STUDY/IN-DEPTH ANALYSIS

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The road to energy efficiency

Policy Department for Economic, Scientific and Quality of Life Policies
Directorate-General for Internal Policies
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The road to energy efficiency

Abstract

This study provides an analysis of the gaps in EU policies aimed at increasing industrial energy efficiency, an assessment of the ability of the electricity grid to absorb large increases in renewables, and an evaluation of the energy efficiency potential of the Renovation Wave. Links to the proposed Fit for 55 package are also made for all three topics.

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LIST OF ABBREVIATIONS

ACER	Agency for the Cooperation of Energy Regulators
ADMS	Advanced Distribution Management Systems
ADMS	Association of Sustainable Process Industry through Resource and Energy Efficiency
B2B	Business-to-business
BATs	Best Available Techniques
BPIE	Building Performance Institute Europe
CAGR	Compound annual growth rate
CAPEX	Capital Expenditure
CBAM	Carbon border adjustment mechanism
CEAP	Circular Economy Action Plan
CEER	Council of European Energy Regulators
CEMBUREAU	The European Cement Association
CEPI	Confederation of European Paper Industries
CHP	Combined Heat and Power
CTP	Climate Target Plan
DEEP	De-risking Energy Efficiency Platform
DR	Demand Response
DS	Distribution System
DSM	Demand-side Management
DSO	Distribution System Operator
E.DSO	European Distribution System Operators for Smart Grids
EC	European Commission
EED	Energy Efficiency Directive
EEFIG	Energy Efficiency Financial Institutions Group
EIB	European Investment Bank
ELENA	European Local Energy Assistance
ENTSO-E	European Network of Electricity Transmission System Operators
EP	European Parliament
EPBD	Energy Performance in Buildings Directive
EPC	Energy Performance Certificates
ESCO(s)	Energy Service Companies

ETD	Energy Taxation Directive
ETS	Emissions trading system
ETS	Energy Trading System
EU	European Union
EV	Electric Vehicle
FMCG	Fast-moving consumer goods industry
GDP	Gross Domestic Product
GHG	Green House Gases
GR	Governance Regulation
H&C	Heating and Cooling
HV	High Voltage
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal rate of return
ISO	International Organization for Standardization
JTF	Just Transition Fund
LCA	Life Cycle Approach
LTRS	Long-term Renovation Strategies
LULUCF	Land Use, Land-Use Change and Forestry
LV	Low Voltage
MEPS	Minimum Energy Performance Standards
MS(s)	Member State(s)
MV	Medium Voltage
NDP	Network development plan
NECPs	National Energy Climate Plans
NRA	National Regulatory Authority
NRRPs	National Recovery and Resilience Plans
OPEX	Operational Expenditure
PCI	Project of Common Interest
PPA	Purchased power agreements
RD&I	Research, Development and Innovation
RDF	Refuse Derived Fuels
RED	Renewable Energy Directive
RES	Renewable Energy Sources

RRF	Recovery and Resilience Facility
RWS	Renovation Wave Strategy
SAIDI	System Average Interruption Duration Index
SCADA	Supervisory Control And Data Acquisition
TEN-E	Trans-European Networks for Energy
TOTEX	Total Expenditure
TRL	Technology readiness level
TS	Transmission System
TSO	Transmission System Operator
TYNDP	Ten-Year Network Development Plan
variable RES	Variable Renewable Electricity Sources
VAT	Value Added Tax
WACC	Weighted Average Cost of Capital

EXECUTIVE SUMMARY

On 14 July 2021, the European Commission proposed the first part of its "Fit for 55" package, aimed at reducing the EU2's carbon emissions by 55% by 2030 compared to 1990 levels. In view of the new European climate ambitions, the Committee on Industry, Research and Energy (ITRE) of the European Parliament (EP) asked for an independent analysis of the main obstacles and gaps for energy efficiency in industry, the implications of the 2030 targets for renewable energy on grid operators, the potential of the new renovation wave on buildings.

Obstacles for energy efficiency in industry

Past investment in energy efficiency by EU industry has resulted in a reduction of 10% of final energy demand and an increase of 20% in energy efficiency between 2000 and 2018. The rates of energy efficiency improvement in the European Union ranged from 13% (Finland) to 65% (Lithuania), with a median value of 34% across all 27 Member States (MSs)[1]. All implemented energy efficiency projects depended on three factors: the industrial sector, the thermal vs electrical energy mix, and the temperature requirements of their production processes. For example, the cement industry invested to reduce the amount of high-temperature (above 400°C) thermal energy used in its kilns, traditionally burning coal, oil, petroleum coke and natural gas, switching from wet to dry processes and nearly doubling their thermal energy efficiency from 6.8 to 3.6 GJ/tonne clinker. As energy costs account for over 40% of aluminium production costs, the aluminium industry has been investing in electric energy efficiency measures already since the 1990s, obtaining a 30% decrease in electricity use. Finally, the pulp and paper industry, whose processes generally have low temperature (below 400°C) requirements, invested in energy efficiency with a result of a 12% decrease in primary energy use and a 30% decrease in carbon emissions between 2005 and 2018.

Energy costs, combined with carbon prices under the EU ETS, drove industry managers to invest in energy efficiency improvements to reduce operational costs and maintain global economic competitiveness[2]. According to industry stakeholders we interviewed, the potential consequences of the Fit for 55 package are still being assessed by most companies. The main impacts of the package on energy-intensive industries (EIIs) include proposed changes to the EU Emissions Trading Scheme (ETS), including less free allocation, new benchmarks, lower emissions caps, and an extension to buildings and transport, which could impact fuel prices for industry; changes to the Energy Taxation Directive (ETD), sustainability criteria for biomass, and the introduction of a carbon border adjustment mechanism (CBAM). Multiple industry representatives said that without an effective CBAM, the risk of carbon leakage and investment leakage is higher.

Future efficiency gains are likely to be modest, with estimates ranging from 0.2% to 0.7% annual energy savings increases between now and 2030. In our analysis, we found the following main barriers to additional energy efficiency improvements: high uncertainty about the long-term value of energy efficiency investments, lack of awareness of the strategic value of energy efficiency projects within firms, and lack of clarity on decarbonisation pathways. We identified the following gaps in EU policy addressing these barriers: energy efficiency is not as incentivised as renewables; the ETD does not favour energy efficiency or decarbonisation; energy savings is confounded with energy efficiency;

[1] ODYSSEE; SWD(2020)176 final – Impact Assessment accompanying the document 'Stepping up Europe's 2030 climate ambition' (Climate Target Plan).

[2] Energy costs in manufacturing accounted for between 1% and 10% of production costs in the period 2010 to 2017 in the EU. However, for energy-intensive sectors such as paper, clay building material, iron and steel and cement these costs accounted for more than 10% of production costs in at least one year in that period. (European Commission, 2020, Study on energy prices, costs and their impact on industry and households. Available at: https://ec.europa.eu/energy/studies_main/final_studies/study-energy-prices-costs-and-their-impact-industry-and-households_en.

there is no EU policy incentive or obligation for firms to implement the recommendations resulting from energy audits; most firms do not have energy management systems; and lack of clarity around development of hydrogen and biomass markets. To fill these gaps, we first recommend the adoption of the proposed pricing updates in the Fit for 55 package. Adopting the pricing updates, including revisions of the ETS, the ETD and the introduction of the CBAM, would send appropriate energy and carbon price signals to industry, encouraging them to further invest in energy efficiency, while establishing precautions to ensure a level playing field.

We recommend the adoption of the proposed updates to energy audit requirements in the Energy Efficiency Directive (EED) recast, which include shifting criterion for audits and energy management systems from the type of firms to levels of energy consumption, energy management system requirements for the largest energy using companies[3], and changing the definition of an audit to include renewables. The updates also require audit results to be communicated to enterprise management; complementing this, the proposed ETS revision would require industry to implement audit findings or risk having free allocation reduced. This could be reinforced through binding decarbonisation targets; we recommend updating the EED so MSs are mandated to establish decarbonisation targets for industry. The targets should be audit (evidence)-based and sector-specific. To take the above recommendation one step further, MSs should also be required to develop long-term industrial decarbonisation plans to achieve targets. Such plans would be conceptually similar to Long-Term Renovation Strategies (LTRS) currently required of MSs for the buildings sector under the Energy Performance of Buildings Directive (EPBD).

Our other recommendations include mainstreaming accounting for the multiple benefits of energy efficiency, creating an energy audit centre for SMEs, and focusing on fuel switching to electricity and biomass in short-term EU-funded industrial energy efficiency projects.

Implications of the 2030 targets for renewable energy on grid operators

To achieve the policy ambitions of the Fit for 55 package, the share of electricity produced from variable renewable electricity sources would have to increase from 20% in 2020 to 48% in 2030, which is 7 percentage points above what MSs foresee in their National Energy and Climate Plans. To integrate these additional power sources successfully, electricity grids will have to be adapted to accommodate intermittent electricity generation.

Both the high-level scenarios of the grid operators and the Commission's scenarios show that the investment in the necessary grid adaptations would require between 50 and 60 billion EUR annually between 2020 and 2030. Although the increase of investment needed is not as significant as what is already considered by current national policies, these investments will be reflected in network tariffs for energy consumers. Rationalisation of investment is therefore highly desirable to keep energy prices affordable.

Since any grid improvement measure takes several years to implement, there is little time to make all the necessary adaptations. Grid operators are generally positive about their ability to prepare the grid for increased level of renewable electricity generation in time, although they report that project implementation is usually delayed by 14-15 months. Smaller grid operators on the distribution system

[3] Article 11 of the recast EED states that, "Member States shall ensure that enterprises with an average annual consumption higher than 100TJ of energy over the previous three years and taking all energy carriers together, implement an energy management system." It also states, "Member States shall ensure that enterprises with an average annual consumption higher than 10TJ of energy over the previous three years and taking all energy carriers together that do not implement an energy management system are subject to an energy audit."

level will wait for the implications of the Fit for 55 package on national policies to change their grid planning, which will also further delay the necessary grid adaptations.

Grid operators are so far also focusing mainly on developing new power lines or on reinforcing the capacity of existing ones. This approach is not necessarily the most cost-effective one, since many improvements can be made by focusing on the efficiency of network operation and by integrating flexibility services, active customers, energy communities and other types of innovative market actors. New demand sectors like electromobility and household heating can also be efficiently integrated, if well managed (for example by offering dynamic electricity price tariffs that influence consumer behaviour).

To overcome these issues, MSs must fully implement the existing EU electricity market design. This entails defining the role of active consumers and citizen energy communities and facilitating the use of flexibility services of improving the network planning process in order to consider all cost-saving alternatives to building new power lines. With regards to the Fit for 55 package, it is crucial that MSs adapt their national targets and policies as soon as possible to reflect the increased targets for renewable electricity production. This would give the right signals and policy certainty to grid operators to further develop their networks. Going beyond the Fit for 55 package, further changes to EU legislation could include streamlining the permitting process for network adaptations, facilitating the cooperation between Distribution System Operators (DSOs) and Transmission System Operators (TSOs) and facilitating the regulatory support for innovations in grid operation.

The potential of the new renovation wave on buildings

Barriers to moving towards a fully decarbonised EU building stock vary between MSs. These barriers include the lack of a stable long-term vision; missing financial attractiveness; low confidence in renovation investments and split incentive problem (financial dimension); skills gap and lack of data (technical dimension); lack of information or awareness, and inconvenience of renovation (social dimension).

Existing EU policies and programmes like the 2018 revised Energy Performance of Buildings Directive (EPBD), and differentiated MS policy frameworks, already address most of these barriers to some extent. Before designing and implementing new policy instruments, the accelerated and strengthened implementation of the existing EU framework should be considered as a priority, improving long-term confidence along the entire value chain from households to the construction sector to build the required capacity. To fully decarbonise the building sector, more integration is required between improving energy performance and switching to renewable and low carbon energy sources, with integrated planning and coordination between several plans. Financial and funding instruments should be mainstreamed in building decarbonisation policy, such as in Long-Term Renovation Strategies (LTRS).

To pave the way to fully decarbonise the building sector, MSs should also address the insufficient action on energy poverty, split incentives and on labour capacity building and upskilling; the lack of accessible data and monitoring; the insufficient accessibility of information; and the lack of technical assistance programmes at all levels. Last but not least, it is key to engage the relevant stakeholders, and especially local authorities, for appropriate and integrated planning.

Additional EU monitoring and guidance would support MSs in their implementation of existing EU policies. The priority should be the LTRS update, implementation and promotion of energy services to build knowledge and mobilise appropriate financial means. More integration of existing planning is needed (e.g. LTRS[4], EED National Comprehensive Assessment[5], RED II renewable potential assessment[6] and National Energy and Climate Plans), and should be emphasised under the Fit for 55 package. Current policy proposals on Energy Performance Certificates (EPCs) should be strengthened to provide useful data to building owners and occupiers. Minimum Energy Performance Standards (MEPS), a top priority, should be set up with accompanying financial measures and targeted funding, driving the ambition at EU level, while giving MSs the flexibility to design according to national contexts. Additional policy recommendations should emphasise the need for integrated local planning, ideally mandating and empowering local authorities to play a large role in building decarbonisation. Financial incentives should be mainstreamed in the planning, especially the LTRS, and long-term availability should be guaranteed (beyond the Recovery and Resilience Plans timeframe). EU funds could also address the development or strengthening of existing technical assistance tools and instruments, and the development of the required skills and knowledge at national level, via digitalisation and industrialisation. The EU should encourage MSs to integrate Lifecycle Assessment (LCA) metrics in the relevant instruments (such as EPC, MEPS, Building Renovation Passport), and to investigate circular renovation and bio-based renovation opportunities.

[4] Each Member State shall establish a long-term renovation strategy to support the renovation of the national stock of residential and non-residential buildings, both public and private, into a highly energy efficient and decarbonised building stock by 2050, facilitating the cost-effective transformation of existing buildings into nearly zero-energy buildings (under Article 2a of EPBD – Directive 2018/844 on the Energy Performance of Buildings).

[5] Member States shall carry out a comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling, the National Comprehensive Assessment (NCA) (under Article 14 of EED - Directive 2012/27 on Energy Efficiency) shall notify the Commission.

[6] Member States shall carry out an assessment of their potential of energy from renewable sources and of the use of waste heat and cold in the heating and cooling sector (under Article 15(7) of RED II - Directive 2018/2001 on renewable energy).

1. INTRODUCTION

1.1. Relevance of the Fit for 55 package

All elements of the Fit for 55 package are relevant to this study. The package's policy mix includes pricing, targets, rules, and support measures. The matrix below shows how each new policy or policy update relates to the topics at hand.

