Policy pathways for reducing energy demand and carbon emissions of the EU building stock until 2030

D4.4 of WP4 from Entranze Project

Written by:

Lukas Kranzl, Andreas Müller, Agne Toleikyte, Marcus Hummel
Energy Economics Group
Vienna University of Technology

Jan Steinbach, Judit Kockat, Clemens Rohde
Fraunhofer ISI

Carine Sebi, Kimon Keramidas, Bruno Lapillone
Enerdata

Reviewed by:

Bogdan Atanasiu
Buildings Performance Institute Europe

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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.

The core part of the project is the dialogue with policy makers and experts and will focus on nine countries, covering >60% of the EU-28 building stock. Data, scenarios and recommendations will also be provided for EU-28 (+ Serbia).

This report documents model based scenarios for the heating, hot water, cooling and lighting energy demand under different policy frameworks. The scenarios were discussed in close contact with policy makers in the all ENTRANZE target countries, which are AT, BG, CZ, DE, ES, FI, FR, IT, RO. For these target countries, which cover more than 60% of current energy demand in buildings, we show detailed results. The results for other countries are documented in a more aggregated way.

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Content

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List of figures

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Co-funded by the Intelligent Energy Europe
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List of tables

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Executive Summary

ENTRANZE created a policy 'laboratory' to develop and analyse the potential impact of national strategies and policy sets to achieve targets regarding the implementation of nearly zero energy building (nZEB) standard and increase the energy performance of the building stock. A key element in this process was the development of scenarios of building related energy demand and renovation activities under different policy packages. This report provides an overview of selected policy packages and their potential impact in several EU Member States.

The scenarios cover the whole EU-28. However, not all activities were carried out at the same level of detail for all Member States (MS). In nine ENTRANZE target countries, the selection of policy packages was carried out in close cooperation and discussion with policy makers in a continuous dialogue. Although the specific design of policies differs by countries, there is a common logic: 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. The results of the model based scenario development was discussed with these national policy groups and experts and led to iterative improvement and adaptation of policy assumptions. These ENTRANZE target countries are Austria, Bulgaria, Czech Republic, Finland, France, Germany, Italy, Romania and Spain covering in total more than 60% of the EU building stock and all important climate regions.

The development of scenarios for space heating, cooling and lighting was based on two complementary models: Invert/EE-Lab and POLES.

Scenario results and derived policy recommendations for each target country are described in detailed country reports[1]. Moreover, overall policy recommendations applicable to all EU Member States and to the European Commission have been developed in the report "Policies to enforce the transition to nZEB: Synthesis report and policy recommendations from the project ENTRANZE."[1]

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%[2] of delivered energy[3] 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. Due to high fuel

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[1] Available at www.entranze.eu/pub/pub-scenario.

[2] Ranges indicated in this paragraph refer to the two energy price scenarios.

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

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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.

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.

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.

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[4] 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.

[4] 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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1. Introduction

What is the potential impact of various policy packages on future energy demand CO_2-emissions and RES-H share in the building sector? How to upscale energy renovation activities in the building stock at faster pace and higher energy savings? How strong is a certain policy option to deliver towards an already committed target? What combination of policies is more efficient in delivering a target? What are the key, fundamental differences of various policy packages regarding their impact and what are the conclusions for effective and efficient policy making?

These questions were the basic motivation of the project ENTRANZE for developing policy scenarios for enhancing the nZEB activities in buiding sector of the nine target countries and EU-28. For this purpose, within a continuous dialogue with policy makers and stakeholders we defined tailor-made policy sets on each country covered by the project. For these policy sets, scenarios have been developed by the model Invert/EE-Lab model while the overall energy system context had been defined with the POLES model.

This report documents methodological aspects and selected results of the scenario development. 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* (i.e. **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 scenario development was closely linked to the policy process and the other results and analyses undertaken in the project ENTRANZE such as the followings:

- 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[5].
- The results of the stakeholder analysis, related barriers and decision criteria of building owners carried out in the project ENTRANZE (Heiskanen and Matschoss, 2012; Heiskanen et al., 2013) were taken into account in the tech-

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

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no-socio-economic modelling of decision making regarding building renovation and heating system investment (Steinbach, 2013a).

- The cost data collected (Fernandez-Boneta, 2013) for the ENTRANZE target countries then 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). These three renovation levels are used as technological options within the model Invert/EE-Lab.

In addition to this report, the results of the policy scenarios are accessible via an **online-scenario tool**, allowing to display aggregate figures as well as detailed results. Moreover, for each target country there is a report available presenting the policy scenarios and key recommendations on country level[6].

The **objective of the scenario development** is not a prediction of future energy demand in the building stock, nor to identify maximum or economic potential for improving the energy performance. Rather, the objective of the scenario development is to **show the potential future impact of pre-defined policies** which are the result of an in-depth discussion process with policy makers. Thus, the modeling of policies should help to derive policy recommendations supporting consequent policy decisions.

The report starts with a description of analysed policy packages in chapter 2. Chapter 3 documents the key methodological aspects and sources for input data. Subsequently, we present the results of the scenarios in chapter 4 for target countries and in chapter 5 for EU28. We conclude with a discussion of uncertainties, open questions and an outlook in chapter 6. The annex includes detailed results of scenarios on country level.

Policy recommendations, which are based on these results are derived in the report "Policies to enforce the transition to nZEB: Synthesis report and policy recommendations" (Kranzl et al., 2014d).

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

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2. Policy packages

Based on the discussion process with policy makers, experts and stakeholders, three policy sets were selected in each target country. As described in the report "Policies to enforce the transition to nZEB: Synthesis report and policy recommendations" (Kranzl et al., 2014d) and the country reports on policy scenarios and recommendations[7], .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 the three following general criteria :

- 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

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.

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, we intended to select reasonable settings in the in-depth discussion process with policy makers. In particular, in some countries (e.g. Germany) the focus was on developing policies which are in line with 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.

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[7] Available at http://www.entranze.eu/pub/pub-scenario/]

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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.

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.

Table 1: Selected policy packages for model based scenario development

Country	Scenario	Title	Scenario and policy description
AT	1	BAU	This scenario investigates the currently implemented policy instruments. It focuses on investment subsidies, support to residential building construction and renovation (Wohnbauförderung), training and advice activities and to a smaller extent on RES-H/C use obligation.
AT	2	Moderate	This scenario includes a) an energy efficiency dependent property tax. Each building has to comply with certain standards which are increased dynamically. If the targets are not reached an additional property tax has to be paid. The maximum tax level starts with 1.1€/m²/yr in 2015 and increases to 3.7€/m²/yr in 2030. b) a fund for financing long term loans for building renovations initiated by the government in which enterprises and households can invest and receive a long term moderate, but highly secure interest rate. d) intensified and targeted coaching to support building owners in the refurbishment process.
AT	3	Ambitious	Same mix of measures as scenario 2 with a higher level of ambition. In particular, the property tax level starts with a maximum of 4.4€/m²/yr and increases to 14.8 €/m²/yr
BG	1	low	The scenario simulates the dynamic of building sector for the case if the current (to the year 2014) building measures are in place: Building performance requirements from 2009, limited financial resources for building renovation (EU and national funds, private investments), sporadic information campaigns and capacity building initiatives.
BG	2	medium	The scenario included the increase of the requirements for the building component in case of building renovation and for new buildings. Further legislative measures are applied for ensuring major renovation if the majority of owners in multifamily buildings agree on this. The level of EU funds and subsidies from the state budget and national funds are kept. Information campaigns for households are foreseen in order to ensure better understanding of the benefits from building renovation and process management.

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Country	Scenario	Title	Scenario and policy description
BG	3	high	The proposed measures in this scenario included legislative changes for the strengthening of the building code in 2015 (30% reduction of the U-values) and in 2020 (additional 20%) with changes in the home owners legislation in order to facilitate the process of major renovation of multi-family buildings. Higher grants are envisaged for the renovation activities for public buildings and use of RES for residential buildings. Low interest loans are introduced for renovation activities in the residential sector. The energy saving obligation scheme will ensure additional support for the building sector. Energy efficient activities in the sector are also supported through wider information campaigns and capacity building according to the roadmaps developed in Build up skills project.
CZ	1	Regulatory	Existing regulatory framework that corresponds to mandatory implementation of EPBD II and EED requirements, for instance: (1) 3% of floor area of central governmental buildings renovated annually; (2) nZEB implementation for new public buildings from 2018 and 2020 for private buildings.
CZ	2	Regulatory +Financial	BAU + current national supporting schemes (Green Investment Scheme PANEL 2013+ Operation Programme Enterprise and Innovation – Eco-energy and Operation Programme Environment according to priority axis 3 Sustainable use of energy sources).
CZ	3	Ambitious	BAU + nZEBs obligation from 2014 for both new buildings and major renovations for all building types. From 2020, requirements on nZEBs are strengthened.
DE	1	BAU	- Energy efficiency requirements as defined in the Energy Saving Ordinance (building code) in the current design (EnEV 2014) including the recent changes in the requirements for new buildings in 2014 and in 2016 - Renewable Heat obligation in new and existing public buildings (EEWärmeG) - KfW programmes Energy Efficient Refurbishment and Energy Efficient Construction with average budget of €1.5 bn/year until 2030 - Market Incentive Programme for renewable heat with average budget of €300 m/year.
DE	2	Regulatory	- Ambitious tightening of energy efficiency requirements for new and existing buildings in 2017 and 2025 - Expansion of the renewable use obligation to all existing buildings in case of heating system change in 2015 - Continuation of financial support with current budget and support levels: €1.5 bn/year for Energy Efficient Refurbishment/ Construction and €300 m/year for Market Incentive programme for renewable heating.
DE	3	Regulation & information	- Ambitious tightening of current energy efficiency requirements for new and existing buildings in 2017 and 2025 - Introduction of an renewable use obligation for all existing buildings in case of heating system change in 2015 - Continuation of financial support with current budget and levels as in BAU. - Increase in compliance rate of energy efficiency requirements and in information awareness of subsidy programmes.
ES	1	BAU	Existing regulatory measures (CTE DB-HE 2013) + existing financial instruments based (Royal Decree 233/2013) and reduced VAT for major renovations (from 21% to 10%) for all residential buildings owners

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Country	Scenario	Title	Scenario and policy description
ES	2	Regulatory	Tightening up to 2030 of the 2013 regulation (CTE DB HE 2013) for new buildings and major renovations of existing buildings + existing financial instruments (Royal Decree 233/2013) for all residential buildings owners +elimination of VAT reduction for major renovations in residential sector
ES	3	Ambitious	Tightening up to 2030 of the minimum mandatory requirements (CTE DB HE 2013) for new buildings and major renovation of existing buildings + increase funding from state budget for financial instruments for residential buildings + reduced VAT value for major renovations in residential sector (from 21% to 10%) +energy efficiency obligations according to Art.7 (EED 2012)
FI	1	BAU	Existing regulations and incentives are applied, with energy efficiency requirements for major renovations and subsidies for selected measures, as well as various informative measures.
FI	2	Target-group specific	Heating system changes are stimulated in single-family homes with a new soft loan instrument, enhanced advice and R&D to improve cost-effectiveness of certain measures. Personal advice is offered to all apartment buildings, almost all of which are supplied with district heat, when they have been used for > 35 years and hence approach major renovations. Further support is offered in the form of long-term finance and R&D for specific measures. Additionally, solar PV and solar thermal receive a subsidy.
FI	3	Energy pricing	Taxes are increased to raise the price of fossil fuels, heat and electricity paid by consumers by 50%, compared to BAU.
FR	1	BAU	The Business as Usual scenario simulates retrofitting rates triggered by the existing package of measures (implemented before 2013),
FR	2	CO2/energy tax	Takes into account BAU measures + Implementation of energy/ CO_2 tax with reallocation of revenue to finance retrofitting investments, in priority for dwellings occupied by low income households. The CO_2 tax reaches 100€/tCO_2 in 2030 (55€/tCO_2 in 2020). Electricity is taxed in the same way as gas. Implementation of dedicated information centers to help consumers retrofitting their dwellings ("PRIS").
FR	3	Proactive	Takes into account BAU measures + implementation of thermal renovation obligation during real estate transactions and major transformation to the least efficient dwellings + increasing information and awareness (Implementation of dedicated information centers to help consumers retrofitting their dwellings "PRIS")
IT	1	BAU+	Regulation requesting limits on building envelope, systems and overall energy performances at cost-optimal level: particularly, for deep renovations, the regulation requests savings > 50% and consumption < 100 kWh/m2/y (total net primary energy, excluding electrical appliances), or cost-optimal (minimum global cost) selected solutions at national level has to be adopted, if their net primary energy demand is lower. Minimum share of primary energy demand supplied with renewables, from 35% in 2015 to 50% in 2025. Regulatory instruments supported by a preferential loan covering 75% of initial investment for refurbishments, with an interest rate of 1%, valid for all buildings. In addition information campaign targeted on the preferential loans opportunity for all sectors.

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Country	Scenario	Title	Scenario and policy description
IT	2	Medium	Regulations as in BAU supported with economic incentives only for selected nZEB levels: tax deductions of 36% of investments for renovation, or an economic incentive for 40% of investment for all building types. Same preferential loan as in BAU but only for action at nZEB level. Information campaigns targeted on all incentives for all sectors. Minimum share of primary energy demand supplied with renewables, from 50% in 2015 to 75% in 2025.
IT	3	Improved	Regulations as in BAU. For all buildings, tax deduction for up to 65% of investments for renovation at nZEB selected level, or economic incentive for 40% of investment. Same preferential loan as in BAU but only for action at nZEB level with higher budget than scenario 2. Information campaigns targeted on all incentives for all sectors. Minimum share of primary demand supplied with renewables as in scenario 2 (50% in 2015; 75% in 2025).
RO	1	BAU+	Smooth but constant improvement of regulatory framework by 2030 Multi-annual budgets for support programmes. Continuation until 2030 of National Programme for thermo rehabilitation of block of flats with slight reduction of grant level and a slightly higher budget. Same structure for the actual renovation programme based on preferential loans and same 'random' approach on renovation of public buildings. Casa Verde Programme to support renewables in new and existing residential and public buildings. Limited programmes for qualification and training in construction jobs.
RO	2	Growing up	Moderate and constant improvement of regulatory framework.Multi-annual budgets for support programmes, double than in BaU+.Continuation until 2030 of thermo rehabilitation programme for block of flats with a moderate gradual reduction of grant level.Increase budget and expanded payback time up to 10-15 years for preferential loans for renovation (interest adjusted according to savings).New renovation programme for public buildings (grant for envelope measure and ESCO for equipment).Casa Verde Programme only for RES in new residential and public buildings.Consistent qualification programme for 'low-energy buildings'. Consistent info, advice and demo actions.
RO	3	Market transformation	Significant and constant improvement of regulatory framework by 2030. Multi-annual budgets for support programmes, triple than in BaU+. Continuation until 2030 of thermo rehabilitation programme for flats with a significant gradual reduction of grant level. Preferential loans programme with a payback time of 15-20 yrs. Renovation programme for public buildings same as in scenario 2. New Buildings Investment Funds from CEC Bank (public bank) integrating preferential loans, ESCO facility for public buildings and co-financing line for the thermo rehabilitation programme of flats. Casa Verde Programme to cover mainly ambitious low-energy buildings. Consistent qualification programme for 'low-energy buildings', improvement of professional and university education Consistent info, advice and demo actions, including one-stop-shops, info networks through municipalities and local agencies, info portal
EU28	1	BAU	Moderate policy ambition with moderate level of subsidies and available budget. No additional effort in information, qualification and training. No strengthening of regulatory instruments and only moderate enhancement of building codes. No innovation in the policy set

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Country	Scenario	Title	Scenario and policy description
EU28	2	New policies - moderate	Some effort in more innovative and consistent policy packages, however with a moderate ambition. Information, qualification and training is intensified. Regulatory instruments (RES-H obligation) and enforcement of building renovation are implemented. A moderate energy tax is introduced. Budgets for subsidies for building renovation and RES-H are increased moderately
EU28	3	New policies - ambitious	Strong effort in more innovative and consistent policy packages, with a high policy ambition. Information, qualification and training is intensified, leading to a comprehensive coaching and support of building owners. Split incentive is addressed in the legal framework leading to a reduction of this barrier. Regulatory instruments (RES-H obligation) and enforcement of building renovation are implemented. A high energy tax is introduced and accompanied with social measures to support in particular low-income households. Budgets for subsidies for building renovation and RES-H are increased

3. Methodology

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. Moreover, the results of the model Invert/EE-Lab were checked with POLES regarding the potential feedback loop on energy prices. In the following, we will provide a short documentation of these two models.

3.1 Invert/EE-Lab

Invert/EE-Lab is a dynamic bottom-up simulation tool that evaluates the effects of different promotion schemes (in particular different settings of economic and regulatory incentives) on the total energy demand, energy carrier mix, CO2 reductions and costs for space heating, cooling, hot water preparation and lighting in buildings. Furthermore, Invert/EE-Lab is designed to simulate different scenarios (energy prices, renovation packages, different consumer behaviours, etc.) and their respective impact on future trends of energy demand and mix of renewable as well as conventional energy sources on a national and regional level. More information is available on www.invert.at or e.g. in (Kranzl et al., 2013) or (Müller, 2012). The model has been extended by an agent specific decision approach documented e.g. in (Steinbach, 2013b), (Steinbach, 2013a).

The key idea of the model is to describe the building stock, heating, cooling and hot water systems on highly disaggregated level, calculate related energy needs and delivered energy, determine reinvestment cycles and new investment of building components and technologies and simulate the decisions of various agents (i.e. owner types) in case that an investment decision is due for a specific building segment. The core of the tool is a myopical, multinominal logit approach, which optimizes objectives of “agents” under imperfect information conditions and by that represents the decisions maker concerning building related decisions.

3.1.1 Coverage and data structure

The model Invert/EE-Lab up to now has been applied in all countries of **EU-28 (+ Serbia)**. A representation of the implemented data of the building stock is given at www.entranze.eu.

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Invert/EE-Lab covers **residential and non-residential buildings**. Industrial buildings are excluded (as far as they are not included in the official statistics of office or other non-residential buildings).

The following figure shows the disaggregated modeling of the building stock within each country. The level of detail, the number of construction periods etc. depend on the data availability and structure of national statistics. We take into account data from Eurostat, national building statistics, national statistics on various economic sectors for non-residential buildings, BPIE data hub, Odyssee, which are finally summarized in the ENTRANZE database (www.entranze.eu).

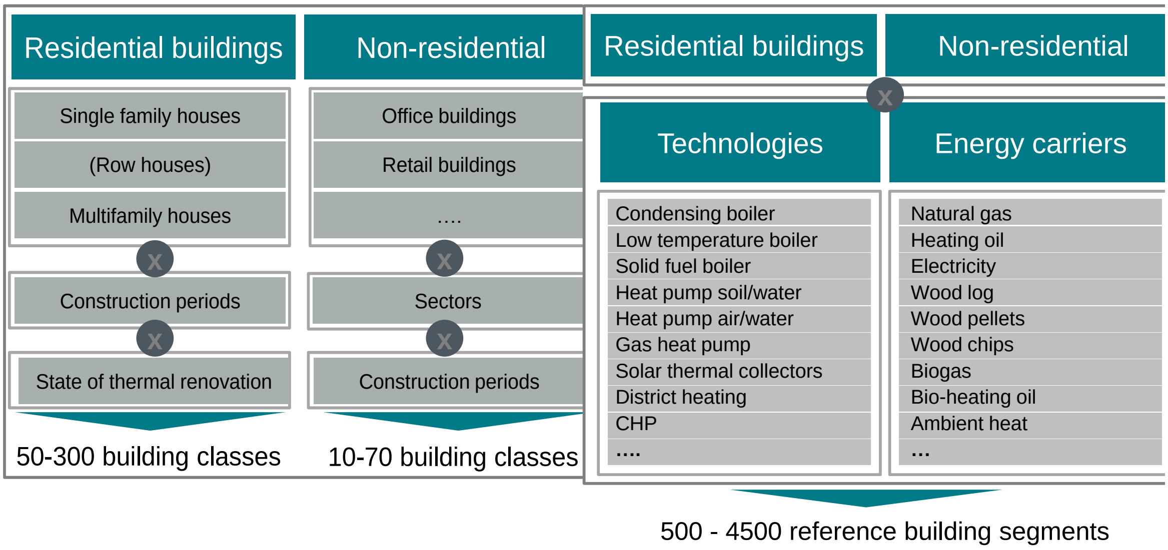

Figure 1. Disaggregated modeling of the building stock within each country. Where relevant, climatic zones are taken into account within a country.

As **efficiency technologies** Invert/EE-Lab models the uptake of different levels of renovation measures (country specific) and the diffusion of efficient heating, hot water, cooling and lighting technologies.

3.1.2 Model structure

The basic structure and concept is described in Figure 2.

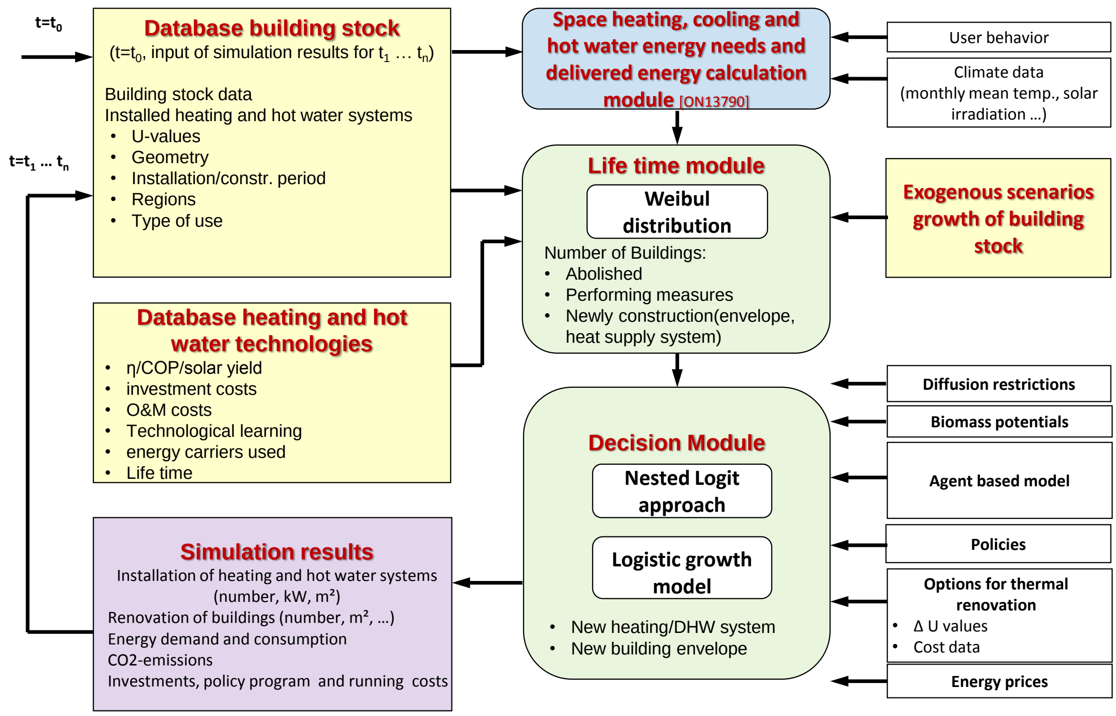

Figure 2: Overview structure of Simulation-Tool Invert/EE-Lab

Invert simulation tool originally has been developed by Vienna University of Technology/EEG in the frame of the Altener project Invert (Investing in RES&RUE technologies: models for saving public money). In more than 30 projects and studies for more than 15 countries, the model has been extended and applied to different regions within Europe, see e.g. (Kranzl et al., 2012), (Kranzl et al., 2013), (Biermayr et al., 2007), (Haas et al., 2009), (Kranzl et al., 2006), (Kranzl et al., 2007), (Nast et al., 2006), (Schriefl, 2007), (Stadler et al., 2007). The last modification of the model in the year 2010 included a re-programming process and accommodation of the tool, in particular taking into account the inhomogeneous structure of decision makers in the building sector and corresponding distributions (Müller, 2010). The current state of the model relies on this new calculation-core (called EE-Lab) leading to the current version of the model Invert/EE-Lab. The model has been extended by an agent specific decision approach documented e.g. in (Steinbach, 2013b), (Steinbach, 2013a).

3.1.3 Basic approach and methodology

The core of the simulation model is a myopical approach which optimizes objectives of agents under imperfect information conditions and by that represents the decisions concerning building related investments. It applies a nested logit approach in order to calculate market shares of heating systems and energy efficiency measures depending on building and investor type. The following equation depicts the market share calculation as logit-model – in order to reduce complexity in the representation:

$$ms_{n\,jb,t} = \frac{e^{-\lambda_b \cdot r_{njb}}}{\sum_{j=1}^{J} e^{-\lambda_b \cdot r_{njb}}}$$

$$r_{njb,t} = \frac{V_{njb,t}}{\sum_{j=1}^{J} ms_{njb,t-1} \times V_{njb,t}}$$

$\mathrm{ms_{njb}}$ = market share of alternative j in building b for investor type n at period t

$\mathrm{r_{njb}}$ = relative utility of alternative j in building b for investor type n

The model enables the definition of a various number of different owner types as instances of predefined investor classes: owner occupier, private landlords, community of owners (joint-ownership), and housing association. The structure is motivated by the different perspectives regarding building related investments. For instance, energy cost savings are only relevant for those owners which occupy the building. The corresponding variable relevant to landlords is a refinancing of energy savings measures through additional rental income (investor-tenant dilemma).

Owner types are differentiated by their investment decision behaviour and the perception of the environment, The former is captured by investor-specific weights of economic and non-economic attributes of alternatives. The perception relevant variables – information awareness, energy price calculation, risk aversion – influence the attribute values. (Steinbach, 2013a), (Steinbach, 2013b)

3.1.4 General approach of modelling policy instruments in Invert/EE-Lab

Invert/EE-Lab models the decision making of agents (i.e. building owner types) regarding building renovation and heating, hot water and cooling systems. Policy instruments may affect these decisions (in reality and in Invert/EE-Lab) in the following ways:

- Economic incentives change the economic effectiveness of different options and thus lead to other investment decisions. This change leads to higher market share of the supported technology in the Invert/EE-Lab (via the nested logit approach).
- Regulatory instruments (e.g. building codes or renewable heat obligations) restrict the technological options that decision makers have; limited compliance with these measures can be taken into account by limiting the information level of different agents regarding this measure (see next bullet point).

- Information, advice, etc: Agents have different levels of information. Lack of information may lead to neglecting of innovative technologies in the decision making process or to a lack of awareness regarding subsidies or other support policies. Information campaigns and advice can increase this level of information. Thus, the consideration of innovative technologies, knowledge about support programmes and compliance with regulatory standards increases.
- R&D can push technological progress. The progress in terms of efficiency increase or cost reduction of technologies can be implemented in Invert/EE-Lab.

3.1.5 Modelling approach for cooling in Invert/EE-Lab

Modelling the development of energy demand for space cooling in INVERT/EE-Lab is mainly based on diffusion theory. The share of cooled area in a defined type of building in a certain year *t* is determined by the logistic function

$$x(t) = \frac{x_{inf}}{(1 + e^{-\lambda t})}$$

where *x_inf* is the maximum penetration of cooled area in this type of buildings. *lambda* is the rate of diffusion, which is calculated based on the development of the shares of cooled area in different types of buildings in a country over the past decades. In general the logistic diffusion model assumes that the diffusion of technology over time is fully reflected in its historical developments. Major changes in parameters influencing the decision whether or not to install a technology are reflected as far as these changes are already represented in the calibration period for determining the values of lambda. Increased renovation activities and high energy efficiency standards for new construction in the building stock may influence the diffusion of space cooling devices. In order to quantify these possible effects the logistic diffusion approach is extended.

