Explore sustainable European futures

Results from EUCalc

Pathways Explorer for the building sector: European and Member States insights

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Short Description
This briefing provides a practical example of how policymakers can use the EUCalc model. Notably, the model can create pathways to mirror the Energy Performance of Buildings Directive long-term renovation strategies with different levels of ambition. It contains projections of energy demand and CO_2 emissions from heating buildings. The purpose and functioning of the EUCalc, and how it has been used for the purpose of this briefing, is explained in detail.

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Name of reviewer	Date
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This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

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List of abbreviations

BEMS – Building energy management systems

CHP – Combined heat and power plants

EED – Energy Efficiency Directive

EPBD - Energy Performance of Buildings Directive

GHG – Greenhouse gas

gCO_2e – Grams of carbon dioxide equivalent

ICT – Information and communications technology

kWh_{therm} – Thermal kilowatt-hour

kWh_{fuel} – Kilowatt-hour in fuel

LTRS – Long-term renovation strategy

MFH – multi-family house

MJ – Megajoule

NECP - National energy and climate plan

NZEB – Nearly zero-energy building

SFH – Single-family house

Glossary

Floor area – living space in residential buildings and used floor space in non-residential buildings

Conditioned space – floor area that is heated, cooled or ventilated

Shallow renovation – energy renovation of the complete building reducing its energy need by 30% on average

Medium renovation – energy renovation of the complete building reducing its energy need by 40% on average

Deep renovation – energy renovation of the complete building reducing its energy need by 60% on average

Inefficient new build – new build that is on average only 30% more energy efficient than the average building stock

Medium efficient new build – new build that is on average 40% more energy efficient than the average building stock.

Highly efficient new build – new build that is on average 60% more energy efficient than the average building stock. The NZEB definition was not used as it varies across EU Member States and, in some cases, new builds in line with NZEB are not highly energy efficient buildings.

1 Executive Summary

EUCalc is a new dynamic modelling tool able to create pathways for sectoral energy demand, GHG trajectories and social implications of lifestyle and energy technology choices in Europe. In this briefing, EUCalc is used to create GHG emissions reduction pathways in the buildings sector that try to mirror Long-term renovation strategies (LTRS) in line with the Energy Performance of Buildings Directive (EPBD). We analyse what this could mean in term of impacts for the EU, selected Member States and for achieving the EU 32.5% energy efficiency target by 2030.

The pathways for this briefing have been generated by using the EUCalc building module and the energy sector modules; all inputs from other modules were kept at a level of ambition that corresponds to "observed trend continuation".

The most ambitious pathway created for this briefing (level 4 pathway) shows an almost total decarbonisation of the demand and supply of heat and power in buildings in the EU, resulting in a decrease of CO_2 emissions of 97% compared to 2015. This reduction can be considered consistent with the legal obligation of the EPBD that requires Member States to develop LTRSs that achieve a highly energy efficient and decarbonised building stock by 2050.

In addition, this briefing shows that if Member States adopt and implement LTRSs that achieve the 2050 decarbonisation objective (in line with the level 4 pathway), and plan intermediate milestones for 2030 accordingly, these measures could contribute around 53% of the 2030 EU energy efficiency target.

By modelling this pathway with EUCalc, it is also possible to have an indication of the scale of the impacts Member States need to achieve. When Member States draft and implement LTRSs that are in line with the requirements of the EPBD, they must put in place policies and measures that lead to a transformation of the building sector compared to today. For example, the level 4 pathway assumes a renovation rate of 3% leading to a refurbishment of all existing buildings by 2050. Out of these renovations, the great majority are assumed to be deep renovations with no shallow refurbishment. The demolition rate is about 1% per year.

To achieve a similar level of impacts, Member States must use their LTRS as an occasion to rethink their policy interventions in the buildings sector and put in place a coherent strategy that mobilises resources and actors towards the long-term decarbonisation goal.

This briefing concludes that large additional effort and major technological advances and breakthroughs compared to the buildings sector's current construction and renovation practices are possible and necessary if Member States are serious in drafting roadmaps that will lead to a highly energy efficient and decarbonised building stock by 2050. If LTRSs are drafted with this ambition in mind, they will also make a significant contribution to the achievement of the 2030 energy efficiency target and will be the driver for accelerating actions by 2030.

2 Introduction

Buildings account for about 36% of CO_2 emissions and 40% of energy consumption in Europe[1] and 97% of the existing building stock is inefficient.[2] This means that a comprehensive strategy to reduce emissions from the buildings sector is needed if the European Union wants to meet the objectives of the Paris Agreement[3] and to achieve climate neutrality by 2050 in line with the objective of the European Green Deal[4] and the new European Commission's proposal for a European Climate Law.[5] In line with the energy efficiency first principle, reducing energy demand from the buildings sector must be prioritised as it is often the cheapest and most effective way to reduce carbon emissions.

With the Clean Energy for All Europeans package recently adopted and now to be transposed in national legislation, Member States have the opportunity to plan policies that go in that direction. For example, the Energy Performance of Buildings Directive (EPBD) already requires Member States to draft a long-term renovation strategy (LTRS) to achieve a highly energy-efficient and decarbonised national building stock by 2050.

With the help of the newly developed European Calculator (EUCalc) model, we are able to present first insights into how the buildings sector in the EU could contribute to greenhouse gas (GHG) emissions reductions until 2050. EUCalc is a new model to provide decision-makers and interested stakeholders with a user-friendly online interface to quantify the sectoral energy demand, GHG trajectories and social implications of lifestyle and energy technology choices in Europe.

For this briefing, EUCalc has been used to create pathways that try to mirror the LTRS in line with the EPBD requirements. The briefing also looks at the implications of designing LTRSs that are aligned with those pathways, also in terms of their contribution to the EU 2030 energy efficiency target.

[1] https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings/overview
[2] Building Performance Institute Europe (BPIE), 2019
[3] The Paris Agreement's central aim is to strengthen the global response to the threat of climate change by keeping average global temperature rise this century well below 2° Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5° Celsius. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement
[4] https://ec.europa.eu/info/sites/info/files/european-green-deal-communication_en.pdf
[5] https://ec.europa.eu/info/sites/info/files/commission-proposal-regulation-european-climate-law-march-2020_en.pdf

3 Policy context

The European Union has recently adopted a new package of climate and energy legislation, the Clean Energy for all Europeans package,[6] to facilitate the transition towards a cleaner energy system and to help the EU meet the commitments of the Paris Agreement. Member States must now implement the different pieces of legislation, including the revised Energy Efficiency Directive (EED) and the amended EPBD.

The EED sets the overarching framework of energy efficiency policy in the EU, including the overall energy efficiency target for 2030, while the EPBD sets specific rules for energy performance of buildings, including for the construction of new buildings and for the renovation of existing ones. The two directives are, however, intrinsically linked as measures in the buildings sector are essential to achieve the 2030 energy efficiency target.

The European Commission's newly published European Green Deal aims at setting a pathway towards achieving the climate neutrality objective while ensuring a green and inclusive transition. The building sector is a key pillar in that respect and the European Commission suggests that EU and its Member States should start a "Renovation wave" to reduce energy consumption, emissions and alleviate energy poverty. The implementation of the EPBD is considered a stepping stone in this direction.

3.1 EPBD long-term renovation strategies

According to the EPBD Article 2a[7], Member States must have submitted their LTRS by 10 March 2020. A LTRS is a strategic planning document with a national roadmap for achieving a highly energy-efficient and decarbonised national building stock by 2050 and for facilitating the cost-effective transformation of existing buildings into nearly zero-energy buildings. While LTRSs focus on renovations, they also cover new builds.

In addition to the long-term decarbonisation objective, the LTRS must include indicative milestones for 2030, 2040 and 2050 and specify how they contribute to the energy efficiency targets. This includes the European Union's overall target of improving energy efficiency by 32.5% by 2030.

[6] https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-all-europeans
[7] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L0844&from=EN

These milestones can be qualitative or quantitative. The European Commission guidance note[8] gives the following non-exhaustive list of examples of milestones:

1. Energy savings (in absolute and relative percentage terms) per building sector (residential, non-residential)
2. Percentage of renovated buildings (per renovation type)
3. CO_2 emissions reduction in the buildings sector (renovation/new buildings)
4. Percentage of nearly zero-energy buildings (NZEBs) per building sector
5. Percentage reduction in people affected by energy poverty
6. Percentage reduction of buildings in the lowest energy class
7. Energy savings in public buildings
8. Percentage of buildings equipped with a building energy management system (BEMS) or similar smart system, per building type
9. Number of one-stop-shop initiatives
10. Raised awareness leading to concrete action.

The European Green Deal announces that the European Commission will assess the LTRS in the course of 2020.

3.2 2030 energy efficiency target

The EED[9] establishes an EU headline target of reducing energy consumption by at least 32.5% by 2030 (Article 1). This target is calculated as a reduction of 32.5% compared to projected energy use in 2030. It translates in a requirement that the EU should not consume more than 1,273 Mtoe of primary energy and/or no more than 956 Mtoe of final energy in 2030.

Member States must communicate to the European Commission their indicative national energy efficiency contributions, which represent their share of the EU target. Those contributions were submitted through the draft national energy and climate plans (NECPs), which were due on 31 December 2018.[10]

The Commission aggregated the national contributions it received from the Member States and found that, with the draft plans, there would be a gap towards

[8] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1557992239852&uri=CELEX:32019H0786
[9] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2002&from=EN
[10] The integrated national energy and climate plans are 10-year planning documents for climate and energy policies that Member States must submit to the European Commission in compliance with the Governance Regulation, https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/governance-energy-union/national-energy-climate-plans

the achievement of the overall EU energy efficiency target of up to 6% in final energy and up to 6.2% in primary energy terms.[11]

Energy savings achieved through energy efficiency measures in the buildings sector are key to meeting the 2030 energy efficiency target. In particular, when setting their national objectives and targets for energy efficiency in their NECP, Member States must also outline the indicative milestones under the LTRS.

4 EUCalc model and how it is used for this briefing

EUCalc is a new dynamic modelling tool able to create pathways for sectoral energy demand, GHG trajectories and social implications of lifestyle and energy technology choices in Europe. For the purpose of this briefing, the EUCalc building module has been used to create pathways that mirror EPBD LTRS.

This chapter explains the architecture of EUCalc, the functioning of its building module and how this module has been used to create pathways that resemble LTRSs.

4.1 What is the goal of the EUCalc model?

EUCalc's scientific mission is to develop a sophisticated, yet accessible, model to fill the gap between integrated climate-energy-economy models and the practical needs of decision-makers. Its easy-to-use web version allows users to construct transformation pathways, and explore and compare their impacts.

EUCalc aims to provide policy- and decision-makers with a highly accessible, user-friendly, dynamic modelling solution and planning tool. As well as delineating emission and sustainable transformation pathways at a European scale, EUCalc may also be used to design country pathways (EU 27 Member States, the United Kingdom a nd Switzerland) and investigate how these could contribute to European scenarios.

EUCalc models energy, land, materials, product and food systems at European and Member State level representing GHG emissions dynamics until 2050. It explores

[11] According to the European Commission, only a few Member States have submitted adequate contributions to the EU energy efficiency target. Those are Italy, Luxembourg and Spain (both primary energy consumption and final energy consumption), Netherlands (for primary energy consumption) and France (for final energy consumption). At the time of this assessment, some Member States had not submitted their contributions yet. The European Commission calculated the gap to the EU efficiency target by making assumptions on the missing ones. No further assessment has been done on the basis of the final NECPs submitted at the end of 2019. https://ec.europa.eu/energy/sites/ener/files/documents/recommondation_en.pdf

different sectors, including transport, buildings, industry, agriculture, power generation, energy usage and lifestyles. The pathways explorer enables users to address technological and societal challenges and to evaluate trade-offs and co-benefits of sector decisions.

For this report, the EUCalc model version 4.1a of March 20th was used.

4.2 Overview of the EUCalc modelling approach

The EUCalc model covers different sectors such as transport, buildings and land use in separate modules and integrates their interactions,[12] as shown in figure 1. The scope are further explained in section 4.4 and Annex I (page 7).

