Policies to enforce the transition to nZEB: Synthesis report and policy recommendations from the project ENTRANZE.

D5.7 of WP5 from Entranze Project

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ENTRANZE Project

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Project consortium:

EEG	Energy Economics Group Institute of Power Systems and Energy Economics Vienna University of Technology
NCRC	National Consumer Research Centre
Fraunhofer	Fraunhofer Society for the advancement of applied research
CENER	National Renewable Energy Centre
eERG	end use Efficiency Research Group, Politecnico di Milano
Oeko	Öko-Institut
SOFENA	Sofia Energy Agency
BPIE	Buildings Performance Institute Europe
Enerdata	Enerdata
SEVEn	SEVEn, The Energy Efficiency Center

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The ENTRANZE project

The objective of the ENTRANZE project is to actively support policy making by providing the required data, analysis and guidelines to achieve a fast and strong penetration of nZEB and RES-H/C within the existing national building stocks. The project intends to connect building experts from European research and academia to national decision makers and key stakeholders with a view to build ambitious, but reality proof, policies and roadmaps.

This report provides a summary of results, conclusions and policy recommendations derived in the project ENTRANZE for different Member States and on the EU level. The recommendations build on the results of the whole project, in particular the data collection of the EU building stock, the analysis of stakeholder behaviour and acceptance of various technologies, cost-optimality calculations and the model based policy scenarios of building related energy demand in EU-28 (+ Serbia). The recommendations have been discussed intensively with policy makers and experts across Europe in face-to-face policy group meetings and expert consultation phases.

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Executive Summary

A very low energy consuming building stock in the EU can become a reality. ENTRANZE created a policy 'laboratory' to develop and analyse the potential impact of national strategies and policy sets for buildings achieving this target. Thus, the core of ENTRANZE (Policies to Enforce the Transition to nearly Zero Energy buildings in the EU-27) was to assist policy makers in developing integrated, effective and efficient policy packages achieving a fast and strong penetration of nearly Zero Energy Buildings (nZEB) and renewable heating and cooling technologies (RES H/C) – with a focus on the refurbishment of existing buildings.

This report provides an overview of the activities and the results of ENTRANZE. The project covers the whole EU-28. However, not all activities were carried out at the same level of detail for all member states (MS). The *key target countries* (**Austria, Bulgaria, Czech Republic, Finland, France, Germany, Italy, Romania, Spain**) cover more than 60% of the EU building stock and all important climate regions.

The research conducted over several years covered the following topics:

- Filling information gaps related to the EU building stock;
- Analysing stakeholder behaviour and acceptance of various technologies;
- Identifying cost-optimal technology configurations of renovation activities;
- Developing scenarios for the development of energy demand in buildings up to 2030;
- Deriving policy recommendations to local, regional, national and EU policy makers.

One of the outstanding elements of ENTRANZE was the in-depth communication process with policy makers through the setting up of policy group meetings and expert dialogues in all target countries.

Main conclusions and recommendations of the project are:

- Clear targets until 2050 for the energy performance of the building stock are required for developing target oriented policy packages. Still, up to now only few countries have adopted such targets.
- A bundle of instruments is needed to properly address the heterogeneous target groups and technology specific barriers. The focus on a single instrument is not sufficient.
- While a strengthening of regulatory measures is essential, at the same time there is the need for much stronger focus on compliance.
- There is a huge lack of data regarding renovation activities and energy performance of buildings. There is a need for a building data observatory, in particular for monitoring policy impacts.
- The EPBD (recast) was a first attempt to create a comparable framework for the the EU MS, however, further enhancement of the legislation is necessary.
- In particular, an enhanced EPBD framework should make clear that cost optimality has to represent the absolute minimum requirements for existing regula-

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tions in the building codes. While nZEB energy performance levels should be cost effective, they still have to be more ambitious than cost-optimal energy performance levels. Thus, an enhanced EPBD has to be very precise in asking MS to present plans to close the gap between nZEB target levels in 2020 and cost-optimal levels of current building codes.

- The EPBD should be considered to gradually increase the binding character of nZEB requirements for existing buildings, too. Thus, also a clear definition of nZEB or deep renovation is required.
- Consistency in terminology and timing between directives and CEN standardisation procedures should be further enhanced.

In the end the research conducted during the project offers policy makers a valuable toolkit and the know-how on how to use it effectively so that they can improve the situation of the EU building stock by achieving ambitious long-term energy savings and CO_2 reductions.

This report is a non-exhaustive source of information regarding the results of the research conducted during this project. It mostly offers hints and guidelines with respect to the project results. More information can be found on the project website and corresponding additional reports and webtools[1].

[1] www.entranze.eu

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1. Introduction

A very low energy consuming building stock in the EU can become a reality. ENTRANZE created a policy 'laboratory' to develop and analyse the potential impact of national strategies and policy sets for buildings achieving this target. Thus, the core of ENTRANZE (Policies to Enforce the Transition to nearly Zero Energy buildings in the EU-27) was to assist policy makers in developing integrated, effective and efficient policy packages achieving a fast and strong penetration of nearly Zero Energy Buildings (nZEB) and renewable heating and cooling technologies (RES H/C) – with a focus on the refurbishment of existing buildings.

1.1 Challenges of building related energy policies

With the recast of the EPBD in 2010 (Directive 2010/31 EU, EPBD recast) the EU Member States (MS) have to move to a 'new era' of constructing. This is because from end of 2020 onwards all new buildings should be nZEB all across the EU, while new public buildings have to be constructed at nZEB standards from the end of 2018 onwards. Therefore, the EU MS have to prepare and report to the EU Commission cost-optimality calculations regarding the consistency of their building codes as well as national plans to increase the number of nearly zero energy buildings (nZEB). The nZEB plans have to comprise detailed application in practice of the definition of nearly zero-energy buildings, a numerical indicator of primary energy use expressed in kWh/m^2/year and intermediate targets for the year 2015. In addition, these nZEB plans have to describe policies and support measures for the promotion of nZEB, including details of national requirements and measures concerning the use of renewable energy generated onsite or nearby, for both new and existing buildings undergoing major renovation (in the context of Art. 13(4) of the renewable energy directive (*Directive 2009/28/EC, RED*) and Art. 6 and 7 of 2010/31/EU).

The implementation of the Energy Efficiency Directive (*Directive 2012/27/EU, EED*) in the EU MS will be very important in the light of enhancing nZEB renovation within the EU. More precisely, Article 4 of EED asks the EU MS to further elaborate long-term plans to support deep renovation of the existing building stock. Therefore, these plans can play a major role in fostering nZEB renovation if they are designed and take into consideration measures tailored or aiming at nZEB levels. The Article 5 of EED is also relevant for boosting the nZEB renovation by providing the leader's example of the public sector which has to increase the renovation rate of buildings owned and occupied by central governments at 3%/yr.

Furthermore, the renewable energy directive (*Directive 2009/28/EC*) in Art 13 (4) asks member states to implement in their building regulations and codes mandatory use of minimum levels of energy from renewable sources in new buildings and in existing buildings that are subject to major renovation.

However, despite of this framework, the implementation on the ground is very different in various Member States and it remains unclear which real impact the directives will have on building's energy performance.

1.2 The project ENTRANZE

In this context, the core objective of ENTRANZE was the **assistance and involvement of policy makers** in target countries and on the European level in order to develop integrated, effective and efficient policy packages and roadmaps achieving a fast and strong penetration of NZEB and RES-H/C. A key element of the project was the in-depth policy discussion process in the target countries. As target countries ENTRANZE covered Austria, Bulgaria, Czech Republic, Finland, France, Germany, Italy, Romania and Spain, which in total cover more than 60% of the EU building stock and all important climate regions. Besides, several tasks an results were also performed for whole EU-28.

In order to achieve this objective, the following outputs have been developed:

- Interactive and user-friendly online data mapper **covering (1) building stock according to thermal quality, use, size, age, (2) type, efficiency of heating and cooling systems in place, (3) structure and typology of users and investors, (4) related energy demand and (5) policy scenarios.**
- Cost-optimal technology configurations **of deep renovation activities for different type of buildings in different countries and climate regions in line with the EPBD.**
- Scenarios for the development of the heating and cooling energy demand **of buildings up to 2030 subject to different sets of policies in EU-28.**
- Policy roadmaps **including recommendations to local, regional, national policy makers in target countries and on the EU-level.**
- **Within each of these activities comprehensive communication efforts will take place.** Policy group meetings **as well as bilateral** high-level expert meetings **will be organized in the nine target countries. Discussion and comprehensive communication efforts will be carried out on the European level.**

1.3 Objective, content and structure of this report

This report provides an overview of the activities and the results of ENTRANZE listed above. Chapter 2 gives an overview of the EU building stock data which has been collected and presented in the online data tool. In chapter 3, we summarize the results of our work regarding stakeholder preferences, barriers and investment behaviour of different types of building owners. Chapter 4 provides selected results and conclusions of the cost-optimality calculations for different reference buildings under different climatic conditions. The outcomes of our analysis regarding the current state of policies, recent developments as well as options for policy improvement are condensed in chapter 5. Chapter 6 describes the policy approach, policy group meetings and discussion process in target countries. Highlights from the scenarios, showing the impact of policy instruments e.g. on final energy demand, renovation activities and CO_2-emissions are presented in chapter 7. Finally, we derive recommendations on member state level, for target countries and on the EU-level regarding a possible enhancement of current legal EU-framework in this field.

This report is a non-exhaustive source of information regarding the results of the research conducted during this project. It mostly offers hints and guidelines with respect to the project results. More information can be found on the project website and corresponding additional reports and webtools at www.entranze.eu.

2. Differences and similarities between national building stock data

This section describes selected quantitative results stemming from the Entranze database.[2] Entranze indicators are also displayed in an interactive data mapping tool accessible via the Entranze website (www.entranze.eu). It contains an in-depth presentation of the structure of buildings and related energy systems in EU-28 (+ Serbia); some trends are given as to the dynamics of some technologies.

In this part of the report, we highlight selected results from this data collection on the EU building stock.

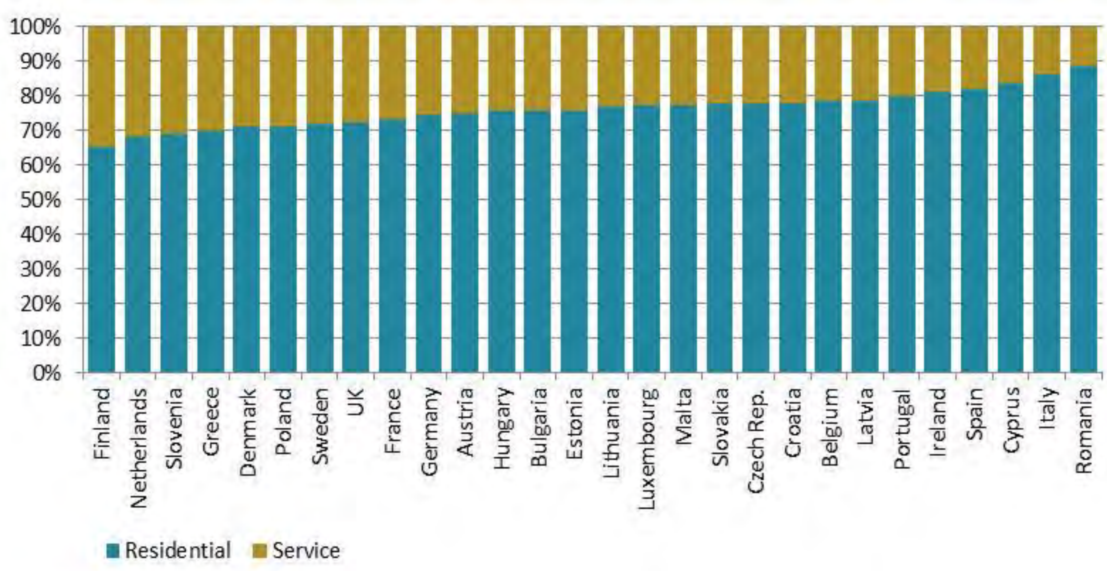

Figure 1. Breakdown of building floor areas by sector in 2008[3]

Source: Entranze

[2] The data have been collected up to the year 2008 in Excel sheets; in a first step, these files have been filled in by Enerdata from existing databases (e.g. Odyssee, BPIE data hub, Tabula, Eurostat,...); they have then been completed by the partners (at national level). 2008 has been chosen as the reference year of the database because it is the last year with enough available data that was not affected by the global crisis.

For more information concerning data collection and sources, please refer to the “Guideline on the databases and webtool” available on line here: http://www.entranze.enerdata.eu/documents/guideline-datatool.pdf

[3] This indicator includes both residential and non-residential floor areas.

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The average age of buildings and the share of new buildings in the total stock represent a good indicator of the average efficiency of the building stock: the higher the share of recent dwelling, i.e. built with more efficient standards, the higher the energy performance of the stock. Up to 40% of dwellings were built before 1945 in UK or Belgium. In most EU countries, half of their residential stock was built before 1970, i.e. before first thermal regulations (Figure 2). In some other countries, the stock of recent dwellings, i.e. built after 2000, represents a significant share (e.g. 36.5% for Cyprus and 30% in Ireland).

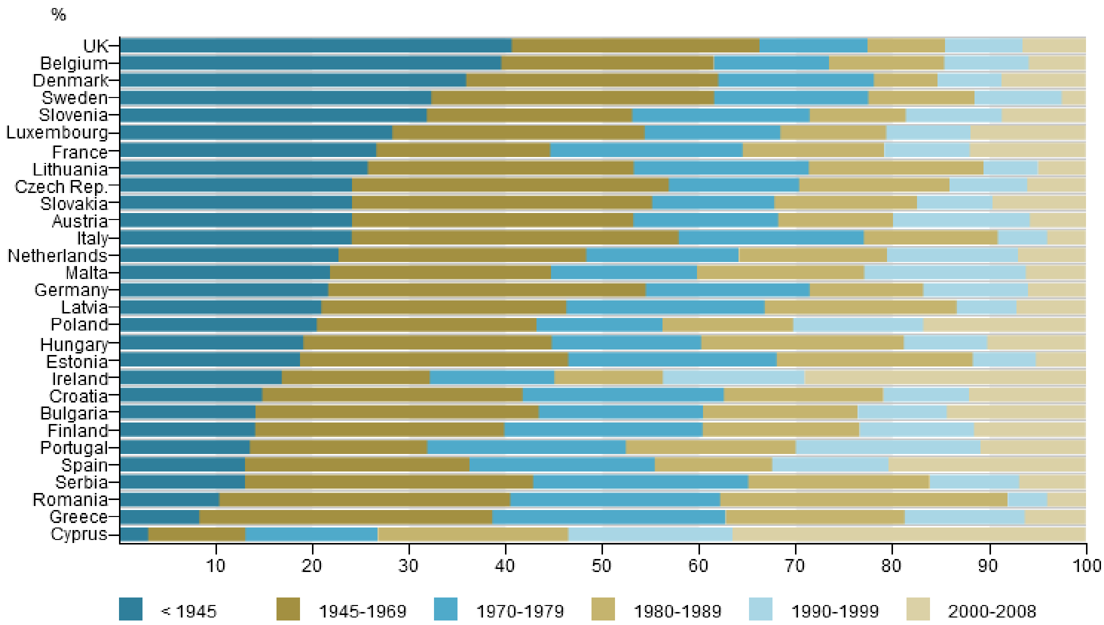

Figure 2. Stock of dwellings according to construction date in 2008

Source: Entranze

The stock by type of dwellings differs significantly across EU. In UK or Ireland, single-family dwellings are dominant (above 80%), while in Italy or Estonia multi-families represent more than 70% of all dwellings. At EU level, there is almost an equal share of both types of dwellings, with on average 47% of multi-family dwellings (Figure 3).

The penetration of heating systems is also different among EU countries: the quasi entire housing stock is heated by central heating systems for instance in Ireland, UK, France or Slovenia; room heating is more frequent in Southern countries where climate is more moderate (e.g. Malta, Cyprus, and Croatia). Collective heating systems (including district heating) represent an important share in Baltic or Scandinavian countries, for instance in Lithuania, Estonia, Poland, Denmark or Finland (Figure 4). At EU level 45% of the stock is heated by collective heating systems (including district heating), 33% by central heating, and the remaining 22% corresponds to room heating.

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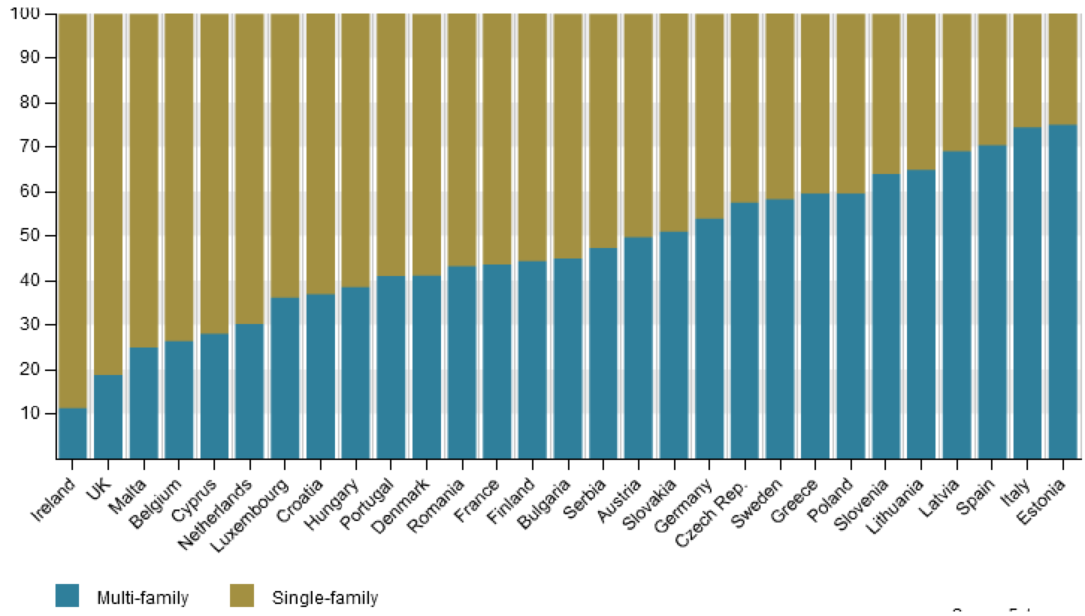

Figure 3. Residential stock according to type of dwelling in 2008

Source: Entranze

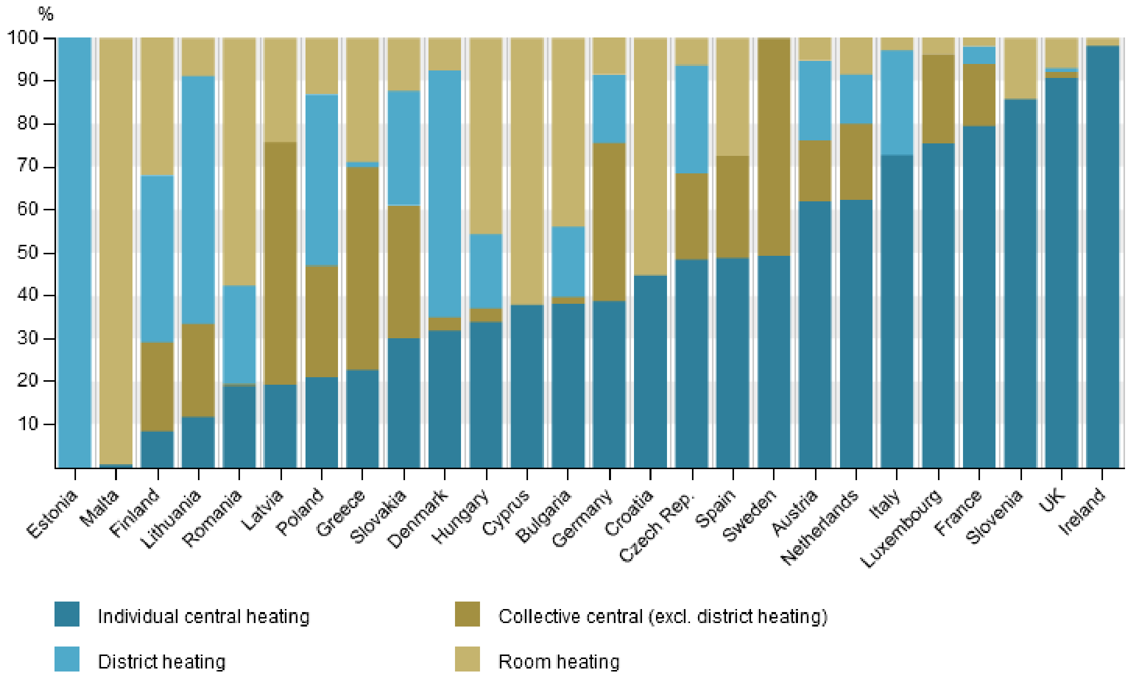

Figure 4. Breakdown of dwellings according to heating systems in 2008

Source: Entranze

Above 75% of dwellings are heated with gas in The Netherlands or UK, and by oil for instance in Greece. Other countries have a more balanced distribution of dwellings by

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energy used for space heating: in France for instance (42% for gas, 31% for electricity[4] and 19% for oil, see Figure 5), Spain or Ireland. At EU level, 26% of the stock is heated with district heating, 23% by gas, 21% by electricity, 18% by oil, 10% by biomass and 2% by coal.

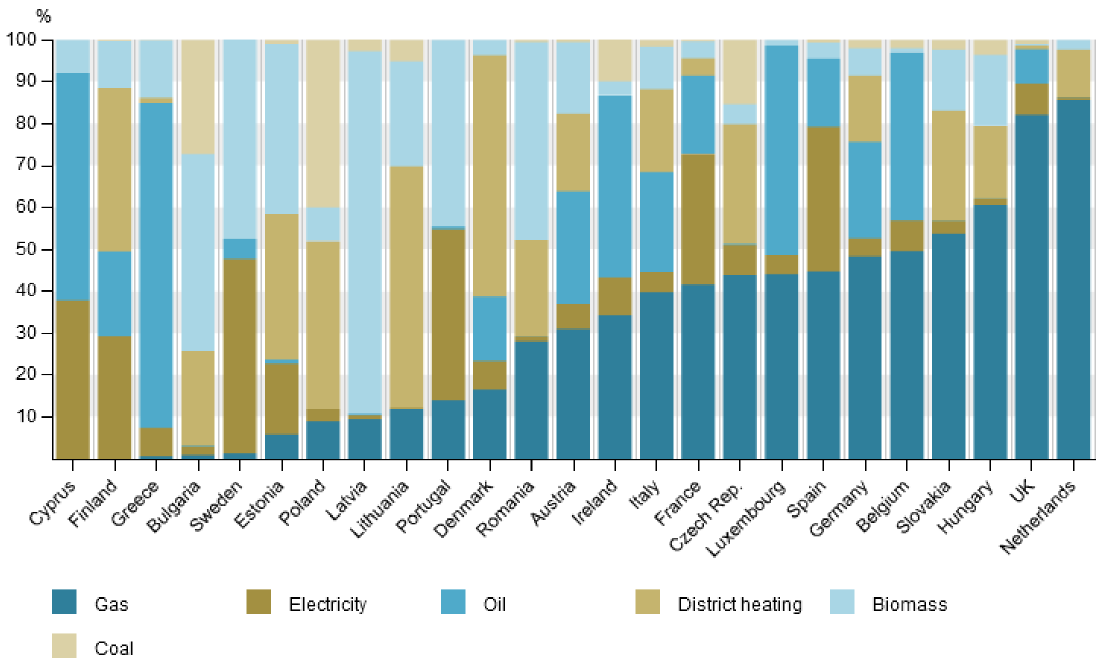

Figure 5. Breakdown of dwellings by energy used for space heating in 2008

Source: Entranze

Space heating consumption per m² is heterogeneous among countries: from 25 kWh/m² in Malta or Portugal, to almost 230 kWh/m² in Finland and Latvia which is significantly higher than EU average (137 kWh/m², Figure 6). However, even for countries with similar climate, significant discrepancies exist (e.g. 150 kWh/m² in Sweden which is 35% lower than Finland).

[4] Note that the share of dwellings heated with electricty is high in France compared to EU average, as well as in Finland (31%) and Sweden (46%).

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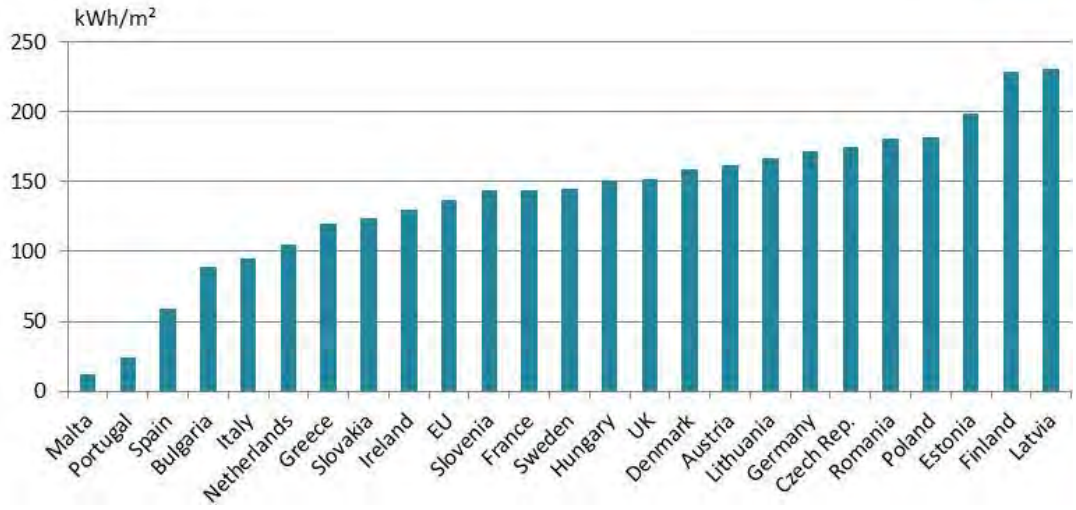

Figure 6. Space heating unit consumption per m² in 2008

Source: Entranze

The distribution of floor areas by service sub-sector is quite homogeneous among countries (Figure 7). Offices (including private and public ones) represent on average a quarter of floor areas, as well as wholesale and retail trade buildings.

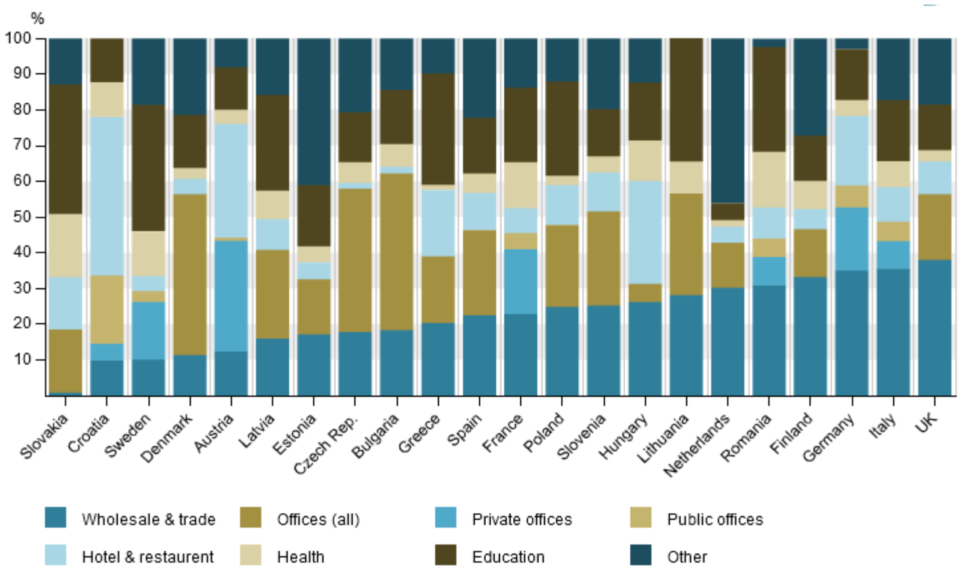

Figure 7. Breakdown of floor areas by non-residential sub-sector in 2008

Source: Entranze

As for residential buildings, energy consumption per m² in services is heterogeneous among countries (Figure 8): below 200 kWh/m² in Bulgaria or Denmark and above 500 kWh/m² in Belgium, Italy or Slovakia; EU service energy consumption is 360 kWh/m².

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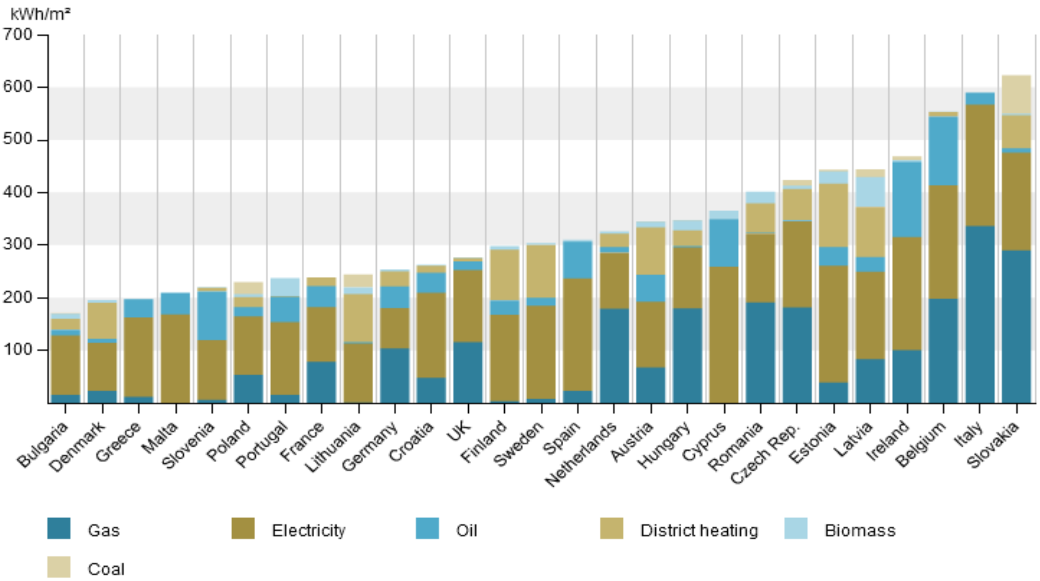

Figure 8. Total unit consumption per m² in non-residential
Source: Entranze

Even if Entranze database has been continuously updated until the end of the project, some relevant quantitative data are still difficult to track. Yet, these data are essential to assess potential savings and effectiveness of national policies and measures:

- Data related to renovation activities are badly covered in EU Member States official statistics. This is the case for instance the rate of renovated stock/area per year with their corresponding level of retrofit (annual expected savings, type of elements implemented, age of building retrofitted…).
- The level and quality of data related to non-residential buildings is significantly lower than residential stock. Non-residential buildings still represent on average 25% of the stock (Figure 1), it is thus crucial to understand its current status. However, basic data, such as the breakdown of stock according to the age of construction or to branches and their corresponding U-values, are missing in several countries.
- Building Energy Management Systems data (such as the diffusion of smart metering or smart devices) are powerful to control and inform energy consumption to final consumers are difficult to collect. Even if these data were not at the core of the Entranze project they should be better considered in building energy efficiency building statistics.

3. Integration of stakeholder behaviour, preferences

One key aspect in developing successful policies is considering the way in which building owners, users and other stakeholders in different countries react to policy measures. Building owners and users are critical in determining the share of the energy efficiency and RES potential in buildings, because most of the renovations are ultimately made at their costs. There are great differences among countries, as well as among owner types, which may be very important for the success of European policies. There are also several types and combinations of solutions for reducing the external primary energy demand of existing buildings, and their current level of public acceptance in different European countries varies.

3.1 Methods for analyzing stakeholder behaviour in ENTRANZE

The ENTRANZE project has attempted to address the challenge of integrating stakeholder behaviour in the modelling of policy outcomes by conducting qualitative and expert-based research on the barriers, drivers and decision making criteria of different categories of building owners and users (Heiskanen and Matschoss, 2012) as well as of particular issues related to different building envelope, HVAC and renewable energy measures that are relevant for shifting existing buildings closer to nearly zero-energy status (Heiskanen et al., 2013).

The report “Literature review of key stakeholders, users and investors” (Heiskanen and Matschoss, 2012) is based on literature, the ENTRANZE partners’ experience, as well as on 29 expert interviews (3 per target country) with public authorities, building owners’ associations and experienced consultants, as well as some representative building owners. These findings were complemented in “Report on specific features of public and social acceptance and perception of nearly zero-energy buildings and renewable heating and cooling in Europe with a specific focus on the target countries” (Heiskanen et al., 2013) with a more detailed analysis of particular nearly-zero energy building and renewable heating solutions as well as an extension of the analysis from the ENTRANZE target countries (Austria, Bulgaria, Czech Republic, Finland, France, Germany, Italy, Romania and Spain) to provide a more aggregated assessment for the focus countries and a rough assessment for these issues concerning all EU-27 countries. For this, we have drawn on several data sources: (1) Research reports and industry association statistics on market developments and major drivers and barriers for particular nZEB and RES-H/C solutions, (2) Research reports and academic studies on consumer and investor acceptance of particular nZEB and RES-H/C solutions, where available, (3) Project partners’ summaries of the situation in ENTRANZE target countries, focusing on the main drivers and barriers for particular solutions at the present moment, as well as on the identification of the most and least promising building owner types for each solution and (4) Research reports on the situation in other than ENTRANZE focus countries, i.e., the rest of EU-27.

While our primary data pertain to the nine ENTRANZE target countries (Austria, Bulgaria, Czech Republic, Finland, France, Germany, Italy, Romania and Spain), the anal-

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ysis of barriers and decision criteria conducted in Heiskanen and Matschoss, (2012) indicated that differences in barriers and drivers are in many cases greater among building owner groups than among countries. We were also able to identify certain other indicators that are closely connected to drivers and barriers, including geography, energy costs, policy developments, heating sources, income and debt levels, etc. These were used in Heiskanen et al., (2013) to group countries and to identify where countries in a certain group are similar or different from each other to produce a more aggregated assessment.

3.2 Factors influencing stakeholder acceptance of NZEB solutions

Drivers and barriers to the adoption of nZEB and RES-H/C solutions can be examined on different levels. On a *macro level*, we can focus on the role of policy, markets and other institutions in pushing, pulling or obstructing certain solutions over several years or decades. The following factors are highlighted in the literature.