Important parameters for the decision whether or not to install a cooling device in a building are the emerging cooling loads and their frequency in the summer period. The higher these values are the higher is the probability of installing a cooling device. In INVERT/EE-Lab these parameters are not calculated. This model uses a monthly time resolution to determine the useful energy demand for space cooling of the buildings. The resulting annual useful space cooling demand per area for a certain cluster of buildings and its change over time is then used to recalculate the respective rate of diffusion *lambda* according to the following formula:

$$\lambda_{adapt} = \lambda_{calibr\ period} * (demand\ ratio_{renovation\ class} * demand\ ratio_{construction\ period})^2$$

The correlation between cooling loads and their frequency of appearance in the summer period and the resulting useful cooling demand over the year is estimated to be quadratic. The demand ratio in case of renovation (demand $ratio_{renovation\ class}$) is defined

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as the relative change of the yearly annual useful cooling demand per area in a certain building cluster undergoing the same renovation actions against buildings of the same type and construction period not being renovated. The demand ratio for newly constructed buildings in the simulation period (demand $\text{ratio}_{\text{construction period}}$) reflects the relative changes against the average useful space cooling demand for all construction periods in the same type of building.

The main input parameters for the calculation of the diffusion of cooling devices and its resulting electricity demand in the buildings are as follows:

- the maximum penetration levels,
- the current state of diffusion in the base year of simulation,
- its historical developments,
- the yearly useful cooling demand as well as the development of the efficiency of the installed devices over the simulation period.

While the useful cooling demand for each year of simulation is determined endogenously in the model the other parameters are exogenous input. These values are estimated for different types of buildings in each country based on an intensive literature review. The main sources that have been analysed are the preparatory studies for the ecodesign directive ((Riviere et al., 2008) and (Riviere et al., 2012)), a study of the barriers and opportunities to improve energy efficiency in cooling appliances in Europe (Pout et al., 2012), as well as (Hitchin et al., 2013), (Adnot et al., 1999), (Adnot et al., 2003), (Pardo et al., 2012) and (Gruber et al., 2007). Furthermore country specific information from the project partners has been used for the target countries as presented in the reports "The challenges, dynamics and activities in the building sector and its energy demand in country …", available for each target country at www.entranze.eu/pub/pub-data. The derived parameters have also been compared to results of other studies and databases namely HARMONAC, ECOHEATCOOL, INSPIRE and ODYSSEE.

3.1.6 Modelling approach for PV in Invert/EE-Lab

The modelling approach for decisions on investments in PV follows the same logic as for space heating and hot water or for the choice between renovation packages (explained above). It is based on two steps: (i) calculate the optimized hourly PV contribution to electricity consumption (either appliances, space heating or domestic hot water contribution) and the hourly PV exports to the grid. Based (ii) on the optimized PV exports and on-site use and the resulting economic effectiveness, the logit approach is used to calculate market growth and installed capacities.

Step 1: PV contribution

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The PV contribution is modelled by comparing the hourly PV production and the hourly load profile in a first step. Therefore, the cumulated monthly solar radiation is equally distributed to every day of the month and the hourly solar radiation is approximated by using a sinus-curve between 6am and 6pm. Furthermore, the annual PV electricity production per m² PV area - for the main climate region with PV oriented towards south - is defined as an input parameter for the model. The so specified electricity yield is then distributed proportionally on an hourly level using the calculated hourly solar radiation. The electricity demand is modelled using average hourly standard load profiles for different consumer types (e.g. households, stores, hospitals, service sector with increase activities on weekends and/or evening hours, industry, general service sector). Each hour is divided into a peak and base load time. Furthermore, an electricity storage (modelled by energy capacity, maximum load and unload power capacity which will be scaled linear with the PV size) can be defined for each PV system and will be considered in the optimization of the PV usage. The difference between PV electricity production and PV electricity usage for appliances can be used to supply energy for space heating and/or domestic hot water or can be exported to the grid. The optimization algorithm chooses the economically most efficient usage, considering (i) the efficiencies of the heating and/or domestic hot water supply system, (ii) the energy prices for the applied energy carriers for heating and domestic hot water, as well as (iii) the electricity revenue when exporting to the grid.

Invert/EE-Lab results show the contribution of PV to electricity consumption (i) for appliances, (ii) for heating and hot water and (iii) for export to the grid. Taking into account the following algorithm, Invert/EE-Lab simulates building owner's decisions regarding the choice for a PV system and the size of installed PV collectors.

The algorithm is based on the presumption that PV-electricity in every hour of the year is used for appliances first. If it is economically efficient – compared to the exporting the electricity on a monthly basis – to use the electricity for hot water preparation and/or space heating, this option will be applied. Thus, the assumption is that electric resistance immersion heaters are installed in central heating system boilers, allowing to replace also fuels like natural gas or biomass with electricity. The electricity which cannot be used for appliances, space heating and/or domestic hot water production will be exported to the grid: The following rules apply:

- PV-contribution for hot water preparation:
  if PV-electricity export specific revenue < hot water energy carrier price / boiler efficiency hot water, then the hot water PV-Contribution = minimum (PVproduction – PVappliances contribution, DHW demand); this is considered on a daily basis.

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- PV-contribution for space heating:
  if PV-electricity export specific revenue < Space heating energy carrier price / boiler efficiency space heating, then Space heating PV-Contribution = minimum(PVproduction – PVappliances contribution - PVDHW contribution, Space heating demand); this is considered on a daily basis.
- PV export to grid = PVproduction – PVappliances contribution – PV DHW contribution - PV SH contribution; this is considered on a daily basis.

Step 2: Modelling of PV market growth

Invert/EE-Lab includes two main assumptions: (i) Building owners consider the installation of PV if there is a need to invest in building services technologies (first of all heating and hot water systems). (ii) Building owners compare the overall cost of the system with and without PV. The market share of buildings with and without PV (and moreover with different PV-collector sizes) is derived from a logit approach.

The result again is subject to a logistic diffusion curve (in the same way as for the diffusion of heating systems technologies). These assumptions are more suitable the more mature a market is. This might lead to overestimations of PV in regions with currently low development of PV. Related uncertainties are discussed in chapter 6

3.1.7 Modelling approach for lighting in Invert/EE-Lab

The scenarios of lighting energy demand is build on literature and mainly on the preparatory study for domestic and office lighting in the frame of the ecodesign labelling directive (Tichelen et al., 2007 and Tichelen, 2009). Thus, in contrast to heating, hot water, cooling, technologies, renovation options and PV, there is no endogenous modelling of consumer and investor decision making for lighting in Invert/EE-Lab. Instead, the scenarios build on assumptions regarding the diffusion of different lighting technologies and their specific energy consumption. These assumptions are based on Tichelen (2009).

The energy demand is calculated from

$$ED = n_L \cdot A \cdot T \cdot P \cdot s$$

with

ED Final energy demand for lighting (GWh)

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n_L specific number of lamps per m² (different for residential and non-residential) (1/m²)[8]
A total floor area for residential and non-residential buildings (Mm²)
T burning hours (h/yr)[9]
P Wattage (power) of the the lamp per technology[10] (source: Tichelen et al 2009, base case technologies)
s share of technology in the total stock[11]

The scenarios differ in the share of technologies in the total stock, which is assumed to be the same for all countries. We did not distinguish between high and low price scenarios.

We distinguished the following four types of technologies as defined in Table 2:

Table 2: Considered lighting technologies

		Technology 1	Technology 2	Technology 3	Technology 4
	burning hours residential (h/yr)	400	500	800	800
	burning hours tertiary (h/yr)	1800	1800	1800	1800
	Wattage (W)	54	35	13	10
	Share of technologies				
	2008	70%	10%	20%	0%
Scenario 1	2020	33%	40%	25%	2%
	2030	15%	20%	45%	25%
Scenario 2	2020	25%	30%	40%	5%
	2030	18%	20%	47%	15%
Scenario 3	2020	8%	40%	50%	2%
	2030	0%	20%	55%	25%

8 Based on Tichelen, 2009, table 2-11

9 Based on Tichelen, 2009, table 2-27

10 Based on Tichelen, 2009, base case technologies

11 Share of starting year according to Tichelen et al 2009; scenarios according to own assumptions and the scenarios in Tichelen et al 2009 and other related work

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3.1.8 Key input data to the model

The model Invert/EE-Lab requires the following main categories of input data:

- Disaggregated description of the building stock: The scenarios presented in this report are based on the building stock data as described in the reports “Building sector and energy demand in target countries” and the corresponding online data tool, both available at www.entranze.eu.

- Cost data of heating and cooling systems as well as of renovation options: These data have been collected by the respective project partners of the target countries and checked with national experts and against literature in the frame of the cost-optimality calculations. Data and results of these techno-economic analyses are documented in the report on “Cost of energy efficiency measures in buildings refurbishment: a summary report on target countries” (Fernandez-Boneta, 2013) and the report on cost/energy curves (Pietrobon et al., 2013).

- Definition of renovation packages and the link to the cost-optimality calculations: As described above, for those measures leading to a reduction of the energy need (e.g. renovation of building envelope or heat recovery systems) Invert/EE-Lab requires a set of pre-defined renovation packages from which agents may select. The selection and definition of these renovation packages was done based on the cost-optimality calculations in this project (Pietrobon et al., 2013) and the derived energy-cost matrices (Fernandez-Boneta, 2014). Based on these calculations, three packages have been selected: The standard renovation package more or less reflects the current practice of thermal building renovation, the “good” renovation package reflects a set of measures near the cost-optimality point whereas the “ambitious” renovation package refers to a level of renovation which is near the “minimum primary energy” level as indicated in Pietrobon et al., (2013).

3.1.9 Outputs from Invert/EE-Lab

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

- Installation of heating and hot water systems by energy carrier and technology (number of buildings, number of dwellings supplied)
- Refurbishment measures by level of refurbishment (number of buildings, number of dwellings)
- Total delivered energy by energy carriers and building categories (GWh)
- Total energy need by building categories (GWh)

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- Policy programme costs, e.g. support volume for investment subsidies (M€)
- Total investment (M€)

Moreover, Invert/EE-Lab offers the possibility to derive more detailed and other type of result evaluations as well. Based on the needs of the policy processes we will have to discuss which other type of evaluations of the result data set might be required.

3.2 Poles

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.

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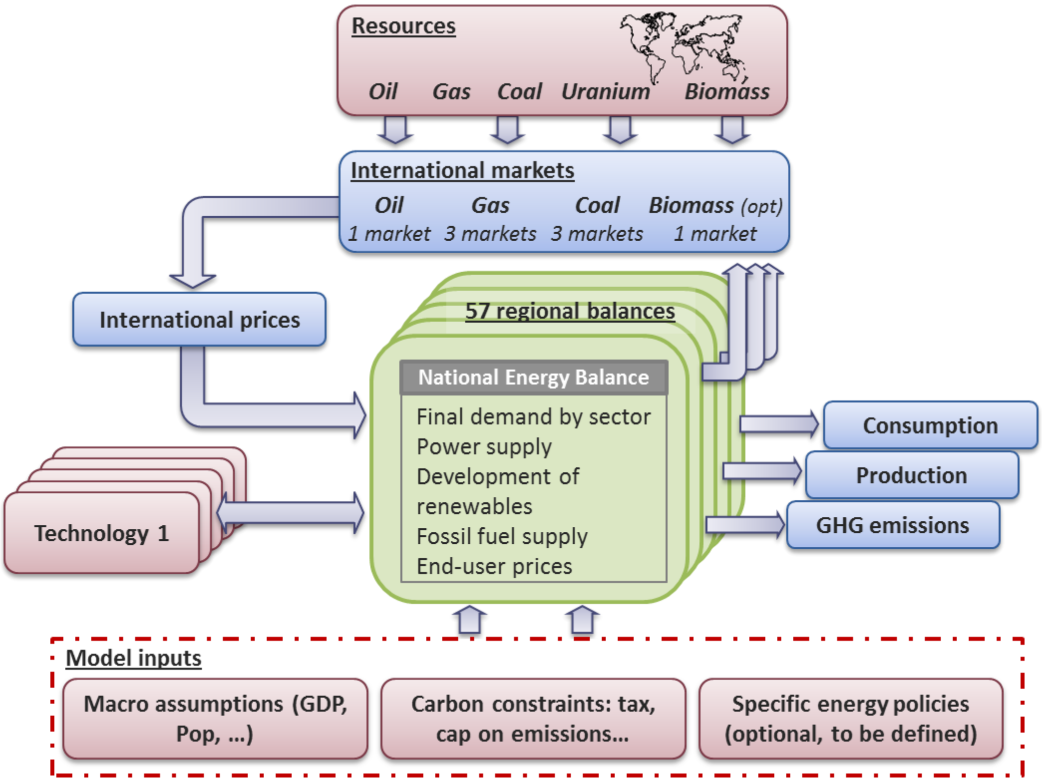

Figure 3: Overview structure of POLES

3.3 Input data and drivers for Invert/EE-Lab

The main input data for Invert/EE-Lab, as building stock data, barriers and stakeholder behaviour, cost data, selection of renovation packages based on cost-optimality results and policy sets and specific policy design have been derived from analyses and data collection within the project ENTRANZE:

- The policies to be modelled were selected by the policy groups established in each target country.
- 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.

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- 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[12].
- The results of the stakeholder analysis, related barriers and decision criteria of building owners carried out in the project ENTRANZE (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) for the ENTRANZE target countries the 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). These three renovation levels are used as technological options within the model Invert/EE-Lab, i.e. we model the building owners choice between these renovation options or – on an aggregate level – the market share of these three renovation levels. The key characteristics of these renovation packages are described in the reports "Policy scenarios and recommendations on nZEB, deep renovation and RES-H/C diffusion" available for each target country at http://www.entranze.eu/pub/pub-scenario.

Data flow from POLES to Invert/EE-Lab

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

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

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projected, taking into account changes in international prices and taxes (excise tax[13], VAT) and a carbon price[14].

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.

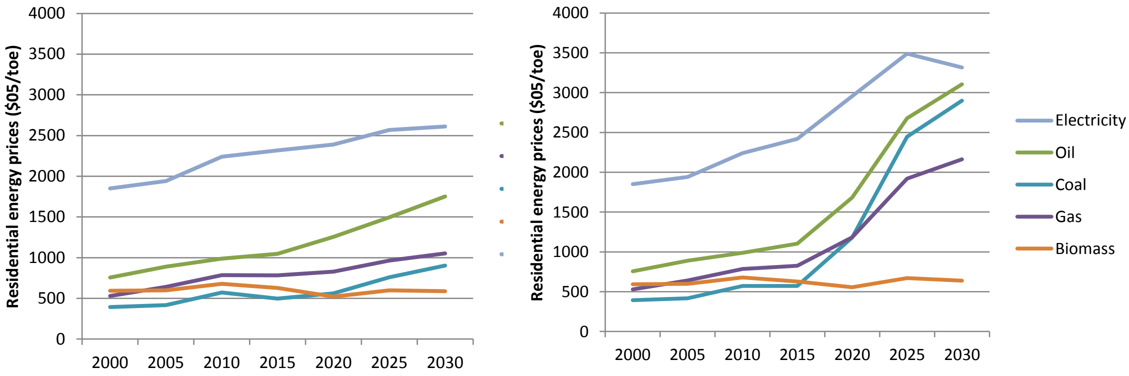

Figure 4: Residential and tertiary energy price scenarios for EU27 average reference scenario (left) and ambitious scenario (right)

Source: POLES-Enerdata

The result of the projections for the 9 target countries[15] and the EU as a whole are presented in more details in a separate report "Exogenous framework conditions for Entranze scenarios". Table 3 and Table 4 show energy price scenarios for ENTRANZE target countries.

[13] Including existing energy & environmental taxes.
[14] 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.
[15] Austria, Bulgaria, Czech Republic, Finland, France, Germany, Italy, Romania and Spain.

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Table 3. Energy price scenarios, Domestic Prices (€05/MWh)[16] (average), Residential – Services, High/ambitious price scenarios

		2010	2020	2030
Austria	Oil	69	113	210
	Gas	56	81	149
	Coal	88	133	253
	Biomass	60	37	37
	Electricity	178	191	207
Bulgaria	Oil	71	115	211
	Gas	29	56	124
	Coal	17	63	184
	Biomass	17	13	27
	Electricity	60	114	122
Czech Re-public	Oil	54	89	185
	Gas	38	64	133
	Coal	15	59	180
	Biomass	53	52	56
	Electricity	104	158	159
Finland	Oil	70	124	220
	Gas	29	64	132
	Coal	26	72	194
	Biomass	31	29	32
	Electricity	119	163	193
France	Oil	66	112	209
	Gas	52	80	148
	Coal	93	137	258
	Biomass	47	38	48
	Electricity	116	147	192
Germnay	Oil	60	105	201
	Gas	59	85	153
	Coal	102	146	267
	Biomass	38	27	37
	Electricity	223	283	315
Italy	Oil	107	151	248
	Gas	65	87	155
	Coal	56	101	222
	Biomass	89	90	95
	Electricity	181	211	236
Romania	Oil	76	131	227
	Gas	24	53	125
	Coal	7	54	174
	Biomass	32	22	33
	Electricity	90	147	149
Spain	Oil	62	107	203
	Gas	50	81	148
	Coal	93	137	258
	Biomass	44	35	42
	Electricity	149	194	218

[16] Converted 1 US Dollar = 0.80612 Euro

Table 4. Energy price scenarios, Domestic Prices (€05/MWh) (average), Residential – Services, Low/Reference price scenarios

		2010	2020	2030
Austria	Oil	69	84	118
	Gas	56	56	72
	Coal	88	89	114
	Biomass	60	31	35
	Electricity	178	165	169
Bulgaria	Oil	71	85	117
	Gas	29	31	47
	Coal	17	19	44
	Biomass	17	12	24
	Electricity	60	75	94
Czech Republic	Oil	54	58	87
	Gas	38	39	55
	Coal	15	15	40
	Biomass	53	49	54
	Electricity	104	119	133
Finland	Oil	70	94	128
	Gas	29	39	55
	Coal	26	29	55
	Biomass	31	27	27
	Electricity	119	138	156
France	Oil	66	83	117
	Gas	52	55	71
	Coal	93	94	119
	Biomass	47	34	43
	Electricity	116	133	155
Germnay	Oil	60	76	110
	Gas	59	60	76
	Coal	102	103	128
	Biomass	38	24	34
	Electricity	223	237	256
Italy	Oil	107	122	156
	Gas	65	63	79
	Coal	56	57	82
	Biomass	89	89	92
	Electricity	181	169	179
Romania	Oil	76	102	136
	Gas	24	29	45
	Coal	7	10	34
	Biomass	32	21	29
	Electricity	90	97	111
Spain	Oil	62	77	111
	Gas	50	56	72
	Coal	93	94	119
	Biomass	44	33	39
	Electricity	149	164	173

The CO_2 emission factor, i.e. the average amount of CO_2 emitted per kWh produced in gCO_2/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.

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As shown in Figure 5, 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.

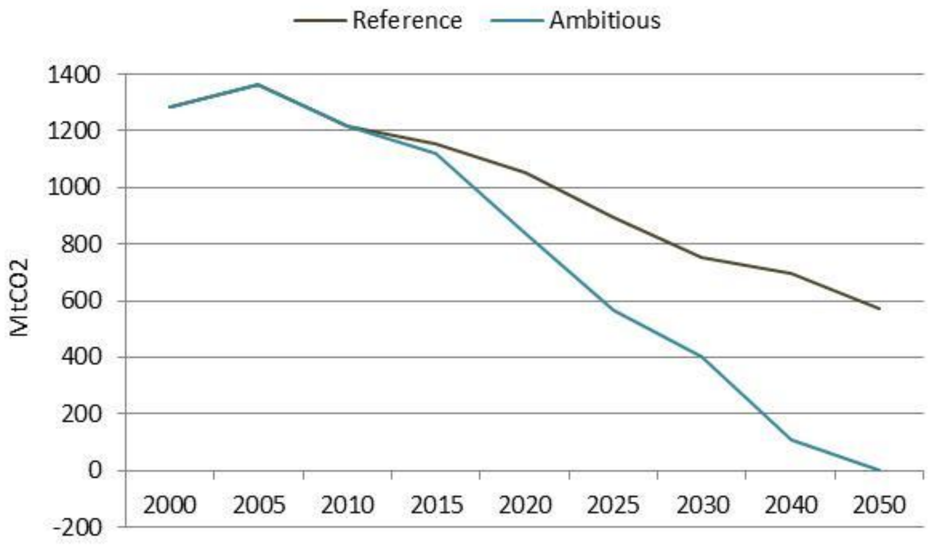

Figure 5. EU-27 CO_2 emission content in power production until 2050

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[17] 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).

[17] Austria, Bulgaria, Czech Republic, Finland, France, Germany, Italy, Romania and Spain.

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3.4 Modelling ambient heat according to the renewable energy directive

According to the renewable energy directive (*2009/28/EC*), Annex VII, ambient heat should only be counted if the seasonal COP > 1.15/eta (with eta = primary energy efficiency of electricity generation). With the primary energy factors (PEF) of electricity generation derived from POLES scenarios, we write this condition as Seasonal COP > 1.15*PEF.

However, the question arises, which values for the seasonal COP should be applied for different types of heat pumps.

In order to implement this accounting approach according to the renewable energy directive (RED), we apply a linear curve of average seasonal COPs derived from Invert/EE-Lab calculations for the case of the German building stock. The following figure shows the seasonal COP which would result in the different parts of the German building stock if they would be equipped with heat pumps. The values are taken from a scenario for the year 2040. The right hand of the figure plots the seasonal COP for values above 2.5. We see that in this part of the curve (figure on the right, with those buildings with seasonal COP>2.5), we can approximate the COP via a straight line. We assume that the result resembles very well the building stock where heat pumps are in practice installed (i.e. focus on new and renovated buildings, not unrenovated buildings with high temperature heating systems).

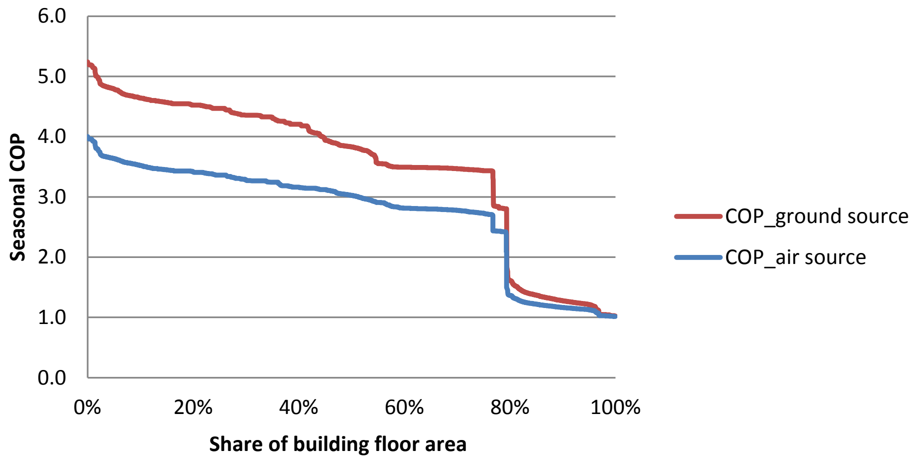

Figure 6. Calculated seasonal COP if the whole German building stock would be equipped with heat pumps (calculated for a scenario result in the year 2040)

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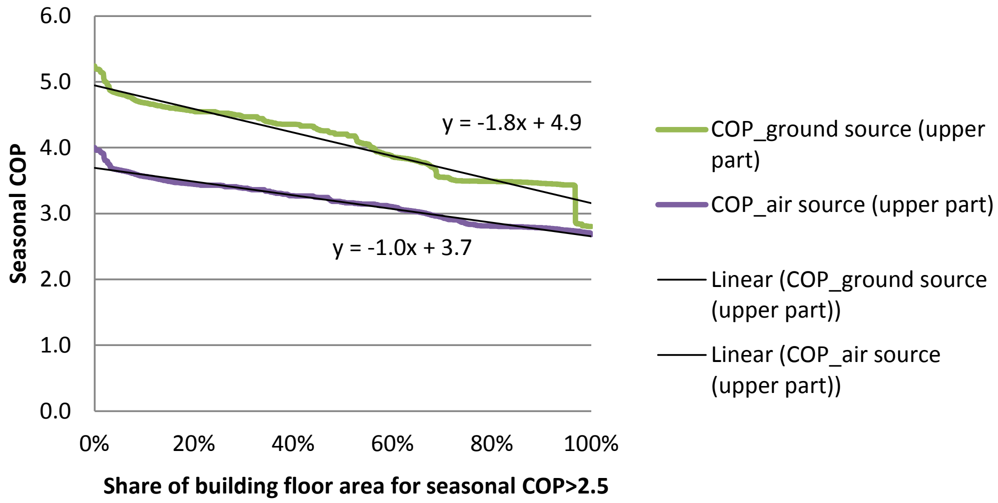

Figure 7. Calculated seasonal COP if that part of the German building stock, where COP values > 2.5 may be achieved, would be equipped with heat pumps (calculated for a scenario result in the year 2040)

This delivers the share of ambient heat accounted according to the RED:

For ground source heat pumps:

$$S_{gshp} = \max(0, \min\left(1, (\frac{4.9 - 1.15 * PEF)}{1.8}\right))$$

S_{gshp} *...Market share of ambient heat accounted*
PEF ...Primary energy factor of electricity generation

The value 4.9 reflects the upper area of achieved seasonal COP of ground source heat pumps and 1.8 reflects the incline, i.e. the reduction of the seasonal COP over the relevant part of the building stock.

And for air source heat pumps:

$$S_{ashp} = \max(0, \min(1, (3.7 - 1.15 * PEF))$$

S_{ashp} *...Market share of ambient heat accounted*
PEF ...Primary energy factor of electricity generation

The value 3.7 reflects the upper area of achieved seasonal COP if air source heat pumps and 1 reflects the incline, i.e. the reduction of the seasonal COP over the relevant part of the building stock.

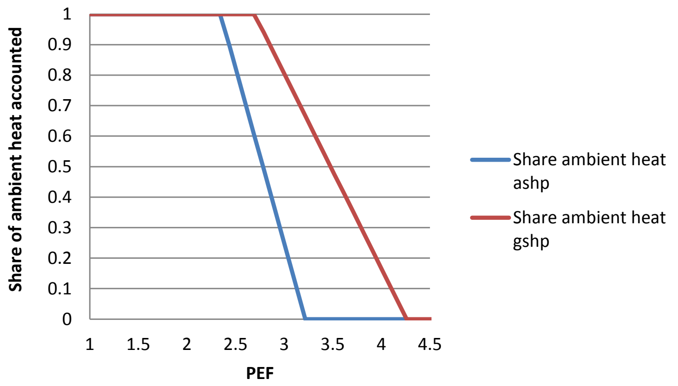

Figure 8. Share of ambient heat accounted in the scenario results

Figure 8 and Figure 9 show the resulting shares of ambient heat according to the RED for reference scenarios in target countries for air source and ground source heat pumps. For ground source heat pumps only in a few countries ambient heat would not be fully accounted, and this only in the first few years of the simulation (i.e. for BGR, CZE, FRA). On the other hand, for air source heat pumps the regulation implemented in the RED could be a relevant restriction for the accountability as renewable energy carrier in a number of countries until 2030 (most relevant among the ENTRANZE target countries for CZE, BGR, FIN, FRA).