The areas of greatest relevance are:

For **industry**, proposed changes in the EU Emissions Trading System (ETS) free allocation, benchmarks, caps, fuel pricing (due to extension to buildings and transport), taxation, and sustainability criteria for biomass are all relevant to industrial decisions to invest in energy efficiency projects. If adopted, these proposals will determine the future types of industrial fuels and derived energy efficient technologies. The proposal will also heavily influence energy prices, with energy efficiency investments largely assessed based on saved energy costs. In addition, the proposed carbon border adjustment mechanism (CBAM) would help ensure a level playing field and minimise carbon leakage. This is key, because industry has less incentive to further invest in energy efficiency if EU imports were made via cheaper, more energy and carbon intensive production processes. Under the Energy Efficiency Directive (EED) update, stricter audit requirements and the inclusion of renewable energy in the definition of an audit both have important consequences for industry.

For the **integration of renewables into electricity grid**, the most relevant change is the increased renewable energy target in the revised Renewable Energy Directive (RED). As a consequence, additional renewable generation capacity has to be integrated into electricity grids, beyond what is already planned for 2030 in the National Energy and Climate Plans. Next to the RED revision, the proposed amendment of the EED introduces additional obligations on Member States (MSs) and National Regulatory Authorities to introduce the energy efficiency first principle into the network planning process. This incentivises the reduction of network losses in their regulatory frameworks and the removal of any unwanted and indirect waste energy incentive for users from network tariff design.

For **buildings**, proposed changes in the EU ETS (mainly the extension to buildings), the Energy Taxation Directive (ETD), effort sharing regulation (ESR), the Renewable Energy Directive and the EED are all relevant proposals in terms of impacting the adoption of renewable and energy efficiency solutions for renovating existing buildings. If these proposals are adopted, they will create a level playing field for renewable and energy efficiency building solutions by increasing the price of fossil fuels via a set price on emissions (via ETS), a tax basis on energy content and increased tariffs on fossil fuels (via ETD), as well as the strengthening of emissions targets (via ESR), RES (via RED), and energy savings (via EED). However, creating a level playing field for EE and RES solutions also constitutes an increase in energy prices, which can put vulnerable households at risk of energy poverty. The proposed Social Climate Fund, partially funded by the building ETS revenues, will help alleviate energy poverty aspects. The new CBAM would indirectly impact the building sector via increases in construction prices due to increase in prices of imported building materials. Additionally, the proposed changes to the LULUCF regulation could incentivise the use of wood-based building material.

Table 1: The Fit for 55 policy mix and relevance to the topics covered in this study

Mechanism	Policy/policy update	Relevance to industrial energy efficiency	Relevance to grid integration of renewables	Relevance to the building renovation wave
Pricing	Stronger emissions Trading System (ETS)	Less free allocation New benchmarks Increase in CO2 prices	None	None
	Extension of ETS to maritime, road transport and buildings	Carbon price uncertainty Fuel price uncertainty	None	Set price on emissions, increase in fuels prices
	Updated Energy Taxation Directive (ETD)	Fewer tax exemptions Less State Aid	None	Tax basis on energy content instead of volume – creates level playing field and stimulates EE/RES Increased tariffs on fossil fuels (via indexing and new tariffs based on environmental performance)
	New Carbon Border Adjustment Mechanism	Levels playing field Increases competitiveness	None	Indirect impact on construction prices due to increase price in imported building materials (e.g. cement, steel)
Targets	Updated effort sharing regulation	None	None	Strengthened emission reduction targets for buildings
	Updated land use, land use change, and forestry (LULUCF) regulation	Biomass supply and price uncertainty	None	Promote the use of wood-based construction products

Mechanism	Policy/policy update	Relevance to industrial energy efficiency	Relevance to grid integration of renewables	Relevance to the building renovation wave
	Updated Renewable Energy Directive (RED)	Power price uncertainty	New renewable energy target means increased need for additional renewable electricity generation	New RES benchmarks Higher H&C RES targets Binding RES targets in district H&C
	Updated Energy Efficiency Directive (EED)	Stricter energy audit requirements High energy savings obligations	Strengthens the role of energy efficiency first principle in network planning and tariff design	Stricter energy audit requirements High energy savings obligations for public buildings Prioritisation of vulnerable/energy poor households
Rules	Stricter CO2 performance for cars and vans	None (Automotive industry out of project scope)	None	None
	New infrastructure for alternative fuels	Fuel choice uncertainty leads to investment uncertainty	None	None
	ReFuelEU: More sustainable aviation fuels	None	None	None
	FuelEU	None	None	None
Support measures	Innovation Fund, Horizon 2020, etc.	Funding schemes for innovative renovation projects that increase energy efficiency	None	None
	Social Climate Fund	None	None	Part of building ETS revenues goes towards mitigating energy poverty

Source: Authors' own elaboration

1.2. Overview of approach

The matrix below summarises the steps we used in our analyses of each topic.

Research/Analysis activity	Industry	Grid	Buildings
Literature review	X	X	X
Expert interviews	X		X
Expert survey		X	
Document market barriers	X	X	X
Mapping of existing EU policies against barriers	X	X	X
Gap analysis	X	X	X
Case studies	X		X
Policy evaluation and recommendations	X	X	X

1.3. Barriers, gaps, and recommendations

For each topic area, we identified the key barriers and policy gaps to achieving additional energy efficiency (or in the case of the grid topic, the technical and economic challenges of renewables grid integration) and we developed policy recommendations to address the barriers. These are summarised below. Analysis leading up to our recommendations is described in detail under each topic heading in this report.

Table 2: Summary of market barriers, policy gaps and challenges, and policy recommendations

Key barriers	Policy gaps/challenges	Policy recommendations
Obstacles to energy efficiency in industry		
High uncertainty about the long-term value of energy efficiency investments; Lack of awareness of the strategic value of energy efficiency projects within firms, and; Lack of clarity on decarbonisation pathways.	Energy efficiency is not as incentivised as renewables; The current Energy Taxation Directive (ETD) does not favour energy efficiency or decarbonisation; Energy savings is confounded with energy efficiency; There is no EU policy incentive or obligation for firms to implement the recommendations resulting from energy audits; Most firms do not have energy management systems; Uncertainty around market developments for key fuels required to decarbonise, particularly hydrogen and biomass.	Adopt the proposed pricing updates in the Fit for 55 package; Expand energy audit requirements under the EED; Use energy audit results to establish binding decarbonisation targets for industry; Require MSs to develop long-term industrial decarbonisation plans; Mainstream accounting for the multiple benefits of energy efficiency; Create an energy audit centre for SMEs, and; Focus EU-funded industrial energy efficiency projects on fuel switching to electricity in short-term.
Analysis of the implications of the 2030 targets for renewable energy on grid operators: are we on track?		
DSOs will wait for the resulting changes in national policies to adapt their plans; grid adaptations will be planned with some delays, limiting the time for implementation of the planned measures before 2030; Many grid adaptation projects are facing delays in implementation. The average delay of electricity (transmission) PCI projects is 15 months; The network development planning process has seen improvements in recent years, but the regulatory framework is still not fully adapted to facilitate cost-efficient network planning. Although there are great differences in the regulatory design between MSs, the regulatory frameworks currently favour the investment into new power lines		Implement further (on the national level) the network tariff structure that facilitates functioning of energy communities and active customers; Introduce a regulatory framework that allows distribution system operators to use flexibility services; Introduce regulatory framework for DSOs that will allow them to cooperate on development of recharging points for electric vehicles. Strengthen the requirements on the consideration of alternative types of investment;

and other infrastructure assets (CAPEX based) over alternative solutions. Moreover, the regulatory frameworks do not incentivise innovative solutions for grid adaptations that could improve the efficiency of network operation for example.		Introduce or strengthen incentives for expenses reduction for the network operators; Distribution Network development plans should include long-term estimates of flexibility service needs; Introduce dynamic price contracts for consumers; Support the TEN-E regulation revision, and the RED and EED updates in Fit for 55; Facilitate regulatory support of innovation by introducing the dynamic regulation concepts.
The potential of the new renovation wave on buildings		
Lack of a stable vision Financial barriers (economic attractiveness, low income access, low investor confidence, split incentives) Technical (lack of sufficient labour, skills gap, lack of data on energy savings) Social (lack of awareness, lack of technical assistance, renovation complexity and disruptions)	Insufficient MS long-term vision and implementation Lack of integrated planning Lack of MS long-term financial planning and implementation Lack of accessible funding and instruments Insufficiently addressing energy poverty and split incentives Insufficiently addressing need for labour capacity and upskilling Lack of accessible data and monitoring Insufficient accessibility of information Lack of large-scale technical assistance programmes	Produce EU guidance on and monitoring of implementation of existing EU policies Produce EU guidance on MS LTRS updates Promote energy services Strengthen EPCs Mandatory MEPS, linked with financing Targeted funding Integrated local planning Financial incentives via LTRS Adequate long-term funding for technical assistance tools/instruments EU guidance on skills development and attract labour via digitalisation and industrialisation Encourage MS integration of LCA Encourage MS investigation into circular renovation opportunities Encourage MS investigation into bio-based renovation opportunities

Source: Authors' own elaboration.

2. OBSTACLES TO ENERGY EFFICIENCY IN INDUSTRY

Industrial energy efficiency in the EU has significantly improved over the last 20 years. Operational cost savings in response to carbon and energy prices have been the main driver of this increased efficiency. However, further improvement is stalled by many pervasive barriers. In this section, we provide a detailed background on energy efficiency in European industry, identify the main obstacles to additional efficiency gains, examine how current EU policy is addressing these obstacles, and develop recommendations for filling policy gaps. Our research is applicable to all industries, with a focus on energy intensive industry (EIIs). Additional detail is highlighted for the industries who agreed to be interviewed for this study, including cement, pulp and paper, aluminium, and consumer goods.

2.1. Background

This section contains an overview of historical energy efficiency improvements implemented by industry in the EU, the reasons these improvements were made, and an assessment of the remaining potential. We also provide background information on current digitalization and circular economy efforts.

The information is based on our review of EU policy and publications, academic and other literature on industrial energy efficiency, as well as interviews with 10 industry stakeholders. Details on the literature review and interviews can be found in the Annex.

2.1.1. Historical energy efficiency gains by industry

Historical investment by European industry in energy efficiency resulted in final energy demand declining by 10% between 2000 and 2018, while production became 20% more efficient[7]. Rates of energy efficiency improvement ranged from 13% (Finland) to 65% (Lithuania), with a median of 34% across all 27 Member States (MSs)[8], while industrial gross value added (GVA) increased by 1% per year (compound annual growth rate, or CAGR)[9]. The figure below reflects aggregate changes in energy efficiency, which includes the implementation of energy efficiency measures, but also larger scale structural shifts in industry and whole economies. For example, a share of the historical energy efficiency gains in Belgium was due to the closure of the Arcelor and Mittal steel plants[10].

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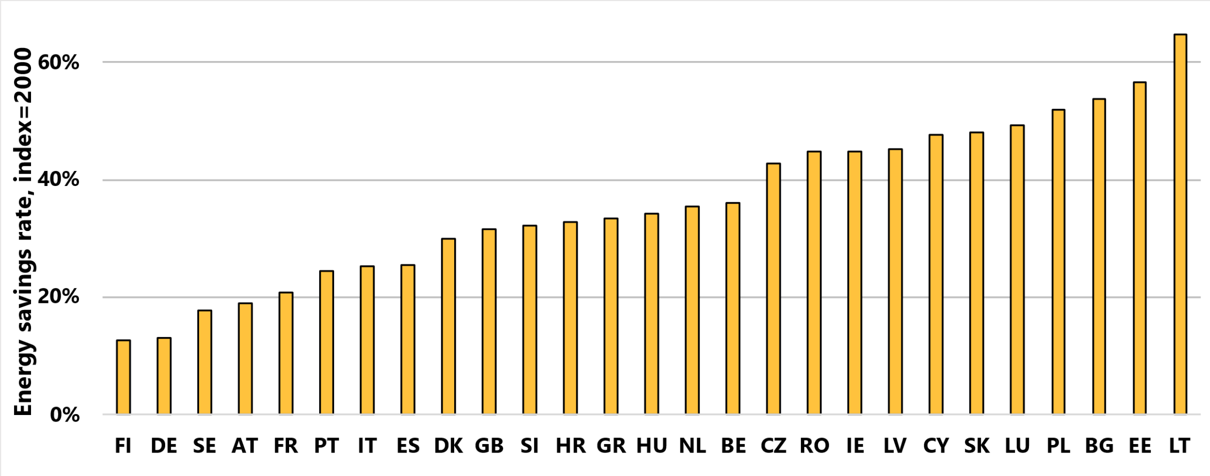
7 Measured as units of energy input per unit of industrial output. ODYSSEE; SWD(2020)176 final – Impact Assessment accompanying the document 'Stepping up Europe's 2030 climate ambition' (Climate Target Plan).

8 ODYSSEE. The Odyssee-Mure project is co-ordinated by the French Environment and Energy Management Agency (ADEME) with technical support from Enerdata and the Fraunhofer Institute, and financial support from the Horizon 2020 programme. The ODYSSEE database, which is managed by Enerdata, contains detailed energy efficiency and CO2-indicators with data on energy consumption, their drivers (activity indicatoYSSEErs) and their related CO2-emissions. See: https://www.odyssee-mure.eu/project.html.

9 Ibid.

10 The closure of these highly energy-intensive facilities led to an improvement in the energy efficiency of industry as a whole in Belgium (total production of goods industry-wide required less energy input).

Figure 1: Industrial energy savings rates in the EU MSs in 2018



Source: Authors' own elaboration of ODYSSEE data.
Note: All savings rates are expressed using 2000 as base year[11].

1. Financial criteria of historical investments

Most energy efficiency upgrades made by industry are financially conservative. This is because industry business managers consider opportunity costs before investing in efficiency; any investment made in energy efficiency is an investment not made in other areas of the business. The main metric used to assess the value of projects is simple payback[12]. The Energy Efficiency Financial Institutions Group (EEFIG) maintains a voluntary database of energy efficiency projects, the De-risking Energy Efficiency Platform (DEEP). DEEP data shows that the median simple payback of projects is less than three years[13]. Paybacks are somewhat higher for waste heat projects, which have high capital expenditure (CAPEX) requirements and require long-term commitments[14].