- **Geography:** Heating solutions are naturally of greater interest in countries with cold climates and cooling solutions in countries with hot climates. Countries also have different endowments of natural resources, which still today influence the relative prices of energy sources, the existence of domestic industrial competencies, and the development effort devoted to related solutions. However, the availability of energy sources does not completely explain the amount of (e.g. policy or industry) effort devoted to certain solutions, as evidenced by the uneven historical development of e.g. solar energy in Europe.
- **Infrastructure:** Examples of infrastructures influencing the feasibility of nearly-zero-energy solutions include the natural gas grid, district heating systems, and the state of the electricity grid. Other relevant existing infrastructures relate to the age, size, structure and current condition of the building stock, or to the availability of central heating. Energy infrastructures exhibit a high level of path dependency, which is not only due to cumulative investments in certain physical infrastructures, but also to related investments in knowledge, production skills and capacity, political power, market expectations, network effects, etc. Hence, it is difficult for new technologies to compete with the dominant technology, even if they hold large future potential or even once they become cost-effective. However, problems with existing technologies (such as sharp rises in fuel prices or declining legitimacy) can also offer opportunities for new solutions.
- **History and culture:** It is well-established that expectations toward energy provision and use in buildings vary both historically and across cultures, even within Europe, as is shown, for example, in literature on the variability of thermal comfort expectations in different countries. Historical and cultural traditions can also influence how buildings and their renovations are typically governed and managed. Western European countries have a long legacy of energy efficiency policy, which started during the first oil crisis in 1973. In contrast, the countries that were closely linked to the former Soviet Union did not suffer from a similar fuel shortage. There are also diverse historical experiences of particular nZEB

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solutions. The existing share of (mainly new) nearly-zero energy, zero-carbon or passive houses in a country can be one such factor influencing overall awareness and acceptance.

- **Policy** is clearly a driver for the adoption of nearly-zero-energy solutions. According to literature, this is the case both for insulation and for various heating and micro-generation solutions. Countries that have supportive policies provide well-coordinated training and quality control mechanisms, and a continual revision of energy standards, as well as ongoing upscaling of best practices from demonstration projects. An additional factor relates to the *political* aspects of policy making. It is likely that nearly-zero energy solutions gain more consistent political support if they can convincingly offer other benefits than climate change mitigation, such as reducing fuel poverty and enhancing job creation.
- **Markets and companies** are important drivers of new solutions, since solutions cannot be adopted unless they are readily available in the market. Most of the solutions discussed above are in principle available throughout Europe but the practical feasibility of selecting them varies from one country to another. Technological learning is an important factor that influences the development of the availability and cost of various nZEB solutions. For mainstream construction companies, solutions need to be simple and quick to implement, replicable, affordable, reliable, cost-effective, readily available and profitable before mainstream companies are willing to consider them. The existence of well-established large companies offering certain solutions can be relevant indicators for their entry into the mainstream market. The competitiveness of new solutions is also naturally influenced by the price of energy, which varies significantly in Europe, with consumer prices for natural gas prices ranging from 3 to almost 12 cents/kWh and electricity prices ranging from about 9 to 30 cents/kWh.
- **Expert and professional communities**, such as universities, consultants and professional associations have an important role in introducing and mediating new ideas such as those represented by nZEB and RES-H/C However, these same expert groups may also be major reproducers of old ideas, which maintain the existing structures. A lack of consensus on what is best practice in nZEB and RES-H/C (especially in refurbishment) can be a factor obstructing public acceptance and creating uncertainty and confusion also among the general public. Such issues like the longstanding existence of voluntary but widely accepted standards or certification schemes might serve as one possible indicator of the level of consensus on appropriate nZEB and RES-H/C solutions in a country.
- **Citizen and social movements:** Apart from formal policies – and usually, before such formal policies mature – various types of social movements have put their stamp on national perceptions of sustainable energy solutions. Examples include the role of citizen movements for solar water heaters in Austria and Spain and the importance of the construction of networks among proponents of the new solutions in the development of the solar PV. Such movements create

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legitimacy for the new solutions before and while they are promoted by public policy.

- **Media:** The role of the media has not been examined in many studies yet; however our experience and the evidence collected in the research suggest that the media has an important role not only in raising awareness of energy issues and the need for renovation, but also in highlighting particular issues. In this respect, studies show that the media do not always promote acceptance, but can also fuel controversies.

The factors operating on a more macro level naturally also have their influence on the micro level, but they combine in different ways in the different particular circumstances of specific renovation projects. In practice, this difference can be seen in the differences between the barriers experienced by different kinds of building owner groups:

- **For owner-occupied single-family homes**, the decision to adopt energy efficient or renewable energy solutions is in principle simple, as the owner makes decisions on their own. However, the notion of a 'comprehensive renovation' is not familiar to single-family homeowners in many countries; in contrast, renovation is an ongoing and largely do-it-yourself process. The small scale rarely enables the contracting of outside planning professionals. High initial costs and lack of access to capital are widespread barriers, whereas improved comfort, energy cost savings and the availability of widely used solutions are common drivers for renovations. This segment, however, is highly heterogeneous, including both the richest urban and often the poorest rural households. It is hence probably likely to host the most innovative pioneers but also the buildings that will never be completely renovated.
- **For owner-occupied multifamily buildings**, decisions about energy renovations are greatly hampered by organizational difficulties of reaching agreement on the need to take measures and on the type of measures to be taken. The share of owner-occupancy among multifamily buildings varies greatly, with the lowest rates in Germany (24%) and the highest in Spain (94%) and Romania (96%). The more widespread owner-occupied multifamily dwellings are, the more diverse the socio-economic background of the inhabitants. When this is coupled with high majorities required for reaching decisions concerning renovations and difficulties in raising collective finance, the barriers to energy renovations are extremely severe.
- **Rental dwelling owners** are extremely diverse in Europe. In many countries, a large share of the entire rental stock is owned by private, individual landlords owning one or two properties. Conversely, the share of professionally owned rental apartments (including social housing) varies greatly by country. In countries where social housing is very rare (Central and Eastern Europe and South Europe), these buildings are particularly problematic, as they only house the poorest people, and there are legal and practical constraints on adding any of the renovation costs to the rent. However, in countries where there is a large and well-established professional rental sector, social housing providers can be the forerunners in solutions for multifamily buildings.

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- **Public building owners and users** are very diverse, both within and among countries. Common barriers throughout Europe and across public building types are the existence of separate budget lines for investments and running costs. Another particular set of problems relates to public procurement rules. However, public buildings are also expected to serve as an example, and individual public buildings do serve as visible demonstrations of exemplary solutions.
- **Office buildings** appear to be more similar to one another across countries. They differ from the other building types discussed here insofar as space and water heating are relatively less important than in other building types, and cooling, ventilation and lighting are more important. Office building owners usually apply sophisticated investment calculus methods and energy efficiency or RES solutions have to compete with other, more productive uses of capital. This said, office buildings can be important and visible sites for nZEB renovation demonstrations.

The barriers and decision criteria are not necessarily the same for different solutions. Comfort, timing, aesthetic factors, investment costs and cost savings are important determinants for investments in the building envelope, whereas investments in HVAC equipment are more related to capital cost and technical performance, branding, as well as particular risks and problems related to particular technologies.

Heiskanen et al. (2013) includes a review of existing consumer acceptance studies, especially of new and renewable-based heating and micro-generation solutions. There are several limitations to the existing research knowledge: there is much more research from Germany, Sweden and the UK than from other countries. There is also more research on single-family home owners than on other types of building owners. However, the few existing studies suggest that multifamily homeowners and tenants might be less likely to accept new solutions; partly because they are less involved in the choice and design of such systems. Existing studies also suggest that the drivers for people choosing "innovative" systems are different than for ones that have become conventional. However, what is an innovative system depends on the country context. People choosing innovative systems are driven by environmental considerations and interests in the technology and its particular benefits. They are usually younger, more educated and wealthier than the population at large (but this could depend on the purchasing price of the innovative system, which is usually high at this stage). Costs, convenience, perceived risks and peer influence play a larger role for the mass market. There is also data suggesting that initial costs are particularly important for low-income households, whereas middle-income households usually consider the heating cost savings as well, and the wealthiest are not sensitive to costs. Social influences (media, advice, recommendations by installers or friends) appear to be important for the majority of owners. The studies (which reflect prosperous West and North European contexts) indicate that single-family home owners' required rates of return for heating systems vary from 12% (heating systems in general), to 16% (for groundsource heat) and 22% (for wood pellets) to 34% for diverse renewable solutions in the UK. There are differences both between countries and among the different solutions. It seems that

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when the solutions are perceived of as innovative and risky, mainstream consumers require higher rates of return than for more conventional and packaged systems.

Certain technologies involve particular risks, concerns or constraints. These include e.g. fuel storage and availability for all kinds of fuels (especially biomass), disruption of the property and garden (groundsource heat, district heat connections), and concerns about dependency on a single provider (district heat). Moreover, concerns may be quite different in different countries and survey studies do not always reveal all constraints or concerns related to particular technologies. Additional concerns raised in other types of studies relate to e.g. permitting problems and time-lags, concerns about indoor air or mould in low-energy buildings, or historical experiences of quality problems in certain heat pump markets.

Several studies suggest that novel solutions, especially heating systems, also have different regional diffusion patterns within countries. There are even quantitative estimates on how much installations in the neighbourhood increase the likeliness of further installations. Many studies stress the importance of social influence, in terms of recommendations from friends, neighbours or installers. However, the strength of the regional effect seems to suggest a broader 'network effect', which is not only due to direct recommendations or imitation, but also to the development of local visibility, competences and service markets.

Studies also reveal the crucial role of various stakeholders in influencing building owners. It is likely that the role of service providers grows when innovative solutions start to enter the mass market. The early adopters are more likely to make efforts to find new solutions, but latecomers are more likely to rely on solutions that are readily available. Hence, the knowledge level and awareness of e.g. engineers or architects, craftsmen, installers, as well as real estate agents, house managers and maintenance service providers can influence the acceptability and actual adoption of new solutions. Another factor that is likely to gain importance is quality assurance, monitoring and verification of savings, which was also highlighted in some of our expert interviews. Guarantees and insurance products may also be important. Mainstream consumers are not likely to accept even unlikely risks, and the risks of new solutions usually gain much more attention than the risks of old ones.

3.3 Particular features of public acceptance and adoption of nZEB and RES-H/C solutions in ENTRANZE target countries

The extent to which knowledge, support and exemplars are available for particular solutions depends on the maturity of the market. On the basis of our analysis, we attempt to characterize the level of maturity of markets for various nearly-zero-energy and renewable heating solutions. This is relevant because the maturity of the market relates to the type and quality of services and commercial solutions available: these can range from quite exceptional and niche market services at premium price, to widely available services. The maturity of the market also influences the evaluation criteria used by building owners. Most building owners are unlikely to invest in solutions that they have

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never seen. If solutions are perceived of as innovative, they will only be chosen by a certain segment of pioneering users. Other users are not likely to choose them unless they fulfill a very specific need.

The main **drivers** for nZEB solutions in ENTRANZE target countries are fairly similar in all countries, although the emphasis varies somewhat from one country to another. Regulations (existing or pending), subsidies and finance schemes, as well as especially local advice agencies are the main drivers in most countries. The state of the existing housing stock is another major driver, more so in some countries than others, as well as the arguments that thermal renovations are cost-effective. The rising price of energy was also mentioned frequently as a driver for energy renovations. Voluntary initiatives, regional energy agencies, existing good examples and individual champions were also mentioned in some countries as important drivers.

Subsidies and finance schemes are important drivers for renewable heating and cooling solutions in many countries. There are also mandatory requirements in several countries, e.g. the Renewable Heat Act in Germany and building regulations in Spain and France. Companies were also often mentioned as promoters of these solutions, especially installers in Austria. In particular, heat pumps have been promoted by energy utilities in Austria, France and Germany. Promotion, marketing and good examples are mentioned as important; this applies especially in the initial market introduction stage of a solution.

Certain solutions have an overall positive image: this is the case for solar energy in most countries (irrespective of whether it is widespread or not). However, biomass is perhaps a solution that has a more positive image in German-speaking countries than outside them. There are also practical arguments for some of the solutions. Cheap fuels are a widely acknowledged argument for biomass, convenience and low maintenance costs for groundsource heat. Ease of use and ease of installation are also important arguments for relatively independent systems like solar water heaters or air-source heat pumps.

Mechanical supply and exhaust ventilation is quite rare; hence the possible scope for ventilation heat recovery systems is limited. Ventilation heat recovery and energy efficient air conditioning are more expert-driven systems, which are usually promoted by standards, requirements and labelling or experts and designers rather than public demand. There are also subsidies and finance schemes in Austria and Germany. However, motivated building owners can also be drivers, as in the case of the Czech Republic.

On the other hand, there are also countries in which air conditioning (i.e., cooling) is extremely rare as well. In countries where air conditioning is only just being introduced

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(e.g. Czech Republic, Finland), reversible air conditioning/heat pumps present an attractive prospect.

Solar PV panels are mainly driven by subsidies, finance schemes and feed-in-tariffs, as well as the overall positive image of solar energy, and the attraction of independent energy production (for some building owners). There are also legal requirements in some countries, and the growing market and rising energy prices increase its attraction in others.

High initial investment costs are a common **barrier** to all solutions, except for air-source heat pumps in most countries. There are also particular barriers related to particular technologies such as space demand and urban air quality issues for biomass heating. Some of these are quite definite technical constraints, such as the low airtightness of existing buildings in the case of ventilation heat recovery. Some barriers, however, relate to the type and development stage of the market. These are, for example, lack of knowledge and dedicated finance for e.g. biomass heating systems, or uncertainties about fuel prices and availability. There is also a competition among many of these systems, and while our experts and the national or local advice schemes referenced above can recommend some solutions for particular buildings or locations, this might not be obvious to building owners. There are also some quality and performance issues related to particular technologies. Especially, the variable quality and performance of airsource heat pumps was mentioned in several countries. Electricity microgeneration (solar PVs) is spreading rapidly due to cost reductions and favourable feed-in tariffs in several countries. Yet in others, it still suffers from unstable feed-in-tariff schemes or electricity revenues and practical problems in grid connections in several countries.

In general, different **building owner types** have specific needs as concerns the identification and promotion of suitable solutions. It was noted in Heiskanen et al. (2012) that single-family homes in many countries often engage in piecemeal and step-by-step renovation. They often save money and repair or replace building components over the years, rather than starting a comprehensive renovation with external capital. Our analysis here has shown that single-family homes are also often the most likely to install various kinds of renewable heating systems and more recently also PV panels. This piecemeal progress toward less energy use and more renewable energy is an opportunity but also a challenge for those wishing to promote nZEB and RES-H/C in the existing building stock. It is an opportunity because there are existing examples and accumulated experience, and developed service structures for the installation of components. It is a challenge because piecemeal replacement and installation of various solutions might not lead to an optimal combination of technologies and renovation measures in the end.

Multifamily buildings have quite different challenges. Especially in multifamily buildings, all kinds of renovations cause difficulties in making decisions, but innovative solutions may be particularly challenging in a collective decision context. All kinds of multifamily buildings experience difficulties of fitting most renewable heating solutions into an urban structure and the management practices of urban buildings. Planning, permitting,

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decision making and financing issues can cause significant delays and time-lags in implementation. Moreover, for technical building systems, issues of the training of maintenance staff and users can be quite important for both the acceptance and the performance of the systems.

Service buildings and public buildings can serve as important exemplars of new solutions. This can serve a very important purpose not only in educating other owners of public or service buildings, but also other building users. People are extremely unlikely to invest their own money in solutions that they have never seen or experienced themselves. Hence, implementation of these solutions in buildings that are open to the general public (and visited regularly by people also long before their own renovation decision is at hand) can be a very important aspect of creating public and social acceptance of nearly-zero energy buildings and renewable heating and cooling solutions.

As concerns **public acceptance in general**, the overall acceptance of the need to save energy is relatively widespread in Europe. However, public understanding of where energy is consumed and how it can be saved is low – especially compared to the relatively complex and ambitious systems connected to nearly-zero energy renovations and renewable heating and cooling systems. Moreover, different solutions are more relevant and/or familiar and institutionalized in some countries than others. nZEB or even nZEB renovation is not a concept that is understood or applied similarly throughout Europe, or even within countries.

3.4 Consideration of stakeholder behaviour in the model based scenario analysis

A relevant part of the ENTRANZE project is the quantitative scenario analysis of energy demand development and technology diffusion in buildings in the EU Member States applying the bottom-up model Invert/EE-Lab.[5] Taking into account the heterogeneity of building owners as outlined above, the ENTRANZE project has a particular focus on integration the results of the stakeholder anlaysis in the model.

(Steinbach, 2013a) provides an overview of energy-economic models for the building sector focusing on *bottom-up* approaches to simulate stakeholder-specific investment decision-making and presents the methodology of the new module INVERT-Agents which allows to model stakeholder behaviour within the scenario analysis. The agent-based decision module allows the definition of different investor types and the simulation of investment decision-making as a function of investor-specific variables reflecting barriers and perceptions. Figure 9 shows the structure of the module. The simulation of investment decision-making in this model is based on different economic and non-

[5] See the report "Policy pathways for reducing the carbon emissions of the building stock in EU28 until 2030" (Kranzl et al., 2014b), http://www.entranze.eu/pub/pub-scenario

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economic criteria which are then calculated for each combination of technologies, buildings and investor types. The defined properties of an investor determine how an investment decision is made (relevance of different criteria) as well as the perception of investment options and influencing parameters. The latter might result in different values of the decision criteria if the same technology is considered by different investors. For instance, dissimilarities of criteria values among investors can result from unequal knowledge of subsidy schemes and their consideration in the investment decision-making process. With respect to regulative policies, such as the minimum efficiency standards defined by building codes, the model allows agent-specific compliance rates to be defined. The usage of the building by the investor is also considered as a parameter in the decision process. Thereby, the model differentiates between investors occupying the whole building, collective ownerships, private landlords and housing associations. Energy cost savings through an energy retrofit or a different heating system are only a relevant parameter for owner-occupiers, whereas the refinancing of an investment through additional rents is considered for private landlords and housing associations.

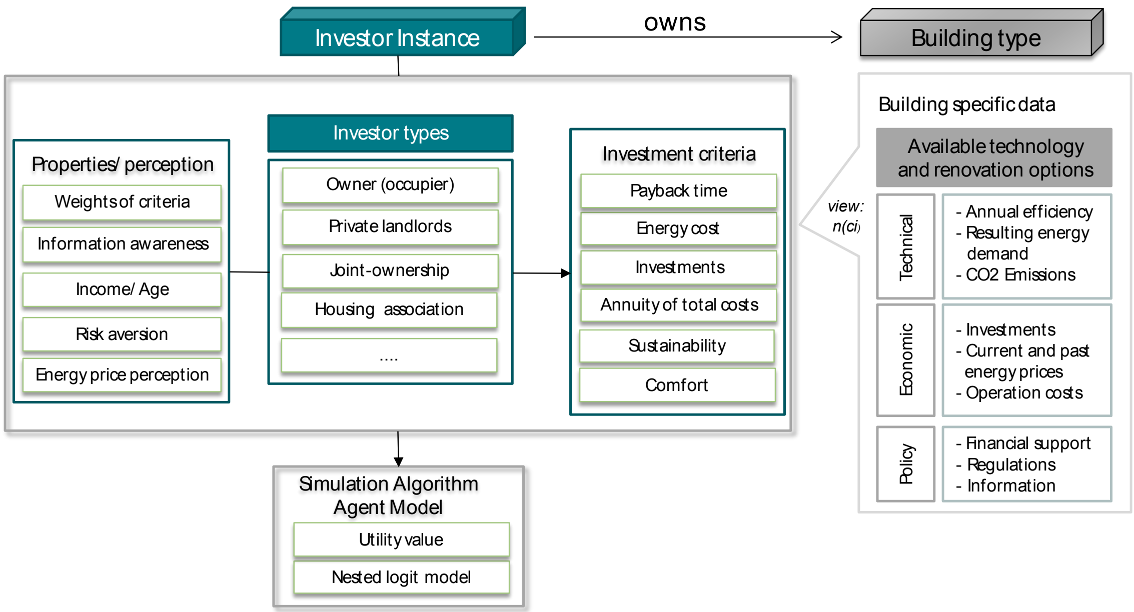

Figure 9. Overview of the agent-specific decision module (INVERT-Agents)

Decision criteria and barriers in Invert-Agents

Since the model is still only a simplified reflection of the real decision processes, a one-to-one transformation of the specific barriers and relevant decision criteria gained in the qualitative analysis is not possible.

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Each investor type is characterised by specific variables which are relevant for the investment decision process. Variables can be differentiated by agent properties which define the perception of investors (Table 1) and by weights on decision criteria which define the decision process. The choice of heating systems and energy efficiency measures is calculated separately. Firstly, the perceived criteria values of each alternative are calculated specific to each investor and building and linearly normalised on a 0 to 100 scale. Secondly, utility values are determined by applying investor-specific weights. The resulting utility values of each option are used to calculate market shares by applying a *logit* function. Basically, the alternative with the highest utility value gains the highest market share while the other alternatives gain market shares equivalent to the difference in utility value.

The following criteria can be set to be investor-specific in the decision process:

1. Economic criteria
    a. Investments (initial costs)
    b. Payback time
    c. Profitability (net present value based calculation)
    d. Energy cost savings
2. Non-economic criteria
    a. Sustainability
    b. Comfort
    c. Existing heating system
    d. Current market share of technology

Table 1. Investor-specific input variables

Perception/ property variables:	Description	Variable settings
Investor class	• Energy savings are relevant for decision (in case of owner-occupier) or • Additional rent (in case of landlords)	• 1: owner-occupier • 2: private landlord • 3: joint ownership (owner-occupied MFH) • 4:Housing association • 5: Owner of non residential buildings
Information awareness	• Share of investors within investor type group with knowledge about financial support instruments • Investor-specific compliance rate with regulation	• Float number between [0,1]
Risk aversion	• Indicates if credit-based support instruments are considered in the investment decision	• 1: risk averse (no consideration of soft loans) • 0: not risk averse
Energy price calculation	• Indicates how the development of energy prices is considered	• 1: Weighted average last three periods • 2: Energy prices of current period • 3: Calculation according to standards: discounted price increase over lifetime
Interest rate	• Investor-specific interest rate if net present value based on *profitability criterion* is considered	• float number between [0,1]

3.5 Transformation of qualitative results into model settings

The model setting of decision criteria and investor-specific barriers are based on the qualitative analysis (Heiskanen et al. (2012). Thereby, the relevance of the decision criteria has been rated on *a 5 point scale* separated according to the defined stakeholder groups. Barriers are rated if they are relevant (A, (B)) or not (-).

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Transformation in criteria weights as model input

The weight of a decision criterion in the model is calculated straightforward by dividing the assigned value by the total sum of assigned values. Thus, each criterion weight is calculated as follows:

$$weight_j = \frac{value_j}{\sum_j^J value_j}$$

value: *assigned relevance on a 5-point scale*

j: *index of criteria*

An explicit transformation of all the decision criteria as investor-specific variables is not possible due to the algorithms implemented in the model. There are several criteria which are not incorporated as investor-specific variables but which are considered implicitly in the model. The following criteria describe the influences of the timing of a renovation or a heating system change rather than the choice among alternatives:

- Timing vis-a-vis previous renovations
- Quality service available

Since the trigger for a renovation or a heating system change is implemented in INVERT/EE-Lab via an age-dependent distribution which describes the breakdown probability of components, these variables are only considered on a aggregated level and not differentiated by specific investors.

Another group of criteria describe the maturity stage of alternatives or the market itself:

- Quick instalment
- Turnkey solutions available
- Widely used solution
- Ease of maintenance
- Recommendation by experts
- Expected future regulations

These variables are also considered only implicitly in the model by means of the diffusion restrictions which set the maximal diffusion of an alternative depending on its current market share.

With regard to economic variables, all the “financial” decision criteria are considered explicitly (see above).

The variable *comfort* is coded by the decision criteria:

- Improved comfort
- Improved value of property

The variable *sustainability* is coded by the decision criteria:

- Environmental considerations

- Social approval/status

Transformation of barriers into investor-specific properties

Most of the barriers are either already reflected in the respective decision criteria or represent general obstacles to changing the heating system or conducting any renovation. As already discussed, these barriers influence the rate of renovation or heating system change, but not the choice between the competing options.

The investor-specific variable ***risk aversion*** is coded by the following barriers derived in the qualitative analysis:

- Access to capital
- Unwillingness to incur debt

An investor agent is assumed to be risk averse if any of these two barriers are relevant – assigned an “A”.

The ***information awareness*** variable is coded by the following information-relevant barriers *($barriers_{inf}$)*:

- Conflicting information, mistrust of information
- Lack of customer attention and interest
- Lack of customer knowledge
- Lack of reliable advice

4. Cost-optimality calculations

4.1 Methodology and calculation steps

In the cost/energy curve calculations developed, we adopted a methodology for analysing and presenting data about performance of nearly zero energy buildings, which offers utmost transparency. Cost/Energy curves are presented and assessed in several analyses, with indications for the selection of cost-optimal and nearly zero energy EE and RES technologies/strategies for different building typologies. The analysis presents also an assessment of curve sensitivity with respect to the main economic input data.

In order to be consistent with the EU process of implementation of EPBD and allow a discussion on the relationship between nearly zero-energy and cost-optimal, our methodology is coherent with the cost-optimal methodology framework, in accordance with Article 5 and Annex III of Directive 2010/31/EU, EU Guidelines (European Commission 2012a) and Regulation (EU) N° 244/2012 (European Commission 2012b). The complete process to assess on cost optimal levels for energy performance requirements of buildings is described in Figure 10.

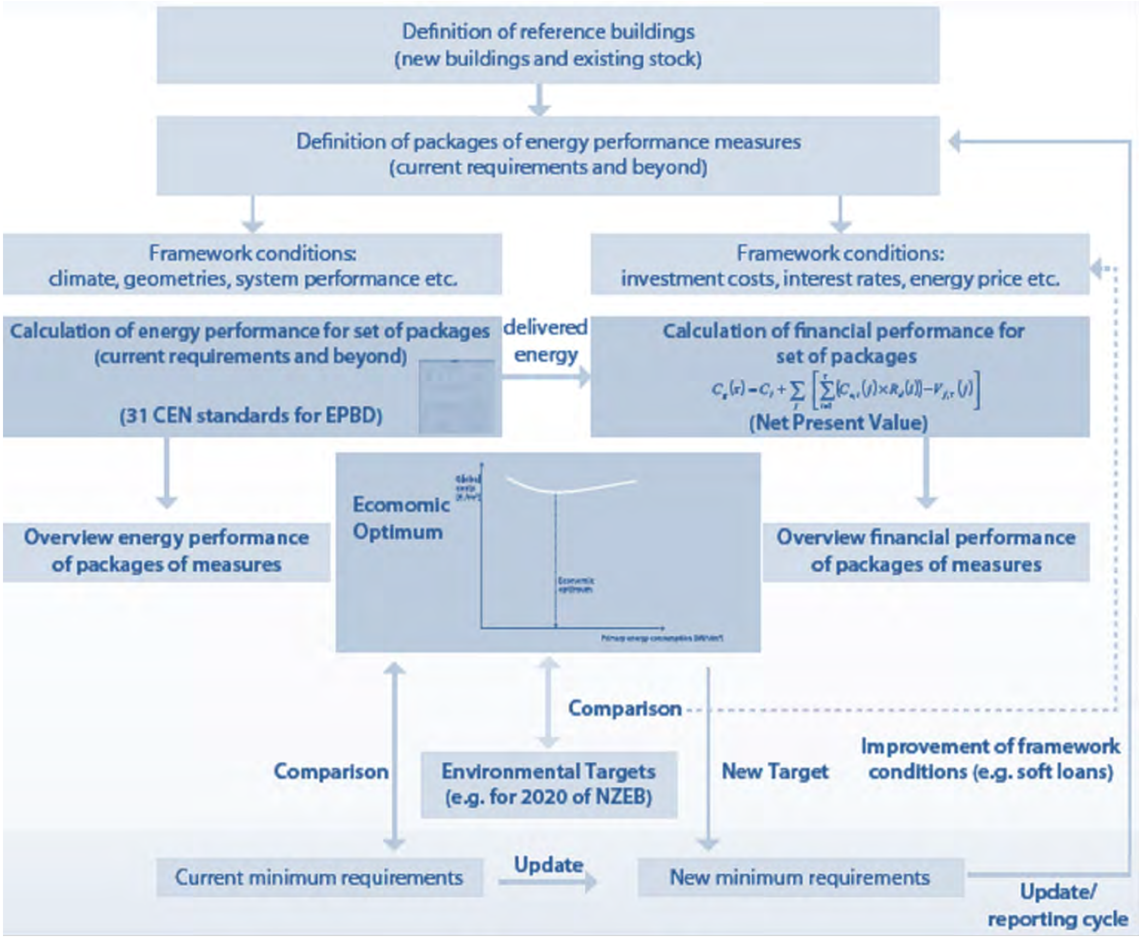

Figure 10. Flowchart comparative methodology. Reproduced from (BPIE 2010)

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About the energy performance calculation, the following steps were performed (Pietrobon et al., 2013):

1. Selection of efficiency technical solutions and their grouping into typical **packages** (since very often these technical solutions are not used as stand-alone measures but in combination with other measures), based on the definition of the reference base case.
2. Calculation of **energy needs** for heating and cooling and energy use for lighting for main models of buildings (building variants) for which simulations are performed where the selected energy efficiency envelope technologies and combinations thereof are implemented; we carried out this quantitative assessment by dynamic simulations (by using the EnergyPlus software).
3. Generation of all **building models**, which can be also indicated as "building families" by variation of energy efficiency measures for envelope and system technologies for each building variants: "building families" are equal to groups of envelope packages (building variants) related to opaque envelop - indicated with (e) in the project report, glazing and air tightness (w), passive cooling techniques (c) and efficient lighting strategies (L), plus plant variants verifying whose system architecture is coherent.
4. Calculation of **delivered energy** values for each building model; the energy saving assessment are performed by associating appropriate performance coefficients to each plant type, in accordance with EN standards and other bibliographic references.
5. Calculation of energy uses for **auxiliary systems** are calculated through a simplified dimensioning.
6. In the models where is implemented a mechanical ventilation system (with or without heat recovery) energy uses for **fans** are calculated.
7. Inclusion of energy generation from **RES** systems (Marszal et Al. 2011) (such as solar thermal panels, photovoltaic (PV) panels, heat pumps[6] and biomass boilers) by simple estimation methods and calculation of **net** (**over a time laps of one year**) **primary energy consumption**[7] for the entire building; the delivered-to-primary conversion factors of the different countries/regions are taken into account.

We consider the "*Net ZEB limited*" definition, that is we calculate the net primary energy (over a yearly balance, and using symmetric weighting for exported energy from building systems to grid) associated to heating, cooling, domestic hot water, ventilation,

[6] About renewable contributions from heat pumps: heat pump systems were considered as "on-site generation from on-site renewables" with limits and method according to EU Commission Decision 2013//114/UE (1/3/2013) (European Commission 2013).

[7] The term (net) primary energy means the result of the following steps: ● (A) calculation of the primary energy associated with the delivered energy, using national conversion factors; ● (B) calculation of primary energy associated with energy exported to the market (e.g. generated by RES or co-generators on-site); ● calculation of (net) primary energy as the difference between the two previous calculated amounts: (A)-(B).

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auxiliaries, lighting, but we exclude the electric consumption of appliances and other plug loads (although we consider their effects on thermal energy needs). For the sake of comparison, we consider lighting both in non-residential and residential buildings.

The overall methodology includes the following main steps about global costs calculation, which were adopted using a properly developed tool for cost-energy calculation (Armani at Al. 2013).

- Association of installation **costs** to each technology, including material and labour costs, remove and disposal of existing technologies, business profit and general expenditure.
- Calculation of **global costs**, (Figure 11) including capital costs, substitution costs, annual maintenance costs, operating energy costs, over a period of 30 years (subtracting final value), all discounted to year zero (where year zero is either 2011 or 2020). For the sake of comparison, we consider a period of 30 years both in non-residential and residential buildings.
- Note that embedded energy (also called grey energy) is not included in the calculation, which does not exclude the possibility that a MS might decide to include it in the definition and calculation.

Costs of construction not directly related to energy (structure, finishing materials, etc.) are not considering in this analysis we have assumed no subsidies hence PV energy is supposed to be sold to the grid at a price comparable to that of conventional generation sources on the wholesale market. Costs of land, property taxes etc. are not included.

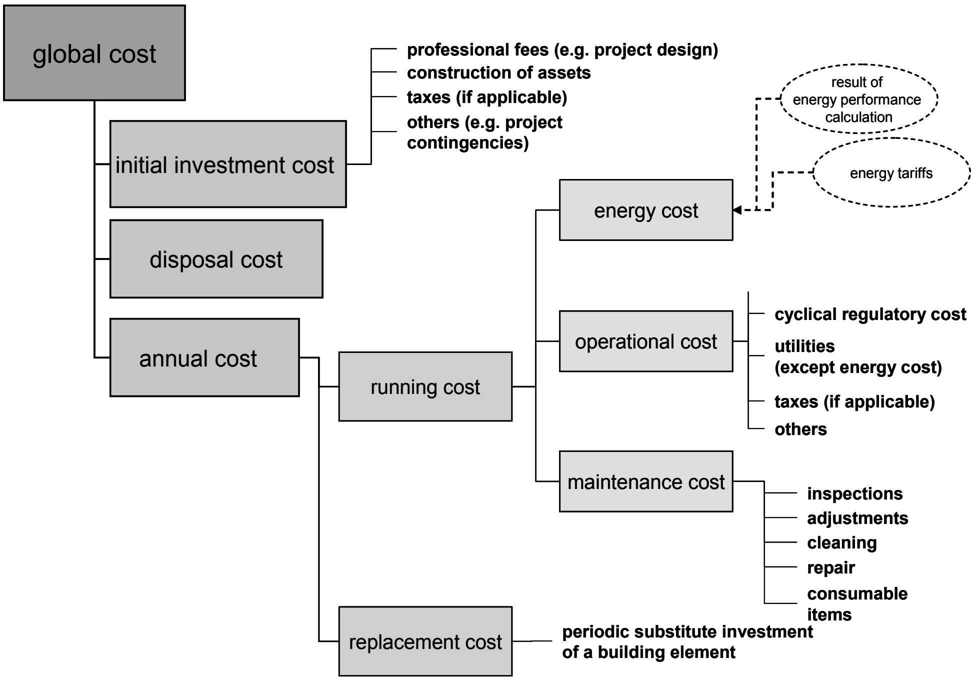

Figure 11. All costs considered in the performed global cost calculations.

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4.2 Reference buildings and climate contexts

The comparative methodology it has been applied at four categories of buildings, differing for use, geometry, envelope and plant system characteristics, as it follows:

- **Single House**: composed by an under ground level and 2 floors over ground level), it has a conditioned surface of about 140 m^2 and a S/V ratio of 0,7.
- **Apartment Block**: it has 4 floors and an under ground level, divided in 12 apartments and its conditioned area is around 1 000 m^2 and a S/V of 0,33.
- **Office**: a medium-size and highly-glazed office building, with 5 floors (of 3 m height each) an S/V ratio of 0,33 and a net heated area of 2 400 m^2.
- **School**: a medium-size and highly-glazed school building, with 2 floors (of 3 m height each) an S/V ratio of 0,46 and a net heated area of 3500 m^2.