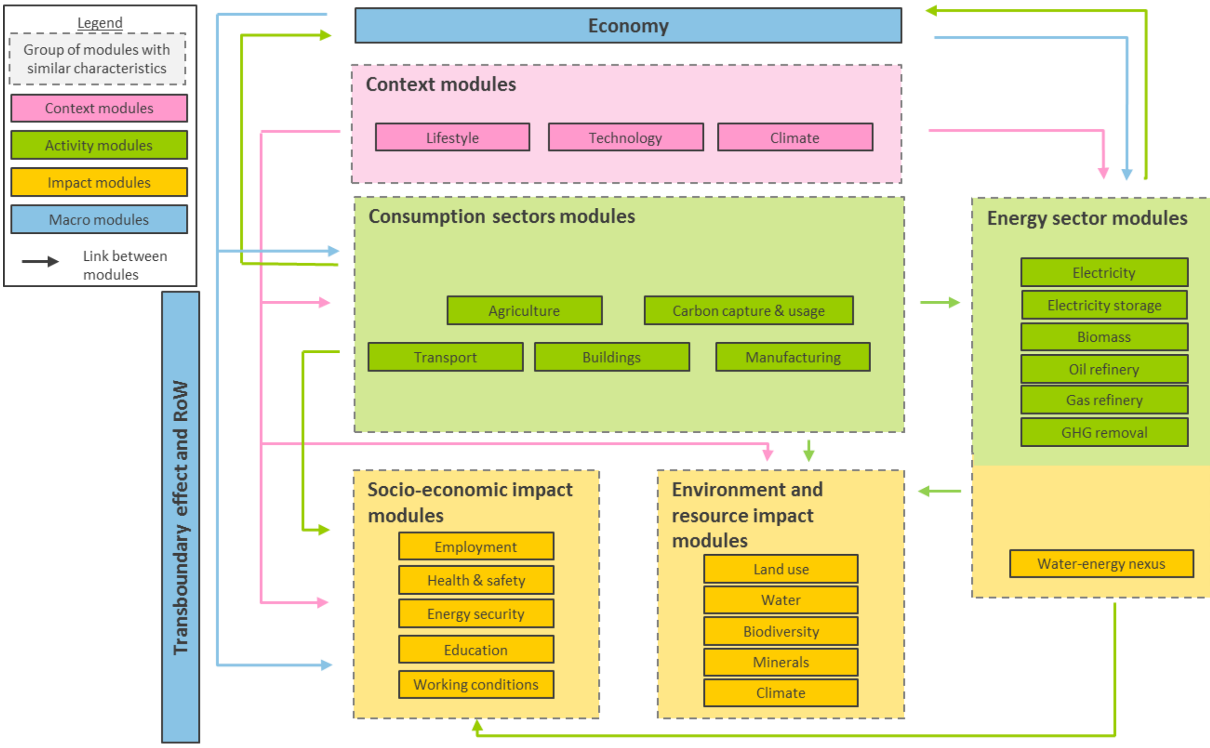


Figure 1: Overview of the EUCalc model architecture

EUCalc allows the user to modify the drivers (called "levers" in the model) that have an impact on GHG emissions for any module.

Each of the levers has four defined positions representing the ambition of the decarbonisation effort in that sector. Table 1 below summarises the four levels of ambition and

[12] Interactions of the building module are described in section 0.

table 2 defines the parameters for these levels. The model allows the user to choose the ambition level of each individual lever (from a level representing observed trends up to maximum technological ambition), enabling them to explore different scenarios or pathways for GHG emissions reductions up to 2050.

Projections of end-use service demand (e.g. buildings heating, appliances usage, car travel, freight demand, etc.), demographic evolution and techno-economic trends are defined by the user for each country (or for Europe as a whole) by moving pre-defined levers. In addition, the user can choose the amount of GHG the rest of the world and Europe can still emit to have a two-thirds chance of staying below 1.5° or 2° warming until the end of the century.

Table 1: Lever level definition used for all modules in the EUCalc tool

Level 1 This level contains projections that are aligned and coherent with observed trends.	**Level 2** This level is an intermediate scenario, more ambitious than business as usual but not reaching the full potential of available solutions.
Level 3 This level is considered very ambitious but realistic, given current technology evolutions and best practices observed in some geographical areas.	**Level 4** This level is considered as transformational and requires large additional efforts such as strong changes in the way society is organised, very fast market uptake of highly ambitious measures, increased development of infrastructures, major technological advances and breakthroughs.

Table 2: Lever level definition for the building levers

Driver / lever		Level 1	Level 2	Level 3	Level 4
building envelope					
renovation rate per annum		1%[13]	1.5%	2%	3%[14]
renovation mix[15] (depth or energy ambition)	shallow[16]	80%	20%	10%	0%
	medium	15%	60%	70%	30%
	deep	5%	20%	20%	70%
demolition rate		0.1%	0.4%	0.7%	1%[17]
construction mix[15]	inefficient[18]	80%	20%	10%	0%
	medium efficient	15%	60%	70%	30%
	highly efficient	5%	20%	20%	70%
heating efficiency[19]		gas 85% wood 65% oil 81%	gas 87% wood 66% oil 83%	gas 91% wood 69% oil 87%	gas 97% wood 74% oil 93%
heating technology and fuel share [20]	reduction of fossil fuels	gas -5% electricity -5% coal -30% oil -10%	gas -50% electricity -50% coal -80% oil -50%	gas -68% electricity -68% coal -90% oil -70%	gas -95% electricity -93% coal -98% oil -97%
	substitution	30% heat pumps 65% biomass 2% geothermal 3% solar	40% heat pumps 50% biomass 4% geothermal 6% solar	50% heat pumps 35% biomass 6% geothermal 9% solar	60% heat pumps 20% biomass 8% geothermal 12% solar

[13] The observed renovation rate lies at 0.5-2.5% (D'Agostino *et al.*, 2016 p. 58; Dean *et al.*, 2016 p. 3; Buildings Performance Institute Europe (BPIE), 2011, p. 103; Hansen, 2005, p. 10)

[14] As a maximum 3% is commonly used for the renovation rate and the whole building stock would be renovated between today and 2050 (European Commission, 2018, p. 90 ; Bettgenhäuser *et al.*, 2014, p. 1 ; Boermans *et al.*, 2012, p. 4 ; Buildings Performance Institute Europe (BPIE), 2011, p. 103 p.3.) However, expert opinion suggests such a renovation rate is not likely to be achieved (Sandberg *et al.*, 2016, p. 10).

[15] Level 1 continues the trend that most observed renovations entail no more measures than the minimum requirements (Umwelt *et al.*, 2018). The low share of efficient renovations and new builds is reflected in the dominant share of shallow and medium renovations. The Level 4 scenario assumes the majority of renovations to include very ambitious measures.

[16] The energy need is reduced by 30% in the shallow category, by 40% in the medium category and by 60% in the deep renovation category.

[17] Lowest and highest value in Sandberg *et al.*, 2016, p. 9

[18] All new buildings constructed shall be NZEB starting 1st January 2021 in line with Article 9 of the EPBD. However, the national definitions of NZEB differ largely accross MS. Therefore, it cannot be assumed that all new constructions in Member States will be highly energy efficient buildings.

[19] The presented assumptions for heating efficiencies represent the aggregate of distributions across different technologies, sizes and their shares across the European building stock gathered by country in Fleiter *et al.*, 2016.

[20] The assumptions for the heating technology and fuel share are aligned with Fleiter *et al.*, 2016.

The capital expenditures for renovations are assumed to be the same for all countries and remain constant over time. This allows a rough estimate of the investment needs of the renovation activity for the different pathways.

Table 3: Capital expenditures for renovation in EUR per m²

	Single-family homes	Multi-family homes	Non-residential buildings
shallow renovation	150	120	150
medium renovation	250	200	250
deep renovation	350	300	350

4.3 Overview of the EUCalc modelling approach for the buildings sector

The building module within the European Calculator follows a modular approach where the delivered energy depends on the evolutions of the floor area,[21] the energy need[22] and the heating systems efficiency. The GHG emissions are calculated using GHG factors specific to the fuel and to the applied heating technology, as shown in the last row of figure 2. The details on the left explain the underlying factors contributing to the evolution of the GHG emissions for buildings,[23] for example the different buildings typologies, the depth of energy renovations and the climate.

[21] Here floor area is the conditioned floor area, meaning heated or cooled space.
[22] The development of the energy need depends on the heating and cooling behaviour, which is a consequence of building automation, control and smart systems.
[23] The reduction of indirect emissions from materials, for example through the material switch from steel and concrete to wood, is covered in the manufacturing module.

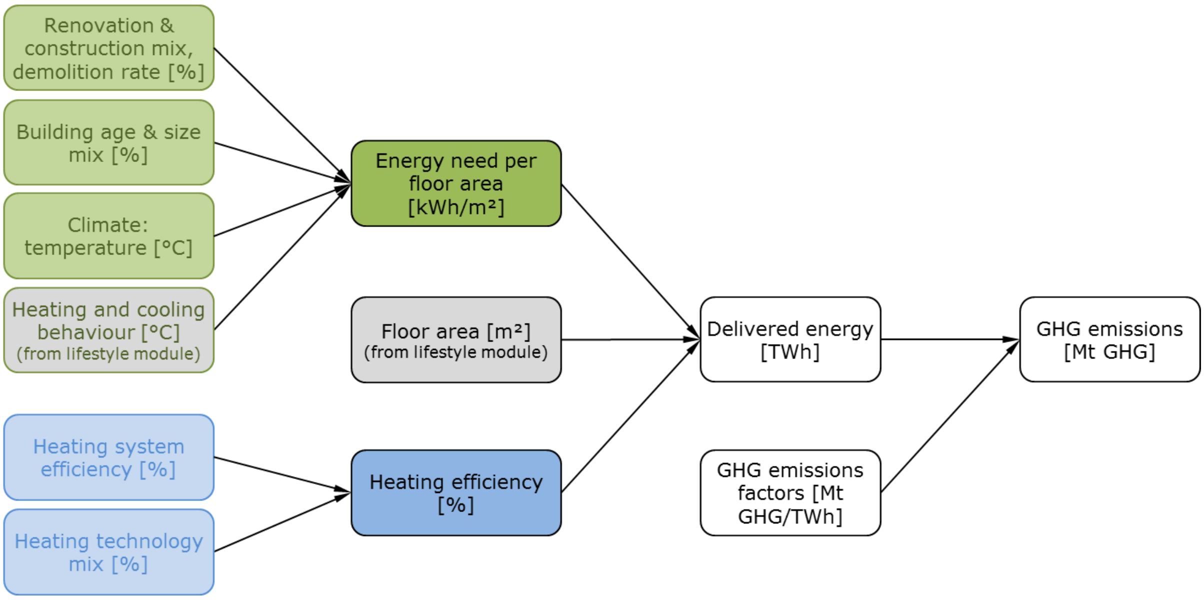


Figure 2: Approach for the calculation of greenhouse gas emissions from buildings

The data sources for the building module are the Building Stock Observatory,[24] Odyssee[25] for buildings stock data and the EU Projects ENTRANZE,[26] Mapping and Analyses of the current and future (2020–2030) heating/cooling fuel deployment (fossil/renewables),[27] and Heat Roadmap Europe for energy data for national building stocks.

The building module is integrated into the EUCalc and receives and delivers data in interaction with other modules. It receives input from the lifestyle module, for example, on the residential floor area development. It receives input from the climate module, for example, on the development of external temperatures. Outputs from the buildings module to other modules include the electricity demand that needs to be delivered by the power module, the constructed and renovated areas to industry and to the minerals module, and emissions to the emission module.

The EUCalc building module does not cover emissions from the electricity used in the building sector, because these emissions occur in the energy sector and are calculated by the power module. Electricity generation and district heating generation are linked through combined heat and power (CHP) plants, which are included in the power module. To display the complete CO_2 emissions of buildings the emissions from the generation of electricity and heat supplied to buildings would need to be isolated from the total emissions in the energy sector. The electricity demand covered in the building module, includes lighting, cooling, cooking and also appliances that are used in buildings, for example, fridges and washing machines.

[24] ec.europa.eu/energy/en/topics/energy-efficiency/energy-performance-of-buildings/eubuildings
[25] www.indicators.odyssee-mure.eu/energy-efficiency-database.html
[26] www.entranze.eu/
[27] Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables);Tender ENER/C2/2014-641, available at ec.europa.eu/energy/en/studies/mapping-and-analyses-current-and-future-2020-2030-heatingcooling-fuel-deployment

4.4 How the building module of the EUCalc Model is used for this report

This briefing is based on the analysis of pathways for GHG emissions in the buildings sector up to 2050; figure 3 visualises its scope. These pathways have been generated by using the EUCalc building and power modules and keeping all inputs from other modules at level 1 (observed trend continuation).

For the purpose of this briefing and for all 3 pathways, population development and living space per person (from the lifestyle module) were kept at the level reflecting observed trends because they cannot directly be influenced by national policymakers when developing their LTRS, but are considered an external factor. Assumptions on the share of the cooled space and the heating and cooling behaviour are also kept at observed trends.

The EUCalc building module also includes energy for most white appliances, some ITC appliances, lighting and cooking, but, for the purpose of this briefing, energy used by appliances has been excluded. This is because the EPBD does not cover the energy used by household appliances,[28] so this is not relevant for creating decarbonisation pathways that mirror LTRS.

As the EPBD does not cover emissions resulting from the production of buildings materials, nor are these covered by the EUCalc building module, these are out of the scope of this briefing.