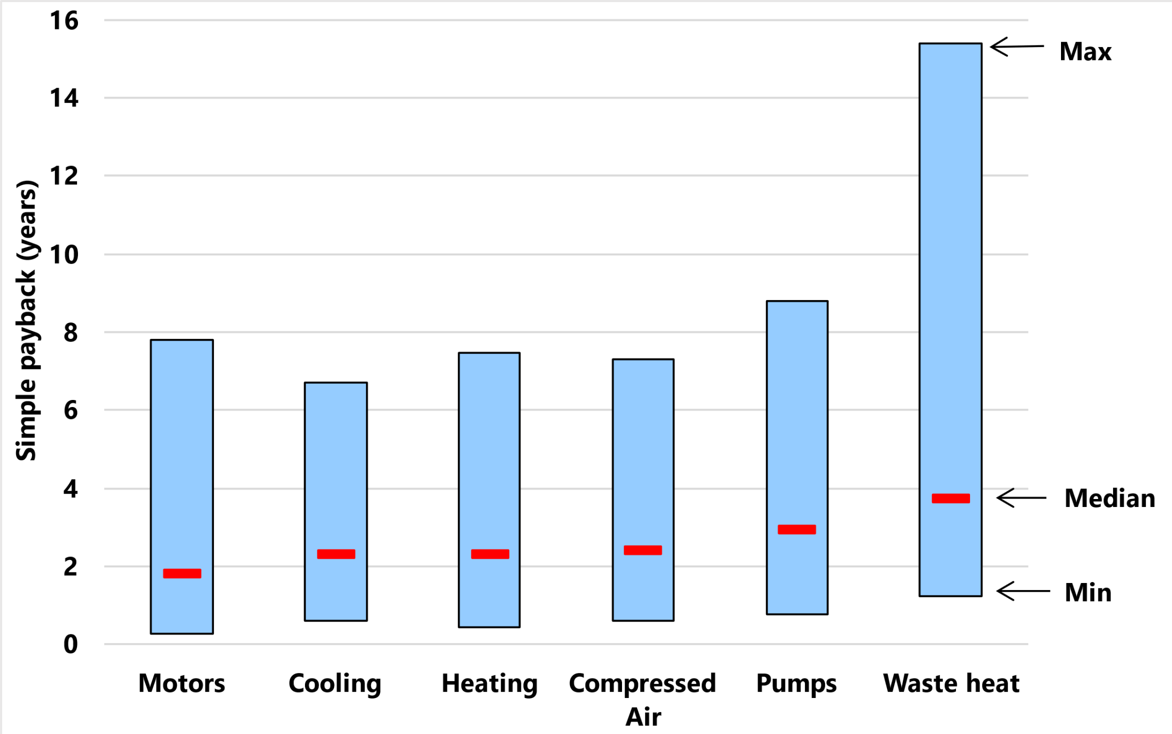
[11] The energy savings rate measures the rate of energy efficiency improvement over a period. For example, the energy savings rate for Hungary is 34%, meaning that overall, production of goods by industry in Hungary was 34% more energy efficient in 2018 than in 2000. Enerdata calculates the industrial savings rate using data from 12 industrial sectors including seven main sectors (chemicals, food (beverage and tobacco), textile (and leather), wood, machinery (and metal products), transport vehicles and other manufacturing; three energy intensive sectors (steel, cement and pulp & paper); two residual sectors (other primary metals (i.e. primary metals minus steel); non-metallic minerals (i.e. non-metallic mineral minus cement); and mining and construction.

[12] Simple payback is the number of years it takes for energy bill savings resulting from an energy efficiency project to equal the project investment cost.

[13] The data includes 2,247 projects for large industry only, which is defined as companies with 250 or more employees. No distinction is made in the database between EIIs and non-EIIs. Waste heat projects included do not involve power generation.

[14] Euroheat & Power, 2021, Recommendation Paper, from Data Centres to District Heating & Cooling: Boosting waste heat recovery to support decarbonisation. Available at: https://www.euroheat.org/wp-content/uploads/2021/05/Boosting-waste-heat-recovery-to-support-decarbonisation.pdf.

Figure 2: Simple payback of industrial energy efficiency projects in the EU



Source: EEFIG, *DEEP Platform,* 2021. Available at: https://deep.eefig.eu/viewcharts/industry/.

Industry representatives we interviewed all said cost reduction was the main driver for historical energy efficiency improvements. Carbon and energy prices motivated business managers to invest in energy efficiency to control costs and maintain competitiveness. Energy efficiency projects were sometimes implemented as part of company-wide "operational excellence" agendas, where they competed with other cost- and risk-reduction measures, including renewable energy investments, for dedicated funds.

The types of energy efficiency projects historically implemented depended on the industry and the extent to which they relied on thermal versus electrical energy. Thermal energy use, which typically relies on fossil fuels, can also be subcategorised into low and high heat requirements.

2. Investments by specific industries

Making **cement** is a high heat production process. Traditionally, cement kilns burn coal, oil, petroleum coke, and natural gas. Most European enterprises have converted their kilns from wet to dry processes[15], nearly doubling thermal energy efficiency from 6.8 GJ/tonne clinker to 3.6 GJ/tonne clinker[16], which is comparable to the efficiency of clinker production in most countries today (Figure 3). Where European cement firms have differed is in reducing carbon emissions from clinker production by switching to alternative fuels, as highlighted in the figure below. Some plants are using alternative fuels such as Refuse Derived Fuels (RDF) and tyre waste in clinker kilns to reduce carbon emissions, although such fuel switching results in a reduction in energy efficiency because RDFs have a lower calorific values than fossil fuels.

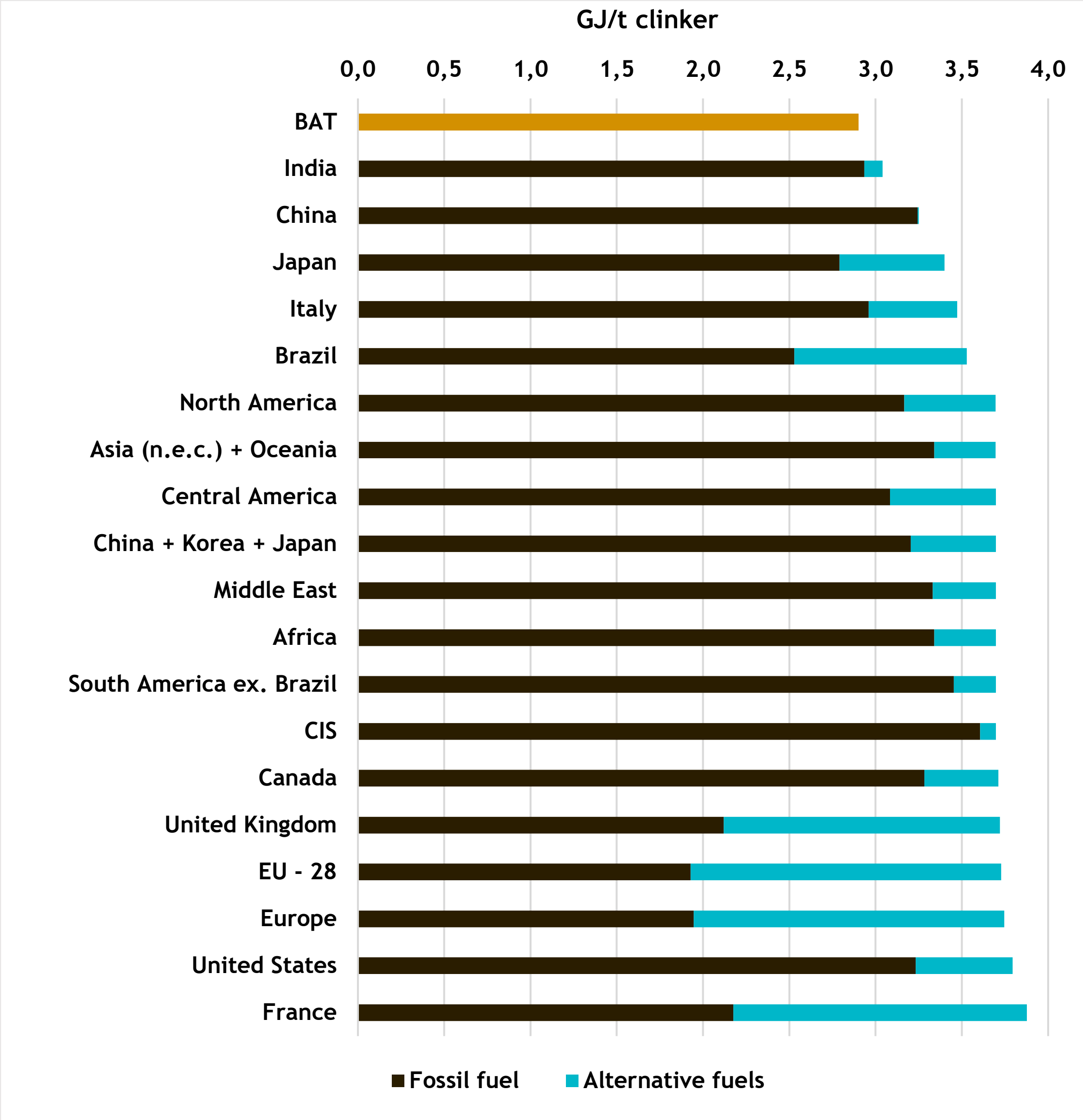
[15] See Box 1 for technical definitions of kilns.

[16] IEA, 2021, Thermal specific energy consumption per tonne of clinker in selected countries and regions. Available at: https://www.iea.org/data-and-statistics/charts/thermal-specific-energy-consumption-per-tonne-of-clinker-in-selected-countries-and-regions-2018.

Less investment has been made by European cement firms in electrical energy efficiency measures than in thermal efficiency improvements in clinker production. Cement grinding is the most electrically-intensive process in producing cement[17].

[17] International Finance Corporation, 2017, Improving thermal and electric energy efficiency at cement plants: International best practice. Available at: https://www.ifc.org/wps/wcm/connect/58ad0376-91e7-44fa-b951-f638ba61dabb/Elect_Enrgy_Effic_Cement_05+23.pdf?MOD=AJPERES&CVID=lOyTvly.

Figure 3: Global cement clinker production energy efficiency[18]



Source: Authors' own elaboration of: IEA data.
Note: BAT refers to best available technology. Asia (n.e.c.) refers to Asia ("not elsewhere counted). CIS refers to the Commonwealth of Independent States.

Energy costs account for over 40% of **aluminium** production costs[19]. European aluminium factories have been investing in electric energy efficiency measures since the 1990s, resulting in a 30% decrease in electricity use. As with cement production, making aluminium has high heat requirements, although not as high as steel. Thermal production elements have mostly been converted from rotary kilns circulating fluid bed (CFB) calciners, resulting in an efficiency improvement of 12% to 13%, and from heavy fuel to natural gas, resulting in a 38% energy efficiency improvement (a decrease from 11 GJ/tonne to 8 GJ/tonne).

[18] GJ/t clinker stands for gigajoules of energy input per tonne of clinker produced.
[19] Authors' interview with Eurometeaux.

Box 1: Glossary of industrial energy efficiency terms

- **Calorific value**: the amount of calories (energy) generated when a unit amount of substance is completely oxidised (e.g., combusting of natural gas in the presence of oxygen).
- **Cement calciners and kiln:** calciners utilise indirect heat to be used in different calcination operations to remove moisture in the production process of materials. A kiln on the other hand utilises direct heat contact between the material and the process gas to process materials.
  - Rotary kilns are used to produce clinker, which is the intermediary product used for the production of Portland Cement. There are different types of clinker kilns; namely wet kilns, semi-wet/dry kilns and dry kilns. Raw materials are first blended and then fed into the kiln, where they undergo a calcination reaction that produces clinker.
  - Wet-process kilns are fed raw material slurry with moisture content ranging between 30% and 40%. A wet-process kiln needs additional length to evaporate the water contained in the raw material feed. A third additional kiln energy is consumed in evaporating the water in the slurry.
- **Electrical energy use:** energy used by industry for production processes to power motors and other equipment
- **Energy efficiency:** defined as the ratio of energy input to useful output (e.g., GJ/tonne of product).
- **Production/Operational excellence**: persistent interest in finding ways to improve performance and profitability in the manufacturing industry. Manufacturing plants can improve their processes and procedures to realize long term sustainable growth through operational excellence
- **Prosumers**: users who both produce and consume. For instance, people producing electricity in their homes using solar panels on their roofs and using this electricity.
- **Refuse-derived fuel (RDF)**: a fuel produced from various types of waste such as municipal solid waste (MSW), industrial waste or commercial waste. It is composed of combustible components of waste that are shredded, dried and baled, then sent to industrial waste to energy facilities to be combusted to produce energy. In cement plants, they are used to partially substitute fossil fuels used in cement production (coal/petcoke), resulting in CO2 emissions reductions.
- **Thermal energy use:** energy used by industry for heating during production processes
  - **Low heat requirements:** production processes requiring temperatures lower than 400°C. Some low heat processes can be electrified.
  - **High heat requirements:** production processes requiring temperatures higher than 400°C. Many high heat processes are challenging or impossible to electrify.
- **Waste energy:** energy that is otherwise disposed of or released into the atmosphere without being fully utilised. Waste heat recovery options for instance offer reduced energy costs and CO2 emissions.

Source: Authors' own elaboration.

The **pulp and paper** sector has also invested in energy efficiency in recent decades, resulting in a 12% decrease in primary energy use and a 30% decrease in carbon emissions between 2005 and 2018. The sector has low temperature heating requirements, some of which could be electrified using electric boilers or heat pumps. But because pulp and paper plants are geographically dispersed throughout Europe, decisions about energy use, energy efficiency, and decarbonisation depend on national, regional, local circumstances, including MS support schemes and legislation, equipment age, and the existing energy infrastructure.

The situation in the **fast-moving consumer goods industry (FMCG)** is different than in energy-intensive industries. FMCG is not a "business-to-business" (B2B) sector because production is mainly driven by consumer demand, not by other industries' demand. Energy efficiency investments are generally part of company-wide operational excellence programmes that also invest in renewable energy and water efficiency measures. Most measures implemented over the last 20 years had simple paybacks of three years or less. These mainly involved soft, low-cost energy efficiency measures such as optimising operating set points, optimising[20] running plant processes and procedures, and chasing energy waste.

2.1.2. Impacts of EU policy

Energy costs combined with carbon prices under the EU ETS motivated industry managers to invest in energy efficiency improvements to reduce operational costs and maintain global economic competitiveness[21].

According to industry stakeholders we interviewed, most companies are still assessing the potential consequences of the Fit for 55 package. The main impacts of the package on EIIs include proposed changes to the ETS, including less free allocation, new benchmarks, lower emissions, caps, and an extension to buildings and transport, which could impact fuel prices for industry, changes to the Energy Taxation Directive (ETD), sustainability criteria for biomass, and the introduction of a carbon border adjustment mechanism (CBAM). Some industry representatives said that the risk of carbon leakage and investment leakage is higher without an effective CBAM.

The European Innovation Fund and the Modernisation Fund are designed to support industrial decarbonisation by de-risking investments. However, most stakeholders we interviewed reported companies in their sectors encountered significant challenges and transaction costs when applying for funds. They also reported the funds are too focused on breakthrough technology and could do more to support implementation of commercially available, but expensive, energy efficient options. This concern was raised in the context of hitting the 2030 decarbonisation targets, which are too near-term to be achieved by breakthrough technology alone.

[20] Optimisation in the context of industrial energy efficiency refers to changes in how equipment is used, with the goal of minimising the energy used to produce a good. Optimisation does not require retrofitting or upgrading equipment, though it can require changes to operational manuals and updating employee training protocols.

[21] Energy costs in manufacturing accounted for between 1% and 10% of production costs in the period 2010 to 2017 in the EU. However, for energy-intensive sectors such as paper, clay building material, iron and steel and cement these costs accounted for more than 10% of production costs in at least one year in that period. (European Commission, 2020, Study on energy prices, costs and their impact on industry and households. Available at: https://ec.europa.eu/energy/studies_main/final_studies/study-energy-prices-costs-and-their-impact-industry-and-households_en.