All the considered reference buildings have a ground floor toward an unconditioned basement and the last slab toward an unconditioned space between the last slab and the "slope roof". Except the office building where the last slab is also the plane roof.

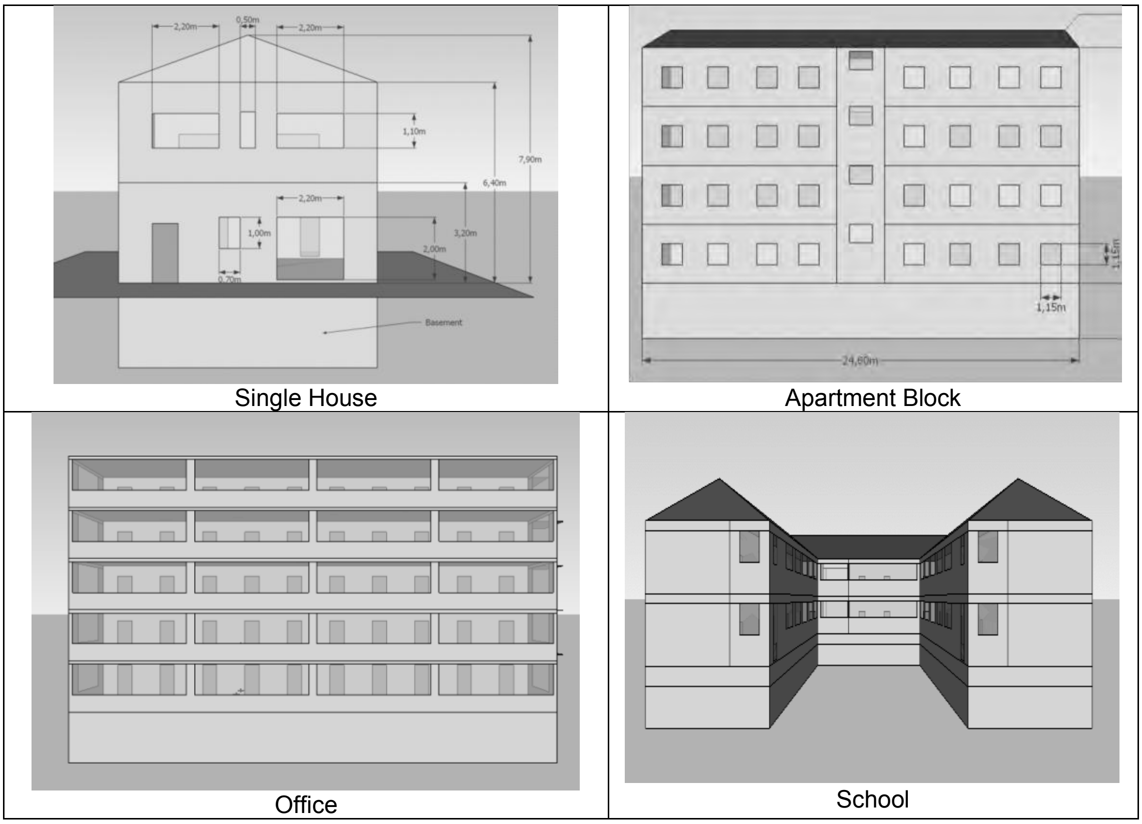

Figure 12. Geometry of reference buildings.

The physical property of envelope components (wall, roof/last slab, basement, windows) and plant system configurations (for heating and cooling) of the building before

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the renovation works are different for each target country. Each partner had to characterize every type of building in term U-value of opaque and transparent envelope and to indicate the more probable configuration of heating and cooling systems.

We focused our calculations and analyses on 10 key climatic conditions within the European area of all Entranze project target countries and analysing data on reference indicators for climate contexts (as Winter and Summer Severity Index and Climate Cooling Potential Index) we selected the following locations as key climate conditions:

Table 2. Characterization of climatic conditions

Context	Climatic characterisation
Seville (ES)	Mediterranean climate (hot summer subtype) with very low climatic cooling potential (extreme summer conditions)
Madrid (ES)	Semi-arid climate with low climatic cooling potential
Rome (IT)	Mediterranean climate (warm summer subtype) with medium climatic cooling potential
Milan (IT)	Humid subtropical climate with medium climatic cooling potential
Bucharest (RO)	Humid continental (hot summer subtype) / Subarctic climate with medium climatic cooling potential
Vienna (AT)	Humid continental climate (warm summer subtype) with high climatic cooling potential
Paris (FR)	Oceanic climate with very high climatic cooling potential
Prague (CZ)	Humid continental climate (warm summer subtype) with high climatic cooling potential
Berlin (DE)	Humid continental climate (warm summer subtype) with high climatic cooling potential
Helsinki (FI)	Humid continental / Subarctic climate (extreme winter conditions)

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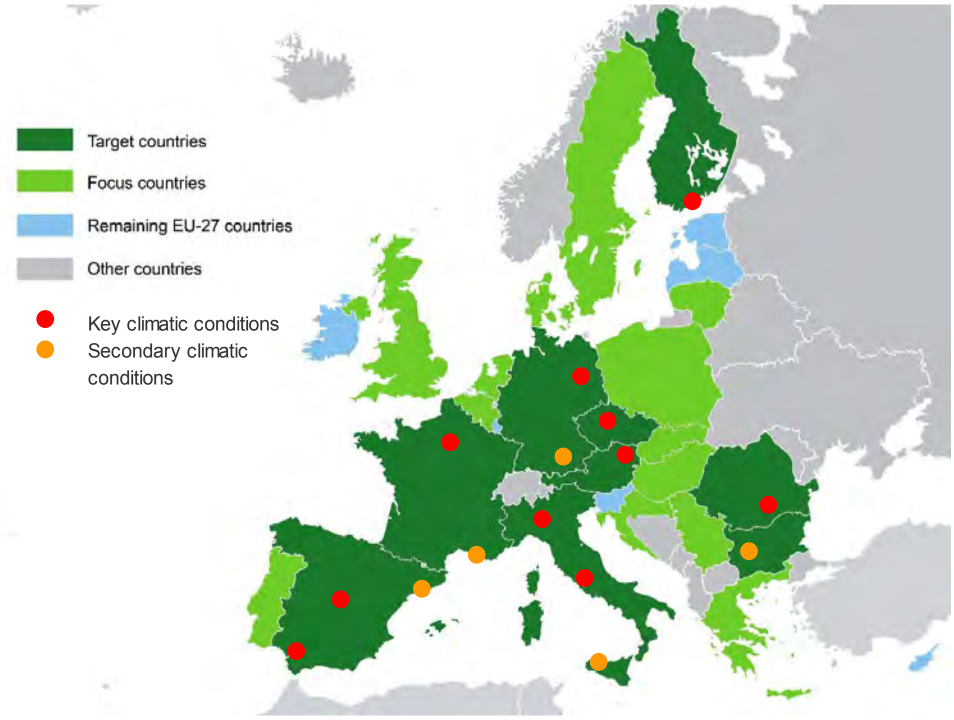

Figure 13. Regional overview of climatic conditions in ENRANZE target countries

4.3 Main cost-optimality results

For every target country and building type, the main results consist in the definition of possible **targets of (net) primary energy** representative of the "**cost optimal**" (a) and "**nearly Zero Energy Buildings**" (b) solutions for buildings **renovations**. In addition to these two energy/costs targets, we defined two further levels (c and d) of possible renovation expressed as fixed percentages of reduction in (net) primary energy respect to the base refurbishment level with minimum performance thresholds. Particularly the following four targets were considered:

a) Minimum global cost: possible *Cost optima*l target,
b) Minimum (net) primary energy: possible *nZEB* target,
c) 50% of reduction of (net) primary energy respect to base refurbishment level[8] with threshold of 100 kWh/(m^2y),
d) 75% of reduction of (net) primary energy respect to base refurbishment level with threshold of 50 kWh/(m^2y).

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[8] The **base refurbishment level** (BRL) corresponds to the adoption of renovation measures only for aesthetic, functional and safety reasons of the same building com-ponents considered for renovation packages. In BRL the old generators and systems is replace with component of the same technology and with efficiency of current state of the market.

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For each targets we selected a **complete refurbishment solution**, which corresponds to one building variants among all calculated ones (in other words to a dot of the cost/energy clouds developed.

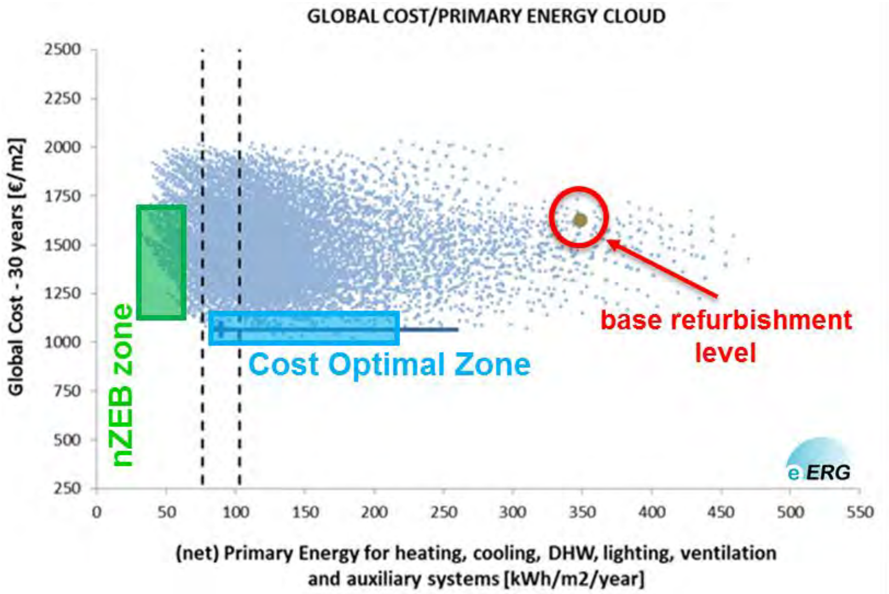

Figure 14. Example of cost/energy cloud with some target zones indicated

Examples of **cost/energy clouds** are here presented for renovation of single family houses in different climates. The graphs represent all building variants (envelope + systems measures) for each climate condition, the cost optimal target and encouraged range according EPBD, and the corresponding base refurbishment level.

We performed also a **sensitivity analysis** respect to calculation starting year (2011 or 2020), the energy prices scenarios (reference or ambitious), economical perspective.

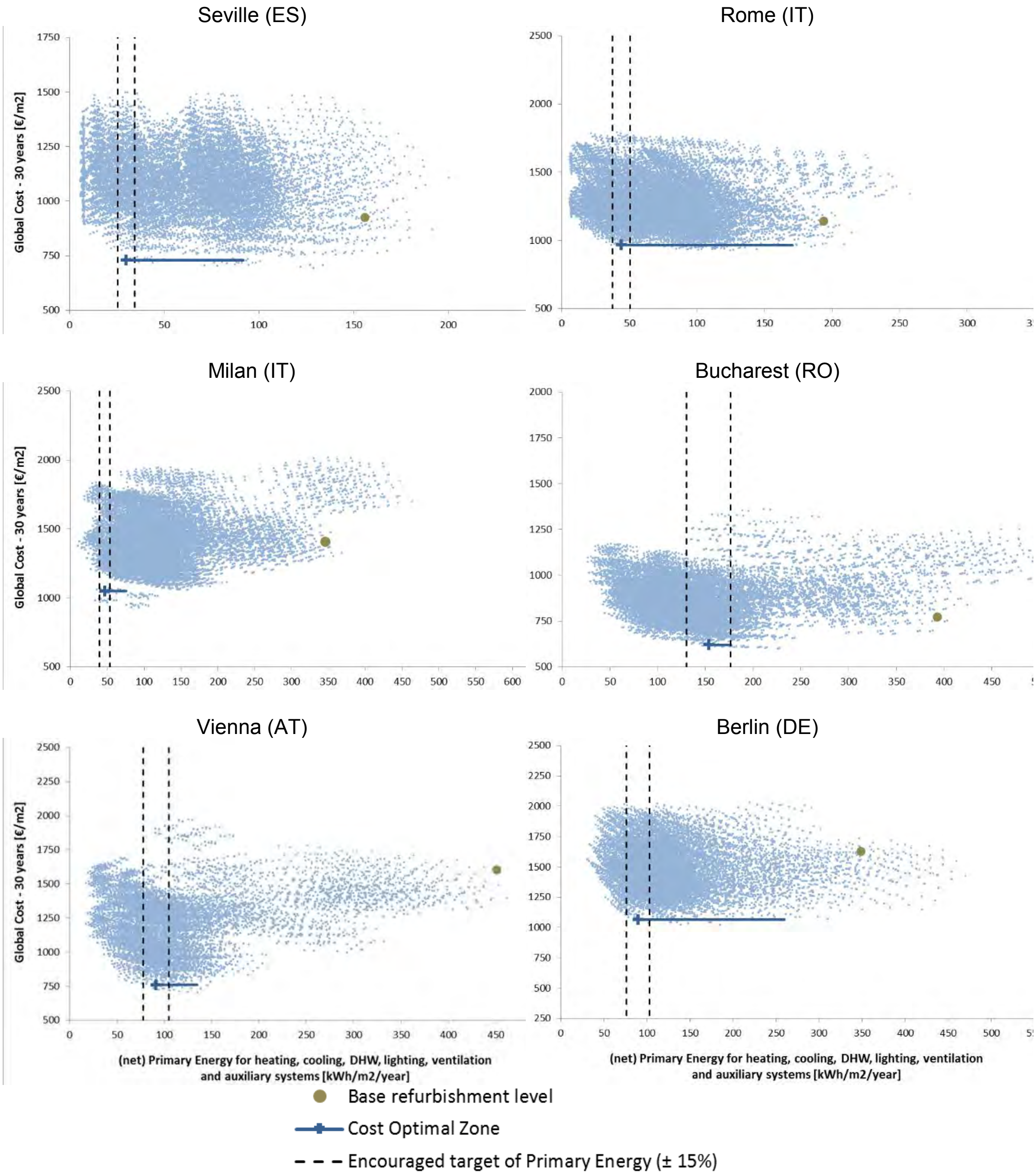

Figure 15. Example of Cost/Energy clouds - financial standard private perspective, reference energy prices (Single Family House)

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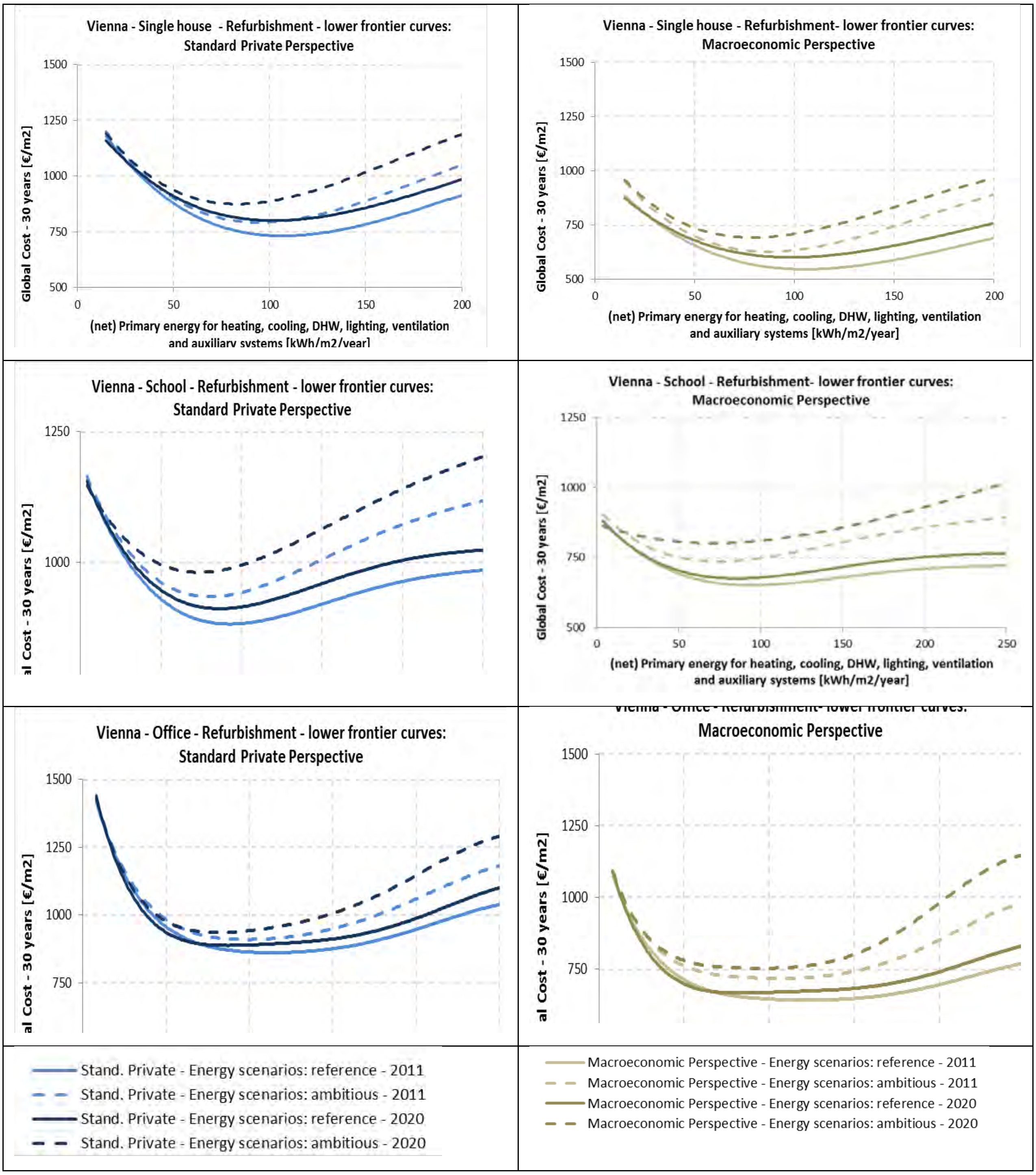

Figure 16. Example of sensitivity analysis on starting year, energy scenarios and economical perspective (Vienna)

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For the **buildings selection**, all features (in term of Energy Efficiency Envelope strategies and combinations of systems) of the corresponding four selected buildings are shown and compared for all building types and climate contexts.

The following graphs (Figure 17, Figure 18 and Figure 19) show an example of results. For what concern the thermal transmittance (U value) of envelope components could be a bit different in the different countries: we have to consider that the renovation levels of different envelope packages are different for every countries for a more consistency of final results, according to information given by Entranze partners on common refurbishment measures in each country.

As we can see in the following results in some cases different targets can be very close reaching to the same building selection. It could be a robust indication on the possible way to be followed. Of course this depends also on the energy performances of the base refurbishment levels. We can see in some contexts we don't go below the 50 $kWh/m^2/y$ threshold in net primary energy for apartment blocks. This because we assumed that efficiency strategies in lighting were not implemented in residential building types, and the corresponding energy demand is not reduce respect the base refurbishment level. In addition for Helsinki (Finland) context, we decided to not improve the thermal transmittance of basement, according local stakeholders indications.

Complete descriptions were given for all selected target buildings. For each building type and climate a table shows corresponding values of net primary energy demand and energy needs, renewable energy systems contributions, cooling and lighting strategies, building envelope features and performances (thermal transmittance, airtightness level, etc.), systems. We present an example of selection in Figure 20. Features of all selected building were presented in the deliverable 3.3 of Entranze project.

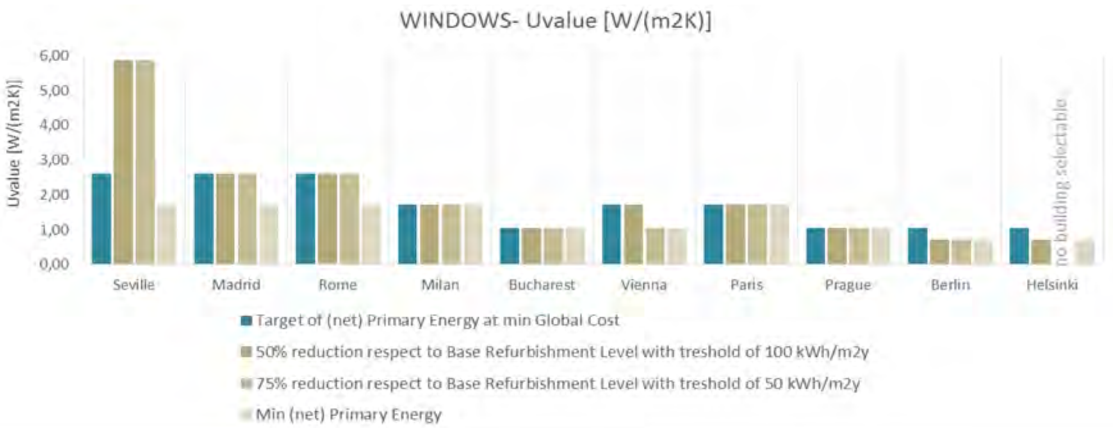

Figure 17. Cross comparison results for WINDOWS of single house (All climates)

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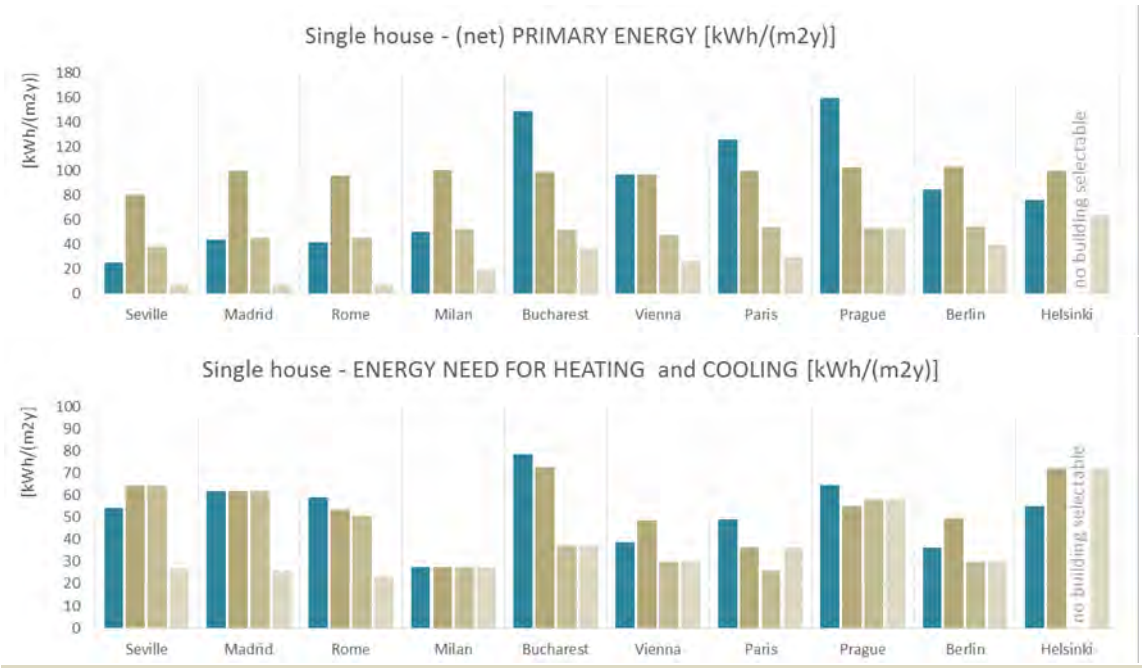

Figure 18. Cross comparison results of (net) primary energy demand and energy needs for heating plus cooling, for single house (All climates)

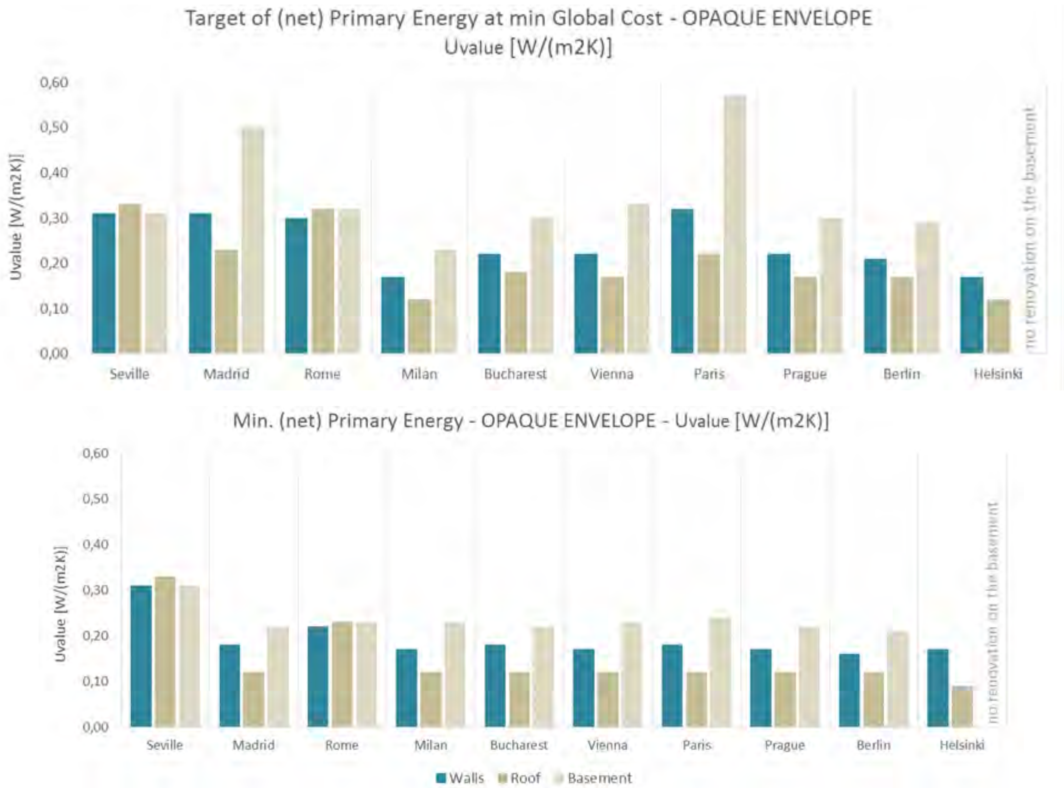

Figure 19. Cross comparison results for opaque envelope components single house

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Vienna SINGLE HOUSE	BUILDING N. 1 Target of (net) PE at min Global Cost		BUILDING N. 2 50% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 3 75% of (net) PE reduction respect to Base Refurbishment level + treshold		BUILDING N. 4 Min (net) Primary Energy	
BUILDING VARIANT:	21		27		33		33	
OPAQUE ENVELOPE-Package:	++		+++		+++		+++	
OPAQUE ENVELOPE-Variant:	description:	U-value $[W/m^2K]$	description:	U-value $[W/m^2K]$	description:	U-value $[W/m^2K]$	description:	U-value $[W/m^2K]$
Wall thermal insulation	15cm insulation -External insulation (EIFS System)	0,22	20cm insulation -External insulation (EIFS System)	0,17	20cm insulation -External insulation (EIFS System)	0,17	20cm insulation -External insulation (EIFS System)	0,17
Roof thermal insulation	20cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,17	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12	30cm insulation - Add on a thermal insulation layer over the last slab in contact with unconditioned space	0,12
Basement thermal insulation	10cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,33	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23	15cm insulation - Install a layer of thermal insulation below the slab in contact with the basement	0,23
WINDOW PACKAGE:	+		+		++		++	
WINDOW Variant (1) :	description:		description:		description:		description:	
Type of window	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m^2K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71	Double glass with air cavity (16mm); low-e glass Ug= 1,7 W/m^2K; Uf=1,4 W/m2K; air permeability: 3rd class EN 12207.	1,71	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m^2K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03	Triple glass with argon cavity (16mm); low-e glass Ug= 1,0 W/m^2K; Uf=1,0 W/m2K; air permeability: 4th class EN 12207.	1,03
	Solar Trasmittance (-)	0,64	Solar Trasmittance (-)	0,64	Solar Trasmittance (-)	0,55	Solar Trasmittance (-)	0,55
	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,65	Visible Trasmittance (-)	0,59	Visible Trasmittance (-)	0,59
	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58	(airtightness) (1/h)	0,58
COOLING STRATEGIES PACKAGE:	n		n		n		n	
	description:		description:		description:		description:	
Solar shading	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-	External window blinds - fixed slat angle - manual control (setpoint 500W/m2 in SUMMER)	-
	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}	description:	h^{-1}
Night Ventilation for Cooling	Night ventilation absent	0	Night ventilation absent	0	Night ventilation absent	0	Night ventilation absent	0
LIGHTING STRATEGIES :	n		n		n		n	
	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)	description:	power [W/m2] (2)
Lighting Loads	No change	3,5	No change	3,5	No change	3,5	No change	3,5
	description:		description:		description:		description:	
Lighting Control	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-	No change -manual ON/OFF	-
PLANT SYSTEMS		POWER [W/m2] Flow Rate $[m^3/s]$		POWER [W/m2] Flow Rate $[m^3/s]$		POWER [W/m2] Flow Rate $[m^3/s]$		POWER [W/m2] Flow Rate $[m^3/s]$
Heating Generation	connection to a district heating	68	connection to a district heating	72	connection to a district heating	58	reversible ground source heat pump	58
Cooling Generation	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-	no cooling generetion system	-
Heating Emission	radiator	-	radiator	-	radiator	-	insulated radiant floor	-
Cooling Emission	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-	no cooling emission system	-
Heating Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Cooling Distribution	insulated pipes	-	insulated pipes	-	insulated pipes	-	insulated pipes	-
Heating Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Cooling Control	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-	climatic with or without room indoor control system	-
Mechanical Ventilation	mechanical ventilation oly for IAQ	0,05	no mechanical ventilation (open window by user)	-	mechanical ventilation oly for IAQ	0,05	mechanical ventilation oly for IAQ	0,05
Heat Recovery	present	0,05	absent	-	present	0,05	present	0,05
Thermal Solar Panels	absent	-	absent	-	present	-	present	-
Photovoltaic Solar Panel	absent	-	absent	-	present	-	present	-
Energy Need for Heating $[kWh/m^2y]$	38,4		48,5		29,6		29,6	
Energy Need for Cooling $[kWh/m^2y]$	0,0		0,0		0,0		0,0	
Energy Need for DHW $[kWh/m^2y]$	13,6		13,6		13,6		13,6	
Energy Use for Lighting $[kWh/m^2y]$	13,6		13,6		13,6		13,6	
(net) Primary Energy demand $[kWh/m^2y]$	96,8		97,0		46,8		25,7	
RES contribution $[kWh/m^2y]$	0,0		0,0		40,2		98,1	
Global Cost $[€/m^2]$	791,9		747,3		893,0		1150,7	
BASE REFURBISHMENT LEVEL								
Energy Need for Heating $[kWh/m^2y]$	199,5							
Energy Need for Cooling $[kWh/m^2y]$	10,5							
Energy Need for DHW $[kWh/m^2y]$	13,6							
Energy Use for Lighting $[kWh/m^2y]$	13,6							
(net) Primary Energy demand $[kWh/m^2y]$	450,8							
RES contribution $[kWh/m^2y]$	0,0							
Global Cost $[€/m^2]$	1604,9							

(1) It is an average value of thermal trasmittance of the all windows with different dimensions in the considered building

Figure 20. Example of a complete description of selected building for the 4 targets (Single Family House in Vienna)

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We performed also a more general analysis to give more general and open results on potential of all different measures available, which could represent open indications for policy makers and stakeholders on *cost-optimal* and *nZEB* solutions for renovations. Here below an example of the frequency analysis on suitable measures is presented. In (Pietrobon et al., 2013), all analyses are shown.

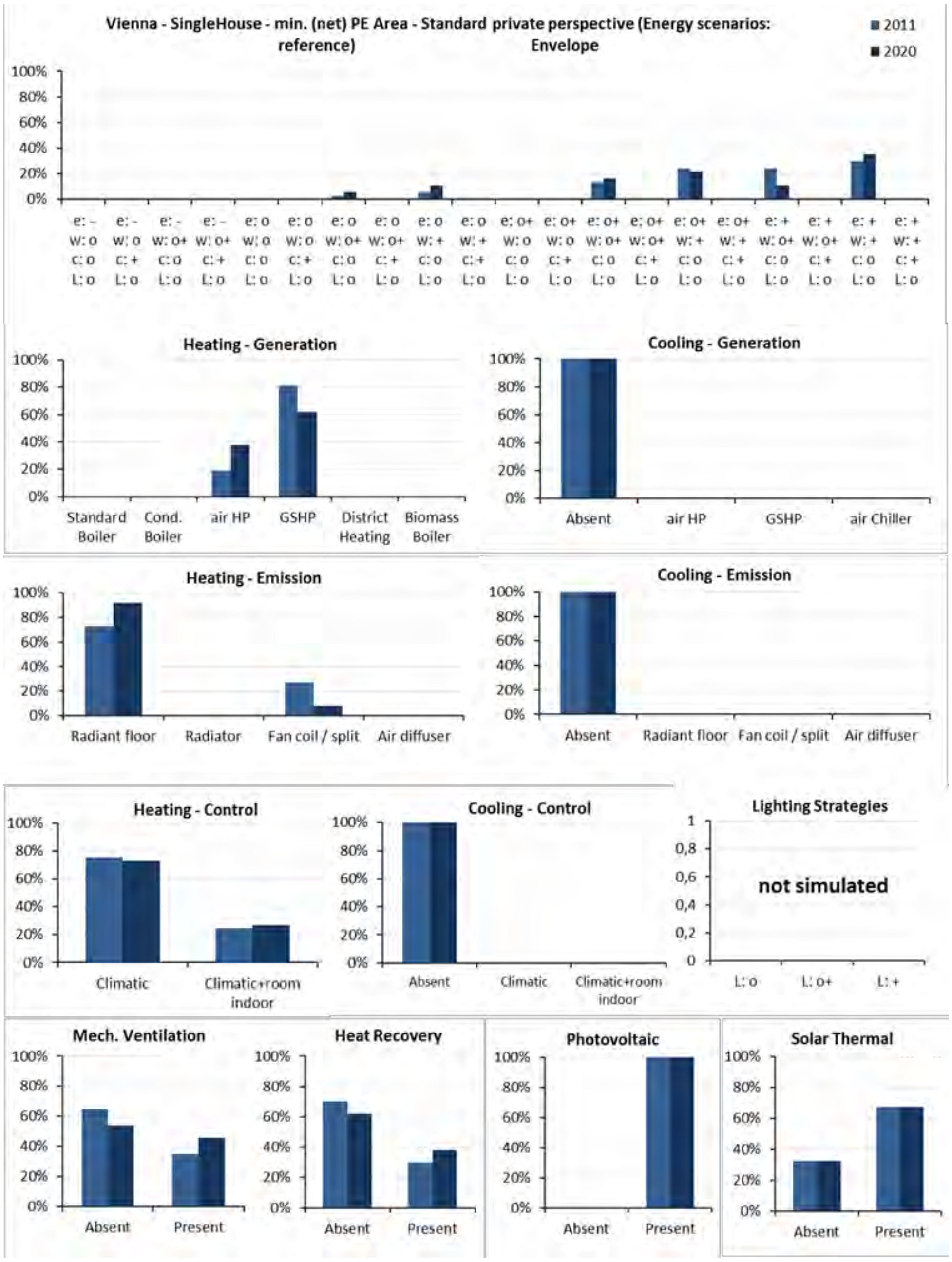

Figure 21. Example of % distribution of envelope and systems measures in the selected area (minimum net primary energy area for Single Family House in Vienna).

