reference another database to find the owner, but this must be done one EPC at a time and is therefore not seen as a major risk. In communication with the Information Commissioner, it was determined that annual, monthly or daily energy consumption is not considered personal data and may thus be shown. Data provided in time steps of 15 minutes or less is considered personal data and is not shown. Another issue was with digital signatures which must now be hidden as they contain the name and VAT number of the expert.

Table discussion

Member State participants discussed the topic of publicly available databases. Most Member States suggest that the format and oversight of the databases should be controlled by the government, either at national or regional level. Many Member States have databases that are made up of several different registers that are linked in some way. In Member States where there are regional databases, the regions do not always use a consistent format so processing data at a national level can be very difficult or, in some cases, impossible.

Member States have a wide range of policies that cover the availability of data. Some are similar to the Estonian system, with all data open-sourced and available for anyone to access. In contrast, some Member States have very strict access rules meaning that very few people can see or use the data. Most Member States have a policy in place that is between the two extremes. For example, one Member State has a policy that makes public building information available to anyone, with the justification being that the public building uses public funds.

The methodologies for data collection across Member States have many similarities and differences. Some Member States have an opt-out policy where all data is collected unless the owner chooses to redact their data. Many Member States have deleted some data in view of the GDPR requirements.

The benefits of collecting data were found to include:

- Creating statistics and research
- Designing financial incentives and policies
- Allowing a history of EPCs for a particular building to be formed
- Supporting quality control
- Supporting mortgage applications
- Targeted marketing based on the building's features.

Highlights of 3.2	Through presentations and discussions, it became evident that the problem of 'public access to EPC information' vs GDPR requirements is approached differently by Member States. A central point of discussion was how open the databases should be and who should be able to see the information stored within the database. An important factor is the local culture. For example, in some Member States, the public are open to data being shared on the internet for various purposes so having an open database is seen as appropriate, while in other countries, the public are much more concerned about privacy, so more data needs to be hidden and access be restricted. Another key question for the databases is: What level of detail should be made available? Very detailed and granular information might be acceptable in some Member States but not in others. One possible strategy was to have multiple registries under one database. This allows all collected data to be in one place, and the flexibility to provide different levels of data to different users. It is also important to define the different level of users so that suitable permissions can be given. All Member States agreed that EPC databases have been a powerful tool for quality control, research, statistics, and policy planning. It is therefore important that the challenges of GDPR are overcome to allow the continued use of these important resources

3.3 Energy Performance Contracting in buildings

In Europe, the Energy Performance Contract (EnPC) market is struggling, and during the CA EPBD V, CCT3 set out to understand why. It was found that there are several reasons. To begin with, there is limited experience in energy performance contracting across Europe and therefore a lack of information about how to issue them. It was found that it is difficult to secure finance in certain Member States. In order to maintain a successful Energy Performance Contract market, it is clear that capacity needs to be built up and the procurement process needs to be well defined and easily implemented.

A main challenge for governments is ensuring that their payments to Energy Service Companies (ESCOs) are 'off balance sheet' or 'Maastricht neutral'. Regular payments to ESCOs from the government can only take place if energy savings exceed the total payment amount, and the contract is a minimum of eight years.

It is sensible to separate the financing of construction (high-risk) from the long-term financing post-commissioning (lower risk) where savings are usually achieved. The challenge with financing a 'Maastricht neutral' EnPC is that more risk is shifted to the private sector. Possible solutions involve standardised templates, sharing of best practice, and the use of European Structural and Investment Fund (ESIF) financial instruments.

A comprehensive renovation often has a repayment time of more than 20 years. A ESIF capital grant can be used to shorten this repayment time for the ESCO; however, State Aid rules require that the benefit is passed on to the client.

3.3.1 Eurostat: A guide to Energy Performance Contracting

One way to support the upscaling of the EnPC market is Eurostat's guidance for statistical offices and a practitioner's guide to the Energy Performance Contract. This EnPC guide translates statistical rules into contractual terms and concepts. More information on the guide can be found in 'A Guide to the Statistical Treatment of Energy Performance Contracts' (europa.eu).

A hypothetical example was presented on how the Eurostat guidance can be applied to a building. It looked at investment in energy efficiency measures for a hospital. With both EU and government grants, the payments would exceed savings and appear on the government balance sheet. Solutions could include increasing the contract period and replacing the government grant with another EU grant or installation of renewable energy technology that would generate an additional revenue stream.

Question	Can you elaborate on State Aid rules with regards to structural finance?
Answer	Maximum 50% of financing can come from the national government (central or municipality). Contributions from the EIB do not count as government financing. Any benefit must go directly to the building owner; therefore, aid cannot be directly linked to the ESCO but must be passed on to building owner to comply with State Aid rules.
Question	**As all payments must be based on energy savings, is the transfer of funds to the building owner?**
Answer	It is the aid – i.e., the renovation work delivered by the ESCO – and not the money - that should be transferred to the building owner. The sum of all payments from the government to the ESCO must be less than the sum of all savings delivered by the ESCO during the period of the contract. In Slovenia, there is a split contract which incorporates both a pure EPC model and a normal works contract. When only EU funding is used in the work contract this is regarded as a neutral situation, as it does not affect the balance.

3.3.2 Slovak model for contracting energy services

There was a need to change the legislative framework for energy service contracting in Slovakia, as the original APES (Slovak Association of Energy Service Providers) approach to contracting was not working well for the public sector. New EnPC /GES (Guaranteed Energy Service) model contracts have been created to enable the use of guaranteed energy service in the public sector without impact on the public debt. These two energy performance contracts involve the standardisation of documents and are applicable in the private sector following a 2019 legislation change. The main changes to the new contracts from the previous APES are the redefinition of who the public sector GES beneficiary is, along with the scope and conditions for the transfer of the beneficiary's assets to the GES provider.

It was deemed that for a successful Energy Performance Contract project, it is crucial to have clearly defined savings assessment rules and a common goal with consistent ongoing communication to O&M personnel as well as building users. A consistent choice of Energy Performance Contract provider with a long-term partnership is also beneficial. Moreover, the contract period should be sufficient to cover both the preparation and implementation phase.

3.3.3 Croatian ESCO model for renovation of public sector buildings

The Croatian model follows the Eurostat guidance with standardised contracts for both the public and private sector. Energy refurbishment of public sector buildings is a key challenge in Croatia. So far, 12 different renovation projects have been completed across seven cities, with a total of 69 buildings refurbished. These projects led to energy savings totalling up to of 51%.

There are various public buildings across Croatia where deep renovation has been carried out using an ESCO model, including government buildings, hospitals and universities. A total of €100 million has been invested with 68% from the private sector, generating €4.4 million of savings. The challenge for the Croatian ESCO model now is to incorporate the additional savings, validated by measurement, into the energy performance contract.

A key take-away message was that the mobilisation of private capital is crucial for a successful ESCO model.

3.3.4 Renovation of the building in Austria via Energy Performance Contract

Independently of the EPBD, the Austrian Ministry of Economy started a contracting initiative for federal buildings in 2001, designed for schools, universities and office buildings. The aim was to raise awareness among building users, reduce energy demand, and bring about ecological benefits.

A lesson learnt from this initiative was that there is insufficient awareness of environmental and ecological issues. Building users are mainly focused on cost reduction rather than energy improvements. Many users also wanted to include additional, not energy related, services in the contract. Concerns were also raised about internal budgets and increasing administration burdens.

To support further progress, the government manages a contracting portal – klimaaktiv – bringing together energy services providers and other stakeholders including consultants, component manufacturers, and operating companies.

3.3.5 Solutions to financing building renovation through Energy Performance Contract

Simple and effective solutions to ESCOs should be developed to circumvent the barriers to using them as a model to reduce the energy demand of the European building stock. Energy service contracting can benefit from the interplay of many different measures, both removable (which can be removed from the building in case of breach of contract) and non-removable (e.g., building envelope renovation).

The implementation of EnPC has not been dealt with clearly and more emphasis should be placed on shifting maintenance to private companies. There is a need to clearly define ESCO projects which can include investments in non-removable assets, removable assets, and intangible assets. Non-removable assets have created many problems from Eurostat's point of view. This deals with deep refurbishment of the building envelope where the ESCO is the financial owner but not the legal owner of the assets. Long payback periods are to be expected and taxation can be an issue. For public buildings, whether a project is on- or off-balance sheet is very important and has implications for Value-Added Tax.

Subsidies for deep renovation are often inadequate to reflect the variation between individual buildings and can present a high administrative burden. Moreover, grants aimed at individual measures do not tend to account for the interaction of measures. A competitive process is important, especially for multi-apartment buildings, and enables compliance with State Aid rules.

In a competitive process, multi-apartment building co-owners would invite ESCOs to tender for the renovation work with grants considered to be a price within that tendering process. Grants would therefore be applied for by the ESCOs and paid upon completion of the renovation.

In summary, the energy service market must be developed as a competitive process with government buildings being the leader. Stringent rules and processes set up for government buildings can provide a framework for renovation of multi-apartment buildings, unlocking a much greater potential

3.3.6 Lesson Learned in Energy Performance Contracting in Europe

Different approaches to energy contracting involve varying methods of risk allocation. Traditional projects are self-financed -- savings are not guaranteed, in these cases, and the client carries all the risk. As for the EnPC approach, the risk lies entirely with the ESCO. With EnPCs, a crucial consideration is whether the financial investment is on- or off- the Government balance sheet.

With so many EnPC models across Member States, how can we define success? Important factors are: clarity on when to use an EnPC, trust among parties, and ensuring at least 30% savings over the lifetime of the contract. There should also be value for money. EnPC transaction costs should be lower than traditional costs; this is helped by a standardised contract and processes.

Therefore, a key lesson learnt is to integrate policy with financial planning for the success of EnPCs. Trust in the marketplace is also important, alongside understanding where the added value is. Other important aspects include the availability of competent and expert facilitators, standardisation of contracts and processes, promotion, and the balance of policy versus market interaction.

Highlights of 3.3	One of the current challenges faced by Energy Performance Contracting models is the shift towards more private financing and the need to keep payments from government off the balance sheet. Solutions involve developing standardised templates, the sharing of best practices, and the use of European Structural and Investment Funds, where possible. The Eurostat guidance should be followed to ensure energy performance contracts are set up correctly from a government debt and deficit point of view.

3.4 Energy poverty – action, definition & mapping – Link to EPBD Article 2a

Energy poverty occurs when individuals are unable to adequately heat their homes or use other energy services at an affordable price. Research shows that energy poverty affected 54 million EU citizens in 2012, with Central Eastern and South Europe particularly affected.

The Winter Package / Clean Energy for all Europeans (Regulation 2018/1999/EU on the Governance of the Energy Union and Climate Action, the amending EPBD 844/2018/EU and amended directive on energy efficiency 2018/1999/EU) require Member States to take measures to combat energy poverty. Article 2a in the amended EPBD requests that Member States outline national actions in their Long-Term Renovation Strategy (LTRS) that contribute to the alleviation of energy poverty. This requires the definition of energy poverty in the national context and identification of vulnerable groups of citizens.

3.4.1 Defining energy poverty

It is crucial for statistical reporting to define energy-poor or vulnerable households in order to guide policies for citizens and households who need assistance. However, there is no single EU definition, partly because of the sensitivity and complexity of many technical and social criteria, insufficient records, the need for consensus across all competent bodies who are responsible for combatting energy poverty, and the need for a fair, measurable and comprehensive definition at the national level.

A few countries (such as the UK, Ireland, France, Cyprus, and Slovakia) have an official definition of energy poverty in their legislation. One of the first definitions is from the United Kingdom: '*A household is energy poor if they needed to spend more than 10% of their income to keep their home at a reasonable temperature*' (Boardman, 1991, UK). In France, a person is considered energy poor if they have significant difficulties with accommodation in the context of meeting basic energy needs due to insufficient financial resources or housing conditions. In Ireland, the household is energy poor if it consumes more than 10% of its resources on energy costs.

Across the Member States, there are various policy measures aimed at combatting energy poverty; these include financial interventions that are crucial to the short-term protection of vulnerable consumers. There is also a diverse array of measures, coordinated by energy supply regulators, such as billing information, code of conduct, and debt protection.

A long-term approach to alleviating energy poverty is the renovation of buildings by applying various energy efficiency measures, including:

- energy auditing and energy certification of buildings for the purpose of energy renovation;
- preparation of project documentation for the energy renovation of the building;
- increasing the thermal protection of the building envelope (roof, façade, windows, etc.);
- Improvement of heating and hot water supply systems;
- Improving heating, cooling, ventilation and air-conditioning.

3.4.2 Case studies tackling energy poverty

Croatia

A programme on the reduction of energy poverty in areas of special state concern, covering comprehensive renovation of buildings in assisted and special government care areas, capacity building to alleviate energy poverty, reduce end-use energy consumption and consequently reduce CO_2 emissions from energy poor or vulnerable households by 2025, was adopted by Government of the Republic of Croatia in December 2021. To date, 413 buildings have been included in the programme, with 102 identified as high priority for renovation. The programme will require €40 million of financial support. The programme targets housing in assisted areas or 'areas of special state concern', which generally covers regions affected by war, as well as areas of poor economic development.

The programme for energy poverty alleviation in ‘areas of special state concern’ focuses on identifying beneficiaries and setting out criteria for energy poverty but does not seek to define energy poverty itself.

According to EU statistics, 7.4% of households in Croatia are unable to keep their homes adequately warm.

Bulgaria

There is no official definition for energy poverty in Bulgaria. However, the Social Assistance Act provides a definition for ‘*vulnerable customers*’. Upon application, vulnerable customers can receive targeted aid for electricity, heat or natural gas. Groups that are not covered by the definition may include elderly people, especially those who live alone in large family houses, and those who require higher temperatures for comfort.

There are plans to expand the definition of ‘vulnerable customers’ to represent a wider range of citizens. Measures for protection of vulnerable customers include the implementation of a social tariff as well as non-financial measures such as banning the suspension of electricity and energy efficiency improvements for households. The current definition for vulnerable customers is expected to cover 500,000 people (14% of the population) and would require €30 million per year from the state budget for energy poverty mitigation.

Portugal

To tackle energy poverty, Portugal first diagnosed the size of the problem using climate and EPC data in view of economic activity and availability. The LIGAR project is a current initiative to map and characterise the most vulnerable portion of the population to create an energy poverty index.

Portugal implements a social energy tariff that reduces the price of electricity and natural gas for those in energy poverty. Application of the social energy tariff was made automatic from 2016. Future measures to address energy poverty will incorporate the LTRS with a focus on improving both thermal comfort and indoor air quality whilst limiting energy consumption and increasing the use of efficient and renewable heating and cooling. The National Energy and Climate Plan aims to define energy poverty, identify vulnerable families, as well as quantify health indicators.