Box 2: The Innovation and Modernisation Funds[22,23]

The **Innovation Fund** provides financial support for the development and testing of innovative industrial technologies and large flagship projects with significant decarbonisation potential, including innovative low-carbon technologies and processes for EIIs, products, carbon capture and utilisation (CCU), construction and operation of carbon capture and storage (CCS), innovative renewable energy generation, and energy storage. It does so by sharing the financial risk with project promoters, and through technology demonstration. A potential technology needs to be well-advanced, and have a viable business model (market for application) to be eligible for Innovation Funding. The fund is paid for by EU ETS revenues and has a total budget of 20 billion Euros for the 2020-2030 period. Projects are selected based on effectiveness of greenhouse gas emissions avoidance, degree of innovation, project maturity, scalability, and cost efficiency. Innovation Fund grants will pay for up to 60% of project costs, and up to 40% of the grant is paid up front, with additional disbursements paid upon achievement of performance milestones.

The **Modernisation Fund** supports 10 lower-income EU Member States (Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, and Slovakia) in their transitions to climate neutrality by helping them modernise their energy systems. The fund supports renewable energy development, energy efficiency, energy storage, modernisation of energy networks, and just transition efforts in carbon-dependant regions. As with the Innovation Fund, the Modernisation Fund is paid for through the EU ETS (with up to 2% of ETS auction revenues), and has a budget of 14 billion Euros for the 2021-2030 period. Member States are responsible for funded operations, in close collaboration with the European Investment Bank (EIB). A MS must demonstrate the potential investments comply with the requirements of the ETS Directive, and that it has sufficient funds available in its Modernisation Fund account to obtain financing. The MS must also show its investment proposal is in line with the State Aid rules and any other applicable requirements of Union and national law, and that the investment is not receiving funding from other EU initiatives.

2.1.3. Future energy efficiency potential

In a detailed bottom-up energy efficiency potential study performed for DG ENER, ICF Consulting estimated cumulative economic energy savings levels of 3.0% to 6.5% between 2015 and 2030, depending on the sector and scenario. For example, ICF forecasted that at the low end, the pulp and paper industry could save 3% during this period, which amounts to 0.2% per year assuming that *all* measures with paybacks of two years or less are implemented (with no barriers to energy efficiency

[22] Commission, 2021, Innovation Fund. Available at: https://ec.europa.eu/clima/eu-action/innovation-fund_en.

[23] European Commission, 2021, Modernisation Fund. Available at: https://ec.europa.eu/clima/eu-action/funding-climate-action/modernisation-fund_es.

other than money). If all measures with paybacks of five years or less are implemented, potential increases by 1 percentage point to 4% over 2015 to 2030, or 0.27% per year[24].

These estimates of industrial savings potential are much more modest than what the Commission forecasts in the Climate Target Plan (CTP). In the Baseline scenario of the CTP, which assumes the current policy mix, industrial energy use declines by 11% in 2030 compared to 2015, a 0.7% decrease per year. In the MIX scenario, which includes most of the elements of the Fit for 55 policy mix, energy use drops by 15% by 2030 or by 1.0% per year[25]. However, ICF's estimates are based on lower energy and carbon prices than the CTP. Because payback is calculated based on the cost of energy, it is possible that ICF's estimates actually reflect less potential than what is realistically achievable.

Table 3: Technical and economic potential estimates of selected industrial sectors in 2030

Sector	Economic potential - low	Economic potential - high
Pulp & paper	3.0%	4.0%
Non-metallic minerals (including cement)	3.3%	3.6%
Chemical and pharmaceutical	4.0%	4.9%
Non-ferrous metals (including aluminium)	5.5%	6.0%
Food and beverage	5.0%	6.5%
Machinery	5.0%	6.5%

Source: European Commission, 2015, Study on Energy efficiency and energy savings potential in industry and on possible policy mechanisms.

Note: Base year: 2015.

3. Potential within specific sectors

According to CEMBUREAU, the maximum thermal energy efficiency potential of the **cement** sector is approximately 10%, and additional gains on the thermal side are likely to be financially unattractive[26]. This statement is difficult to verify, and energy efficiency potential varies by plant. It is likely that there is little efficiency potential in some facilities, while others could be ready for upgrades. According to the IEA, best available technology in clinker production is 2.9 GJ/tonne; European cement firms have an overall clinker production efficiency of 3.7 GJ/tonne[27], suggesting that technical efficiency potential is closer to 20%. However, as noted above, many European cement plants use alternative fuels in clinker production, which lowers carbon emissions but decreases energy efficiency. This may indicate that fuel

[24] European Commission, 2015, Study on Energy efficiency and energy savings potential in industry and on possible policy mechanisms. Available at: https://ec.europa.eu/energy/sites/default/files/documents/151201%20DG%20ENER%20Industrial%20EE%20study%20-%20final%20report_clean_stc.pdf.

[25] Authors' analysis of: European Commission, 2020, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Stepping up Europe's 2030 climate ambition (Climate Target Plan). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0562. See also "Supplementary information: data for the graphs presented in the impact assessment", available at: https://ec.europa.eu/clima/eu-action/european-green-deal/2030-climate-target-plan_en.

[26] Authors' interview with CEMBUREAU.

[27] IEA, 2021, Thermal specific energy consumption per tonne of clinker in selected countries and regions. Available at: https://www.iea.org/data-and-statistics/charts/thermal-specific-energy-consumption-per-tonne-of-clinker-in-selected-countries-and-regions-2018.

switching is occurring before energy efficiency upgrades is some cases, which would be inconsistent with the energy efficiency first principle[28].

Taking all this under consideration, realistic additional energy efficiency potential of clinker production is likely to be somewhere between 10% and 20%, assuming that firms are focused not just on energy savings but on decarbonisation. Some decarbonisation potential remains on the electric side, especially with the replacement of cement ball mills with vertical roller mills, although this technology also has its pros and cons. Vertical roller mills lower the electrical energy required for cement grinding between 35% and 70%[29], although they can result in lower cement quality (the dry cement produced is sometimes less fine)[30].

Most **aluminium** plants in Europe have converted from calciners to kilns, increasing energy efficiency by nearly 40%. There are a few examples of new aluminium plants with higher production efficiency, including Hydro's pilot facility in Karmøy, Norway, which uses an innovative technology for aluminium electrolysis lowering electrical production efficiency to less than 13 kWh/kg, which is about 15% better than the global average[31,32].

Box 3: Electrification of industry – opportunities and limits[33,34]

Electrification requires substituting fossil-fuel fired systems with electrically powered technology. Electric options also tend to be more energy efficient than combustion-based technologies. Most commercially available electric technologies, such as boilers and heat pumps, work well in industrial processes with low temperature requirements. But significant barriers remain for high temperature applications. For example, the CemZero, project, which is investigating electrification of cement production through thermal plasma, is still in the R&D phase. To meet the 2030 and 2050 decarbonisation targets, investing in other high-temperature technology may be more viable, such as biomass co-firing and low carbon cement types (e.g. Solidia and Aether cement).

Pulp and paper companies are now looking at innovative technologies for energy efficiency upgrades that will change the way paper is made, for example, by electrifying processes to remove water without

28 Under the energy efficiency first principle, energy efficiency projects should be implemented prior to energy supply projects to minimise the amount of additional supply required. For further information, see: European Commission, 2021, Annex to the Commission recommendation on energy efficiency first: from principles to practice. Guidelines and examples for its implementation in decision-making in the energy sector and beyond. Available at: https://ec.europa.eu/energy/sites/default/files/eef_guidelines_ref_tbc.pdf.

29 International Finance Corporation, 2017, Improving thermal and electric energy efficiency at cement plants: International best practice. Available at: https://www.ifc.org/wps/wcm/connect/58ad0376-91e7-44fa-b951-f638ba61dabb/Elect_Enrgy_Effic_Cement_05+23.pdf?MOD=AJPERES&CVID=lOyTvly

30 A cement ball mill is usually a horizontal cylinder that is filled with steel balls, used to grind clinker (intermediary product from the cement industry) with other additives to produce cement. While the vertical roller mill is based on the action of 2-4 grinding rollers supported on hinged arms and riding on a horizontal grinding table or bowl. In comparing the two grinding options, ball mills consume more energy than vertical roller mills, however, they are more suitable for grinding to great fineness compared to vertical roller mills, and have fewer maintenance requirements.

31 Light metal age, 2017, Hydro Inaugurates Karmøy Pilot Plant. Available at: https://www.lightmetalage.com/news/industry-news/smelting/hydro-inaugurates-karmoy-pilot-plant/.

32 Hydro, 2019, The world's most energy-efficient aluminium production technology. Available at: https://www.hydro.com/en/about-hydro/stories-by-hydro/the-worlds-most-energy-efficient-aluminium-production-technology/.

33 Silvia Madeddu et al, 2020, The CO2 reduction potential for the European industry via direct electrification of heat supply power-to-heat, Environ. Res. Lett. 15 124004. Available at: https://iopscience.iop.org/article/10.1088/1748-9326/abbd02/pdf.

34 European Cement Research Academy, 2017, CSI/ECRA-Technology Papers 2017, Development of State-of-the-Art Techniques in Cement Manufacturing: Trying to Look Ahead. Available at: http://docs.wbcsd.org/2017/06/CSI_ECRA_Technology_Papers_2017.pdf.

evaporation. The Confederation of European Paper Industries (CEPI) created the Energy Solutions Forum to accelerate this process by collaborating on technology development. CEPI is also looking at switching from oil boilers to CHP and electrifying some processes. However, sector electrification comes with limitations related to the grid and the cost of electricity. Even though electrification technology is mature, implementing these measures risks interrupting production and stranding existing assets (functioning equipment normally goes into disuse even if it still has economic value after it is replaced). Waste heat is generally underexploited and could be used to power heat pumps, or for district heating.

Additional energy efficiency investments in the fast moving consumer goods **(FMCG)** sector are generally limited to "production excellence" measures that meet certain financial and risk mitigation criteria. Industry decarbonisation plans tend to favour renewables instead of energy efficiency because it is simpler for company central procurement offices to sign a purchased power agreement than implement efficiency measures requiring plants to stop production or alter operational procedures.

2.1.4. Energy management systems

The Energy Efficiency Directive (Directive 2012/27/EU) (EED) requires large enterprises[35] to conduct energy audits every four years and encourages energy audits in SMEs. An energy audit is a comprehensive assessment of the company's energy use, including in buildings, industrial processes, and transport use. The goal is to identify cost-effective ways to save energy[36].

Annex VI of the EED establishes the minimum criteria for large companies' energy audits:

a) be based on up-to-date, measured, traceable operational data on energy consumption and load profiles (for electricity only);
b) provide a detailed review of the energy consumption profile of buildings or groups of buildings, industrial operations or installations, including transportation;
c) build, whenever possible, on life-cycle cost analysis (LCCA) instead of Simple Payback Periods (SPP) to take account of long-term savings, residual values of long-term investments and discount rates; and
d) be proportionate, and sufficiently representative to draw a reliable picture of overall energy performance and reliably identify the most significant opportunities for improvement.

For ETS-covered sectors, energy audits are required if the firm wants to receive indirect cost compensation (free allocation of ETS credits). In the Fit for 55 Package, the Commission suggests energy audits must be performed for a firm to continue receiving free allocation.

The EED also encourages companies to set up an energy management system (EMS) in line with ISO 50001 standards. Companies are exempted from the audit requirement if they have an EMS in place.

35 The current EED defines "large enterprise" based on number of employees and financial turnover. The recast EED in the proposed Fit for 55 package redefines "large" as enterprises having three-year average annual energy consumption of more than 10 TJ. Note: 1 GWh = 3.6 TJ, whereas TJ = terajoule and GWh = gigawatt hour.

36 European Commission, 2016, A Study on Energy Efficiency in Enterprises: Energy Audits and Energy Management Systems. Available at: https://ec.europa.eu/energy/sites/ener/files/documents/EED-Art8-Implementation-Study_Task12_Report_FINAL-approved.pdf.

Box 4: ISO 50001 and Energy Management Systems (EMS)[37]

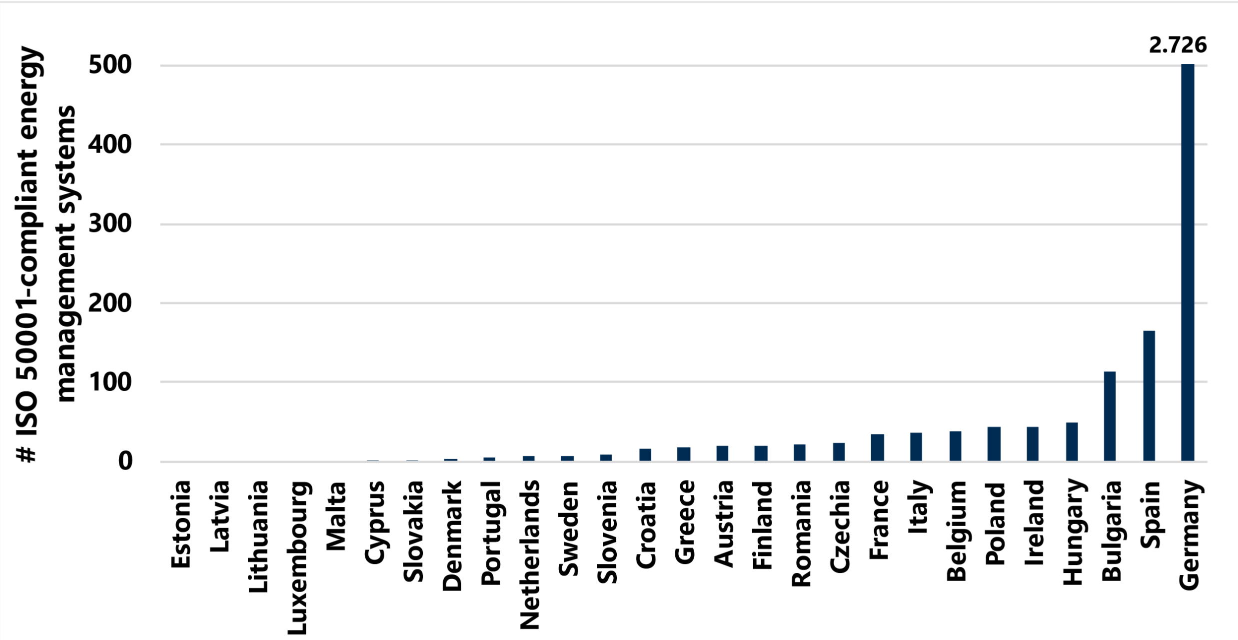
ISO 50001 and Energy Management Systems (EMS)

ISO 50001 is a voluntary standard that aims at helping organisations in the design, implementation, and maintenance of an energy management system (EMS). It provides a framework of requirements for organizations, including developing a policy for more efficient use of energy, fixing targets and objectives to meet the policy, and using data to better understand and make decisions about energy use.