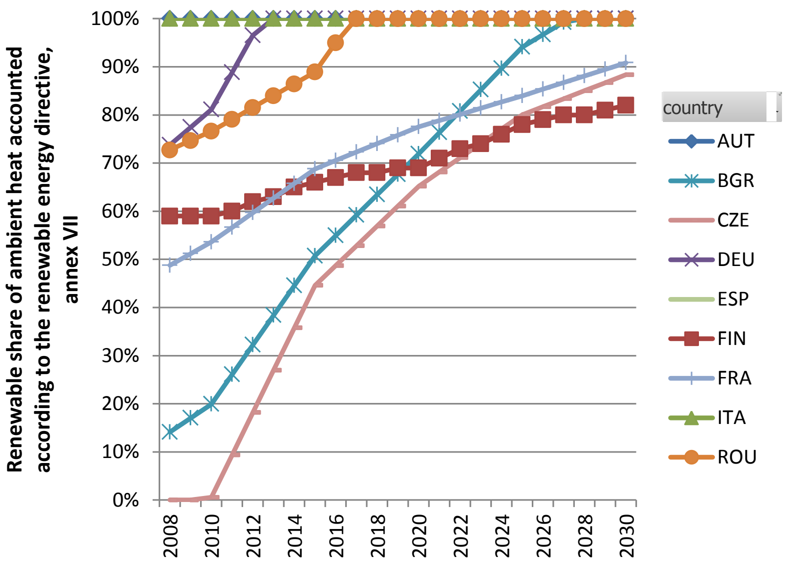

Figure 9. Share of ambient heat from air source heat pumps in reference scenarios for ENTRANZE target contries

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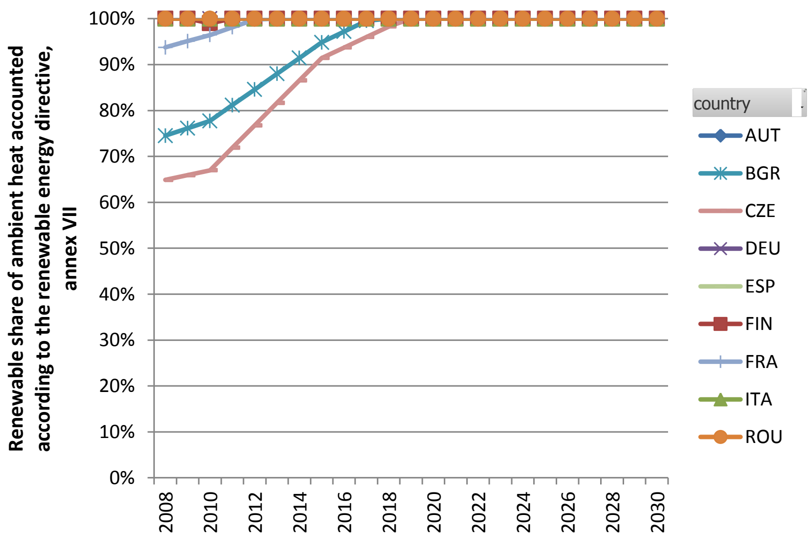

Figure 10. Share of ambient heat from ground source heat pumps in reference scenarios for ENTRANZE target contries

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4. Scenario results for target countries

What drives the future development of renovation activities and market share of different heating, hot water, cooling and lighting technologies? How can policies shape 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.

In this chapter, we present selected results of policy scenarios. Some outcomes are shown for all policy scenarios and for both energy price paths. Some other results are only shown for selected scenarios and energy price paths. Additional results are shown in the Annex. Moreover, 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. For every target country the scenario results and recommendations are documented in a specific report (AT: Kranzl et al., 2014c, BG: Georgiev et al., 2014, CZ: Zahradnik et al., 2014, DE: Steinbach et al., 2014, ES: Fernandez-Boneta et al., 2014, FI: Heiskanen et al., 2014, FR: Sebi et al., 2014, IT: Pietrobon et al., 2014, RO: Atanasiu et al., 2014, all accessible at www.entranze.eu/pub/pub-scenario).

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 3.1.4), 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.

4.1 Aggregated results for ENTRANZE target countries

With around 2550 TWh (219 Mtoe)[18] 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. About 28% of this energy demand is used in non-residential buildings, the remainder in residential buildings.

[18] 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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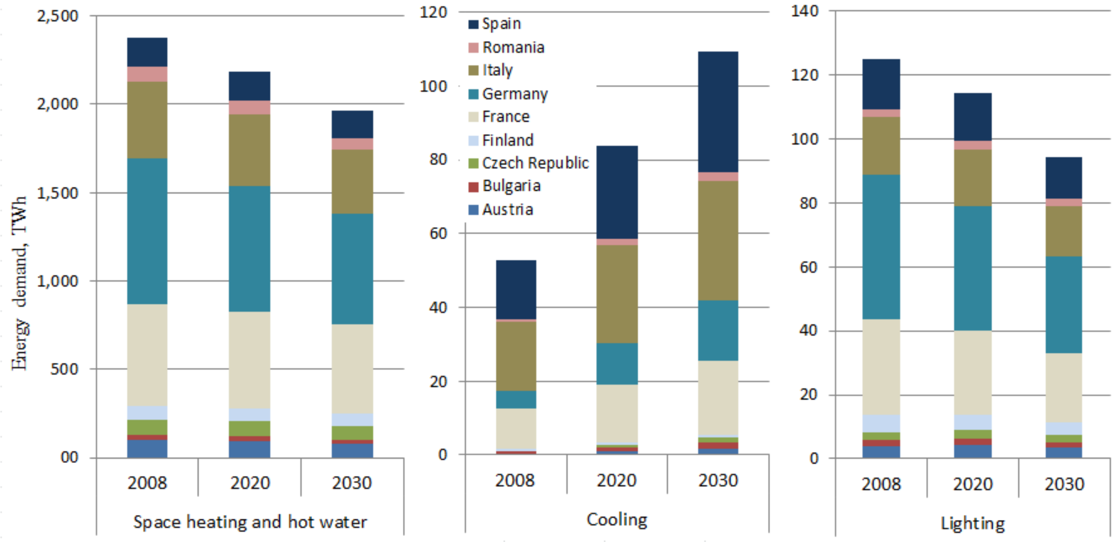

Figure 11. Final energy demand for space heating and hot water, cooling and lighting in ENTRANZE target countries in 2008, 2020 and 2030, Policy Scenario 1, low energy price scenario[19]

Figure 11 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.

[19] Results for the high energy price scenario are shown in the annex.

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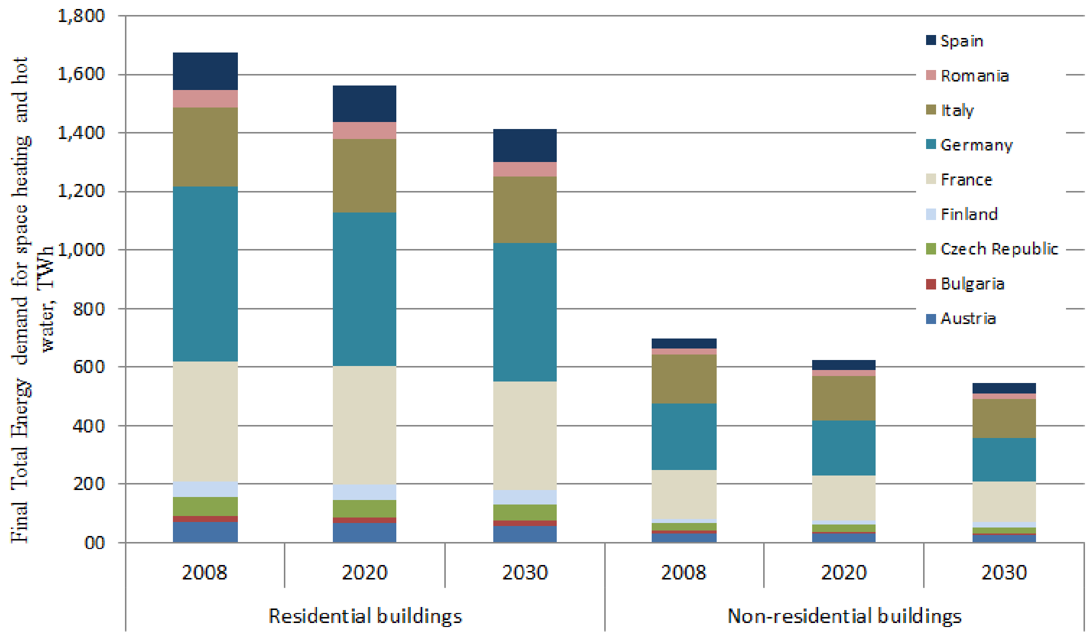

Figure 12. Final total energy demand for space heating and hot water in residential and service building sectors in all ENTRANZE target countries in 2008, 2008 and 2030, Policy Scenario 1, low energy price scenario[20]

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 heating energy savings, which can be achieved by introducing more ambitious measures in 2020 is much smaller than in 2030 (see Figure 13 and Figure 14).

4.2 Comparative analysis of country results

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

[20] Results for the high energy price scenario are shown in the annex.

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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. What are main reasons for these differences?

In this chapter we highlight some country specific characteristics and discuss reasons for different developments in different policy scenarios for different countries.

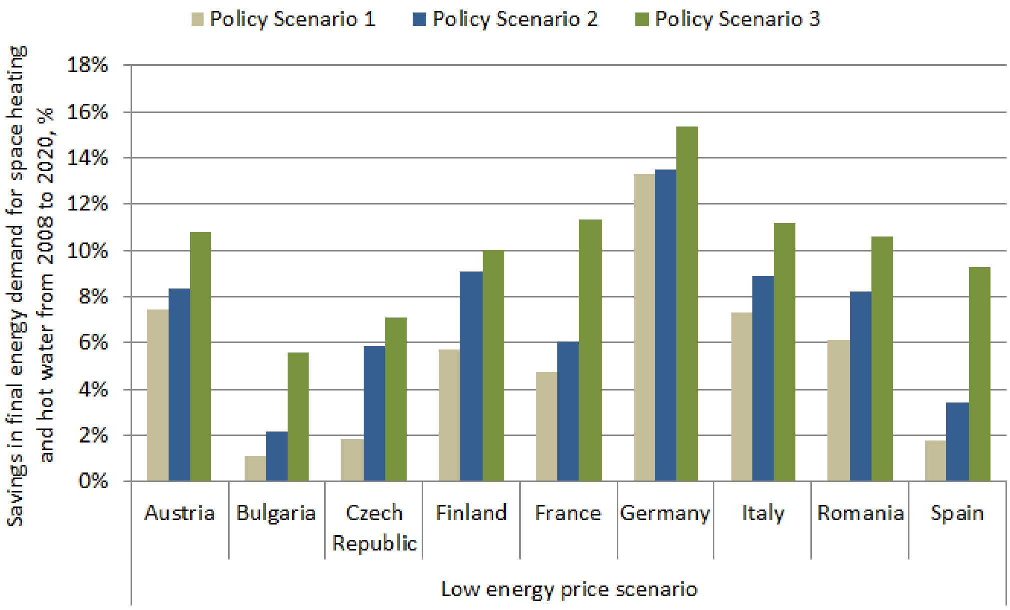

Figure 13 Savings in final energy demand for space heating and hot water in target countries in three policy scenarios, from 2008 to 2020, low energy price scenario[21]

[21] Results for the high energy price scenario are shown in the annex.

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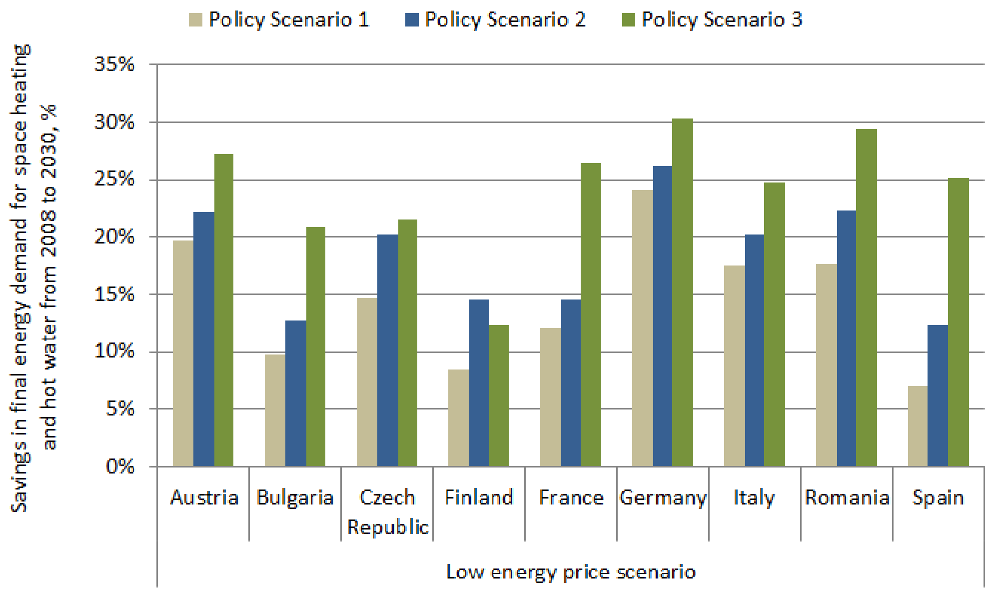

Figure 14 Savings in final energy demand for space heating and hot water in target countries in three policy scenarios, from 2008 to 2030, low energy price scenario[22]

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 15 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-

[22] Results for the high energy price scenario are shown in the annex.

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ferent and in the former countries increasing comfort demand offset, more than in latter countries, a substantial part of energy efficiency improvement.

Energy prices are a **trigger for renovation activities and energy savings** (partly due to renovation activities and partly due to a shift to more efficient heating and hot water systems), in particular if the price signal is used as a leverage by a strong and effective policy environment. The comparison between Figure 15 and Figure 16 reveals that the price effect is different in different countries and in different scenarios.

The **different price effect between countries** can be explained by the following arguments:

- The price increase from low to high price scenarios varies among energy carriers. Thus, the difference in the energy mix between countries leads to different price effects.
- Poles results in different price signals for different countries (see chapter 3.1.8).
- The behaviour and preferences of building owners in different countries are different (according to the findings in Heiskanen et al., 2013, Heiskanen and Matschoss, 2012 and Steinbach, 2013a). Thus, the weight on running energy costs which building owners in average put in their decision making process varies between countries.
- The policies which are part of the country specific policy packages have an impact on the price effect.
  E.g. the price effect in Germany, in particular for policy scenario 3 in general is lower than in most other countries. This can be explained by the strong focus on regulatory measures, combined with information campaigns and activities to guarantee high compliance. Thus, the price signal does not lead to a substantially higher renovation rate and energy savings.

The reasons for **different price effects in different policy scenarios for the same country** are lying in the characteristics of the specific policy sets. If policy packages are pushing efficient heating systems or deep renovation packages near (economic) effectiveness and attractiveness, and if the policy packages create an overall favourable environment, an additional incentive (e.g. from rising energy prices) can lead to a strong push of energy savings.

What are the reasons for different energy savings in the countries in detail?

On the one hand, the **share between light, medium and deep renovation** provides an explanation for the different energy savings in different countries. On the other hand, there is also a difference in the definition of light, medium and deep renovation

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between the target countries[23]. 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 the least ambitious policy scenario 1 (low energy prices) for Bulgaria and up to 60% and beyond in the most ambitious 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).

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

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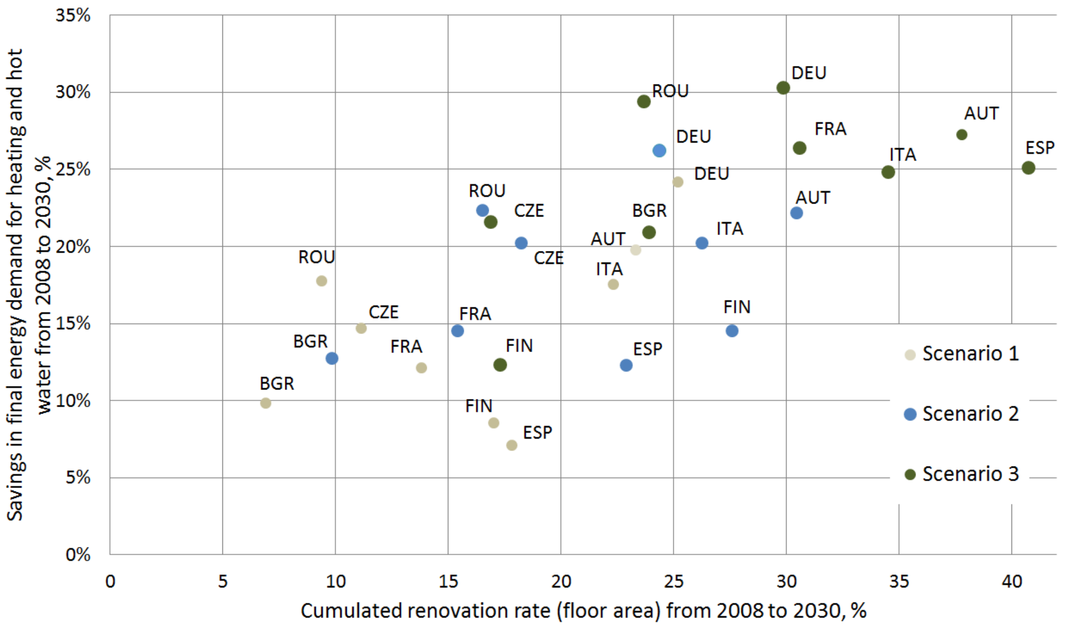

Figure 15 Savings in final energy demand for space heating and hot water from 2008 and 2030 and cumulate renovation rate from 2008 to 2030, low energy price scenario

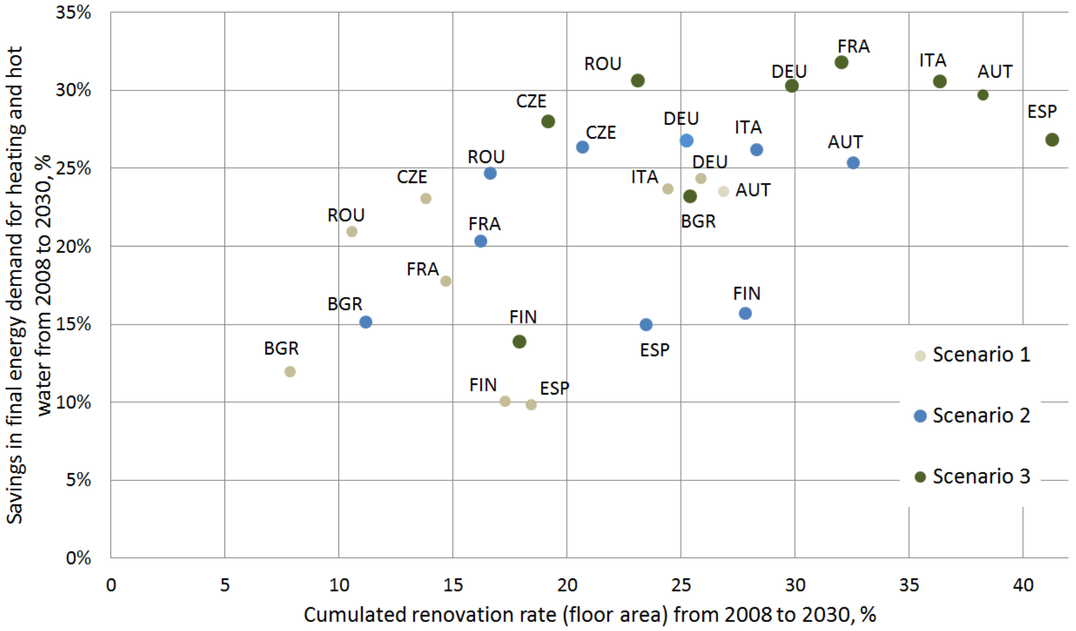

Figure 16 Savings in final energy demand for space heating and hot water from 2008 and 2030 and cumulate renovation rate from 2008 to 2030, high energy price scenario

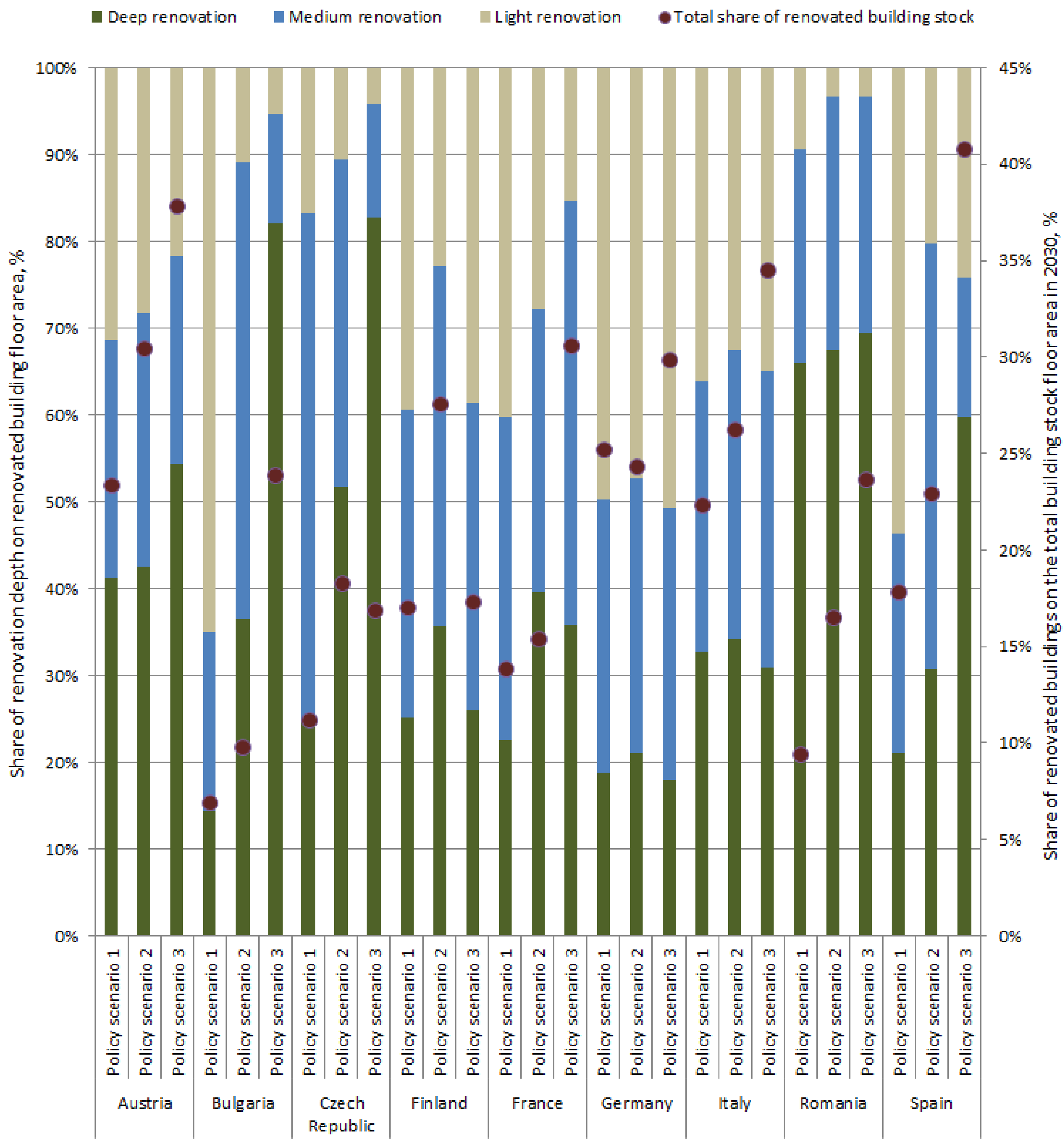

Figure 17 Share of cumulated deep, medium and light renovated floor area on the total floor area in 2030, in three policy scenarios in target countries, low energy price scenario[24]

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[24] Results for the high energy price scenario are shown in the annex.

Figure 18 shows final energy demand for space heating per useful floor area with and without climate correction[25]. 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.

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 increaseing 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 Kranzl et al., (2014d), chapter 8).

[25] 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).

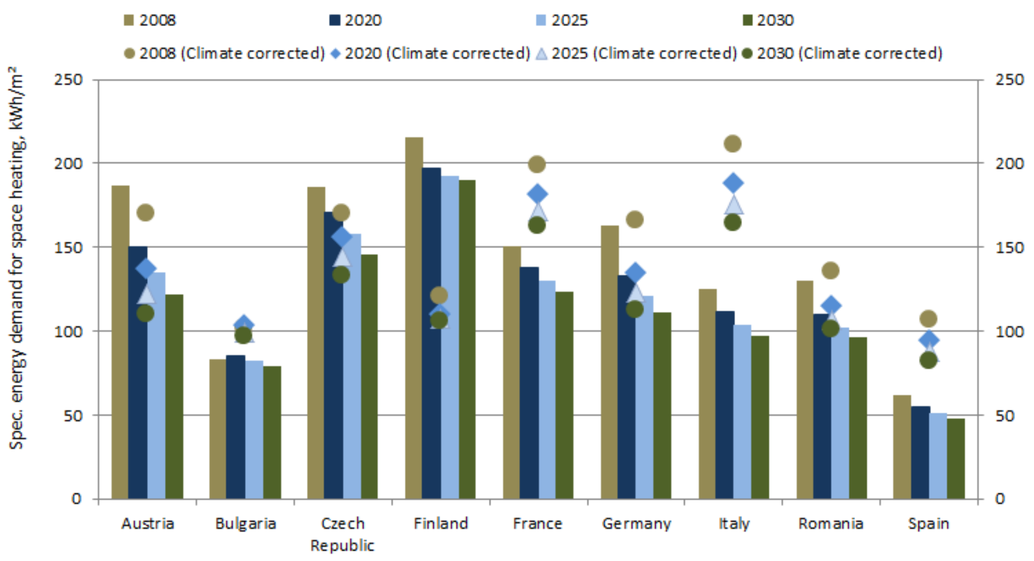

Figure 18 Specific final energy demand per floor area[26] for space heating and climate corrected[27] specific final energy demand per floor area for space heating in target countries in 2008, 2020, 2025 and 2030 in scenario 1, low energy prices[28]

Figure 19 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 6.1). However, the specific energy demand for most countries, and in particular for those with highest cooling demand can be reduced mainly due to more effective shading, but also increased efficiency of chillers and AC systems.

[26] Specific final energy demand is calculated by dividing total final energy demand through useful floor area. Useful floor area in general is about 20% lower than total building floor area.

[27] Climate correction has been done on the basis of mean heating degree days in EU-27 from 2000-2009.

[28] Results for the high energy price scenario are shown in the annex.