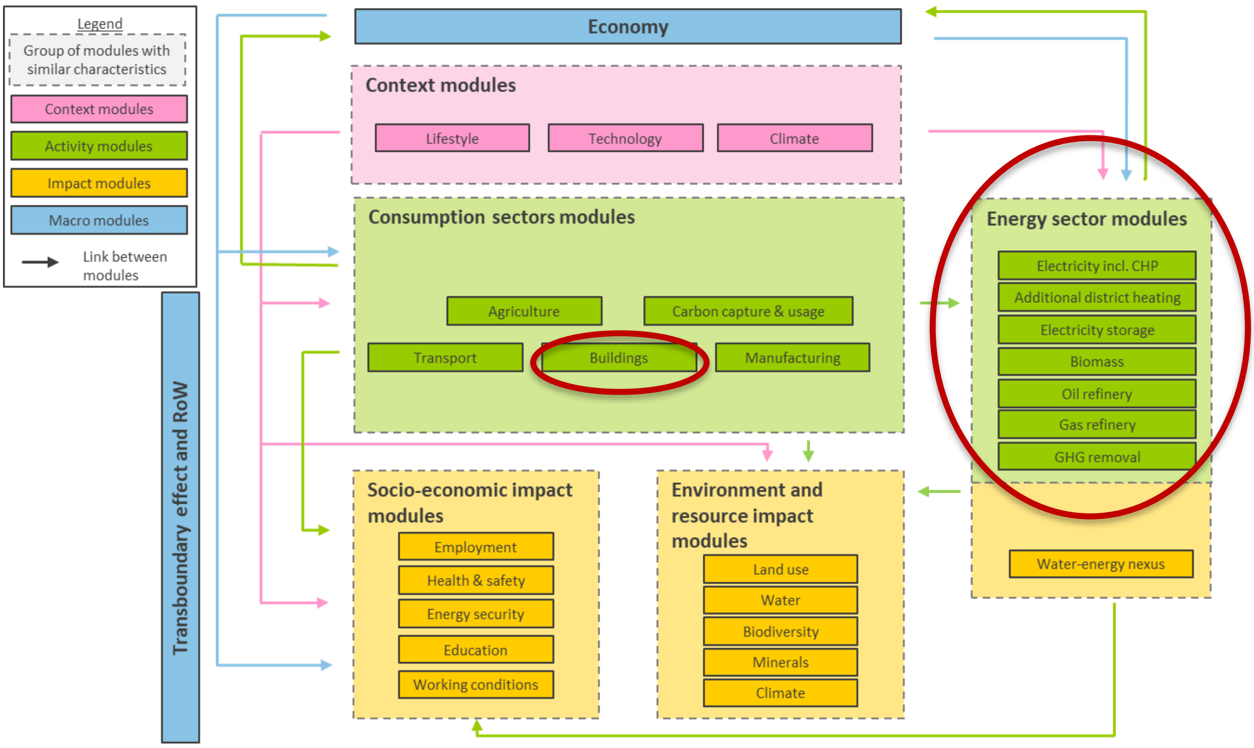


Figure 3: Visualisation of the scope of the briefing

[28] Energy efficiency of appliances is regulated by Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products.

For this briefing we created three pathways. In each pathway all levers of the buildings and of the energy sector module are set at the same level. However, with EUCalc it is possible to create several additional pathways by mixing the levels of ambition of the different levers.

This briefing presents the impacts resulting from changing the ambition of selected levers of the building module and the energy sector module simultaneously at observed trends[29], level 3 (ambitious but realistic) and level 4 (transformational). We did not create a pathway in which all levers are set at level 2 because such a pathway would fall too short of mirroring a decarbonised building stock in line with EPBD requirements. Annex I summarises the scope of the three pathways.

5 Using EUCalc to support the drafting and analysis of national long-term renovation strategies

In this briefing, EUCalc is used to create GHG emissions reduction pathways in the buildings sector that try to mirror LTRSs in line with the EPBD. We analyse what this could mean in term of impacts for selected Member States and for achieving the EU 32.5% energy efficiency target by 2030.

5.1 Modelling 2050 objectives: EU results

Within the framework of the modelling assumptions explained in the previous section, EUCalc can be used to model different pathways for reducing CO_2 emissions of the buildings sector up to 2050 for the EU as a whole.

The pathway level 1 (“observed trends continuation”) shows a decrease of buildings’ CO_2 emissions of 8% compared to 2015,[30] while the level 3 and level 4 pathways result in a reduction of emissions of 83% and 97% respectively.

The level 3 pathway is in line with ambitious but realistic current technologies and practices that, while not mainstream, are already applied in Europe. Level 4 demands transformational change in current demolition, construction and renovation practices to achieve an almost total decarbonisation of the demand and supply of heat in buildings.

[29] The observed trend ambition is considered to be at Level 1 for buildings and at level 1.4 for the power module.

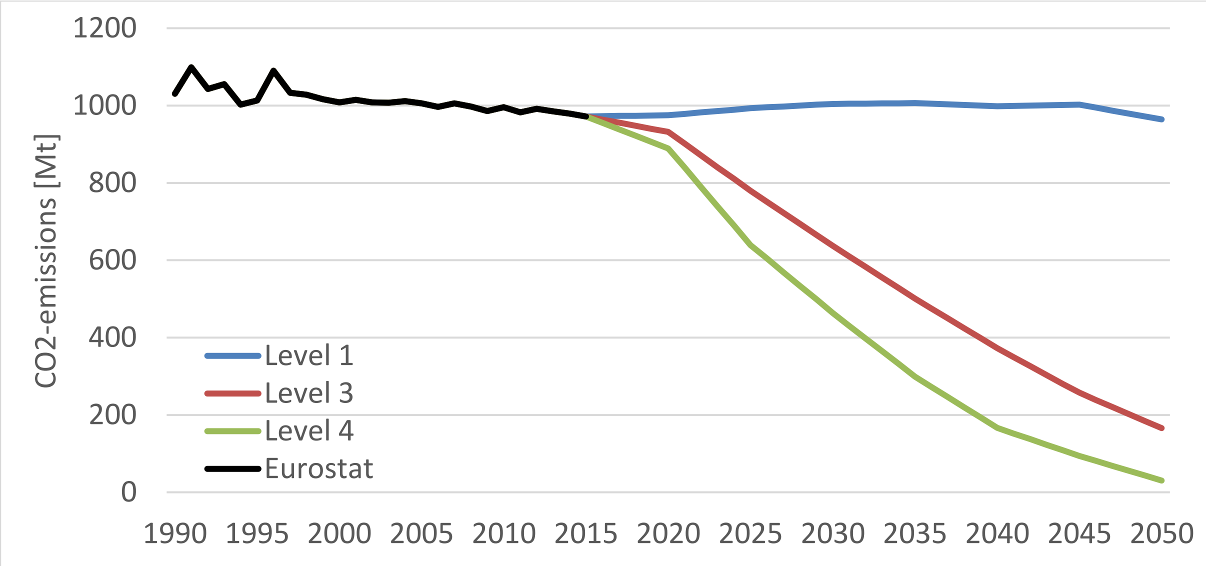


Figure 4: CO_2 emissions for the EU28 following decarbonisation ambition level 1, 3 and 4 in buildings

This most ambitious pathway can be considered consistent with the legal obligation of the EPBD that requires Member States to develop LTRSs that achieve a decarbonised building stock by 2050. EUCalc gives an indication of the scale of the impacts Member States need to achieve to comply with this obligation and the transformative effects that LTRS policies and measures would require. The level 4 pathway assumes a renovation rate of 3%, leading to a refurbishment of all existing buildings by 2050; out of these renovations, the great majority are assumed to be deep renovations with no shallow refurbishment. Also, level 4 assumes a demolition rate of 1%, which would mean about 37% of existing buildings will be demolished and replaced by new nearly zero-energy buildings by 2050. Finally, the electricity and heat used in the buildings sector would need to be almost fully decarbonised (Figure 5).

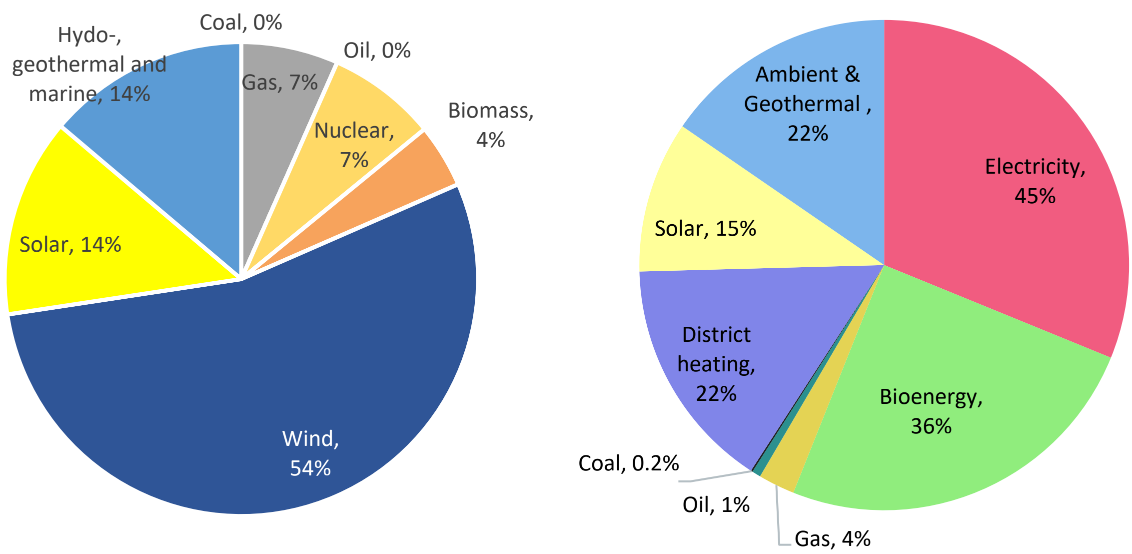


Figure 5: EU Fuel mix of the electricity and CHP-heat production in 2050 (left graph); EU Fuel mix of the decentral heat and additional district heat generation in 2050 (right graph) - EUCalc Level 4 pathway.

In addition, the EUCalc model also allows to decompose emissions of the building stock per energy use. This allows comparing how the emssions resulting from the different energy uses, for example space heating or hot water, could change for the different pathways.

In the observed trend pathway (Level 1) the CO2 emissions remains at the same level. The electricity for space cooling demand remarkably increases largely counteracting emission savings in the space heating, hot water and district heating (See Figure 6).

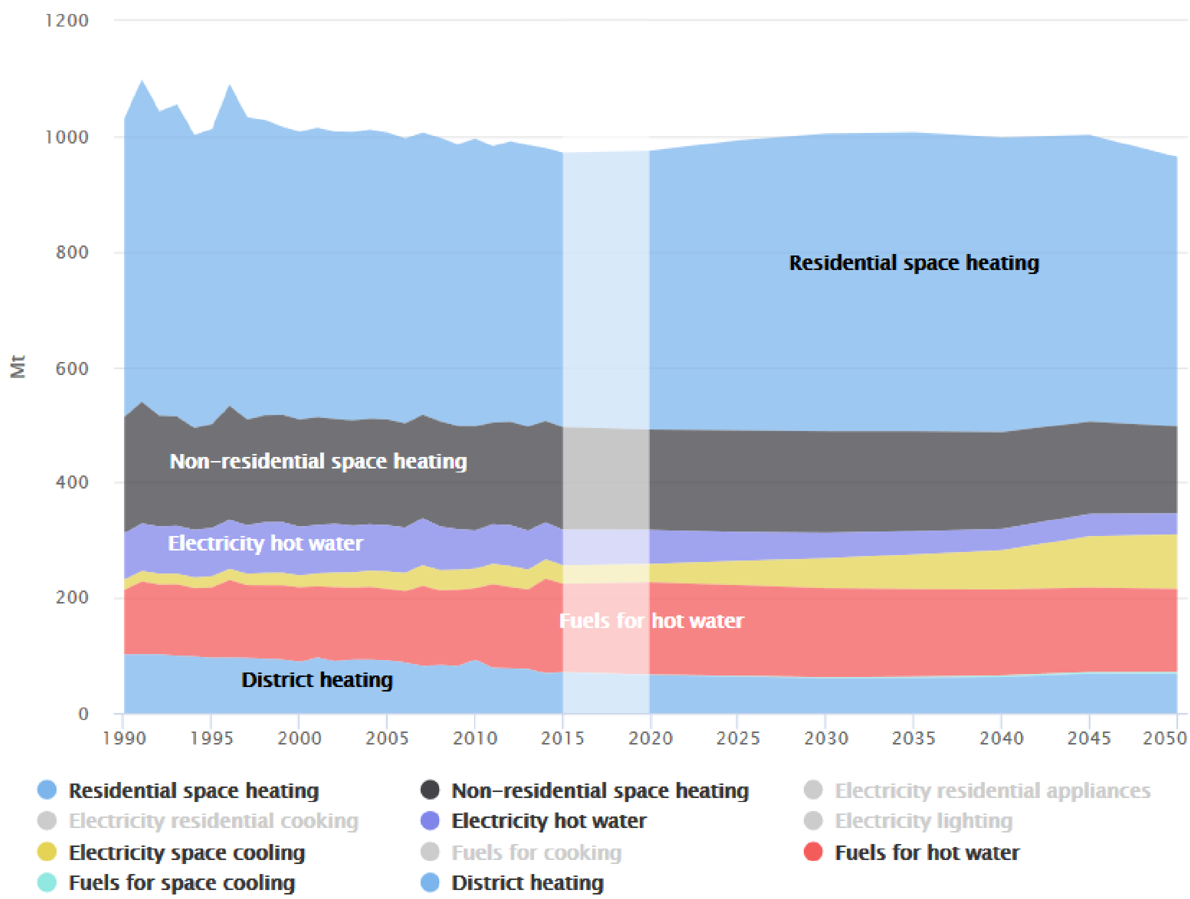


Figure 6: CO_2 emissions in buildings for the EU28 following decarbonisation ambition level 1 split by energy use

For Level 3 and Level 4 pathways, the emissions relative to all energy uses are drastically reduced. However, in the Level 3 pathway the reduction of emission is driven a bit further by the decarbonisation of electricity, while for Level 4 pathway there is almost full decarbonisation of the heating sector.