An EMS is a system that helps organisations better manage their energy use and improve their productivity. It involves developing an energy policy, setting achievable targets for energy consumption and developing action plans to reach these targets. It also involves measuring the results obtained and reviewing the effectiveness of the policy, while ensuring continual improvement of the EMS.

A recent ISO survey shows that the EU has the highest number of ISO 50001 certificates in the manufacturing sector globally. Germany is the leader with a total of 2,726 in 2018[38]. The following chart shows the number of certificates in manufacturing across the EU. While Germany has the largest number, this still covers just 1.3% of the total number manufacturing enterprises in the country. EU-wide, only 0.2% of manufacturing enterprises are ISO 50001 compliant[39, 40]. There is no distinction in the ISO data between large and small, or between energy-intensive and non-energy-intensive industry.

Figure 4: Number of ISO 50001 certificates in 2018 in manufacturing, by MS



Source: Authors' own elaboration of: ISO Survey 2018 results.

37 International Organization for Standardization, 2018, ISO 50001 Energy Management Systems. Available at: https://www.iso.org/files/live/sites/isoorg/files/store/en/PUB100400.pdf.

38 ISO, 2018, Survey of certifications to management system standards - Full results. Available at: https://isotc.iso.org/livelink/livelink?func=ll&objId=18808772&objAction=browse&viewType=1.

39 Ibid.

40 Eurostat, 2021, Annual enterprise statistics for special aggregates of activities (NACE Rev. 2.). Available at: https://ec.europa.eu/eurostat/databrowser/view/sbs_na_sca_r2/default/table?lang=en.

2.1.5. Digitalisation (Industry 4.0)

Adoption of an energy management system is a precursor to industrial digitalisation. Most industry stakeholders interviewed reported that digitalisation is not pervasive and its impact on improving energy efficiency and reducing carbon emissions has not been assessed. However, most plants have strong process control and monitoring systems in place. Our impression is that digital "success stories" are not communicated within industries for competitiveness reasons, although some interviewees did provide examples of digitalisation efforts.

- In the **pulp and paper industry**, CEPI is exploring digitalisation in its Energy Solutions Forum;
- Some **aluminium** smelters are fully digitalised, resulting in optimised operations. Information was not provided on resulting energy or carbon savings, and;
- In the **FMCG** sector, digitalisation is showing some promising results, for example in sequencing of systems and machinery automation, however companies generally do not have internal competences or capacity to interpret data correctly and apply the changes recommended through digital analytics.

Box 5: Digitalisation of industry[41]

Digitalisation describes the growing application of information and communications technology (ICT) across the economy, including energy systems. Digitalisation can be thought of as the increasing interaction and convergence between the digital and physical worlds. The digital world has three fundamental elements:

- Data: digital information
- Analytics: the use of data to produce useful information and insights
- Connectivity: the exchange of data between humans, devices and machines (including machine-to-machine), through digital communications networks.

The trend towards greater digitalisation is enabled by progress in all three areas: increasing volumes of data thanks to the declining costs of sensors and data storage, rapid progress in advanced analytics and computing capabilities, and greater connectivity with faster and cheaper data transmission.

Industry has a long history of using digital technologies, originally to improve safety and increase production through automation. Additional benefits include less downtime, lower operating costs, reduced energy consumption and better product quality. The impact of digitalisation on industry can be divided into the changes that take place within a particular plant and those that have implications outside the plant. Changes within plants might include application of smart sensors and industrial advanced process control systems, and changes outside of plants might include remote-controlled operations and connected supply value chains.

2.1.6. Circular economy

The circular economy is a model of production and consumption that involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible to extend a

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[41] IEA, 2017, Digitalization and Energy. Available at: https://www.oecd-ilibrary.org/energy/digitalization-energy_9789264286276- en.

product's life cycle. In practice, it implies reducing waste to a minimum. When a product reaches the end of its life, its materials are kept within the economy wherever possible. These can be productively used again and again, thereby creating further value. This is a departure from the traditional, linear economic model, which is based on a take-make-consume-throw away pattern. This model relies on large quantities of cheap, easily accessible materials and energy[42]. In 2020, the European Commission published its Circular Economy Action Plan[43].

The adoption of circular economy methods varies across industries, depending on the nature of activities, wastes and by-products generated, energy mix, geographical location, and the available infrastructure.

In the **cement** sector, slag[44] generated from coal-fired power plants and blast furnaces in the steel industry are used to replace raw clinker material to reduce carbon emissions resulting from the calcination process.

Today, the clinker to cement ratio is around 72.5%[45]; reducing this ratio further is a challenging prospect because coal-fired power plants and blast furnaces in the steel industry which used to produce slag are both being phased out. Finding a substitute material for slag is problematic. However, it is expected that the clinker to cement ratios could decrease to 65%. The construction industry also plays an important role in the circular economy value chain of the cement industry because they are the largest consumer of cement yet re-using cement for construction can result in structural and safety issues, which are not yet resolved. There is strong potential for concrete waste recycling, although the environmental impacts of the recycling process need to be mitigated (e.g., grinding and transportation of concrete waste).

In the **pulp and paper** industry, recycled content is part of paper-making process and recycling rates are relatively high. Forest residues which are used in industry to produce energy and sludge from onsite wastewater treatment or from agricultural residues could be used more to produce energy on-site using anaerobic digestors. Replacement of fossil fuel-based products with biogenic ones (e.g., textiles, chemicals as in inputs) is becoming more common in the industry. The pulp and paper industry is also the largest industrial user of biomass in Europe, accounting for over than 60% of the sector's primary annual energy consumption. Much of the biomass used is sourced from side-streams of its production

[42] European Parliament, 2021, Circular economy: definition, importance and benefits. Available at: https://www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circular-economy-definition-importance-and-benefits.

[43] European Commission, 2020, A new Circular Economy Action Plan For a cleaner and more competitive Europe. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN.

[44] Slag is the glass-like by-product left over after a desired metal separation from its raw ore.

[45] The world average clinker/cement ratio is 0.81, with the remaining content comprising gypsum and additives such as blast furnace slag, fly ash, and natural pozzolana. As clinker production is the most energy-intensive and carbon-emitting step of the cement-making process, reductions in the clinker/cement ratio (through use of clinker substitutes) results in lower energy use and process-related CO2 emissions. One possible way to reduce energy and process emissions in cement production is to blend cements with increased proportions of alternative (non-clinker) feedstocks, such as volcanic ash, granulated blast furnace slag from iron production, or fly ash from coal-fired power generation.
Climate Technology Centre and Network, 2021, Clinker replacement. Available at: https://www.ctc-n.org/technologies/clinker-replacement.

processes[46]. Black liquor[47] gasification[48] is also one of the techniques that can be used in the pulp and paper industry to generate electricity or biofuel, where concentrated black liquor is converted into inorganic compounds and combustible fuel gas (H2 and carbon monoxide) that can be used to generate electricity. It is a promising technology to improve energy efficiency and reduce CO2 emissions in this industry, and also has a high technology readiness level (TRL=9)[49], but high CAPEX requirements (101 – 500 Euros/ton of product)[50]. The pulp and paper industry is also one of the largest electric "prosumers" in Europe because half the electricity consumed is produced on-site with high-efficiency Combined Heat and Power (CHP) cogeneration (note some CHP plants are running on bioenergy, black liquor in particular).

In the **FMCG** sector, the main focus of circular activities is on packaging and recycling polyethylene terephthalate (PET), but stronger legislation is needed to further advance recycling efforts. The food industry works to valorise food waste streams by using them as by-products or feedstock for other industries (in dairy and beer industries for example).

Recycled **aluminium** accounts for 36% of aluminium supply in Europe[51]. This reduces dependence on bauxite imports and decreases energy consumption; using recycled metal to produce the industry's main products is 95% less energy-intensive than using raw bauxite[52].

2.2. Key barriers to future energy efficiency investment by industry

Based on the literature review, interviews, and our professional judgment, we believe that **the top three barriers to further investment in energy efficiency by industry are**:

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46 European Commission, 2021, Proposal for a Council Directive restructuring the Union framework for the taxation of energy products and electricity (recast). Available at: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12227-EU-Green-Deal-Revision-of-the-Energy-Taxation-Directive_en.

47 Chemical pulping is an important part of the process of turning timber into paper. Wood chips are digested in a pulping liquor of sodium sulphide and sodium hydroxide. Once the wood fibres are separated, the remaining black liquor is concentrated and then incinerated in recovery boilers, generating steam that produces electricity.
European Commission, 2005, Integrated energy and fibre production by a sulphur-free and carbon dioxide neutral process (EFPRO). Available at: https://cordis.europa.eu/project/id/ENK5-CT-2000-00306.

48 Black liquor gasification (BLG) is a process that uses a recovery boiler and other systems to produce synthetic gas from black liquor. The gas can subsequently be converted to a variety of motor fuels such as Fisher Tropsch, methanol, and hydrogen. , Currently black liquor is simply combusted, while the future (more efficient approach) is gasification.
IEA, 2007, Black liquor gasification. Available at: https://www.ieabioenergy.com/wp-content/uploads/2013/10/Black-Liquor-Gasification-summary-and-conclusions1.pdf.

49 Technology Readiness Levels (TRL) are a type of measurement system used to assess the maturity level of a particular technology. A technology with a TRL of one is the least mature, whereas a technology with a TRL of 9 is either commercially available or at least "proven" in actual applications. The full scale is as follows: TRL 1 – basic principles observed; TRL 2 – technology concept formulated; TRL 3 – experimental proof of concept; TRL 4 – technology validated in lab; TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies); TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies); TRL 7 – system prototype demonstration in operational environment; TRL 8 – system complete and qualified; L 9 – actual system proven in operational environment.
NASA, 2012, Technology readiness level. Available at:
https://www.nasa.gov/directorates/heo/scan/engineering/technology/technology_readiness_level.
European Commission, 2015, Technology readiness level. Available at:
https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf.

50 European Commission, 2018, Impact on the Environment and the Economy of Technological Innovations for the Innovation Fund. Available at:
https://op.europa.eu/en/publication-detail/-/publication/669226c7-b6ff-11e8-99ee-01aa75ed71a1/language-en/format-PDF/source-77120765.

51 European Aluminium, 2020. Circular Aluminium Action Plan. Available at: https://www.european-aluminium.eu/media/3263/european-aluminium-circular-aluminium-action-plan.pdf.

52 Ibid.

1. High uncertainty about the long-term value of energy efficiency investments;
2. Lack of awareness of the strategic value of energy efficiency projects within firms; and
3. Lack of clarity on decarbonisation pathways.

In our opinion, the biggest issue is that industry is less confident about the long-term value of energy efficiency compared to other decarbonisation options, especially renewables. One reason for this is complexity. Investment in renewables only requires a contract, whereas investment in energy efficiency requires making changes to production processes, and its benefits are harder to quantify. Lack of awareness also contributes to this problem: there may be additional energy efficiency potential within a plant, but business managers may not be aware of it, and it is rare for companies to account for and internally communicate any non-energy benefits of energy efficiency, such as lower maintenance costs, increased workforce productivity, and reduced CO2 risks[53]. This is unfortunate because the non-energy benefits are often greater than energy cost savings.

Lack of clarity on decarbonisation pathways is also a major issue for industry, especially for high temperature processes that are hard-to-decarbonise and may require use of fuels for which there is currently no market (green hydrogen) and/or where definitions are unclear (e.g., sustainability criteria for biomass).

1. High uncertainty about the value of energy efficiency investments

Valuing energy efficiency can be a complicated process that requires accounting for a wide range of benefits and costs. There can also be high uncertainty around these values, and non-energy benefits and costs are often unaccounted for. Some of the specific issues are identified below.

Table 4: Key challenges in valuing energy efficiency benefits and costs

Benefits	Costs
Energy bill savings are realised over the long-term	High upfront capital expenditures are paid in the short-term
The long-term cost of energy is uncertain	Opportunity costs of plant energy efficiency upgrades
Incomplete accounting of non-energy benefits	Hidden costs of plant upgrades

Source: Authors' own elaboration.

Energy efficiency investments have financial benefits that can pay for years or decades, but the further out benefits accrue, the more they are discounted.[54] However, upfront investment (CAPEX) costs need to be paid immediately by firms and investors. High CAPEX makes some investments economically infeasible using standard industry criteria such as simple payback and internal rate of return (IRR). Energy efficiency projects sometimes compete and lose as part of wider corporate operational excellence initiatives, or decarbonisation strategies. In such cases, a company sets a total budget for potential decarbonisation projects that meet business criteria (payback, engineering risk, etc.), and

[53] Horizon 2020, 2021, Multiple benefits of energy efficiency. Available at: https://www.mbenefits.eu/final-conference/.

[54] In discounted cash flow analysis, a discount rate is applied to both benefits and costs. A benefit assumed to occur in the future is valued less than a benefit assumed to occur today. This is because the present value of a benefit or cost decreases exponentially over time such that the present value (PV)=Value at time t / (1+discount rate)^time t. A benefit worth €100.000 assumed to occur in one year at a discount rate of 10% is worth €100.000 / (1+0,10)^1, or €90.009 today, whereas the same benefit in 10 years is worth €100.000 / (1+0,10)^10 or €38.554 today.

project promoters internally compete for financing. Procurement for such projects is often a centralised business function, and it is easier for central departments to sign large contracts for renewable power, such as purchased power agreements (PPAs), than to implement energy efficiency projects.

Perceptions about the value of energy bill savings are further damaged by uncertainty around the cost of energy. The main concerns are about hydrogen (lack of regulation, market, and infrastructure), biomass (LULUCF rules) and insufficient biogas, and electricity system decarbonisation (it can be hard to justify industrial electrification if firms suffer indirect carbon costs).

The opportunity costs of making energy efficiency retrofits can be significant, such as stoppages in production (lost revenue) and stranded assets. Some opportunity costs can be anticipated, while others are difficult to quantify and are more hidden, such as the cost of retraining staff and updating operational, health and safety manuals, and unanticipated maintenance or supply chain issues.

Incomplete accounting of energy efficiency project benefits occurs when plant managers or business managers do not account for the multiple benefits of energy efficiency measures in making investment decisions. Resulting operational, shareholder, health, environmental, and other benefits are usually not counted. This can lead to artificially low paybacks, and a misunderstanding of the project's alignment with the company's strategic interests. Many companies are simply unaware of multiple benefits because they are focused on the energy and bill savings.

2. Lack of awareness of the strategic value of energy efficiency projects within firms

Ex-post evaluation of current EU policy found that for industry, "a key [energy efficiency] barrier is likely to be that most businesses do not have the expertise to know what technical energy saving opportunities are available, or what their economic benefits might be for the business"[55]. This finding is supported by the low penetration rate of ISO 50001 energy management systems noted above in section 2.1.4. Further, based on our research and experience, we found that cultural and communication barriers between company business managers and plant managers can lead to lost opportunities. This happens when plant managers are aware of potential energy efficiency improvements, but a cultural divide within the company inhibits communication with managers, or plant managers do not know how to "sell" projects to business management. In addition, energy plant managers often serve multiple roles within the company and are not allocated sufficient resources to find, assess, and implement energy efficiency projects.