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In the economic analysis it is evident how energy costs are very relevant in buildings with low performance and how this component is reducible improving the energy performance of the building (reducing energy needs). Obviously, in most cases, **the initial investment** grows toward the nearly zero energy buildings. The governments could be help the owner to realize the renovation of buildings and overcome the difficulties of initial investment with specifics policies, incentives, subsides, tax deduction and so on.

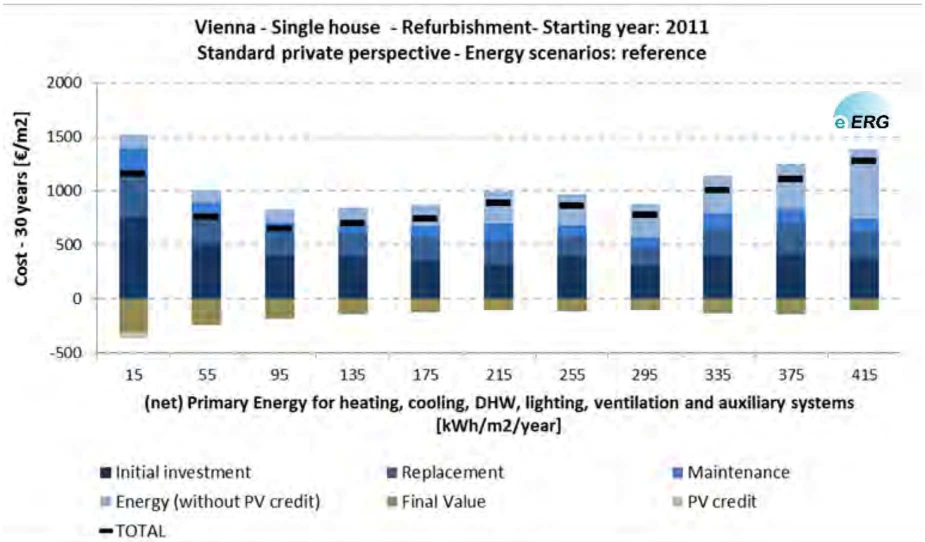

Figure 22. Example of disaggregation of building costs for several building variants positioned on the lower profile of the energy/cost domain.

The global cost calculation over a period of 30 years allows to demonstrate that buildings with a low energy needs for heating and cooling (EN on horizontal axis of Figure 23) and with a higher initial investment costs, in term of global cost, don't cost more than respect to the building with higher EN and less initial investments costs.

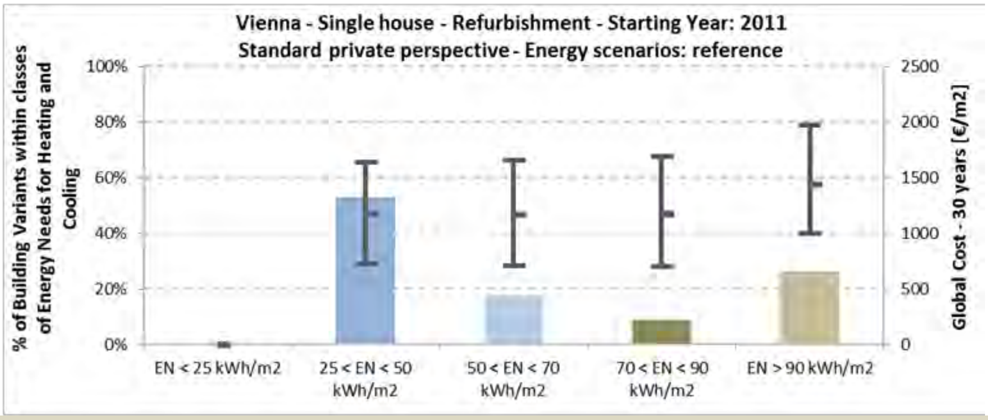

Figure 23. Example of % of building variants by different classes of energy needs for heating and cooling with indication of minimum/mean/maximum global cost

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4.4 Cost-optimality lesson learned

The quantitative results obtained in this study are obviously depending on the hypothesis made on the typologies of buildings (e.g. window-to-wall ratio, surface-volume ratio, etc.) and can hence result different under different boundary conditions. One should also consider that in a large scale study as the present one, which used quite conservative assumptions, certain assumptions cannot be as detailed as it would be possible in a national or regional study or in the design of a specific building. What is extremely important for a proper use of the results is that in this and other similar studies the assumptions, boundary conditions and methodology should be explicitly so that results can be compared and lessons learned from.

In general we can see the minimum (net) primary energy (*nZEB*) zone appears characterized by medium-high/high recurrences of efficient/RES technologies in all countries and for both the building destinations.

In general the minimum global cost zone is characterized by medium level of efficiency for the envelope strategies, probably due to a more equilibrate balance between initial investment costs and energy savings.

For the single family house it is quite evident that, also within the minimum global cost zone, the penetration of renewable energy technologies is more effective in Mediterranean climates (characterized by higher solar radiation) than the other target countries. Similar tendency is observed for office buildings, but with less differences between South and North Europe. This is due to a more relevant role played by photovoltaic systems in a building type characterized by higher electric consumptions for auxiliary systems and mechanical ventilation.

In the following Table 3, we can see that net primary energy saving percentages for cost-optimal and nZEB targets are more close in residential buildings than in office and school buildings. In residential sector, considered apartment building type shows lower energy saving potential respect to single house, due to geometric limits (e.g. lower available roof surface for solar systems respect total floor area respect single house).

In many cases, global cost of selected nZEB solutions (minimum net primary energy) are lower and more advantageous than global cost of corresponding base refurbishment levels (see orange bar and cells in Figure 24 and Figure 25). In general for the buildings selected both in cost optimal zone both in nZEB zone the initial investment cost are higher respect to base refurbishment level. This mean that the building with a minimum global cost (over a time laps of 30 years), in front of an higher initial investment the energy saving plays a fundamental role.

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Figure 24. Target buildings energy and costs variations respect to base refurbishment level (graphs and tables) - min. net primary energy (nZEB) selections

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Figure 25. Target buildings energy and costs variations respect to base refurbishment level (graphs and tables) - min. global cost (cost-optimal) selection

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Table 3. Saving potential in net primary energy demand respect to base refurbishment level

net primary energy demand

	Building type	Base refurbishment level	Minimum global cost Target (**)		Minimum net primary energy Target (**)	
Seville (ES)	single family house	156 kWh/(m^{2}y)	-84%	25 kWh/(m^{2}y)	-96%	7 kWh/(m^{2}y)
	apartaments block	127 kWh/(m^{2}y)	-72%	35 kWh/(m^{2}y)	-83%	22 kWh/(m^{2}y)
	office	225 kWh/(m^{2}y)	-36%	145 kWh/(m^{2}y)	-97%	6 kWh/(m^{2}y)
	school	189 kWh/(m^{2}y)	-56%	83 kWh/(m^{2}y)	-96%	8 kWh/(m^{2}y)
Madrid (ES)	single family house	236 kWh/(m2y)	-82%	43 kWh/(m2y)	-97%	7 kWh/(m2y)
	apartaments block	182 kWh/(m2y)	-73%	49 kWh/(m2y)	-84%	30 kWh/(m2y)
	office	298 kWh/(m2y)	-58%	124 kWh/(m2y)	-97%	9 kWh/(m2y)
	school	262 kWh/(m2y)	-69%	80 kWh/(m2y)	-97%	7 kWh/(m2y)
Rome (IT)	single family house	193 kWh/(m2y)	-79%	41 kWh/(m2y)	-97%	7 kWh/(m2y)
	apartaments block	157 kWh/(m2y)	-56%	69 kWh/(m2y)	-80%	31 kWh/(m2y)
	office	296 kWh/(m2y)	-49%	151 kWh/(m2y)	-94%	19 kWh/(m2y)
	school	357 kWh/(m2y)	-58%	149 kWh/(m2y)	-98%	8 kWh/(m2y)
Milan (IT)	single family house	346 kWh/(m2y)	-86%	50 kWh/(m2y)	-95%	19 kWh/(m2y)
	apartaments block	260 kWh/(m2y)	-62%	98 kWh/(m2y)	-85%	40 kWh/(m2y)
	office	400 kWh/(m2y)	-60%	162 kWh/(m2y)	-98%	9 kWh/(m2y)
	school	357 kWh/(m2y)	-51%	175 kWh/(m2y)	-98%	9 kWh/(m2y)
Bucharest (RO)	single family house	392 kWh/(m2y)	-62%	149 kWh/(m2y)	-91%	36 kWh/(m2y)
	apartaments block	307 kWh/(m2y)	-59%	125 kWh/(m2y)	-76%	73 kWh/(m2y)
	office	379 kWh/(m2y)	-48%	198 kWh/(m2y)	-92%	29 kWh/(m2y)
	school	381 kWh/(m2y)	-38%	237 kWh/(m2y)	-96%	15 kWh/(m2y)
Vienna (AT)	single family house	451 kWh/(m2y)	-79%	97 kWh/(m2y)	-94%	26 kWh/(m2y)
	apartaments block	344 kWh/(m2y)	-70%	103 kWh/(m2y)	-85%	52 kWh/(m2y)
	office	525 kWh/(m2y)	-86%	75 kWh/(m2y)	-98%	9 kWh/(m2y)
	school	540 kWh/(m2y)	-86%	77 kWh/(m2y)	-97%	14 kWh/(m2y)
Paris (FR)	single family house	363 kWh/(m2y)	-65%	126 kWh/(m2y)	-92%	29 kWh/(m2y)
	apartaments block	336 kWh/(m2y)	-71%	99 kWh/(m2y)	-84%	54 kWh/(m2y)
	office	493 kWh/(m2y)	-64%	180 kWh/(m2y)	-98%	9 kWh/(m2y)
	school	452 kWh/(m2y)	-51%	222 kWh/(m2y)	-98%	8 kWh/(m2y)
Prague (CZ)	single family house	519 kWh/(m2y)	-69%	159 kWh/(m2y)	-90%	53 kWh/(m2y)
	apartaments block	303 kWh/(m2y)	-46%	164 kWh/(m2y)	-68%	97 kWh/(m2y)
	office	615 kWh/(m2y)	-81%	118 kWh/(m2y)	-96%	24 kWh/(m2y)
	school	579 kWh/(m2y)	-81%	110 kWh/(m2y)	-98%	10 kWh/(m2y)
Berlin (DE)	single family house	348 kWh/(m2y)	-76%	85 kWh/(m2y)	-89%	39 kWh/(m2y)
	apartaments block	319 kWh/(m2y)	-49%	161 kWh/(m2y)	-79%	66 kWh/(m2y)
	office	442 kWh/(m2y)	-85%	68 kWh/(m2y)	-97%	12 kWh/(m2y)
	school	398 kWh/(m2y)	-88%	49 kWh/(m2y)	-96%	16 kWh/(m2y)
Helsinki (FI)	single family house	203 kWh/(m2y)	-62%	76 kWh/(m2y)	-69%	63 kWh/(m2y)
	apartaments block	195 kWh/(m2y)	+13%	219 kWh/(m2y)	-52%	94 kWh/(m2y)
	office	371 kWh/(m2y)	-71%	109 kWh/(m2y)	-91%	35 kWh/(m2y)
	school	339 kWh/(m2y)	-47%	179 kWh/(m2y)	-92%	26 kWh/(m2y)

(**) Percentage variation respect Base refurbishment level

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In addition the following features can be seen

- For many climates, cost/energy curves low frontiers are quite flat.
- Higher energy prices scenarios increase the minimum global cost range and lead to a lower value of net primary energy for cost optimal levels.
- Higher prices for CO_2 emissions and eventual costs related to environmental damages (taken into account by the macro-economical perspective) and other externalities could increase the minimum global cost range and lead to a lower value of net primary energy for cost optimal levels.
- About solar RES, photovoltaic systems are very frequent in minimum net primary energy area, while it's less frequent in minimum global cost area. The solar thermal systems don't seem to show so clearly this difference.
- Medium/low temperature emission systems for heating are present both in many variants of minimum net primary energy area both in minimum global cost area.
- In office buildings, efficient lighting strategies appear always as good intervention to reach the minimum net primary energy area.
- In some climate contexts, biomass and district heating systems appear with low frequency in benchmark areas. This could be associated to difficulties to define actual primary energy factor, initial costs for installation (due to different installation conditions) and energy prices (due to private negotiation).
- In benchmark areas generally heat recovery for ventilation appear with low frequency. It produces effective energy savings but with higher initial costs for ventilation systems installations (an example in Figure 26). In this studies, the penetration of mechanical ventilation with or without heat recovery, is compared with a good user behaviour of occupants, who open windows in proper way when air changes need, avoiding excessive openings. This helps to reach natural ventilation solutions in cost optimal and sometimes also in minimum net primary energy area. The trainer of occupants, in this way, could be a cost effective strategy to reduce the initial investment, annual, and energy costs in a renovation activity, without to reduce the indoor air quality.

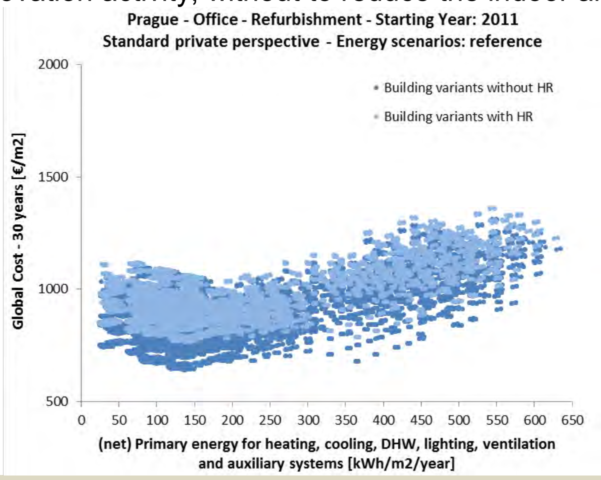

Figure 26. Sensitivity analysis on heat recovery in ventilation - office in Prague

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Applying the European common methodology for cost optimal calculation in a quite large amount of buildings and variants allowed to develop the following comments on the common methodology.

• Cost/energy curves and clouds show important information on net primary energy values and global costs, but can't show explicit information on **energy needs** for different energy end uses. For this further analysis, as some of presented ones, could be useful to study energy needs (for heating, cooling, domestic hot water, energy use for lighting, etc.) in detail.
• Cost optimal zone selection can be very wide in terms of net primary energy range.
• The fixed **±15% encouraged target**, by EPBD, for net primary energy respect the minimum global cost area, could lead to very low values for low net primary energy value (e.g. for total net primary energy < 20 kWh/m^2/y). For this field of low values, maybe a fixed threshold of increment/decrement in [kWh/m^2/y] could be defined.
• Global cost over calculation period is an important economic indicator to show the long term behaviour of a building. However not specialist people are used to consider **initial investment** costs and they don't have sensibility respect global cost values. So it could be important to give references for the obtain results. The indication of **base refurbishment level** could be an useful reference for a direct results evaluation.
• Great care has to be taken to produce **accurate and consistent cost data base** for the considered buildings. Considering building sector and buildings variability, determined costs for a not specific and detailed building project could be difficult and a kind of confidence interval should be determined for the results.
• Cost/energy clouds and curves are very useful to determine net primary energy values and cost optimal targets, also analysing the **sensitivity** respect the main calculation outputs (as energy prices scenarios, primary energy factors, eventual environmental damages cost, etc.).
• Further studies could be useful to consider with more detail also **costs related to environmental damages** and environmental externalities due to energy consumption and emissions. This could bring to very advantageous results for energy efficiency improvements and renewable energy systems development.
• Often, also in the methodology, the attention is focused on low frontier of cost energy curves. Of course this part of the graphs represents the most profitable solutions in terms of global cost. But in general also **higher dots in the graphs** could represent interesting solutions in terms of energy efficiency or environmental value, maybe consisting in technological actions to be advantageously supported with policy and financial solutions.

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5. Current state of policies and recent developments

With the recast of the EPBD in 2010 (Directive 2010/31 EU, EPBD recast) the EU Member States (MS) have to move to a 'new era' of constructing. This is because from end of 2020 onwards all new buildings should be nZEB all across the EU, while new public buildings have to be constructed at nZEB standards from the end of 2018 onwards. Therefore, the EU MS have to prepare and report to the EU Commission national plans to increase the number of nearly zero energy buildings (nZEB). The nZEB plans have to comprise detailed application in practice of the definition of nearly zero-energy buildings, a numerical indicator of primary energy use expressed in kWh/m^2/year and intermediate targets for the year 2015. In addition, these nZEB plans have to describe policies and support measures for the promotion of nZEB, including details of national requirements and measures concerning the use of renewable energy generated onsite or nearby, for both new and existing buildings undergoing major renovation (in the context of Art. 13(4) of the renewable energy directive (*Directive 2009/28/EC, RED*) and Art. 6 and 7 of 2010/31/EU).

The implementation of the Energy Efficiency Directive (*Directive 2012/27/EU, EED*) in the EU MS will be very important in the light of enhancing nZEB renovation within the EU. More precisely, Article 4 of EED asks the EU MS to further elaborate long-term plans to support deep renovation of the existing building stock. Therefore, these plans can play a major role in fostering nZEB renovation if they are designed and take into consideration measures tailored or aiming at nZEB levels. The Article 5 of EED is also relevant for boosting the nZEB renovation by providing the leader's example of the public sector which has to increase the renovation rate of buildings owned and occupied by central governments at 3%/yr.

5.1 Building codes requirements and RES-obligations

Incorporating energy-related requirements during the design or retrofit phase of a building is a key driver for implementing energy efficiency measures which in turn highlights the role of building energy codes in reducing CO_2 emissions and reaching the energy saving potential of buildings. Several Member States introduced from long time ago building code requirements (prescriptive-based[9]) associated with the thermal performance of buildings following the oil price increases in the 1970s while in some Scandinavian countries have been in place even since the mid-1940s.

[9] Prescriptive-based requirements= energy requirements are set for each building component (windows, walls, roofs) as well as heating, ventilation and air conditioning and lighting equipment

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Currently and following the implementation of the Energy Performance of Buildings Directives (EPBD) form 2002 and 2010, all the EU MS have now in place prescriptive minimum requirements for thermal performances of buildings components (i.e. walls, floors, roofs, windows), both for new buildings and in the case of major renovation of existing ones.

The EPBD (2002/91/EC) was the first major attempt requiring all EU MS to introduce a general framework for setting building energy code requirements based on a “whole building” approach (so called performance-based[10]). Although subsidiarity applies to implementation of the EPBD, Member States had been required to introduce a methodology at the national or regional level to calculate the energy performance of buildings based upon this framework and apply minimum requirements on the energy performance of new buildings and large existing buildings subject to major renovation.

Following the EPBD in 2002, performance-based requirements have gradually started to be introduced all over the EU MS and this has been regarded as a major change in the building code trends. Currently almost all the EU MS have in place energy performance requirements for new buildings and major renovation of the existing ones.

Nevertheless, there are different approaches and methodologies applied in the EU MS for setting energy performance requirements and no two countries have adopted the same. It is important not to attempt to compare the performance requirements across the EU, given the variety of calculation methods used to measure compliance and major differences in definitions (e.g. definitions of primary and final energy, heated floor area, carbon conversion factors, regulated energy and total energy requirement etc.). The setting of building code requirements with legally binding performance targets, is normally based on either an absolute (i.e. not to exceed) value, generally expressed in kWh/m^2a, or on a percentage improvement requirement based on a reference building of the same type, size, shape and orientation. Some countries (e.g. Belgium) express the performance requirement as having to meet a defined “E value” on a 0 to 100 scale, or on an A+ to G scale of the energy certificates (e.g. Italy and Cyprus).

There is a growing interest in having an EU harmonized methodology as a first attempt to have a comparative framework for the energy performance requirements within the EU MS. A first step in this direction has been made by the mandates given by the EU Commission to the European Standardization Committee for elaborating and further improve standardized approaches and methodologies into support of EPBD implementation. This is likely to become an increasingly important issue in the context of the EPBD recast Article 2.2 and Article 9 requirements associated with nearly Zero Energy Buildings (nZEB) and cost optimality (EPBD recast Article 5) since the European

[10] Performance-based requirements= energy requirements are set on a building’s overall (primary or final) energy consumption.

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Commission will need to demonstrate that all Member States deliver equivalent outcomes. A harmonised approach for setting and measuring nZEB targets and cost-optimality implies that a broadly equivalent methodology will be required.

With the recast of the EPBD from 2010 (2010/31/EU) a cost optimality methodology has been introduced. Member States had to set their energy performance and thermal requirements for buildings and components in accordance to cost optimal levels resulted by applying a harmonised methodology for cost-optimal calculation (i.e. according to Article 5 and annex III of EPBD recast and the EU Commission delegated regulation 244/2012). However, the impact of cost-optimal calculations undertaken at level of the EU MS seems to be limited or even zero in case of countries with a more consistent historical development of energy requirement in their building codes. On other hand, in countries with less experience in implementing energy related requirements for buildings, the cost-optimal calculations shows important deviations compared to actual regulations that have to be filled-in within the up-coming years. A more detailed overview of the situation in the EU MS covered by the ENTRANZE project is presented in the followings.

In addition, cost optimal levels should also harmonise with future nearly zero energy standards which would comprise a requirement for new buildings from 2020 onwards. According to EPBD and also to national rules from many EU MS, the minimum requirements for buildings and buildings components have to be cost-effective. Therefore also the nZEB levels should be cost-effective and at least cost-optimal to not conflicting to EPBD. However, the directive leaves flexibility on how to understand the difference between cost-optimality and nZEB-standard and EU MS may decide to have nZEB requirements for new buildings stricter than cost-optimal levels. Due to these foreseen changes, building codes are anticipated to be in a dynamic phase by the end of this decade and beyond.

The integration of renewable energy generation in buildings is additionally requested by Article 13 of the Renewable Energy Directive (2009/28/EU) which stipulates that by 2014 all EU MS should consider specific minimum requirements in their building codes. So far most of the EU MS implemented RES in the building regulations. Most of requirements address new buildings and mainly RES heating. In Cyprus and to a certain limit in Portugal, solar thermal installations are mandatory for all residential buildings while additional obligation for power generation from RES is for new buildings. In some EU MS, solar thermal is compulsory for buildings with floor area or district heat and water - consumption bigger than a certain threshold (e.g. Denmark, Belgium-Wallonia).

In Germany, one of the ENTRANZE target countries, the Renewable Heat Act (Erneuerbare-Energien-Wärmegesetz EEWärmeG) introduced the obligation of renewable heating and cooling use for all new buildings. The minimum shares are fixed according to technology. In the case of solar thermal the minimum share is 15%, 30% in the case

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of biogas, and 50% if bio-oils, solid biomass (e.g. wood pellets) or geothermal energy are used or a heat pump is installed.

In France, the actual RT2012 buildings regulations stimulate the use of renewable energy heating for new buildings offering a 'premium' primary energy conversion factor of 0.5.

In Austria, while there are no RES obligations at federal level, some regions implemented specific minimum requirements. Moreover, there are several support instruments for new buildings at both federal (Wohnbauförderung) and regional (Bundesländer) levels which have RES use as a precondition for receiving the financing.

In Spain, the Technical building code 2006 includes an obligation to consider a minimum RES share and in particular on solar thermal energy which, according to region and climate, should cover between 30% and 70% of the DHW needs.

Excursus: Experiences from the Brussels region with the ordinance on passive house standard

In 2007, implementing the first EPBD and following some major climate events (e.g. unusually high power of hurricane Katrina) Brussels-Capital Region government decided to strength the environmental and energy related policies. In order to transpose EU Directive 2002/91/EC into Belgian law, on June 7, 2007 the Brussels regional authorities passed the Energy Performance and Indoor Climate of Buildings Order (OPEB)[11].

Among other measures, the government specifically took actions on stimulating the enhancement of energy performance of buildings, by introducing measures to incentivise exemplary buildings, to increase the skills of professionals form the construction sector and to provide technical assistance to stakeholders.

Therefore the local market evolved and encouraged by the positive results the Brussels-Region government passed in 2010 an Ordinance imposing the passive house standard on all regional new public buildings and in 2010 an Ordinance announcing the new energy regulations for all new construction (housing, offices and schools) to enter into force in 2015[12].

[11] OPEB/Ordonnance relative à la performance énergétique et au climat intérieur des bâtiments http://www.ejustice.just.fgov.be/cgi_loi/change_lg.pl?language=fr&la=F&cn=2007060770&table_name=loi

[12] *Arrêté du Gouvernement de la Région de Bruxelles-Capitale du 5 mai 2011*

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The new regulation foresees that the new buildings in Brussels-Capital Region have to meet a passive house level and to fulfil several minimum requirements such as in the followings:

1. A net space heating requirement of less than 15/kWh/m2/yr
2. A net cooling requirement of less than 15/kWh/m2/yr (only for offices and schools)
3. An air tightness of 0,6 volume .h-1
4. An overheating over 26C time -limited to 5%
5. A primary energy consumption limited to:
   - 45 kWh/m2/yr for housing (heating, hot water, ventilation, pumps and fans);
   - (90 – (2,5 x compactiveness)) kWh/m2/yr for offices and schools.

While the market uptake had been organised from 2007, support measures become more vigorous around the new piece of legislation. Therefore, the Brussels Region has now in place a complex set of financial and technical advice/coaching actions with the aim to gradually prepare the market to naturally migrate to new buildings regulations by 2015 (EnEffect, 2013). The aim of the Brussels Region government is that by support measures in place to support the eco-construction on the market by enhancing qualifications of local contractors, by stimulating the market demand for very low-energy buildings and to reach a critical mass of demonstrative buildings, easily replicable later on at mass scale.

Therefore, the actual budget of Brussels Region for supporting households to implement energy savings measures is 10 times higher than in 2004, i.e. around 60 mn Euro/yr. This budget is secured by a tax of 0.04% applied to energy suppliers from the region and based on issued energy bills (which are at around 1.5 bn Euro/yr). This budget financed the Exemplary Buildings (Battiment Exemplaire) Programme offering a premiums to new buildings or renovation activities reaching a more ambitious standard, secure measures offering technical support and guidance to stakeholders and buildings owners in alliances with the private sector and supply awareness campaigns.

As a result, the number of new passive buildings constructed in Brusssels Capital Region increased year by year and in 2014 it is expected that half of the new construction will reach passive house standards[13]. As a result of these concerted policies, the costs for a passive house construction it decreased towards the actual costs for buildings meeting current standards[14].

[13] http://documentation.bruxellesenvironnement.be/documents/BXL_GreenCapital_2012_EN.PDF

[14] http://www.wsed.at/fileadmin/redakteure/WSED/2014/PPTs/09_Atanasiu.pdf

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In conclusion, Brussels-Capital Region approach is a very good practice on how to promote ambitious buildings nZEB regulations and how to additionally prepare the market to become ready to cope to these standards. The good practices of Brussels Capital Region is even more powerful while proves that a strong commitment at political level doubled by a set of well-balanced policies (comprising regulatory, financial, training and coaching, awareness and information measures) can transform the buildings practices and market of a region in only few years' time.

5.2 Nearly zero-energy buildings

According to Art 9 of recast EPBD, the EU MS had to draw up national plans for increasing the number of nearly Zero-Energy Buildings, with targets that may be differentiated according to different building categories. In order to prepare the first progress report as requested by the EPBD, the EU Commission asked the EU MSs in autumn 2012 to show the status of the nZEB implementation. By the end of 2012 only 9 MSs have sent a feedback and out of these only up to 5 MSs have been reported on the progress in defining national nZEB approaches and implementation plans. Up to date, i.e. September 2014, 18 EU MS out of EU-28 submitted their national nZEB definitions to the EU Commission[15.]

The MS chose very different approaches to report their national nZEB plans to the EU Commission and consequently these plans are not comparable. In most of the cases, the national reports present only intentions, not always with clear timelines, for elaborating the nZEB plan.

Recognising this large variety of nZEB national plans and trying to create a comparative framework, the EU Commission asked for a study on defining common nZEB principles under the EPBD (Hermelink et al., 2013). This study had been implemented in 2012/2013 and, as part of it, the information provided by the EU MS on the nZEB implementation has been consolidated on two common reporting templates[16]. One template is a questionnaire for reporting information on intermediate targets and policies in order to achieve the overall nZEB targets 31st December 2018 and 2020 respectively while the second reporting template is a table comprising a breakdown on each of the

[15] National nZEB plans submitted to the EU Commission are available here: http://ec.europa.eu/energy/efficiency/buildings/implementation_en.htm

[16] The consolidated nZEB reports are available at: http://ec.europa.eu/energy/efficiency/buildings/implementation_en.htm

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aspects related to the detailed national application of the nZEB definition under the EPBD.

NZEB action plans: Cost optimality and targets

Only around seven EU MS report a numerical indicator for future nZEB national definitions (i.e. in primary energy, in kWh/m^2/yr.), as it is requested by EPBD. The approaches in defining the nZEB targets (i.e. the interim target by 2015 and the 2020 target) vary largely among the national plans. Some EU MS define nZEB in terms of minimum energy performance requirements (e.g. Brussels Region-Belgium, Cyprus and Denmark), other MS decided to set requirements on basis of energy labels (e.g. Bulgaria, Lithuania, Czech Republic)[17]. In some cases the nZEB national definitions include additional minimum requirements for the renewable energy share (e.g. Bulgaria, France and Cyprus), while in few countries the nZEB target is defined as minimum requirement for carbon emissions of the building (e.g. the United Kingdom and Ireland, the latter having two indicators, one on carbon emissions and the other on energy consumption). Furthermore, in several national plans, the nZEB targets are based or compared to the cost-optimal levels as resulted from the implementation of Art 3 from recast EPBD[18].

The nine EU MS within the main focus of the ENTRANZE project[19] submitted by September 2014 both nZEB and cost-optimal reports to the EU Commission[20]. A brief description of the actual status on implementing cost-optimality and nZEB as well as in some of these countries the cost-optimal calculations didn't identify major gaps between existing regulations and cost-optimal levels (i.e. more than 15% as comparing to current requirements). For these countries, we can conclude that the cost-optimality criteria did not lead to a strengthening of building codes. However, strengthening of current buildings requirements to cost-optimal levels resulted to be necessary in Bulgaria, Romania (mostly for technical systems of the building), Italy and partially in Spain (i.e. for new buildings in coldest regions and for existing buildings in warmest climates). In France, the actual energy performance and thermal requirements for buildings and buildings components (i.e. RT2012 regulation) appeared to be slightly stricter than cost-optimal levels. Overall, out of the nine ENTRANZE target countries,

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[17] However, in fact this should be equivalent since the labels should also have some benchmarks for primary energy etc.

[18] The reports of the EU MS to the European Commission on implementing cost-optimal methodology at national levels are available at: http://ec.europa.eu/energy/efficiency/buildings/implementation_en.htm

[19] These nine target countries are Austria, Bulgaria, Czech Republic, Germany, Spain, Finland, France, Italy and Romania.

[20] Due to late delivery of one part of the Austrian nZEB national plan, it has not yet been available on the Website of the European Commission in September 2014.

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only France has a clearer commitment to the buildings regulations currently in force, (RT 2012) which is considered to be already very ambitious. In Germany, debates are around adopting the KfW efficiency house 40 - standard as an nZEB target by 2020, the main concern being about reaching the cost-effectiveness by the time. Similarly, in the other ENTRANZE countries the nZEB definitions and implementation plans are at varying stages of debate and not yet legally binding. Having in mind that at the EU level only few countries committed to an nZEB implementation plan, it will be not likely to have major changes in buildings regulations by 2015 when, according to recast EPBD, the nZEB interim target has to be defined and implemented. Therefore, the implementation of nZEB requirements in the EU seems to be lagging behind the schedule. Moreover, with the recast EPBD it has been anticipated a significant impact in EU buildings regulations by implementing nZEB, but so far seems that the cost-optimal calculations are mainly driving the buildings codes evolution by 2020. The initial debates around nZEB definitions has been always related to its cost effectiveness and how to potentially further influence the market for moving nZEB levels closer to cost-optimal values, which has been seen as lowest values for nZEB. Nowadays, by analysing the nZEB reports, it is almost clear that cost-optimal levels prevails and identified to nZEB values.

A summary of cost-optimal calculations and nZEB approaches in the EU MS within the ENTRANZE focus is provided in Table 4.

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Table 4. Status of cost-optimality results and nZEB implementation in the 9 ENTRANZE countries

Country	Actual requirements as comparing to cost optimal levels	Comments on cost-optimality (c-o)	Intended nZEB target for 2020	Current level of commitment to nZEB target
AT	No major gaps (c-o calculation done so far only for residential)	Actual energy performance requirements close to c-o levels	nZEB target in line to c-o levels in 2020	Not transposed legally
BG	Identified gaps	Gaps to be bridged by strengthening actual requirements	Energy class A, 50%-20% RES share, 30%-40% electricity share (bdgs≥500m^2)	Not transposed legally
CZ	No major gaps	Actual energy performance requirements close to c-o levels	Heat transfer coef. to be 30% less than now, RES share	Not transposed legally
DE	No major gaps	In 2016: potential strengthening by 25% in primary energy and 20% heat loss requirements	Under cost-effectiveness consideration	Not yet defined, under debate EB40 (KfW)
FI	No major gaps	-	Coming in 2015	Not transposed legally
FR	No major gaps	Actual regulations (RT2012) stricter than c-o	RT2012 (very strict, also imposing RES share)	Commitment to RT 2012
IT	Identified gaps	Actual regulations to become stricter for energy performance and technical equipment	nZEB 2020 should be stricter than actual requirements	To be further evaluated and detailed
RO	Identified gaps	Gaps to be bridged by strengthening actual requirements	In line with c-o by 2020, much stricter than today	Not transposed legally
ES	Partial gaps	Major gaps for residential for new buildings in cold regions and for existing buildings in warm regions	nZEB target in line to c-o levels in 2020	To be further evaluated and detailed

NZEB action plans: policies and measures

Around 12 EU MS include in their national nZEB plans measures to support the renovation of the existing building stock (e.g. Brussels Region-Belgium, Bulgaria, Germany, Denmark, Finland, France, Ireland, Lithuania, The Netherlands, Sweden and the UK).