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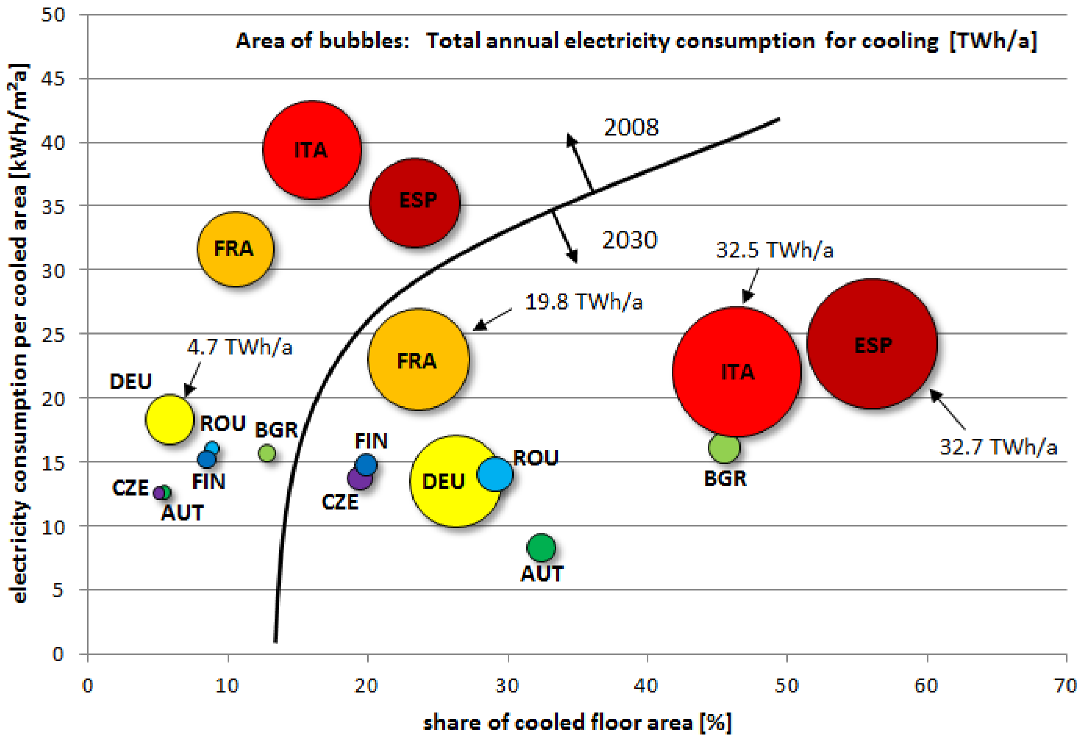

Figure 19 Electricity demand for space cooling per cooled floor area and share of cooled floor area[29] from 2008-2030 in policy set 1 – low energy prices

4.3 Energy carrier mix and share of renewables

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. 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 . Another trend is the increase of ambient energy and solar

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

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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 3.3 and 3.4. Regarding uncertainties, in particular regarding the expansion and potential market growth and corresponding barriers, see chapter 6.1.

On top of the RES-H technologies biomass, ambient energy (heat pumps) 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 (see 3.1.6). The scenario results (Figure 21 and Figure 42) 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.

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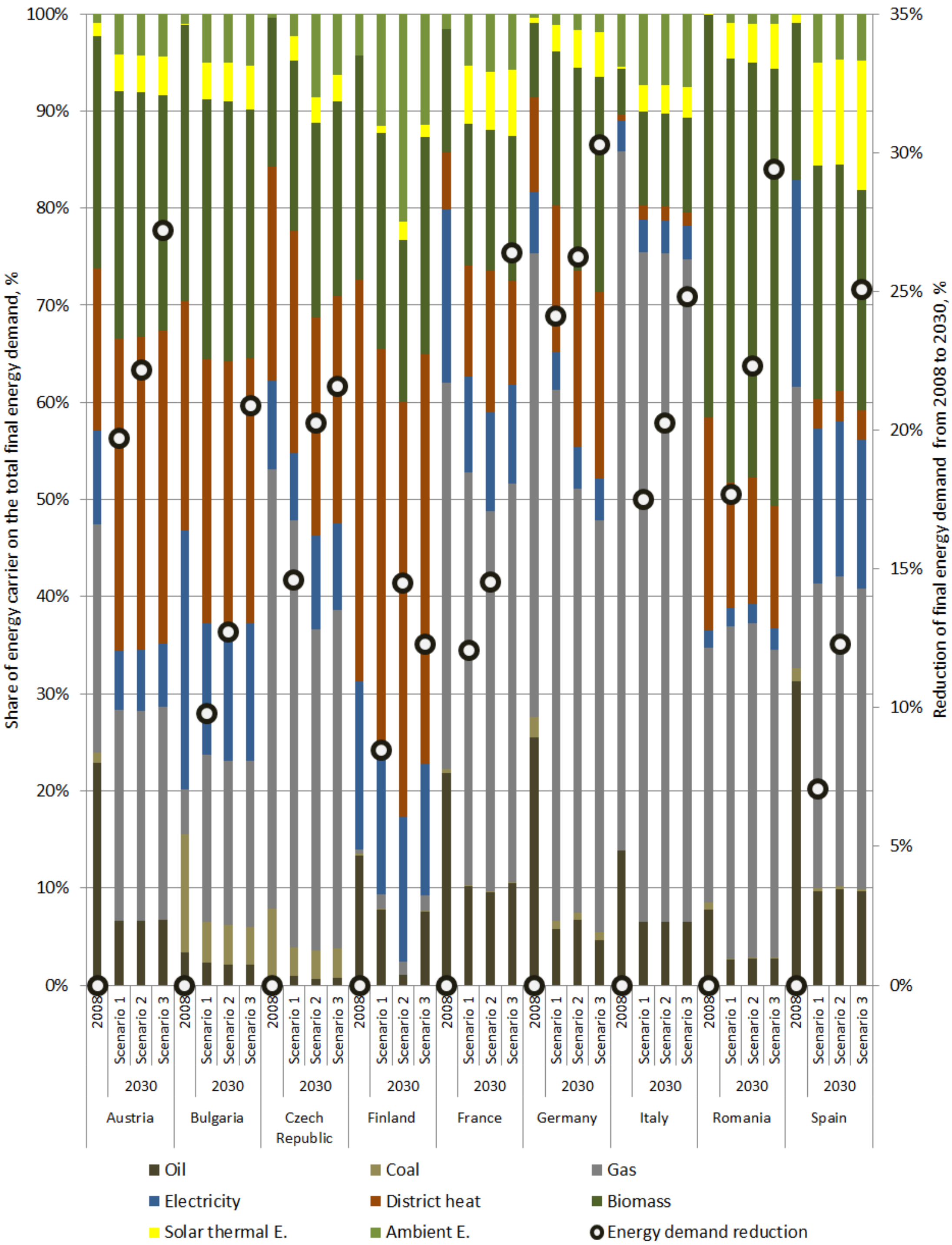

Figure 20 Share of energy carriers on the total final energy demand and reduction of final energy demand in target countries in three policy scenarios, low energy prices

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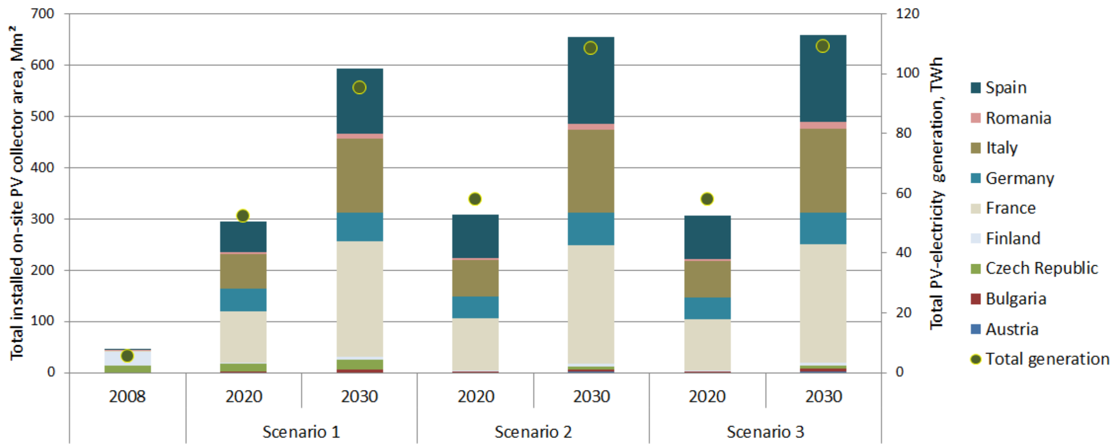

Figure 21 Total installed on-site PV collector area, Mm² and total PV-electricity generation, TWh in ENTRANZE target countries in 2008, 2020 and 2030, in policy scenario 1, 2 and 3, low energy price scenario[30]

4.4 CO_2-emissions

Figure 22 to Figure 24 show the specific CO_2-emissions in kg/(m²yr) caused by the energy demand for space heating, hot water, cooling and lighting related to the share of renewable energy[31] on the total final energy demand for space heating and hot water. The size of the bubbles show the total final energy demand for the space heating, hot water, cooling and lighting, where the value for selected countries is indicated.

There are several key drivers for the specific CO_2-emissions per floor area in the scenarios. (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, which is already quite substantial in policy scenario 1. However, by more additional and deeper renovation measures, more efficient

[30] Results for the high energy price scenario are shown in the annex.

[31] Only on-site RES-H is counted in these graphs. PV-contribution to space heating and hot water preparation as well as the share of renewable in the electricity mix is not considered.

heating systems and enforcement of the RES-H share, CO2-emissions can be further reduced in Policy scenario 2 and 3.

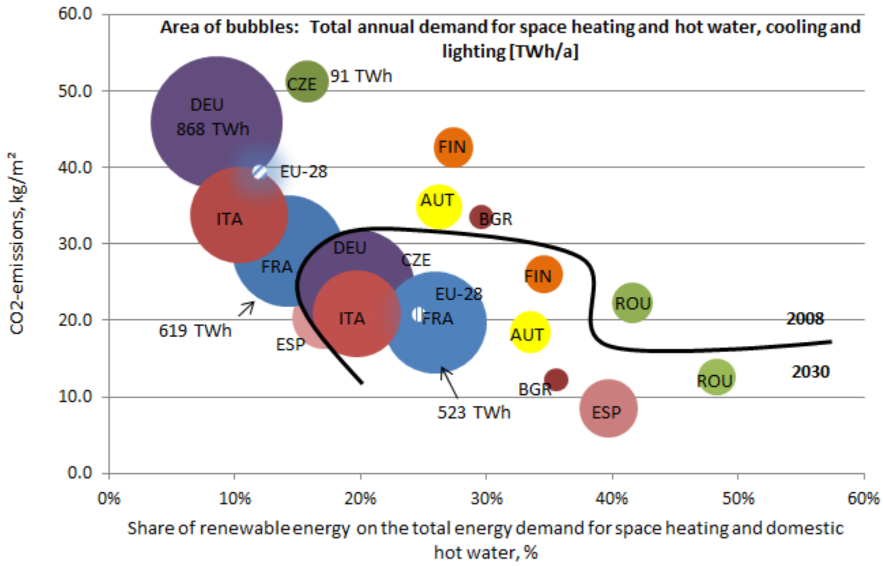

Figure 22 CO_2-emissions caused by space heating, hot water, cooling and lighting and RES-H share[32]. Policy scenario 1, low energy prices.

[32] Only on-site RES-H is counted in this graph. PV-contribution to space heating and hot water preparation as well as the share of renewable in the electricity mix is not considered.

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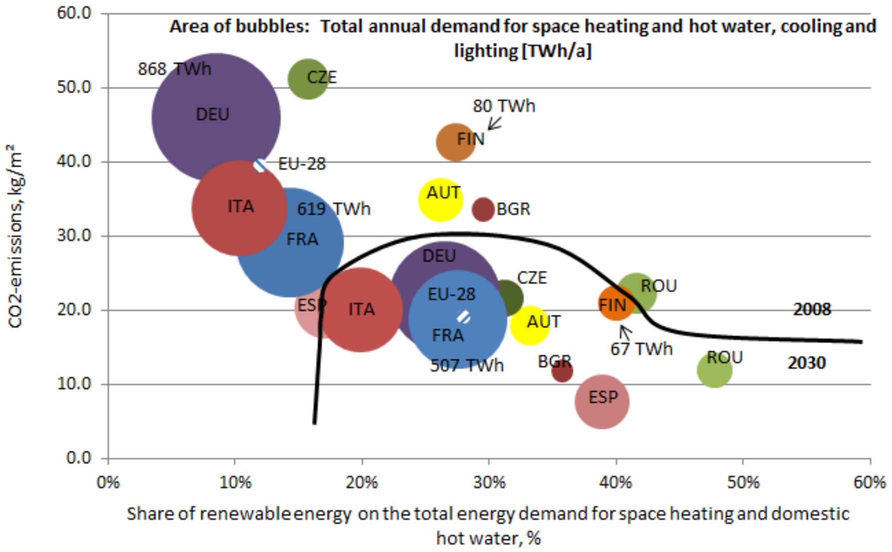

Figure 23 CO_2-emissions caused by energy demand for space heating, hot water, cooling and lighting and RES-H share. Policy scenario 2, low energy prices.

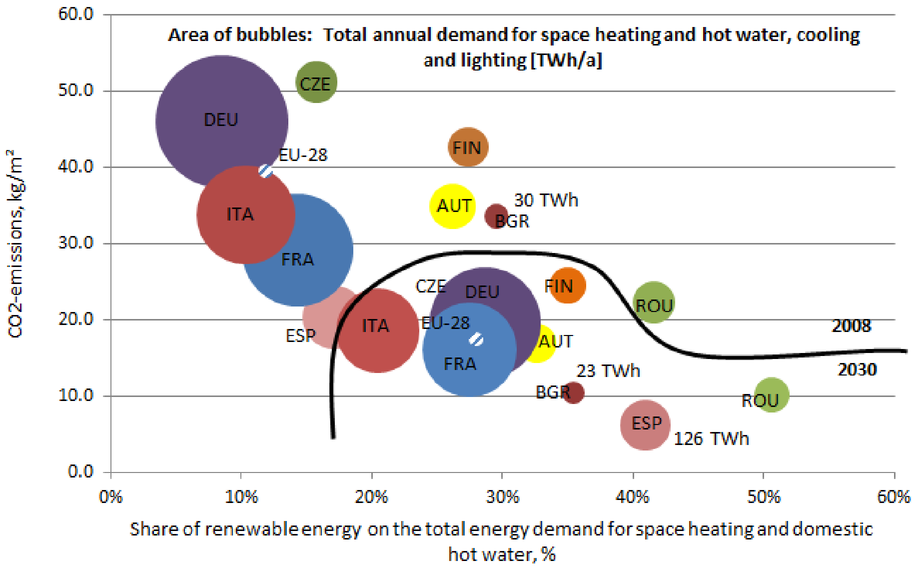

Figure 24 CO_2-emissions caused by energy demand for space heating, hot water, cooling and lighting and RES-H share[33]. Policy scenario 3, low energy prices.

[33] Only on-site RES-H is counted in this graph. PV-contribution to space heating and hot water preparation as well as the share of renewable in the electricity mix is not considered.

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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.

In all scenarios, the decline in heating oil plays a key role for the reduction of CO_2-emissions.

4.5 Investments, public expenses and fuel costs

Energy efficiency measures are typically associated with corresponding investments. Figure 25 shows the energy savings from 2008-2030 and the related specific investments per total floor area for each target country and scenario. Within the scenarios 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 between the scenarios and countries. Thus, this amount is substantially lower than investments per *renovated* floor area.

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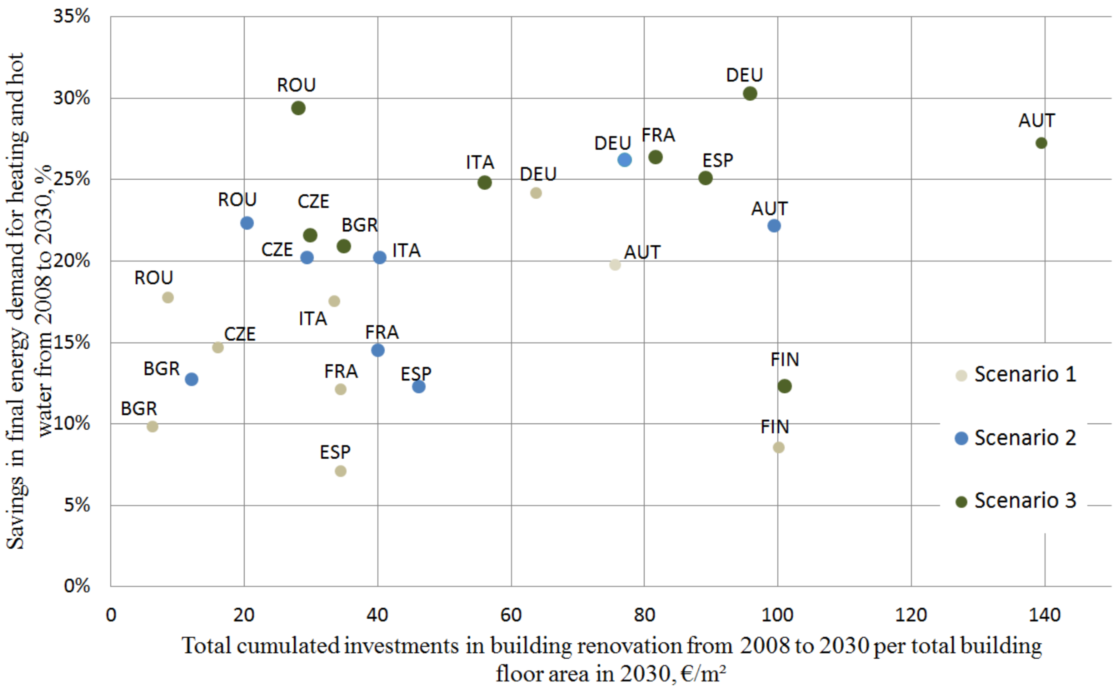

Figure 25 Savings in final energy demand for space heating and hot water from 2008 and 2030 and total investments in renovation per total building floor area[34] from 2008 to 2030[35], low energy prices[36]

A key element of investigated policy packages are investment subsidies for thermal building renovation. Figure 26 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 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) region-

[34] 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.

[35] 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

[36] Results for the high energy price scenario are shown in the annex.

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al 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 43), (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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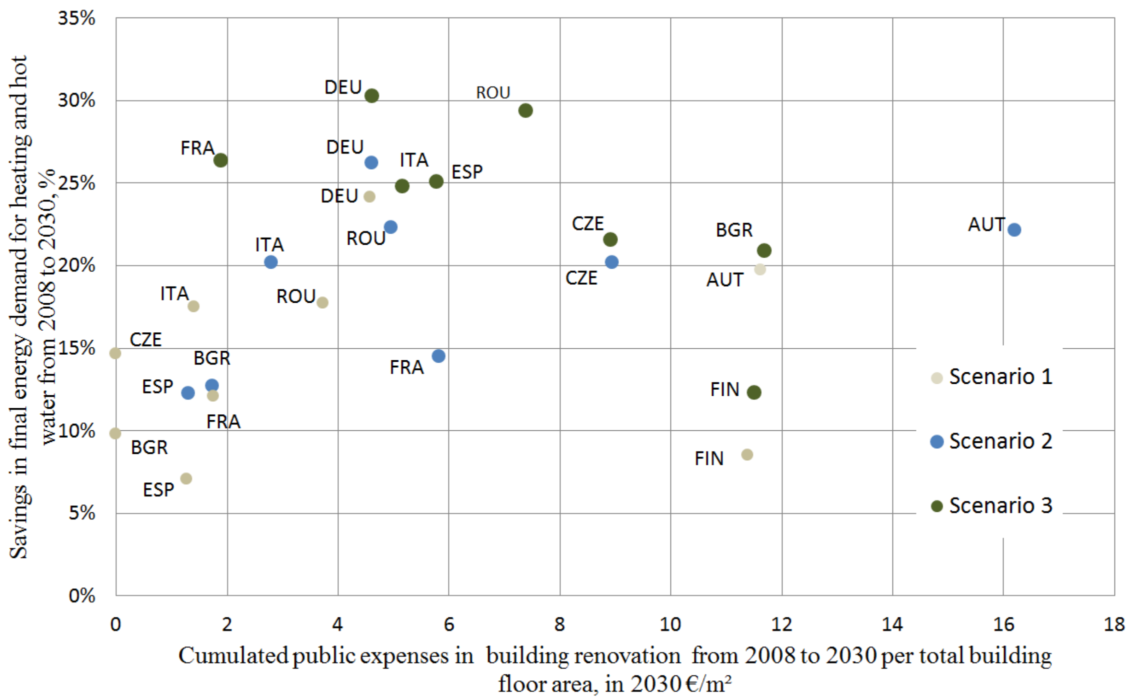

Figure 26 Savings in final energy demand for heating and hot water from 2008 to 2030 and cumulated public expenses in renovation per total building floor area from 2008 to 2030 (low energy price scenario[37])[38]

[37] Results for the high energy price scenario are shown in the annex.

[38] 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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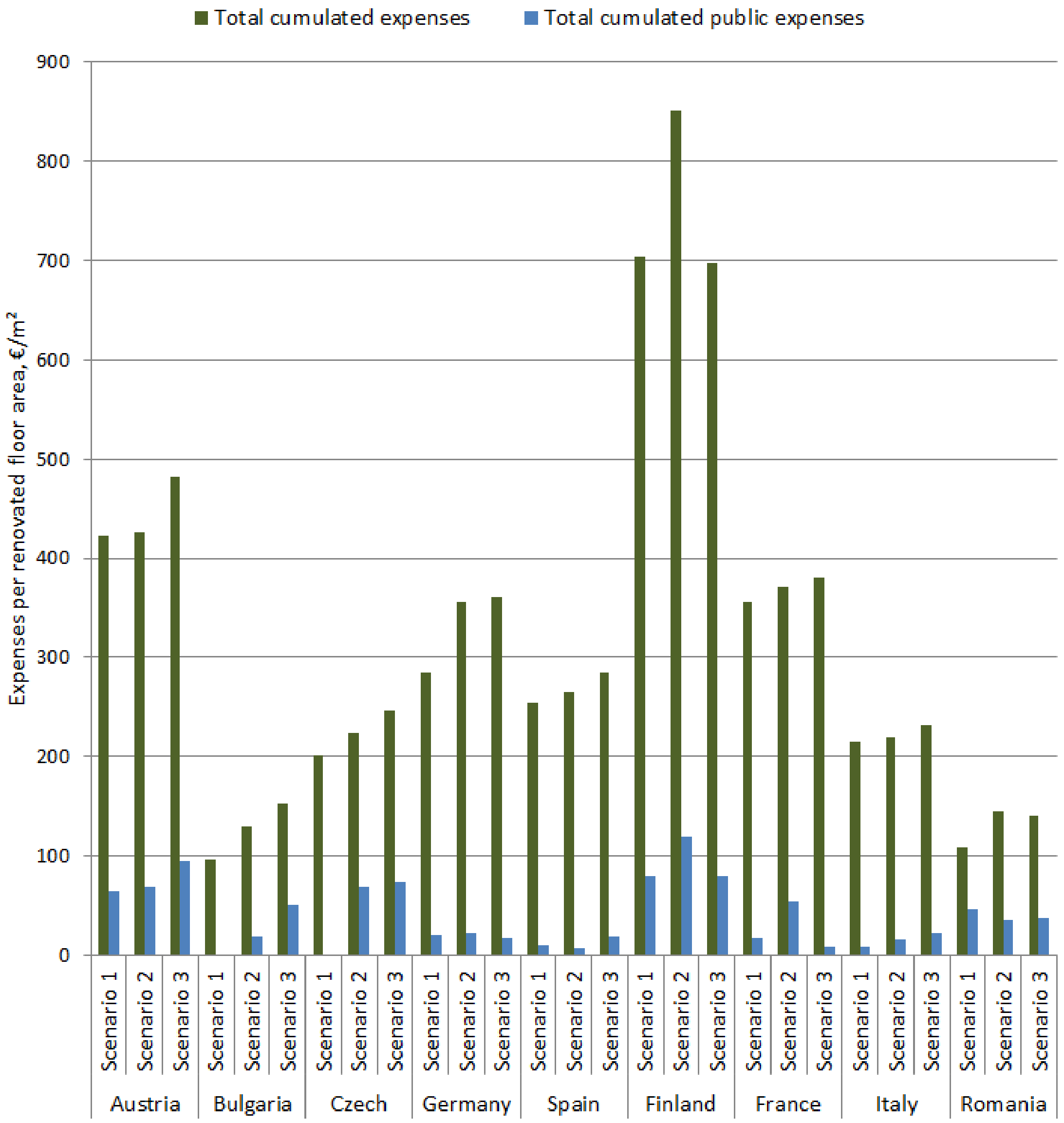

Figure 27 Total cumulated expenses and total cumulated public expenses in building renovation from 2008 to 2030 per total renovated floor area in 2030, in all three policy scenario in ENTRANZE target countries, low energy price scenario[39]

[39] Results for the high energy price scenario are shown in the annex.

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

4.6 Scenario summary by countries

Detailed scenario results are documented in the country reports “Policy scenarios and recommendations on nZEB, deep renovation and RES-H/C diffusion”. Moreover, the online scenario tool includes a lot of more detailed results and indicators. Both country reports and scenario tool are available on the project website at: http://www.entranze.eu/scenario-results/online-scenario-results . The annex of this report documents the development of final energy demand by energy carrier for each target country and scenario.

In the following, we will shortly highlight for each target country the main idea for policy packages and the corresponding overall results. Policy recommendations from these scenarios are derived in the documents mentioned above as well as in the report “Policies to enforce the transition to nZEB: Synthesis report and policy recommendations from the project ENTRANZE.”[40]

Austria

The Austrian policy group decided to investigate the potential impact of innovative policy packages mainly based on the following elements, on top of the existing ones:

[40] www.entranze.eu/pub/pub-scenario/.

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- A property tax depending on the energy efficiency of buildings;
- Intensified coaching of building owners before and during a thermal building retrofit;
- Innovative financing of thermal building retrofit by initiating public/private funds providing the financial support for building renovation at low interest rates. Partly, increased tax revenues from the property tax could also be used as a source for this fund.

Three model-based scenarios were developed: (1) a business-as-usual (BAU) scenario with the current schemes remaining constant, (2) a scenario with a new policy approach described above, however, with a low ambition and (3) a new policy approach with a higher ambition.

While the BAU scenario leads to about 20% -24% reduction of final energy demand and almost 25% -30% of delivered energy demand (under moderate and high energy prices) from 2008-2030, the additional measures in scenario 2 induce only very moderate additional reduction of energy demand. Thus, new policies as such do not guarantee a substantial progress. They have to be designed and implemented in an ambitious way. The third scenario indicates a significant increase of renovation activities and related energy performance. However, it has to be taken into account that the implementation of a property tax related to the energy efficiency of buildings would require a comprehensive building registry and corresponding energy performance certificate registry. Thus, corresponding activities have to be enhanced. Moreover, there is a need for further work and elaboration of coaching of building renovation activities. Corresponding pilot projects should be intensified. The options how to initiate funds to finance building renovation needs to be investigated more concretely. Although building codes and the regulatory framework were not the focus of the scenario work, the comparison with other countries revealed that the Austrian nZEB definition is not at the forefront of the European standard. Thus, stricter regulatory measures would be required to achieve ambitious long term climate and energy policy targets.

Bulgaria

The building stock in Bulgaria has had a very high level of energy consumption for heating and also for cooling in the recent years. First legislative initiatives for heat energy conservation were introduced in 1961, strengthened for the panel buildings in 1979 and for all buildings subsequently in 1987, 1999, 2004 and 2009. The official approval of the national definition for nZEBs and an additional increase in the energy efficiency requirements for new buildings and also in the event of a major renovation are expected by the end of 2014. The economic incentives to support the national policy for energy efficiency and the use of RES in the building sector up to now were limited mainly to public buildings and multi-family apartment blocks. The current legislation does not address barriers relating to the renovation of condominiums.