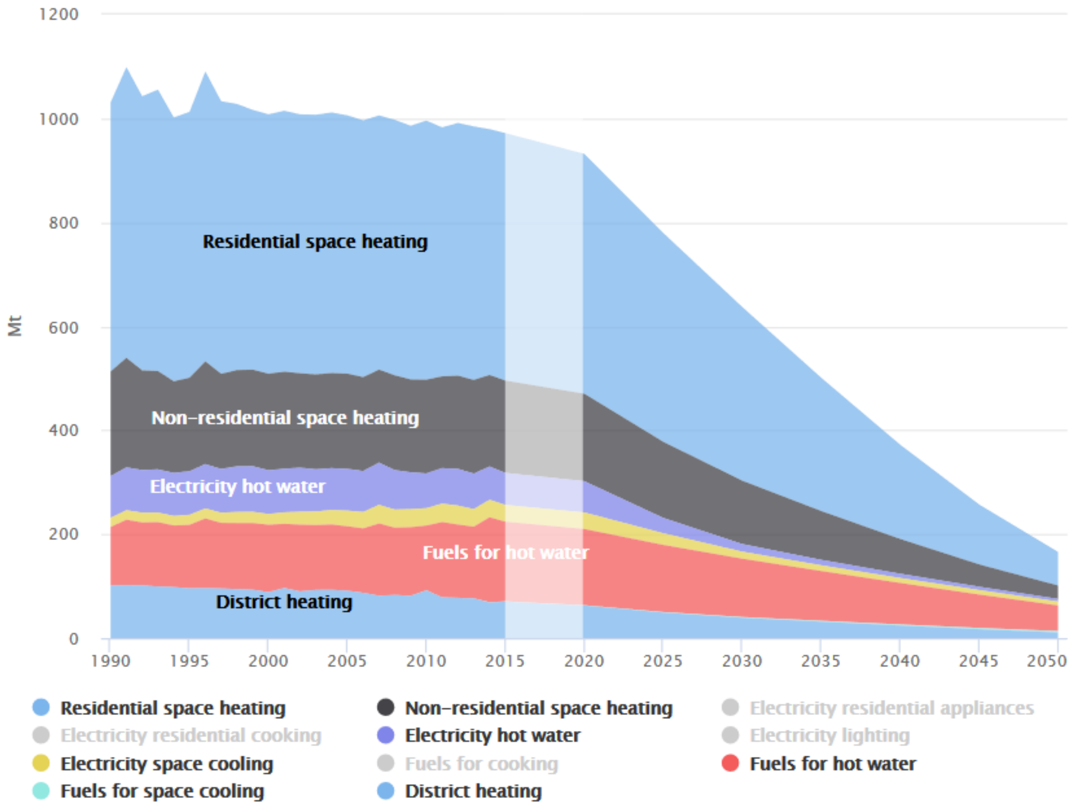


Figure 7: CO_2 emissions in buildings for the EU28 following decarbonisation ambition level 3 split by energy use

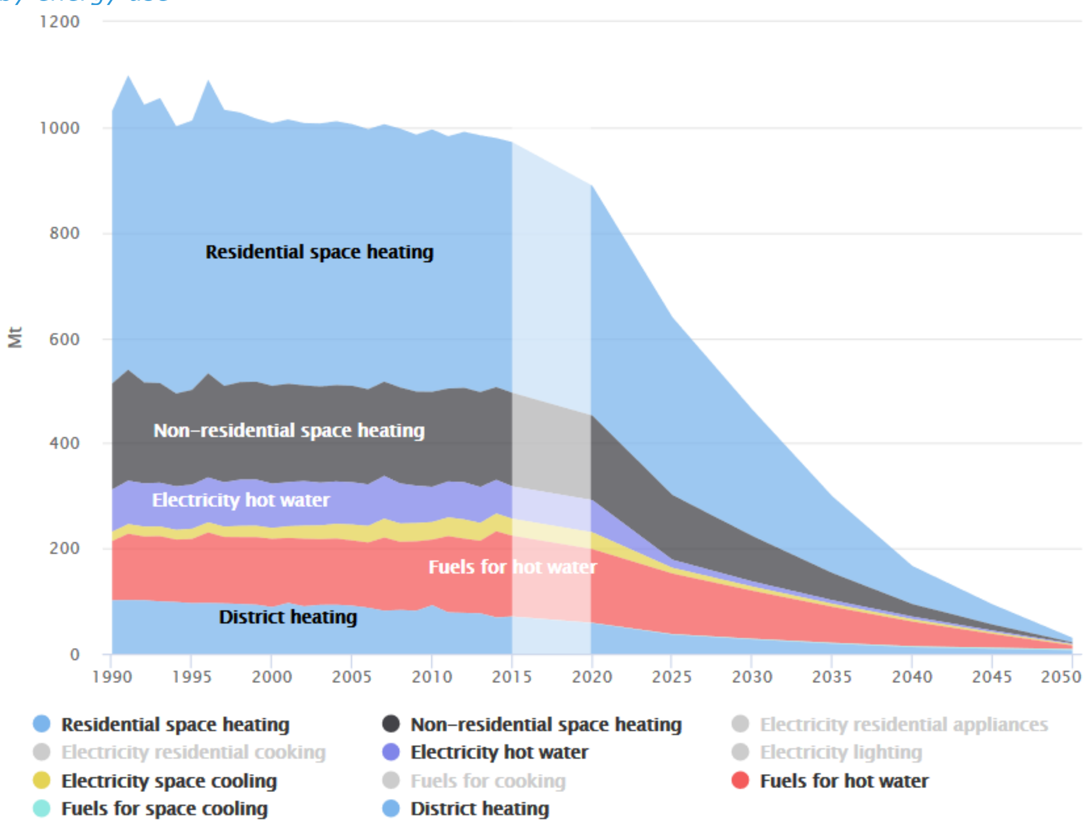


Figure 8: CO_2 emissions in buildings for the EU28 following decarbonisation ambition level 4 split by energy use

5.2 Modelling 2050 objectives: national results

As EUCalc is able to model country-specific pathways for all 28 Member States and Switzerland, it can also be used to draw indicative national pathways towards a decarbonised building stock by 2050 in line EPBD obligations. Member States could use the tool to make comparisons with the scenarios they have created for their LTRSs. It can also be a useful resource for the European Commission to get an indication of how Member States' LTRSs comply with the 2050 decarbonisation objective.

The following section illustrates some potential national results and presents pathways to achieving decarbonisation of demand and heating in buildings for selected countries (Annex II provides an example of pathways for additional countries).

GERMANY

For Germany, the level 1 pathway would result in a decrease of CO_2 emissions of 18%, level 3 of 84% and level 4 of 96% compared to 2015, as shown in figure 5 below.

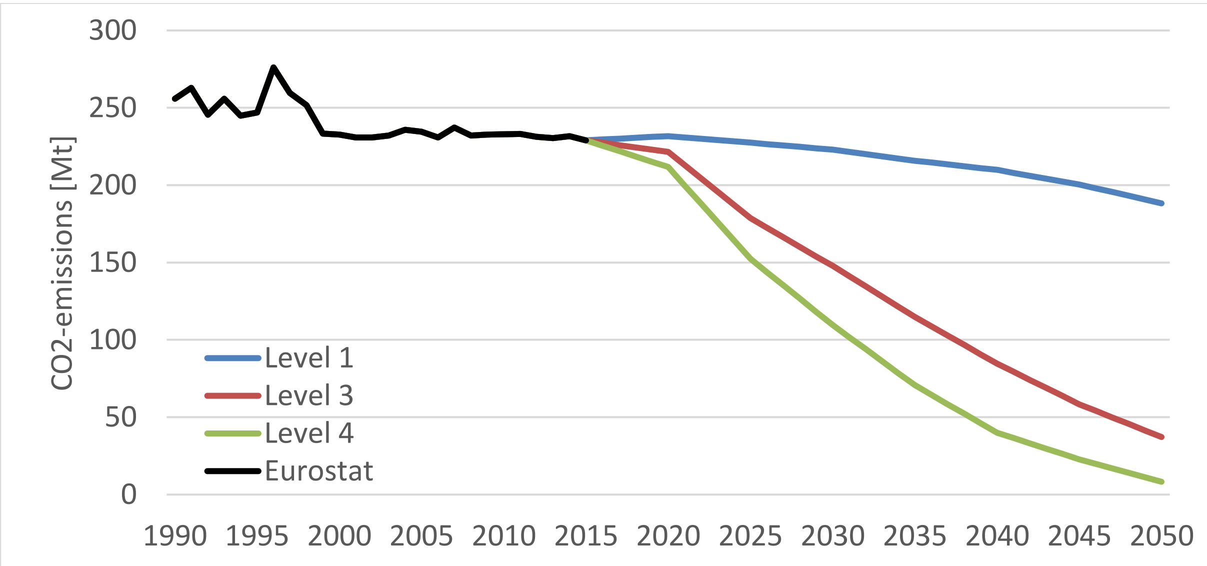


Figure 9: CO_2 emissions for Germany following decarbonisation ambition level 1, 3 and 4 in buildings

FINLAND

For Finland, the level 1 pathway would result in a decrease of CO_2 emissions of 5%, level 3 of 91% and level 4 of 98% compared to 2015.

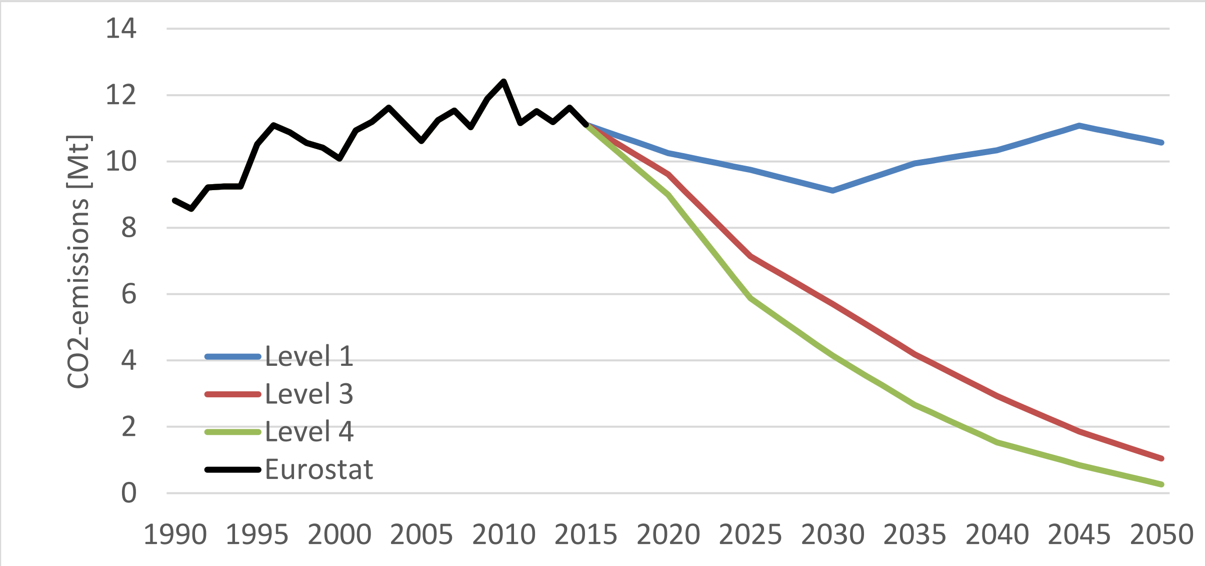


Figure 10: CO_2 emissions for Finland following decarbonisation ambition level 1, 3 and 4 in buildings

POLAND

For Poland, level 1 would result in a decrease of CO_2 emissions of 29%, level 3 of 92% and level 4 of 97% compared to 2015.