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These measures vary from one country to another and include one or more of regulatory, economic (and financial), EPCs, information and advice, educational and training or demonstrative measures. The measures mainly focus on refurbishment activities in general, and not especially on reaching the nZEB level.

The most often listed and partly explained measures in the existing plans are economic instruments for existing buildings, and information, motivation and advice-measures. There are some interesting approaches for funding programmes, with preferential loans being the most frequent economical instruments. Some Member States offer preferential loans depending on the family income or for low-income families only. In Germany the preferential loans will only be granted for ambitious energy standards which usually exceed cost-effectiveness. The "Green Deal"[21] in the United Kingdom only funds cost-effective refurbishment measures which have to be paid back by the occupier as part of the fuel bill. So far tax incentives and third party financing are rather rare instruments. There is a quiet big variety of information, motivation, and advice-measures, too. They reach from the implementation of energy accounting and management tools, energy audits, to the development of an energy monitoring and reporting system to facilitate public bodies.

Regulatory instruments for new and existing buildings are also named very often. They mainly target on the tightening of the requirements for the refurbishment of existing buildings in technical and building standards, and on the building standards for new buildings. The Netherlands introduce some interesting new instruments, such as the Rental House Assessment System, which makes the maximum rental price for a house or flat dependent on the energetic standard reached. They also implemented a number of voluntary agreements; unfortunately the impact of these agreements is not described in the national nZEB plan. Instruments aiming at demonstration, capacity building, and supply side measures such as research and development have been implemented by half of the Member States with a national nZEB plan. The support of the construction of pilot buildings to demonstrate the technical and economic feasibility is an often used instrument, too.

The instruments and measures listed in the national plans mainly don't focus on nZEB, but on energy efficiency in the building sector in general. The majority of these measures will be reasonable steps towards more nZEB in the future. However, in most evaluated countries the named measures by far will not be sufficient to increase the number of nZEB significantly. Some instruments even might create lock-in effects that hamper the transformation of buildings toward nZEB. This might be true for funding energy efficiency refurbishment of buildings without combining the funding with a re-

[21] In detail the conditions for Green Deal–funding are not very good (e.g. very high interest rate of 7%), and only few loans had been committed so far this year.

quirement to meet certain high energy standards, and is dependent on the ambition of the nZEB-definition[22].

Altogether the analysis of the available national plans showed that there is still a long way to go to provide a suitable framework to increase the number of nZEB in the EU Member States. Only three MS reported measures and activities suitable to increase the energy performance of buildings towards the nZEB standard (Belgium, The Netherlands, and Germany). Generally it must be said that the information about instruments and measures are not detailed enough to be sufficient for a solid evaluation in most cases. That's why it was not possible to make general statements of the political approach of nZEB on a Europe wide scale. However, it can be stated that the described mix of instruments will be not sufficient to increase of the number of nZEB in the European building stock significantly, not to forget that ten EU MS didn't yet deliver a national plan and moreover, the already submitted plans don't really show a clear commitment, nor provide sufficient detailed description as indicated by recast EPBD. It also is of significant importance to provide a reporting template for future reports to improve the quality of the national plans, and to enable evaluating and cross-analysing. The first step towards a template has already been made with the above mentioned Ecofys-study (Hermelink et al., 2013). Unfortunately, the template developed in course of the mentioned study was too late for the reporting at this stage.

5.3 Policy approach

Additionally to the overview of the current state and the recent development of existing policies addressing the energetic refurbishment of buildings within the ENTRANZE project there has been developed an overview and analyses of new and innovative policies towards nZEB (Bürger, 2013). The resulting "policy toolbox" served as one basis for the discussion of possible policies and instruments within the national policy groups. This policy toolbox provides a long list of different instrument options all of which targeting modernisation measures in the building sector and addressing the multiple and often target-group specific barriers in the built environment.

There have been instruments covered that either target insulation measures at the building envelope (e.g. insulation of the outer walls or the roof, replacement of the windows, installation of insulated window frames) or aim at increasing the efficiency or reducing the carbon-intensity of the active heating and cooling systems in a building. A focus was put on instruments that aim at triggering ambitious refurbishment measures

[22] Instruments and nZEB definitions might be sufficient regarding low ambition targets, however not with long term targets.

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in the building stock (deep renovation) thus converging to the nearly zero energy standard as introduced by the EPBD recast.

Implementing one of these instruments in one of the target countries would require an adaption of the detailed instrument design to the specific national context of that country. The detailed “fine-tuning” and region-specific adaptation has to take into account several factors such as the market maturity of different technologies, the stimulation and assurance of ambitious technological standards and the potentially limited availability of specific resources (e.g. renewable energy sources) for heating and cooling purposes.

With regard to the important role of the building sector for achieving ambitious climate targets it is necessary to elaborate clearly defined long-term plans/strategies setting final goals and interim milestones to be reached by subsequent policies. Here especially the long reinvestment cycles in the building sector need to be taken into account when designing instruments addressing the refurbishment of buildings: Energy standards should be set to comply with the long-term targets and policies should be that ambitious as to stimulate a sufficient number of refurbishment projects.

The following tables lists the instruments described more detailed in Bürger 2013 and describes key characteristics and examples.

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Table 5. Types of instruments and their main characteristic

Instrument type		Main characteristic	Examples
Regulatory instruments		Command and control type regulations, works with orders and/or bans	– Building codes – Refurbishment obligations – RES-H obligations
Economic instruments	Grants and prefential loans	Different ways of financing the programs	– Financed through state budget – Financed through state-like budget – Financed through surcharge on energy or climate taxes – Financed through levy on buildings
Economic instruments	Tax incentives	Positive or negative incentives (add. fiscal burden)	– Tax incentives for investors o Tax deductions o Tax credits o Reduced VAT – Property tax (bonus/ malus) – Property purchase tax (bo-nus/malus)
Economic instruments	Energy tariffs	Tariff structure that is incentivis-ing the reduction of energy consumption	– Progressive energy tariffs
Economic instruments	Instruments strengthen-ing support and financing activities within the mar-ket	Financial support or finance pro-vided by market actors -> state budget independent sup-port	– Energy saving obligation – Quota system for RES-H – Bonus/Premium scheme – Contracting type of instruments – Bank obligation to grant interest reduced loans
Capacity building, qualifica-tion and quality assurance		Assure quality -> keep confi-dence high; targets at sufficient number of skilled manpower along whole value chain	– Professional training/ Vocational education – Branded quality standards – Qualified building specific refur-bishment plans
Information, motivation, ad-vice		Motivate home owners to invest in modernisation measures; allow home owners to do in-formed decisions	– Energy performance certificates – Combining financial support with mandatory advice – Competence centres for energetic building refurbishment
Market transformation (sup-ply side) measures		Shape the market for new tech-nologies by “working” with the supply side	– R&D support – Technology procurement – Premiums for providers of efficient technologies – Organising competitions or tenders between technology providers – Creating networks – Labelling, testing and certification
Target-group specific ap-proaches	Owner associations	Targets the heterogeneous barriers in multi-family houses	- Mandatory renovation funds – Governmental debt guarantees – Professional housing compa-nies/property managers
Target-group specific ap-proaches	Rental homes	Split incentive problem	– Toleration rules – Cost allocation rules – Rent reduction claims
Target-group specific ap-proaches	Low-income owners	Financing barrier	– Public debt guarantees – Grants for low income owners
Target-group specific ap-proaches	Public buildings	Exemplary role, poor state of public finance	– Committed renovation rate – Development of refurbishment strategies

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The group of economic instruments aims at incentivising the investment in efficiency measures or a changed (more energy efficient) user behaviour. For all economic approaches two elements need to be distinguished, the (i) revenue perspective and the (ii) support (expenditure) perspective:

i. The revenue perspective mainly addresses the question how the financing of the support scheme is organised; in other words who finally is providing the financial resources that are required for the economic incentives given to those who are supposed to invest in refurbishment measures.
ii. The support perspective deals with the question how the support is organised; here especially the specific support conditions and support eligibility are key design parameters.

Most instruments combine both elements which means that financial incentives are offered to investors to take efficiency measures while support is financed through the state-budget or other non-fiscal means (such as levies, surcharges on the energy prices etc.). Resulting from the two perspectives two different steering mechanisms need to be distinguished. One effect is directly linked to the support side: By providing an attractive support framework building owners should be incentivised to take appropriate efficiency measures. The other steering effect is resulting from how the financing of the support side is organised. For several instrument options the financial burden is either borne by the building owners or by the residents. This additional financial burden is corresponding to an incentive to lower this burden while the level of impact is depending on the elasticity how the different actor groups will react on such price signals.

Since several barriers inhibit the energy saving potentials in the building sector at the same time, a single instrument will not be enough to stimulate modernisation measures to the necessary extent. In addition, barriers can be rather target-group specific. In general it is difficult to design an isolated instrument that addresses several barriers simultaneously. In fact a bundle of instruments is required to properly address the most relevant barriers at the same time, which would be necessary to intensify investments in modernisation measure. In other words, target specific barrier bundles call for target specific instrument bundles (policy packages).

For the combination of different instruments into a policy package the following considerations should be taken into account:

- Instruments should be designed as to address the main barriers that hamper investments in the efficiency of buildings. In addition the policy package should include elements that target the needs of the major target groups. The instruments in the policy package should reflect the market maturity of the different technologies within the considered region.
- If a certain barrier (e.g. a financial barrier) is addressed by two or more instruments at the same time, this should be adequately justified (e.g. by the fact, that

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the instruments offer different accesses to financial support which might aim at different target groups). It should be avoided that instruments are simply redundant (which might only lead to higher administrative costs).

- In general administrative costs of a policy package should be kept as low as possible. This includes the transaction costs for the state but also all other system participants. For that reason it should be assessed to which extent synergies could be exploited when administering several instruments at the same time.
- In order to increase public acceptance from the communicative perspective the policy package should be kept as simple as possible. The main elements of a package should be easy to communicate.

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6. Policy approach and interaction with policy makers

All throughout the project there was constant communication with key stakeholders and target groups in order to refine our data collection and ensure a quality check of our findings. Communicating with national stakeholders also supported efforts to identify the market status of different efficient and renewable energy technologies, and to update the ongoing policies and options to assist the implementation of nZEB policies and programmes as well as deep renovation of the building stock towards nZEB levels. These were the main arguments in choosing to develop a strong and continuous collaboration with national experts and policy makers in selected countries both to understand the actual framework and to define together pathways to further improve the nZEB policies.

Therefore, seminars and bilateral meetings have been organised at recurrent intervals in order to substantially contribute to the process of refining and adapting the proposed nZEB scenarios and modelling results. These periodical consultations with stakeholders ensured both the policy feasibility of the project results and stimulated the interest of decision makers to assume and implement these results into the policy elaboration process. The feedback of national stakeholders was considered as valuable input to the final recommendations. This process led to the integration of ENTRANZE scenarios into the national policy debate and to an overall agreement among decision makers on the next steps to take.

Each partner nurtured existing contacts and developed new ones with stakeholders in their countries. Several meetings with policy makers and experts were foreseen along the implementation stages of the project, aiming to better identify the real needs for further developing nZEB policies, strategies and roadmaps and having a particular focus on the public and residential sectors. Therefore, each partner organised a complex communication process comprising of meetings with policy makers and experts as well as wider consultation through the organisation of national workshops. In brief, for each target country of the project the following events took place:

- four policy group meetings, one at each stage of project's implementation, including a final meeting to discuss the policy recommendations;
- three expert consultations, one at each stage of the project, i.e. for data collection and policy identification processes, to define policy sets to be assessed and analyse the main findings of the project;
- mid-term and final dissemination workshops, addressing a wider audience and trying to find consensus between policy makers and stakeholders relating to policy pathways assumed in ENTRANZE;
- several bilateral meetings when the need occurred.

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The outcomes of this consultation process triggered high interest around the project, increased its visibility and made the results more relevant for both policy makers and stakeholders.

For the ENTRANZE target countries the policy process is described in more detail in the following chapters.

6.1 Austria

In Austria, the responsibility for building related issues including building codes and support of small scale RES-H is in the responsibility of the nine regions. On the national level, two ministries are involved in the nZEB policy topic: The ministry of science, research and economy regarding energy and buildings and the ministry of agriculture, forestry, environment and water management regarding climate mitigation targets and environmental policies. Thus, it was important for the success of the Austrian policy process in the project ENTRANZE to involve the energy commissioners from three regions (Upper Austria, Styria and Vorarlberg) as well as the two federal ministries. The highly constructive, efficient discussion in the four meetings was characterized by the strong will to develop new, innovative ideas for effective policy instruments to increase the amount and quality of renovation activities. Since the persons in the policy group were well known with each other already before, the policy group meetings provided a stimulating atmosphere to exchange experiences and information and develop new, creative approaches. The policy group members found an agreement to investigate a new, innovative policy approach in the modeling work of ENTRANZE: an ambitious bundle of measures, built on intensified coaching, innovative financing models and a progressive real estate taxation based on the energy efficiency of the buildings. The policy group members expressed that projects like ENTRANZE are highly relevant since they develop and analyse solutions and policy elements which can be put into practice as soon as the political situation opens a window of opportunity.

6.2 Bulgaria

The nZEB policy process in Bulgaria is still in the beginning of its development and improvement. There are two main ministries that are responsible for this – the Ministry of Economy and Energy and the Ministry of Regional Development. It is fact that during the duration of the project ENTRANZE this state administrations have undergone several structural changes and the main responsibility for developing nZEB policies has been transferred between them and among different departments in them. The communication with the ministries was very slow and sometimes very hard, e.g. due to bureaucracy. The first invitations to cooperate in the project were kindly declined and it took time to involve the relevant representatives in the process of the implementation of the project.

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The members of our policy group, the representatives of the above mentioned ministries, also changed during the project running time. However, all of them were convinced that this political process is of great importance for the future of our country as an EU Member State. They agreed and promised to take into consideration all conclusions and aspects that our project reached. On the final conference of the ENTRANZE project the representatives of the Ministry of Regional Development also stated their willingness to continue the cooperation. However, at the moment the political situation in Bulgaria is very unstable as we again have preliminary elections for parliament and after 05.10.2014 the political picture of the country will be different. We hope that the above mentioned ministries will continue the same line of developing nZEB policies and in this way they will keep the positions reached by their predecessors. Hopefully the good collaboration with the ministries can be continued in the future.

6.3 Czech Republic

The energy policy, energy efficiency targets fulfilment and partly also building sector is under responsibility of the Ministry of Industry and Trade. The ministry was considered as the most relevant partner in development of energy policies and scenarios. However, there were involved many different stakeholders within the project duration.

Following types of stakeholders were involved in data collection, verification of collected data and development of the national policies and scenarios:

The first group was created by the relevant professional bodies, such as unions and professional chambers. They were involved especially in data collection and data verification. These policy group members attended the 1st and 2nd policy group meeting and increased our database for new important data sources.

The second group of stakeholders consist of the governmental institutions, relevant ministries, energy efficiency funds and NGOs involved in policy making process. They were involved especially in the second phase of the project when the policies and scenarios were developed.

The project ENTRANZE cooperated also with the Build Up Skills project. Build Up Skills project focuses on "blue collars" education, skills and quality improvement to implement properly nZEB in the country. Some outputs and also the project participants of the Build Up Skills project were helpful for the ENTRANZE project via sharing of personal experience and data collection.

Results of the final workshop could be considered as the highlight among the project meetings and workshops. The national workshop was organized as closed for public; however three ministries, three supporting programmes, the Czech chamber of Civil Engineers, two lobbyists and the biggest Czech energy supplier participated at the workshop (25 participants - all invited came). The end of the workshop was postponed from 12:30 to 15:00, because there was opened a crucial discussion on future energy efficiency programmes starting in 2015. Conclusions of the workshop should increase quality of the energy savings evidence across the supporting schemes in the Czech Republic to fulfill EED requirements.

6.4 France

In France in total, 16 members participated to the policy group. Most of them participated to all meetings, implying continuity in the discussions. Members came from ADEME[23], the French Energy and Environment Agency, the Ministry in charge of Energy[24] and the Ministry of Housing[25]. ADEME experts were specialised both in energy efficiency and building policy design and evaluation.

First of all, each policy group meeting was the occasion to inform regularly the participants about the recent developments, results and publications of Entranze. The second part of the meeting aimed at defining policy sets for France and to benchmark with the other target country policy sets. It was also an opportunity for ADEME and Ministries representatives to discuss about current building policy implementation in France.

[23] http://www2.ademe.fr/servlet/getDoc?id=38480&m=3&cid=96
[24] Ministry of Ecology, Sustainable Development and Energy (http://www.developpement-durable.gouv.fr/).
[25] http://www.territoires.gouv.fr/

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6.5 Finland

The Finnish policy group members held a meeting five times during the project. Almost all members were present at each meeting. The policy group members came from the environmental administration in Finland such as the Ministry of Environment: Juha-Pekka Maijala, Erkki Laitinen and Harri Hakaste, and the Finnish Environment Institute Pasi Tainio and Maija Mattinen; from the universities such as the University of Tampere, Juhani Heljo and Aalto University in Helsinki, Kai Siren; from RAKLI,the Finnish Association of Building Owners and Construction Clients Erkki Aalto and Petri Pylsy from the Finnish Real Estate Federation. The policy group was very interested in the project and the members shared the view that it was very good that Finland took part in the project. One of the policy group members has executed similar research focused in the Finland situation, which gave good comparison for the results of the ENTRANZE project.

6.6 Germany

The policy process in Germany was part of a very vital national discussion process about how to reach the emission targets of the building sector. Members of the policy group formed in the beginning of the project have been representatives of the Ministry of Building and the Ministry of Finance, additionally representatives of the Federal Office of Energy Efficiency, the Federal Development Bank KfW, the WWF and the Climate Policy Initiative as NGO representatives. The first policy group meeting was not carried out as a physical meeting of the whole group, but instead as in depth communication with the individual members of the policy group. Within the second meeting, held in Berlin, the policy packages were defined.

However, during the running time of the project there have been some major changes in the responsibilities within the ministries. Following the federal elections in fall 2013 the political topics within the ministries have been rearranged and the responsibility for energy use by the building sector is now shared between the Ministry of Economics and Energy and the Ministry of Environment. For this reason some of the members of the policy group have changed after 1.5 years of project lifetime. For several months the distribution of responsibilities within the ministries has been completely unclear. Following this relatively long period of uncertainty and stagnation there is now a very active phase with several projects addressing energy efficiency in the building sector going on.

The third policy group meeting took place in Berlin in July 2014 with some new policy group members, e.g. from the Ministry of Environment. During this meeting the results of the scenario calculations have been discussed.

Within the ongoing discussion process between different ministries and researchers of different consultancy institutes, including the two German ENTRANZE consortium

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members, there are meetings every two to three weeks. In these meetings policies, instruments and measures suitable to reach the energy efficiency target for the building sector are discussed deeply. Within this ongoing intensive discussion process also recommendations for the increase of the number of nZEB are discussed. The national partners were able to feed the results of ENTRANZE into this process, leading to a large impact.

6.7 Italy

In Italy, during several expert consultations and meetings, the policy process and the diffusion of Entranze results was carried out involving people which represent and they are part of different institutions. Today, in Italy, the regions can legislate on field of energy efficiency of buildings. Particularly, by several years, *Regione Lombardia*, which is involved in the Entranze process, is leader at the national level for what concerns the introduction of regulations with the aim to improve the energy efficiency of building and relative calculation methods for energy performance. *Regione Lombardia* is a reference for the other Italian Regions. The Ministry of Economic Development (*Ministero dello Sviluppo Economico*) is working to define the new legislative decree to give final adoption of the European Directive 2010/31/UE. The Ministry of Economic Development charged CTI (Comitato Termotecnico Italiano), ENEA (the national energy agency), RSE (the national organization in charge for research on the electrical system) for writing the national report about the application of comparative methodologies in order to evaluate the cost optimal level and the comparison with the national regulation. For these reasons the bilateral discussions done during the policy group meetings and expert consultations involved these organizations which are working on definitions of new law about energy efficiency of building and penetration of nZEBs in the new and renovated buildings sector. In parallel, consultations were conducted with associations representative of main players of the construction sectors, as important real estate companies or the national associations of thermal insulations companies. This strategy allowed to obtain ideas and comments from institutions with different points of view putting in contact, by bilateral discussions, different stakeholders as policy makers (at local and national level), research and consulting organizations, real estate company). A relevant opportunity to communicate and discuss the Entranze results was also an official report produced by eERG research group for ENEA about the cost optimal and nZEB renovation on the basis of ENTRANZE project results and methodology. The report was delivered directly to one of the responsible for the policy process held by the Ministry. The report in Italian will also be published and it will publicly available on the ENEA web site.

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6.8 Romania

In Romania, ENTRANZE activities stimulated a very high interest, policy makers and stakeholders contributing enthusiastically to all consultation processes by participating to lively debates and providing useful inputs during all project stages.

BPIE was the project partner that covered Romania activities within ENTRANZE, having an already ongoing country initiative. This programme was founded in 2010 to precisely support the development of buildings policies in the country.

The “on the ground” approach developed through the project was crucial for a successful and fruitful cooperation with local experts and policy makers, leading to tailor-made policy analysis and recommendations. Therefore, it is fair to say that all ENTRANZE results in Romania are co-branded by all national collaborators that actively participated to our consultation process.

In brief, the methodological approach in Romania was based upon some key guidelines:

1. Initial discussions on existing and planned policies and programmes aimed at enhancing the energy performance of buildings, trying to identify main concerns and challenges in the particular context of the country.
2. A consistent consultation to collect data on the building stock, costs and dynamics of the construction and renovation sector, involved local experts, industry associations and representatives of relevant ministries and cities’ administration.
3. Constant attention was given to directly address the local needs in terms of policies. Thus, the activities undertaken in Romania were tailor-made to fit the lack of information on buildings data and policy gaps relating to the energy performance of buildings.
4. Anticipating and building on the most stringent needs for policy development to implement the nZEB and cost-optimality requirements from EPBD, developing long term renovation plans (EED) and using ERDF funds to increase the energy performance of the existing building stock through deep renovation.
5. Taking into account the national legislation processes so that we have a timely input.

As a result, strong relations were built with both the Ministry of Regional Development and Public Administration and stakeholders such as representatives from energy auditors associations, construction companies, home owners associations, municipalities, NGOs, industry and so forth. Representatives from these groups participated to project’s workshops organised in Bucharest and were also available for bilateral meetings. The conclusions of these fruitful debates were integrated in the policy scenarios definition and modelling. Communication channels were always open between BPIE and

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Romanian stakeholders and we foresee that they will remain as such even after the project completion.

Moreover, the diversity of the stakeholders involved in this process provided a complete picture of the policy expectations. It was also interesting to see that in spite of this diversity when experts and policy makers came together they were open to each other's input and always found common ground. In the end, there were no strong differences of opinion. These events created a real debating platform on the EU buildings policies, contributing in this way to a better understanding of them and their importance for the country.

The success of the ENTRANZE workshops organised in Romania was also made possible due to a careful preparation of the agenda, having always guest speakers from the EU Commission, DG ENERGY, and from Poland, Czech Republic and France who shared good practices in implementing buildings policies in their countries.

The impact of ENTRANZE can also be measured by the fact that policy sets and scenario defined within the project and their modelling results became part of the new renovation strategy that the Romanian Government reported to the European Commission[26] under Article 4 of the EED.

All in one, Romania is one of the success stories within the project and can be considered as a good practice to develop strategies and policy evaluations in close cooperation with policy makers and stakeholders.

[26] Strategy to mobilise investment in the renovation of residential and non-residential existing building stock, Ministry of Regional Development and Public Administration, 2014, http://ec.europa.eu/energy/efficiency/eed/doc/article4/2014_article4_ro_romania.pdf

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6.9 Spain

In Spain, the responsibility for building related issues including building codes and mandatory requirement of RES-H is in the responsibility of Central Government, which enforces to the 17 Spanish's autonomous regions to meet the mandatory requirements.

Two ministries are involved in the nZEB policy topic: Ministry of Public Works and Ministry of Industry, Energy and Tourism. Hence, in Spain, four policy group meetings have been taken place in Madrid with representatives of Directorate-General of Architecture and Housing and Land (Ministry of Public Works[27]), Ministry of Industry, Energy and Tourism[28] and IDAE[29] (Institute for Energy Diversification and Savings) in order to discuss about the policy process to enforce the transition to nZEB of existing buildings. In total, 7 members participated to the Spanish policy group and most of them attended to all meetings.

The meetings were held in June 2012, July 2013, March 2014 and September 2014. They have allowed the definition and revision of policy sets in order to provide national policy scenarios. At the same time, the discussion with the policy makers about each particular instrument involved, has allowed the trend identification about the policy process in Spain in order to take feasible instruments into account.

In particular, policy makers showed their interest in having results from WP3 during the 2nd policy group meeting, since they had submitted to the Commission the first cost-effective analysis from Spain and they would like to discuss and share some information. They also agreed that projects like ENTRANZE are high helpful for the Spanish administration, since they develop and analyse solutions which could be implemented in the near future.

[27] http://www.fomento.gob.es/mfom/lang_castellano/

[28] http://www.minetur.gob.es/es-ES/Paginas/index.aspx

[29] http://www.idae.es/

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7. Policy scenario development

What is the potential future impact of different policy packages on energy demand, CO2-emissions, RES-H share, renovation activities in the building stock? What are the key, fundamental differences between the impact of various policy packages and what are the conclusions for effective and efficient policy making?

These questions were our basic motivation for developing policy scenarios in target countries and EU-28. For this purpose, we apply the model Invert/EE-Lab with a soft link to the model POLES.

The scenario development was closely linked to the policy process and the other results and analyses in the project ENTRANZE.

- The policies to be modelled were selected by the policy groups established in each target country.
- The results of the scenarios were discussed in the policy groups and with other national experts in each target country. The outcome of this discussion process was used to revise the policy and modelling assumptions in an iterative process leading to revised and well based, broadly accepted scenario results.
- The building stock data builds on the data collected in the project ENTRANZE and presented in the online data tool and the national reports on the building sector and energy demand in target countries[30].
- The results of the stakeholder analysis, related barriers and decision criteria of building owners (Heiskanen and Matschoss, 2012; Heiskanen et al., 2013) were taken into account in the techno-socio-economic modelling of decision making regarding building renovation and heating system investment (Steinbach, 2013a).
- The cost data collected in (Fernandez-Boneta, 2013) form the basis of the economic part of the scenario development.
- From the results of the cost-optimality calculations (Pietrobon et al., 2013 and Fernandez-Boneta, 2014) we derived three levels of renovation packages: light renovation (standard, typical case of thermal renovation), medium (cost-optimal standard) and deep (more ambitious energy performance than cost-optimal level, which could correspond to nZEB renovation). (Kranzl et al., 2014b; Kranzl et al., 2014a)

The results of the policy scenarios are accessible via an online-scenario tool, allowing to display aggregate figures as well as detailed results. The report Kranzl et al., (2014b) presents key results for all target countries, comparative views between coun-

[30] http://www.entranze.eu/pub/pub-data

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tries and scenarios as well as results for EU-28. Moreover, for each target country there is a report available presenting the policy scenarios and key recommendations on country level[31].

The **objective of the scenario development** is not a prediction of future energy demand in the building stock, and neither a maximum nor a realisable potential for improving the energy performance. Rather, the objective of the scenario development is to **show the potential future impact of policies** which are the result of an in-depth discussion process with policy makers. Thus, the policies should help to derive policy recommendations supporting policy decisions.

7.1 Policies selected for model based analysis

Based on the discussion process with policy makers, experts and stakeholders, three policy sets were selected in each target country. As described in chapter 6, the rationale and background for the selection of these policy sets was very different in each country. In some countries the policy makers and stakeholders supported a contextual approach in defining the policy sets, i.e. to coagulate holistic policy packages including all regulatory financial, information and support measures and aiming to further significant improvements of the current policy framework. In other countries where buildings policies are well established in time, the interest was higher for testing adjustments to existing policies or the impact of a specific new policy instrument rather than a very comprehensive policy package. Furthermore, in defining the policy sets for each country the project team imposed a set of three general criteria such as in the followings:

- To be realistic and adapted to the local context
- To address in a fair way a larger spectrum of policy options, from BaU to ambitious ones aiming to transform buildings activities towards nZEB levels
- To consider innovative policy instruments currently under debate in the country

Although there are country specific deviations and exemptions, the general logic for the scenario is as follows: Scenario 1 refers to a moderate ambitious scenario according to current national and EU legislation, Scenario 2 and 3 are more ambitious, innovative and stringent policy packages. For the target countries, the decisions on policy packages were made in policy group meetings, for other EU28 countries, generic sets of policy packages were derived. In the following, we show the main ideas and features of these policy sets which were selected for model based analysis in each target country.

[31] See http://www.entranze.eu/pub/pub-scenario.

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Table 6. Overview of modelled policy packages in target countries

Target country	Policy set 2	Policy set 3
Austria	property tax depending on energy efficiency standards, innovative financing, intensified coaching of building owners	The same as in policy set 2, but with a higher ambition level.
Bulgaria	stricter building codes from 2015, subsidies, information campaigns	stricter building codes from 2015 and from 2020, subsidies, loans for private sector, wider information campaigns
Czech Republic	Business as usual[32]	nZEB obligation introduced in 2014, nZEB obligation broadened to major renovations, strengthened nZEB requirements from 2020
Finland	target group specific policy package: single-family homes: support shift from oil and electricity to ground-source-heat pumps and wood apartment and service buildings: support renovation to reduce energy demand by 50 % for buildings older than 35 yrs.	Energy taxation: price of energy (electricity, heat and fossil fuels) raised by 50%
France	progressive CO_2/energy tax reaching 100€/tCO_2 in 2030; tax is accompanied by complementary measures for low income households	Mandatory renovation enforced at the occasion of real estate transaction of dwellings with energy performance certificate above D with a temporary tax; intensive coaching of building owners
Germany[33]	Ambitious tightening of building codes, RES-H use obligation	Additional enforcement / information and ambitious tightening of building code, RES-H use obligation
Italy[34]	Financial incentives only for selected nZEB levels, preferential loans only for nZEB-level-refurbishment; minimum share of RES	Higher financial incentive for renovation at selected nZEB-level (tax deduction or subsidies), preferential loans only nZEB-level refurbishment with higher budget; tailored information campaigns; minimum share of RES
Romania[35]	increasing compliance 2nd step; qualification programmes for construction workers starting 2015; creation of a national network to raise awareness and guide action in key cities	increasing compliance 3rd step; additionally to PS 2 improving criteria in basic and high level education; additionally to PS 2: Information and guidance networks of one-stop-shops available in all localities with more than 10000 inhabitants.
Spain	“Moderate” tightening of regulatory requirements; Capacity building, qualification and quality assurance; Competence centres for energetic building refurbishment	Additionally to Polset 2: Increase amount of financial instrument financed from the state budget (grants and preferential loans); Energy efficiency and energy refurbishment obligations

[32] For the Czech Policy Group it was important to investigate also a policy without current subsidies. Therefore, for the Czech Republic Policy Set 1 is less ambitious as the current policy framework and Policy Set 2 is the business as usual scenario.

[33] For Germany, four policy scenarios were developed (Steinbach et al., 2014). For reasons of consistency, in the online scenario tool, only three scenarios were presented.

[34] For Italy, the first policy set was defined as BAU+, i.e. with slightly more ambitious measures as currently in place.

[35] For Romania, the first policy set was defined as BAU+, i.e. with slightly more ambitious measures as currently in place.

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We want to emphasize that none of the investigated three policies should be understood as optimum policies. “Optimum” would mean that the policy package would be perfect and optimised considering all relevant side conditions. We know that this is never possible since the number of variables which can be set is too large and uncertainties are high. Rather, in the in-depth discussion process with policy makers we intended to select reasonable settings. In particular, in some countries (e.g. Germany) the focus was on developing policies which are in line with achieving energy and climate policy targets. Thus, the objective was to learn from the simulation runs for these three policy sets to derive sound and science based recommendations. However, these recommendations may deviate from the detailed settings of the policies if it turned out that some elements of a policy package could or should be further improved in order to take into account additional aspects.

7.2 Methodology: the models Invert/EE-Lab and POLES

The development of scenarios for space heating, cooling and lighting was based on two models: Invert/EE-Lab and POLES. POLES delivered the projection of key input data with regard to the overall energy system such as end-user energy prices and average primary energy and emission factors of electricity generation in each country (respectively, toe/kWh and gCO2/kWh). Invert/EE-Lab was used to derive scenarios for space heating, hot water, cooling and lighting energy demand scenarios. In the following, we will provide a short documentation of these two models. A more detailed description of these two models is given in Kranzl et al., (2014b). Moreover, the results of the model Invert/EE-Lab were checked with POLES regarding the potential feedback loop on energy prices.

7.2.1 The bottom-up model Invert/EE-Lab

Invert/EE-Lab is a dynamic bottom-up techno-socio-economic simulation tool that evaluates the effects of different policy packages on the total energy demand, energy carrier mix, CO2 reductions and costs for space heating, cooling, hot water preparation and lighting in buildings. The model is based on a highly disaggregated description of the building stock. Each building segment is described by geometry data, U-values of building components, construction period, age and type of installed heating and hot water system etc. Taking into account regional climate data, a standard static monthly balance approach calculates energy needs and delivered as well as final energy demand. By using a Weibul distribution, those buildings and components are identified, which have to be replaced or abolished. An agent specific (Steinbach, 2013b), nested logit approach combined with a logistic diffusion curve models models the choice between technologies (renovation measures, HVAC systems). By this approach, In-

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vert/EE-Lab models the decision making of agents (i.e. building owner types) regarding building renovation and space heating, hot water and cooling systems. Policy instruments, such as economic incentives, regulatory instruments, information, advices may affect these decisions. The module for the cooling energy demand in addition simulates the diffusion of cooling devices in buildings. The lighting module focuses on a vintage model based on regulatory instruments and technological progress without endogenous modelling of investment decisions.

The model requires the following main categories of input data: disaggregated description of the building stock, cost data of heating and cooling systems as well as of renovation options, definition of renovation packages and other technologies, energy price scenarios, policy settings. Main output categories comprise energy demand by energy carriers, renovation activities, investments, public expenses for subsidy programmes, etc. More information is available on www.invert.at or e.g. in (Müller, 2012) or (Kranzl et al., 2013).

7.2.2 The Poles model

The model divides the world into 57 countries or regions. For each region, the model articulates five main modules dealing with:

- Final energy demand by main sector
- New and renewable energy technologies
- Carbon Capture and Sequestration technologies and infrastructures
- Conventional energy and electricity transformation system
- Fossil fuel supply

POLES is a recursive, step by step simulation model in which investment decisions are based on a discrete choice process between explicit technologies or fuels through a logit approach. POLES distributes the market share of each technology given the relative economic competitiveness and additional non-price related factors reflecting "hidden" costs and historical deviations from a pure economic competition.