Compared to the existing policy scenario, the “medium term policy” scenario and “policies in two steps+” show good results for the period up to 2030. It is expected that less electricity will be used for heating and DHW as the share of natural gas, solar thermal and ambient heat will increase. The scenarios foresee investments between EUR 6 and EUR 14 billion in the building sector for the period 2030.

The policy recommendations for Bulgaria include the introduction of building codes with stronger requirements for energy performance characteristics and use of RES for new buildings and also in the event of major renovation. This should be implemented in two phases in 2015 and in 2020. The financial support from the EU funds is limited and additional resources should be mobilised – national funds, private resources (through public private partnership) and bank resources (soft loans), as tax reductions are a workable option which are already giving some results. Important policy instruments are related to ensuring the quality of renovation, and information and awareness-raising campaigns targeted at the relevant stakeholders.

Czech Republic

In the Czech Republic, energy efficiency in buildings requirements are being revised since their introduction in late 1960´s. Hand in hand with implementation of the recast EPBD into national legislation, the strengthening of minimum standards for buildings has been done within updates of the energy efficiency law as well as providing a regulation in 2013. The introduction of requirements on nZEBs was a part of this update. Future updates are expected after gaining relevant experience under the existing legislation.

Although keeping the present system of supporting schemes for a wide range of building types and keeping the volume of funding (scenario 2) can lead to fulfilment of EED requirements, still higher savings and efficiency can be achieved by implementation of a more ambitious approach (scenario 3) by the earlier introduction of the nZEB standard. Such acceleration would be feasible because the legal national requirements on nZEBs are not as strict in the country at present. Figure 8 shows the development of final energy demand in the Czech Republic by energy carriers that relates to the different policy scenarios defined. The three policy sets relate to basic regulatory framework fulfilment without the involvement of support schemes (Scenario 1), “business as usual” that takes into account existing support schemes in the same intensity (Scenario 2) and

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the third policy set (Scenario 3) that involves mandatory requirements[41] for nearly Zero-Energy Buildings in 2014 already, in addition to the previous scenario. The decrease in natural gas and coal demand is visible as well as the increase in the share of ambient energy (i.e. renewable sources). The policy sets reflect mainly the direct subsidy programmes as these already have a considerable tradition.

The differences in the scenario results defined above lead to two main recommendations:

- Focus shall be put on increased renovation of the existing building stock in order to intensify it and support complex solutions.
- Revision of requirements on nearly Zero-Energy Buildings as their effect on energy performance (compared to present requirements on buildings) is quite low and the nZEB level is not ambitious enough.

Finland

Finland was one of the first countries to introduce stringent energy standards in the building code in 1976, with several revisions in the subsequent decades. The most recent revision has been the introduction of specific energy efficiency standards for buildings undergoing renovation in 2013. Because of this, policy makers would like to first test the effects of this regulation before introducing new regulatory instruments.

However, the Finnish ENTRANZE Policy Group was eager to evaluate two new ideas:

- A target-group specific approach, where separate instruments are implemented for single-family homes (most outside the district heating system) and multifamily homes and other larger buildings (most served by the district heating system). Single-family homeowners gain support for changing their heating system from electric and oil to heat pumps or biomass, which are cost-effective. Multifamily buildings gain tailored advice when approaching the age of major renovations. Both groups are offered private finance with loan periods that correspond to the lifetime of the renovated building components. Technology procurement is used to reduce the cost of certain measures.
- The other idea evaluated was a tax on fossil fuels, district heat and electricity, which raises the price paid by the consumer by 50%. Economic instruments are

[41] Energy Management Act 406/2000 Coll. and Regulation 78/2013 Coll. on energy performance of buildings

popular in Finland and it was considered interesting to see what they can deliver in principle with an extreme scenario.

Compared to the existing policy scenario, the target group specific scenario shows good results. Energy demand is reduced and a large share of purchased energy is replaced with “ambient energy”, i.e., energy gained from the ground and air via heat pumps. However, this requires technology procurement to develop cost-effective solutions for single-family homes lacking central heating. Scenario 3 also reduces energy demand, but is not feasible in practice and could lead to social problems. Moreover, this scenario outcome also requires additional measures to restrict the use of biomass in urban areas, which can cause local air pollution.

France

Despite five updates of building codes since 1974 for new construction and the fact that the last building code implemented (RT2012) is one of the most stringent in EU[42], the specific energy consumption per m² and per heating degree days in buildings in France is still significantly higher than in other EU countries. Indeed, buildings built before the first regulation still represent today 64% of the stock. Many economic incentives for building renovation have been implemented, such as subsidies or tax credits, and still the renovation rate remains very low. Therefore, the scenarios mainly considered are measures targeting existing buildings. Beyond a BAU scenario including existing measures as of end of 2012, two scenarios with additional measures have been considered[43]:

- The implementation of a progressive **energy or CO_2 tax reaching 100 €/t CO_2** (*CO_2/energy tax scenario*)**, with reallocation of the tax revenue as a priority to low income households** to provide additional resources to subsidise energy efficiency investments, reduce fuel poverty and increase the cost-effectiveness of the investments.

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[42] Limit of 50 kWh/m^2 in primary energy (kWhep) since January 2013 for all new dwellings for 5 end-uses (space and water heating, air conditioning, lighting and auxiliaries (ventilation, pumps). With the next update in 2020, all new buildings will be energy positive (consumption below 0 kWhep/m^2, or 12 kWhep/m² for heating).

[43] Both CO_2/energy tax and proactive scenarios include an increased effort on information for households.

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- A **mandatory** thermal **retrofitting** of the least efficient dwellings during real estate transactions and major transformations (when economically feasible) *(Proactive scenario*).

The energy demand for space and water heating is expected to decrease by up to 32% in 2030 compared to the 2008 level in the proactive scenario. The CO_2/energy tax scenario would allow an intermediate reduction of 20%[44]. As the proactive scenario implements more stringent measures on existing buildings, the renovation dynamics are significantly higher: in 2030 around 30% of the stock would be renovated with a strong share of deep renovation.

Germany

In Germany there is already a well-established instrument portfolio addressing the energy refurbishment of buildings. The main policy instruments are: the energy efficiency requirements defined by the building code; low-interest loans and a repayment bonus for energy efficient refurbishment and new buildings depending on the energy standard achieved; investment grants (existing buildings) and use obligation (new buildings) for the implementation of RES-H; and a variety of instruments for information and motivation as well as supply side measures.

However, calculations about the expected future development of energy consumption by the building sector show that the impact of the existing instruments will not be sufficient to reach the targets set for energy consumption. These results have also been validated by the scenario calculation within the ENTRANZE project.

A business as usual (BAU) scenario - assuming a continuation of current policy design – and two additional policy sets – considering further policy measures – have been analysed. The second policy set (regulatory) considers a tightening of the building code requirements as well as an expansion of the RES-H use obligation for existing buildings. In addition to the regulatory policies, enforcement and information measures to improve compliance are included in the third policy set (regulatory & information). The final energy demand for space heating and hot water declines in the period 2008 to 2030 by 24% in the BAU scenario and by 27% in the regulatory policy set. The combination of tightened regulations and additional measures to improve compliance results in a decrease of 30% by 2030. Driven by the RES use obligation for existing buildings,

[44] A sensitivity analysis showed that increasing the CO_2/energy tax from 100 to 200€/tCO2 in 2030 will reduce energy consumption by an additional 20% and would have the same result as the proactive scenario.

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RES-H accounts for 33% and 36% of total final energy demand in 2030 in the second and third policy set, respectively. In the BAU scenario, a RES-H share of 28% is achieved by 2030.

The results clearly show that the enforcement of regulatory instruments and the improvement of information in combination with an ambitious tightening of the building codes and the implementation of use obligations for RES-H will have the highest impact on energy efficiency and the RES-H share.

Italy

Three possible policy sets were developed for Italy in strong collaboration with the national policy makers and experts involved in the dialogue groups. In line with EPBD requirements, the focus was put on cost-optimal solutions to determine **regulation limits for refurbishment**. In those few cases where the cost-optimal solutions have been already incorporated in the current regulations, we selected more ambitious renovations levels to keep on the regulation improvement process.

With these goals in mind the following regulations were suggested:

- Renovation has to reach savings greater than 50% in total net primary energy (excluding electrical appliances), in respect to base refurbishment level.
- Total net primary energy has to be lower than the maximum threshold of 100 kWh/m^2/y.
- Alternatively the most cost-optimal solutions have to be adopted if it is calculated that they lead to lower net primary energy demand.
- And in general the indicated minimum percentages of primary energy demand have to be covered by renewable energy systems.

In more ambitious policy sets selected solutions and performances for nZEB were considered as limits to take advantage of proposed incentives. In the three policy sets for renovations, indicated respectively as *BAU Plus, Medium* and *Improved,* the policy measures considered consist of: **regulatory instruments, tax deductions, economic incentives, preferential loans and information campaigns**. Also a regulation for new buildings has been proposed, mainly focused on nZEB levels in regulations, starting from 2020.

Among the main recommendations which the process led to we can highlight:

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- the need of more **complete indices** (e.g. energy needs, load matching indices, long-term comfort indices, etc.) for description / ranking of buildings and NZEBs as foreseen by EPBD;
- policy instruments which will remain in force **certainly for long periods**, mainly giving financial support to initial investments, integrating private and public sources; and there is need for **investment in quality control** over renovation interventions;
- the crucial importance of **information campaigns** particularly for the demand side;
- adopting solutions of **progressive tariffs** with unitary energy price growing with consumption and making **real time consumption data** available to customers;

Romania

The policy scenarios for Romania have been elaborated in close cooperation with policy makers and stakeholders through dedicated meetings and workshops organised over the project lifetime. Up for debate were the following topics: data on the building stock, analysis of behavioural aspects relating to investing in energy performance and, finally, existing buildings policies in Romania, support programmes and potential ways to improve them by 2030.

As a result of the continuous dialogue with Romanian stakeholders, three policy sets were defined, exploring different levels of policy ambition. Based on the results of the modelling exercise, policy recommendations are provided for securing the transition to nZEB in Romania:

- Need to further improve the strategic planning and dynamic regulation based on a periodical evaluation of policies in close cooperation with main stakeholders
- The energy performance and thermal requirements from buildings regulations have to be stricter and properly enforced in order to ensure a high level of compliance in construction work
- Need to further improve measures for information and provision of guidance to buildings owners and stakeholders
- Need to introduce qualification trainings of the workforce and to improve the education curricula from high schools and universities in order to prepare the workforce to properly implement nZEB construction.
- Need for financial support programmes. These programmes can be built on existing ones, but by increasing predictability (through cross-party support, multi-annual budgets, transitioning from high intensive grants to more commercial instruments).

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- Buildings renovation programmes have to be in close coordination to complementary programmes and measures on urban development and district heating in order avoid inconsistency between them, to minimise costs and therefore to increase their effectiveness.

The modelling results show a decrease of final energy demand for heating and domestic hot water leading to energy savings of up to 31% (as comparing to 2008) in the most ambitious scenario. Renewable energy share will also increase from about 41.6% in 2008 up to 51-56% by 2030 in the most ambitious policy scenario. In all policy scenarios modelled, the contribution of oil, coal and district heating to final demand decreased by 2030.

Spain

The current Technical Building Code (TBC-updated in 2013) is in line with the minimum requirement for energy efficiency associated with the cost-optimal analysis that has been submitted to the European Commission by Spain. There are already quite attractive subsidies for building renovation and yet the renovation rate remains very low. Three policy sets have been chosen and their impact calculated with Invert/EE-Lab: (1) business as usual, (2) focus on regulatory measures and (3) ambitious scenario.

The scenarios show that the most ambitious policy set 3 leads to the highest energy saving (around 27% in 2030 compared to 2008). In addition, the following main findings have been identified:

- It is estimated that the **current policies** regarding the energy efficiency of buildings implemented in Spain will result in energy savings (for heating and hot water) of between 2% and 4% in 2020 compared to 2008.
- Achieving more **ambitious savings** (e.g. 15% -25%) in 2020 and 2030 necessarily requires the implementation of more ambitious policy instruments. In some cases the currently implemented policy instruments can be strengthened or improved (e.g. strengthen minimum requirements of regulatory instruments), in other cases new and innovative instruments are needed (e.g. related to building owners' information/motivation to invest in energy efficiency in order to strengthen the impact of financial support programmes).
- A **market transformation** is needed in order to meet the quality assurance requirements of the implemented energy efficiency measures. Several experts point to the development of an effective surveillance system which will ensure

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the quality of the whole process (from project design to implementation and maintenance) in order to ensure compliance with the TBC[45] requirements.

[45] Technical Building Code (updated in 2013)

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5. 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 28 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% of delivered energy 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.[46]

[46] Invert/EE-Lab also has been applied in the "Study evaluating the current energy efficiency policy framework in the EU and providing orientation on policy options for realising the cost-effective energy-efficiency/saving potential until 2020 and beyond" (Eichhammer et al., 2014) ordered by the European Commission. Since the objective of this project was not the same as in ENTRANZE and because of different policy assumptions and framework conditions, the results of the two projects are slightly different. Taking into account the different side conditions and assumptions the results can be considered as consistent with each other.

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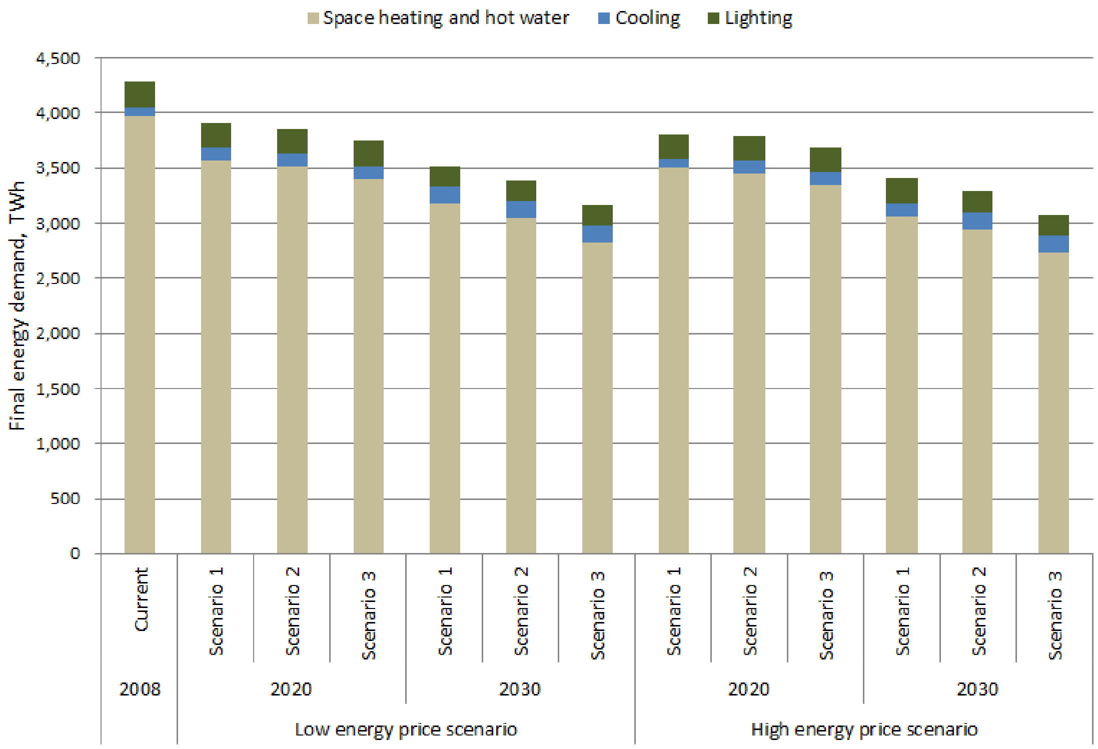

Figure 28 Final energy demand for space heating, hot water, lighting and cooling in 2008 and in 2030 in EU-28 in policy scenarios 1, 2, 3.

The figure also confirms for EU28 the findings from Figure 11, 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 29 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 energy is accounted according to the reporting requirements of Member States for the renewable energy directive (see chapter 3.4).

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.

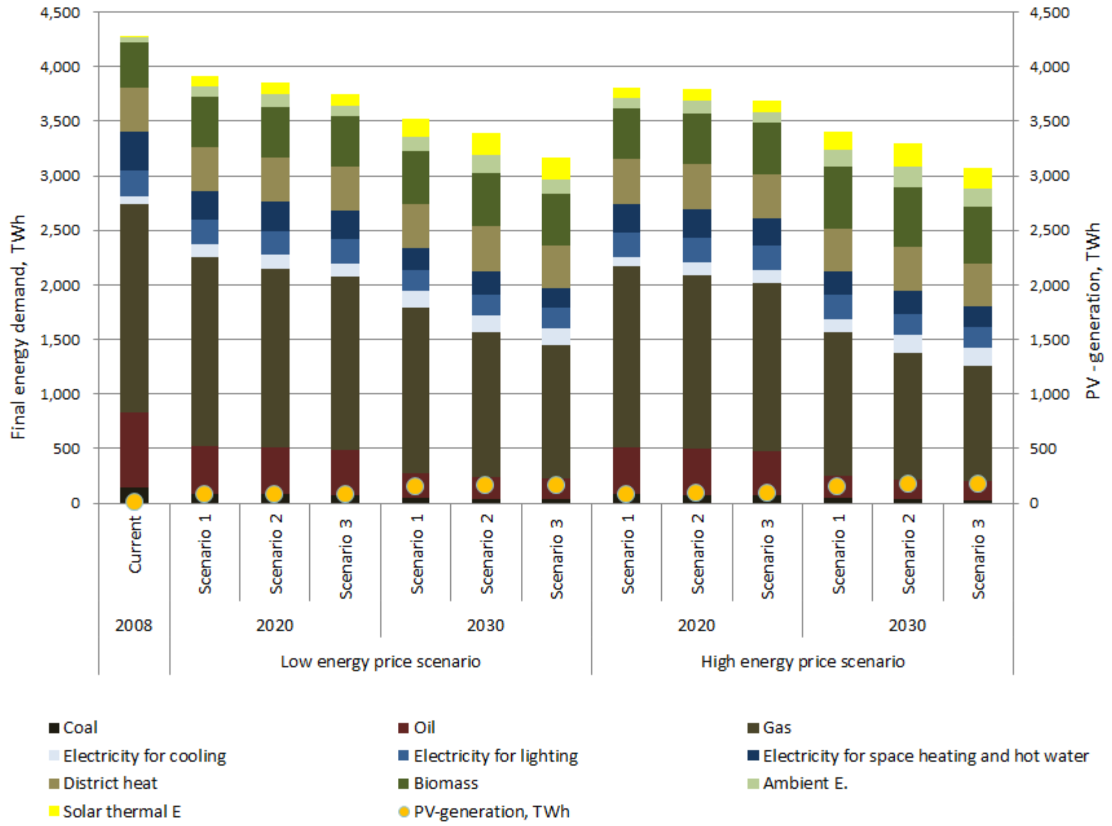

Figure 29 Final energy demand for space heating, hot water, cooling and lighting by energy carriers in EU-28 in policy scenarios 1, 2 and 3.

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Table 5 Final energy demand for space heating and hot water in EU-28 and Serbia in 2008, 2020, 2030 in policy scenarios 1,2,3, low energy price scenario[47]

		Low energy price scenario					
		Scenario 1		Scenario 2		Scenario 3	
TWh,	2008	2020	2030	2020	2030	2020	2030
Austria	101.3	93.7	81.3	92.8	78.8	90.3	73.7
Belgium	133.1	126.1	116.5	124.5	113.4	117.3	97.3
Bulgaria	27.3	27.0	24.7	26.7	23.9	25.8	21.6
Cyprus	3.6	3.6	3.4	3.5	3.2	3.4	2.8
Czech Rep.	89.1	87.5	76.1	83.9	71.1	82.8	69.9
Croatia	19.0	19.4	17.8	19.2	17.2	19.0	16.8
Denmark	59.2	55.9	54.3	53.9	50.7	53.4	52.1
Estonia	12.6	12.4	10.8	11.9	10.1	11.8	10.0
Finland	73.9	69.6	67.6	67.1	63.2	66.4	64.8
France	578.4	550.9	508.7	543.5	494.4	512.9	425.9
Germany	821.5	712.1	623.4	710.7	606.0	695.4	572.8
Greece	58.8	57.4	54.0	56.4	51.1	52.8	43.2
Hungary	82.4	80.8	70.2	77.5	65.6	76.5	64.5
Ireland	41.7	39.6	38.5	38.2	36.0	38.0	37.1
Italy	436.2	404.4	359.8	397.3	347.9	387.3	328.0
Latvia	22.0	21.6	18.8	20.7	17.6	20.5	17.3
Lithuania	19.2	18.9	16.5	18.1	15.4	17.9	15.2
Luxembourg	3.0	2.5	2.0	2.5	1.9	2.4	1.7
Malta	0.4	0.4	0.4	0.4	0.3	0.4	0.3
Netherlands	169.4	145.6	125.3	145.2	121.3	142.0	114.2
Poland	240.6	183.5	147.4	179.3	138.4	175.1	128.5
Portugal	24.5	24.4	23.4	24.0	21.9	22.7	19.1
Romania	82.1	77.1	67.6	75.4	63.8	73.4	58.0
Slovakia	40.8	39.8	34.4	38.1	32.0	37.7	31.5
Slovenia	14.7	14.0	12.8	13.6	11.8	13.0	10.6
Spain	165.0	162.0	153.3	159.3	144.7	149.6	123.6
Sweden	85.6	80.9	78.5	78.0	73.4	77.3	75.4
UK	570.2	420.8	338.4	417.4	330.6	408.2	309.6
Serbia	22.7	22.4	20.5	22.2	19.8	21.4	17.9

[47] Results for the target countries (AT, BG, CZ, DE, ES, FI, FR, IT, RO) have been reviewed and discussed with policy makers and experts in an iterative way. For the other countries, the reviewing process and data collection process was less rigorous.

Table 6 Final energy demand for space heating and hot water in EU-28 and Serbia in 2008, 2020, 2030 in policy scenarios 1,2,3, high energy price scenario[48]

		High energy price scenario					
		Scenario 1		Scenario 2		Scenario 3	
TWh,	2008	2020	2030	2020	2030	2020	2030
Austria	101.3	88.5	77.5	87.8	75.6	85.6	71.2
Belgium	133.1	122.8	109.5	123.9	112.4	113.8	90.4
Bulgaria	27.3	26.2	24.1	26.0	23.2	25.1	21.0
Cyprus	3.6	3.5	3.4	3.5	3.1	3.3	2.7
Czech Rep.	89.1	83.9	68.6	80.7	65.6	79.7	64.2
Croatia	19.0	19.2	17.3	18.9	16.6	18.8	16.2
Denmark	59.2	55.4	53.4	53.5	50.0	53.0	51.1
Estonia	12.6	11.9	9.8	11.4	9.3	11.3	9.1
Finland	73.9	69.1	66.5	66.7	62.3	65.9	63.6
France	578.4	535.1	475.8	540.9	491.6	496.5	394.5
Germany	821.5	712.6	622.1	711.2	601.5	697.3	572.9
Greece	58.8	56.0	52.2	55.1	49.3	51.6	42.0
Hungary	82.4	77.6	63.4	74.6	60.6	73.7	59.2
Ireland	41.7	39.3	37.9	37.9	35.5	37.7	36.5
Italy	436.2	391.8	333.2	385.0	321.9	375.5	302.8
Latvia	22.0	20.7	17.0	19.9	16.2	19.7	15.9
Lithuania	19.2	18.1	14.8	17.4	14.2	17.2	13.9
Luxembourg	3.0	2.5	1.9	2.5	1.8	2.4	1.7
Malta	0.4	0.4	0.4	0.4	0.3	0.4	0.3
Netherlands	169.4	145.6	124.2	145.2	119.8	142.3	113.9
Poland	240.2	183.3	147.0	181.2	137.2	176.6	126.7
Portugal	24.5	24.1	22.9	23.6	21.4	22.4	18.8
Romania	82.1	75.7	65.0	74.0	61.9	72.1	57.0
Slovakia	40.8	38.5	31.2	36.9	29.7	36.6	29.1
Slovenia	14.7	14.1	13.4	13.6	12.3	13.0	11.1
Spain	165.0	158.6	148.9	155.9	140.3	146.7	120.7
Sweden	85.6	80.2	77.3	77.4	72.4	76.7	74.1
UK	570.2	409.4	323.3	406.1	317.2	399.3	298.7
Serbia	22.7	21.8	20.0	21.6	19.3	20.8	17.4

[48] Results for the target countries (AT, BG, CZ, DE, ES, FI, FR, IT, RO) have been reviewed and discussed with policy makers and experts in an iterative way. For the other countries, the reviewing process and data collection process was less rigorous.

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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 leads to a reduction of total CO2-emissions for heating cooling and lighting from 43-50% in policy scenario 1 and 50-57% in policy scenario 3 from 2008 to 2030.