Energy poverty remains an important challenge for Portugal. There should be a focus on the energy efficient renovation of the building stock, without the expectation of any significant payback via energy savings. Despite the lack of a concrete national diagnosis or plan, there are several ongoing initiatives tackling energy poverty and a strong focus on developing a LTRS to support this issue.

3.4.3 Conclusions on discussion on vulnerable households

Possible criteria for identifying vulnerable households facing energy poverty are identified as follows:

- health impact (quantified)
- affordability of a ‘comfortable *home*’
- low income (selected as the preferred criteria by 3 groups)
- low level of insulation / building energy label
- age of occupant

Other criteria that were discussed included mortality rates, the percentage of citizens threatened by gentrification, the affordability of homes themselves, elderly citizens living in rural areas or with low pensions, and people with health conditions.

Highlights of 3.4	Many Member States have yet to define energy poverty despite the fact that it affects millions of citizens across the EU. Outlining a set of criteria to identify those in energy poverty is a good first step to understanding the scale of the challenge in each Member State and in which areas the population is most vulnerable. Both stakeholder dialogue and data collection on the building stock can help with the selection of these criteria.

3.5 Energy renovation of cultural heritage building

Directive 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on energy performance of buildings and Directive 2012/27/EU on energy efficiency, states that improving the energy performance of historic buildings and sites should be encouraged, while also safeguarding and preserving cultural heritage. Energy renovations of historic buildings that have the status of cultural property are more demanding, while costs are higher, and achieving requirements for energy efficiency is a big challenge.

Historic buildings are the symbol of European cities, towns, and villages; entire districts are unique proof of the European cultural heritage. About 35% of the EU's buildings are more than 50 years old, and approximately 75% of the building stock is energy inefficient. The dominant opinion in many countries is that historic buildings, particularly those with superior protection, should be exempt from implementing new technologies and energy-efficient solutions.

A certain degree of caution should be exercised when devising renovation plans for historic buildings. The argument that they cannot be adapted to integrate renewable energy installations for fear of changing their nature and appearance is not acceptable, nor is it future-proof or reliable. There are many great examples showing how historic buildings, renewable energy, and energy efficiency can dance together to be part of the solution moving into a sustainable future.

Beyond the opportunity for energy savings and carbon emission reduction, the built heritage needs continuous care and maintenance to sustain functionality and avoid decay. Energy renovation will improve usability and the preservation of historic buildings.

3.5.1 Results from Member States

Member States were asked some questions to get a sense of their progress and intentions regarding the renovation of protected buildings.

1) Does your country have a register of protected heritage buildings?

The questionnaire was filled in on a voluntary basis and answers were not fully representative. Some Member States confirmed having registers for heritage buildings and some countries, such as Croatia were currently working on developing databases to document additional information such as EPCs.

2) Do you have any national or regional programme for the energy renovation of buildings with cultural or protected heritage status? And do you keep a record of the number of heritage buildings to be renovated?

In most Member States, no programmes were identified. However, it was not easy for Member States to answer the second part of the question. In fact, it seemed difficult to estimate the number of heritage buildings because there is a wide variety of buildings, ways of registration, and degrees of conservation. However, Member States reported that they could provide approximate numbers and some even keep databases for each municipality.

3) Do you have any national or regional programme for energy renovation of buildings with status of cultural/protected heritage?

Most Member States responded that they have experience with heritage buildings (Figure 2). A very small number declared having experience with renovation of heritage buildings through co-financing with EU funds. The question whether costs are considered eligible in co-financing from EU building energy renovation funds returned mixed responses.

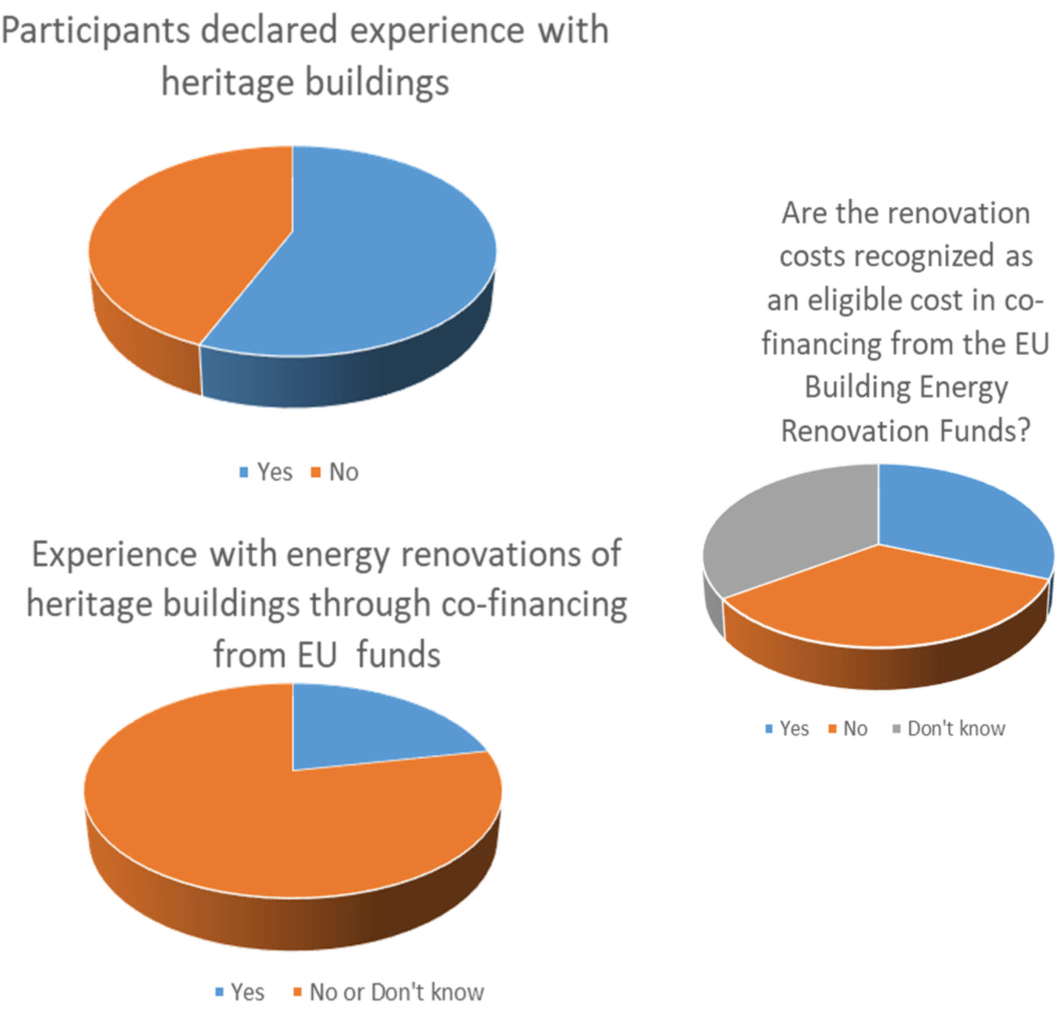

Figure 2. Questionnaire results on Member States' experience with heritage buildings.

4) If your country has experience with renovation of cultural/heritage buildings, please indicate which elements were found most difficult (e.g., walls, roof, windows, heating, etc.)

The external insulation was found to be the most problematic element to implement, as this would have a significant impact on the historic / protected elements of the buildings.

5) Are there any examples of projects where energy renovation of heritage buildings is part of a larger programme (related to structural and moisture remediation, healthy indoor climate conditions, fire safety and risks related to intense seismic activity)?

Some examples of projects were presented:

- Office building transformation, Aleksanterinkatu 7 Helsinki Finland
- Research project BioVernacular
- Renovation of the main building of Aalto University, Otakaari 1, Espoo Finland
- Bračak Castle, transformation of the ruined Bračak castle into a modern energy efficient center (balkangreenenergynews.com)

A little more than half of the responses showed that guidelines were provided. It was stressed that it is important to provide guidelines because cultural heritage buildings often do not represent the biggest share of the building stock and include specific challenges, and therefore professionals are not always properly trained to deal with these buildings.

3.5.2 The Croatian renovation programme for cultural heritage buildings

Croatia began a National Energy Renovation Programme for cultural heritage buildings. The programme proposal is still in the drafting stage. Croatia is rich in protected buildings, with considerable heritage from the Roman Empire. There is therefore a high potential for future development to bring neglected cultural heritage buildings back into operation, with a sustainable approach that can reduce energy consumption and maintenance costs.

According to estimates from the Croatian ministry of culture, there are around 1,950 individually protected cultural buildings and building complexes and around 100,665 buildings located within protected cultural and historical groupings. The variety of buildings is very wide, encompassing public buildings, apartment buildings, family houses over different climates (continental and coastal). To put this in perspective, the total area covered by protected buildings reaches over 26 million m^2.

Two approaches for cultural heritage building renovations can be considered: the first takes an **integral approach**, applying all energy efficiency measures (including the outer shell and technical systems of the building) and additional renovation measures in accordance with EU Directive 2018/844 (constructive renovation, fire protection, indoor climate conditions, etc.); the second approach only explores a **financially feasible option**, intended for buildings that qualify for heritage renovation programmes, but due to specific conservation conditions or other reasons, only some individual measures for energy renovation can be implemented. This approach does not envisage the application of the additional renovation measures in accordance with EU Directive 2018/844.

Three models, incorporating various levels of renovation measures were explored:

1. **A basic set of measures that can cover 50% of the heritage building stock**. The measures include thermal insulation of the roof/ceiling with unheated attic, regulation and balancing of heating systems, centralisation and modernisation of the domestic hot water system with the application of renewable energy systems, and modernisation of the lighting systems.

2. **A more extensive set of measures that can only cover 30% of the heritage building stock**. In addition to the measures mentioned under the first model, also windows and outer doors would be replaced.

3. **A model for a complete integral renovation covering only 20% of the heritage building stock**. Additional measures would include full restoration, moisture remediation, structural renovation, improving fire protection, improving healthy indoor temperature and humidity conditions, increased accessibility.

Currently, the project is in its first phase, where guidelines, financial models and instruments are defined, and awareness raising activities to attract interest from potential applicants are being implemented. In a second phase, the project will be further detailed and a call for project proposals will be launched. Then, construction works will begin for selected projects. The final phase will concern all post-renovations activities.

In the light of the recent earthquake (March 2020), many of the affected buildings will need to be renovated and options to prevent damage from future earthquakes should be evaluated.

3.5.3 The PRO-HERITAGE project

As part of the Horizon 2020 call for ’construction skills’, the PRO-Heritage project was created to protect traditional heritage skills. The project is coordinated by Burghauptmannschaft Österreich (BHO) in collaboration with nine partners from five countries. It started in February 2019 and is due to last 36 months.

The BHO was established in 1434 and manages 110 historic buildings owned by the Republic of Austria. In leading this project, the BHO aims to share experience and resources with other partners in Europe.

The management of heritage buildings is facing a skills shortage because in the next 5 to 10 years, approximately 30% of current experienced staff will retire. There is very little training available for maintenance managers and few certifications are available to validate those competencies. It is becoming urgent to preserve traditional craft, with sensitivity to cultural differences between regions and countries (architectural styles, regional building materials, relevant fields of management).

The PRO-Heritage project builds on two pre-existing schemes: the MODI-FY project (2014-2017) which was developing certified training courses in heritage asset management, and the European Heritage Academy (EHA), (since 2017) which trains and certifies heritage maintenance managers. Despite these programmes, there was still a need for further education of craftspeople, with a worsening experience gap. It is crucial to preserve traditional handcrafts as tourism depends on cultural heritage. Many jobs are directly and indirectly created by maintaining cultural heritage. Running a project on a European level creates opportunities for networking and for joining forces.

A deep understanding of a cultural heritage building is necessary in order to maintain it appropriately. The major needs addressed by the PRO-Heritage project are:

- to keep cultural heritage in good condition and available for future generations;
- to keep historic sites ‘accessible and adequate for current and future generations requirements’;
- to protect traditional competencies and skills for built cultural heritage;
- to involve adequately educated and trained professionals and craftsmen in conservation, maintenance and ongoing care;
- to maintain a high level of competence and skills;
- to certify professionals and craftsmen, and to keep these certificates up to date.

Highlights of 3.5	Through a questionnaire, Member States indicated that despite the widely recognised need to renovate protected buildings, only a few Member States declared having experience with heritage buildings and a very small number declared having experience with renovation of heritage buildings through co-financing with EU funds. The registers of heritage buildings and renovation guidelines are not uniform amongst Member States. Energy renovation of protected buildings is challenging and requires taking an individual approach to each building.

3.6 Renovation of buildings – impact of fire protection & risk of seismic activity

Buildings represent 36% of our CO2 emissions and 40% of the EU ‘s energy consumption. As part of the European Green Deal's key actions, increasing building renovations, via a ‘Renovation Wave’, is needed to ensure that the ambitious EU energy saving and decarbonisation goals by 2030 and 2050 can be reached.

The EPBD reported that 75% of EU buildings are energy inefficient and 80% of the building stock is over 30 years old. The current European existing building stock is thus ageing. It has structural safety challenges that require significant renovation efforts. Those buildings are neither safe nor energy efficient.

One of the main challenges of the 21st century is to increase the sustainability of our cities. However, to be considered sustainable, a town must, above all, be safe, particularly from natural hazards, which in Europe are mostly related to climate change (e.g., hurricanes, floods, storms, and landslides) and seismic events (earthquakes). With about one-quarter of buildings in Europe located in active seismic zones, these buildings are thus also at seismic risk. Unfortunately, sustainability is still not a priority in most European cities, especially those located in seismic countries such as Italy, where at least 50% of the residential stock is earthquake prone. In comparison, over 80% of the same stock is highly energy-consuming and carbon dioxide-emitting, and therefore triggers climate change hazards.

Article 2a of Directive (EU) 2018/844 states that Member States may use their LTRS to address fire safety and risks related to intense seismic activity affecting energy efficiency renovations and the lifetime of buildings. Combining seismic resistance measures with energy renovation is not new, but the need for such an approach is crucial and obvious.

The Joint Research Centre (JRC) addressed an opportunity to combine energy efficiency renovation with seismic resistance renovation. The preliminary results of the study showed that a combined seismic and energy renovation leads to cost benefits in moderate to high seismic zones.

For earthquake resistance to be included in energy renovation, particularly for Southern European countries which are more prone to earthquakes, seismic mitigation and energy efficiency must also be combined with fire safety in the building renovation. Fire regulations must also be uniform throughout Europe in order to avoid catastrophes, and all relevant EU policies should be linked, while introducing national policies to make the existing building stock fit for purpose for the decades to come.

To ensure a highly energy-efficient and decarbonised building stock and ensure that the LTRS delivers the envisaged goals, it is important to implement modern solutions and rules in fire protection and account for risks of increased seismic activity during energy renovation of buildings.