In the power sector there is an explicit representation of each technology (30 plant types). The economic competition takes into account detailed power generation costs including endogenous technology learning ("by searching" & "by doing") and technical & resource limitations. POLES' modelling of the power sector a very detailed implementation of all relevant policies affecting electricity markets, such as feed-in tariff, investment grants and other subsidies or taxes.

Final energy demand (buildings, transport, industry) is mainly based on a top down approach which means investments in equipment or technologies are indirectly captured in the final energy demand per fuel. The global level of demand per sector depends on price effects, activity effect and "autonomous technological change" (which captures improvements in energy efficiency for instance). The competition between fuels allows to take into account end-user fuel prices but also additional factors that reflect the efficiency, the cost-efficiency or the specific limitations of the underlying technologies.

7.2.3 Drivers and input data

As explained above, in the introduction of chapter 7, the main input data for Invert/EE-Lab, as building stock data (see chapter 2), barriers and stakeholder behaviour (see chapter 3), cost data, selection of renovation packages based on cost-optimality results (see chapter 4) and policy sets and specific policy design (see chapter 5 and 6) have been derived from analyses within the project ENTRANZE.

Price and electricity generation mix projections in ENTRANZE are derived from two scenarios of the world energy systems simulated with POLES: a "Reference" scenario and an "Ambitious Climate" scenario. The two scenarios have the same macroeconomic context. They mainly differ on the carbon policies.

The **"Reference"** (low energy price) scenario assumes that only on-going and already planned climate policies are taken into account and that no consensus is reached at international level. Sustained growth of China and other emerging countries is a powerful driver of energy demand at world level leading to high international oil and gas prices but to lower domestic prices. Energy prices for end-users at country level were then projected, taking into account changes in international prices and taxes (excise tax[36], VAT) and a carbon price[37].

The **"Ambitious Climate"** (high energy price) scenario explores the implications of more stringent climate policies and reinforced support for renewables at world level driven by successful. negotiations between advanced and emerging economies on climate change. International fossil fuel prices are lower as a result of a lower demand but domestic prices are higher due to higher taxes and the cost of policies to reach the emissions abatement targets.

The resulting two energy price scenarios were then used in Invert/EE-Lab as an input, as well as the corresponding primary energy factors and CO2-emission factors of electricity, based on POLES projections of the power mix and CO2 emissions by country.

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[36] Including existing energy & environmental taxes.
[37] Carbon prices are different from EU ETS prices and refer to an aggregate metric in POLES used to characterise the effort necessary to reach climate objectives: they might be seen as "shadow prices" for policies stimulating low-carbon technologies.

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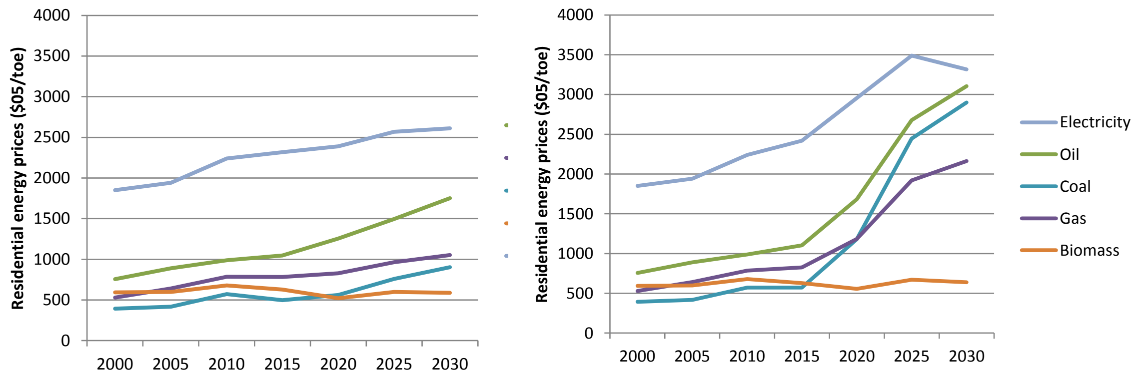

Figure 27. Residential and tertiary energy price scenarios for EU27 average reference scenario (left) and ambitious scenario (right)

Source: POLES-Enerdata

More detailed data on price scenarios in all 9 target countries is documented in the report “Policy pathways for reducing carbon emissions in the EU building stock” (Kranzl et al., 2014b).

The CO2 emission factor, i.e. the average amount of CO2 emitted per kWh produced in gCO2/kWh, is linked to the production mix of electricity, especially to the share of fossil fuels in the power mix and the efficiency of power plants.

As shown in Figure 28, the average CO2 emission factor of the power sector will improve significantly over time: in the ambitious scenarios, it is expected to decrease by 7%/year over the period 2010-2030 and by 4%/year in the reference scenario. This decarbonisation is obtained thanks to the increasing use of renewables, the increasing use of carbon capture storage (CCS), and of course thanks to the decreasing use of fossil fuels.

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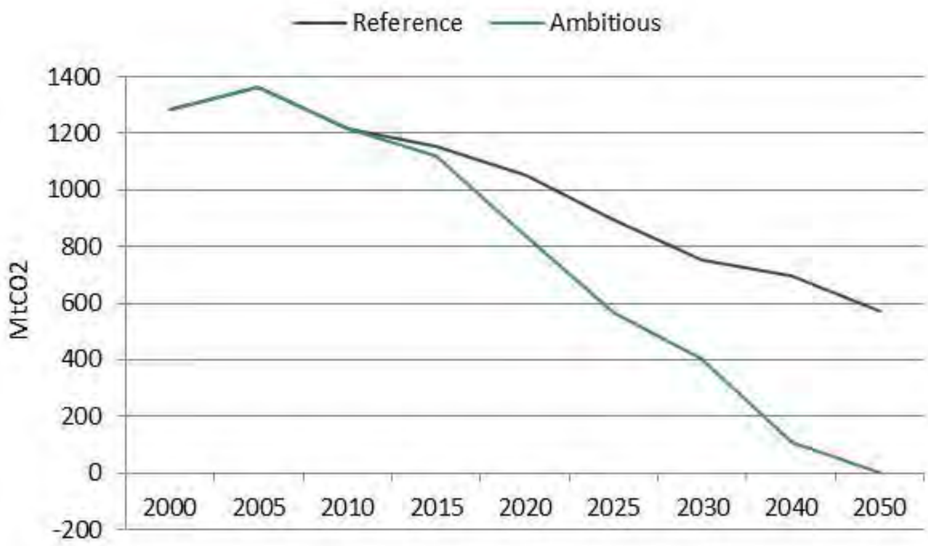

Figure 28. EU-27 CO2 emission content in power production until 2050

Source: POLES-Enerdata

Even if the average carbon emission factor in power production is decreasing in all target countries, there are different trends. In the ambitious scenario, the decrease over 2010-2030 is going from almost 4%/year in France and Italy to more than 10%/year in The Czech Republic, Romania, Bulgaria or Finland.

The result of the projections for the 9 target countries[38] and the EU as a whole are presented in more details in a separate report "Exogenous framework conditions for Entranze scenarios" (Sebi et al., 2013) and in the report "Policy pathways for reducing the carbon emissions of the EU building stock until 2030" (Kranzl et al., 2014b).

7.3 Scenario analysis for target countries

With around 2550 TWh (219 Mtoe)[39] in the year 2008, the ENTRANZE target countries cover about 60% of the EU-28 final energy consumption for space heating, hot water, cooling and lighting. The majority of this energy consumption is used for space heating and hot water preparation (2370 TWh, 204 Mtoe), whereas lighting accounts for only about 120 TWh (10 Mtoe) and space cooling for about 50 TWh (4.3 Mtoe) in 2008.

[38] Austria, Bulgaria, Czech Republic, Finland, France, Germany, Italy, Romania and Spain.
[39] Climate corrected, based on ODYSSEE data. Not all data which were required for the calibration of the model are included in ODYSSEE. This refers e.g. to electricity consumption for

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About 28% of this energy demand is used in non-residential buildings, the remainder in residential buildings. Figure 29 shows the development of final energy demand for space heating and hot water, cooling and lighting in the policy scenario 1, low price. The figures highlight that for space heating and hot water, Germany, France and Italy account for more than 75% of the whole energy consumption of the ENTRANZE target countries, whereas for cooling, Italy, Spain and France consume more than 85% of whole energy demand of the ENTRANZE target countries for this end-use category. While for space heating, hot water preparation and lighting the implemented policies and instruments will most probably lead a reduction of energy demand, for cooling the opposite is the case, which is first of all due to a growing market diffusion of air conditioning in the building stock.

So, what drives these developments and how can policies impact future energy demand in the building stock? In the following, we want to highlight some relevant results, which were derived in the scenario development for target countries.[40]

In the following, some results are shown for all policy scenarios and for both energy price paths. Some other results are only shown for policy scenario 1 and for low energy prices[41]. Complete results for all scenarios for heating, hot water and cooling in non-residential and residential buildings are accessible via the online scenario tool on www.entranze.eu and in the report "Policy pathways for reducing energy demand and carbon emissions of the EU building stock until 2030" (Kranzl et al., 2014b).

[40] Although the following figures include comparative illustrations of country results, we want to emphasize that there are limitations of the comparability of these scenario results: As pointed out above (see chapter 7.1), the policy sets have been developed on a highly individual basis according to the specific needs of policy makers, experts and stakeholders to understand specific features of policy sets and their design. Thus, the level of ambition in these policy sets to increase energy efficiency, the share of RES-H and the number of nZEBs and also the focus on different type of policy instruments is strongly different. Nevertheless, the comparative view may help to highlight a few insights and main results which in the end helped to derive model based policy recommendations.

[41] "Low energy price scenario" means here "Reference scenario" of energy carrier prices derived with POLES (see chapter 7.2.3 for the detailed description).

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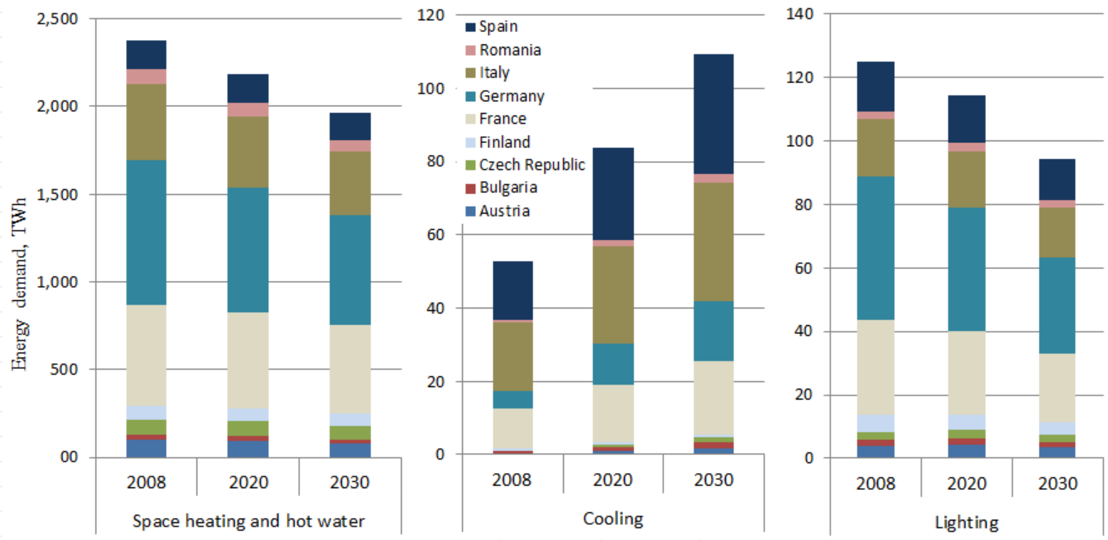

Figure 29. Final energy demand for space heating and hot water, cooling and lighting in ENTRANZE target countries in 2008, 2020 and 2030, Policy Scenario 1, low energy price scenario

The time frame of the policy scenarios is from 2008-2030. While the base year of the scenarios is 2008, the new and more ambitious policies were implemented only in 2015. This means that the policy scenarios 2 and 3 which are more ambitious than policy set 1 only have 5 years to show their impact until 2020 and 15 years until 2030. Due to the high inertia, it needs really strong measures to show an impact in the short period of 5 years until 2020. Thus, the spread of space heating energy savings, which can be achieved by introducing more ambitious measures in 2020 is smaller than in 2030. Until 2020, under low energy prices, energy demand savings compared to the base year 2008 is in the range of 1-5% for cases like Bulgaria, for most countries in the range of about 5-10% and for Germany 13-15%. Until 2030 the three policy scenarios lead to energy savings (compared to the base year 2008) of about 15-25% for most countries and up to 30% for the cases of Germany and Romania. However, the achieved savings as well as the spread between the three policy scenarios vary strongly between the countries. The spread of energy demand reduction levels in 2030 between the three policy sets is particularly high for France and Spain. In both cases, policy set 3 has been designed in a highly ambitious way (Fernandez-Boneta et al., 2014; Sebi et al., 2014)

What are main reasons for these differences? In the following, we will discuss three main drivers: (1) renovation rate, (2) renovation depth and (3) specific final energy demand for space heating in the base year of the building stock. While the latter determines the energy efficiency potentials and the economic effectiveness of renovation measures, the first two aspects are also driven by the policy intensity, which varies between scenarios and between the different countries.

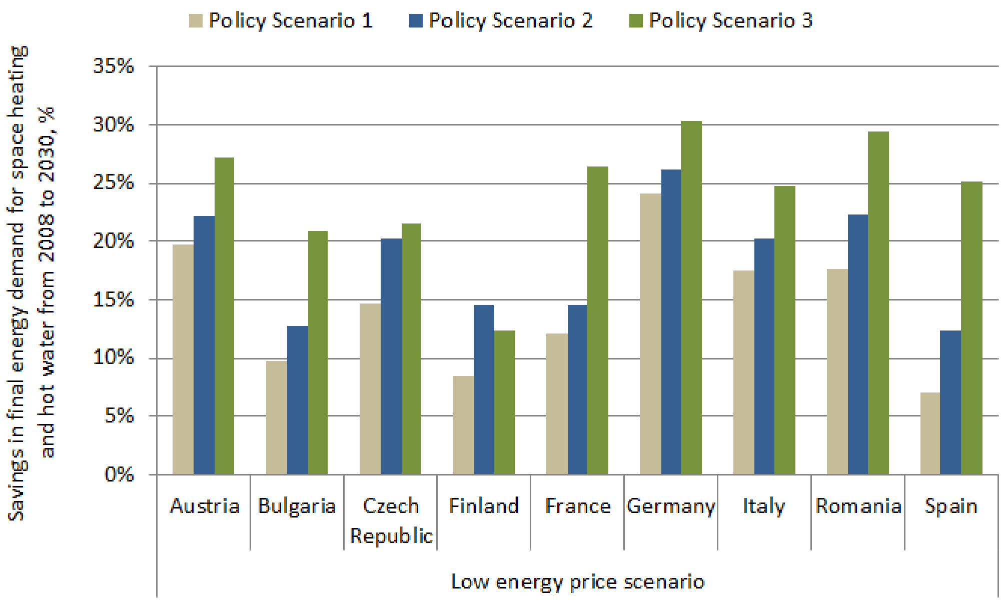

Figure 30. Savings in final energy demand for space heating and hot water in target countries in three policy scenarios, from 2008 to 2030, low energy price scenario

The renovation rate of the building stock and thus the cumulated share of renovated buildings are often referred as the main indicator of effective policies. Figure 31 shows that there is also a clear connection between renovation rate and energy savings in the different scenarios. However, it is not only the renovation rate which matters. Even more, and in particular in the period beyond 2030, renovation quality, i.e. the level of achieved energy savings in renovated buildings matters. Germany achieves the highest savings of final energy demand for space heating and hot water with about 30% of renovated floor area in the 22 years period in the most ambitious policy set, whereas the cases of Italy and Spain achieve even higher cumulated renovation rates, however with significant lower energy savings.

The figure also shows that besides for Finland in all countries energy savings of at least 20% from 2008-2030 can be achieved, even with policy packages which have been reality checked and discussed and agreed with policy makers in intensive discussion processes. So, it becomes clear that not only in countries with low tradition of energy performance standards (e.g. Bulgaria, Romania) high efficiency potentials exist, but also in countries like Germany and Austria. However, the challenges are quite dif-

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ferent and in the former countries increasing comfort demand is compensating for a substantial part of energy efficiency improvement.

On the one hand, the share between light, medium and deep renovation provides an explanation for this result. On the other hand, there is also a difference in the definition of light, medium and deep renovation between the target countries[42]. These three renovation packages have been derived based on the cost-optimality calculations (chapter 4). Thus, the different climatic conditions and different reference buildings which are typical for different countries also lead to different definitions of most economic renovation packages for achieving certain energy performance levels.

Overall, the cumulated share of buildings renovated in the highest considered quality for each of the countries varies between 15% e.g. in policy scenario 1 (low energy prices) for Bulgaria and up to 60% and beyond in policy scenario 3 (low energy prices) for the cases like Spain, Czech Republic or Romania. This indicates that in the latter examples, the policy group decided to analyse either more rigorous regulatory schemes including compliance measures for building renovation or specific incentives for deep renovation. Where the impact of deep renovation and a high quality of renovation activities might only partly be visible in the scenario results for 2030, previous studies have shown their essential impact for achieving ambitious energy and GHG saving targets in the building stock until 2050, e.g. Ürge-Vorsatz et al., (2015), Henning et al., (2013), Müller et al., (2010), IEA, (2013).

[42] See country reports on policy scenarios and recommendations: http://www.entranze.eu/pub/pub-scenario

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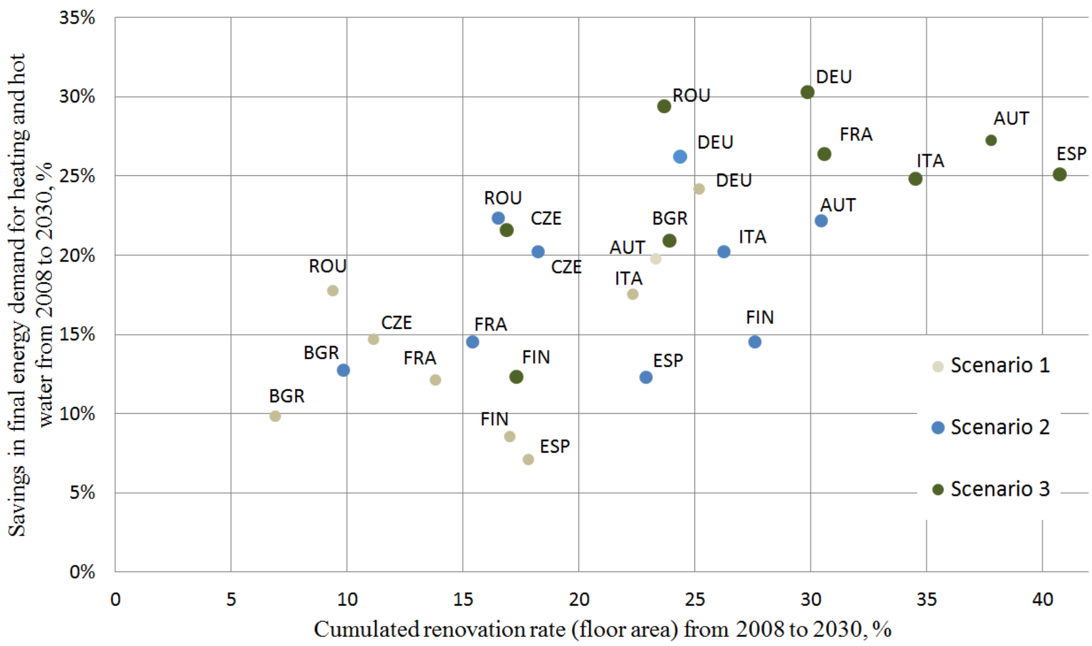

Figure 31. Savings in final energy demand for space heating and hot water from 2008 and 2030 and cumulate renovation rate from 2008 to 2030, low energy price scenario

Figure 32 shows final energy demand for space heating per useful floor area with and without climate correction[43]. Finland, Austria and Czech Republic have the highest specific final energy consumption (without climate correction) in the base year among the ENTRANZE target countries due to climate conditions, user behaviour, mix of installed heating systems and overall energy performance of the building stock. However, if we apply the climate correction, it becomes clear that the Finnish building stock is among the most effective ones, whereas Italy and France have the highest specific energy demand. This is the effect of early introduction of energy performance requirements in the Finnish building codes (Heiskanen et al., 2014). Besides the effect in the base year, this also leads to the effect that the potential for efficiency improvement is lower than in other countries and the remaining potential is less economic than in other countries.

[43] Climate corrections enable to compare European countries without the influence of the climatic conditions. The calculation of climate corrected final energy demand is based on the specific energy demand in a certain country, HDD (heating degree days) in EU-27 and HDD in the estimated country. Mean HDD are taken from the Eurostat statistic which provides mean HDD in EU-27 and in each European country from 2000 to 2009 (Eurostat 2014).

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Since the graph does not show energy needs but total final energy consumption (for 2008) and total final energy demand (for the scenario years), it also implicitly includes user behaviour, and comfort levels. E.g. the low values of specific climate corrected energy demand in countries like Bulgaria and Spain are mainly due to low comfort level and not due to high energy performance of the building stock. Thus, it is most likely that in these countries increasing comfort requirements in the coming years will compensate for the energy efficiency gains (e.g. by higher effective indoor temperature after building envelope insulation). Also the share of room heating systems plays a strong role. This share is particularly high in Bulgaria, Spain (and to some extent Romania). Due to the fact that the comfort level (service factor) of room heating systems in practice is significantly lower than for central heating systems, the shift from room heating (like solid fuel single stoves) to central heating systems may lead to an increase of final energy demand, since the increasing comfort outweighs the efficiency gains of the heating systems. Besides the different policy ambition levels, this is also one of the reasons for lower energy efficiency gains in the Bulgarian policy scenario 1 compared to countries like Italy or the Czech Republic.

The case of Bulgaria also reveals that the current policies have a very low impact due to high barriers and transaction costs (see recommendations in chapter 8).

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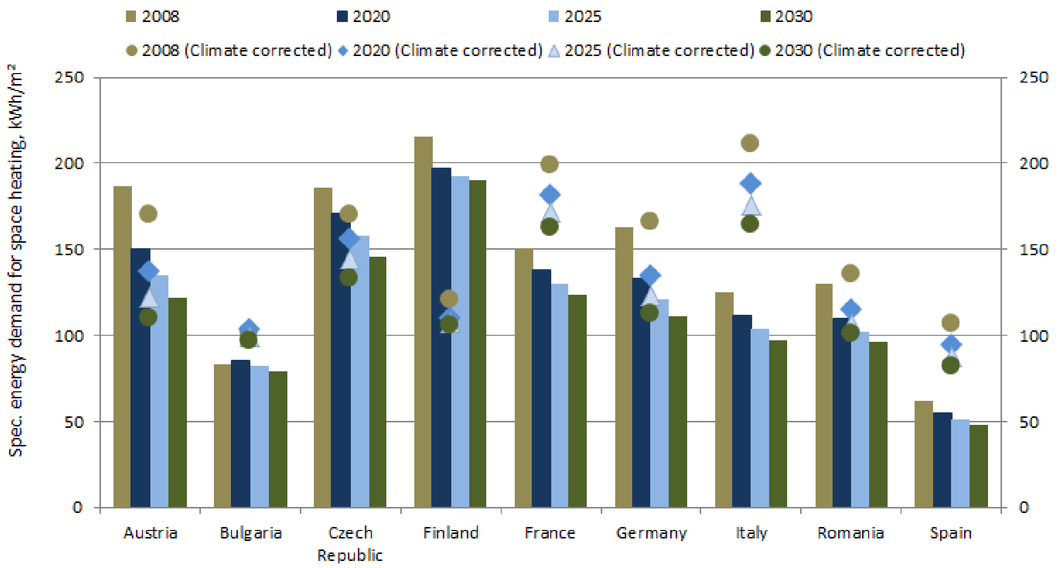

Figure 32. Specific final energy demand for space heating and climate corrected specific final energy demand for space heating in target countries in 2008, 2020, 2025 and 2030 in scenario 1, low energy price scenario[44]

There are several key drivers for the specific CO_2-emissions per floor area in the scenarios (Figure 33). (1) The overall energy demand and energy performance of buildings, (2) the share of renewable heating, (3) the shift from coal and oil heating systems to gas and (4) the reduction in CO_2-intensity of electricity generation. All these factors lead to a reduction of specific CO_2-emissions, already in policy scenario 1.

The average specific CO_2-emissions in EU28 are about 40 kg/(m²*yr) in 2008 and between 20.9 and 17.5 kg/(m²*yr) in 2030 in policy scenario 1 and 3, respectively.

[44] Specific final energy demand is calculated by dividing total final energy demand through useful floor area.

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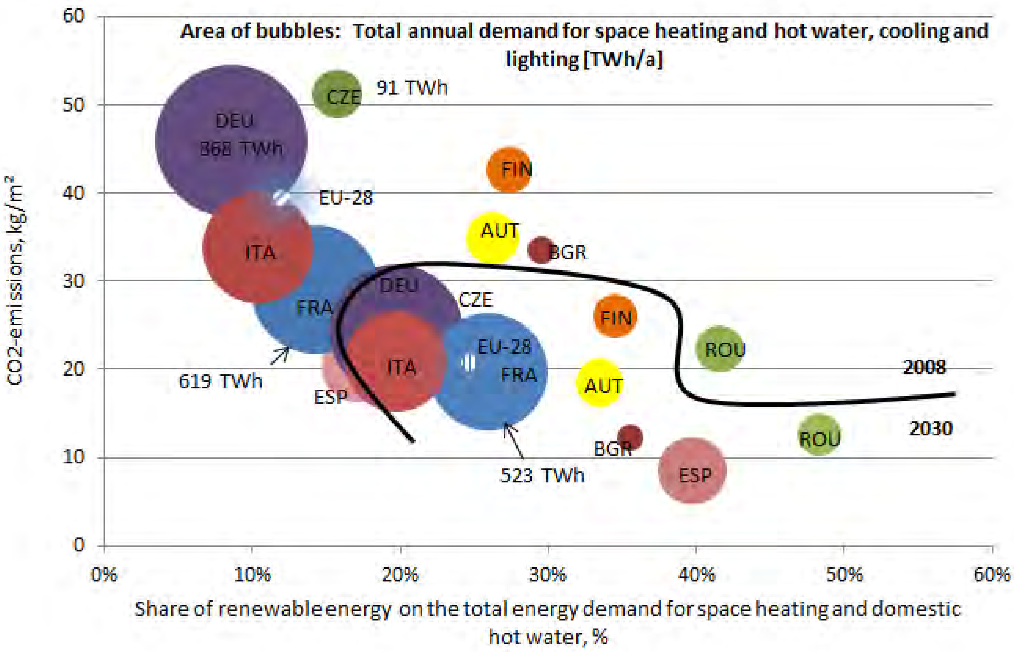

Figure 33. CO_2-emissions caused by energy demand for space heating, hot water, cooling and lighting per floor area. The bubble size shows total annual final energy demand for space heating, hot water, cooling and lighting in 2008 and in 2030 in ENTRANZE target countries. Policy scenario 1, low energy price scenario

For the reduction of CO_2-emissions, in all scenarios the decline of heating oil plays a key role. Heating systems typically have a shorter lifetime than building envelope components like façade, roof or windows. Thus, the structure of heating systems and the resulting energy carrier mix may change faster than the uptake of renovation measures concerning the building envelope. The following figure shows the energy carrier mix in the target countries and the three policy scenarios for 2008 and 2030.

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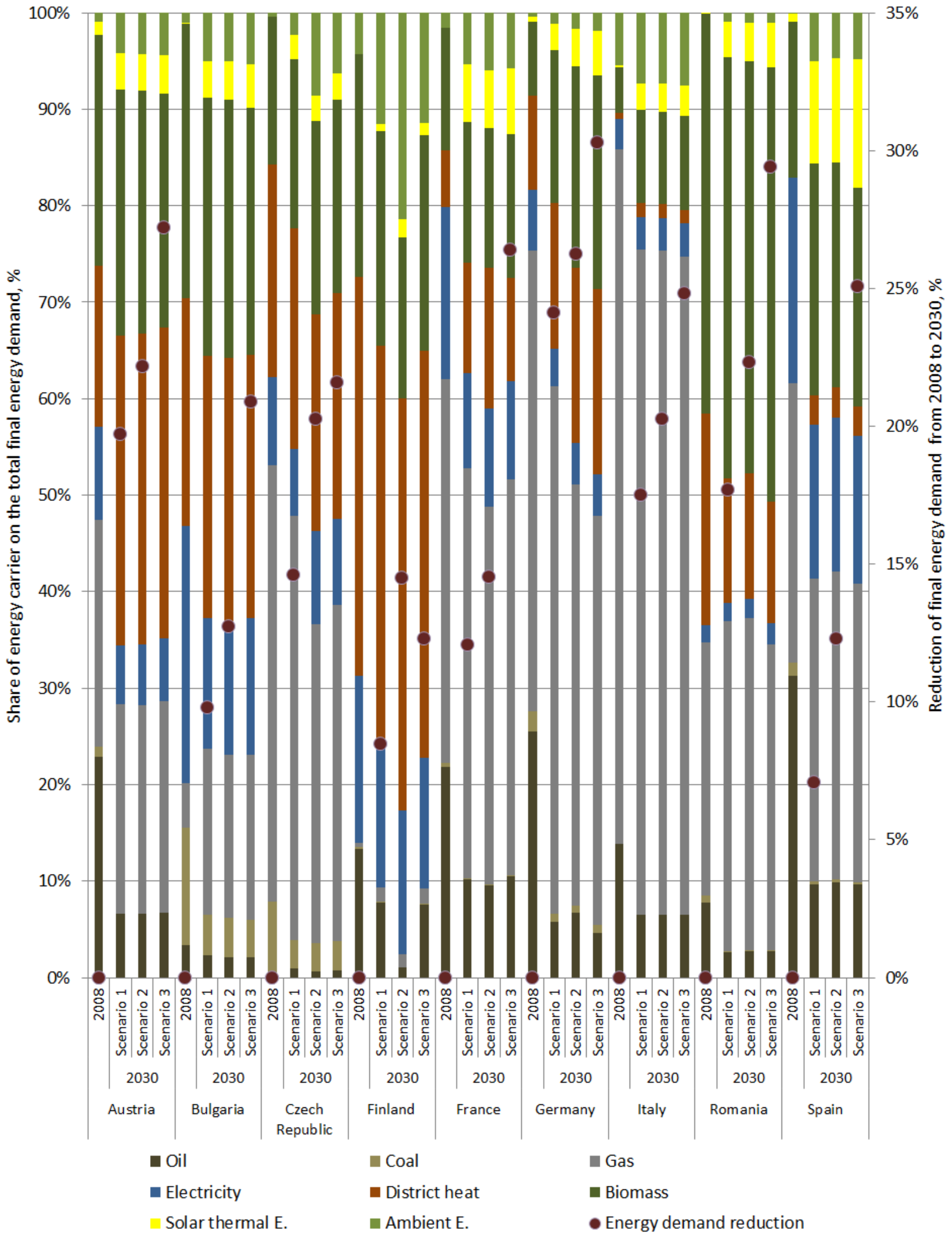

Figure 34. Share of energy carrier on the total energy demand for space heating and hot water and reduction of final energy demand from 2008 to 2030 in Entranze target countries, in 2008 and in policy scenario 1, 2 and 3 (low energy price scenario)

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A general trend is the significant decrease of heating oil in all scenarios. This is on the one hand due to high fuel prices for heating oil and on the other hand due to corresponding policies to phase out heating oil (e.g. in Finland, Policy Scenarios 2) or in general according to the nZEB concept and the assumed implementation of the RES-H use obligation according to the renewable energy directive (see chapter 5). Another trend is the increase of ambient energy and solar thermal systems, which in some countries and some scenarios is significant. Regarding ambient heat, we follow the accounting requirements according to the renewable energy directive (*2009/28/EC*), Annex VII. For this purpose, we take into account the primary energy factors of electricity generation according to 7.2.3.[45] Regarding uncertainties, in particular regarding the expansion and potential market growh and corresponding barriers, see chapter 7.5.

On top of the RES-H technologies biomass, ambient energy and solar thermal energy, the ENTRANZE scenarios also include PV generation. PV generation in the policy sets is triggered by economic incentives (subsidies, feed-in-tariffs) on the one hand and by regulatory instruments (RES use obligation in new buildings or buildings undergoing major renovation) on the other hand. The scenario results show that under current market conditions, in most countries PV is near competitiveness with retail household electricity prices. Thus, the model results in a robust expansion of small scale PV appliances allowing to substitute household electricity consumption from the grid with PV generation and export only a small share of PV generation to the grid. Additional incentives in more ambitious scenarios show some impact, but the additional effect in most countries is relatively small due to the economic effectiveness, which is already given for policy scenario 1. It remains the question of barriers, challenges to finance PV plants, transaction costs and availability of trained staff. Overall, our scenarios show an increase in on-site PV generation for ENTRANZE target countries from about 5 TWh in the base year 2008 to about 50 TWh in 2020 and 95-100 TWh in 2030.

Figure 35 shows the two main drivers for cooling energy demand: (i) the electricity demand per m² of cooled floor area and (ii) the share of cooled floor area on total (heated) floor area. According to the scenario results in this project, the share of cooled area is expected to increase in all countries and all scenarios (for a discussion regarding related uncertainties, see chapter 7.5). However, the specific energy demand for most countries, and in particular for those with highest cooling demand can be reduced

[45] For more details regarding the accounting of ambient heat according to the renewable energy directive in Invert/EE-Lab see the report “Policy pathways for reducing energy demand and carbon emissions of the EU building stock until 2030” (Kranzl et al., 2014b) available at http://www.entranze.eu/pub/pub-scenario

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mainly due to more effective shading, but also increased efficiency of chillers and AC systems.