3. Lack of clarity on decarbonisation pathways

Some firms may not invest today in commercially available technologies, let alone innovative plant upgrades, to improve energy efficiency if they do not know the fuels that technology will require in the long-run. If an industry stops operations to retrofit plants, they need to be reasonably confident they will not need to replace the equipment again in 10 or 20 years to accommodate another carrier. Many factors contribute to this barrier, not just EU policy but also MS policy, as well as global energy market developments that even the most robust forecasts cannot account for. Some factors include:

- Uncertainty around fuel costs due to the Fit for 55 energy package. For instance, expanding the ETS to buildings and transport will impact the costs of related fuels for industry. Electricity prices are expected to increase as industry, buildings, and transport all accelerate electrification, but how much prices will rise is unclear;

[55] European Commission, 2021, Proposal to amend the Energy Efficiency Directive. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/DOC/?uri=CELEX:52021PC0558&from=EN.

- Green hydrogen could plan a key role in industrial decarbonisation but there is currently no regulation, infrastructure, or market for it; it could be first be available to industrial clusters near ports (such as refineries) but is totally unclear today how long it will take to become available to all industries;
- The use of biomass as an alternative fuel to replace fossil fuels in industry is of increasing concern, since biomass definitions are still being settled, and supply may not be sufficient to meet the demands of fuel supply across all industries[56].

2.2.1. Mapping existing and proposed EU policy frameworks against barriers

All energy policy influences industry decisions to invest in energy efficiency. The fuels available on the supply side determine what types of energy efficient equipment can be installed on the demand side, and its long-term financial value. Therefore, in mapping EU policy against obstacles to energy efficiency we looked at the Energy Efficiency Directive (EED), and the Renewable Energy Directive (RED) as well as all major policies that drive energy prices. This mapping can be found in the Annex. Below, we identify the major gaps we found in current and proposed policy in tackling the barriers described above.

2.2.2. Gap analysis

<u>Gaps in addressing barrier 1</u>: High uncertainty about the long-term value of energy efficiency investments

Energy efficiency is not as incentivised as renewables. The EED does not prioritise energy efficiency investments for industry in the way the updated RED does for renewables. In the proposed RED update, industry is directed to "mainstream" renewables in specific ways, and to do so quickly by advancing the share of renewables by at least 1.1% per year through 2030 to reach a target of 50%. By contrast, the EED only has EU- and country-level savings targets and obligations. The renewables target under the RED will translate directly into the deployment of new renewable energy assets by MSs, whereas under the EED the targets need to be adapted by each MS for each sector before energy efficiency investments are triggered. Also, under Article 7 of the EED on energy savings obligations (Article 9 in the proposed revision of the directive), industry is given more flexibility: MSs are required to "assess and, if appropriate, take measures to minimise the impact of the direct and indirect costs of energy efficiency obligation schemes on the competitiveness of energy-intensive industries exposed to international competition"[57].

The current Energy Taxation Directive (ETD) does not favour energy efficiency or decarbonisation. The current ETD disincentivises energy efficiency investment for non-ETS covered industry by artificially lowering the cost of energy avoided (fossil fuel costs); new, less carbon-intensive fuels are taxed based on volume and so at rates similar to their fossil equivalent if the new fuel emerged since 2003. Many exemptions for fossil fuel taxes (de facto taxes, or "tax expenditures") also exist in the current ETD.

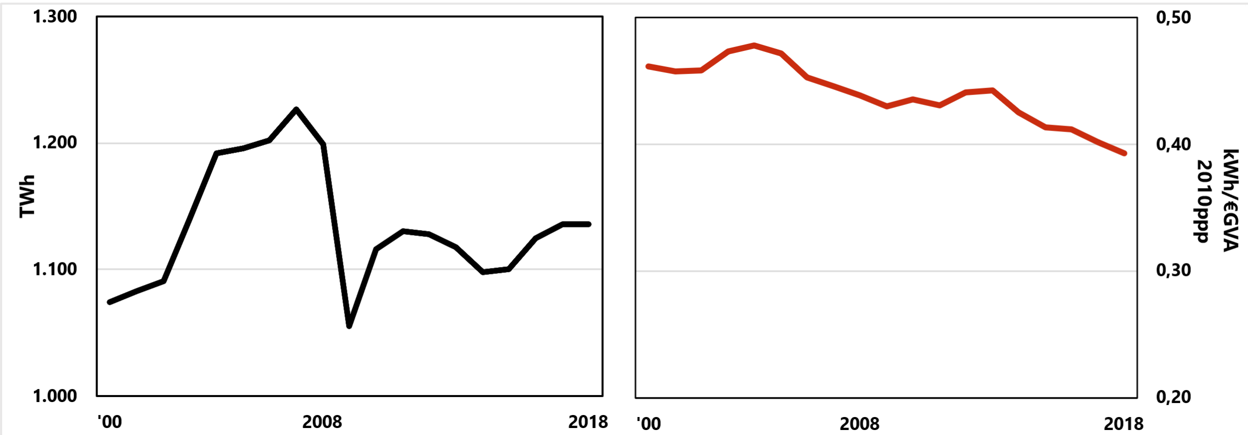
Energy savings is confounded with energy efficiency. The updated EED lifts the energy savings ambition for the EU27 from 32.5% to 40% by 2030, compared to 2007 base values. However, energy

[56] Material Economics, 2021, EU Biomass Use in a Net-Zero Economy. A course correction for EU biomass. Available at: https://www.climate-kic.org/wp-content/uploads/2021/06/MATERIAL-ECONOMICS-EU-BIOMASS-USE-IN-A-NET-ZERO-ECONOMY-ONLINE-VERSION.pdf.

[57] European Commission, 2021, Proposal to amend the Energy Efficiency Directive. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/DOC/?uri=CELEX:52021PC0558&from=EN.

savings is an unreliable indicator of energy efficiency. Total energy use by industry was higher in 2018 than in 2000, but energy intensity[58] improved by about 1% annually during this period. Using energy consumption to measure energy efficiency makes it difficult to track the results of efficiency gains because consumption is strongly tied to macroeconomic fluctuations. For example, after the 2008 financial crisis, industrial energy use fell by 12% in 2009, while energy intensity declined by 2%. The trend on the left chart of Figure 5 (below) suggests industry might have become less efficient than it was in 2000, whereas the trend on the right shows that industry became in fact more efficient, and that there must have been continuous investment in energy efficiency measures, not simply energy conservation[59]. To take another example from the proposed EED update, "*the 2020 energy efficiency [savings] target may have been achieved due to the exceptional circumstances created by the Covid-19 pandemic*"[60].

Figure 5: Industrial Total final energy consumption (left) vs. Energy intensity (right), 2000-2018



Source: Authors' own elaboration of ODYSSEE data.

<u>Gaps in addressing barrier 2</u>: Lack of awareness of the strategic value of energy efficiency projects within firms

There is no EU policy obligation for firms to implement the recommendations resulting from energy audits. Although the proposed ETS revision under Fit for 55 would reduce free allocation to firms who do not implement audit findings or make upgrades that result in equivalent carbon savings.

Most firms do not have energy management systems. Our analysis of ISO and EUROSTAT data showed that less than 1% of manufacturing enterprises in Europe have ISO 50001 energy management system (EMS) certificates. Our research also showed that most large firms do have an EMS in place. Therefore, is it likely that the remaining 99% who are uncertified are small to medium enterprises (SMEs).

<u>Gaps in addressing barrier 3</u>: Lack of clarity on decarbonisation pathways

58 Energy intensity is a metric that is normally used to illustrate energy efficiency at higher levels of abstraction, e.g., at the level of all industry, or the economy. In this case, industrial energy intensity is measured as kWh of energy use per Euro of gross value added (using 2010 purchasing power parity as the currency basis); this is denoted on the y-axis on the right hand chart above as kWh/€GVA 2010ppp.

59 The difference between energy conservation and energy efficiency is that conservation is implemented in response to short-term needs, such as the sudden loss in grid capacity after the Fukushima-Daichi reactor meltdown in 2011 and can be easily reversed. On the other hand, energy efficiency projects require installation of equipment or structural changes to plants, operations lasting for years or decades, which cannot be easily reversed. To make the business case for energy efficiency investments, plant managers need direction on the right metrics; focusing on energy savings instead of intensity sends the wrong message and decreases the incentive to install measures that result in long-term energy efficiency improvements.

60 European Commission, 2021, Proposal to amend the Energy Efficiency Directive. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/DOC/?uri=CELEX:52021PC0558&from=EN.

The main issue is that to achieve decarbonisation targets, industry must start making energy efficiency and renewable energy investment decisions now, yet these decisions are complicated by uncertainty about future market developments. While no one solution exists for industry, or even for every plant owned by a particular company because infrastructure and policy considerably vary by MS, region and sometimes even by local circumstances, in general this issue is of greatest concern for hard-to-decarbonise thermal processes where electrification is not technically feasible, but where hydrogen and biomass appear to be the most viable alternatives:

- **Hydrogen** is poised to play an important role in the EU energy transition for hard-to-decarbonise sectors, as indicated by the EU Hydrogen Strategy, the impact assessment for the 2030 Climate Target Plan, and the Long-term Strategy. But today, "There is no green hydrogen market…and basically no valuation of the lower GHG emissions that green hydrogen can deliver. Hydrogen is not even counted in official energy statistics of total final energy consumption, and there are no internationally recognised ways of differentiating green from grey hydrogen" [61].
  - To facilitate the large-scale development of the hydrogen sector adequate policies will be necessary to enable the deployment of hydrogen production, trade, supply, transmission/distribution, storage, importation, as well as of end-use equipment and appliances at the pace required for the energy transition.
  - EU regulation of hydrogen will need to consider a complex array of criteria, including but not limited to:
    - Energy system costs ;
    - Security of supply;
    - Network tariffs level;
    - End-user adaptation costs;
    - Interoperability of interconnected hydrogen systems / deployment of hydrogen end-use equipment/appliances;
    - Level of support for system flexibility / renewable electricity;
    - Allowance of repurposing of methane infrastructure when efficient;
    - Planning and use of hydrogen cross-border infrastructure;
    - Consumption by transport and large-scale industry, and ;
    - Development of large scale storage[62].
- With regards to **biomass**:
  - Biomass sustainability criteria are currently being revised, so uncertainty may remain until a new RED has been adopted;
  - MSs are currently implementing already agreed sustainability criteria (REDII), and they keep the discretion to put in place additional sustainability criteria as they see fit (e.g., thermal efficiency thresholds, limits to feedstocks, etc.). This may provide further uncertainty;
  - The proposed ETS revision would exclude from the ETS installations that are fueled by 95% or more biomass[63], which could impact industry decarbonisation pathways;

[61] IRENA, 2020, Green hydrogen: A guide to policymaking. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Nov/IRENA_Green_hydrogen_policy_2020.pdf.

[62] Trionomics' analysis for DG ENER (forthcoming report on hydrogen regulation).

[63] European Commission, 2021, Proposal for a Directive of the European Parliament and of the Council: amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757. Available at: https://eur-lex.europa.eu/legal content/EN/TXT/?uri=CELEX%3A52021PC055.

- Additionally, the LULUCF Regulation may increase ambition. This poses uncertainties about domestic biomass supplies, as MSs and practitioners might increasingly adapt their management practices to keep more carbon stored in land/forests[64].

While passage of the final Fit for 55 package should provide a clearer line of sight for industry, many of the possible updates will take time to implement (e.g., gradual introduction of the CBAM, as currently proposed), and decarbonisation solutions will vary considerably by country, industry, and plant; this will require extensive dialogue between industry, MS policymakers, and the EU to agree on the best individual paths forward.

2.3. Policy recommendations

Based on our assessment of the gaps in policy, we recommend the following actions are taken up at EU level to increase uptake of energy efficiency measures by industry:

1. Adopt the proposed pricing updates in the Fit for 55 package;
2. Expand energy audit requirements under the EED;
3. Use energy audit results to establish soft energy efficiency targets for industry;
4. Require MSs to develop long-term industrial decarbonisation plans;
5. Mainstream accounting for the multiple benefits of energy efficiency;
6. Create an energy audit centre for SMEs, and;
7. Prioritise fuel switching to electricity in short-term EU-funded industrial energy efficiency projects.

Our recommendations do not comment on digitalisation or circular methods. Both are important trends in decarbonisation but focusing on them as a means to further improve energy efficiency of industry distracts from the key barriers identified in our research. We find that there are fundamental issues in how energy efficiency is regulated and valued that need to be addressed. Having appropriate and clear energy and carbon price signals is a precursor to adopting energy efficient technologies with the most cost-effective decarbonisation potential. Underperformance and underutilisation of energy audits and audit results means there is unidentified energy efficiency potential, and that identified potential is often not realised by firms.

Our recommendations are designed to address industrial energy efficiency in the context of decarbonisation. This is necessary because energy efficiency policies should align with the framework and goals of the Fit for 55 package. It also reflects how most industry seems to value energy efficiency, which is part of a larger decarbonisation agenda.

1. Adopt the proposed pricing updates in the Fit for 55 package

Adopting the pricing updates, including revisions of the ETS, the Energy Taxation Directive (ETD), and the introduction of the CBAM would send appropriate energy and carbon price signals to industry, incentivising them to further invest in energy efficiency, while establishing precautions to ensure a level playing field.

[64] Authors' analysis based on Trinomics' involvement in the RED II impact assessment.

To help industry to accurately assess the value of energy efficiency projects, greater clarity is needed around energy and carbon prices. History shows industry is responsive to the ETS.[65] Under the proposed ETS revision in the Fit for 55 package the number carbon credits and free allocation would both decrease, resulting in higher carbon and energy prices for industry. The proposed ETS revision would also require non-SMEs to follow up on the results of energy audits, "free allocation is made conditional on decarbonisation efforts in order to incentivise the uptake of low-carbon technologies. Installations covered by the obligation to conduct an energy audit under the current Article 8(4) of the Energy Efficiency Directive ('EED') will be required to implement recommendations of the audit report, or to demonstrate the implementation of other measures which lead to greenhouse gas emission reductions equivalent to those recommended by the audit report. Otherwise, they would see their free allocation reduced."[66] Note that under the current EED SMEs are not subject to the audit requirement, and non-SMEs with energy management systems in place are exempted from the audit requirement[67].

The proposed pricing and rule changes should motivate firms to further decarbonise but would also increase the risk of carbon and investment leakage. These risks can be minimised with a carbon border adjustment mechanism (CBAM) if the mechanism is "watertight". A watertight CBAM would ensure the cost of industrial products imported to Europe account for the cost of carbon used to produce it; ideally, the CBAM will safeguard the competitiveness of European industry against imported products[68]. As proposed, the CBAM would gradually be phased in and tested during a transition period during which free allocation would also gradually be reduced[69].