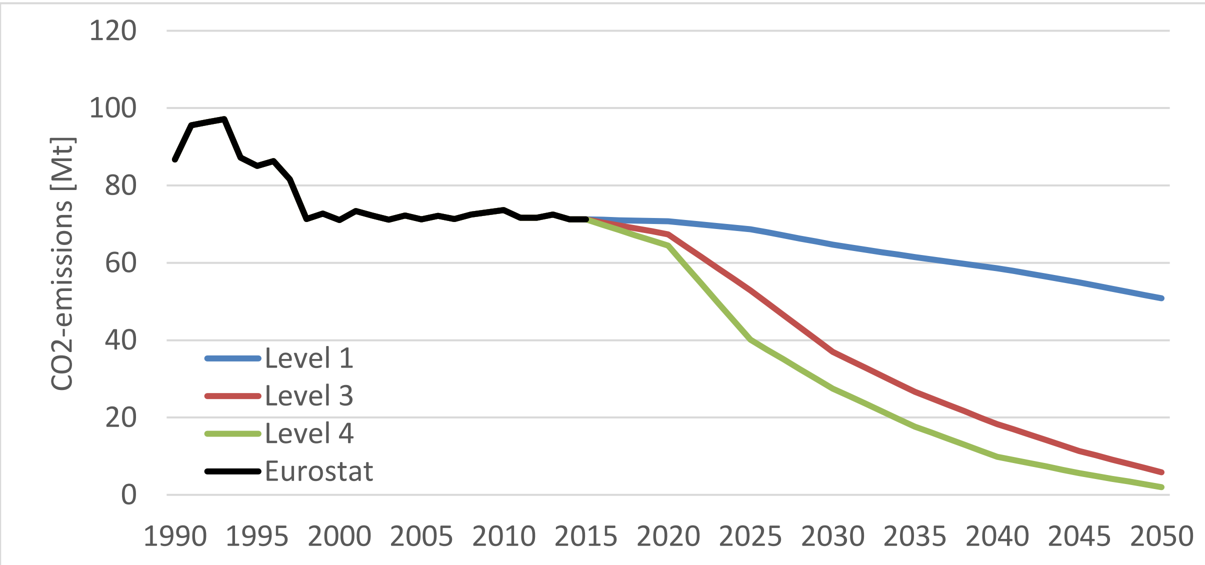


Figure 11: CO_2 emissions for Poland following decarbonisation ambition level 1, 3 and 4 in buildings

The above examples give an indication that if Member States implement very ambitious, but realistic, practices and technologies for reducing energy consumption in buildings (in line with the level 3 pathway), a substantial reduction of GHG emissions could happen by 2050. For Poland, for example, the implementation of measures in line with level 3 could already reduce CO_2 emissions by 92% compared to 2015.

If Member States embarked on large-scale additional efforts based on major technological advances and breakthroughs (in line with the level 4 pathway) this could lead to almost complete decarbonisation of energy demand and heat in buildings by 2050 – a reduction of 96% of CO_2 emissions for Germany, of 97% for Poland, and of 98% for Finland. This implies following a pathway that will completely transform the current practices of today's buildings sector, as these pathways are based on ambitious assumptions, such as, for example, increasing the renovation rate to 3% per year and the demolition rate to 1% per year and almost completely decarbonised the energy used in buildings.

5.3 Modelling 2030 milestones

As explained in Section 3.1, when Member States draft their LTRSs, they must also establish intermediate milestones for 2030, 2040 and 2050 that will contribute to the achievement of the 2050 decarbonisation goal. When EUCalc is used to generate indicative country-specific pathways leading to a decarbonised building stock by 2050, as shown in the previous section, it can also be a useful tool to investigate how the intermediate milestones for 2030 could look.

For example, out of the non-exhaustive list of milestones included by the European Commission in its guidance note, EUCalc could be used to model the percentage of renovated buildings and the percentage of highly efficient buildings.

The section below provides illustrative examples for Croatia and France on how EUCalc can be used to model selected 2030 milestones.

For Croatia, the following graphs show the amount of renovated buildings according to the depth of renovation (shallow, medium and deep) and the amount of new builds out of the total heated floor area for the level 1, level 3 and level 4 pathways. The pie charts show the composition of floor area in 2030 according to the different pathways. For the level 4 pathway 44 % of buildings are still unrenovated in 2030, compared to 76% for level 1; 32% of buildings will have been deep renovated and 14% have undergone medium renovations, with no shallow renovations. These figures give an idea of the milestones Croatia might want to set up when developing its LTRS in line with a decarbonised building stock by 2050.

CROATIA

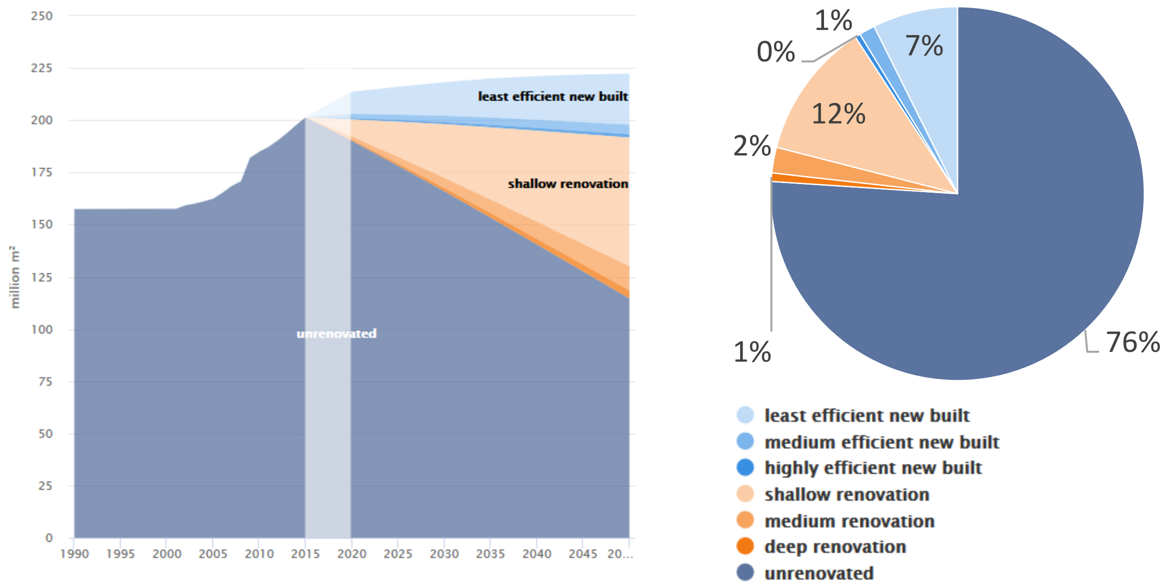


Figure 12: Floor area development due to renovation and new construction[31] and their percentage of the stock in 2030 according to level 1 pathway (Croatia)

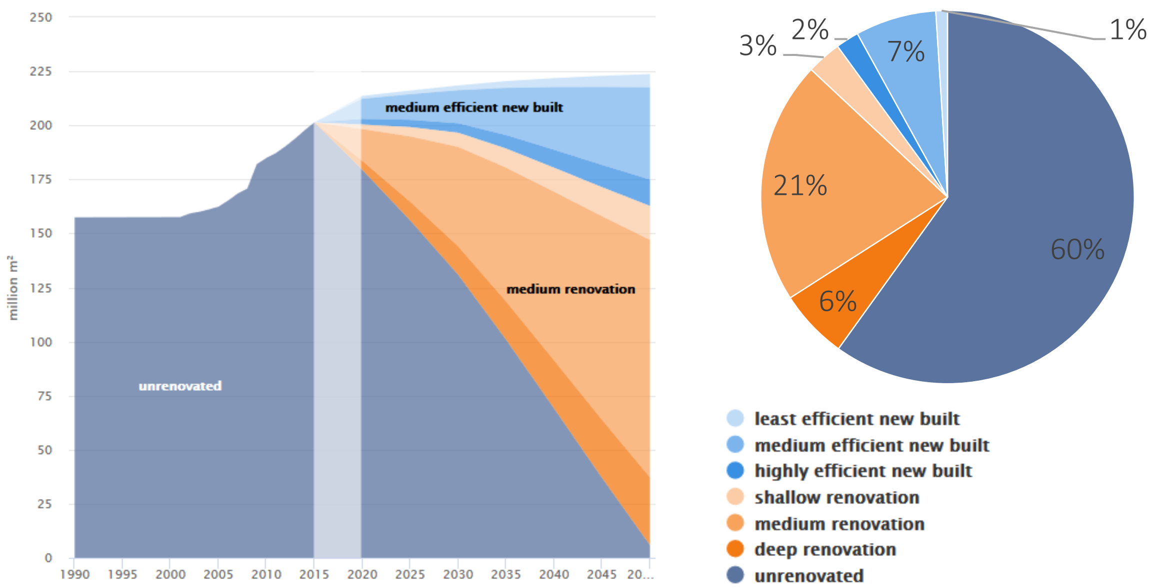


Figure 13: Floor area development due to renovation and new construction and their ***Error! Bookmark not defined.****percentage of the stock in 2030 according to level 3 pathway (Croatia)*

[31] All new buildings constructed shall be NZEB starting 1st January 2021 in line with Article 9 of the EPBD. However, the national definitions of NZEB differ largely accross MS. Therefore, it cannot be assumed that all new constructions in Member States will be highly energy efficient buildings.

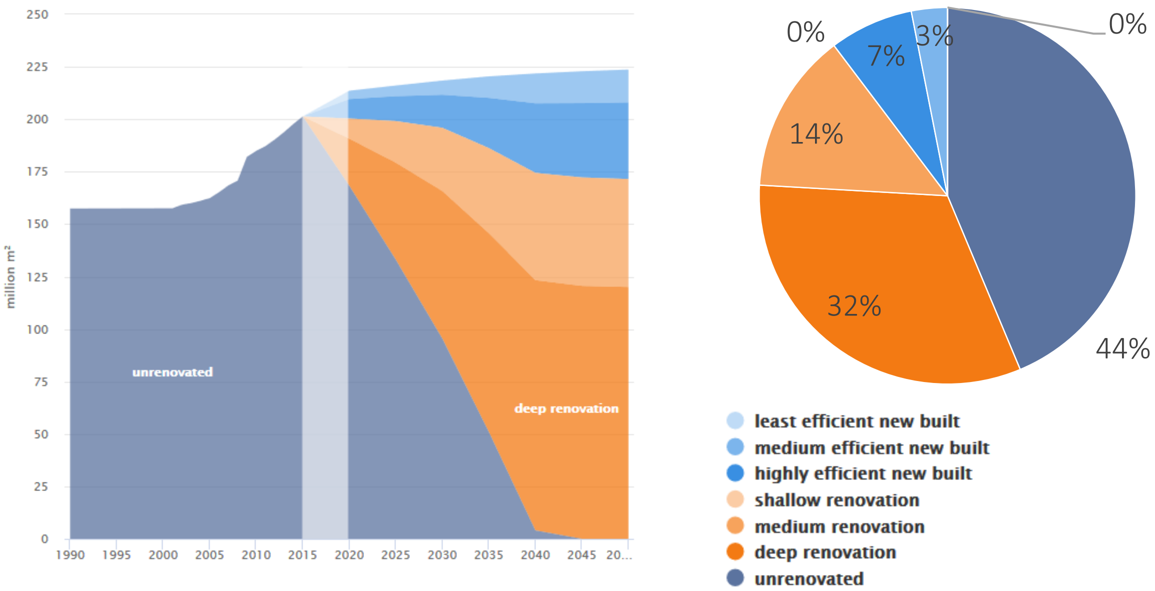


Figure 14: Floor area development due to renovation and new construction and their percentage of the stock in 2030 according to level 4 pathway (Croatia)

For France, the following graphs show the composition of the floor area in 2030 according to pathways that model different level of ambition. In 2030, for the level 4 pathway, 43% of buildings are still unrenovated; 31% have undergone deep renovation and 13% medium-depth renovations, with no shallow renovations. These figures give an idea of the milestones France might want to set up for 2030 when developing its LTRS in line with a decarbonised buildings stock by 2050.