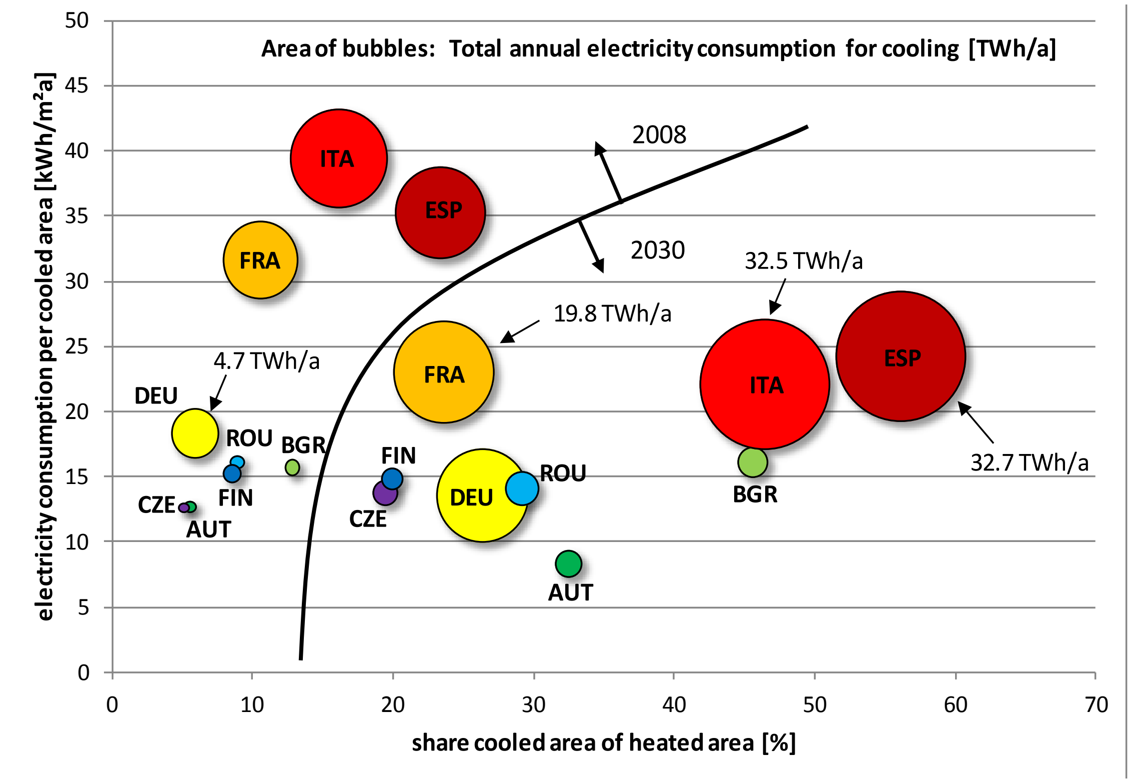

Figure 35. Electricity demand for space cooling per cooled floor area and share of cooled floor area[46] from 2008-2030 in policy set 1 – low energy prices

Energy efficiency measures are typically associated with corresponding investments. Figure 36 shows the energy savings from 2008-2030 and the related specific investments per total floor area in each target country for each scenario. For each country we see a clear trend of higher investments leading to higher energy savings. The differences between countries are due to climatic differences, differences in cost structure and differences in the quality of the existing building stock and thus existing energy efficiency potentials, rebound effects, change of heating systems etc.

For the indicator on the x-axis, total floor area includes the *total* useful building stock floor area, not only the renovated floor area, in order to allow for a proper comparison

[46] Share of cooled floor area is calculated as ratio of cooled floor area and heated floor area.

between the scenarios and countries. Thus, this amount is substantially lower than investments per *renovated* floor area.

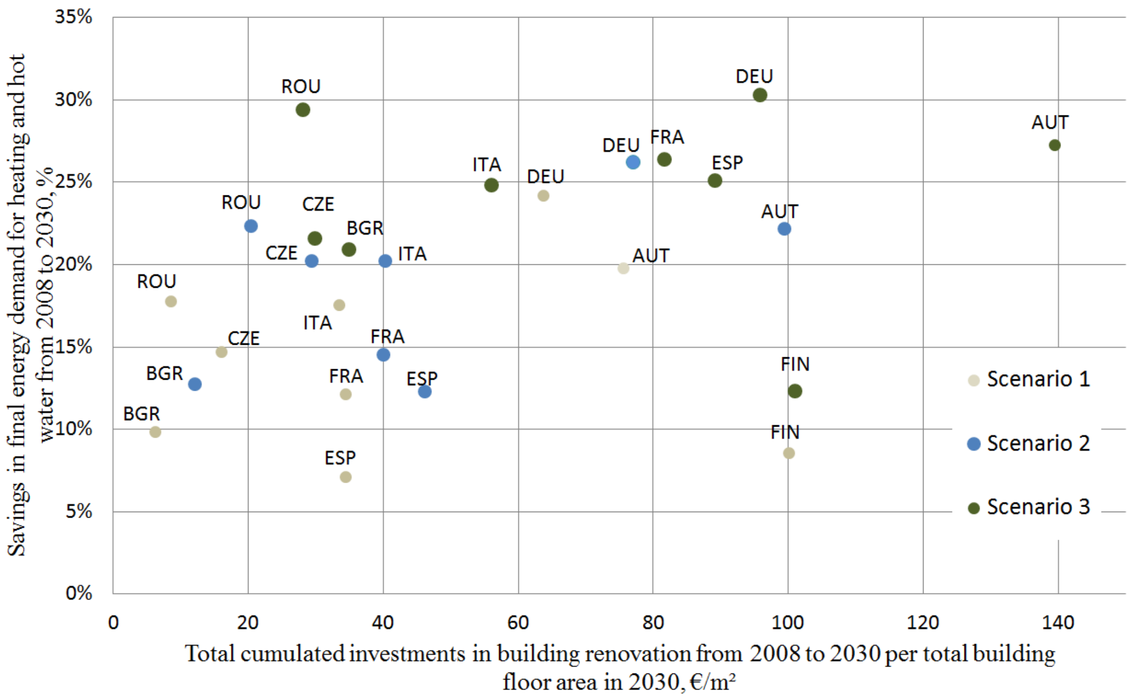

Figure 36. Savings in final energy demand for space heating and hot water from 2008 and 2030 and total cumulated investments in renovation[47] per total building floor area[48] from 2008 to 2030[49], low energy price scenario

A key element of investigated policy packages are investment subsidies for thermal building renovation. Figure 37 links savings in final energy demand with the public expenses which are granted as subsidies for energy efficiency improvement in the building envelope in the different scenarios. Again, as for the previous figure we relate the

[47] Renovation includes insulation measures on the building envelope and the installation of heat recovery systems. Investments for heating system change are not considered in this graph.

[48] Please take into account that total floor area includes the whole building stock floor area, not only the renovated floor area, in order to allow for a proper comparison between the scenarios and countries.

[49] There is one outlier indicating results for Finland excluded from the graph. Policy scenario, saving in energy demand for space heating and hot water from 2008 to 2030 and cumulated public expenses in building renovation from 2008 to 2030 are as follows: Policy Scenario 2, 15% and 197 €/m² for Finland

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costs to the *total* floor area, no the *renovated* floor area. It shows that not necessarily those countries and scenarios with the highest public expenses per total floor area lead to the highest savings. There are several drivers for the results in this graph: (i) regional differences as explained above for the case of investments and savings; (ii) different design of policies and the relevance of economic support instruments in the policy packages. Obviously, policy packages with a strong regulatory element may achieve substantially higher energy savings with the same amount of public expenses for investment subsidies. Examples for such policy scenarios are the ambitious policy scenario 3 in France, which leads to about 27% of energy savings from 2008-2030 with public expenses for subsidies of less than 2 €/m² total floor area. This is achieved with a mix of regulatory instruments (obligation to renovate the least efficient buildings in case of real estate transactions), moderate subsidies and strong target oriented information instruments and coaching (Sebi et al., 2014). The German scenarios show the impact of stepwise increasing compliance and information measures to ensure a high effectiveness of regulatory instruments (Steinbach et al., 2014). These examples are in strong contrast to scenarios e.g. for Austria. Scenario 2 leads to 22% energy savings from 2008-2030 with about 11.5 €/m² total floor area public expenses. Scenario 3 achieves 25% of energy savings with public expenses of 27 €/m² public expenses. So, this huge difference to the prior examples can be explained by (1) the higher specific investments in Austria (see Figure 36), (2) a strong tradition in subsidies for building renovation (and new building construction) and (3) the type of investigated policy mix: the subsidies (which are counted here as public expenses) are financed through a property tax on low energy efficient buildings. In particular in the Austrian policy scenario 3, the additional revenues from the property tax would even overcompensate the expenses for subsidies (Kranzl et al., 2014c).

Even though there are regional differences in cost structure, policy traditions, climatic conditions and ways of financing public subsidies, the general conclusion is that the effectiveness of policy scenarios which are located on the right hand side of the graph could probably be improved by giving more weight on measures which do not require high public expenses, i.e. stronger regulatory instruments (building codes, RES use obligation) including measures to increase compliance, building specific renovation roadmaps and more effective information activities, quality checks, training and coaching of building owners.

Besides the private and public investments for building renovation, the total expenses for final energy for space heating and hot water are crucial for the economic effectiveness.

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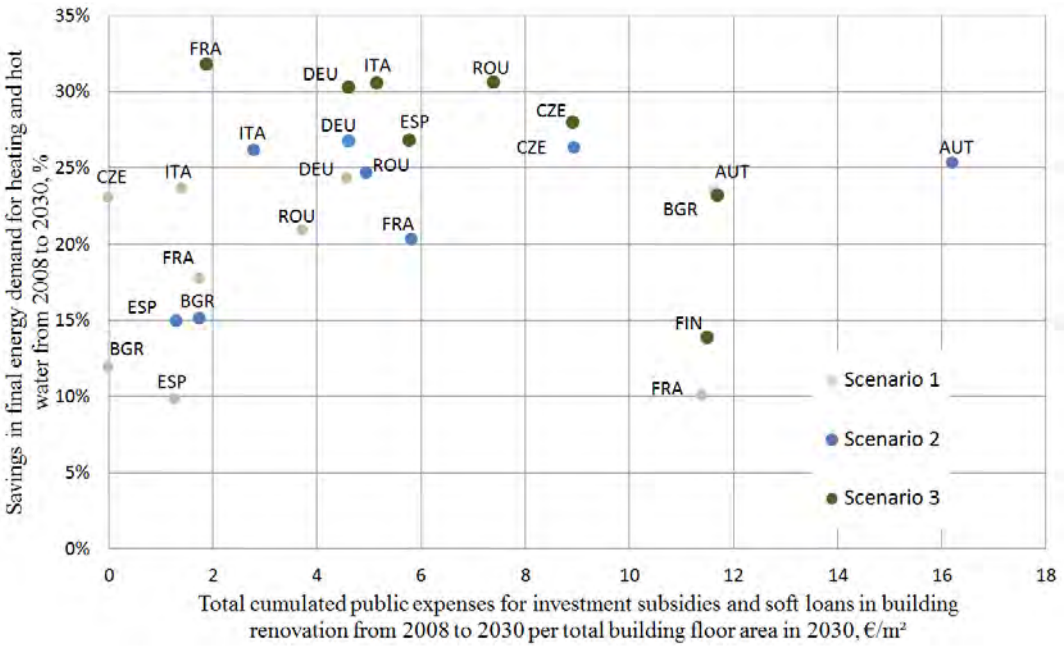

Figure 37. Savings in final energy demand for heating and hot water from 2008 to 2030 and cumulated public expenses for investment subsidies and soft loans in building renovation per total national building floor area from 2008 to 2030 (low energy price scenario) [50]

For evaluating fuel costs savings vs. investments, it is necessary to take into account the savings beyond the investment period, since investments trigger savings also in the period beyond 2030. For the example of the low energy price scenario, cumulated fuel cost savings in the scenario 3 compared to scenario 1 for the period from 2008-2055 vary between 660 bn€ and 290 bn€ for the total of all target countries in policy scenario 1. In contrast, the NPV of additional investments in the period from 2008-2030 in policy scenario 3 compared to policy scenario 1 are 460 bn€ to 660 bn€. The range of results is due to different assumptions for interest rates (starting with a cumulated value without discounting and a long-term macro-economic discount rate of 3%).

Thus, it becomes clear, that the discount rate is the crucial factor in this assessment. In case of a very low interest rate (which might reflect the view of a responsible-minded, long-term approach taking into account fair intergenerational allocation of ressources),

[50] There are two outliers indicating results for Austria and Finland excluded from the graph. Policy scenario, saving in energy demand for space heating and hot water from 2008 to 2030 and cumulated public expenses in building renovation from 2008 to 2030 are as follows: Policy Scenario 3, 25% and 27 €/m² for Austria and Policy Scenario 2, 15% and 27 €/m² for Finland.

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fuel cost savings in the long term are slightly higher than the required investments, even in the scenario with low energy prices.

7.4 Selected scenario results for EU-28

The following part highlights selected results for the aggregate energy demand in the EU-28 building stock. The scenario results build strongly on the policy packages and results from the target countries, which cover in total about 60% of the overall EU-28 energy consumption by space heating, hot water, cooling and lighting. For the other countries, generic policy sets were applied, with the same logic as for the target countries: Scenario 1 refers to a moderate ambitious scenario according to current national and EU legislation, Scenario 2 and 3 are more ambitious, innovative and stringent policy packages. However, it was not possible to carry out an in-depth policy discussion process and a thorough analysis of the current state of policies in the remaining countries of the EU-28.

As a starting point, Figure 38 shows the substantial energy savings which can be achieved in the different policy scenarios starting from about 15.5 EJ (~ 4300 TWh or 370 Mtoe) in the base year 2008 until 2030. I.e. according to the model results for EU-28, the current policy framework could lead to savings of about 20%-23% of final energy demand and about 25-30%[51] of delivered energy[52] from 2008-2030. In contrast, policy scenario 3, with more ambitious policies, but still not the maximum of achievable effort and policy innovation, would lead to savings of 29-31% in final energy and 36%-39% in delivered energy.

[51] Ranges indicated in this paragraph refer to the two energy price scenarios. For more details see the reports on http://www.entranze.eu/pub/pub-scenario.

[52] Where delivered energy is defined as total final energy demand minus solar thermal and ambient energy.

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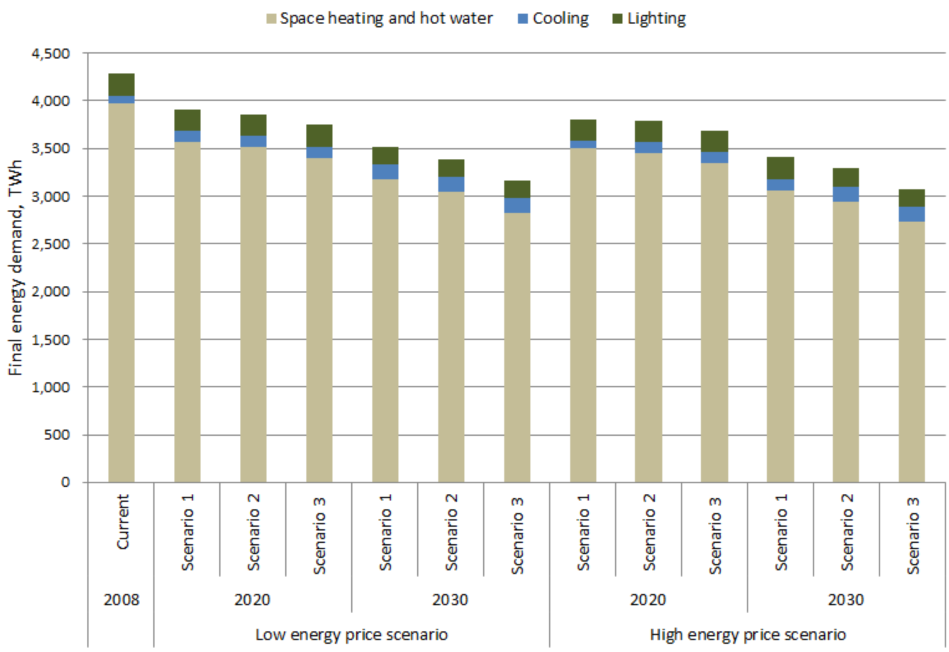

Figure 38. Final energy demand for space heating, hot water, lighting and cooling in 2008 and in 2030 in EU-28 in policy scenarios 1, 2, 3.

The figure also confirms for EU28 the findings from Figure 29, i.e. that the lion's share of the energy demand in buildings is for space heating and hot water, while cooling and lighting represent much smaller shares of total energy demand.

The current policies implemented for lighting energy efficiency is expected to reduce lighting energy consumption in our scenarios by about 20% from 2008 to 2030. These savings however could be more than doubled with even more stringent and more ambitious measures. In contrast to the considerable savings in space heating and lighting energy demand, which could be achieved, cooling energy demand is increasing in all scenarios (by more than 110% for EU-28 from 2008 to 2030). This is mainly related to an expected increase in comfort demand in accordance with developments in recent years. However, with a stringent implementation of efficiency measures (mainly shading, but also the efficiency improvement of chillers), this increase could be reduced.

Figure 39 indicates the energy carrier mix for space heating, hot water, cooling and lighting as well as PV generation. Due to high fuel costs, heating oil systems are more and more being phased out in all scenarios. However, natural gas still plays a crucial role up to 2030, though with different intensities. Almost 50% of final energy demand for heating and hot water is covered by natural gas in 2008, (about 1900 TWh or 165 Mtoe). According to Invert/EE-Lab scenarios, the business-as-usual framework could reduce natural gas demand in 2030 by about 21-31% and under policy scenario 3 by almost 36-45%. Thus, energy dependency regarding natural gas could be halved by 2030. All scenarios show a significant growth of solar and ambient energy. Ambient

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energy is accounted according to the reporting requirements of Member States for the renewable energy directive (see chapter 7.2).

The share of RES-H increases from about 12% in 2008 to about 25-29% in 2030 under policy scenario 1 (under low and high energy prices respectively) and to 28%-33% under more ambitious policies. However, considerable uncertainties remain, e.g. regarding the growth of solar thermal, which are discussed in chapter 7.5. In contrast to renovation of the building envelope, the growth of renewable heating technologies can happen faster due to higher exchange rates. This is one of the reasons why the growth of renewables is more sensitive regarding the level of energy prices than the renovation activities and overall energy demand.

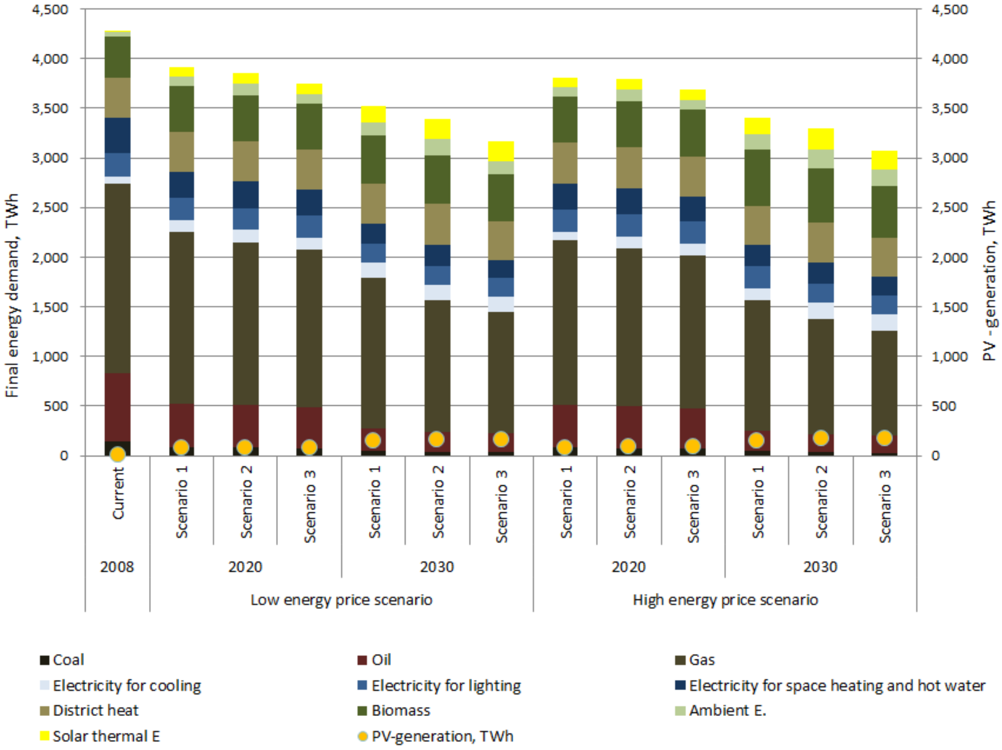

Figure 39. Final energy demand for space heating, hot water, cooling and lighting by energy carriers and PV-generation in EU-28 in policy scenarios 1, 2 and 3.

The increasing energy performance of the buildings stock, the strong phase-out of heating oil and coal in the building sector, which could occur in the coming decades (partly due to environmental and climate policy considerations and partly due to higher comfort requirements and high fuel prices) and the expected move towards the decarbonisation of the electricity sector[53] leads to a reduction of total CO_2-emissions for heating cooling and lighting from 43-50% in policy scenario 1 and 50-57% in policy scenario 3 from 2008 to 2030.

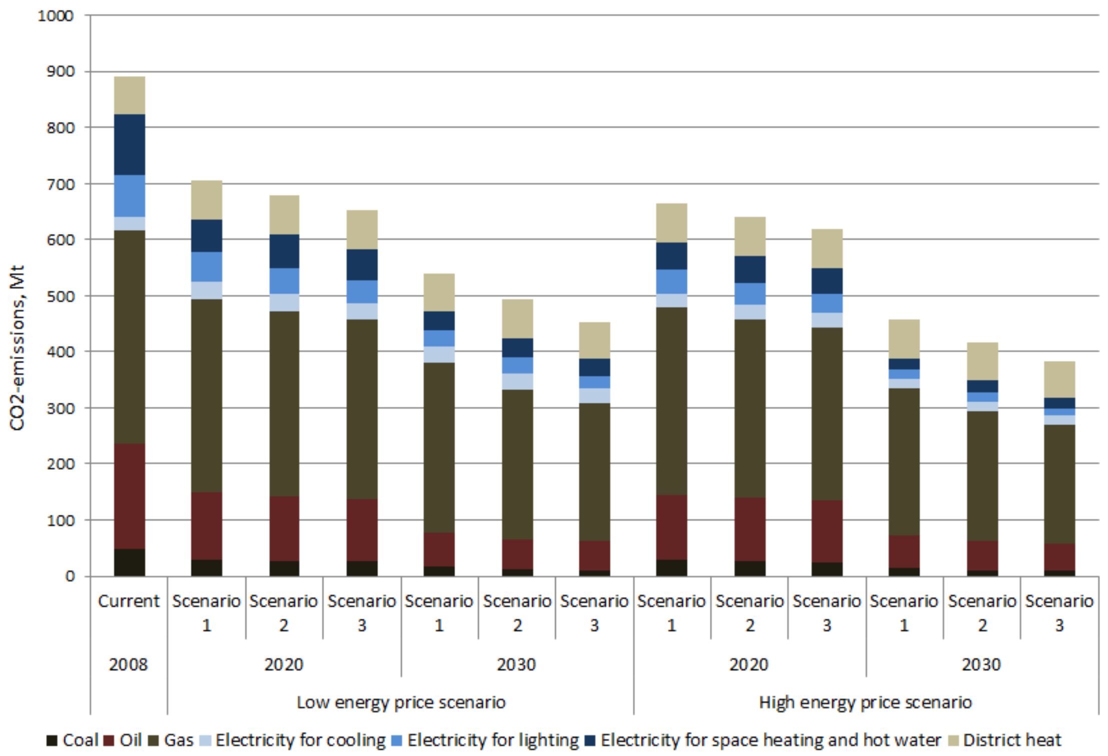

Figure 40. CO_2-emissions caused by energy demand for space heating, hot water, cooling and lighting by energy carrier in EU-28, in policy scenario 1, 2 and 3, low and high energy price scenarios

In particular, for consistency with long-term targets, a high renovation depth is crucial. The share of deep ("nZEB") renovation in the renovation activities increases in our scenarios to only about 25% under BAU-policies and to about 50% under policy scenario 3. Although 50% of deep ("nZEB") renovation would be a strong improvement compared to the current state, we want to emphasise that the remaining 50% are locked-in for more substantial improvements until the middle of the century. Thus, the activities to improve high quality renovation, leading to substantial savings per floor area, have to be substantially increased.

[53] CO_2-emission factors for electricity generation have been developed with the model POLES and corresponding scenarios. For more details see the ENTRANZE report "Policy pathways for reducing the carbon emissions of the building stock until 2030".

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The cumulated investments in building renovation (improvement of building envelope, without heating systems) varies from about 1,150 billion Euro in scenario 1 (low energy prices) to 1,975 billion Euro in scenario 3 (high energy prices) and thus would be a relevant push for the European overall economy. These results confirm that a macro-economic evaluation of policies in the building sector should also be taken into account in the policy decision making process.

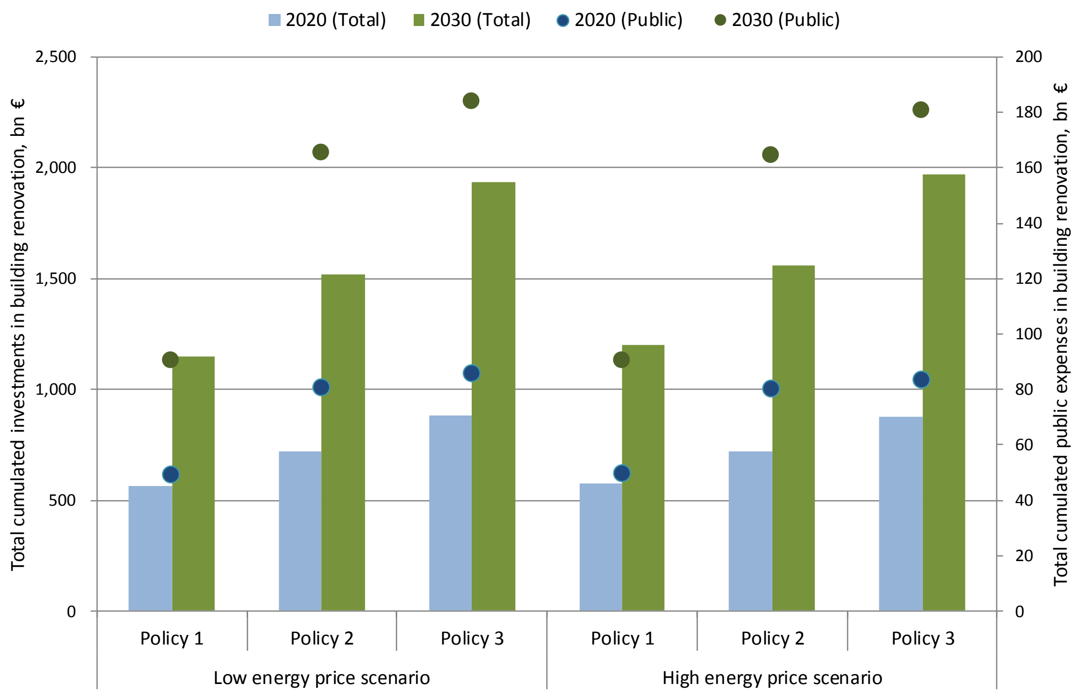

Figure 41. Total cumulated investments in building renovation from 2008 to 2020 and from 2008 to 2030 and total cumulated public expenses (investment subsidies and soft loans) in building renovation in EU-28

7.5 Uncertainties and open questions

Uncertainties are an intrinsic element of every modelling approach. So, the interpretation of results and the formulation of conclusions and recommendations should be done in careful consideration of these uncertainties. Hence, in the following part we will list and shortly discuss the most relevant of these open points and related questions.

- In **policy scenario 1**, for most target countries and on the level of EU-28 current policies remain in place and we assumed at least some **ambition to implement the EPBD-recast.** However, we should also take into account that a failure in the implementation of the EPBD is still possible and Member States could also reduce their current efforts, e.g. regarding financial support of build-

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ing renovation. Moreover, as we pointed out in chapter 5, a number of Member States die not yet definitely decide on the concrete implementation of the EPBD (e.g. in terms of nZEB definition). These aspects could lead to the results that the significant amount energy saving under current policies (more or less reflecting policy scenario 1) from 2008-2030 could also be lower than indicated in this report.

The role of different heating systems and energy carriers

- We assumed a certain concrete implementation of the renewable energy directive regarding the **accounting and reporting of ambient energy**.[54] However, in practice there are uncertainties how to determine the seasonal performance factor of heat pumps with different types of heat sources (e.g. air source vs. ground source heat pumps) and installed in different types of buildings (e.g. with low temperature vs. high temperature heating system). Moreover, the results depend strongly on the primary energy factor of electricity generation, which was derived from POLES scenarios and which was not in the key focus of this project. So, the amount of ambient heat reported by Member States in the frame of the renewable energy directive very well could also be higher or lower, even with the same amount of heat pumps installed.
- The **role of district heating** depends on a number of complex interactions of impact factors like energy related spatial planning, the investment strategy of district heating companies, the (currently low) economic effectiveness of CHP, the development of heat densities in various regions etc. In ENTRANZE, our focus was on the building side and on investment decisions of building owners regarding the choice of renovation packages and heating, hot water, cooling and lighting systems, not on the development of district heating grids and not on specific policies for district heating. Thus, the results for district heating might be revised when taking into account the modelling of grid expansion.[55]
- With the market slowdown of **solar thermal** in the past years (Observ'ER, 2013) the further development is uncertain. The model calibration in periods with discontinuous to market development leads to ambiguities. Our results for solar thermal reflect the assumption that markets for solar thermal under gener-

[54] See documentation of the methodology in the report "Pathways for reducing the carbon emissions of the building stock in the EU28 until 2030" (Kranzl et al., 2014b), http://www.entranze.eu/pub/pub-scenario

[55] In this context we want to refer to the H2020 project "Supporting the progress of renewable energies for heating and cooling in the EU on a local level (progRESsHEAT)", which will start early 2015.

ally favourable market conditions would lead back to a market growth as it has been the case until around 2008. However, this assumption might be too optimistic in particular in the view of low learning effects and the growing competition with more attractive technologies like PV (in contrast e.g. to PV almost no cost reductions were achieved in the past years for solar thermal collectors).

- **Biomass** currently is the dominating renewable energy source for heating. A relevant share of this amount is covered by old, inefficient stoves or boilers. Examples from the past have shown that countries with a high tradition in biomass heating often shift to modern, more efficient types of biomass heating. However, this will depend on cost development, availability of high quality equipment and qualified staff, support policies, dust emission regulations, trends and the migration from rural to urban regions. Even more, in the long term, towards 2050 and beyond the crucial question arises of optimal biomass allocation for different energy related and non-energy related end-uses.
- **Small scale on-site PV systems** turn out to be either economic effective or very near to economic effectiveness, in particular in southern countries, if the design of the systems is carried out in a way to allow the replacement of household electricity consumption by PV and export only a low share of PV to the grid. Thus, the scenarios show a robust market growth of these technologies. However, still there might be non-economic barriers and barriers in the information of users, in particular also barriers for the financing of PV installations.
- **Power to heat** might play a relevant role in future energy systems with a high share of volatile renewable electricity generation. There are several options for power to heat in large scale heat pumps integrated in district heating grids or small scale systems within buildings. If power to heat will become more relevant, this could provide an additional incentive for heat pumps. Since the link between heating and electricity system was not part of the ENTRANZE project we leave this question for future research.
- In a few countries, first of all Poland, **coal** still covers a significant share of space heating energy demand. Due to our results, coal would decrease strongly, not only in ambitious policy scenarios but also in policy scenario 1. This is the result both of economic considerations and non-economic barriers (comfort aspect etc). However, part of the coal for small scale end-uses is traded in informal markets and thus is economic effective. Moreover, if there is a high tradition with solid fuel heating, people might be used to it and the barriers and comfort requirements might play a different role. Since Poland was no target country, it was not possible to investigate the future role of coal in more detail in this country. However, we consider this question as worth to be further analysed in future studies.

Input data and drivers

- In general, all type of **input data is related to some amount of uncertainty and different levels of reliability**. E.g. building stock data, in particular the amount of previously renovated buildings remains an open issue. Almost no countries do have sufficiently reliable data available regarding renovation activities or even more regarding renovation depths. This is a considerable source of uncertainty. Thus, data availability – also in order to allow for a proper monitoring of policies – should be strongly improved, if possible in a consistent European building stock data observatory.
- Future **development of the building stock**, number and distribution of floor area, migration between regions within Europe and within countries are important drivers. We assumed that floor area will develop mainly according to the demographic development in different countries and that the newly constructed dwellings slowly adapt to the same levels across Europe. New buildings are much less relevant for overall energy demand compared to existing ones. However, still these assumptions drive the results.
  In some target countries (e.g. Finland, Romania) we distinguished between rural and urban regions, since this turned out to be relevant for specific policy questions. However, we did not investigate the impact of such a split in all target countries.
- **Data regarding cooling** energy needs, final energy demand for cooling, penetration of cooling devices in the building stock are hardly available. We relied on several data sources from the literature[56]. However, official, national statistics have large gaps in this field. Even more, the possible future diffusion of cooling devices is highly uncertain and strongly drives the future demand of cooling energy demand.
- **Energy prices** play a relevant role in the incentive structure for building renovation and heating system choice. We built on POLES scenarios regarding the future development of energy prices. However, prices could very well develop also outside of the range which we have covered (labelled with low vs. high energy prices above).
- We dedicated an important part of this project on the investigation of **barriers and drivers** for investment in energy efficiency in the building stock. However, these barriers may substantially change in periods of **economic crises or even shocks and discontinuous economic development**. In particular in countries like Spain, the question of availability of capital to carry out renovation

[56] See the report “Pathways for reducing the carbon emissions of the building stock in the EU28 until 2030” (Kranzl et al., 2014b), http://www.entranze.eu/pub/pub-scenario

measures for different groups of building owners is crucial and would need further investigation.

Modelling approaches and considered aspects

- The model Invert/EE-Lab endogenously models the **impact of rebound effects**, e.g. when it comes to the replacement of manually fed solid fuel single stoves by central heating systems or comfort increase after increasing the thermal performance of the building envelope. However, these approaches have been calibrated on data from countries like Germany and Austria. In countries like Bulgaria, the relevance of increasing comfort and rebound effect might be much higher and different. Further research on this question would be highly important to correctly estimate this effect and derive the corresponding policy recommendations.
- **Training, qualification measures, R&TD, awareness raising** etc are important measures and should have a direct impact to cost of technologies and renovation packages as well as their actual impact on energy performance. However, there is little empirical evidence on the quantification of these effects. Thus, there are still open questions how to consider these aspects in quantitative modelling work as done in this project with Invert/EE-Lab.
- It has been shown that **climate change** will have an impact on future heating and cooling energy demand. For our scenarios, we did not take into account climate change signals but rather assumed a constant climate. The temperature change signal in most climate models and climate change scenarios remains ambiguous until around 2030, which is the time frame of the ENTRANZE scenarios. Only towards 2050 and beyond, the climate signal towards increasing temperature levels becomes unambiguous and significant.
- The **impact of Invert/EE-Lab results on international prices** of oil, gas or coal can be neglected: even if the fuel demand in EU buildings was much lower than simulated in Poles this would not really change the volumes of oil, gas or coal exchanged on the world market (marginal effect). Concerning **electricity**, the situation is different as the power mix is more dependent on each country situation and in particular on its power demand. Since the share of electricity in the heating sector for France is quite large, we investigated the possible feedback loop of electricity demand scenarios in the heating sector for this country by the model POLES. The result was that the price effect of electricity demand scenarios from Invert/EE-Lab in POLES was very small and in fact negligible.[57]

[57] See the report “Pathways for reducing the carbon emissions of the building stock in the EU28 until 2030” (Kranzl et al., 2014b), http://www.entranze.eu/pub/pub-scenario

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This led to the conclusion that this feedback loop can be neglected. However, due to budget restrictions we were not able to analyse this in more detail and also for other countries. Thus, there are still questions open regarding the impact of heating energy demand scenarios on other energy markets on the European scale.