3.6.1 New study by the JRC

The iRESIST+ project stands for **I**nnovative Seismic plus energy **R**etrofitting of the **E**xi**S**ting Bu**i**lding **S**tock. It aims to develop integrated techniques for the seismic strengthening and energy efficiency of existing buildings. The project is supported by the JRC, which has the mission of supporting EU policies with independent evidence throughout the policy cycle.

The current policy goals are:

1. Green transition: European Green Deal, Renovation Wave, New European Bauhaus, Energy Performance of Buildings Directive
2. Risk reduction: Action Plan on the Sendai Framework, Sustainable Development Goal 11
3. Industrial strategy: New Industrial Strategy for Europe, New Circular Economy Action Plan
4. Cultural heritage: European Framework for Action on Cultural Heritage, European Agenda for Culture.

The green transition is the first priority of this Commission, and the seismic scheme is in line with the policy goals of ‘risk reduction’ and ‘cultural heritage’.

The JRC is also supporting **the EQUIFIRE project** which focuses on the safety of buildings subject to fire following earthquakes (FFE). The aim of the project is to understand FFE behaviour of structural components and fire protection systems through hybrid testing. Ultimately, it would lead to an improvement of design standards.

Experimental testing was performed on a full scale 4-storey building using a hybrid testing method where part of the building is a real lab prototype, and the rest is numerically simulated.

Recently, the mandate M/515 called for improving Eurocodes[1] by extending the scope of structural Eurocodes to improve fire safety engineering approaches. Fire safety engineering refers to fire resistance providing for safe evacuation, safe firefighting, fire barriers, and compartmentation. The next generation of fire safety codes should harmonise models, methods and design rules.

3.6.2 Seismic risk inclusion in LTRS

In the context of the Renovation Wave, key considerations are:

- Energy efficiency being the first priority
- Affordability, energy poverty
- Decarbonisation and integration of renewables
- Lifecycle thinking and circularity
- **High health and environmental standards – fire and seismic safety fall under this consideration**
- Smartness
- Aesthetics and architectural quality

Even though fire and seismic safety are outside of the scope of the energy performance of building, it is still crucial to integrate them into the Renovation Wave strategy.

Under the EPBD, fire safety and seismic safety considerations are raised in two articles:

- Article 2a: Each Member State may use its long-term renovation strategy to address fire safety and risks related to intense seismic activity affecting energy efficiency renovations and the lifetime of building
- Article 7: Member States shall encourage, in relation to buildings undergoing major renovation, high-efficiency alternative systems, in so far as this is technically, functionally and economically feasible, and shall address the issues of healthy indoor climate conditions, fire safety and risks related to intense seismic activity

The inclusion of fire and seismic safety in the LTRS is particularly important for countries like Bulgaria, Croatia, Cyprus, Greece, Italy, Malta and Romania. For example, Cyprus requires that prior to major renovation, 'the owner of a building or a building unit where the building permit was issued before 1994, must appoint a suitable designer, who will prepare a report on the valuation of the load-bearing structure in accordance with the Eurocodes in force'. The SupERB project[2] was mentioned because it offers an integrated approach for seismic and energy upgrading of existing buildings.

3.6.3 Including earthquake resistance during energy renovation

Destructive earthquakes mainly happen in the southern part of Europe. When developing a strategy for updating buildings, the question of what to prioritise will depend on local needs: mechanical stability, fire safety, access for all, use of energy, making it functional, etc. The age of the building stock closely correlates to how resistant buildings are to earthquakes – older buildings are in higher risk of seismic damage.

EU policies focus on sustainability issues such as zero CO_2, circular economy, accessibility. Several EU co-funding programmes exist: financial programmes, EU budget, several EU funds/, the new Resilience and Recovery fund, and more. However, programmes are considered individually, and the apparent lack of integration may hinder the renovation progress. It is important to define a unified solution starting from the basics: from the function of the building, the structure, safety while integrating energy efficiency improvements.

A renovation programme for seismic stability of endangered buildings was designed after the following realisation: 'All across the world, the same pattern is being observed: after an earthquake, national governments and international communities invest enormous resources into repairing the damage, but practically no effort is being done to prevent the consequences of earthquake before it happens.'

Efforts are underway to link all relevant EU policies and to introduce national policies to make the existing building stock fit for purpose for the decades to come. The programme is twofold: firstly, it will assess the state of buildings and technical solutions; secondly, it will develop financial frameworks, action plans and promotion campaigns. The presentation was concluded by opposing two scenarios: the first one only takes energy efficiency into consideration during the renovation of a building, but the building will be destroyed when an earthquake happens, or it will need new major renovations; the second scenario would start by renovating the building to be seismic- and fire-safe while also improving its energy efficiency. It is obvious that the second scenario is the sensible option for long-lasting benefits.

3.6.4 Linking energy renovation, fire safety and seismic risk management

Climate change is one of the great responsibilities of the building industry. Decisions taken during the design phase of a building project have an important long-term impact and must be comprehensive and ensure long-lasting impacts.

The Fire Information Exchange Platform (FIEP) was created in 2017 to enhance cooperation among Member States, as well as to facilitate the exchange of information with stakeholders. It identifies five priority areas: statistics, fire prevention, innovation in products and applications including high-rise buildings, experience from fire accidents and fire engineering. The FIEP comprises the seven layers of fire safety that must be considered in order to protect citizens and buildings, and documents how each of these can be improved.

To meet energy efficiency requirements, one of the energy effective solutions is the construction of buildings with an energy-enhanced exterior sheath/façade. The most common solution today is the External Thermal Insulation Composite Systems known as ETICS. But, unfortunately, the behaviour of this thermal insulation at high temperatures was not properly considered.

In Croatia, the basic requirements are gathered in the Building Act. The energy efficiency renovation had no impact on the seismic resistance of buildings. Yet, in Croatia, about 30% of the total stock of buildings was built before 1963 when the earthquake risk was not considered in building design. Since 1964, Croatia has significantly increased requirements to account for seismic risk, and since 2008 European regulations have been reinforced. In addition to the energy renovation of buildings, it is possible to apply many technical measures to reduce the risk of fire and the impact of seismic activity. Such actions can, however, increase the cost of renovation by an average of 1,500 Kuna/m^2 or approximately 200 euro/m^2.

3.6.5 Results

The discussions on the topic of energy renovation, fire protection and seismic resistance were supported by the results of an internal poll. The first question investigated whether the measures for improving fire protection are financially supported in energy renovation programmes (beyond legal requirements). The overarching response from around 70% of Member States was that measures are not financially supported, around 20% of participants said they do not know, and only around 15% said they are supported. Equally, there are generally no measures for improving seismic resistance of buildings as an integral part of energy renovation requirements, while around 20% of participants said they do not know if they exist. On the question whether measures for seismic resistance are financially supported through energy renovation programmes, as per the other questions, the overall response was that there are currently no support measures (over 80% of responses). 11% of the respondents said that there are measures in place, and 6% did not know.

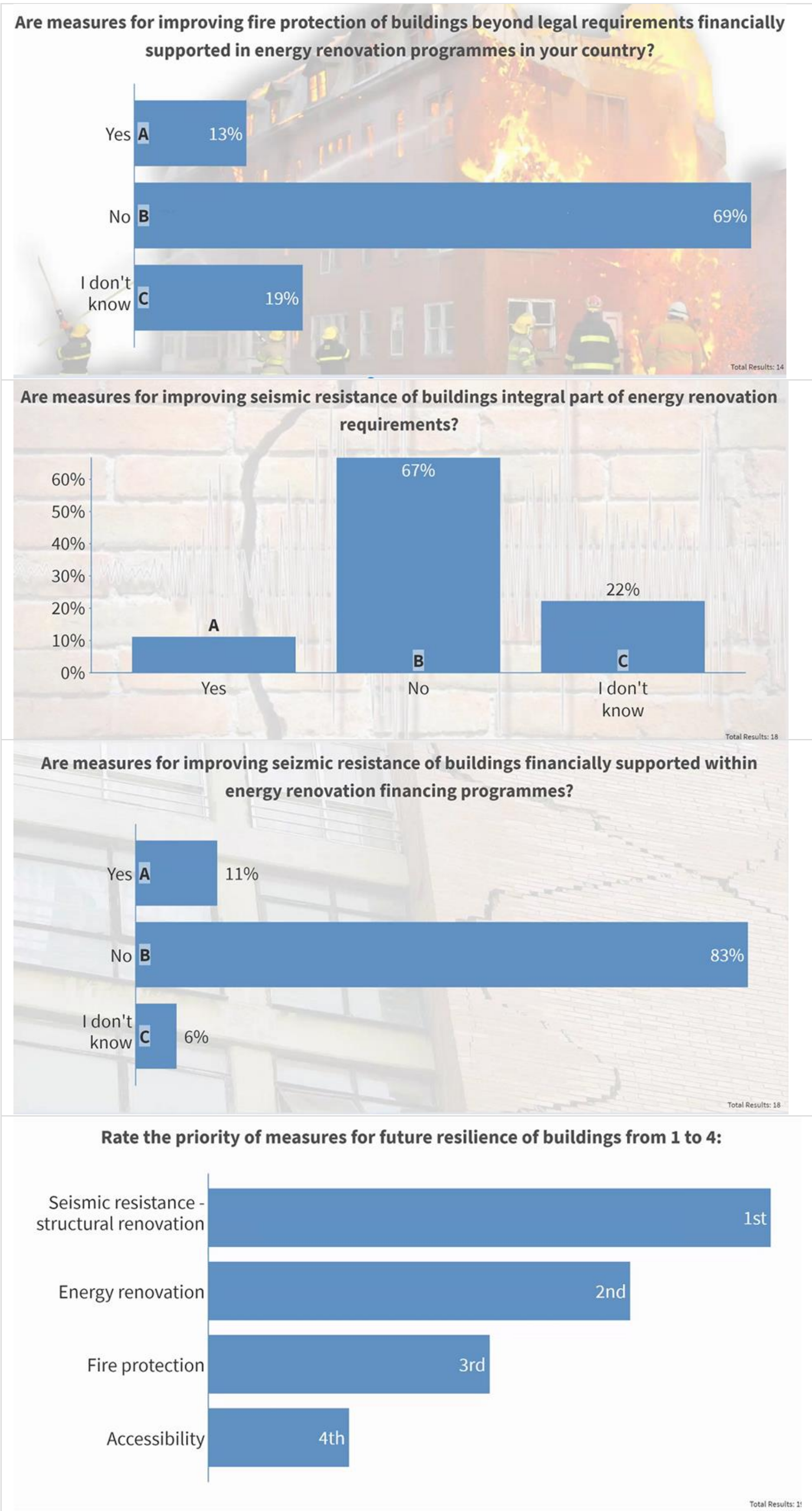

Figure 3. Questionnaire results on building energy renovation, fire safety and seismic risk.

Highlights of 3.6	This topic provided an opportunity to discuss arguments for including earthquake resistance during energy renovation, particularly for Southern European countries which tend to be more prone to earthquakes. Energy renovation must also consider country-specific vulnerabilities. In seismically active areas, energy renovations must be linked to fire and seismic resistance in order to be truly sustainable.

3.7 Worst-performing buildings – scope, policy and measures (Renovation Wave)

Article 2a of Directive (EU) 2018/844 states that Member States may use their LTRS to address the range of policies and actions to target the worst-performing segments of their national building stock. Additionally, in the upcoming revision of the EPBD, Minimum Energy Performance Standards (MEPS) are expected to be introduced to tackle the worst-performing buildings.

A dedicated CA EPBD session explored differences in starting positions in Member States and measures provided for the renovation of the worst-performing buildings, including Minimum Energy Performance Standards (MEPS). It aimed to compare how the LTRS of Member States determine the measures for worst-performing buildings and how they solve the gap between initial state and post-energy renovation in worst-performing buildings.

The scope and measure to address the worst-performing segment of the building stock varies across Member States. In some Member States, the worst-performing buildings are also in poor structural condition or at risk from seismic activity. Energy improvements therefore need to be planned as part of a more comprehensive renovation that can also increase the safety and efficiency of the building stock.

In some cases, the worst-performing buildings could be social housing or buildings housing people at risk of energy poverty. Renovated, healthy and safe homes will thus also reduce energy poverty which is a focus of the Renovation Wave.

This session was an opportunity to compare how worst-performing buildings are identified across Member States and how they aim to promote renovation. It explored policies targeting worst-performing buildings reported in the recently submitted LTRS.

3.7.1. LTRS and worst-performing buildings

A first presentation during the session re-established the need to tackle worst performing buildings within the LTRS. Indeed, it is the most cost-effective approach - the return on investment is most obvious in the case of worst-performing buildings. It can also improve the safety of poor-quality buildings that are often linked with energy poverty as they are usually occupied by low-income households.

Worst-performing buildings are considered in the Renovation Wave and the revision of the EPBD through the introduction of mandatory MEPS.

The LTRS that have been submitted so far have already addressed this issue and provide existing or planned policy for tackling worst-performing buildings.

Bulgaria

The main elements of the Bulgarian LTRS are:

- Cost-effective approaches to renovation
- Energy savings measures packages
- Roadmap 2021-2050
- Strategic objectives, priorities, and policy measures
- Financing.

All aspects of the LTRS are interconnected, as the Bulgarian national building stock observatory allows the determination of cost-effective approaches. Once the approaches are established, examples of packages of measures can be developed to align with the 2050 goals. And finally, financial models can be explored to support the uptake of the renovations.

Through the Bulgarian national building stock observatory, the state of the building stock can be assessed:

- 65% of residential buildings and 35% of non-residential buildings need to be renovated;
- 90% of residential buildings are single-family homes and 96.6% of residential buildings are owned by individuals;
- of non-residential buildings, 56.6% are privately owned and 29% are owned by the state and municipalities, the rest are unknown or have mixed ownership;
- the total floor area of public buildings is only half that of the residential buildings.

Understanding the building stock allowed them to establish their most important target: residential buildings.

The Roadmap 2021-2050 aims to renovate 111 million m^2 of residential buildings (equivalent to 144,56 MWh/year energy savings) and 16.5 million m^2 of non-residential buildings (2283 MWh/year energy savings).

The building stock is generally inefficient, with poor energy performance. Consumers who face financial difficulties and cannot renovate their homes are not concentrated in separate buildings or territories. Therefore, in Bulgaria it is inefficient to try to establish a 'narrow' segment of worst-performing buildings. However, they do focus renovation policies on buildings with energy classes E, F and G for all building categories.

Bulgaria established a regulatory framework to create conditions for investments in sustainable construction, prepared buildings for smart management and for tracking and reporting the results of energy renovation programmes. Bulgaria also investigated sustainable financial instruments suitable for different target groups and building types. Finally, administrative issues were considered, such as building professionals' capacity at the level of state and local authorities, national communication campaigns, and measures to support research and innovation.