FRANCE

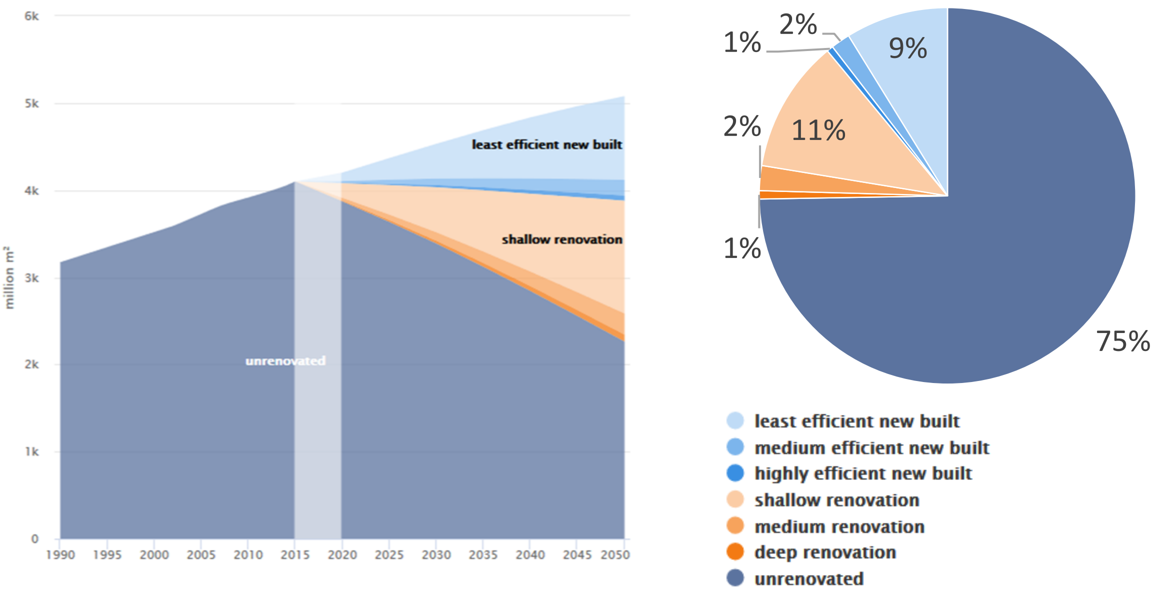


Figure 15: Floor area development due to renovation and new construction and their percentage of the stock in 2030 according to level 1 pathway (France)

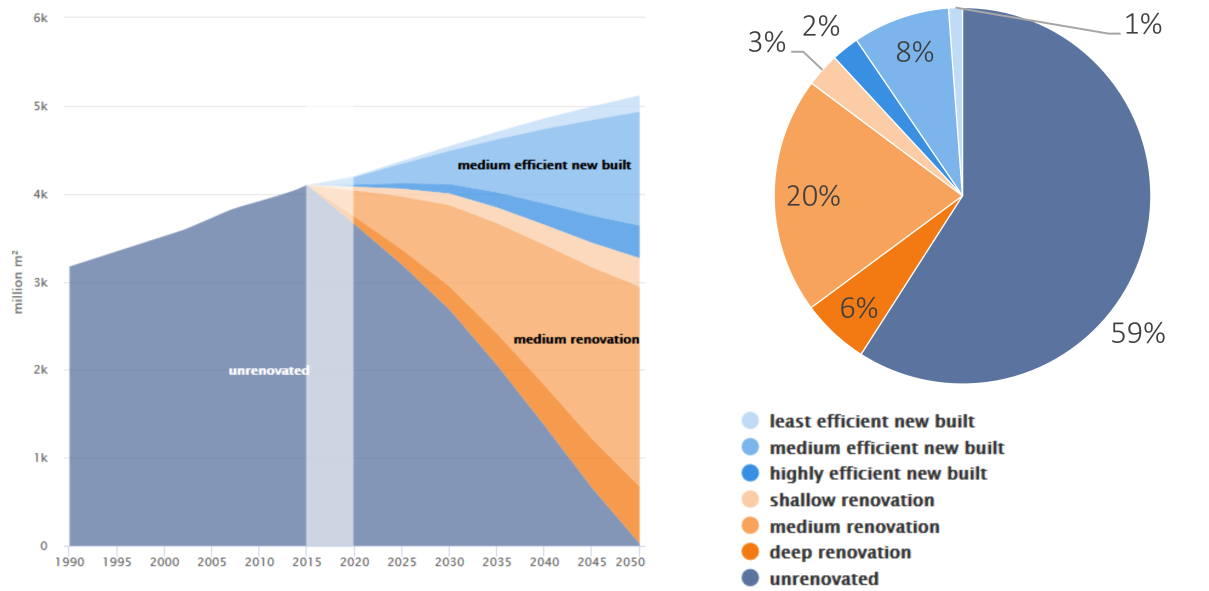


Figure 16: Floor area development due to renovation and new construction and their percentage of the stock in 2030 according to level 3 pathway (France)

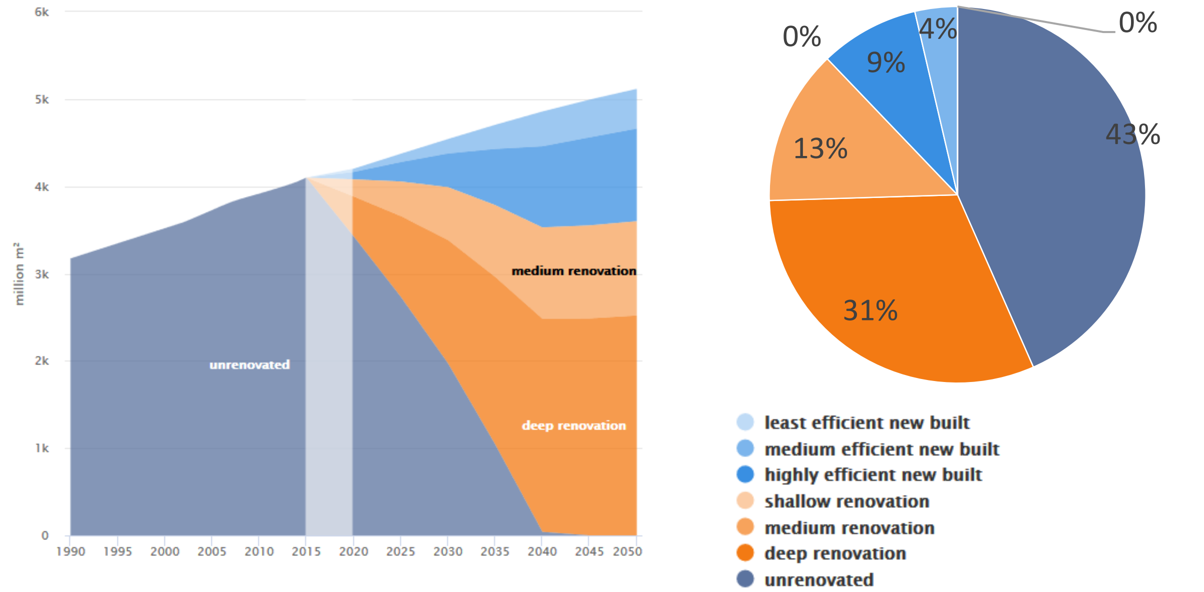


Figure 17: Floor area development due to renovation and new construction and their percentage of the stock in 2030 according to the level 4 pathway (France)

5.4 Using EUCalc for modelling buildings' contribution to the 2030 energy efficiency target

According to the EPBD, indicative LTRS milestones for 2030, 2040 and 2050 must contribute to the European Union 2030 energy efficiency target and Member States must specify how.

The 2030 EU energy efficiency target of at least 32.5% is a reduction in primary and/or final energy consumption compared to energy projections. It translates into a maximum energy consumption for the EU of no more than 1,273 Mtoe of primary energy and/or no more than 956 Mtoe of final energy in 2030.

EUCalc can provide an indication of how the aggregated 2030 milestones for the EU28 could contribute to the achievement of this target. To do so, this section compares the EU energy efficiency target and the EUCalc pathways that try to mirror LTRSs, constructed as explained in section 4.4. The figure below shows the final energy demand for the three pathways previously outlined.

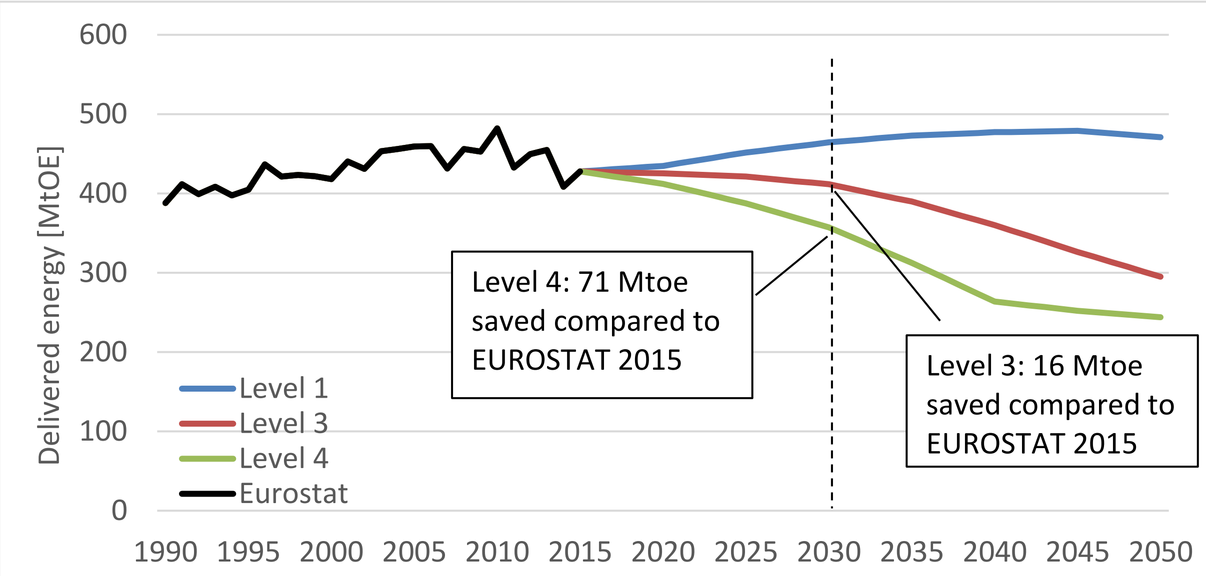


Figure 18: Final energy demand for the level 1, 3 and 4 pathways

First, the 2030 EU energy efficiency target (no more than 956 Mtoe of final energy in 2030) has been expressed in terms of energy savings compared to 2015 Eurostat data of final energy consumption, which is 1090 Mtoe.[32] This means that the 2030 EU energy efficiency target, for the purpose of our comparison, is expressed as energy savings of 134 Mtoe.[33]

Next, we used the pathways in the EUCalc building module to calculate an aggregated final energy consumption in 2030 for the EU28 of 464 Mtoe for level 1, 412 Mtoe for level 3 and 357 Mtoe for level 4. Comparing these with 2015 Eurostat data gives an increase of energy use of 36 Mtoe for level 1 and energy savings of 16 Mtoe and 71 Mtoe for level 3 and level 4 respectively in 2030.

Finally, those figures are compared to show the possible contribution of aggregated 2030 milestones, in line with level 3 and level 4 pathways, to the 2030 EU energy efficiency target.

[32] https://ec.europa.eu/eurostat/databrowser/view/t2020_34/default/table?lang=en
[33] If the latest 2017 Eurostat data were to be used for this briefing, the total energy savings would amount to 166 Mtoes as final energy consumption in the EU in 2017 was higher than in 2015.

The pie charts give an indication of the potential contribution to the 2030 EU energy efficiency target. This contribution is achieved by reducing energy demand through envelope improvement and efficient supply systems for hot water, space heating and also for cooling in the building sector and in the district heating sector. If Member States adopt policies in line with the level 3 pathway, and plan intermediate milestones for 2030 accordingly, efficiency measures to reduce demand and supply of heat in buildings could contribute around 12% of the 2030 energy efficiency target expressed in final energy savings (figure 15). The contribution for this level appears to be quite low, this is mainly because the elevated renovation rate only starts in 2020, therefore making a quite smaller contribution to the 2030 target for Level 3.

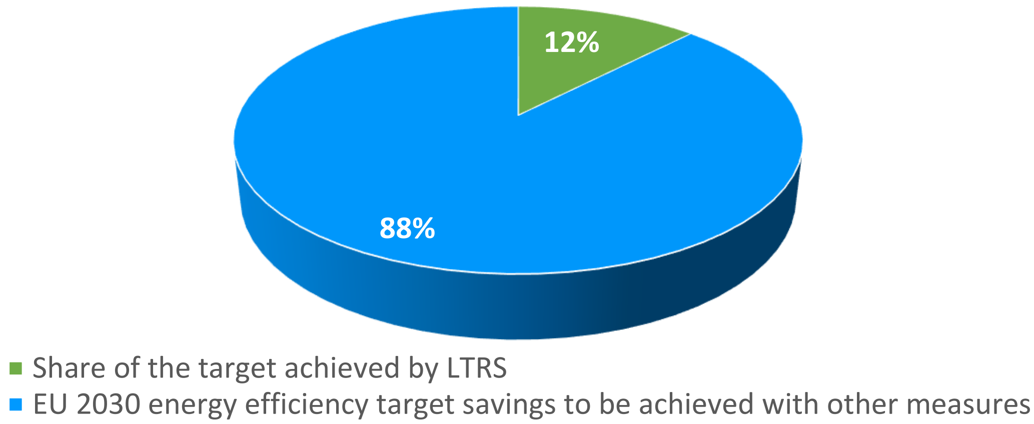


Figure 19 : Contribution to EU 2030 energy efficiency target of 2030 milestones with the level 3 pathway

If Member States adopt and implement LTRSs that achieve the 2050 decarbonisation objective (in line with the level 4 pathway), and plan intermediate milestones for 2030 accordingly, these measures could contribute around 53% of the 2030 energy efficiency target (figure 16). It is clear that if Member States plan measures to achieve a decarbonised building stock by 2050 in line with level 4 pathway, and then back-cast 2030 milestones accordingly, the LTRS could largely contribute to the 2030 EU energy efficiency target.