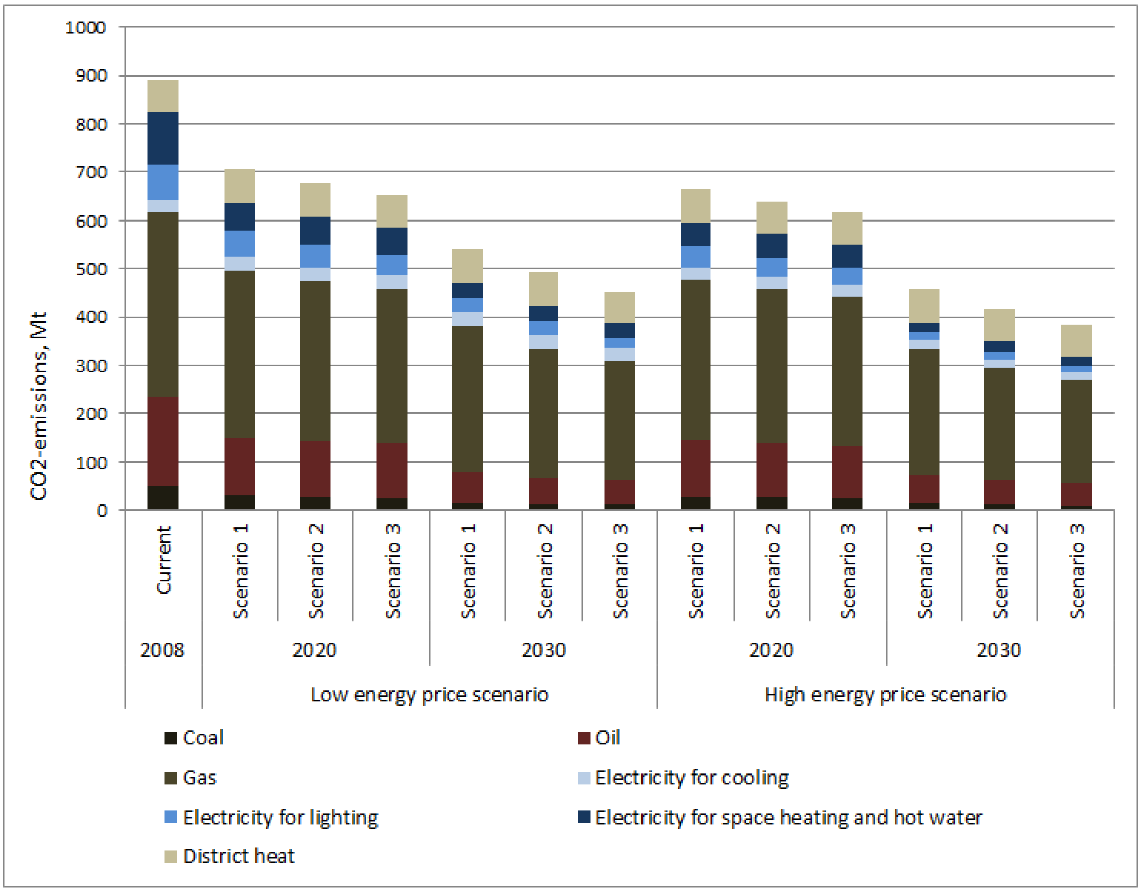

Figure 30 CO_2-emissions caused by energy demand for space heating, hot water, cooling and lighting by energy carrier in EU-28, in policy scenario 1, 2 and 3, low and high energy price scenarios

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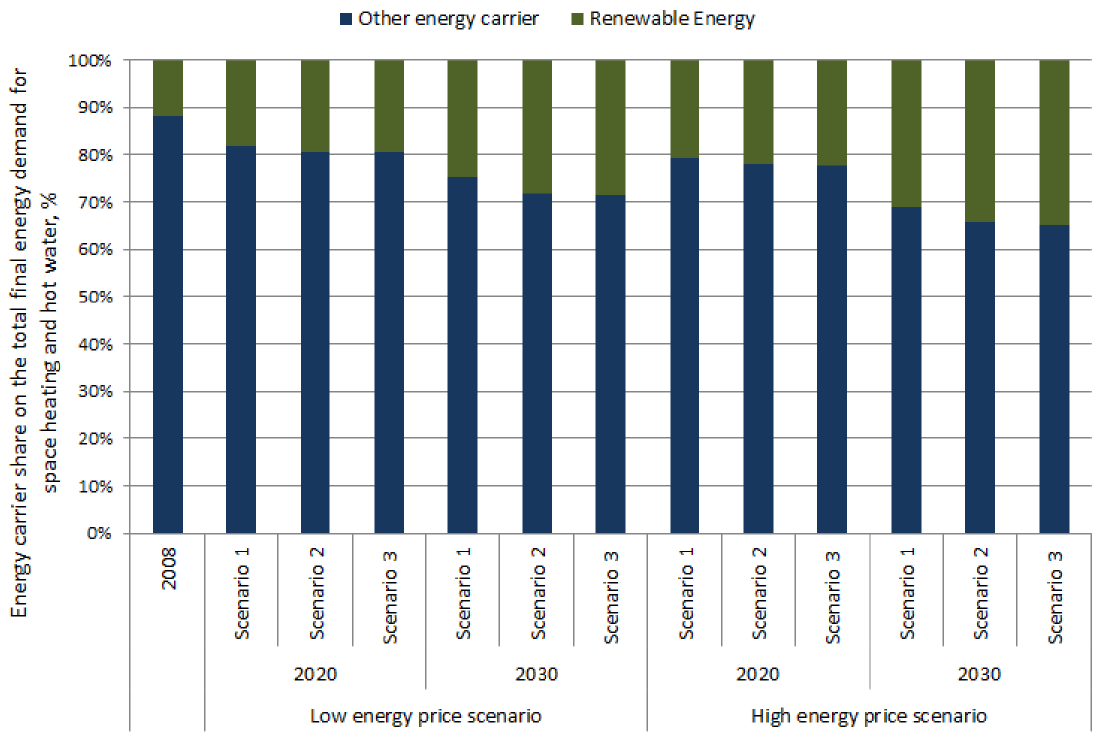

Figure 31 Renewable energy share on the total final energy demand for space heating and hot water in EU-28 in policy scenario 1, 2, 3, low and high price scenario

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.

The cumulated investments in building renovation (improvement of building envelope, without heating systems) from 2008-2030 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.

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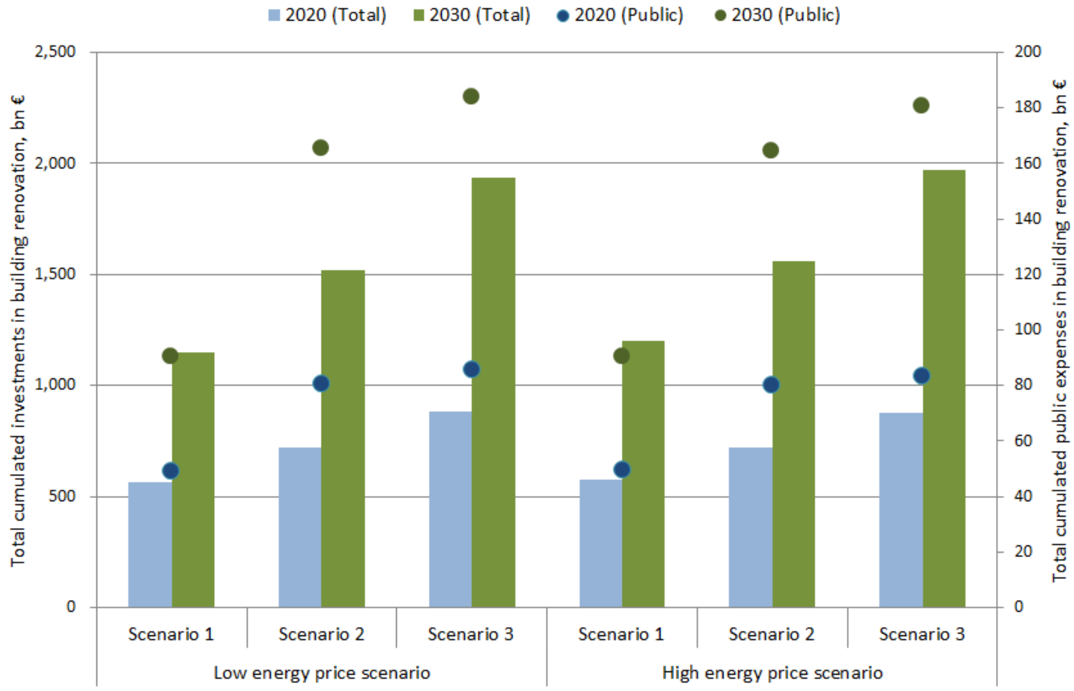

Figure 32 Total cumulated investments in building renovation from 2008 to 2020 and from 2008 to 2030 and total cumulated public expenses (investment subsidies and soft loans) in building renovation in EU-28

6. Uncertainties, open questions and outlook

6.1 Uncertainties

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 building 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**.[49] 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.

[49] 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

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- 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.[50]
- 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 generally 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.

[50] 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.

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- **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.

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- **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[51]. 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 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. On the one hand, specific staff costs might increase due to higher qualified staff. On the other hand, the qualification would pay of by higher quality of work and higher effectiveness of work. However, there is little empirical evidence on the

[51] 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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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.

6.2 Feedback of the building's energy demand on electricity markets: the case of France

The **impact of Invert/EE-Lab results on international prices** of oil, gas or coal is another relevant question and potential uncertainty of model results. For this reason, this section we check the need of the feedback loop from ENTRANZE Invert/EE-Lab results to the POLES energy price projections. Indeed, it may have some feedbacks on energy prices as Invert/EE-Lab has used the result of the POLES projections regarding energy price projections and primary energy factors of electricity generation.

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. In other words if the electricity demand in very strong (e.g. France), policy scenarios simulated in Invert was much lower than what was simulated in POLES, hence this could affect the power mix and thus the price of electricity. However, as only the part of electricity used for heating, water heating, cooling and lighting is concerned (appliances are excluded), this will represent in most EU countries a small part of the total electricity demand and again the impact of the policy scenario can be neglected. However in some countries with higher use of power for thermal uses like France the impact has to be checked.

To compare scenario results[52], we isolated the electricity demand simulated in Invert/EE-Lab from the electricity demand simulated in POLES for residential buildings. Before implementing Invert/EE-lab price effect in POLES, we observe 18% of difference between both models in 2030 in total electricity demand demand.

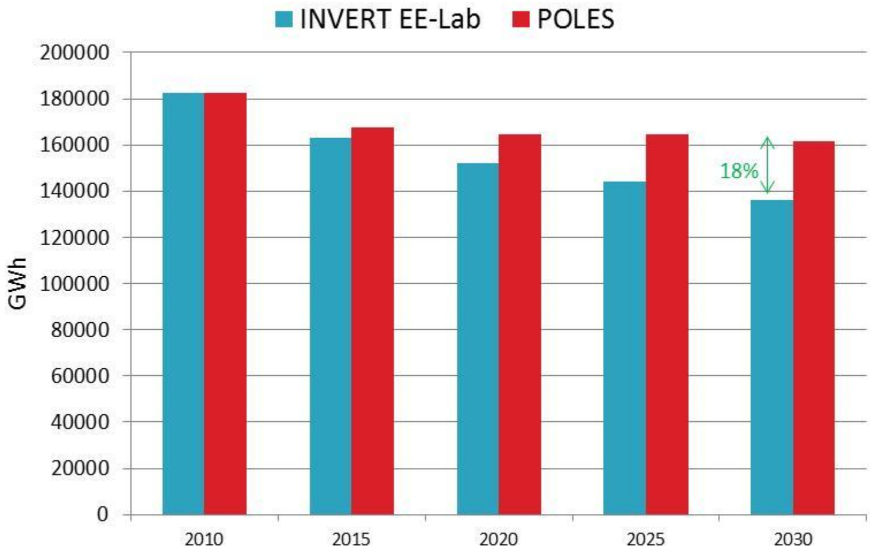

Figure 33: Electricity demand in residential sector in POLES compared to Invert/EE-Lab Policy scenario 3, high price

Source: Entranze

We then check the potential price effect of the Invert/EE-Lab demand scenarios on electricity price in the case of France, i.e. what would be the impact on electricity price if we decrease POLES electricity demand demand up to ENTRANZE INVERT/EE-lab 2030 level. To adjust electricity demand in POLES at ENTRANZE INVERT/EE-lab level we assumed:

- Energy efficiency factor or a substitution effect for space heating or cooking (switching electricity demand toward other energy)
- Change in demand behaviors : i.e. decreasing preference of final end-users for electricity
- Strong energy efficiency factors for electrical appliances (including air cooling).

[52] To benchmark scenarios we considered the most ambitious Entranze policy set (e.g. scenario 3 “proactive” in the case of France) in case of high price and the POLES “reference” scenario (more information available in chapter 3.3)

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In France, the share of electric space heating is currently high compared to other European countries. In our forecasted variant scenario, the electricity demand for space heating is decreasing substantially: this could be explained by a big switch towards non-electricity space heating (other energy carriers), or towards more efficient electric heating systems (e.g. heat pumps).

As a result POLES price slightly increased in 2030 with the INVERT/EE-Lab adjustment (only by 1.9% in 2030, see Figure 34.

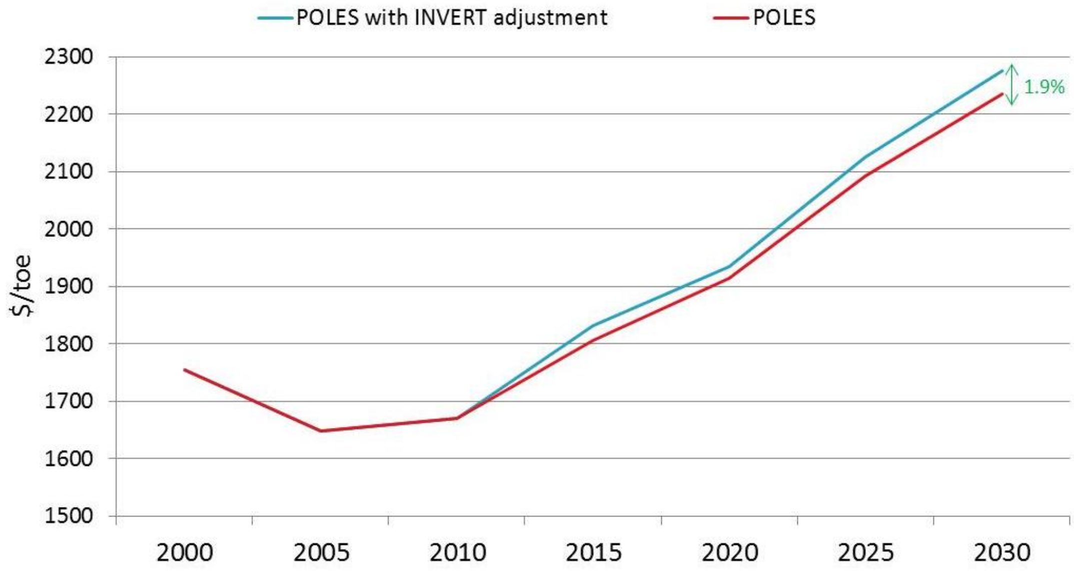

Figure 34: Electricity prices in residential sector
Source: Entranze

The fact that price is increasing (at the margins) can be explained by the fact that installed power generation capacities are used fewer hours, and thus amortize their costs on fewer sales of electricity. Indeed, demand is decreasing sharply; supply of electricity is adapted to that, as is the capacity planning, however the latter cannot adapt as quickly to the decreasing demand, leading to a situation of overcapacities and slightly higher prices.

Hence we can conclude in the case of France that the Invert/EE-lab price effect in POLES is marginal.

As France is among those countries with a very high share of electric heating, we can extrapolate this result to any other EU countries and conclude that price effect is very low. Hence, it turned out that there is no need for establishing an iterative feedback loop between Invert/EE-Lab and POLES within this project.

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6.3 Outlook

Based on the scenario results developed in ENTRANZE and presented in this report, conclusions and policy recommendations have been derived and iteratively discussed with national policy makers and experts. The results of these recommendations are presented in country reports (www.entranze.eu/pub/pub-scenario) and in the report "Policies to enforce the transition to nZEB: Synthesis report and policy recommendations from the project ENTRANZE." (Kranzl et al., 2014d).

Scenario development is a continuous, never ending process. New insights regarding data, modelling aspects, policies, building owner's and occupants behaviour etc has to be integrated in the modelling framework.

Scenario development and modelling strongly builds on reliable, up-to-date data. ENTRANZE provided a comprehensive set of data and at the same time we also identified the gaps. For well based, reliable monitoring, adaptation and foresight in the context of energy efficiency policies it would be highly important to close these data gaps, in particular regarding monitoring of market activities, renovation measures and market maturity towards nZEB. The IEE project ZEBRA2020 (Nearly zero energy building strategy 2020) covers some of these elements. It focuses on tracking the market transition to nearly Zero-Energy Buildings (nZEBs) to derive recommendations and strategies for the building industry and policy makers and to accelerate the market uptake of nZEBs.

Thus, the scenarios and the online tool to access their detailed indicators should be understood as a means for a structured discussion which has to be adapted according to the detailed question to be answered and according to new insights and data. Following such a process, the scenario development and modelling should form one of the key elements for evidence based policy decision making towards an nZEB building stock in Europe.

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A.1 Comparative result graphs for high-price scenarios

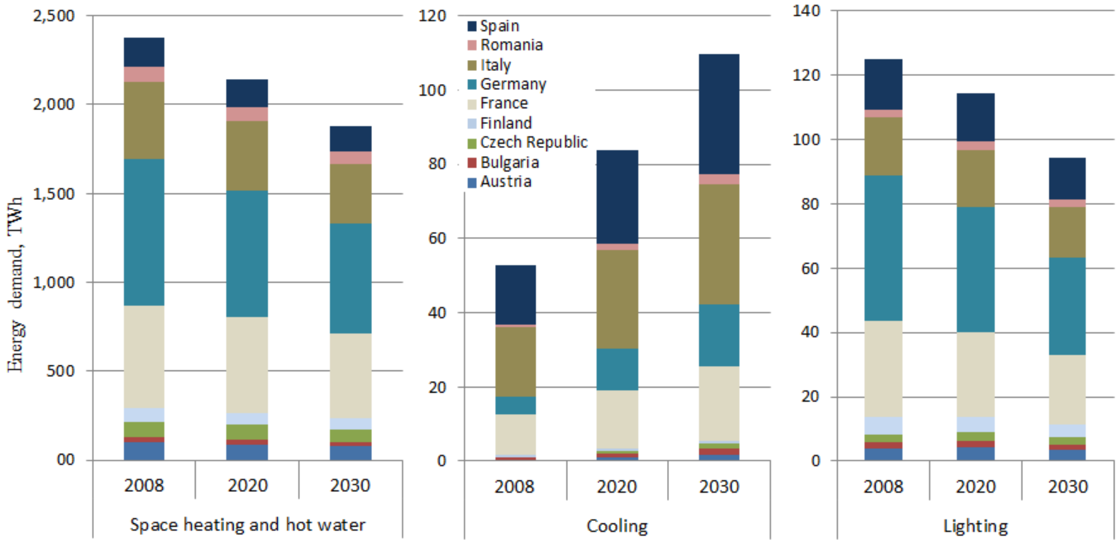

Figure 35 Final energy demand for space heating and hot water, cooling and lighting in ENTRANZE target countries in 2008, 2020 and 2030, Policy Scenario 1, high energy price scenario

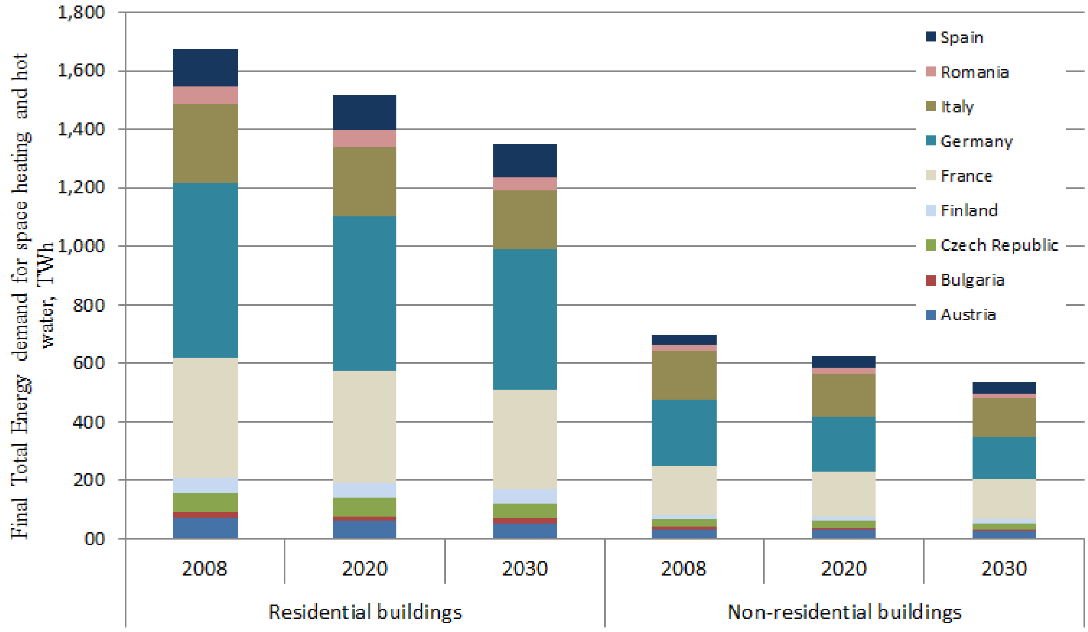

Figure 36 Final total energy demand for space heating and hot water in residential and service building sectors in all ENTRANZE target countries in 2008, 2008 and 2030, Policy Scenario 1, high energy price scenario

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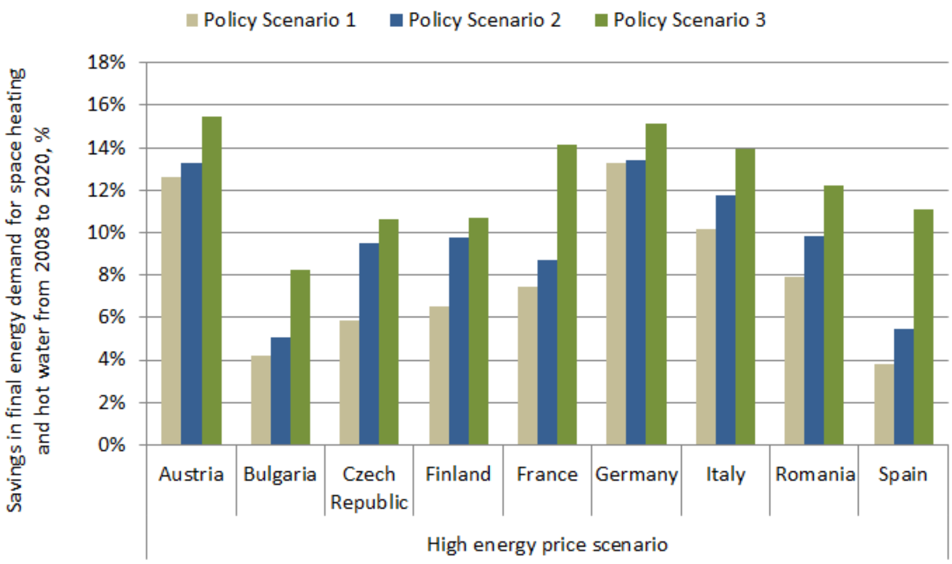

Figure 37 Savings in final energy demand for space heating and hot water in target countries in three policy scenarios, from 2008 to 2020, high energy price scenario

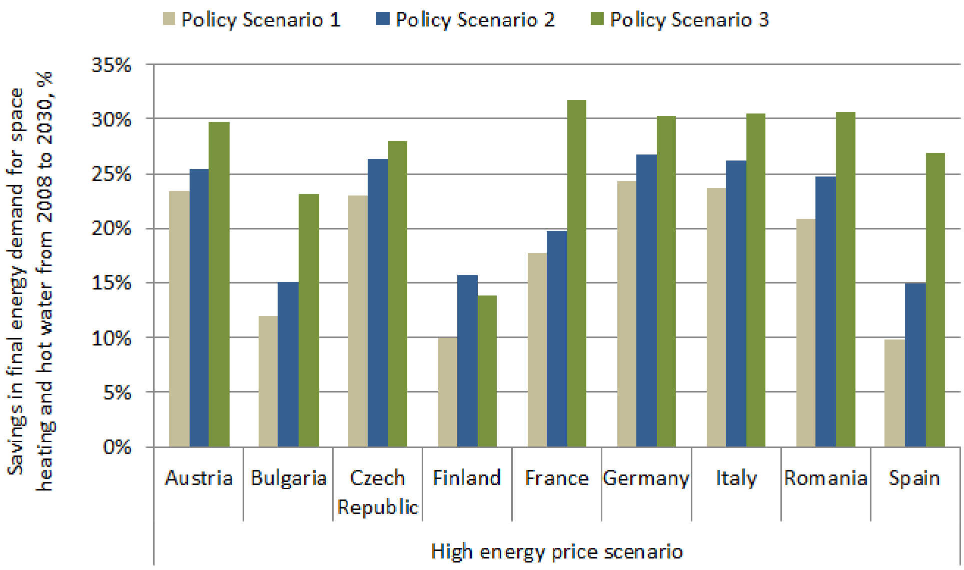

Figure 38 Savings in final energy demand for space heating and hot water in target countries in three policy scenarios, from 2008 to 2030, high energy price scenario

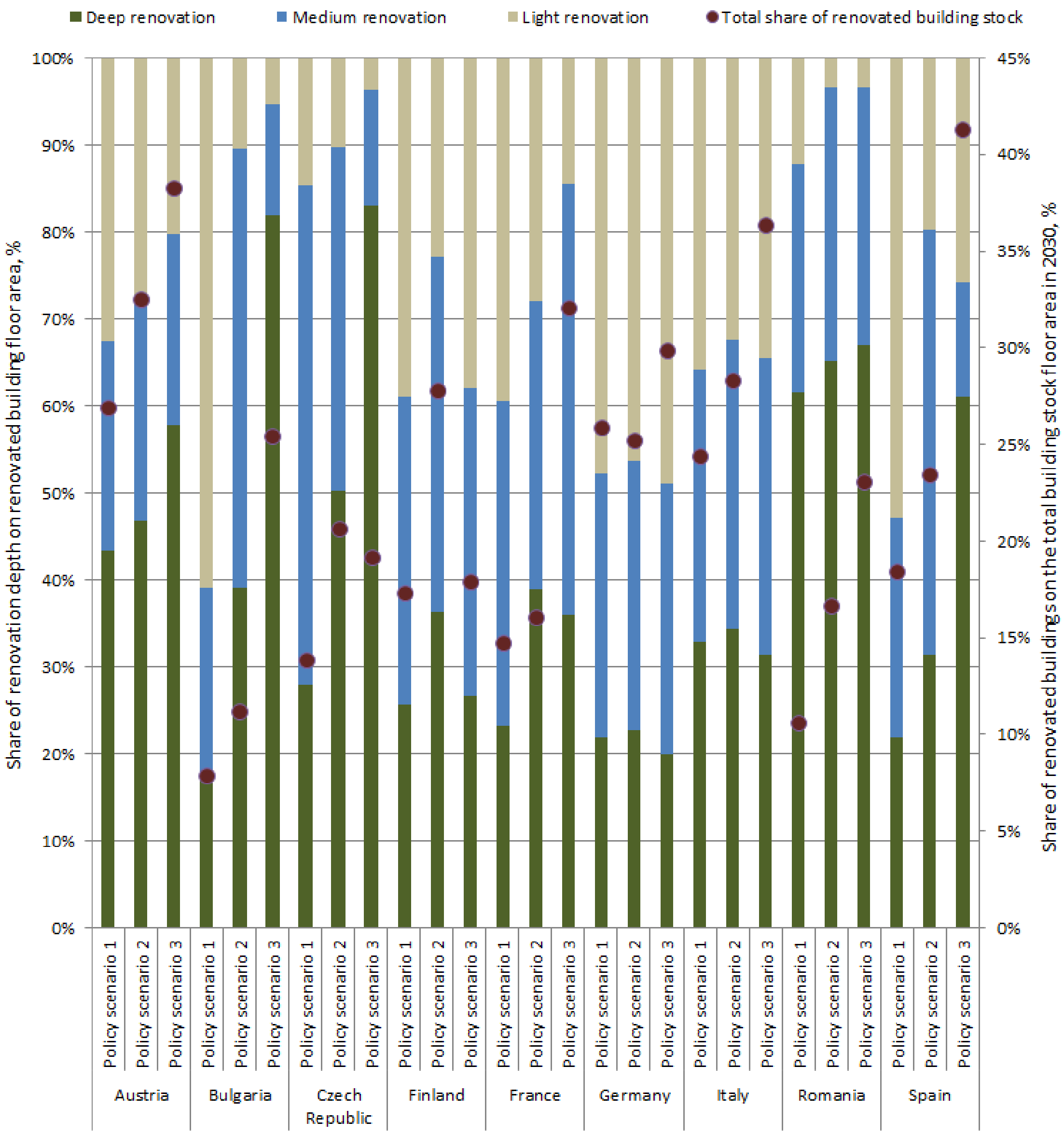

Figure 39 Share of cumulated deep, medium and light renovated floor area on the total floor area in 2030, in three policy scenarios in target countries, high energy price scenario

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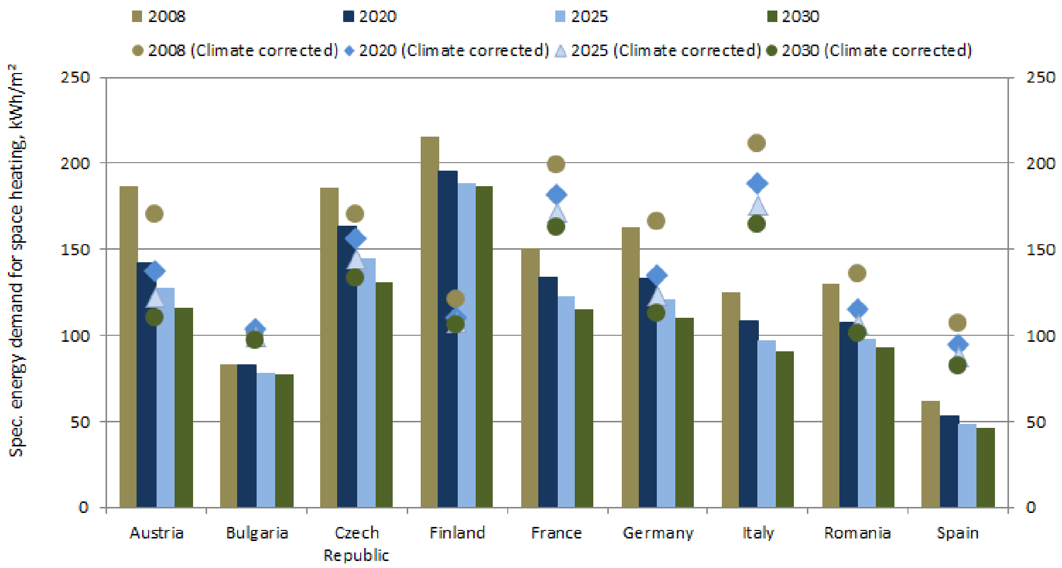

Figure 40 Specific final energy demand per floor area for space heating and climate corrected[53] specific final energy demand per floor area for space heating in target countries in 2008, 2020, 2025 and 2030 in scenario 1, high energy price scenario

[53] Climate correction has been done on the basis of mean heating degree days in EU-27 from 2000-2009.