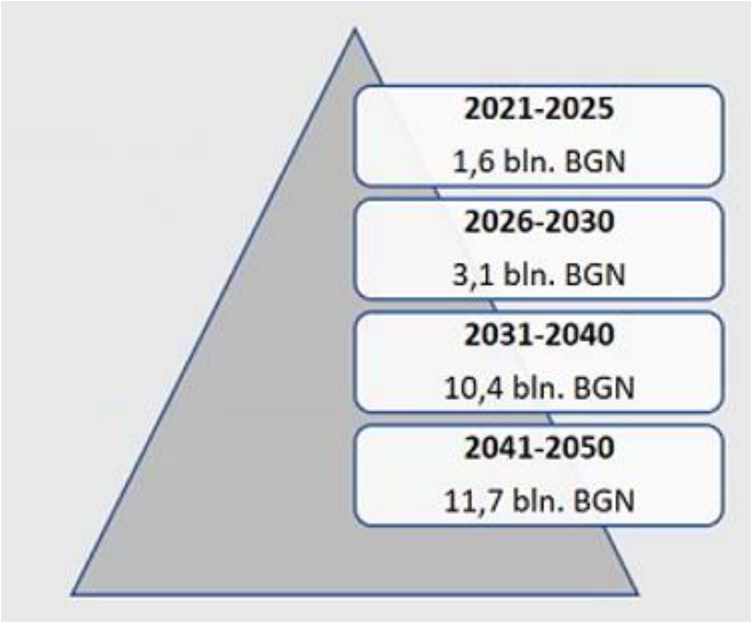

Figure 4. Investment needed in Bulgaria to achieve the LTRS targets.

The LTRS dedicated a chapter to funding mechanisms such as green bonds, energy efficient mortgages, specialised credit lines, on-bill financing, guaranteed funds and credit risk sharing mechanisms, energy performance contracts (with energy services companies (ESCOs)) and revolving energy efficiency funds. The investment needed is described in Figure 4.

Lastly, the presentation discussed the Bulgarian National Resilience and Recovery Plan (which was still in draft). It comprises four pillars: Innovation (26% of resources allocated), Green (35.6% of resources allocated), Connected (21.9% of resources allocated) and Fair (16.5% of resources allocated). Within this plan, the building sector is addressed through:

- the establishment of a national decarbonisation fund;
- the development of a definition of energy poverty for the purpose of financing energy efficiency projects;
- suggested mechanisms for financing energy efficiency and RES projects together with electricity bills; and
- one-stop-shops.

Poland

The Polish building stock in its LTRS is grouped into the following building categories: multi-family buildings, single-family buildings, collective accommodation buildings, public buildings, production/utility/warehouse buildings, and uncategorised buildings.

The biggest share of family buildings was built after World War II and are in need of better thermal insulation as well as the replacement of the central heating. Most of the pre-war urban buildings are still in poor technical condition and the dominant source of heat is still a coal-fired boiler. Flow water heaters are also common. Some apartments are equipped with central heating powered by gas or solid fuel boilers.

Poland focuses public interventions on the modernisation of multi-family residential buildings in order to address the problem of high emissions resulting from heating single-family houses with poor-quality fuel as well as energy poverty.

In 2016, 12.2% of the Polish population was affected by energy poverty, according to the measure High Cost-Low Income; and 65% of all energy poor households lived in single-family houses. Energy poor single-family houses are generally older than other single-family houses in Poland. More than one-fifth of the poor energy buildings are pre-war buildings, and one-third are houses built between 1961 and 1980.

Poland uses a multidimensional energy poverty index (MEPI) which shows that the risk of energy poverty in Poland is strongly related to the characteristics of the dwelling. Expenditure-based indicators show a much higher risk of energy poverty among households living in detached houses. The dwelling area in detached houses is much larger than the dwelling area in multi-family buildings, which translates into higher heating costs. Finally, the subjective indicators show that households living in multi-family buildings are at a slightly higher risk of poverty, which may be due to lower energy efficiency standards in those types of dwellings.

Policies and measures to support the renovation of buildings

There are four measures in place in Poland: two programmes under the Ministry of Climate and Environment's Priority programme of National Fund for Environmental Protection and Water Management, 'Clean Air' and 'Stop Smog'; and two programmes under the Thermo-modernisation and Renovation Fund.

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CLEAN AIR is a Priority programme of National Fund for Environmental Protection and Water Management. The purpose of the programme is to co-finance the replacement of old and ineffective heat sources using solid fuel with modern heat sources that meet the highest standards; and the necessary thermal modernisation works of the building.

Owners or co-owners of single-family residential buildings with a monthly income per capita below a given threshold can access the programme.

There is a basic grant of 30,000 PLN (about €7 000) and an extended grant of 37,000 PLN (about €8 600) when photovoltaics are included.

The programme runs from 2018 to 2030 with a budget of around €30 billion.

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STOP SMOG is a priority programme of the National Fund for Environmental Protection and Water Management. The purpose of this programme is to replace high-emission heat sources with low-emission sources, connect the dwellings to the heating or gas network, and improve the insulation of single-family residential buildings.

The programme is targeted at municipalities located in areas which are particularly affected by pollution from poor fuels - the so-called anti-smog resolution referred to in the Act of April 27, 2001, Environmental Protection Law.

Municipalities up to 100,000 residents can access up to 70% co-financing. Municipalities with more than 100,000 residents will access less than 70% co-financing.

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The **THERMAL MODERNISATION BONUS** programme is part of the Thermo-modernisation and Renovation Fund.

The aim is to support projects related to thermal modernisation or renovation of buildings, including municipal buildings, reinforcing of buildings with concrete slabs construction, and assembling renewable energy micro-installations in the buildings.

The bonus can be allocated to housing cooperatives and commercial law companies, local government units, housing associations, local heating networks, local heat sources as well as social housing and private owners (including owners of single-family houses).

An investor is entitled to the thermal modernisation bonus for repayment of a loan taken for a thermal modernisation project. It cannot be used by investors who carry out a thermo-modernisation project solely using their own funds.

The amount of the thermal modernisation bonus is 16% of the costs for a thermal modernisation project, 21% of the costs of a thermal modernisation project along with the installation of micro-installations of renewable energy sources (RES), and up to 50% of the cost for strengthening a large-panel building with the so-called ‘Big Plate’.

RENOVATION PREMIUM is another programme under the Thermo-modernisation and Renovation Fund

This fund supports similar projects to the thermal modernisation bonus but is targeted at owners or managers of multi-family buildings, which were used:

- from 14 August 1961, or
- at least 20 years before the date of submitting the application for a repair premium to the crediting bank and
    - the building belongs to a social housing initiative or a social housing association
    - the building was constructed with the use of a loan granted by BGK.

The renovation premium is available only for the repayment of a loan taken for implementing a renovation project.

The amount of the renovation bonus is 15% of the cost of the renovation project. If the conditions of Art. 9a of the Act on supporting thermo-modernisation and renovation are met, the renovation bonus can reach 50% of the renovation project costs for municipal buildings or 60% of the costs for historic municipal buildings.

Croatia

In Croatia, the building stock has consistently increased over the years. In 2011, buildings represented 198,133,193 m² and in 2018 they represented 209,656,157 m². This is an estimate based on census data and amended by issued building permits, buildings survey data, and demolished buildings data. The demolition rate is very low in Croatia (0.1% of the building stock).

On the other hand, the area of vacant buildings for permanent use has more than doubled over a 10-year period (2001-2011). In Croatia, most of the construction ends up as vacant buildings as Croatia is strongly hit by depopulation.

Croatia must deal with a poor population which is strongly linked to energy poverty. They face leaking roofs, damp walls and floors, and the inability to keep their homes warm.

Croatia developed a programme for mitigation of energy poverty embedded in the Integrated National Climate and Energy Plan Programme from 2021 to 2030. The programme aims to introduce renewable energy sources in areas of special concern as well as in areas identified through detailed research of publicly owned worst-performing buildings.

damage and losses	
housing	9.13 bn €
education	2.21 bn €
health care	2.43 bn €
culture	2.52 bn €
business	1.03 bn €
	17.31 bn €

Table 1. Cost of repair of buildings per type after the 2020 earthquake.

In 2020, when an assessment of progress and achievements was due, Croatia was hit by an earthquake affecting about 10% of the building stock. Considering the construction rates, it will take 20 years to fix the damage. The repair costs per sector are described in Table 1.

Energy refurbishment will be included in the damage repairs. However, the new priority in Croatia is to have an earthquake proof building stock.

3.7.2. Results

The discussions on this topic were supported by the results of a poll. The first question investigated the criteria used to determine worst-performing buildings in Member States. The predominant response from around 79% of respondents was only the energy performance, from 17% energy performance and construction stability, and from 4% multiple criteria. Concerning the question whether energy renovation of worst-performing buildings in Member States is combined with structural renovation, 52% responded that an energy renovation cannot be performed on a building which is not structurally safe. A further 40% said it was not relevant in their country. On the question whether buildings that are not structurally safe were excluded from the building stock used for renovation targets set in Member States' LTRS, the predominant answer (55%) was no, while 36% did not know, and 9% said yes, they were. The priority measures for future resilience of buildings, presented from the most important to the less important, were: energy renovation, fire protection, seismic resistance – structural renovation, accessibility.

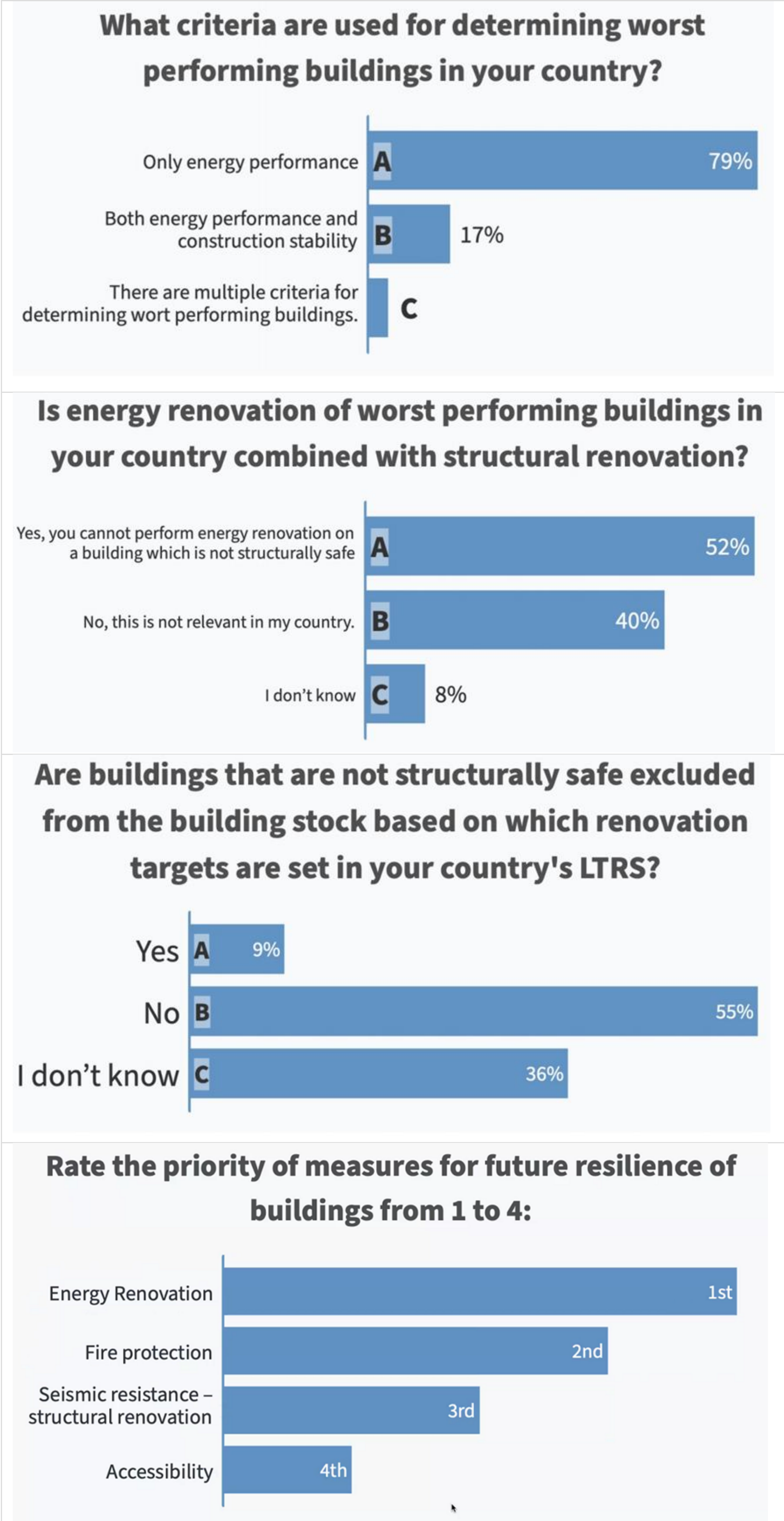


Figure 5. Questionnaire results on Member States' views about LTRS and worst-performing buildings.

This session showed that national circumstances affect how worst-performing buildings are defined and which measures are set up to tackle specific problems.

In **Bulgaria**, it is difficult to identify a narrow segment of worst-performing buildings as most buildings are generally poor-performing. As such, the worst-performing buildings are identified based on their energy class (E, F and G). Bulgaria developed a regulatory framework to create conditions for investments in sustainable construction, prepare buildings for smart management and for tracking and reporting the results of energy renovation programmes. They also investigated several financial instruments such as green bonds, energy efficient mortgages, specialised credit lines, on-bill financing, guaranteed funds and credit risk sharing mechanisms, energy performance contracts (with energy services companies (ESCOs)), and revolving energy efficiency funds.

In **Poland**, there are significant pollution problems due to old and inefficient heating systems, therefore such dwellings are prioritised. Several programmes have been introduced to co-finance investments in upgrading heating systems and improving building insulation.

In **Croatia**, an earthquake in 2020 caused great damage to major cities, shifting the priority to repairing the damages.

A questionnaire to participants gauged the general sense of priorities at EU level. Most reported that worst-performing buildings are identified based on the energy performance class. For future resilience of buildings, the priority continues to be energy renovation.

Highlights of 3.7	Discussion on the topic LTRS and worst-performing buildings showed that national circumstances affect how worst-performing buildings are defined and which measures are taken to address specific problems. Most Member States reported that worst-performing buildings are identified based on the energy performance class. For future resilience of buildings, the priority continues to be energy renovation.