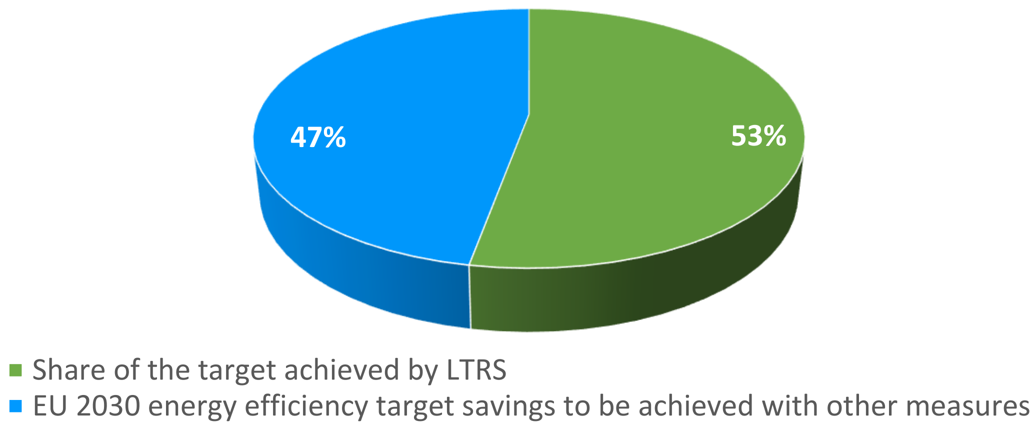


Figure 20: Contribution to EU 2030 energy efficiency target of 2030 milestones with level 4 pathway

5.5 Capital expenditures for renovations and their implications on different pathways

This section gives an indication of the possible capital expenditures associated with renovation activities for the different pathways (capital expenditures for new constructions and changes in the heat distribution systems to buildings are not included in this assessment). Capital expenditures relate directly to the cost of the renovation activity that is initiated and incurred in a given year.[34]

The 3 different pathways presented so far (Level 1, Level 3 and Level 4) would also have very different implications in term of capital expenditures and how those are distributed in the period up to 2050 (See Figures 21, 22 and 23).

In more ambitious pathways, renovations are preponed compared to less ambitious pathways: earlier renovations lead to higher capital expenditures in the first decades of this century and then decrease when approaching 2050. For the level 4 pathway, this results in a complete renovation of most building types by about 2043 and therefore a substantial decrease of costs after that date. The EUCalc model does not assume double renovations (i.e. renovating the same building twice) as those are not considered to be in line with sustainability and circulatrity principles, such as minimising construction and demolition waste.

The most ambitious pathway, in addition to preponing renovations, also forsees that refurbishement are deep renovations.

Both aspects, the deeper renovations and the earlier renovations explain the difference in the total capital expenditures between more and less ambitious pathways at the beginning of the modelled period, for example between 2015 and 2030. The total amount of floor area renovated in this period adds up to 9.6 billion m² in the observed trends pathway, while it totals 19.8 billion m² and 30.3 billion m² in the level 3 and 4 pathways respectively. In this period, not only the renovation activity increases by 3 and 4 times but also the quality of renovations is more ambitious. While in the observed trend pathway 5% of the renovation achieve a reduction in energy need of more than 40%, in level 3 and 4 this share grows to 30% and 70% respectively.

The above considerations have also an impact on the total amount of capital expenditures for renovations in the whole period. Total capital expenditures in Level 3 are 3 times higher than the observed trend pathway and 4.5 times higher for Level 4 pathway.

[34] While capital expenditures for a renovation may incur and be spread over several years, the model accounts for the overall expenditure in the first year only.

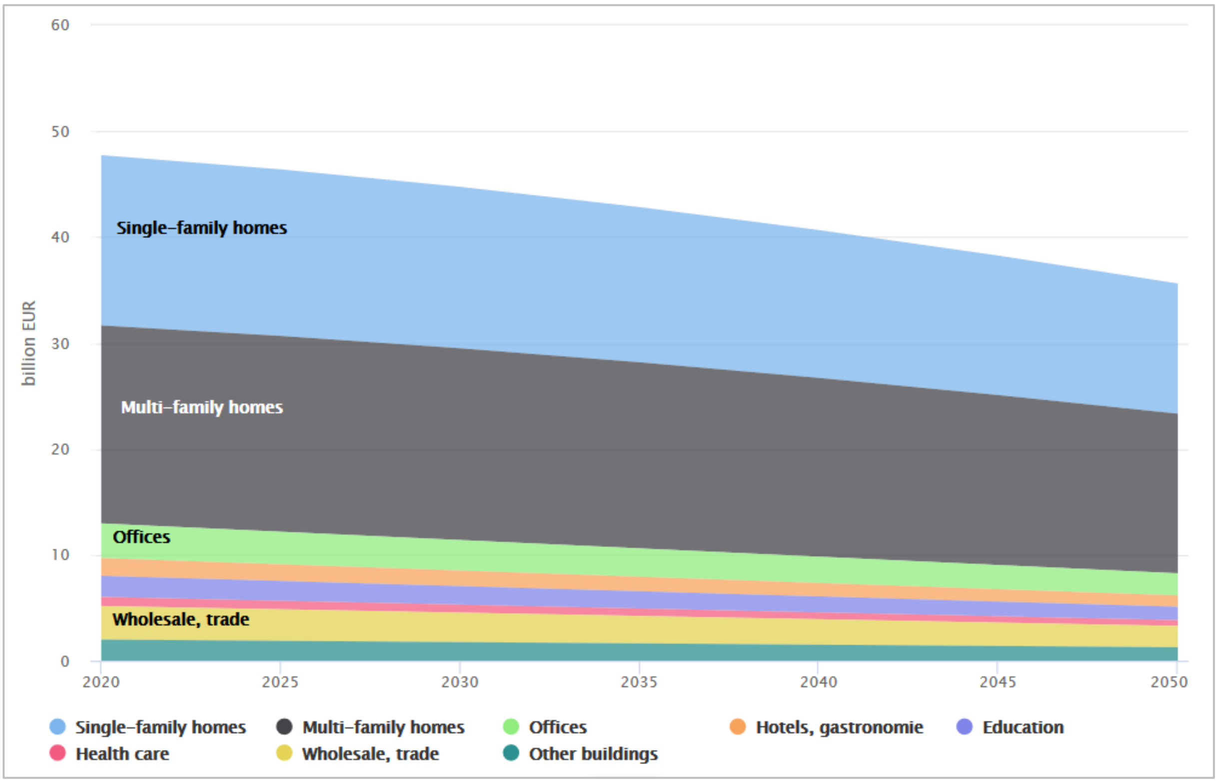


Figure 191: Capital expenditures for renovation in the Level 1 pathway.

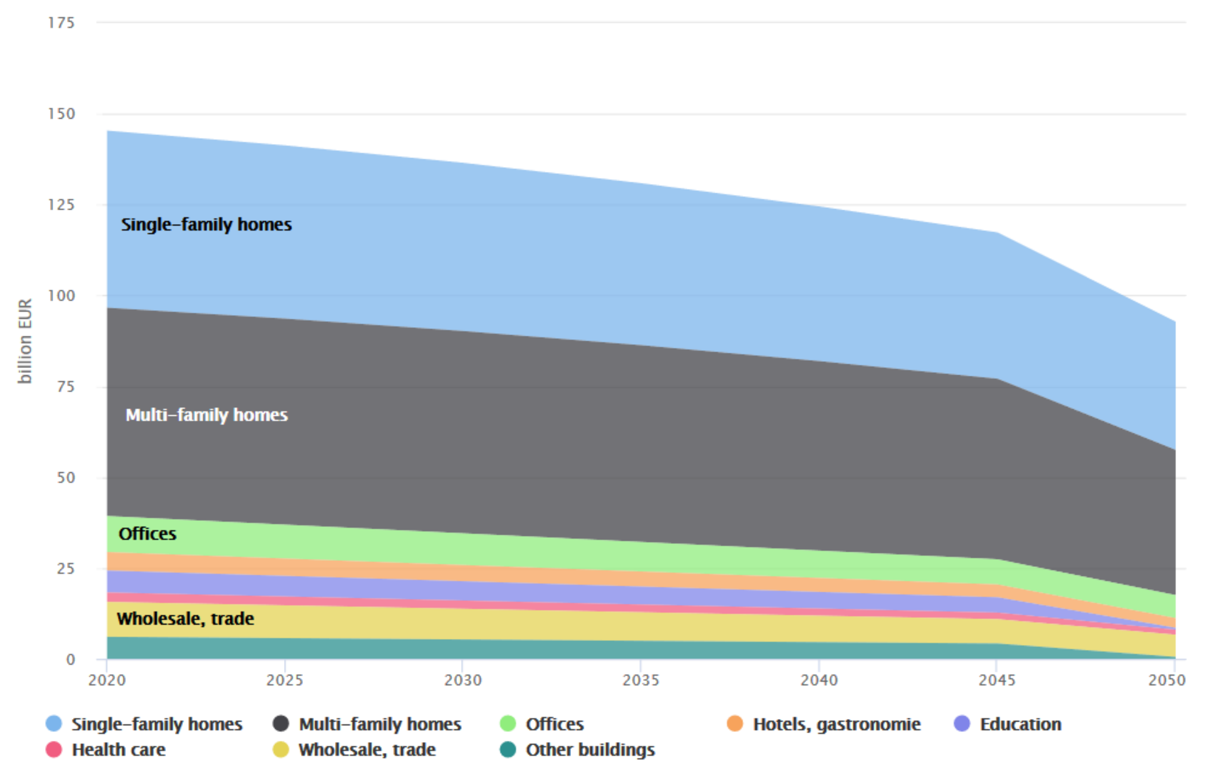


Figure 20: Capital expenditures for renovation in the Level 3 pathway.

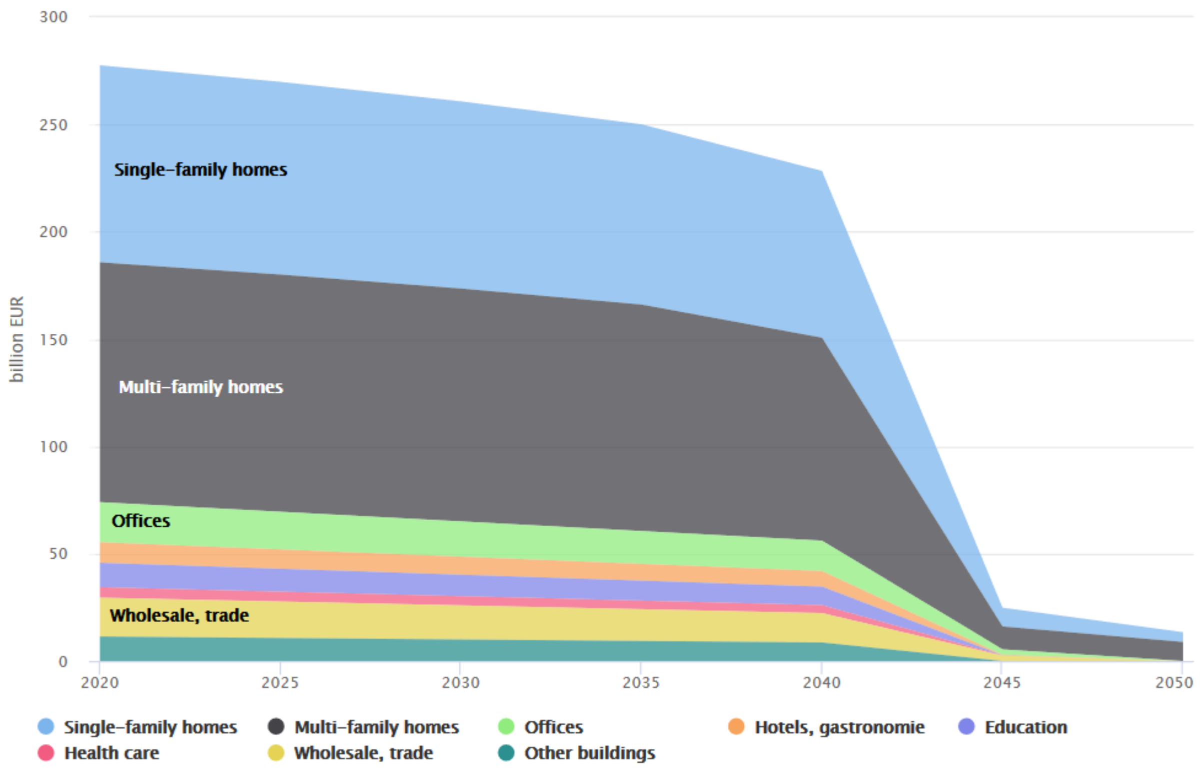


Figure 23: Capital expenditures for renovation in the Level 3 pathway.

6 Policy implications[35]

When Member States draft and implement LTRSs that are in line with the objective of decarbonising their national building stock, therefore contributing to the climate neutrality objective of the European Green Deal, they must put in place policies and measures that lead to a transformation of the building sector compared to today.

For example, the level 4 pathway, which can be considered consistent with the EPBD LTRS requirements of achieving a highly energy efficient and decarbonised building stock by 2050, assumes a renovation rate of 3% leading to a refurbishment of all existing buildings by 2050. Out of these renovations, the great majority are assumed to be deep renovations with no shallow refurbishment. The demolition rate is about 1% per year.