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8. Recommendations

The data collection regarding the EU building stock, the analysis of stakeholder behaviour and decision criteria, the cost-optimality analyses, the detailed policy analysis and the development of scenarios simulating the potential impact of policy packages led to a wide range of recommendations. These recommendations were also subject to an in-depth discussion and communication process with experts and stakeholders, in particular in the policy groups of the project ENTRANZE. In the following, we describe the key recommendations derived from the ENTRANZE results and the discussion process. The policy recommendations address three different levels: (1) policy guidelines applicable to all EU member states (and beyond) (2) Specific recommendations for target countries; they are mainly included in the country reports on policy scenarios and recommendations[58] and thus will only be summarized shortly; and (3) recommendations to the European Commission.

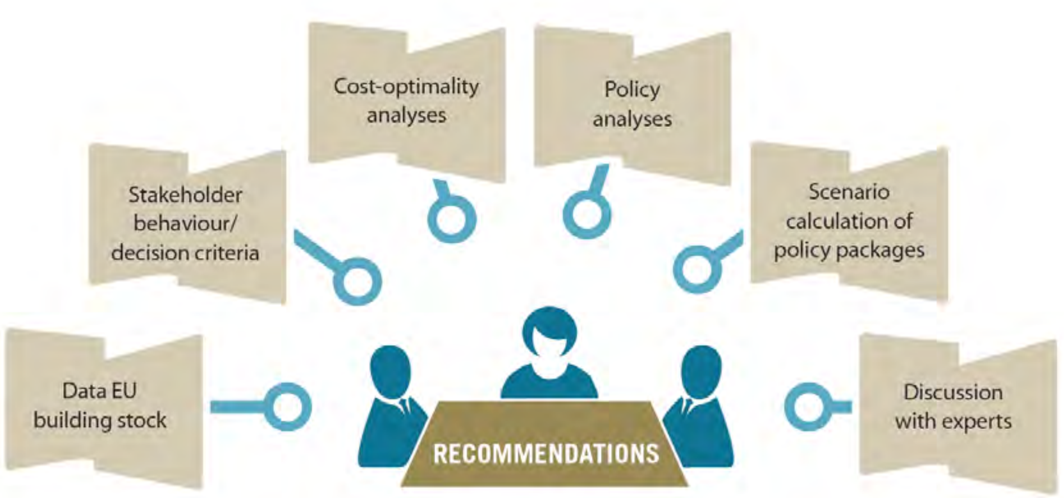

Figure 42. Elements for deriving policy recommendations in the project ENTRANZE

58 http://www.entranze.eu/pub/pub-scenario

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8.1 Creating an effective target oriented policy environment with a clear focus

- Policies should be **target oriented**.
  Policy intensity and specific design of instruments should be in line with and sufficient to reach mid- and long-term targets regarding CO_2-emissions, primary and final energy demand in the building sector. However, currently only a few countries implemented unambiguous targets until 2050 which is a considerable barrier for target oriented, effective policy making.

- **Long-term and ambitious targets** for the building sector up to 2050 are needed that provide targets on nZEB-buildings with intermediate steps.
  To design efficient policy instruments the targeted CO_2-emissions or the targeted energy consumption of the building stock has to be defined. The target definition should be properly balanced between indicators like CO2-emissions, primary and final energy demand or RES deployment. Moreover, the targets for the building stock should be embedded in a coherent target scenario and vision of the overall energy system's development. In many MS there are no targets at all, or often there are not consistent with long term climate mitigation targets. Targets are also necessary to evaluate the impact of a policy instrument. Interim targets are necessary to design suitable instruments and to monitor the attainment.

  E.g. in Germany there are clear targets for the reduction of energy demand of the building stock: By 2050 a reduction of primary energy consumption by 80% shall be achieved. Moreover, intermediate targets are set.

- **Focus on deep renovation of existing building stock** and avoid lock-in effects
  So far some MS mostly targeted new buildings, e.g. by building codes. There should be put more emphasis on policies addressing efficiency and RES-measures in *existing* buildings.
  Deep renovation activities targeting high energy standards up to the nZEB-standard should be stimulated. This is necessary to reach the long-term-target for CO_2-emission-reduction of the EU for 2050. The simulation runs showed that the current policy instruments do not provide sufficient incentive for high renovation depth. Even in ambitious scenarios a considerable share (about 50%) of renovation activities until 2030 is not renovated towards a level which could be called "nZEB renovation". We have to be aware that these buildings are locked for further efficiency improvement for the next decades.
  Deep renovation should also include long-term compatible staged renovations. Building specific renovation roadmaps are an effective means for ensuring a target oriented execution of staged renovation over a longer period.

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- **Long term signals** to the market are necessary.
  Policy and regulatory framework should be stable and predictable (avoiding stop and go). This is important not only to ensure investment security but also for developing know how and trained staff.

- **Macro-economic benefits** of building policies should always be considered when designing an instrument.

8.2 Effective set-up, implementation and monitoring of policy packages

Guidelines for the effective design of policy packages

- **A bundle of instruments** is required to properly address the often heterogeneous target groups and/or technology specific barriers at the same time. The focus on a single instrument is not sufficient.

  The example of the current Bulgarian policies show that subsidies remain ineffective if they are hampered by administrative barriers and a lack of trained staff. Integrated, target oriented policy packages are able to address these barriers and create a synergetic impact of different policy instruments.

- **Tailored instruments** are strongly recommended for increasing their effectiveness, limiting market distortions and fostering the market uptake.
  Policies need to reflect the national context including the building stock and ownership structure, target group specific barriers, climate conditions, demographic and migration, energy poverty aspects etc. in order to increase their efficiency and acceptance. Target group specific policies are required. Instruments addressing non-residential buildings should also consider different uses of the buildings.

  For instance the share of owner occupied dwellings in apartment buildings varies from less than 25% in countries like Austria or Germany to more than 90% in Romania or Bulgaria. Also the required majorities for the decision making of renovation of condominiums range from 50% to 75%. These differences have to be carefully considered in order to address specific barriers in an effective way.

- The mix of instruments must be adapted to the **maturity of the market conditions**, the investment potential and environment in the specific country. The policy mix has to be adapted to changes in the market, public budget available and cost structure. The mix of instruments also needs to be coordinated (e.g. different legislation, different funding programmes). Since the market conditions change in time, the policy makers face the challenge to adapt the policy packages to the market

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conditions and at the same time create a stable and foreseeable policy environment.

- **Innovative / good practices from other MS**, and local/regional authorities should always be considered. While they are not entirely transferable, elements of them can provide good solutions.

- Measures that address the **behavior** of the user have to be implemented with the same priority as technical ones. Especially information instruments could also focus on behavioral aspects influencing energy consumption of residential buildings like taking shorter showers, selecting lower indoor-temperatures, properly airing-out rooms during the heating period etc. Comfort requirements and rebound effects should be considered.

- MS should implement regulations that **distribute the costs in a fair way between landlord, tenant and the society**. "Fair" means, that refurbishment measures should not lead to a social misbalance, or to energy poverty while it should be ensured that there are sufficient incentives in place to conduct deep renovations.

Guidelines for the implementation of policies

- Proper implementation of policies is essential: **enforcement/compliance check** of energy regulations must be strengthened. Special budget should be dedicated to improve compliance and quality control.

  The ENTRANZE scenario results, in particular for the case of Germany, have shown the high relevance of compliance for effective policies. Tightening of regulations without increasing information and enforcement leads to a reduction of final energy demand in the year 2030 of about 20% compared to a frozen policy scenario. On the other hand, the scenario with simultaneously enhancing regulation and increasing information and enforcement may lead to a reduction of almost 50% compared to the case of frozen policies.

- The **commitment of all relevant stakeholders**, and proper information and advice to all market actors including building owners are strongly influencing the effectiveness of policies and regulations. Thus, a strong involvement of stakeholders in the policy design and implementation process is important, while it must not lead to a weakening of targets due to particulate interests.

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- As investors' **transaction costs** associated to renovation are often high and underestimated, there should be a focus on policy instruments minimising these transaction costs. This includes one-stop shops, independent energy advice and coaching, awareness raising, increasing the number of trained craftsmen etc.

  Moreover, also the specific design of support instruments can help to decrease transaction costs. For instance in Bulgaria, support programmes up to now did not turn out to be very successful, since the programme directly addresses the owners of the dwellings who together have to decide on the renovation and also care for the renovation process together. Even though there is an appointed project manager, the results depend strongly on the commitment of this project manager and overall this leads to high transaction costs for the owners. On the other hand, in Romania, the support programme provides grants to the municipalities who care for the whole renovation process. The latter case led to a much higher effectiveness and number of renovated buildings. However, also in Romania there are claims that the design of the programme leads to a low level of building owner's involvement and related drawbacks. Overall, it becomes clear that the impact on transaction costs should be carefully taken into account in the policy design (and monitoring).

Guidelines for monitoring and evaluating policies

- **Monitoring and evaluation** are key elements for enabling the policy sector to improve implemented instruments and react to undesirable effects if necessary. That's why the policy measures should always include monitoring and evaluation of its impact.

- **Macro-economic benefits** of building policies should be acknowledged and included in policy evaluation and monitoring processes.

- Using a **common methodology for the evaluation of supporting schemes** and a close cooperation of responsible stakeholders could improve the quality of the evaluation process. Moreover, a common evaluation methodology in all MS would help to implement an efficient EU-wide monitoring.

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- **Data availability about renovation activities** including data on costs has to be improved. The current state of data availability to track the effectiveness of policies, in particular regarding renovation activities, by far is not satisfactory[59]. Suitable instruments to collect data must be implemented; comparable data should be exchanged on EU-level.
  It should be acknowledged that data from a comprehensive building registry linked to energy performance certificate database are also a precondition for some policy instruments (e.g. property tax related to energy efficiency). Thus such registries should also be consistent with the requirement of these type of policy instruments.

8.3 Recommendations by type of instruments

Besides the general policy guidelines listed above, the following general recommendations **by type of instrument** have been derived from ENTRANZE results. As indicated above, policy packages always need a proper balancing between all these different types of instruments:

Economic instruments

- **Incentive schemes** for thermal building renovation should be adjusted to the achieved energy efficiency standard, possibly combined to the amount of energy saved. The policy scenario modelling has shown that deep, high quality renovation needs higher incentives than standard renovation to be effectively stimulated. Thus, technology specific support levels reduce free rider effects and overall support program costs.

- **The level of support** should orient towards the market maturity of a region. High initial levels of support always need to be accompanied by training activities of staff, technology and market development. A dynamic decrease of these support schemes should be envisaged as soon as the market allows to do so.

  For instance, the policy scenarios for Romania have shown how the dynamic, stepwise shift of high support levels to more target oriented measures and soft loans can lead to substantial progress in building renovation and more effective and efficient policies.

[59] In this context projects for tracking the market maturity and progress of nZEB activities should be enhanced, e.g. like in the IEE project ZEBRA2020 (Nearly Zero Energy Building Strategy 2020, http://zebra2020.eu/)

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- **Energy/CO_2 taxes** and cost-intensive instruments (such as renovation obligations etc.) should be accompanied by complementary measures to alleviate the effects especially for low income households. Moreover, technology specific incentives and regulatory schemes are required to address the heterogeneous barriers effectively. In particular, progressive energy taxation (e.g. per capita or per dwelling) should be considered more strongly in order to avoid undesirable social imbalance and at the same time provide effective incentives for renovation of those buildings with a high energy consumption .

  The policy scenarios for the cases of France and Finland revealed that technology specific incentives are required in order to avoid lock-in effects by short-term reaction to carbon prices where investors might not reflect the long-term horizon of the targeted improvement of energy performance. Both scenarios with energy taxes led to only moderate additional energy savings while target oriented policy packages increased renovation activities and energy savings much more effectively. In particular the case of Finland showed that energy taxes mainly lead to a shift of energy carriers and heating systems and do not significantly incentivize building renovation of the building envelope.

- **Property taxes depending on building's energy performance** can provide effective incentives for renovation activities. However, this requires reliable and comprehensive data in the building registry. Thus, these databases should be further enhanced and they should be designed to support possible future taxation instruments which are based on the building's energy performance.

  The Austrian scenario example showed that the effective implementation of such an instrument, combined with a package of other instruments can trigger additional energy savings of about 7% in the period from 2008-2030. However, open questions remain regarding the availability of corresponding building data (if no energy performance, even age of the buildings or time since last renovation) and administrative costs.

Regulatory instruments

- The tightening of **building codes** should be combined with compliance instruments.

  The case of the German policy scenarios has shown that a stand-alone enforcement of building codes and regulations (i.e. without additional information and compliance measures) only leads to moderate exploitation of the energy efficiency potential. For an effective reduction of energy demand, additional compliance and information measures are required.

- **Renewable heat obligations** (in line with Art 13 of the renewable energy directive) should be enhanced. Substitution measures for improving the energy performance of the building can be foreseen.

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- Building codes could and should also integrate the installation of **low-temperature central heating systems** (for new buildings and stepwise also for building renovation) since this is a precondition for efficient, modern RES-H supply.

- There could be **mandatory renovation requirements** in case of change of ownership.
  The policy scenarios for France showed that this can be a very effective instrument to increase the renovation rate. For increasing renovation depth and quality, additional incentives are necessary. Moreover, there should be special accompanying measures for low-income households and building owners.

- At local level, building policies (both for new and renovation) should be inter-linked to **spatial planning** and other community level policies (such as for district heating, expansion of gas distribution networks, urban heat island mitigation effects, cool surfaces, green areas etc.)

- The relation between **building codes** (regulatory schemes) and requirements to receive support schemes has to be properly balanced.

- **Building specific renovation roadmaps** could be suitable to trigger renovation activity. For instance, owners of old buildings (e.g. older than 40 years) which have not yet been renovated could be obliged to set up a renovation roadmap which has to be implemented. Building specific renovation roadmaps can also serve as information instruments. Finally two levels of obligation could be introduced: (1) an obligation to develop a renovation roadmap and (2) an obligation to implement the content of the roadmap.

Information / Motivation / Advice Instruments

- **Coaching building owners** during building renovation is essential and should last until the renovation is completed. Building owners often are overstrained with the organization of a complex renovation process and with coordinating and negotiating different craftsmen. Thus, coaching should go beyond usual advice and should be more intensive and cover the whole renovation process.

- If **building specific renovation roadmaps** (mentioned above) are not implemented as a mandatory scheme, they can serve to increase the awareness and information level during energy advice programmes. Building specific renovation roadmaps should provide a clear guideline how to improve the energy performance of a building towards nZEB standard either in a single major renovation activity or in step by step renovation over the coming years (or even decades).

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Supply side / Qualification Instruments

- **Training and qualification** of all 'blue and white collars' involved in the building sector is a must (i.e. from workers to engineers and architects) and a key factor for the success of policies.

- Investment in **R&D** to reduce costs of technologies is necessary

- **Public procurement** for RES-H and energy efficiency technologies can help to reduce the costs, e.g. when it comes to technologies for passive house refurbishment.

  The example of the Finnish policy scenarios showed that the shift from direct electric heating to water based central heating (based on heat pumps, solar thermal or biomass) is a key precondition for reducing CO_2-emissions and increasing primary energy efficiency. Common, large scale procurement of water based central heating systems or passive house technologies could help to reduce the costs significantly and thus it could stimulate this heating system shift.

Legal framework

- Adapting property law and tenancy law can have a signficant leverage effect. In particular this is the case for countries with a high share of privately owned dwellings in appartment buidlings (e.g. Romania or Bulgaria).

8.4 Recommendations by heating technologies

Different heating and hot water technologies are associated with different costs, barriers, opportunities and challenges. These should be carefully considered in the design of policy packages in order to avoid lock-in effects, take into account possible rebound effects and reduce unwanted side effects.

- With almost 90% of RES-H **Biomass heating** currently (2012) provides by far the largest share of renewable space heating and hot water in EU28 (Observ'ER, 2013). One of the key challenges is the stepwise replacement of outdated single stoves with low efficiency and high emissions by modern systems. However, it also has to be acknowledged that this change usually is connected with substantial rebound effects. Overall, for the further expansion of biomass, more and more the limited availability of biomass or competing utilization should be considered as well as unwanted fine particulate emissions especially in urban regions. Due to the high

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share of biomass which is currently used in the heating sector, biomass heating has to be carefully integrated into any kind of strategic plan of using biomass resources.

- About 8% of RES-H is currently (2012) covered by **heat pumps**. About three quarters of these installations are air source heat pumps. This high relevance of air source heat pumps is also reflected in the market statistics of new installations. Considering that only a part of these heat pumps is installed in buildings with low temperature heating systems, the achievable seasonal COP and thus overall primary energy efficiency remains a crucial issue. Special attention should be put on an effective integration of heat pumps in **low-temperature heating systems** and special support programmes for ground source heat pumps.

- The market for **solar thermal collectors** slowed down strongly in the past few years. There seem to be different reasons for that, partly the economic crisis. The future role of solar thermal on the heating space heating and hot water sector remains an open issue, in particular with the strong growth of PV which gains more and more economic attractiveness. Additional support measures will probably be required in the coming years if policy makers want reach the targets for solar thermal according to the national renewable energy action plans. (Observ'ER, 2013)

- The relevance of **low temperature heating systems** has been mentioned above regarding the impact on achievable COP values of heat pumps. Even more, low-temperature heating systems also form a basis for high solar fractions in solar space heating systems. Thus, the shift from single stoves or direct electric heating to central heating systems is not only one of the preconditions for modern and efficient renewable heating but provides also the potential for substantial comfort gains. However, it has to be noted that this also leads to rebound effects.

8.5 Selected examples of country specific recommendations

Based on all the previous work during the ENTRANZE project, especially the discussions in the policy group and the scenario calculations, we developed recommendations for policies and instruments that are suitable to increase the energy standard of the building stock and finally the number of nZEB in the target countries. Results of this process are country specific recommendations for the target countries that mirror the different frame and conditions in these countries. On the other hand during the discussion within the project consortium there have been identified policy guidelines that are applicable to all member states.

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In each of the target countries different types of instruments (see chapter 5.4) have been analysed.

The following Table 7 summarizes the key recommendations in target countries.[60]

Table 7. Key messages, overview and examples of recommended instruments in target countries

Type of instrument	Key messages from scenario calculations	Examples for recommended instruments
Information	Information/advice alone is not sufficient -> involving citizens, coaching, "one-stop-shops" etc. are key (AT, FR, ES, RO, DE)	• One-stop-shops for building renovation should be set up by the companies obliged to initiate energy efficiency measures (AT) • Owner-occupied multifamily apartment buildings that are due for major renovations (e.g., buildings that are 35 years of age) are identified, e.g. by using the building registry, and tailored on-site advice is provided (FI) • Building specific renovation roadmaps, (which alternatively could also be a mandatory instrument), (AT)
Regulation	Regulatory instruments (e.g. building codes) need to be properly implemented (enforce compliance!) (RO, ES, DE) All scenarios achieving high savings in energy demand and CO_2-emissions include also a strong regulatory component. Thus, effective policy making requires also the consideration of strong regulatory instruments (e.g. DE, ES, FR, RO).	• "Mandatory" renovations (when economically feasible), can be enforced at the occasion of real estate transaction and heavy non-energy renovations (FR) • Tightening of minimum requirements in building regulations, especially for existing buildings (ES) • Creation of suitable and cost efficient enforcement instruments for the national implementation of the EnEV (DE) • Implement use obligation of RES-H in case of boiler replacement in existing buildings combined with the introduction of a maximum boiler age (DE)
Economic: tax based	Price signals can trigger savings if they are sufficiently high (FI, FR) Unexpected effects of price signals need to be thoroughly analysed -> additional technology specific instruments are necessary (FI, FR)	• Energy and CO2 taxes may create an additional incentive but should be accompanied with additional instruments; otherwise, high taxation levels would be required to achieve ambitious targets, which might not be politically acceptable (FR, FI) • Energy efficiency dependent property tax can trigger thermal renovation but needs a comprehensive and reliable database on the building stock; thus, a thorough improvement of building registries in combination with energy performance certificate databases is required (AT)

[60] The recommendations for the ENTRANZE target countries are presented in more detail in country-specific reports available on the ENTRANZE website www.entranze.eu.

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Type of Instrument	Key messages from scenario calculations	Examples for recommended instruments
Economic: grants / soft loans	In countries with high interest rates, preferential loans may be attractive (RO) Proper balancing of subsidy rates is crucial (RO, IT) Subsidy levels should be take into account the achieved energy saving level (DE)	• Short-term investment subsidies for building owners directed e.g. towards solar heat and power in order to open up the market, give their diffusion a boost, and start the learning process in installation services which will eventually bring down installation costs. (FI) • Create a national energy efficiency fund for buildings around the actual preferential loan scheme managed by CEC Bank (public bank) (RO) • Additional subsidies for low temperature heating systems; increase the funding of KfW-efficiency house 70 and better and cease funding of KfW 100 houses and worse (DE)
Supply side, qualification	Market transformation, R&D and qualification instruments are essential to support the formation of an energy efficiency market (all target countries)	• Establishing qualification and training schemes for white and blue collars from the construction sector, strong need of improving qualification and skills of workforce for coping to nZEB needs (RO) • Address the training sector (ES)
Cross cutting, general recommendations	Data availability about renovation activities and the building sock should be improved (all target countries) Cooperation/exchange between MS should be strengthened (all target countries)	• Introduce a scheme for nZEB renovation of public buildings (RO) • Improve the role of public buildings as best practices (DE) • Establish a long term dialogue between all relevant stakeholders and decision makers (CZ)

8.6 Recommendations on EU level

A result of the work in the ENTRANZE project was the conclusion that the EU framework for the improvement of energy efficiency in buildings and the increase in the number of nZEBs is not sufficient yet. The project conclusions of the different tasks and the recommendations in the ENTRANZE target countries revealed quite a few shortcomings at MS level resulting from an insufficient and partly ambiguous framework at EU level. Differences between MS are high, and in general policies should accommodate genuine differences. The EU legislation should also try to highlight the opportunities in common policies more strongly. The reporting effort in MS could be reduced by providing sufficient, clear and harmonised reporting templates. This would also reduce the effort for evaluating the reports.

Partly, these recommendations are directly based on the analyses and modelling results in the project ENTRANZE. Partly, they are the result of the extensive discussion process with policy makers, experts and within the consortium. And last but not least

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they partly are also based on similar ongoing projects and their results, like Cohereno, Episcope, Atanasiu et al., (2011) or Hermelink et al., (2013).

The recommendations shown in the figure below have been elaborated.

Figure 43. Recommendations at EU level

- **Savings targets for the building sector are needed**

Quantitative savings targets for CO_2-emissions, primary and final energy demand including intermediate targets for the building sector are needed to specify what level of efficiency should be targeted by the policies. There should be a close link to the existing 2030 efficiency target and the 2050 climate mitigation target. Clear targets by 2030/2050, potentially binding, will provide more motivation and guidance to the policy making process from the EU MS and may stimulate positive ambitions and shared actions.

- **Implementation and compliance is the key**

Proper implementation of policies such as EPBD, EED, and RED is vital for ensuring their impact. While formal transposition of the EU legislation is pursued by the European Commission, the implementation and real impact of specific requirements is mainly in the jurisdiction of the EU MS. Additionally implementation and impact are not always sufficiently monitored. Therefore, while the EU legislation increases complexity and currently includes many necessary ‘ingredients’ for boosting the buildings towards higher energy performance, in almost all EU countries there are failures in properly implementing the requested measures. Consequently there is a serious risk of falling

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short in reaching the anticipated impact of EPBD and EED. Therefore the country-reporting to the Commission should be improved: it should include more evidence on the existence of viable capacity and control mechanisms at country level and on the actual delivery of energy and carbon savings, e.g. also an indication of the budget spent for compliance and monitoring measures or the reporting on measures like mandatory quality check of construction and renovation activities, e.g. by thermographic images. A clear and EU-wide harmonised monitoring scheme is recommended.

- **The EPBD should be more precise and more demanding**

With the 2010 recast of the EPBD (2010/31/EU) the concept of cost-optimality has been introduced. Member States had to set their energy performance and thermal requirements for buildings and components in accordance with cost-optimal levels determined by applying a harmonised EU methodology. As a consequence, the cost-optimal calculations reveal that no changes are necessary in some MS with a history of integrating energy requirements in their building codes. However, in other MS with less experience in implementing energy related requirements for buildings, the cost-optimal calculations show more important deviations compared to actual regulations.

In a brief analysis of the nZEB reports for the EU Commission we found that most of the EU MS equate the cost-optimal level with the nZEB level. Following this rationale, the impact of the nZEB requirement in the EPBD is reduced significantly and does not present a breakthrough for more ambitious standards for new buildings. We, however, believe that the EPBD should be interpreted in such a way that nZEB levels should be at least cost-optimal, and not be limited to cost-optimal levels.

This means that whereas nZEB-levels which are based on a very low to almost zero energy consumption, may not be cost-effective today, but by 2020 they could be. Therefore, the EU MS should aim at more ambitious nZEB levels and measures to achieve their cost-effectiveness by 2020 should be presented in the nZEB plans.

Thus, an enhanced legal framework should make clear that **cost-optimality has to represent the absolute minimum requirements for existing regulations** in the building codes. **While nZEB energy performance levels should be cost effective, they still have to be more ambitious than cost-optimal energy performance levels.** Thus, an enhanced EPBD has to be very precise in asking MS to present plans to close the gap between nZEB target levels in 2020 and cost-optimal levels of current building codes. Examples from, for example, the Brussels-region have shown that strict building codes, combined with comprehensive advice and coaching instruments may lead to a closing of this gap[61].

[61] For more details see the excursus on the Brussels region in chapter 5.1.

The definitions and conditions in the EPBD under which renovations underlie certain requirements should be clarified; for example a clearer guidance for 'major renovation' and a definition of nZEB renovation should be given. Net yearly primary energy use is insufficient to characterise nZEBs; it is proposed to implement several indices for a more complete and correct description and ranking of nZEBs (Hermelink et al., 2013).

Also to be considered is a gradual increase of the binding character of nZEB requirements for existing buildings, too. A clear **definition of nZEB or deep renovation** is required (Atanasiu et al., 2013).

A clear framework stimulating renovation should be developed within the EPBD. One could think of implementing requirements to ensure that staged renovation measures have to be compatible with the modernisation of adjacent components and in particular with the long-term goals. Building specific renovation roadmaps or building passports could also be instruments which could be more strongly embedded in the EU legislation.

There are different approaches possible how to enforce building specific renovation roadmaps:

- *building owners would be legally obliged to create a building specific renovation roadmap which would serve as information tool, e.g. in case of a heating system change, in case that a building or dwelling is sold or rented etc.; the building owners would get the information when the specific components of the building should be renewed or renovated*
- *the creation of a building specific renovation roadmap as information tool could be the prerequisite to obtain public subsidies*
- *building owners would be legally obliged to develop a building specific renovation roadmap whose implementation would be mandatory (or could e.g. be linked to progressive property taxes)*
- *the creation and implementation of a building specific renovation roadmap could be a possible compensation if a RES-H obligation in case of heater exchange cannot be implemented due to technical or other reasons.*

More attention should be given to non-residential buildings. The legal requirements applying to residential buildings should be adapted to the specific use and characteristics of buildings.

There is a growing interest in having a harmonised EU methodology and framework for setting the energy performance requirements for buildings properly considering the cultural, climatic, economic and historical differences between MS. Whereas the EPBD (recast) was a first attempt to have a comparative framework within the EU MS, further enhancement of the legislation should go beyond that. Common monitoring activities of

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nZEB progress and market maturity, e.g. as currently developed in the IEE project ZEBRA2020[62], should be further enhanced.

With the common template for national plans, elaborated in Hermelink et al., (2013)[63], there is a profound basis for a better comparability and quality of national plans. This should be further and continuously checked in the next round of national plans to be submitted.

- **Renovation of public buildings and renovation plans according to the EED should be enhanced**

The results of the ENTRANZE project showed that the 3% renovation target of public buildings has a very limited impact. The weak definition of "public buildings" according to the Energy Efficiency Directive (EED) leads to the fact that in most countries only a small share of the building stock may fall under this definition. Therefore, a further extension of the scope of Art. 5 to all public buildings owned by the public sector, both at central and regional level, is necessary. In addition, Art. 5 EED indicates that the renovation of public buildings has to meet the minimum energy performance requirements in place. The minimum energy requirements in place are the ones required by EPBD Art. 7, i.e. in case of major renovations. Therefore, the renovation of public buildings may not be sufficiently ambitious to have 'an exemplary role'. In the next EED recast the Art. 5 of EED should clearly specify that renovations of public buildings have to be undertaken at nZEB levels.

- Article 4 of the EED asks the EU MS to further elaborate long-term plans to support deep renovation of the existing building stock. Therefore, these plans can play a major role in fostering nZEB renovation if they are designed and take into consideration measures tailored towards or aiming at nZEB levels. Hence, more attention should be paid to and more guidance offered to MS to properly implement the long-term renovation plans as required by Art. 4 EED. In view of the long investment cycles, renovation plans should have a 2050 perspective and include a strategy for how the sector could be transformed in the long-term.
- Moreover, there is a lack of consistency in the terminology, e.g. of the term deep renovation should be clarified and quantitatively defined. At the moment there are two terms used: 'deep renovation' in EED and 'major renovation' defined and regulated by EPBD. Due to the lack of a definition for deep renovation in the EED, confusion often happens between the two terms[64]. Consequently, in

[62] www.zebra2020.eu

[63] Idem 39.

[64] A good example of the confusion between 'deep' and 'major' renovation is the revised work programme of Horizon 2020 on Secure, clean and efficient energy (an official document of

the next EED recast the term 'deep renovation' have to be properly defined or, alternatively, replaced by 'nZEB renovation' which can be immediately linked to the national nZEB definitions already in place.

- Energy efficiency funds as they are addressed in the EED should also be specifically dedicated to deep / nZEB renovation.

- **RES-H use obligations according to the Renewable Energy Directive (RED) should be strengthened**

The integration of renewable energy generation in buildings is requested by Article 13 of the Renewable Energy Directive (2009/28/EU) which stipulates that by 2014 all EU MS should consider specific minimum requirements in their building codes. So far some of the EU MS have implemented RES requirements in their building regulations. Most of the requirements address new buildings and mainly RES heating. For example, in Cyprus and to a certain degree in Portugal, solar thermal installations are mandatory for all new residential buildings and there are additional obligations for power generation from RES for new buildings. In some EU MS, solar thermal is compulsory for buildings with floor area or heat and water - consumption bigger than a certain threshold (e.g. Denmark, Belgium-Wallonia).

The scenario results show that the impact of RES-H use obligations remains very small if it is restricted to new buildings. A further strengthening of the implementation of Art. 13(4) RED for renovated buildings could increase the impact if one-off early effects and restrained investment behaviour can be minimised.

Thus, there is a strong need to **further enhance the requirements for RES-H in the building code, in particular for major renovation**, as required in the RED. Moreover, proper implementation shall be strengthened. At the current stage, it can be expected that this requirement will only be partly implemented in MS by the end of 2014. The EC should foresee special attention to the proper implementation of this article.

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the European Commission). Therefore, in the footnote 27 from page 15 it is mentioned that 'deep renovation should lead to a refurbishment that reduces both the delivered and the final energy consumption of a building by a significant percentage compared with the pre-renovation levels (c.f. Directive 2012/27/EU on Energy Efficiency). In the footnote 31 from page 18, it is mentioned that 'Deep (or major) renovation means the renovation of a building where: (a) the total cost of the renovation relating to the building envelope or the technical building systems is higher than 25% of the value of the building, excluding the value of the land upon which the building is situated; or (b) more than 25% of the surface of the building envelope undergoes renovation (Energy Performance of Buildings Directive)'. More at:

http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/main/h2020-wp1415-energy_en.pdf

- **The Energy Taxation Directive should be adapted to the needs of the building sector**

Energy taxation may contribute positively to the reduction of energy consumption in buildings. However, the scenario results for the cases for France and Finland showed that energy or CO_2-taxes alone are not expected to provide sufficient incentive. Rather, it also needs additional measures (as shown in the other recommendations). Moreover, at least a share of the revenue of energy and environmental taxation should be clearly dedicated to the support of end-use energy efficiency and renewables in buildings. This budget may furthermore finance an Energy Efficiency Fund as recommended by Art. 20, EED, a buildings renovation fund or schemes such as energy savings obligation for suppliers indicated by Art. 7, EED.

In particular, progressive energy taxation (e.g. per capita or per dwelling) should be checked strongly in order to avoid undesirable social imbalance and at the same time provide effective incentives for renovation of those buildings with a high energy consumption (Pagliano et al., 1999), (Pagliano et al., 2001).

- **The coordination and timeline between the different Directives and to the CEN activities should be improved.**

An improved and harmonised framework of indicators should be based on common CEN definitions and calculation procedures. As has been mentioned above, there are currently inconsistencies in the terminology used in the relevant Directives. It is necessary to further strengthen the synergies and convergence between EU Directives addressing buildings from different perspectives, such as energy, environmental, industrial, or social ones. Otherwise there is the risk of negative impacts, such as slowing down market development and creating a negative perception at policy and social levels.

- **Cooperation of Member States and development of consistent database should be intensified**

In the sense of the Concerted Actions, the EC should further increase efforts to better support the MS. So it could be helpful for the MS to provide more data about energy efficiency measures already implemented by all MS, or best practices respectively. So far there is no knowledge about the quality of the implementation of energy efficiency measures. Information from collected energy performance certificates could lead to a wider knowledge on the quality of renovation activities regarding energy efficiency and renewable energies, the number and quality of renovations as well as information about the current state of existing buildings.

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Moreover, there is a need to establish a transparent EU database reflecting the status and progress of energy performance of buildings and update it periodically on a statistic basis. In this way, the monitoring processes of implementing buildings legislation and longer-term planning will be consistently improved and simplified. Currently there are several EU projects dealing with the topic such as Odyssee-Mure, TABULA/EPISCOPE and ENTRANZE, but none of them is legally supported. Therefore the Commission should establish a transparent EU Buildings Observatory (including an online tool), which could be supplied by similar national observatories. The establishment of such observatories should be further considered at the next EPBD recast.

Using a common methodology for the evaluation of supporting schemes and EU-wide close cooperation of responsible stakeholders would improve the quality of the policy evaluation process. Options for a common evaluation methodology in EU MS could be further explored.

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