3.8 Linking finance & EPCs for energy renovations with energy savings

The aim of the session was to evaluate how Member States distribute funding for energy renovation projects and identify tools that can help calculate and verify energy savings from renovations in order to improve procedures for awarding subsidies.

Results from a questionnaire to Member States conducted prior to the session showed that:

- Most financing mechanisms rely on grants
- In most cases, the documentation needed to access financing mechanisms are an EPC, design documentation and a quote from the contractor
- The technical requirements also include proof that the renovation will achieve defined savings in energy consumption. In most cases, this evidence was provided with EPCs pre- and post-renovation

The following presentation provided an overview of the European Commission activities including an overview of available funding resources, the EU taxonomy, summary of various policy strategies encouraged by the Commission (LTRS, MEPS, deep renovation) and discussed the role of EPCs related to these activities.

There was a presentation of two projects which develop tools for better decision-making processes for distributing funding:

- The iBRoad project developed a Building Renovation Passport (BRP) comprising a customised roadmap for the building's stepwise and deep renovation, along with a digital logbook containing the history and information of the building. The project thereby contributes to enhancing the quality of input data and advice, and facilitating better distribution of funding. The iBRoad2EPC project, as the successor of iBRoad, aims to integrate elements of the iBRoad Building Renovation Passport into EPC schemes.
- The EPC RECAST project focused on improving EPCs and making them more comparable between countries in order to fairly and efficiently distribute funding on the EU scale.

The final part of the session discussed the following topics:

- How to improve EPCs while keeping them affordable
- The role of measured versus calculated energy consumption
- How to calculate and report energy savings from renovations
- How to stimulate deep renovation.

3.8.1. Main discussions and outcomes – questionnaire results

A questionnaire was conducted amongst Member States prior to the session to learn about the financing mechanisms available and the required documentation to obtain financing.

Responses to the questionnaire showed that most financing mechanisms rely on grants, and soft loans are prominent in the residential sector. In some Member States, financing mechanisms are not available for commercial and public buildings.

Regarding documentation required to obtain financial support, in most cases building owners must provide the building's EPC, design documentation and a quote from the contractor. Energy passports are generally not used for this purpose.

Following the session, participants were asked if they believe it is excessive to require an EPC in addition to the design documentation and a quote from the contractor to access financing. Opinions were split evenly.

The questionnaire helped to understand the technical requirements to obtain financing. In many cases, the following technical requirements must be provided:

- The energy class prior renovation
- Building elements and technical systems to be upgraded
- Proof that the renovation will achieve savings equivalent to a defined percentage of the energy consumption of the building

The vast majority of Member States said that evidence to prove the energy savings achieved after renovation comes from an EPC after renovation.

Session participants were asked to rate their confidence in EPC savings after renovation (ranging from 1-none to 5-absolute). The answers were mostly concentrated around rate 3-medium. Some participants added that EPCs represent a standard situation, and therefore the savings may vary depending on how the building is being used.

3.8.2. EU Commission activities

The presentation started with an overview of three EU funds available for regions, municipalities, companies, and individuals:

1. The Recovery and Resilience Facility has a budget of €672.5 billion to drive investments and reforms (for example, the French project ORE or the Spanish Euro PACE project)

2. The Cohesion Policy Funds with a proposed budget of €330 billion to be used for direct investments, leverage private investments, and provide technical assistance

3. The Just Transition Fund (with a proposed allocation of €17.5 billion) will be used for energy efficiency and circular economy investments

It was pointed out that to access these funds, minimum improvement targets must be reached.

Four EU funds to leverage private investments are also available:

1. InvestEU which is to support unlocking necessary private financing via dedicated financial products and an advisory hub

2. The EIB initiative for building renovation which helps create portfolios of building renovation projects and provides tailored financial support

3. The Private Finance for Energy Efficiency (PF4EE) combines lending from EIB to private banks with guarantees and technical assistance

4. The EU ETS modernisation fund supports investments in the modernisation of energy systems and energy efficiency improvements of the 10 lower-income Member States

There was an overview of the EU Taxonomy activities that relate to the building sector: construction of new buildings, renovation of existing buildings, individual measures, and professional services, as well as acquisition of buildings. Most of these investments covered by the EU taxonomy are evaluated based on the EPC. It is recognised that although the EPC is not perfect, it is the most common instrument across the EU. In addition, the EPC methodology is not privately handled, and the EPC is recognised as a legal document.

The presentation then focused on the European Commission's ambitions for renovating existing buildings, aiming to encourage the renovation of worst-performing buildings. The key elements of their plan to support this ambition are:

- The enhanced LTRS

- The MEPS which must be coherent with national targets set within the LTRS and should be based on EPCs
- The introduction of a clear definition for deep renovation

Finally, it was made clear that measuring improvements is a key aspect to encouraging renovation. Examples of tools mentioned included the EPCs, the BRPs and the use of databases. The presentation concluded with a reminder that EPCs are a key tool and Member States should focus on improving them.

3.8.3. iBRoad2EPC project

The iBRoad2EPC project aims to integrate BRP elements into EPC schemes to improve the quality and depth of renovation advice and thereby enable financing for deep energy renovations. The predecessor of iBRoad2EPC, the iBRoad project, developed a Building Renovation Passport (BRP), comprising a customised roadmap for the building's stepwise and deep renovation, along with a digital logbook containing the history and information of the building.

The roadmap is developed following an assessment through an on-site visit, an interview with the building owner and a calculation of the current energy performance of the building. The outcome of the assessment is a report detailing the current state of the building, a roadmap overview, and a detailed plan of renovation steps.

The roadmap ensures the order in which renovation steps should be performed to be most efficient and supports the implementation of bundles of suitable energy efficiency measures including issues to take into account to avoid lock-ins. The logbook contains the roadmap, the building's history of measures and any other building related information, as well as information and links to relevant funding schemes. BPRs can minimise the risk for investment by third parties and can be used as a business plan to negotiate better terms. The BRP can also support verifications, to check that the expected impacts have been achieved.

Public money should be spent in order to achieve the greatest impact. BRPs and other advisory services can help in the policy process while targeting low-income households. Indeed, the risk of increasing minimum standards is to make them only achievable for rich homeowners. BRPs can help to provide a variety of options to reach the increased standards in a cost-effective way.

The iBRoad digital logbook and roadmap were adapted and implemented in five countries. Results of the trials showed that they offer noticeable improvements and helped avoiding mis-investments.

The iBRoad2EPC project now aims to integrate the BRP within EPC schemes in six Member States and will expand from single-family houses to more building types.

The presentation concluded by summarising the five guiding principles of the project:

1. To reach the highest possible energy efficiency;
2. To tailor the roadmap to each building and context;
3. To adopt a long-term perspective which can include one or multiple steps;
4. To adapt the timing and sequencing of the renovation steps to favour an efficient and cost-optimal renovation process;
5. To motivate action.

The guiding principles were then linked to financing approaches along with good practice examples and suggestions for improvements.

Finally, Member States were encouraged to consider the recovery package as a major opportunity for deep renovation.

3.8.4. EPC RECAST

The EPC RECAST project develops an innovative process and digital toolbox for a new generation of EPCs. They aim to improve reliability of EPCs and the related renovation recommendations. The EPC RECAST is a collaborative project comprising 11 partners across seven countries, with more than 150 pilot buildings.

The topics covered by the project are the following:

- Developing consistent metrics for energy savings: Key Performance Indicators (KPIs);
- Improving the data collection and reporting process;
- Improving quality checking;
- Renovation recommendations and roadmaps.

They identified three steps for improving EPCs:

1. Data collection and inspection process;
2. Energy performance calculation;
3. EPC recast certification renovation roadmap building passport.

The presentation started by focusing on the metrics to evaluate savings. The common metric needed to access renovation financing is an energy performance indicator, usually a numerical indicator of primary energy use expressed in kWh/m^2 per year. This indicator comes with challenges: the primary energy factors are difficult to quantify and may vary significantly depending on the method used; and the definition of floor area also varies. This seemingly simple metric highlights the need for uniform definitions without which there can be no efficient EU/national policy for financing renovation.

As part of the EPC RECAST project, research was conducted to compare which energy performance indicators are included in national/regional EPCs. It was no surprise that Member States use varying indicators for EPCs making it difficult to compare EPCs between regions. In addition, information on energy consumption per end-use is not available across all countries, and some countries choose to only include specific end-uses such as hot water and space heating. This makes it difficult to compare renovation actions between countries.

The project aims to find solutions at EU scale to enable EU funds to be fairly and efficiently distributed. Building on the work done as part of the ALDREN project, which focused on non-residential buildings, the EPC RECAST focused on residential buildings and develops a European energy performance scale along with a voluntary European EPC template. The template includes reporting formats compliant with LEVEL(s) and new sets of CEN standards.

The EPC RECAST project also aims to identify and promote the use of innovative data collection methods such as on-site geometrical scanning apps on a tablet or smartphone.

Another focus of the project is to improve quality checks by introducing mandatory minimum quality checks, including control indicators and data sources. For example, they suggest cross-checking the data against databases of similar buildings.

3.8.5. Results

The discussion started with an important question: how to increase the value of EPCs while maintaining them affordable. Participants suggested contracting external groups to create tools that would improve processes for assessors. Some also said that in the case of non-residential buildings, improving EPCs and increasing their cost is relatively feasible, but it becomes more complicated for residential buildings.

The second discussion was about whether EPCs should rely on measured or calculated consumption. There was a consensus that both are needed. The calculated consumption is used to produce an asset rating whereas the measured consumption helps to provide tailored information to the homeowner.

The session concluded with a poll to engage with participants. Main results (Figure 6) are summarised below:

- Most participants said that their states do report energy savings from energy renovation;
- Most answered that savings are calculated based on engineering estimates;
- Most participants thought that the most appropriate proof for potential savings from a renovation project is an EPC before and after the renovation;
- Asked what they consider most important for stimulating deep renovation, participants gave the following answers:
    - consensus that ‘grants’ are essential;
    - data;
    - financing linked to requirements;
    - a plan;
    - EPC;
    - financing based on reliable assessment;
    - regular mandatory property checks;
    - savings;
    - MEPS;
    - CO_2 tax;
    - awareness of benefits;
    - enforcement.

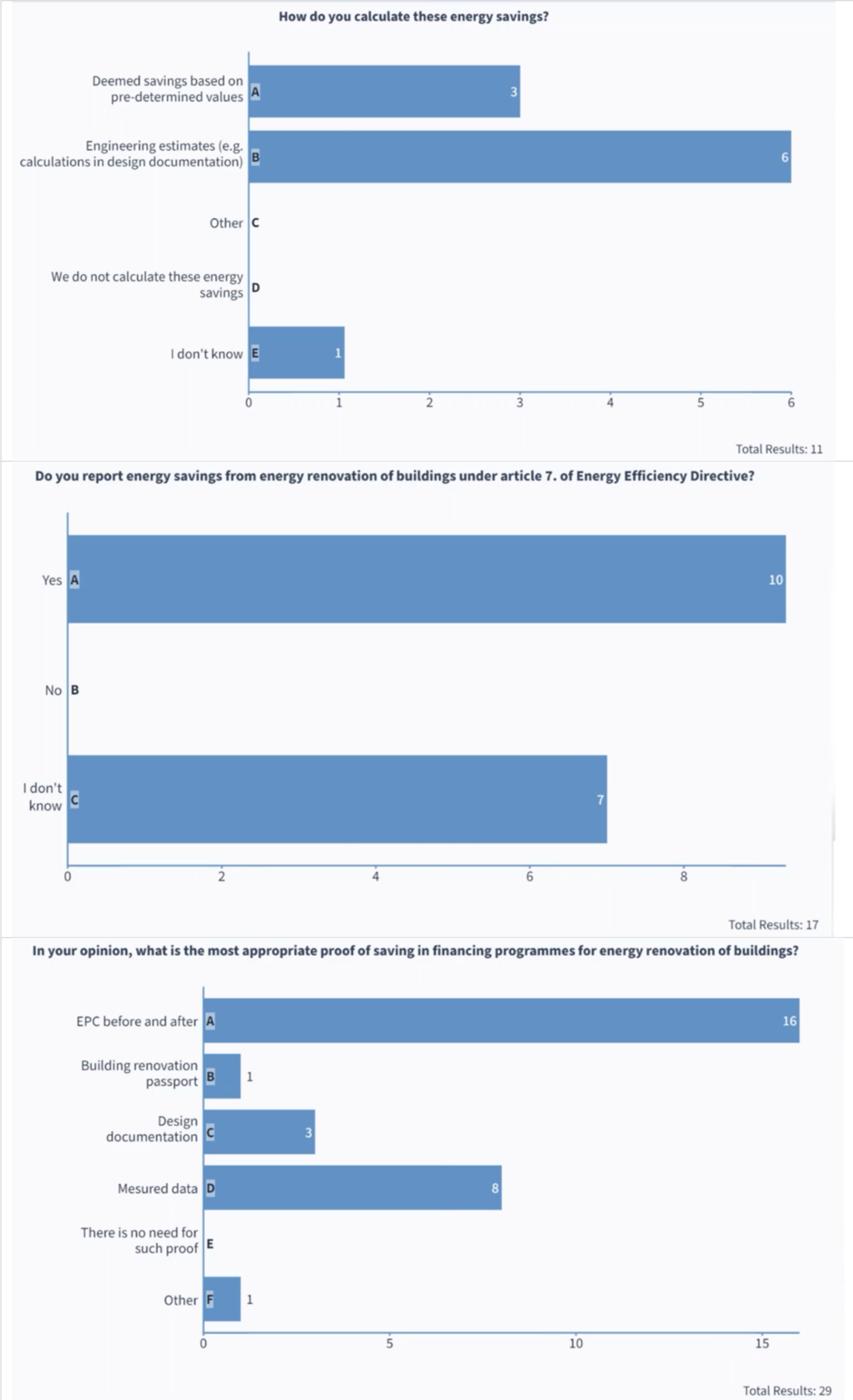


Figure 6. Questionnaire results on Member States' approaches to linking finance & EPCs for energy renovations and energy savings.

Highlights of 3.8	Through the analysis of the questionnaire completed by Member States prior to the session, participants identified the types of documentation needed to access funding. The session provided insight into how the decision-making process for awarding grants could be improved, based on a presentation by two projects: the iBRoad2EPC and the EPC RECAST. The session was also an opportunity to gain insight into the European Commission activities in funding energy renovation. Finally, the session triggered helpful discussions around the role of EPCs and other advisory tools in stimulating energy renovation.

3.9 Energy renovation in National Recovery and Resilience Plans

Energy renovations of buildings is a significant part of the National Recovery and Resilience Plans (NRRPs) submitted by the Member States. This is evidenced by the considerable amount of funding allocated for this purpose in each of the afore-mentioned plans – accounting for 7%-10% on average for 26 of the Member States. Despite this, other funding sources are still needed, e.g., the European Regional Development Fund, the Cohesion Fund, and private/commercial sources. Other challenges highlighted include the complexity of renovating historic buildings, and the difficulty/expense of performing seismic renovations.