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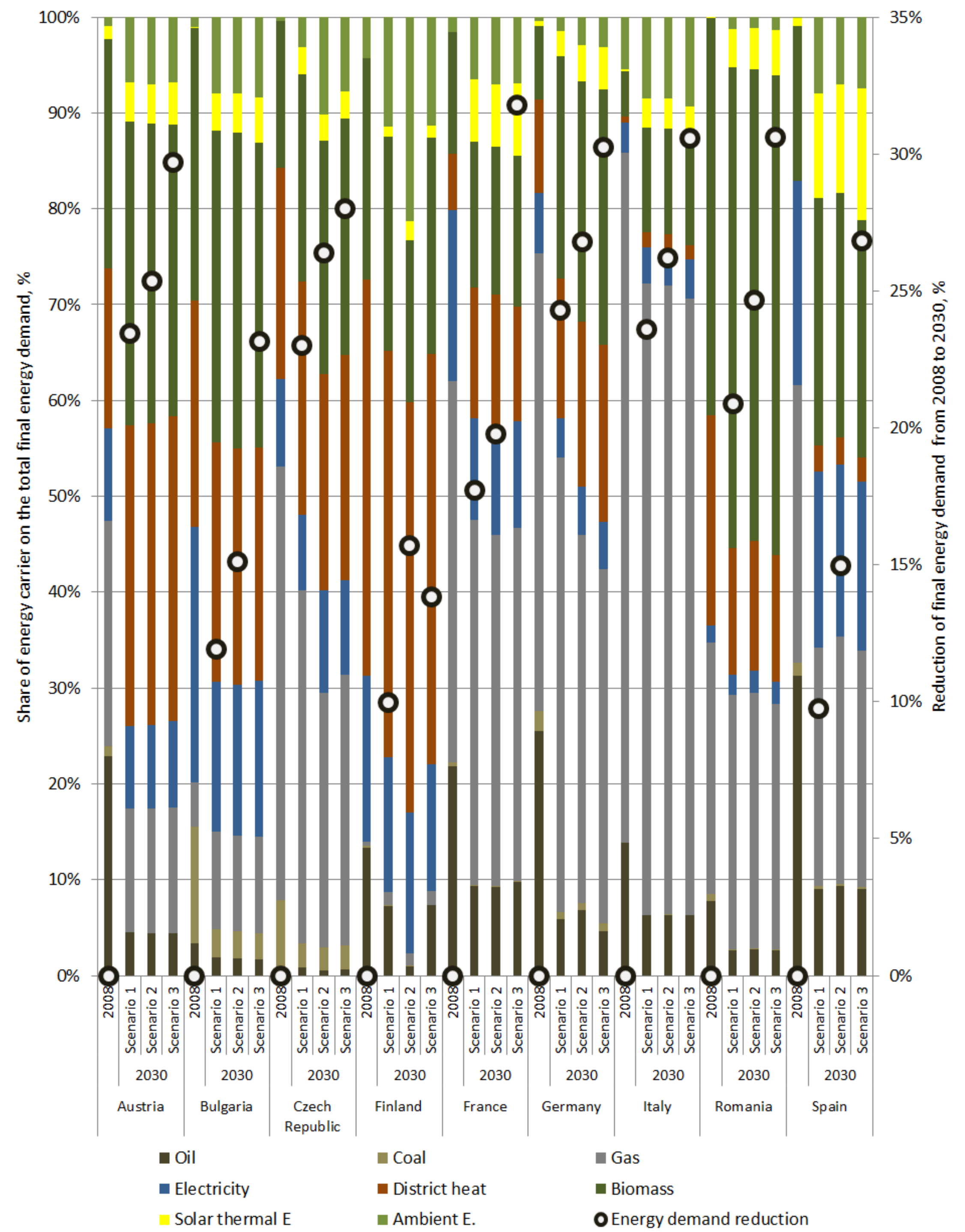

Figure 41 Share of energy carrier on the total final energy demand and reduction of final energy demand in target countries in three policy scenarios, high energy prices

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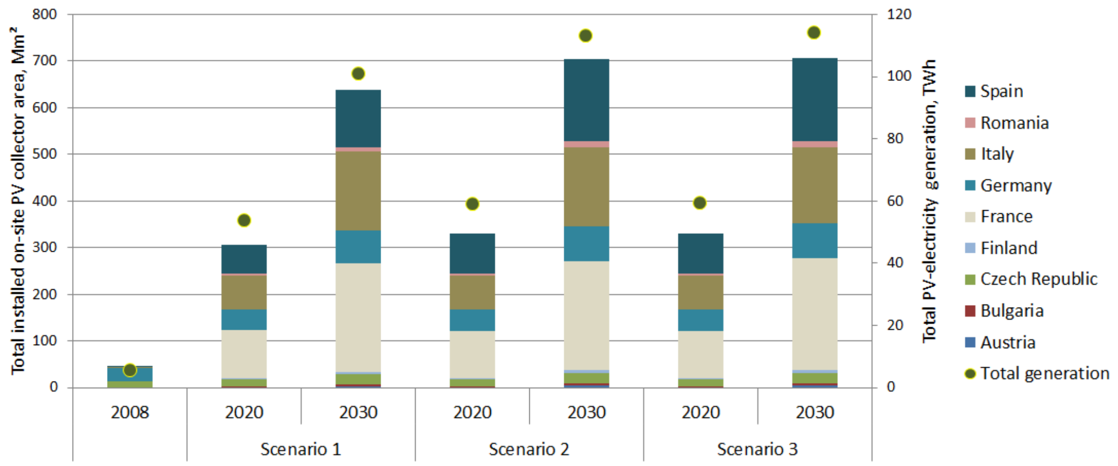

Figure 42 Total installed on-site PV collector area, Mm² and total PV-electricity generation, TWh in ENTRANZE target countries in 2008, 2020 and 2030, in policy scenario 1, 2 and 3, high energy price scenario

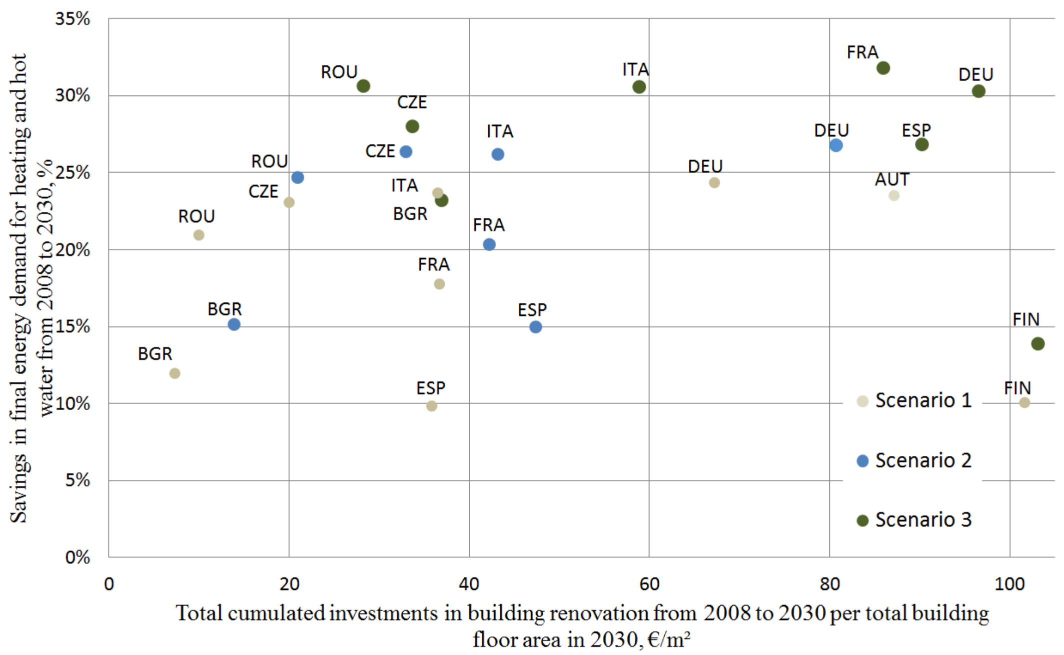

Figure 43 Savings in final energy demand for space heating and hot water from 2008 and 2030 and total investments in renovation per total building floor area from 2008 to 2030, high energy prices

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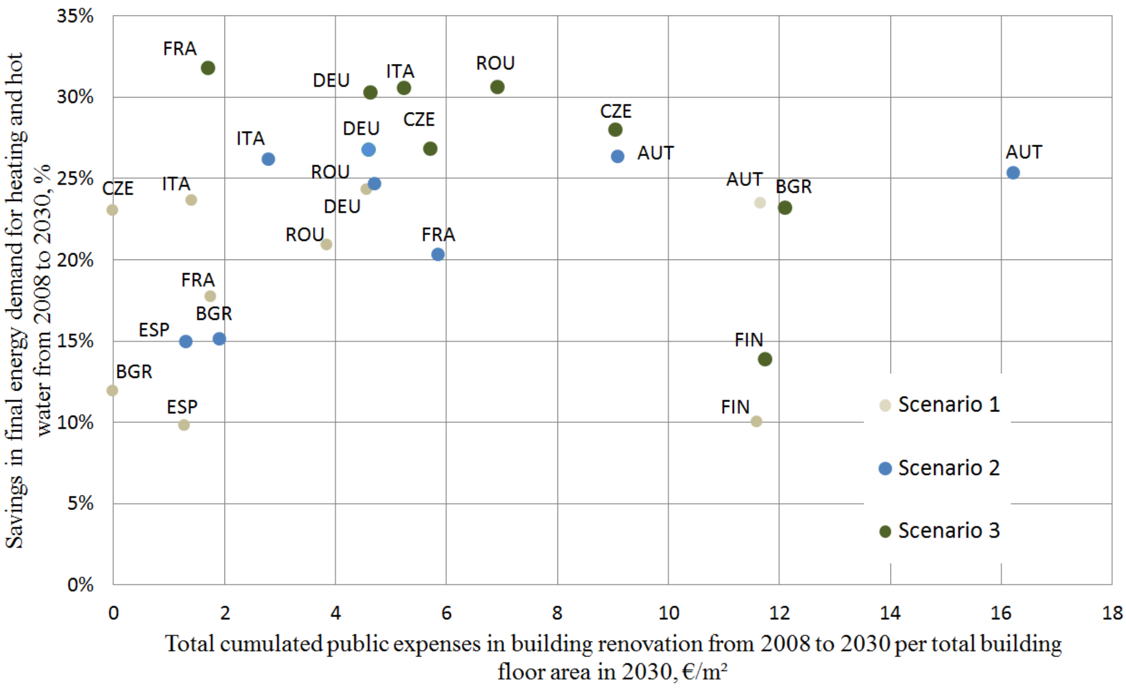

Figure 44 Savings in final energy demand for heating and hot water from 2008 to 2030 and cumulated public expenses in renovation per total building floor area from 2008 to 2030 (high energy price scenario)

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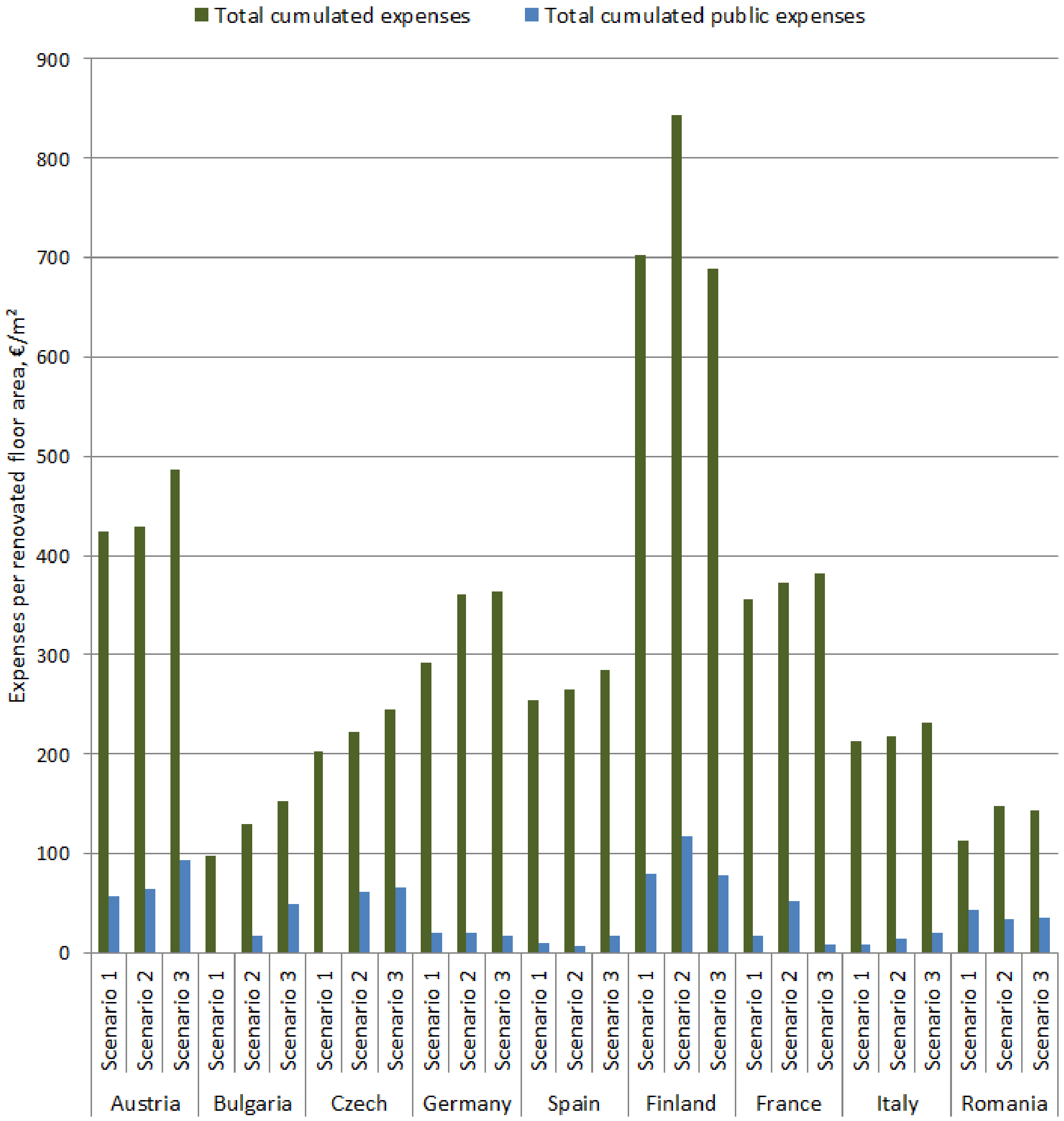

Figure 45 Total cumulated expenses and total cumulated public expenses in building renovation from 2008 to 2030 per total renovated floor area in 2030, in all three policy scenario in Entranze target countries, high energy price scenario

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A.2 Annex 2: Final energy demand for space heating, hot water, cooling and lighting by energy carrier and PV-generation. Scenario results for target countries.

Table 7 Austria: Final energy demand for space heating, hot water, cooling and lighting by energy carrier and PV-generation

		Low energy price scenario					
		Scenario 1		Scenario 2		Scenario 3	
TWh,	2008	2020	2030	2020	2030	2020	2030
Coal	1.05	0.38	0.04	0.37	0.03	0.34	0.03
Oil	23.18	15.76	5.36	15.56	5.17	15.16	4.92
Gas	23.83	21.86	17.60	21.71	17.08	21.30	16.15
Electricity	9.74	6.97	5.01	6.86	4.93	6.83	4.81
Heat	16.92	21.63	26.08	21.52	25.42	20.85	23.79
Biomass	24.21	22.54	20.77	22.20	19.78	21.33	17.83
Ambient	0.99	2.47	3.42	2.47	3.42	2.41	3.22
Solar	1.34	2.09	3.02	2.07	2.98	2.08	2.98
Space heating	101.26	93.69	81.30	92.76	78.82	90.30	73.73
Cooling	0.33	0.89	1.56	0.89	1.56	0.89	1.54
Lighting	3.82	4.30	3.60	3.74	3.46	3.32	2.64
Total	105.41	98.88	86.47	97.39	83.84	94.51	77.91
PV-generation	0.14	0.15	0.21	0.18	0.28	0.18	0.28
		High energy price scenario					
Coal	1.05	0.33	0.03	0.32	0.02	0.29	0.02
Oil	23.18	12.58	3.46	12.45	3.34	12.15	3.13
Gas	23.83	18.04	9.98	17.95	9.77	17.71	9.35
Electricity	9.74	7.41	6.72	7.38	6.63	7.20	6.37
Heat	16.92	21.30	24.27	21.19	23.82	20.81	22.69
Biomass	24.21	24.13	24.63	23.79	23.60	22.82	21.67
Ambient	0.99	2.62	5.28	2.64	5.28	2.56	4.88
Solar	1.34	2.07	3.16	2.07	3.14	2.07	3.10
Space heating	101.26	88.49	77.53	87.80	75.59	85.61	71.21
Cooling	0.33	0.89	1.55	0.89	1.55	0.88	1.51
Lighting	3.82	4.30	3.60	3.74	3.46	3.32	2.64
Total	105.41	93.67	82.67	92.43	80.60	89.80	75.36
PV-generation	0.14	0.19	0.39	0.23	0.53	0.23	0.53

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Table 8 Bulgaria: Final energy demand for space heating, hot water, cooling and lighting by energy carrier and PV-generation

		Low energy price scenario					
		Scenario 1		Scenario 2		Scenario 3	
TWh,	2008	2020	2030	2020	2030	2020	2030
Coal	3.33	2.23	1.04	2.20	0.97	2.08	0.83
Oil	0.93	0.75	0.57	0.73	0.51	0.72	0.46
Gas	1.26	2.79	4.23	2.78	4.03	2.71	3.69
Electricity	7.27	5.33	3.35	5.29	3.27	5.22	3.07
Heat	6.47	7.24	6.71	7.17	6.54	6.89	5.91
Biomass	7.77	7.59	6.59	7.48	6.38	7.10	5.54
Ambient	0.28	0.70	1.24	0.68	1.19	0.67	1.15
Solar	0.03	0.40	0.94	0.40	0.96	0.41	0.98
Space heating	27.33	27.02	24.65	26.74	23.85	25.80	21.63
Cooling	0.53	1.14	1.92	1.14	1.95	1.12	1.76
Lighting	1.91	1.80	1.51	1.55	1.45	1.35	1.08
Total	29.77	29.96	28.08	29.43	27.26	28.27	24.47
PV-generation	0.00	0.27	1.01	0.28	1.10	0.30	1.29
		High energy price scenario					
Coal	3.33	1.81	0.71	1.79	0.67	1.69	0.56
Oil	0.93	0.73	0.44	0.71	0.41	0.69	0.36
Gas	7.27	5.20	3.74	5.18	3.64	5.10	3.42
Electricity	7.27	5.20	3.74	5.18	3.64	5.10	3.42
Heat	6.47	7.08	6.01	7.04	5.72	6.79	5.11
Biomass	7.77	7.64	7.84	7.61	7.65	7.22	6.67
Ambient	0.28	0.68	1.92	0.68	1.84	0.67	1.77
Solar	0.03	0.40	0.93	0.40	0.95	0.40	0.99
Space heating	33.34	28.75	25.35	28.57	24.53	27.67	22.31
Cooling	0.53	1.14	1.92	1.14	1.96	1.12	1.75
Lighting	1.91	1.80	1.51	1.55	1.45	1.35	1.08
Total	35.77	31.69	28.78	31.26	27.95	30.13	25.14
PV-generation	0.00	0.27	1.00	0.28	1.09	0.31	1.26

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Table 9 Czech Republic: Final energy demand for space heating, hot water, cooling and lighting by energy carrier and PV-generation

	Low energy price scenario						
		Scenario 1		Scenario 2		Scenario 3	
TWh,	2008	2020	2030	2020	2030	2020	2030
Coal	6.67	4.49	2.26	4.30	2.10	4.33	2.12
Oil	0.34	0.69	0.71	0.48	0.44	0.60	0.51
Gas	40.37	39.11	33.48	32.48	23.49	33.79	24.37
Electricity	8.12	6.87	5.20	7.92	6.89	7.10	6.19
Heat	19.60	19.62	17.44	18.75	15.97	19.26	16.36
Biomass	13.63	14.35	13.31	14.63	14.20	14.44	14.02
Ambient	0.35	1.26	1.73	4.28	6.12	2.19	4.41
Solar	0.06	1.10	1.98	1.04	1.88	1.09	1.91
Space heating	89.13	87.49	76.11	83.89	71.09	82.80	69.90
Cooling	0.26	0.70	1.16	0.70	1.19	0.69	1.19
Lighting	2.70	2.77	2.43	2.39	2.33	2.08	1.74
Total	92.08	90.96	79.69	86.98	74.61	85.57	72.83
PV-generation	1.31	1.61	2.05	1.62	2.10	1.62	2.08
	High energy price scenario						
Coal	6.67	10.37	4.91	9.99	4.29	10.04	4.58
Oil	0.34	109.32	36.36	119.15	40.99	101.62	26.48
Gas	8.12	30.76	25.45	32.35	30.00	30.15	28.47
Electricity	8.12	30.76	25.45	32.35	30.00	30.15	28.47
Heat	19.60	88.92	91.09	93.87	103.55	98.81	105.66
Biomass	13.63	87.83	143.79	99.50	150.86	111.73	152.92
Ambient	0.35	7.06	9.11	7.21	17.81	7.75	17.81
Solar	0.06	11.44	16.58	12.29	22.48	14.21	25.31
Space heating	56.88	376.45	352.74	406.70	399.99	404.45	389.70
Cooling	0.26	10.99	16.72	11.13	17.94	11.14	17.92
Lighting	2.70	38.92	30.24	33.77	29.04	29.83	21.94
Total	59.83	426.35	399.70	451.59	446.97	445.42	429.56
PV-generation	1.31	11.16	14.10	11.17	14.80	11.15	14.75

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Table 10 Finland: Final energy demand for space heating, hot water, cooling and lighting by energy carrier and PV-generation

		Low energy price scenario					
		Scenario 1		Scenario 2		Scenario 3	
TWh,	2008	2020	2030	2020	2030	2020	2030
Coal	0.14	0.10	0.04	0.10	0.04	0.10	0.04
Oil	9.85	7.90	5.25	4.01	0.63	7.48	4.93
Gas	0.34	0.99	1.04	0.83	0.83	0.98	1.01
Electricity	12.73	11.10	9.76	10.73	9.41	10.18	8.80
Heat	30.59	29.47	28.14	28.68	26.98	28.47	27.32
Biomass	17.03	14.55	15.04	13.38	10.58	13.77	14.49
Ambient	3.17	5.26	7.78	8.85	13.51	5.07	7.39
Solar	0.01	0.28	0.55	0.57	1.19	0.41	0.81
Space heating	73.86	69.64	67.60	67.14	63.16	66.45	64.78
Cooling	0.43	0.69	0.92	0.69	0.92	0.69	0.92
Lighting	5.34	4.84	3.92	4.21	3.76	3.73	2.87
Total	79.63	75.18	72.44	72.04	67.84	70.87	68.57
PV-generation	0.00	0.14	0.51	0.14	0.66	0.13	0.57
		High energy price scenario					
Coal	0.14	0.10	0.04	0.10	0.04	0.10	0.04
Oil	9.85	7.90	5.25	4.01	0.63	7.48	4.93
Gas	12.73	11.10	9.76	10.73	9.41	10.18	8.80
Electricity	12.73	11.10	9.76	10.73	9.41	10.18	8.80
Heat	30.59	29.47	28.14	28.68	26.98	28.47	27.32
Biomass	17.03	14.55	15.04	13.38	10.58	13.77	14.49
Ambient	3.17	5.26	7.78	8.85	13.51	5.07	7.39
Solar	0.01	0.28	0.55	0.57	1.19	0.41	0.81
Space heating	86.25	79.76	76.32	77.04	71.74	75.65	72.58
Cooling	0.43	0.69	0.92	0.69	0.92	0.69	0.92
Lighting	5.34	4.84	3.92	4.21	3.76	3.73	2.87
Total	92.02	85.30	81.16	81.94	76.42	80.07	76.36
PV-generation	0.00	0.14	0.51	0.14	0.66	0.13	0.57

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Table 11 : France: Final energy demand for space heating, hot water, cooling and lighting by energy carrier and PV-generation

	Low energy price scenario						
		Scenario 1		Scenario 2		Scenario 3	
TWh,	2008	2020	2030	2020	2030	2020	2030
Coal	2.33	0.10	0.04	0.10	0.04	0.10	0.04
Oil	126.28	7.90	5.25	4.01	0.63	7.48	4.93
Gas	229.95	0.99	1.04	0.83	0.83	0.98	1.01
Electricity	103.22	11.10	9.76	10.73	9.41	10.18	8.80
Heat	33.99	29.47	28.14	28.68	26.98	28.47	27.32
Biomass	73.35	14.55	15.04	13.38	10.58	13.77	14.49
Ambient	8.78	5.26	7.78	8.85	13.51	5.07	7.39
Solar	0.51	0.28	0.55	0.57	1.19	0.41	0.81
Space heating	578.42	69.64	67.60	67.14	63.16	66.45	64.78
Cooling	11.21	0.69	0.92	0.69	0.92	0.69	0.92
Lighting	29.94	4.84	3.92	4.21	3.76	3.73	2.87
Total	619.56	75.18	72.44	72.04	67.84	70.87	68.57
PV-generation	0.12	0.14	0.51	0.14	0.66	0.13	0.57
	High energy price scenario						
Coal	2.33	1.36	0.56	1.33	0.57	1.28	0.49
Oil	126.28	82.65	44.41	81.33	42.58	77.49	38.51
Gas	103.22	72.17	50.80	71.76	50.78	67.66	43.68
Electricity	103.22	72.17	50.80	71.76	50.78	67.66	43.68
Heat	33.99	49.69	64.63	50.16	65.25	42.23	47.32
Biomass	73.35	74.03	72.70	73.19	71.77	69.58	62.34
Ambient	8.78	15.75	30.80	16.13	32.53	15.62	27.34
Solar	0.51	16.29	30.90	16.21	30.38	15.92	29.57
Space heating	451.69	384.11	345.61	381.86	344.62	357.45	292.93
Cooling	11.21	15.74	19.92	15.75	20.05	15.87	19.55
Lighting	29.94	26.16	21.54	22.59	20.68	19.83	15.53
Total	492.83	426.00	387.08	420.21	385.36	393.15	328.01
PV-generation	0.12	13.45	28.54	13.25	28.29	13.33	29.22