The proposed revisions to the ETD would remove unfair advantages for fossil fuels and should be adopted. In the updated ETD, energy taxation based on the energy content of energy products and electricity and their environmental performance, and for fossil fuel, tax exemptions, are phased out.

2. Expand energy audit requirements under the EED

We recommend the adoption of the proposed updates to energy audit requirements in the EED recast. In the updated EED under the proposed Fit for 55 package, the Commission states: "[The EED] was also key to promoting the use of energy audits across the Union (Article 8). However, important limitations remain such as follow up to audits and challenges related to application of the [small to medium enterprises] SMEs definition, lack of requirements and incentives for implementing energy management systems." To address these issues, the Commission proposed updates to Article 11 of the EED, "Article 11 shifts the criterion for energy audits and energy management systems from the type of enterprises to the levels of energy consumption[70] and requires a sign off of the audit

65 European Commission, 2018, Communication A Clean Planet for all – A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy. Available at: https://ec.europa.eu/energy/sites/ener/files/documents/european_commission_-_a_european_strategic_long_term_vision_for_a_prosperous_modern_competitive_and_climate_neutral_economy.pdf.

66 European Commission, 2021, Proposal for a Directive of the European Parliament and of the Council: amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757. Available at: https://eur-lex.europa.eu/legal content/EN/TXT/?uri=CELEX%3A52021PC055.

67 Ibid. Under the proposed EED revision, the audit requirement is based on energy consumption, not on whether an enterprise is an SME, or a non-SME. The current EED defines "large enterprise" based on number of employees and financial turnover. The recast EED in the proposed Fit for 55 package redefines "large" as enterprises having three-year average annual energy consumption of more than 10 TJ. Note: 1 GWh = 3.6 TJ, whereas TJ = terajoule and GWh = gigawatt hour.

68 If the price of energy is increasing due to the ETS then a CBAM could be seen as leveling the playing field. But implementing a CBAM alone could be seen as protectionism.

69 Ibid.

70 Article 11 is updated to require enterprises with three-year average annual energy use of more than 100 TJ to have an energy management system (e.g., ISO 50001 or similar) in place, and for enterprises with three-year average annual energy use of more than 10 TJ to undergo energy audits.

recommendations by the management of the company. It also requires energy management systems for the largest energy using companies, which are likely to be more effective at ensuring that more cost saving energy saving investments will be made while probably having a lower overall cost burden on the company".

The recast EED also changes the definition of an audit to include renewables. "Energy audit" means a systematic procedure with the purpose of obtaining adequate knowledge of the energy consumption profile of a building or group of buildings, an industrial or commercial operation or installation or a private or public service, identifying and quantifying opportunities for cost-effective energy savings, *identifying the potential for cost-effective use or production of renewable energy* [emphasis added] and reporting the findings". This is a significant and important change in definition because it will facilitate a more comprehensive approach by industry in selecting their decarbonisation pathways.

3. Use energy audit results to establish binding decarbonisation targets for industry

The proposed EED recast would strengthen and expand energy audit requirements for industry; it also requires audit results to be communicated to enterprise management. Further, the proposed ETS revision would require non-SMEs to make energy efficiency upgrades, or implement equivalent decarbonisation projects based on audit findings, or risk having free allocation reduced[71].

This requirement could be reinforced through binding decarbonisation targets. The idea would be for industry to use the results of audits to develop detailed, bottom-up decarbonisation roadmaps that include both energy efficiency and renewable investments. Audit results could be aggregated to the sector level and used to set sector-specific binding or indicative decarbonisation targets. Using audit results to set targets would ensure they are realistic and achievable, as opposed to "top-down" targets, which sometimes have no quantitative basis.

Individual firms could then decide on mixes of energy efficiency upgrades and renewable energy investments in a flexible way that makes sense for each plant and for their overall business.

Soft targets do not impose requirements on companies or sectors but should result in commitments that drive implementation. Soft targets are sometimes used to drive environmental and climate policy because they motivate companies to make changes without the threat of penalty. For example, a soft energy efficiency target under the EED would require audited firms to establish targets, and set basic rules to ensure compliance, such as clear milestones and target years.

Hard targets would require setting mandatory decarbonisation improvement goals. A hard target would require the EED to specify how the target would be measured, including exemptions and flexibilities, milestones, and penalties for missing milestones or targets.

Given the overall focus of the Fit for 55 package on decarbonisation, and the wide range of industrial decarbonisation pathways, **we recommend updating the EED so MSs are mandated to establish soft decarbonisation targets for industry**. The targets should be audit (evidence)-based and sector-specific.

[71] European Commission, 2021, Proposal for a Directive of the European Parliament and of the Council: amending Directive 2003/87/EC establishing a system for greenhouse gas emission allowance trading within the Union, Decision (EU) 2015/1814 concerning the establishment and operation of a market stability reserve for the Union greenhouse gas emission trading scheme and Regulation (EU) 2015/757. Available at: https://eur-lex.europa.eu/legal content/EN/TXT/?uri=CELEX%3A52021PC055.

To ensure effective implementation of audit findings, soft target schemes should adopt the following best practices:

- Decarbonisation targets must reflect pathways for industry that are more ambitious than "business-as-usual";
- The targets should mirror industrial decarbonisation goals set forth in European policy;
- Targets should be clearly quantified and include milestones (e.g., for 2030, 2040, and 2050);
- Energy efficiency metrics tracked should include both energy savings and measures of energy efficiency (e.g., GJ/tonne);
- Results need to be independently verified by third parties unaffiliated with industrial firms;
- A transparent public reporting procedure on progress towards decarbonisation should be established, and;
- A platform should be developed for information sharing and awareness raising of lessons learned[72].

This recommendation is supported by the recast EED, which states in 2012/27/EU recital 24, "A specific European standard on energy audits is currently under development. Energy audits may be carried out on a stand-alone basis or be part of a broader environmental management system [emphasis added] or an energy performance contract."

4. To take the above recommendation one step further, **MSs should be required to develop long-term industrial decarbonisation plans** to achieve targets. Such plans would be conceptually similar to Long-Term Renovation Strategies (LTRS) currently required of MSs for the buildings sector under the Energy Performance of Buildings Directive[73]. The plans should include:

- An overview of industrial economic activity, energy use, energy efficiency, and carbon emissions;
- Policies and actions to stimulate cost-effective decarbonisation;
- Policies and actions to target the most carbon-intensive industries and plants;
- An overview of national initiatives to promote awareness within industry of energy efficiency, renewable energy, digitalisation, and the circular economy;
- Measures and measurable progress indicators;
- Indicative milestones for 2030, 2040 and 2050, and;
- An estimate of expected energy and carbon savings and wider benefits, as well as the contribution to the Union's decarbonisation targets.

5. Mainstream accounting for the multiple benefits of energy efficiency

Installing innovative technology will help decarbonise industry, but only if business managers are convinced of the benefits. Many projects involving commercially available technologies and practices are not implemented because decision makers are unaware of them, or energy managers are not versed on all the benefits or how to quantify them. Innovation programmes tend to focus on hardware, not communication.

[72] Ibid.

[73] European Commission, 2021, Long-term renovation strategies. Available at: https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/long-term-renovation-strategies_en.

One of the reasons for the climate crisis is that people who were not directly affected by climate change did not yet feel its impacts. The success to date of the coal phase-out in Europe is partly attributed to campaigns that focused on the direct health impact of coal, not the climate impacts[74]. The same problem exists with industry's view of energy efficiency investments: saving money on energy bills is not enough, the business case needs to be expanded for it to be compelling. The M-benefits project under Horizon 2020[75] has proven this point: monetising non-energy benefits can make a big difference in business managers' decisions to go ahead with energy efficiency investment. Benefits such as reduced downtime of machines, reduced maintenance costs, reduced CO2 costs, and simplified health and safety procedures (for example reduction of monitoring sampling activities) are normally not accounted for or communicated. The M-benefits project has documented 60 non-energy benefits of energy efficiency, 40 of which are quantified. However, accounting for all benefits is not enough, the investments also need to be presented in the right way, and typically energy efficiency projects are presented as "single issue" problems rather than in their strategic context.

Mainstreaming could be accomplished by expanding or building upon the work of the M-benefits project, which is now ending. The project conducts industry trainings on the strategic value of energy efficiency at three company levels: top management, operational (middle and front line management) and energy management. The training includes information on organisational strategies to support better decision making on energy efficiency projects, and on an analytical process (company analysis, energy and operational analysis, value-cost-risk analysis, and communication of results), including the use of an excel tool to document the analysis. Fifteen successful pilot projects were performed with companies of varying size and complexity. Conducting more pilots and widely communicating the impacts will help transform company culture and bridge organisational barriers to energy efficiency. Ideally, multiple benefits would be accounted for in mandatory energy audits under the EED.

6. Create an energy audit centre for SMEs

The EED recast requires energy audits for enterprises who annually consume over 10 TJ of energy, and to have an EMS in place for enterprises with more than 100 TJ in annual use. However, 99% of manufacturing firms in Europe do not have an EMS. To help bridge this knowledge gap, energy audit centres (EACs) should be created in Europe to provide free or highly subsidized energy audits to SMEs. Centres could be based in universities, with a central database for collecting and communicating audit results. A similar programme administered by the United States Department of Energy (US DOE) has conducted almost 20,000 energy audits of SMEs since 1987, resulting in about 150,000 recommendations[76].

7. Prioritise EU-funded industrial energy efficiency projects focused on fuel switching to electricity in short-term

Some of the above recommendations involve leveraging energy audits to improve energy policy and increase industrial energy efficiency. Audit results can also be used to better focus EU support programmes. Some projects could be implemented with commercially available technologies but they require additional funding to make them cost-effective for companies. These projects are often plant-specific. Audits will also show where innovation is most needed within sectors.

74 Europe Beyond Coal, 2021, Overview: National coal phase out announcements in Europe. Available at: https://beyond-coal.eu/?s=Overview-of-national-coal-phase

75 Horizon 2020, 2021, Multiple benefits of Energy Efficiency. Available at: https://www.mbenefits.eu.

76 U.S. Department of Energy, 2021, Industrial Assessment Centers (IACs). Available at: https://www.energy.gov/eere/amo/industrial-assessment-centers-iacs.

It is therefore difficult for us to make specific recommendations about where EU funds should focus their efforts without reviewing audit results.

Nonetheless, we provide some general recommendations below on where the EU could focus its efforts to fund energy efficiency in industry (via the Innovation and Modernisation Funds for example). The recommendations are distinguished by short- and long-term needs, or what could best help industry meet 2030 decarbonisation milestones versus what breakthrough research should be strengthened to support full decarbonisation by 2050.

Options for deployment by 2030

For industry to meet a carbon emissions reduction target of 60% by 2030, decarbonisation pathways need to be based on technologies that are commercially available or are close to commercialisation. Electricity is a more energy efficient fuel than fossil fuels and biomass, and many low temperature (up to 400°C) thermal industrial processes could be electrified before 2030. These include options for drying, evaporation, distillation, and activation, as well as for washing, rinsing, and food preparation (up to 100°C). Energy use by these applications accounts for a third of total energy consumption by industry, and most of this is fossil fuel driven [77]. Electric alternatives include heat pumps (up to 25% substitution), boilers, heaters, and mechanical vapour recompression (MVR) equipment. These technologies are already available at some scale[78,79,80,81].

The financial attractiveness of these electric applications heavily depends on comparative fuel prices. If electricity prices are significantly higher than fossil fuels, then industry has little incentive to electrify. This links to our first policy recommendation to adopt the proposed Fit for 55 pricing updates, which should disincentivise fossil use and encourage electricity use. Nonetheless, it would be very helpful for industry business managers to see more demonstration of low temperature electrification, including financial results.

Medium- to long-term options

Biomass could be used in the mid- to long-term as a fossil fuel substitute for industrial processes; biomass boilers and combustion of biomass are widely available and applicable today; the uncertainty around the use of biomass has more to do with LULUCF and other regulation. Solid biomass boilers are one option for certain low temperature (e.g., in vehicles manufacturing) and steam processes (e.g., in the food and drink, chemicals, and paper sectors). Solid biomass and waste combustion could be used for processes with high temperature requirements in the cement, glass, ceramics, and other non-metallic minerals sectors sector (up to 80% substitutes). Key challenges with biomass are the high level of uncertainty around scale and cost of sustainable supply, and that industrial fuel-switching applications compete with domestic heating and CHP, and potentially with production of green gas[82].

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77 McKinsey and Company, 2020, Plugging in: What electrification can do for industry. Available at: https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/plugging-in-what-electrification-can-do-for-industry.

78 MVR is an energy recovery process that can be used to recycle waste heat to improve efficiency.

79 McKinsey and Company, 2020, Plugging in: What electrification can do for industry. Available at: https://www.mckinsey.com/industries/electric-power-and-natural-gas/our-insights/plugging-in-what-electrification-can-do-for-industry.

80 Institute for European Studies, 2018, Industrial Value Chain A Bridge Towards a Carbon Neutral Europe. Available at: https://www.ies.be/files/Industrial_Value_Chain_25sept.pdf.

81 Jacobs, 2018, Industrial Fuel Switching Market Engagement Study. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/824592/industrial-fuel-switching.pdf.

82 Ibid.

Hydrogen could be a potential fuel substitute for many applications because of the relative similarity between hydrogen and natural gas, especially direct high temperature heating, where biomass and electricity are unlikely to work. However, the ability of industry to use hydrogen is unclear today due to the lack of infrastructure and fuel cost uncertainty. Further hydrogen boilers and burners are not yet widely available at scale. Another concern is that while the use of green hydrogen could contribute to decarbonisation, it requires large amounts of electricity to produce. From a primary fuel standpoint, it may be less energy efficient than other fuels[83].

For the ETS-covered industries we interviewed, below are some examples of technologies whose readiness levels are currently low to medium, but have high energy efficiency and/or decarbonisation potential:

Cement: Research and development is needed on new binders to reduce carbon emissions from the calcination process; these also lower process temperatures, thus demanding less thermal energy. New types of cement are currently being piloted but mostly at lower technology readiness levels. These include very low carbon cements such as Celitement (-50% carbon reduction potential), which is produced at low temperature (around 200 °C), and low carbon cement (-30% carbon reduction potential) such as Aether, which is produced at lower temperatures than to ordinary Portland cement (normally at 1300 °C)[84].

Pulp and paper: Enzymatic pre-treatment technology involves pre-treatment of wood chips using enzymes, which reduce the mechanical energy needed for wood processing thus leading to improved energy efficiency and electricity savings (expected be to between 10% to 40% depending on the type of enzyme and process design)[85].

Aluminium: Inert anodes combined with wetted drained cathodes, known as the "Elysis process", in the aluminium industry could substantially improve energy efficiency of the sector. The combination of both inert anodes with wettable cathodes reduces the energy requirements of the electrolysis process and anode manufacturing process, and also results in significant carbon emissions reductions[86].