3.9.1. Renovation strategies and recovery plans

The building sector is one of the largest energy consumers in Europe, responsible for more than one third of the EU's energy-related GHG emissions. At the EU level, approximately only 1% of buildings undergo energy efficiency renovation every year. This number falls far too short of our current ambitions. Another challenge stems from the difficulty in renovating historic buildings from European Regional Development Fund and the Cohesion Fund. An estimated 75% of these buildings are energy inefficient. By 2030, the goal of the Renovation Wave is to have 35 million buildings renovated, in turn creating additional green jobs in the construction sector and in all sectors surrounding the supply chain in energy efficient renovation. A major source of funding for each Member State will come from the Recovery and Resilience Facility (RRF).

The aim of the RRF is to '*mitigate the economic and social impact of the coronavirus pandemic and make European economies and societies more sustainable, resilient and better prepared for the challenges and opportunities of the green and digital transitions*'. The process in order to access the funding from the RRF is the following:

1. The Member State submits a National Recovery and Resilience Plan (NRRP);
2. The European Commission will assess and approve on a case-by-case basis;
3. The EU will pay upfront up to 13% of the total support needed to kickstart the recovery.

Then, up to twice a year until the end of 2026, a Member State can request disbursements from the Commission which will be granted, provided that the Member State has met their milestones and targets.

This report provides an overview into three NRRPs and their contributions to their national renovation targets.

3.9.2. The Croatian National Recovery and Resilience Plan

Under the Croatian Recovery and Resilience Plan there is a fund total of €9.9 billion of which €6.3 billion are grants and the remainder are loans. There are five components:

- Economy;
- Public Administration, Justice and State Assets;
- Education Science and Research;
- Labour Market and Social Protection;
- Health.

+ One flagship initiative: Building Renovation. This initiative is worth 12% (almost €1 billion) of the total NRRP.

Post-earthquake renovation

In Croatia, 30% of the buildings were built before 1963 and designs during this time period did not consider horizontal loads. Since 1964, the building requirements significantly improved, and in 2008 the European regulations came into force which further increased the seismic resistance of the building stock.

The 2020 earthquake impact can be summarised as follows:

- Significant material damage especially to older buildings;
- A total damage of €11.4 billion for the capital of Zagreb and its surroundings;
- A total damage of €5.5 billion in the region of Banovina;
- More than €17 billion of damage in total
- Psychological damage: understandably, most people found the earthquake more stressful than the COVID-19 pandemic, with children especially finding it difficult to cope with the trauma.

NRRP – Building renovation initiative

The deep and comprehensive renovation of multi-dwelling and public buildings is encouraged. For buildings with the status of cultural property, a special category has been introduced. Such buildings have not been included so far in energy renovation programmes co-financed by National and European funds. Furthermore, energy poverty reduction measures will be put in place.

The minimum energy renovation requirement:

- For multi-dwelling buildings and public buildings, the minimum is a 50% reduction in annual energy consumption for heating. This equates to a minimum of 30% reduction in annual primary energy consumption.
- For buildings with cultural property status, the minimum is 30% reduction in primary energy or a 30% reduction of direct and indirect GHG emissions at the level of the entire building stock. For each specific building the minimum requirement is a 20% reduction in the designed energy consumption for heating or 20% of primary energy on an annual basis.

Funding allocation of the three renovation components to be implemented in the period 02/2020-06/2026:

- Energy renovation of buildings in total: €133.4 million:
  o €40 million for the renovation of multi-dwelling buildings;
  o €93.4 million for the renovation of public sector buildings;
- Reconstruction of earthquake-damaged buildings, including energy renovation: €594 million;
- Energy renovation of buildings with the status of cultural property: €40 million;

Relationship between renovation goals and grants:

50% reduction in annual energy consumption for heating	60% grant
Deep renovation 50% reduction in annual energy consumption for heating, 50% reduction in annual primary energy consumption	80% grant
Comprehensive renovation 50% reduction in annual energy consumption for heating Measures for healthy indoor climate Fire protection Seismic retrofitting	80% grant

Challenges of energy renovation and seismic retrofit

- Seismic retrofit is a very expensive construction process;
- Low capacity of building owners to spend on renovation and a large number of low-income retired citizens;
- There is an increased need for workers and services but the price of work and the shortage of labour in the construction sector are also increasing;
- Complexity of the renovation process of buildings of protected cultural property.

Policies and measures until 2030

- Programme for the energy renovation of public sector buildings;
- Programme for the energy renovation of family houses;
- Programme for the development of green infrastructure;
- Programme for the development of the circular building and space management;
- Programme for the energy renovation of buildings with a status of a cultural good until 2030;
- Programme for the energy renovation of multi-dwelling buildings until 2030;
- Energy poverty programme until 2025, covering comprehensive renovation of buildings in assisted and special government care areas.

3.9.3. Boosting building renovation within Slovak Recovery Plan

The renovation of buildings should be included in the NPPR because it supports the recovery of the economy, and it is crucial to achieving climate goals of each Member State and the EU as a whole. The government in Slovakia understands the need for modernisation in public buildings and residential buildings especially single-family houses. Therefore, the Slovak NRRP places a lot of emphasis on the renovation of these two sectors.

The Slovak NRRP has 18 components, and it has been allocated a total of €6,300 million, of which €1,577 million is allocated to climate measures for buildings, while €1,149 million is allocated to other building measures, e.g., indoor environmental quality.

Renovation focus	Amount (million €)
Single-family houses	506
Historic public buildings	200
Kindergarten buildings	142
Primary and secondary school	123
University buildings and dormitories	184
Hospitals	128
Health care centres	82
Social care buildings	254
Court buildings	208

Table 2. Renovation investment breakdown in Slovakia.

There is also an €817 million investment for newly built hospitals. There is a goal to renovate 30,000 single-family houses by the end of the NRRP (i.e., mid 2026). This is one of the flagship components of the Slovak NRRP as it directly benefits the citizens and will be very ambitious to implement.

There are plans to support low-income houses by providing soft loans and grants (up to 50% of the total cost) in order to reduce the impact of energy poverty as well as additional support to help them to carry out energy efficiency renovations.

Principles and requirements

- The building renovations should achieve at least 30% primary energy savings, as required by the EC;
- Every investment in the NRRP needs to respect the principles of '*do no significant harm*' as laid out in the first delegated act of the European Taxonomy:
    - climate change adaptation measures;
    - sustainable use of water;
    - support circular economy;
    - assess materials that could lead to pollution;

- Green public procurement principles;
- Newly-built hospitals at BREEAM Excellent standard;
- Supporting principles of the New Bauhaus – a Commission initiative focusing on the aesthetics, inclusivity, and sustainability of a building.

Challenges and opportunities

- Time pressure – there are only a few years to create a strategy.
- Implementation capacities – the ministry and the market/construction sector have to be able to implement all of the investments related to the renovation of buildings.
- Execution of new requirements – the NRRP will be the first time the '*do no significant harm*' principles are applied so it will be challenging to create the appropriate frameworks.
- Considerable funds are allocated to building development in the NRRP. This size of investment could trigger a Slovak '*Renovation Wave*'.
- The opportunity to create '*lead by example projects*' which will give practical form to the NRRP and the Commission energy efficiency renovation goals.

3.9.4. Romania's commitment for deep renovations of buildings

It is very important to link LTRS and the NRRP. Romania has a very ambitious LTRS supported by the generous NRRP.

Overview of building stock

- Most residential buildings were built between 1961 and 1980, in the absence of specific energy efficiency standards for buildings. Approximately 53% of residential buildings were built before 1970.
- In urban areas, 72% of the dwellings are in multi-family apartment buildings, while in the rural area 94.5% of dwellings are single-family.
- One in seven families are living in energy poverty. Romania has committed to renovating the dwellings of these types of households.
- Although 58% of the building stock concerns single-family houses, in the last seven years there has not been a strategy for the renovation of single-family houses. This was rectified in the last year when Romania launched a renovation programme targeting this dwelling type, financed by ETS (the EU Emissions Trading System).
- At the end of 2020, 6% of the total building stock was renovated - a very small portion of which most concerned shallow renovations.

NRRP budget

- Total budget of €29.2 billion in loans and grants.
- Nearly 7.5% (€2.2 billion) of this has been earmarked for the '*Renovation Wave*', split roughly in half between multi-family residential buildings and public buildings. In terms of single-family houses, the support from the NRRP is viewed as complementary to the priorities identified in the LTRS which encompasses all building types;

- A further €2.6 billion has been allocated for the construction of new social housing and retirement homes, hospitals and healthcare facilities, and pre-school programmes;
- Creation of the National Buildings Registry and implementation of the energy building passport: (€5 million);
- Strengthening the professional capacity of specialists and construction workers for buildings: (€10 million);
- Support to circular economy and increasing the energy efficiency of historic buildings: (€15 million).

Outside of the specific Renovation Wave component:

- Creation of a new financial instrument for energy efficiency for SMEs and individuals: (€0.2 billion);
- Measures for larger enterprises - covering energy efficiency and renewable energy: (€0.1 billion).

NRRP details

According to LTRS analysis, in order to achieve at least a 3% deep renovation rate, €12.8 billion needs to be allocated. Where these funds will come from is yet to be decided, however it has always been clear that it would place immense pressure on the state budget. Therefore, the NRRP would be a key source of funding. The NRRP does not contain any specific details on deep renovations or the application of the '*Energy Efficiency First*' principle, yet there is a set target that all investments will achieve energy savings of at least 30%.

Of the funding for multi-family building renovations, 20% will target buildings occupied by economically disadvantaged communities. It will be a challenge to evaluate this category of buildings, because the National Building Registry has not yet been implemented, so the exact location of these communities is unclear.

Another aspect of the NRRP is to support strategy implementation through training and skills development. Funding is provided for training, including creating at least eight (8) centres to provide specialised courses in the field of energy efficiency performance.

Recommendations to improve the NRRP

- Develop a long-term financing strategy including sources of financing and targets to accelerate the rate of deep renovations in line with LTRS targets.
- Strengthen efforts to leverage private finance and develop more market-based mechanisms (e.g., energy performance contracting). It has been a struggle for the past six years to develop the EnPC business model and integrate it into the national legislation. This is a much needed and necessary contribution from private funding.
- Ensure initiatives are carried out on a national scale by providing financing and technical assistance to end users across the public and private sectors (e.g., support for municipalities, one-stop-shops, public education about energy and support policies, digitalisation).

3.9.5. Results

Renovation Strategies and Recovery Plans

The Renovation Wave

On 14 October 2020, the European Commission presented the Renovation Wave Strategy to enhance energy and resource efficiency.

There are two crucial elements to the recovery plans:

- Accelerate renovations to double the current rate in 10 years.
- Ensure that the focus is not only on shallow renovations but more on deep renovations.

Taking these two points into account, the Renovation Wave emphasises the full implementation of the EPBD, national LTRS, and access to finance.

The Commission has received the LTRS from 26 Member States, with one Member State's LTRS still being finalised. All 26 have been translated into English and can be found at: https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/long-term-renovation-strategies_en

A preliminary analysis, reviewing the main elements of the strategies, was published in March 2021. A final analysis of the LTRS will be published. It is important that the main actions in Member States' LTRS are also present in their NRRPs. Completion of the LTRS is one of the conditions to receive regional funds.

Main conclusions of the LTRS analysis

Member States have developed many best practices in all categories of renovation - for public buildings as well as for energy poverty and the phasing out of fossil fuels for heating and cooling. These elements have been translated into many of the NRRP, which makes it much easier for the Commission to support the proposals of the Member States. Analysis of the LTRS was made somewhat difficult due to the lack of comparability between the data, but some Member States also did not have key targets for 2030, 2040, and 2050. These milestones should show the peak of NRRP investment sustained by long term financing and resources.

Analysis of these plans is still ongoing however:

- There is an energy efficiency renovation plan component in almost all the NRRP submitted. Very often it accounts for 7%-10% of the total funds allocated to the NRRP fund overall. This is extremely high compared to other investments.
- The Commission has encouraged Member States to coordinate their best practices in the LTRS with the NRRP and has given advice on how to foster deep renovations. The Commission is aligned with the minimum 30% energy efficiency improvement.

NRRP state of play

- As of October 2021, 22 NRRP were adopted by the Commission.
- The combined climate-related investment so far is around €177 billion, representing around 40% out of a total of €445 billion of RRF funds allocated to these Member States

- 28% (€50 billion) of funds has been allocated to building renovation and other energy efficiency measures. This is an unprecedented effort in terms of public financing. However, even with this amount, it will not be possible to renovate 35 million buildings without the strong involvement of the private sector.

Other sources of funding

On top of the budget provided by the NRRF, the EU budget for 2021-2027 will provide support for the EU Green Deal and energy transition, including building transition. The European Regional Development Fund and the Cohesion Fund will allocate 30% and 37% of their funds respectively for the achievement of new climate objectives. The Commission has opened discussions with local and regional authorities to encourage the alignment of their funds into one well-coordinated stream of investments.

In order to support Member States, the Commission has also established the Renovation Wave flagship technical support project. It is targeted at Member States wishing to design and implement reforms in support of building renovation. There are three main aims:

- Renovation along the themes of the Renovation Wave, e.g., heating and cooling, energy poverty etc.
- Implementation of planning tools, especially long-term renovation strategies and recovery plans.
- Develop Member States regional fund strategy.

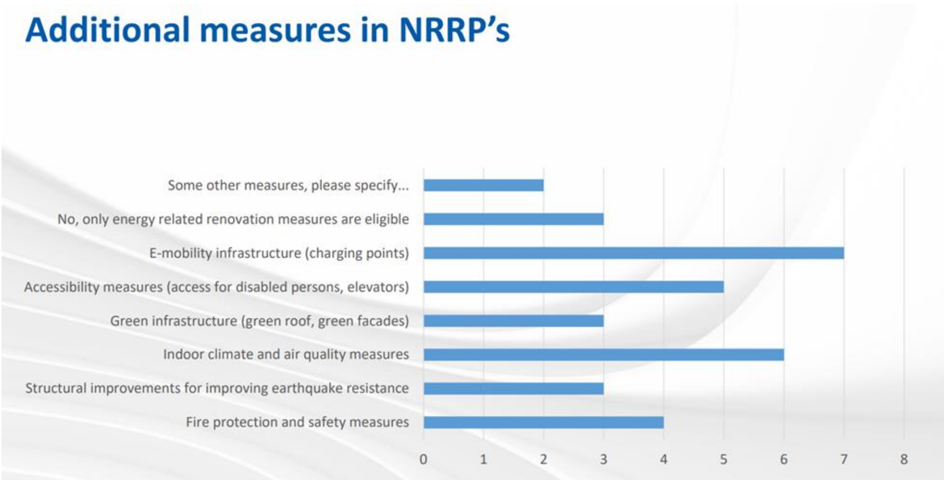


Figure 7. Additional measures in Member States NRRPs.