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Table 12 : Germany: Final energy demand for space heating, hot water, cooling and lighting by energy carrier and PV-generation

				Low energy price scenario			
		Scenario 1		Scenario 2		Scenario 3	
TWh,	2008	2020	2030	2020	2030	2020	2030
Coal	17.27	10.39	5.02	9.99	4.36	10.00	4.59
Oil	209.86	108.97	36.02	118.85	40.94	101.39	26.38
Gas	392.18	375.03	341.15	344.54	264.46	333.03	243.27
Electricity	51.20	30.79	23.76	32.37	26.08	30.28	24.69
Heat	80.77	89.04	94.69	93.91	109.68	98.82	109.62
Biomass	62.69	79.07	98.42	91.17	126.57	99.27	127.01
Ambient	3.46	7.27	6.87	7.38	10.31	8.07	10.52
Solar	4.11	11.55	17.44	12.46	23.63	14.57	26.76
Space heating	821.54	712.10	623.36	710.67	606.05	695.43	572.85
Cooling	4.65	10.98	16.45	11.12	17.70	11.12	17.69
Lighting	45.20	38.92	30.24	33.77	29.04	29.83	21.94
Total	871.39	761.99	670.06	755.56	652.78	736.37	612.48
PV-generation	3.11	10.91	12.53	10.85	13.29	10.86	13.20
				High energy price scenario			
Coal	17.27	10.37	4.91	9.99	4.29	10.04	4.58
Oil	209.86	109.32	36.36	119.15	40.99	101.62	26.48
Gas	51.20	30.76	25.45	32.35	30.00	30.15	28.47
Electricity	51.20	30.76	25.45	32.35	30.00	30.15	28.47
Heat	80.77	88.92	91.09	93.87	103.55	98.81	105.66
Biomass	62.69	87.83	143.79	99.50	150.86	111.73	152.92
Ambient	3.46	7.06	9.11	7.21	17.81	7.75	17.81
Solar	4.11	11.44	16.58	12.29	22.48	14.21	25.31
Space heating	480.56	376.45	352.74	406.70	399.99	404.45	389.70
Cooling	4.65	10.99	16.72	11.13	17.94	11.14	17.92
Lighting	45.20	38.92	30.24	33.77	29.04	29.83	21.94
Total	530.41	426.35	399.70	451.59	446.97	445.42	429.56
PV-generation	3.11	11.16	14.10	11.17	14.80	11.15	14.75

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Table 13 Italy: Final energy demand for space heating, hot water, cooling and lighting by energy carrier and PV-generation

	Low energy price scenario						
		Scenario 1		Scenario 2		Scenario 3	
TWh,	2008	2020	2030	2020	2030	2020	2030
Coal	0.04	0.07	0.07	0.06	0.07	0.08	0.07
Oil	60.32	40.62	23.27	40.15	22.70	39.13	21.19
Gas	314.34	286.81	248.33	281.05	239.26	274.23	223.66
Electricity	13.82	12.41	11.98	12.28	11.68	11.90	11.33
Heat	2.62	4.55	5.26	4.33	5.02	4.26	4.67
Biomass	20.75	29.60	34.55	29.13	33.47	28.54	32.05
Ambient	23.74	24.58	26.43	24.26	25.54	23.18	24.81
Solar	0.78	5.79	9.96	5.99	10.14	6.02	10.21
Space heating	436.40	404.43	359.84	397.26	347.88	387.35	327.99
Cooling	18.85	26.83	32.52	26.78	32.33	26.69	32.22
Lighting	18.14	17.93	15.61	15.65	15.00	13.93	11.59
Total	473.39	449.20	407.97	439.68	395.21	427.97	371.80
PV-generation	0.20	12.08	22.20	12.54	24.24	12.59	24.45
	High energy price scenario						
Coal	0.04	0.06	0.05	0.07	0.07	0.06	0.04
Oil	60.32	38.99	20.94	38.50	20.44	37.88	19.12
Gas	13.82	12.21	12.80	12.00	12.44	11.62	12.33
Electricity	13.82	12.21	12.80	12.00	12.44	11.62	12.33
Heat	2.62	4.51	4.98	4.47	4.90	4.32	4.46
Biomass	20.75	29.44	36.69	29.14	35.34	28.37	33.81
Ambient	23.74	23.98	28.13	23.40	27.19	22.35	28.26
Solar	0.78	5.83	10.16	6.01	10.29	6.05	10.16
Space heating	135.88	127.24	126.55	125.59	123.12	122.25	120.51
Cooling	18.85	26.83	32.52	26.78	32.33	26.68	32.23
Lighting	18.14	17.93	15.61	15.65	15.00	13.93	11.59
Total	172.87	172.00	174.69	168.01	170.46	162.87	164.34
PV-generation	0.20	12.75	25.54	12.71	25.30	12.69	24.44

Table 14 Romania: Final energy demand for space heating, hot water, cooling and lighting by energy carrier and PV-generation

	Low energy price scenario						
		Scenario 1		Scenario 2		Scenario 3	
TWh,	2008	2020	2030	2020	2030	2020	2030
Coal	0.59	0.36	0.10	0.35	0.09	0.35	0.09
Oil	6.38	3.83	1.78	3.76	1.75	3.68	1.59
Gas	21.53	25.57	23.09	24.92	21.91	23.77	18.38
Electricity	1.46	1.29	1.29	1.30	1.30	1.27	1.23
Heat	18.02	12.04	8.70	11.93	8.26	11.64	7.34
Biomass	34.10	32.32	29.52	31.41	27.29	31.01	26.12
Ambient	0.01	0.26	0.66	0.27	0.64	0.27	0.62
Solar	0.04	1.45	2.46	1.46	2.56	1.46	2.64
Space heating	82.14	77.12	67.61	75.40	63.80	73.44	57.99
Cooling	0.66	1.47	2.39	1.47	2.46	1.47	2.48
Lighting	2.25	2.66	2.51	2.32	2.41	2.07	1.88
Total	85.05	81.25	72.51	79.19	68.68	76.98	62.35
PV-generation	0.00	0.82	1.83	0.89	2.58	0.90	2.68
	High energy price scenario						
Coal	0.59	0.27	0.07	0.26	0.06	0.26	0.06
Oil	6.38	3.82	1.68	3.75	1.66	3.67	1.51
Gas	1.46	1.28	1.38	1.28	1.38	1.27	1.31
Electricity	1.46	1.28	1.38	1.28	1.38	1.27	1.31
Heat	18.02	12.29	8.61	12.25	8.40	11.96	7.56
Biomass	34.10	32.28	32.62	31.37	30.45	30.90	28.51
Ambient	0.01	0.25	0.79	0.24	0.73	0.27	0.75
Solar	0.04	1.45	2.59	1.45	2.65	1.47	2.71
Space heating	62.07	52.93	49.11	51.89	46.71	51.08	43.72
Cooling	0.66	1.47	2.41	1.47	2.49	1.47	2.49
Lighting	2.25	2.66	2.51	2.32	2.41	2.07	1.88
Total	64.98	57.06	54.03	55.68	51.61	54.62	48.09
PV-generation	0.00	0.84	1.91	0.92	2.71	0.93	2.83

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Table 15 Spain: Final energy demand for space heating, hot water, cooling and lighting by energy carrier and PV-generation

		Low energy price scenario					
		Scenario 1		Scenario 2		Scenario 3	
TWh,	2008	2020	2030	2020	2030	2020	2030
Coal	2.30	1.30	0.49	1.28	0.48	1.20	0.38
Oil	51.69	32.26	14.86	31.80	14.31	29.99	11.90
Gas	47.82	49.79	48.15	49.13	46.19	45.86	38.24
Electricity	35.33	29.61	24.43	29.23	23.16	27.32	19.08
Heat	0.00	3.13	4.80	3.15	4.54	2.95	3.69
Biomass	26.65	33.48	36.84	32.59	33.79	30.18	28.14
Ambient	0.08	4.23	7.72	4.13	6.80	3.81	6.01
Solar	1.49	8.52	16.31	8.31	15.68	8.62	16.42
Space heating	165.36	162.31	153.59	159.63	144.96	149.94	123.87
Cooling	15.79	25.49	32.66	25.23	31.17	24.62	29.01
Lighting	15.46	14.93	13.02	13.02	12.51	11.57	9.61
Total	196.61	202.73	199.27	197.87	188.64	186.13	162.49
PV-generation	0.51	13.28	27.53	18.32	36.05	18.45	36.32
		High energy price scenario					
Coal	2.30	1.23	0.40	1.20	0.38	1.11	0.29
Oil	51.69	31.40	13.49	31.19	13.08	29.33	10.86
Gas	35.33	29.46	27.33	28.78	25.28	27.15	21.31
Electricity	35.33	29.46	27.33	28.78	25.28	27.15	21.31
Heat	0.00	2.98	4.06	2.96	3.93	2.70	3.13
Biomass	26.65	33.68	38.57	33.13	35.86	30.48	29.91
Ambient	0.08	4.49	11.85	4.04	9.83	4.12	9.06
Solar	1.49	8.69	16.31	8.50	16.00	8.78	16.59
Space heating	152.88	141.39	139.34	138.59	129.64	130.82	112.47
Cooling	15.79	25.48	32.58	25.22	31.11	24.64	28.97
Lighting	15.46	14.93	13.02	13.02	12.51	11.57	9.61
Total	184.13	181.80	184.94	176.83	173.25	167.02	151.05
PV-generation	0.51	13.27	26.66	18.51	37.55	18.78	38.24

A.3 Renovation and investment indicators. Scenario results for target countries.

Table 16 Austria: Renovation and investment indicators

	Low energy price scenario					
	Scenario 1		Scenario 2		Scenario 3	
	2020	2030	2020	2030	2020	2030
Cumulated renovated floor area since 2008 (Mm²)	52.8	103.0	61.2	134.4	77.3	166.8
Renovated floor area on the total floor area, %	11.4	23.4	13.3	30.5	16.7	37.8
Deep renovation, %	5.3	9.2	6.4	12.4	9.2	19.6
Medium renovation, %	3.2	6.1	3.8	8.5	3.9	8.7
Light renovation, %	3.0	7.0	3.0	8.2	3.6	7.8
Total cum. Investments since 2008, bn €	23.7	43.6	27.8	57.3	38.1	80.4
Total public investments since 2008, bn €	4.1	6.7	5.1	9.3	7.4	15.7
	High energy price scenario					
Cumulated renovated floor area since 2008 (Mm²)	57.7	118.6	64.5	143.4	77.2	168.6
Renovated floor area on the total floor area, %	12.5	26.9	14.0	32.5	16.7	38.3
Deep renovation, %	5.9	11.2	7.1	14.5	9.8	21.1
Medium renovation, %	3.0	6.2	3.5	7.9	3.5	8.1
Light renovation, %	3.5	8.4	3.3	8.6	3.5	7.4
Total cum. Investments since 2008, bn €	25.7	50.2	29.2	61.6	38.4	82.0
Total public investments since 2008, bn €	4.1	6.7	5.1	9.3	7.5	15.7

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Table 17 Bulgaria: Renovation and investment indicators

	Scenario 1		Scenario 2		Scenario 3	
	2020	2030	2020	2030	2020	2030
Low energy price scenario						
Cumulated renovated floor area since 2008 (Mm²)	7.4	17.3	8.9	24.5	21.2	59.5
Renovated floor area on the total floor area, %	2.9	6.9	3.5	9.8	8.3	23.9
Deep renovation, %	0.4	1.0	1.2	3.5	6.2	19.1
Medium renovation, %	0.6	1.4	1.7	5.0	1.1	2.9
Light renovation, %	1.9	4.4	0.6	1.0	0.9	1.3
Total cum. Investments since 2008, bn €	0.7	1.7	1.1	3.2	3.2	9.1
Total public investments since 2008, bn €	0.0	0.0	0.1	0.5	1.0	3.0
High energy price scenario						
Cumulated renovated floor area since 2008 (Mm²)	7.8	19.6	9.4	27.8	21.4	63.3
Renovated floor area on the total floor area, %	3.0	7.9	3.7	11.2	8.4	25.4
Deep renovation, %	0.4	1.4	1.3	4.3	6.3	20.2
Medium renovation, %	0.6	1.6	1.8	5.5	1.1	3.2
Light renovation, %	2.0	4.7	0.6	1.1	1.0	1.3
Total cum. Investments since 2008, bn €	0.8	1.9	1.2	3.6	3.2	9.6
Total public investments since 2008, bn €	0.0	0.0	0.1	0.5	1.0	3.2

Table 18 Czech Republic: Renovation and investment indicators

	Scenario 1		Scenario 2		Scenario 3	
	2020	2030	2020	2030	2020	2030
Low energy price scenario						
Cumulated renovated floor area since 2008 (Mm²)	13.4	34.6	24.8	56.4	23.2	52.3
Renovated floor area on the total floor area, %	4.3	11.2	7.9	18.3	7.4	16.9
Deep renovation, %	0.7	2.7	4.2	9.3	5.2	13.7
Medium renovation, %	1.7	6.4	1.8	6.8	1.5	2.2
Light renovation, %	1.9	1.9	1.9	1.9	0.7	0.7
Total cum. Investments since 2008, bn €	2.6	7.0	5.7	12.7	5.7	12.9
Total public investments since 2008, bn €	0.0	0.0	2.1	3.9	2.0	3.9
High energy price scenario						
Cumulated renovated floor area since 2008 (Mm²)	15.1	42.8	26.8	63.9	24.9	59.4
Renovated floor area on the total floor area, %	4.8	13.9	8.5	20.7	7.9	19.2
Deep renovation, %	0.8	3.8	4.4	10.2	5.6	15.7
Medium renovation, %	2.0	7.8	2.1	8.0	1.6	2.5
Light renovation, %	2.0	2.0	2.1	2.1	0.7	0.7
Total cum. Investments since 2008, bn €	2.9	8.7	6.0	14.2	6.0	14.6
Total public investments since 2008, bn €	0.0	0.0	2.1	3.9	2.0	3.9

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Table 19 Finland: Renovation and investment indicators

	Scenario 1		Scenario 2		Scenario 3	
	2020	2030	2020	2030	2020	2030
Low energy price scenario						
Cumulated renovated floor area since 2008 (Mm²)	21.4	44.4	33.1	72.0	21.5	45.1
Renovated floor area on the total floor area, %	8.3	17.1	12.8	27.6	8.3	17.3
Deep renovation, %	2.2	4.2	4.5	9.7	2.2	4.5
Medium renovation, %	2.9	6.0	5.0	11.3	2.9	6.1
Light renovation, %	3.2	6.6	3.3	6.2	3.1	6.6
Total cum. Investments since 2008, bn €	17.4	31.2	32.9	61.3	17.4	31.5
Total public investments since 2008, bn €	2.0	3.6	4.5	8.6	2.0	3.6
High energy price scenario						
Cumulated renovated floor area since 2008 (Mm²)	21.5	45.1	33.2	72.6	21.6	46.7
Renovated floor area on the total floor area, %	8.3	17.3	12.8	27.8	8.3	18.0
Deep renovation, %	2.2	4.4	4.6	10.0	2.2	4.7
Medium renovation, %	2.9	6.1	5.0	11.2	2.9	6.3
Light renovation, %	3.2	6.7	3.3	6.3	3.1	6.7
Total cum. Investments since 2008, bn €	17.4	31.7	32.9	61.2	17.5	32.1
Total public investments since 2008, bn €	2.0	3.6	4.5	8.6	2.0	3.7

Table 20 France: Renovation and investment indicators

	Scenario 1		Scenario 2		Scenario 3	
	2020	2030	2020	2030	2020	2030
Low energy price scenario						
Cumulated renovated floor area since 2008 (Mm²)	130.9	353.3	137.6	392.7	319.2	780.1
Renovated floor area on the total floor area, %	5.0	13.9	5.3	15.4	12.3	30.6
Deep renovation, %	1.1	3.0	1.8	5.9	4.3	10.7
Medium renovation, %	1.9	5.0	1.8	4.9	5.9	14.6
Light renovation, %	2.0	5.4	1.7	4.2	2.0	4.6
Total cum. Investments since 2008, bn €	46.3	125.8	50.1	145.7	120.5	297.3
Total public investments since 2008, bn €	3.4	6.4	6.3	21.1	3.6	6.9
High energy price scenario						
Cumulated renovated floor area since 2008 (Mm²)	132.5	375.7	139.4	409.1	323.1	818.1
Renovated floor area on the total floor area, %	5.1	14.8	5.4	16.1	12.4	32.1
Deep renovation, %	1.2	3.3	1.8	6.1	4.4	11.3
Medium renovation, %	1.9	5.4	1.8	5.2	6.0	15.4
Light renovation, %	2.0	5.7	1.7	4.3	2.0	4.5
Total cum. Investments since 2008, bn €	46.9	133.8	50.8	152.2	122.0	312.9
Total public investments since 2008, bn €	3.5	6.4	6.4	21.4	3.6	6.2

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Table 21 Germany: Renovation and investment indicators

	Scenario 1		Scenario 2		Scenario 3	
	2020	2030	2020	2030	2020	2030
Low energy price scenario						
Cumulated renovated floor area since 2008 (Mm²)	520.1	1,029	508.2	993.5	595.7	1,221
Renovated floor area on the total floor area, %	12.5	25.2	12.2	24.4	14.2	29.9
Deep renovation, %	2.2	4.6	2.3	4.9	2.4	5.2
Medium renovation, %	4.1	7.7	4.0	7.4	4.6	9.0
Light renovation, %	6.1	12.1	5.6	11.1	7.0	14.7
Total cum. Investments since 2008, bn €	154.9	293.5	169.0	353.7	200.5	440.5
Total public investments since 2008, bn €	11.0	21.0	11.1	21.1	11.2	21.2
High energy price scenario						
Cumulated renovated floor area since 2008 (Mm²)	522.1	1,058	508.8	1,029	589.4	1,220
Renovated floor area on the total floor area, %	12.5	25.9	12.2	25.2	14.1	29.9
Deep renovation, %	2.2	5.5	2.4	5.5	2.5	5.7
Medium renovation, %	4.1	7.6	4.0	7.5	4.6	9.0
Light renovation, %	6.0	12.0	5.6	11.3	6.8	14.1
Total cum. Investments since 2008, bn €	156.2	309.2	169.8	370.3	199.2	443.6
Total public investments since 2008, bn €	11.1	21.0	11.0	21.1	11.2	21.3

Table 22 Italy: Renovation and investment indicators

	Scenario 1		Scenario 2		Scenario 3	
	2020	2030	2020	2030	2020	2030
Low energy price scenario						
Cumulated renovated floor area since 2008 (Mm²)	268.8	495.8	319.1	581.9	401.5	765.1
Renovated floor area on the total floor area, %	11.7	22.4	13.9	26.3	17.5	34.5
Deep renovation, %	3.7	7.0	5.0	8.6	5.3	10.3
Medium renovation, %	3.7	6.7	4.8	8.4	6.4	11.4
Light renovation, %	4.3	7.8	4.2	8.2	5.8	11.7
Total cum. Investments since 2008, bn €	56.5	106.4	69.5	127.4	92.0	177.4
Total public investments since 2008, bn €	4.4	4.4	8.4	8.8	10.4	16.3
High energy price scenario						
Cumulated renovated floor area since 2008 (Mm²)	276.3	542.0	326.9	627.5	408.9	806.4
Renovated floor area on the total floor area, %	12.0	24.5	14.2	28.3	17.8	36.4
Deep renovation, %	3.8	7.7	5.1	9.4	5.4	11.0
Medium renovation, %	3.8	7.4	4.9	9.1	6.6	12.0
Light renovation, %	4.4	8.4	4.3	8.8	5.8	12.1
Total cum. Investments since 2008, bn €	57.9	115.7	71.1	136.7	93.7	186.4
Total public investments since 2008, bn €	4.5	4.5	8.4	8.8	10.5	16.6

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Table 23 Romania: Renovation and investment indicators

	Scenario 1		Scenario 2		Scenario 3	
	2020	2030	2020	2030	2020	2030
Low energy price scenario						
Cumulated renovated floor area since 2008 (Mm²)	17.5	46.3	30.5	81.6	43.5	117.3
Renovated floor area on the total floor area, %	3.5	9.4	6.0	16.5	8.6	23.7
Deep renovation, %	1.9	6.0	3.6	10.8	5.2	16.0
Medium renovation, %	1.2	2.3	1.9	4.7	2.6	6.3
Light renovation, %	0.3	0.9	0.5	0.5	0.8	0.8
Total cum. Investments since 2008, bn €	1.9	5.0	4.6	11.8	6.3	16.4
Total public investments since 2008, bn €	1.0	2.2	1.3	2.9	1.9	4.3
High energy price scenario						
Cumulated renovated floor area since 2008 (Mm²)	18.8	52.2	31.4	82.3	44.7	114.7
Renovated floor area on the total floor area, %	3.7	10.6	6.2	16.7	8.8	23.1
Deep renovation, %	2.0	6.4	3.7	10.5	5.4	15.1
Medium renovation, %	1.3	2.7	1.9	5.1	2.6	6.6
Light renovation, %	0.3	1.3	0.5	0.5	0.8	0.8
Total cum. Investments since 2008, bn €	2.0	5.9	4.7	12.2	6.5	16.5
Total public investments since 2008, bn €	1.0	2.2	1.3	2.7	1.9	4.0

Table 24 Spain: Renovation and investment indicators

	Scenario 1		Scenario 2		Scenario 3	
	2020	2030	2020	2030	2020	2030
Low energy price scenario						
Cumulated renovated floor area since 2008 (Mm²)	140.3	325.9	176.2	418.2	321.1	746.3
Renovated floor area on the total floor area, %	7.5	17.9	9.4	22.9	17.1	40.8
Deep renovation, %	1.5	3.7	2.2	6.8	7.6	23.7
Medium renovation, %	2.1	4.4	3.6	10.9	2.7	6.4
Light renovation, %	3.9	9.3	3.5	4.5	6.8	9.6
Total cum. Investments since 2008, bn €	35.8	82.7	46.5	110.5	90.1	212.9
Total public investments since 2008, bn €	1.7	3.1	1.7	3.1	5.6	13.8
High energy price scenario						
Cumulated renovated floor area since 2008 (Mm²)	141.0	337.2	177.2	428.4	324.3	755.6
Renovated floor area on the total floor area, %	7.5	18.5	9.4	23.5	17.3	41.3
Deep renovation, %	1.5	3.9	2.3	7.1	8.1	24.5
Medium renovation, %	2.1	4.5	3.6	11.1	1.6	5.3
Light renovation, %	3.9	9.5	3.5	4.5	7.6	10.4
Total cum. Investments since 2008, bn €	36.0	86.0	46.8	113.5	90.9	215.5
Total public investments since 2008, bn €	1.7	3.1	1.7	3.1	5.6	13.7

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A.4 Policy Modelling in Invert/EE-Lab

In the following, we give some examples how policy instruments can be modelled and which level of detail we can cover.

A.1.1 Investment subsidies

Investment subsidies for renovation measures

For simulating the impact of investment subsidies for renovation measures, it is required to define:

- The standard of renovation measures being supported (e.g. in terms of U-values for building components; may differ between building categories; three different levels of renovation packages can be defined for each building category).
- The percentage of overall investment costs being granted by the scheme (may differ between building categories).
- Optional: maximum support level in €/m² floor area and/or €/building (Investment subsidies)
- Optional: Total support budget (M€ on an annual basis, can change from year to year)

The agents in Invert/EE-Lab decide among the options "no thermal renovation measure" and several different renovation measures including policy measures, as defined above, targeting on them individually. The policy instrument will increase the market uptake of this specific type of renovation measure addressed in the policy instrument depending on the agents awareness of the instrument and the relevance of economic aspects in the decision making process of different agents.

Investment subsidies for renewable heating

For simulating the impact of investment subsidies for renovation measures, it is required to define:

- The percentage of overall investment costs being granted by the scheme for different heating technologies.
- Optional: maximum support level €/building and/or dwelling (Investment subsidies)
- Optional: Total support budget (M€ on an annual basis, can change from year to year)

The agents in Invert/EE-Lab decide among the different heating and hot water options. The instrument will increase the market uptake of the specific type of (renewable) heating system addressed in the policy instrument depending on the agents awareness of the instrument and the relevance of economic aspects in the decision making process of different agents.

Investment subsidies for renewable heating independent on public budget

Similar to the conventional investment subsidies financed by the public budget Invert/EE-Lab is able to simulate the impact of instruments financed e.g. on a levy on fossil fuels. (see e.g. (Bürger, 2013) for “Non-fiscal instruments strengthening support and financing activities within the market”). There are different specific options for adapting the levy automatically on the support level of renewable heating systems.

A.1.2 Regulatory schemes

Building codes for new buildings

Minimum standards for new buildings are defined exogenously in Invert/EE-Lab. All new buildings will have at least this minimum standard. So, the definition of this standard is a relevant regulatory instrument. For this definition, the U-values of relevant building components or performance based criteria have to be defined.

Building codes for renovation of buildings

As a default, in Invert/EE-Lab building owners are free to select either “no thermal renovation measure” or some level of renovation measures. However, it is possible to introduce an obligation to carry out at least a minimum set of thermal renovation measures in case that a building is being refurbished. This minimum set should be defined in terms of U-values of relevant building components or performance based.

Moreover, Invert/EE-Lab is able to define certain thresholds after which a renovation has to take place (e.g. in case that a building or building component has reached a certain lifetime).

RES-H obligations

For an obligation to use renewable heating, there are the following options to be defined in Invert/EE-Lab:

- When will the obligation come into force? (a) in case of new building construction, (b) in case of renovation of buildings or (c) in case of each change of heating systems

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- Which share of renewable heating is obligatory for this specific building? (e.g. 25%, 50%, 75%?)
- Are there penalties in case that the obligation is not being fulfilled? How high are they (€/m² floor area).
- Optional: the penalty may also be linked to increasing the thermal efficiency of the building
- Optional: there might be a weighting between different renewable energy carriers, i.e. solar thermal might be weighted higher than biomass.

A.1.3 Information, training, advice

Information, training advice may lead to higher awareness level of different type of agents. Invert/EE-Lab is able to model the impact of a higher level of awareness from different type of agents.

A.1.4 R&D

For each technology implemented in Invert/EE-Lab, we can define cost reduction (or increase) or efficiency development over time up to 2030/2050. This changes the attractiveness of the different options and subsequently (according to the logit-approach) the market share of different measures, energy carriers and technology options.

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