To achieve a similar level of impacts, Member States must use the drafting of their LTRS as an occasion to rethink their policy interventions in the buildings sector and put in place a coherent strategy that mobilises resources and actors towards the long-term decarbonisation goal. The first step in that direction is for Member States to construct their LTRS around this long-term goal and to plan the appropriate policies and measures to achieve it. In addition, they must also plan short-term measures that are consistent with this long-term goal. If the goal of achieving a highly energy efficient and decarbonised building stock is not integrated correctly in the planning, the LTRS risks being a patchwork of conventional measures that will not deliver the changes in the sector at the scale needed. On the contrary, new innovative policies need to be mainstreamed across the EU.

Member States have at their disposal a broad range of policy instruments, which must be tailored to the national situation and different starting point of every country. An increase in the renovation rate of existing buildings from the current 1% to 3% would require the adoption and mainstreaming of policy measures such as minimum energy performance requirements for existing buildings (e.g. when a building is sold or rented[36]) or advisory tools like one-stop-shops to help citizens in their renovation journey. It would also require industrialised and prefabricated renovation solutions, on the model of the Dutch Energiesprong,[37] which would reduce costs of deep renovations and increase their rate. Achieving an increased renovation rate would also require large mobilisation of investment, especially to support the renovation of residential buildings.[38]

Increased demolition also plays a role in the most ambitious pathway modelled, with a demolition rate assumed to increase from 0.1% to 1%. This means that some of the worst-performing buildings, which are more costly to renovate than to rebuild, would be demolished. Any demolition strategy should be carefully designed by prioritising commercial buildings that already have a shorter lifespan

[35] The policy implications presented in this briefing are not a direct output, nor a direct result, of the EUCalc model.

[36] bpie.eu/publication/renovation-in-practice

[37] energiesprong.org/country/the-netherlands

[38] See as well the European Investment Bank draft energy lending policy available at www.eib.org/attachments/draft-energy-lending-policy-26-07-19-en.pdf

and a higher demolition rate than residential buildings. It must also take into account circular economy principles, including the need to reduce construction and demolition waste.

Additionally, to enable the decarbonisation of heat and electricity used in buildings in line with the most ambitious pathway, a much more integrated planning approach that captures the interdependencies between supply and demand must be put in place. The deployment of renewable heat technologies, like the latest generation district heating and cooling systems or heat pumps, is more effective with very low energy buildings. Combining the planning of renovations in both buildings and heating systems can effectively avoid unnecessary investments and lock-in effects. LTRSs should capture and plan how to maximise these synergies.

The briefing also shows that if Member States draft LTRSs with a clear 2050 decarbonisation goal in mind and then back-cast 2030 milestones, these alone could contribute 53% of the EU 2030 energy efficiency target. With this level of ambition in LTRSs, Member States' aggregated national energy efficiency contributions would be likely to overachieve the 32.5% energy efficiency target, instead of falling short by up to 6%.

To conclude, this briefing demonstrates that decarbonising the building stock is a societal challenge that will require wide socio-economic transformation. Achieving the level of impacts in line with the most ambitious pathway will require acceptance and support from a wide spectrum of stakeholders, from local authorities to the construction industry, to civil society organisations, to installers and builders. In this context, the European Green Deal suggests the Commission will work with stakeholders on a new initiative on renovations in 2020. Ultimately, only a shared ownership of the long-term decarbonisation objective and collective support for the building renovation measures that must happen on the ground can make the "renovation wave" materialise.

7 Conclusions

This briefing shows how the EUCalc model can be used to develop pathways for reducing GHG emissions that mirror EU and national policies. In particular, it creates and explores the impacts and implications of three pathways that potentially reflect the national LTRSs, which Member States had to submit to the European Commission by 10 March 2020 in compliance with the EPBD. It concludes that large additional effort and major technological advances and breakthroughs compared to the buildings sector's current construction and renovation practices are possible and necessary if Member States are serious in drafting roadmaps that will lead to a highly energy efficient and decarbonised building stock by 2050. If LTRSs are drafted with this ambition in mind, they will also make a significant contribution to the achievement of the 2030 energy efficiency target and will be the driver for accelerating actions by 2030.

8 Annex I Summary of the scope for this briefing

Table 3: Scope of the EUCalc model, of the building module and of this paper

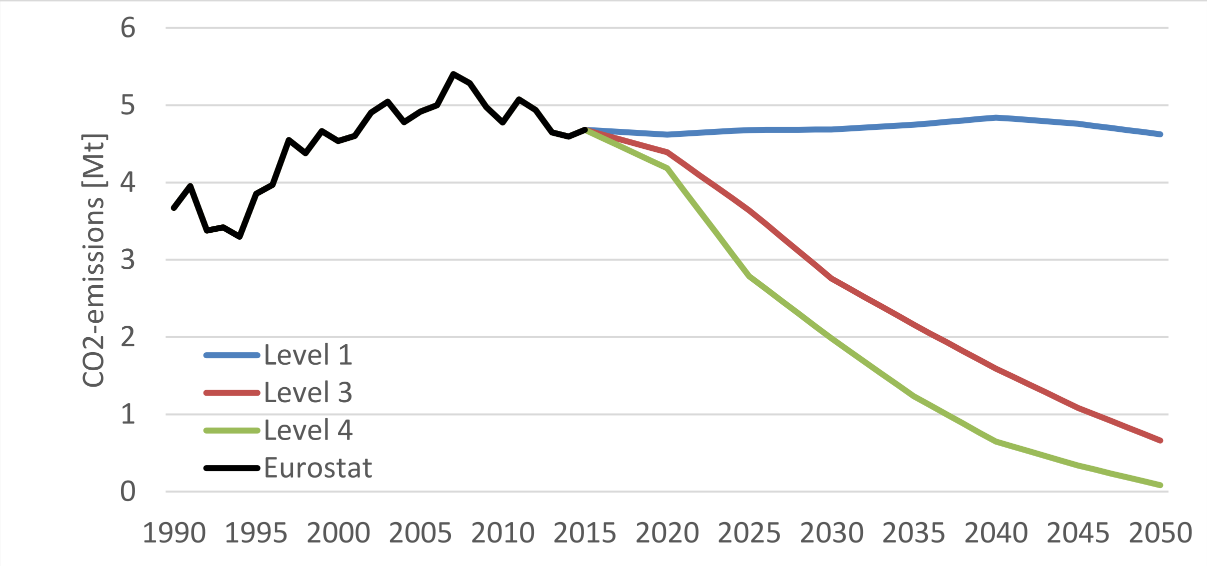
Building sector input sections and results scope	Where is it covered in the EUCalc model?	Is it covered in the building module?	Is it covered in this report?
Building sector inputs			
Residential buildings		Yes	Yes
Single-family homes			
Multi-family homes		Yes	Yes
Non-residential buildings		Yes	Yes
Offices			
Educational buildings		Yes	Yes
Health buildings		Yes	Yes
Trade and wholesale		Yes	Yes
Hotels and restaurants		Yes	Yes
Other		Yes	Yes
Energy uses			
Space heating		Yes	Yes
Space cooling		Yes	Yes
Lighting		Yes	Yes
Cooking		Yes	Yes
Appliances		Yes	Yes
Energy carriers/ Technologies			
Gas	Building module	Yes	Yes
Oil	Building module	Yes	Yes
Coal	Building module	Yes	Yes
Electricity	Building module	Yes	Yes
CHP	Power module	Yes, it is received from the Power module	Yes it is implicit in district heating.
Waste heat from industry	not included	Yes, the interface is there	Yes, it is implicit in district heating.
Result coverage			
Capital expenditures	buildings	Yes,partly: renovations	Yes
CO_2 emissions for heating	Building module	Yes	Yes
CO_2 emissions for electricity	Power module	No	Yes.
CO_2 emissions for district heating	Power module	No	
Primary energy	Power module	No	No
GHG emissions	Climate module	No	Yes, partly, only CO2 emissions
Material substitution	Manufacturing module	No	

9 Annex II Additional countries' CO_2 emissions

This annex presents pathways to achieving decarbonisation of demand and heating in buildings for Croatia, France and Spain.

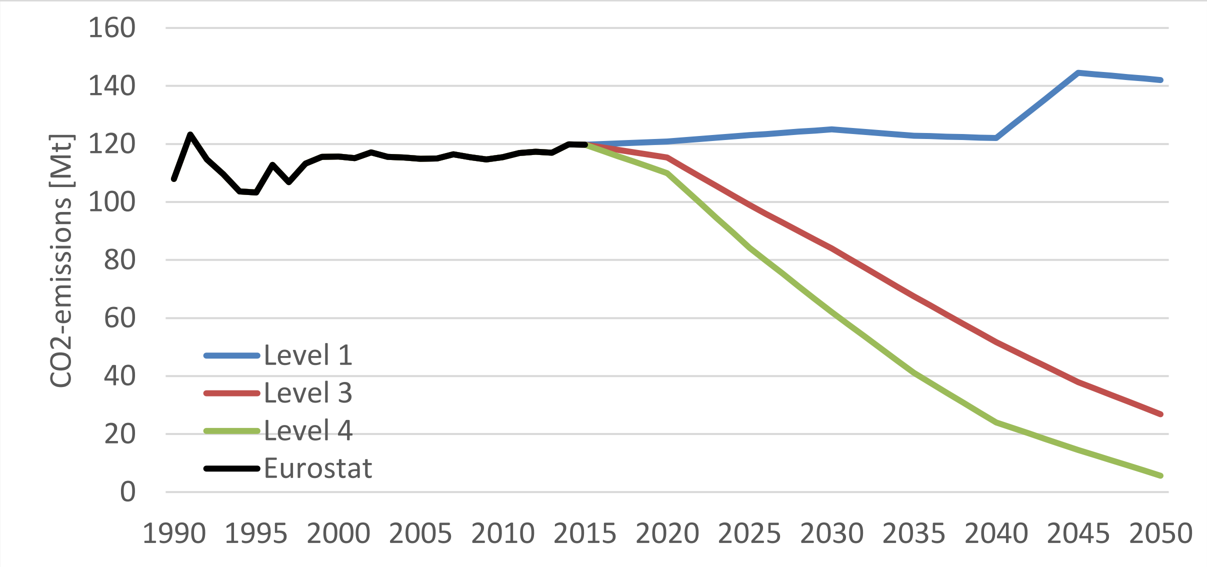
Croatia

For Croatia, the level 1 pathway would result in a increase of CO_2 emissions of 1%, whilst level 3 and 4 result in a decrease of 86% and 98%, respectively, compared to 2015.



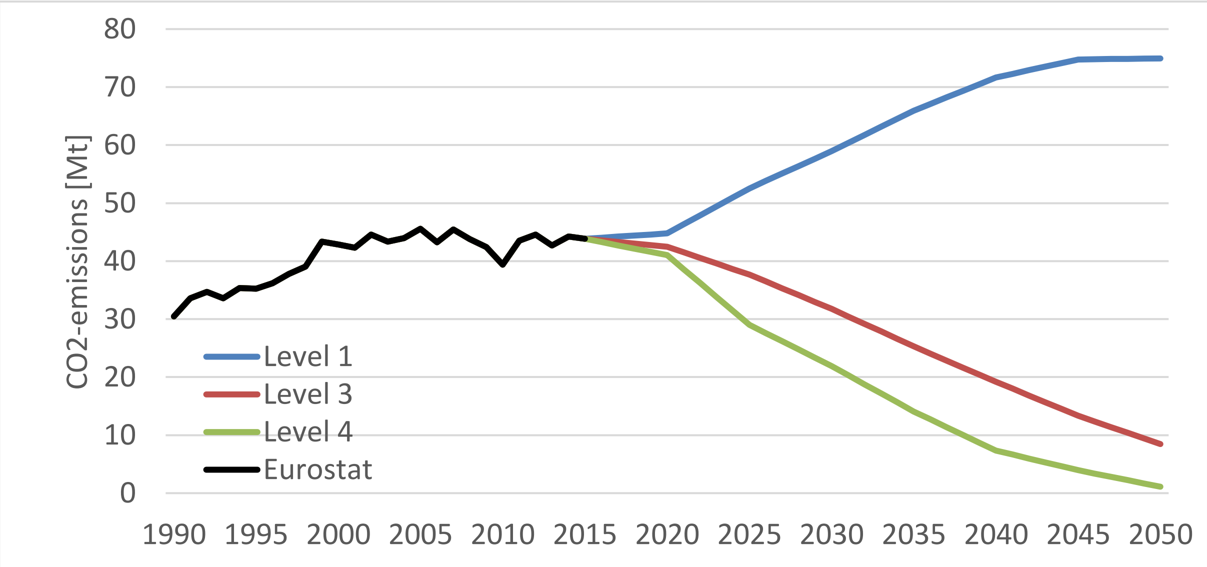
France

For France, the level 1 pathway would result in a increase of CO_2 emissions of 19%. The strong increase between 2040 and 2050 is due to an increase in electricity use for space cooling. The pathways on ambition levels 3 and 4 reduce CO_2 emissions compared to 2015 by 78% and 95%, respectively.



Spain

For Spain, the level 1 pathway would result in an increase of CO_2 emissions of 71%, compared to a decrease of 81% for level 3 and 97% for level 4 compared to 2015 emissions.



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