Highlights of 3.9	An NRRP provides an essential and significant contribution to each Member States' building renovation goals as evidenced by Croatia, Slovakia, and Romania. However, even this unprecedented amount of public funding falls short of what is required in order to accomplish the EU wide goal of renovating 35 million buildings. Other EU sources of funding include the ERDF and the Cohesion fund. The necessity of acquiring private/commercial financial investments was also discussed. Other challenges include the lack of guidelines for the renovation of historic buildings, shortage of labour, and the tight timescale given to execute renovation targets. Member States will encourage training to upskill and grow the renovation workforce and its relevant sectors and continue to develop other financial streams in the future.

4. Main Outcomes

Topic	Main discussions and outcomes	Conclusion of topic	Future directions
How to combine measured and calculated data	Differences were found to be caused by different users before and after, rebound effects, occupancy patterns and behaviour, different assumptions or methodologies before and after, and many other factors; so this can be a very difficult problem to solve. Member States require energy use in their public buildings to be metered and data to be made publicly available as all is paid by public money. Calculated data on an EPC and data measured serve different purposes. The first is a label to inform a potential owner how the building may perform, while the second represents the actual use and potential savings. The difference should be communicated to the public. There is no systematic collection of data before and after renovation projects in many Member States.	The differences between calculated and measured data were explored in order to find ways to narrow the gap between them. For an effective renovation of the building stock, it is important to understand which buildings would benefit the most. This can be identified by using EPC databases which are held by most Member States. However, there is a question about whether the calculated result is a reliable way of choosing which buildings to renovate. As has been seen in most Member States, actual data can vary widely from calculated data due to many factors, e.g., user behaviour, climatic conditions and poor assumptions. EPCs can therefore over- or underestimate the energy use of a building.	A building with a good, calculated EPC rating may not be renovated even if it performs poorly in actual use. This can make using the EPC an inappropriate way to analyse the building stock. It was also discussed that using actual data would be more useful however this would be more expensive than calculated data and often requires a greater level of engagement from the building owner. Combining these two methods could therefore be the ideal solution.

Topic	Main discussions and outcomes	Conclusion of topic	Future directions
Public Access to EPC information – on individual building level	Most Member States have EPC databases that are proven to be very useful for numerous reasons, e.g., national stock statistics, quality control and designing renovation strategies. With the introduction of the GDPR, Member States must reconsider what should be accessible and to whom. Member States follow different approaches in relation to accessibility of data with some being very open and others being very strict, linked to the local mindsets.	If implemented correctly, the EPC databases can continue to be a powerful resource for all parties. Some Member States have an opt-out policy where all data is collected unless the owner chooses to redact some. Many Member States have deleted some data in light of the GDPR.	For collecting data, there are different approaches across Member States but also many similarities. The benefits of collecting data were found to include: • Creating statistics and supporting research • Designing financial incentives and policies • Allowing a history of EPCs for a particular building to be formed • Quality control • Mortgage applications • Targeted marketing based on the building's features
Energy Service Contracting in buildings	Successful projects were marked by clearly defined savings assessment rules and good communication to Operation & Maintenance personnel as well as building users.	Governments have a crucial role to play in encouraging higher mobilisation of private capital and can help by standardising the process and providing platforms for stakeholders to communicate and access information.	Government support and clarity of policy can help alleviate the financial risk perceived by the private sector and strengthen the market for Energy Services Contracting.
Energy poverty – action, definition & mapping – Link to EPBD Art.2a	Many Member States have no definition of energy poverty, despite the fact that it affects millions of citizens across the EU. Outlining a set of criteria to identify those citizens	The energy renovation of existing buildings will be instrumental in tackling energy poverty as it provides a means of prevention rather than simply aiding those in a vulnerable position through financial measures.	Delegates prioritised the following criteria for indicators for energy poverty: • low income • affordability of a comfortable home environment

Topic	Main discussions and outcomes	Conclusion of topic	Future directions
	in energy poverty is a good first and needed step to understanding the scale of the challenge in each Member State, and in what areas the population is most vulnerable. Stakeholder dialogue and data collection on building stock is crucial in the selection of these criteria.	However, renovation, through either passive measures or the introduction of technical systems, may not provide a monetary payback through energy savings alone, but it entails wider social and economic benefits, such as improved health and productivity, which are not easily quantified.	• the level of insulation • energy rating of the building • the age of the occupant It is considered important to move forward to using these criteria, or similar, to help identify where renovation support is needed. This will help Member States to work towards the alleviation of energy poverty through a set of national actions in their LTRS, as required in Article 2a of the amended EPBD. What this set of actions is, in many cases, still needs to be decided.
Energy renovation of cultural heritage buildings	Buildings that have the status of cultural heritage represent a small share of the building stock. They are important because of the social interest in maintaining them for the future, while retaining their existing purpose or converting them to new uses. Cultural heritage buildings should be renovated, as far as they can reduce energy demand by a renovation, while still protecting the cultural property. This is a	A questionnaire to Member States showed that despite the widely recognised need for renovating protected buildings, the registers of heritage buildings and renovation guidelines are not uniform through Member States. This is likely because energy renovation of protected buildings is challenging and requires taking an individual approach to each building.	The discussion allowed to identify areas of challenges and topics which would benefit further discussions to pave the road to larger scale renovation of protected buildings: • Lack of clear and cohesive system for using available financing resources (national and EU) • Insufficient training, information, awareness, interest of all stakeholders in the process • Different traditional skills must exist

Topic	Main discussions and outcomes	Conclusion of topic	Future directions
	specific challenge both in terms of costs and in terms of need for technical solutions.		together with new technical solutions.
Renovation of buildings – impact of fire protection & risk of seismic activity	Countries in seismically active areas have strong arguments for including earthquake resistance during an energy renovation. There is a need to combine not only seismic mitigation with energy efficiency but also fire safety during the building renovation.	In order to ensure a highly energy efficient and decarbonised building stock and to ensure that the LTRS delivers the stated goals, it is important to deal with implementation of modern solutions and rules in the area of fire protection and risks of increased seismic activity during energy renovation of buildings.	Opportunity to provide strong arguments for including earthquake resistance during energy renovation, particularly for Southern European countries which tend to be more prone to destructive earthquakes. There is a need for linking all relevant EU policies and to introduce national policies to make the existing building stock fit for purpose for decades to come.
Worst-performing buildings – scope, policy and measures (Renovation Wave)	National circumstances affect how worst-performing buildings are defined and which measures are set up to tackle specific problems.	Most reported that worst-performing buildings are identified based on the energy performance class.	For future resilience of buildings, the top priority remains energy renovation.
Linking finance & EPCs for energy renovations with energy savings	The session helped to identify the types of documentation needed to access funding across Member States. The session also provided insights into how the decision-making process for awarding grants could be improved via the presentation of 2 projects: the iBRoad2EPC and the EPC RECAST.	The session provided an opportunity to get some insights into the European Commission activities with regards to funding energy renovation.	The session triggered helpful discussions around the role of EPCs and other advisory tools in stimulating energy renovation.

Topic	Main discussions and outcomes	Conclusion of topic	Future directions
Energy renovation in National Recovery and Resilience Plans	A NRRP provides an essential and significant contribution to Member States building renovation goals as evidenced by experience in Croatia, Slovakia, and Romania. However even this unprecedented amount of public funding falls short of what is required in order to accomplish the EU wide goal of renovating 35 million buildings under the Renovation Wave.	Other sources of funding include the ERDF and the Cohesion fund. The necessity of acquiring private/commercial financial investments was also discussed. Other challenges faced include the lack of guidelines regarding the renovation of historical buildings, shortage of labour, needed skills, and the tight timescale given to execute renovation targets.	It appears that Member States will encourage training to upskill and grow the renovation workforce and its relevant sectors, and continue to develop other financial streams in the future.

5. Lessons Learned and Recommendations

There is an identified gap between measured and calculated data of energy efficiency in buildings. This is true for both new, as well as for existing buildings. The way that data is approached and interpreted is essential for further conclusions, as well as for initiatives and actions that are based on those conclusions.

While experts and researchers are trying to explain the causes and value of those gaps, it is important to clarify state-of-the-practice and possible improvements to ensure the best use of data.

How open the databases should be and who should be able to see the information stored remains an important topic for discussion. One of the key questions is: What level of detail should be available in the databases? Very detailed and granular information can be acceptable in some Member States but not in others. All Member States agreed that having EPC databases has been a powerful tool for purposes such as quality control, research, statistics, and policy planning. It is therefore important that any challenges raised by GDPR requirements should be overcome so that these important resources can continue to be used.

The current challenges faced by EnPC models are, in particular, shifting to more private financing and the need to keep government payments off the balance sheet. Solutions involve developing standardised templates, the sharing of best practice, and the use of European Structural and Investment Funds, where possible. Eurostat guidance should be followed to ensure energy performance contracts are set up correctly to properly present government debt and deficit.

Many Member States have yet to define *energy poverty* even though it affects millions of citizens across the EU. A set of criteria to identify those citizens in energy poverty would be a good first step to understanding the scale of the challenge in each Member State and to locate the areas where the population is most vulnerable. Both stakeholder dialogue and data collection on building stock are crucial in the selection of these criteria.

A questionnaire to Member States showed that despite the widely recognised need to renovate protected buildings, energy renovation of this segment of the building stock is not reaching the targeted rate. The registers of heritage buildings and renovation guidelines are not uniform amongst Member States. Energy renovation of protected buildings is challenging and requires an individual approach to each building.

Discussion on *impact of fire protection & risk of seismic activity* offered strong arguments for including earthquake resistance during energy renovation, particularly for Southern European countries that are more prone to destructive earthquakes. Energy renovation must also consider country-specific vulnerabilities. In seismically active areas, energy renovations must consider fire and seismic resistance in order to be truly sustainable.

Overall, the topics covered by CCT3 (including energy performance data, EPC databases, Energy Performance Contracts, cultural heritage buildings, as well as fire protection and risk of seismic activity) are all topics that need further discussion and action from Member States. All topics are in the early stages of implementation in the Member States.

Worst-performing buildings – scope, policy and measures (Renovation Wave) depends on national circumstances and how worst-performing buildings are defined as well as the measures that are taken to tackle specific problems. Most Member States reported that worst-performing buildings are identified based on the energy performance class. For future resilience of buildings, the top priority remains energy renovation.

Linking finance & EPCs for energy renovations with energy savings – the session helped to identify the types of documentation needed to access funding across Member States. The session also provided insights into how to improve the decision-making process for awarding grants and offered insights into the European Commission activities for funding energy renovation. There were helpful discussions around the role of EPCs and other advisory tools in stimulating energy renovation.

Energy renovation in National Recovery and Resilience Plans provides an essential and significant contribution to each Member States' building renovation goals as evidenced by Croatia, Slovakia, and Romania. However, even this unprecedented amount of public funding falls short of what is required to accomplish the EU wide goal of renovating 35 million buildings under the Renovation Wave. Other sources of funding include the ERDF and the Cohesion fund. The need for private/commercial financial investments was also discussed. Other challenges include the lack of guidelines for the renovation of historic buildings, shortage of labour, and the tight timescale to meet renovation targets. It appears the Member States will encourage training to upskill and grow the renovation workforce and its relevant sectors and continue to develop other financial streams in the future.

6. Endnotes

1. http://eurocodes.jrc.ec.europa.eu (http://eurocodes.jrc.ec.europa.eu)
2. superbcy.com (http://superbcy.com)

7. ANNEX: Case Studies

7.1. Energy Performance Certificates in buildings

Bulgaria: An illustrative example showcasing good practice application of an Energy Performance Contract is the Hospital Svidnik (224 beds, 14,000m^2). This involved a total investment of €743,597 with planned annual economic savings of approximately €156,000. This was a private endeavour designed to implementing an Energy Performance Contract project as the guarantee of energy savings. Other drivers included ensuring the safety and comfort of employees and patients, the replacement of unreliable devices, and the reduction in energy consumption.

As part of the Energy Performance Contract, activities included energy audits, provision of 5-year financing and implementation of energy saving measures, the monitoring and evaluation of energy consumption, and insurance of compliance. The old plant room and steam boiler in the hospital were transformed with the installation of new heat generating equipment, pumps, control system, etc. The expected payback period was five years, with energy savings of at least 30%. Contract conditions also guaranteed additional savings that would be paid by the Energy Performance Contract provider if not achieved. However, the guaranteed savings were achieved every year along with CO_2 savings of 799 tonnes, with payback over four years.

7.2. Energy renovation of cultural heritage buildings

Energy Centre Bračak

The Energy Centre, the Bračak castle, is located in the area of the town of Zabok. The building is registered as an individually protected cultural heritage property.

The Bračak Castle was built by the Kulmer family in 1889 in a historical style along the newly built Zagreb-Budapest railway. After World War II, the castle became a hospital. Following the construction of a new hospital on the neighboring hill in 2007, Bračak Castle was left to decay.

The castle is owned by the county of Krapina-Zagorje, the renovation was managed by REGEA, and transformed the castle into the Bračak Energy Centre. The project was supported by 10 counties of the Republic of Croatia: the city of Zagreb, Istria, Karlovac, Koprivnica-Križevci, Međimurje, Primorje-Gorski Kotar, Varaždin, Virovitica-Podravina, Sisak-Moslavina and Zagreb County, as well as every Croatian energy agency and a number of collaborating institutions from Croatia and abroad.

The project was financed through the Fund for Environmental Protection and Energy Efficiency (state funds). About €3,2 million was invested in the project.

The building is now used as the office space for REGEA with its education and training centre and business incubator. The business incubator rents business office space and is designed to assist entrepreneurs in the energy sector, sustainable development, and IT sector.

The Bračak Castle was built to low-energy standards, and it has enormous energy-saving potential. The energy efficient renovation of the castle raised the building from energy performance class E to the level of a low-energy building – energy performance class B/C using 88% renewable energy sources. Energy consumption for heating has been reduced by up to 70%. The property now includes chargers for e-vehicles.

Renovating a protected building required approvals from conservation officials, meaning some works, such as painting façades and outdoor details on façade had to be done by hand.

The main part of the renovation centered on reinforcing the structure and making the building safe and comfortable:

- Structure reinforcement with concrete slabs;
- New ceilings;
- Waterproofing walls;
- Insulation;
- Mineral wool for noise protection.

Additionally, as the aim of the project was to be a test demonstration, all sorts of technologies were implemented, with few cost restraints:

- Rainwater toilet flush system;
- photovoltaic system will be installed and integrated to the building;
- Wood pellet boiler (with nominal heat output 80 kW and efficiency rate up to 94.9 %);
- high efficiency variable refrigerant flow system with an installed capacity of 95.2 kW;
- natural gas micro cogeneration plant (with 6 kW of installed electric and 14.9 kW of installed heat capacity for domestic hot water preparation);
- central monitoring and control system that manages heating, ventilation and air-conditioning and indoor lighting;
- high efficiency LED indoor lighting;
- Included chargers for e-vehicles.

New Giraffe Park - Schönbrunn – Vienna Zoo

The zoo was founded in 1752, by Franz Stephan von Lothringen, husband of the empress Maria Theresia.

The aim of the new project was to renovate the Giraffe Park to operate energy efficiently by using innovative technologies.

It is not the first development undertaken in the Giraffe park: in 1828, the buildings were adapted to welcome the first giraffes; in 1930 the roof was improved with lanterns; and after damage during World War II, there were various other developments.

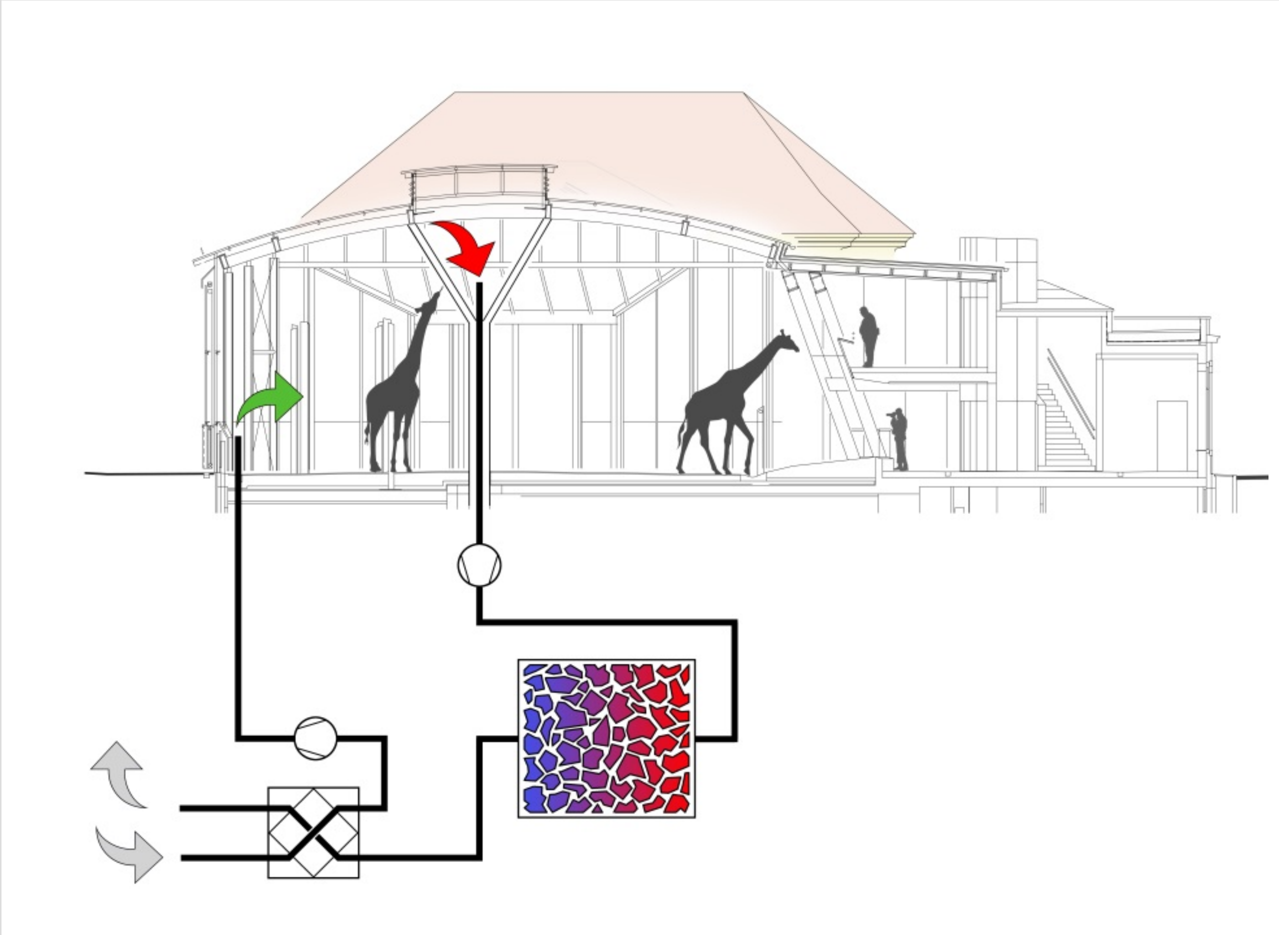
The listed building for the giraffes needed to be refurbished and the enclosure enlarged in order to meet modern standards of animal care. Behind the building, a large winter garden-like structure was added. The inside space is now three times bigger. The Giraffe Winter Garden (greenhouse) project included two innovative measures: glazed photovoltaic panels and an interim thermal energy storage solution that uses gravel as a storage medium.

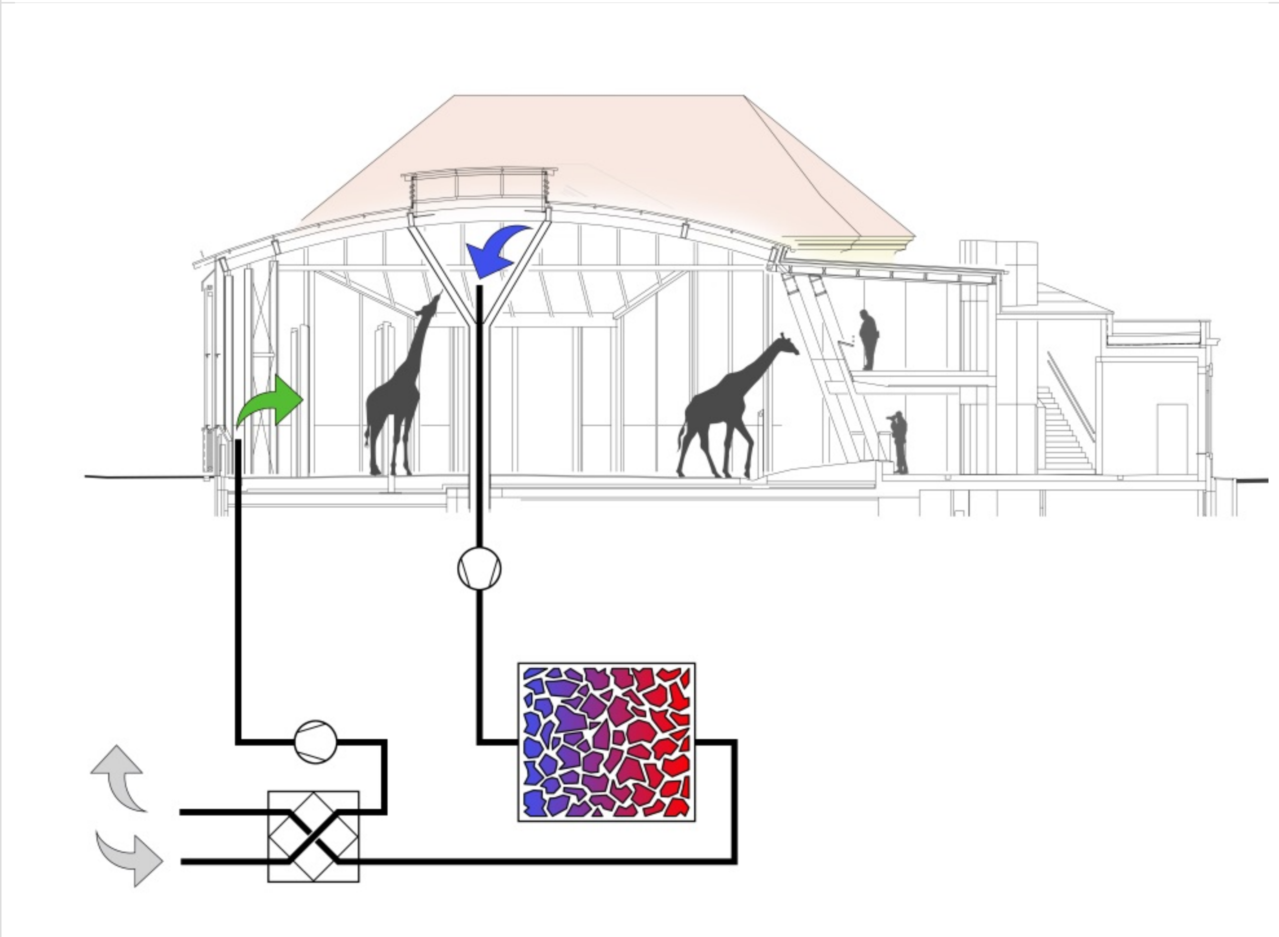
The photovoltaic modules use a glass-glass structure with monocrystalline thin film solar cells, produced by *Ertex Solar Technik GMBH*. The module area is approximately 237 m², with a peak output of 16.02 kWp. The wafers, or solar cells, measure 12.5x12.5 cm and can be arranged on the glass area in any way. The glass-integrated photovoltaic cells offer multiple functions: power generation, shading, bird protection and a pleasant design.

'Power generation, shading and design, all combined into one solution: the combined use of photovoltaic technology with laminated safety glass results in a unique, multifunctional energy saving symbiosis.'

The winter garden is made of steel and glass, and rests on a supporting structure that imitates the canopy of an acacia tree that allows glimpses of the real sky. The trunk branches upwards into the glass areas and their photovoltaic cells.

A thermal energy storage system is situated underneath the giraffes' winter garden. Relying on gravel and air circulation, it stores heat during the day and releases it at night. During the cold season, and even more so in the transition periods, there is a heat surplus during the day, while additional heating is required at night. The heat captured during the day can be stored in an air-flooded gravel pit underneath and released for heating at night.





Calculations and simulations showed that a storage entity of 60 m^3 was needed for this project. The pit underneath the foundation respects these dimensions, measuring 8.6 x 3.6 x 2 m, which equals to 62 m^3 in total. It was backfilled with approximately 122 t of gravel (marble quarry, grain size 63/150). Conventional drainage elements were used to ensure air circulation.

Hot air is sucked away from the upper areas of the winter garden and transported through the gravel body – as a result, the gravel heats up. When additional heating is required, cool air is sucked away and transported through the warm stones, which increases the temperature of the airflow. Then, the outside air is heated with the help of a heat exchanger. For hygienic reasons, only exhaust air is transported through the gravel storage system.

The gravel pit has a storage capacity between 17,190 and 20,500 kWh depending on the calculation method used. Consequently, around 30% of the demand for heating can be covered. Once the operating period had started, surveillance monitoring was carried out in order to determine optimum use and real-time figures.

Technisches Museum Vienna

A call for innovative solutions to cool the Technisches Museum of Vienna during summer heat attracted lively interest: 21 ideas featuring a wide array of measures were presented. The BHO and Technisches Museum of Vienna invited five companies to participate in an 'innovation dialogue' in order to clarify open questions. Subsequently, calculations and simulations were made to select the most appropriate measures.

As of 2020, several innovations were being considered: reflective roof coating, shading of glass domes, shading the entrance area, and installing a photovoltaic system.

Reasons that measures were not retained included:

- High demand of human resources
- Security issues as a result of windows being open throughout the night
- Impossibility to control air quality
- Risks due to bad weather
- Difficult accessibility of some windows
- Probably suboptimal flushing

An interesting measure which was retained was to apply a cooling coating on the roof which increases the reflectivity. According to the simulation, the overall hours of indoor climate above 28°C may be reduced by 37% compared to the reference year by applying a finish to the metal sheets on the roof. The roof reaches temperatures of about 75 °C during the summer season. The area to cover is approximately 4,950 m^2. The coating can be applied using a brush, roller or spray. It takes comparatively little effort. It does not affect in any way the operation of the museum and conforms with heritage protection principles. The cost is around €120-140/m^2 and it has a lifespan of over 25 years. In addition, the roof will be refurbished, and its lifespan increased; the stress on problematic areas that had to be refurbished periodically because of exposure/stress and temperature changes will be reduced. This is likely to result in future savings.

Another measure to be undertaken in 2021 is to reduce heat input through external shading of the two glass domes (area of approx. 400 m^2 each) by installing a ventilated textile shading system. This system is practically maintenance-free and has a lifespan of approximately 10 years.

These two measures together will allow for a heat reduction of 55-60% when indoor temperatures are over 28 °C.

The Upper Belvedere

The Belvedere Castles were built as a summer residence by famous Baroque architect Johann Lucas von Hildebrandt for Prince Eugene of Savoy (1663-1736). The ensemble, which counts among the most beautiful Baroque buildings in Europe, has been put on the UNESCO World Heritage list. The Upper Belvedere Castle accommodates the most important collection of Austrian art from the Middle Ages to the present. It also features the exhibition 'Art around 1900' (*Kunst um 1900*), with the largest collection of Gustav Klimt paintings at its heart.

In 2016, despite having recently refurbished windows, significant humidity issues remained such as condensation, icing, draught, mould at the window reveals, and a relative humidity at 26%.

A prototype of a box-type window was developed to remedy these issues. An improved inner layer of the box-type windows positively affects the energy balance of the building without interfering with the architectural/visual aspects. The optics of the box-type windows will be preserved on the inside. Also, the view-profile of the wings will be retained, with the original espagnolettes. The original sleeves will be retained, while the hinges must be reinforced.

The existing window shutters strongly affect the micro-climate in the box-type window and in its immediate surrounding. Their construction does not constitute any vapour barrier. As a result, steam enters the box-type windows. With the measures taken so far, condensation occurs as the windows cool down more quickly. In the future, optimised glass properties will reduce UV radiation entering the building while granting an unobstructed view outside.

Many improvements are involved:

- Sashes refurbished to function smoothly
- Glass rabbet instead of historic weather-stripping
- Increasing the size of the sash rabbets
- Installation of bars
- Conservation of the box
- Sealing and water-tight connections
- Re-construction of the entire inner timber layer
- Adjustable espagnolettes
- Replacement of hinges
- Installation of insulated glass with special properties
- Installation of two sealing levels - a frame seal and a sash seal
- Glazed coating

These measures should improve the airtightness of the windows, improve the stability of the sashes, lead to a better heat insulation of the windows and reduce risks of overheating in summer. As a result, the U value of the windows should improve from 2.9 W/m²K to 0.8 W/m²K.

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