[83] Green hydrogen incurs significant energy losses at each stage of the value chain. About 30-35% of the energy used to produce hydrogen through electrolysis is lost. In addition, the conversion of hydrogen to other carriers (such as ammonia) can result in 13-25% energy loss, and transporting hydrogen requires additional energy inputs, which are typically equivalent to 10-12% of the energy of the hydrogen itself. Using hydrogen in fuel cells can lead to an additional 40–50% energy loss. The total energy loss will depend on the final use of hydrogen.
IRENA, 2020, Green hydrogen: A guide to policymaking.
Available at:
https://www.irena.org/publications/2020/Nov/Green-hydrogen

[84] European Commission, 2018, Impact on the Environment and the Economy of Technological Innovations for the Innovation Fund. Available at: https://op.europa.eu/en/publication-detail/-/publication/669226c7-b6ff-11e8-99ee-01aa75ed71a1/language-en/format-PDF/source-77120765.

[85] Ibid.

[86] Ibid.

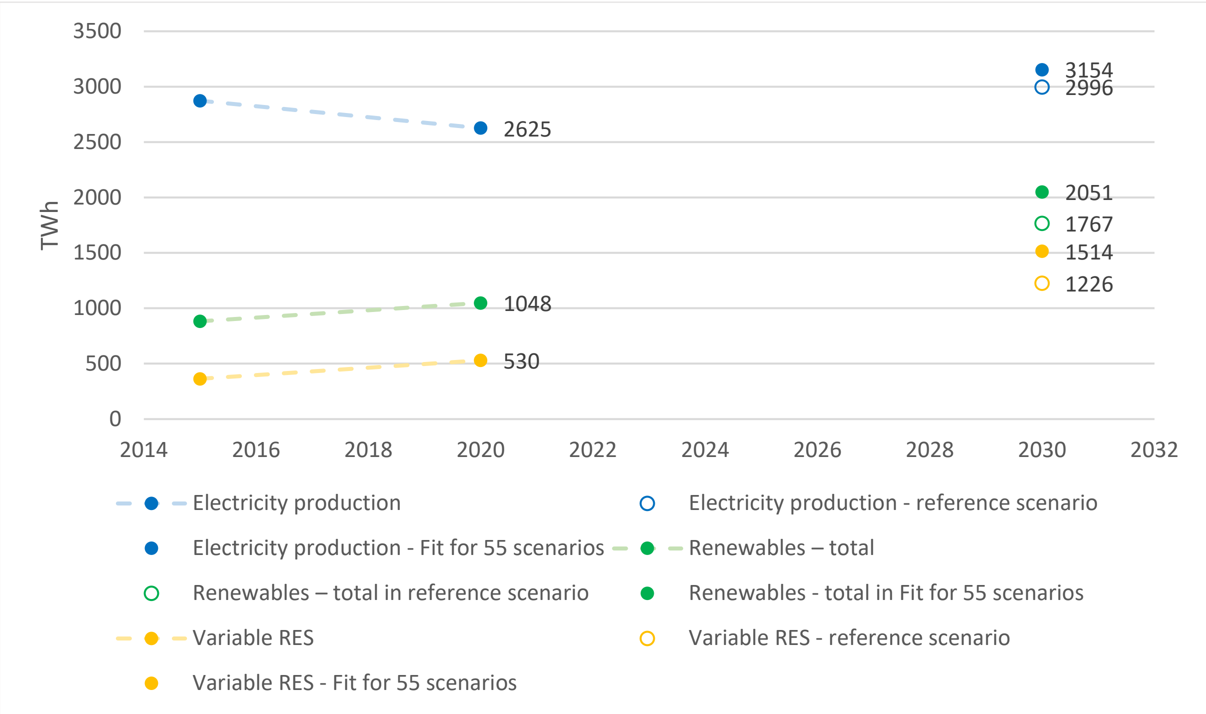
3. IMPLICATIONS OF THE 2030 TARGETS FOR RENEWABLE ENERGY ON GRID OPERATORS

3.1. Background

The revision of the Renewable Energy Directive (RED II) will lead to the increase of the 2030 target for renewable energy share in the EU energy mix from 32% to 40%.

According to the scenarios modelled for the impact assessment to the Fit for 55 package[87], this revision would increase the share of electricity produced from variable renewable electricity sources[88] from 20% in 2020 to 48% in 2030. This marks an increase of ambition in comparison to current policies, such as those planned by Member States in their national energy and climate plans (NECPs), which would lead to a variable renewable electricity sources share of 41%[89] in the European Commission reference scenario. Similarly, the adoption of the Fit for 55 package will lead to an increased share of the installed electricity capacity of variable renewable electricity sources from 33% in 2020 to 61% in 2030, compared to 56% in the reference scenario[90,91].

Figure 6: Expected EU renewable electricity production in the Fit for 55 package



Source: Author's analysis of the EC scenarios.

[87] The figures presented here represent the MIX and MIX-CP scenario that are more closely aligned with the actual policy proposals. The scenarios examined by the European Commission in their impact assessment, including results on national level, are available at: https://ec.europa.eu/energy/data-analysis/energy-modelling/policy-scenarios-delivering-european-green-deal_en#scenario-results.

[88] Meaning non-dispatchable sources of electricity with varying level of production (depending on weather condition for example). In practice, those are mainly on- and off-shore wind and solar power plants.

[89] European Commission, 2021, EU Reference Scenario 2020. Available at: https://ec.europa.eu/energy/data-analysis/energy-modelling/eu-reference-scenario-2020_en.

[90] Ibid.

[91] European Commission, 2021, Policy scenarios for delivering the European Green Deal. Available at: https://ec.europa.eu/energy/data-analysis/energy-modelling/policy-scenarios-delivering-european-green-deal_en#scenario-results.

Box 1: Proposal for revised Energy Efficiency Directive

The proposed EED revision in Fit for 55 package newly specifies that the National Regulatory Authorities (NRAs) shall apply the "energy efficiency first" principle when regulating the gas and electricity sector, including their decision on network tariffs. NRAs shall also:

1. Remove any incentives in the network tariffs that are detrimental to energy efficiency of generation, transmission distribution and supply of electricity;
2. Limit the possibility for transmission and distribution network operators to recover avoidable network losses from tariffs paid by consumers.

Member States should also ensure that gas and electricity grid operators:

1. Apply the energy efficiency first in their network planning, network development and investment decisions. MSs shall also ensure that grid operators avoid investment in stranded assets;
2. Map network losses and take cost-effective measures to reduce them;
3. Encourage transmission and distribution network operators to develop innovative solutions to improve the energy efficiency of existing systems through incentive-based regulations.

The network regulation and tariffs set by NRAs shall also follow the principles set out in the Annex XII of the directive:

1. Network tariffs shall reflect cost savings achieved from demand-side and demand- response measures and distributed generation, including savings from lowering the cost of delivery or of network investment and a more optimal operation of the network;
2. Network regulation and tariffs shall not prevent network operators or energy retailers making available system services for demand response measures, demand management and distributed generation on organised electricity markets;
3. Network or retail tariffs may support dynamic pricing for demand response measures by final customers.

Source: Author's own elaboration.

3.1.1. Electricity grids landscape in Europe

Electricity grids can be divided into the transmission level (covering extra- and ultra- high voltage, as well as the vast majority of high voltage networks) and the distribution level. However, there is no single definition of the threshold between transmission and distribution voltage levels, with significant variations across Europe[92].

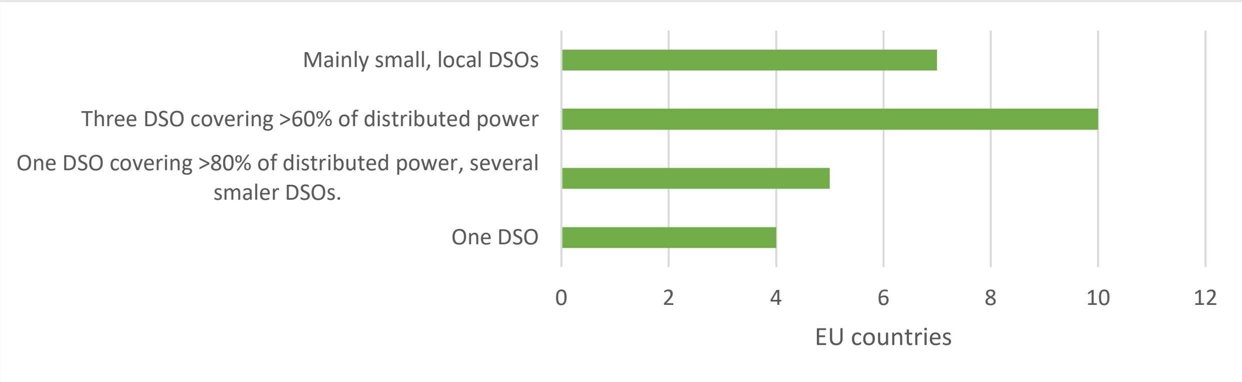
While there is only **one operator in most EU countries** for the transmission level (with Germany as a notable exception, counting 4 TSOs), the landscape of distribution networks operated by separate entities is very diverse. There are currently around 2,400 electricity distribution system operators in

[92] CEER, 2016, 6th CEER Benchmarking Report on all the Quality of Electricity and Gas Supply.

EU[93]. Figure7 below illustrates the significant differences in the size of the grids owned by the individual DSOs[94].

In nine EU countries, one DSO covers all or over 80% of distribution grids, which can result in very different roles and capabilities of the operators, compared to countries where there are large numbers of small DSOs[95] with a more local perspective on the problem of network management and renewable energy integration.

Figure 7: DSO distribution in EU Member States



Source: Eurelectric, 2020.

The variety in DSOs in Europe also suggests they are facing different challenges in variable energy integration. While for the smallest ones it might simply be a question of being able to connect the additional renewable electricity sources, larger DSOs covering significant portions of a national territory might be considering procuring their own ancillary services to balance the increasingly variable power flows in their networks.

3.2. Assessment of progress and delivery gap in renewable sources grid integration

This assessments follows three steps. Firstly, high-level assessments of the needs for investments into electricity grids are assessed. This analysis presents the views of TSOs, DSOs, as well as of the EC to provide a different perspective. Secondly, the progress of grid operators in integrating variable renewable electricity sources (variable RES) is investigated. On the transmission system (TS) level, this concerns mainly the development of cross-border interconnections[96], while on the distribution system (DS) level a broader perspective, focusing on new modes of consumption, flexibility and cost savings, is adopted to reflect the changing views on the role of distribution system operators. Finally, the means for financing further efficient grid developments are explored such as network planning, regulatory frameworks incentivising efficient grid operation, and network tariff design influencing the behaviour of consumers.

93 Eurelectric, 2020, Power distribution in Europe: Facts & figures. Available at: https://cdn.eurelectric.org/media/1835/dso_report-web_final-2013-030-0764-01-e-h-D66B0486.pdf.

94 Ibid.

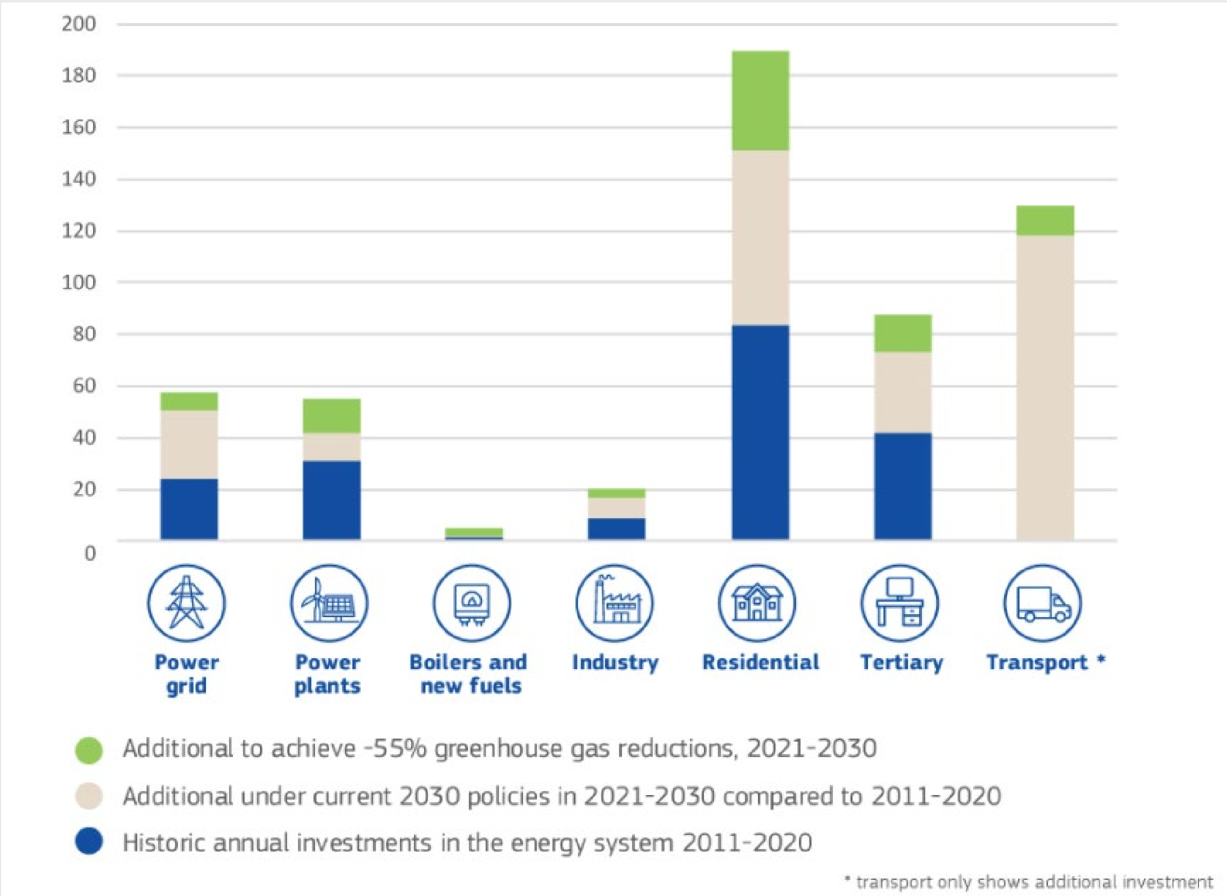
95 Although there is at least 1 large DSO with over 100,000 customers in every EU Member State.

96 Other actions for TSOs include for example cross-border integration of energy and balancing markets and opening them for new market players. This was however left out of the limited scope of the study

3.2.1. Electricity grid development needs by 2030 to meet the increased ambition

According to Commission calculations and its assessment of final National Energy & Climate Plans (NECPs)[97], the expansion, replacement and refurbishment of the power grid to integrate renewable energy production necessary for reaching the 55% emission reduction target would require annual investments[98] of **EUR 59 billion**. As shown in Figure 8, this is more than double the historic investment rate in the last decade[99]. Reaching the 55% emission reduction target would also mean additional investments on top of the currently planned measures considered in the NECPs.

Figure 8: Commission assessment of the additional investment needs for 2021-30



Source: European Commission, 2020.

a. Transmission system development progress and delivery gap

The EU level development of the transmission electricity grid is elaborated in the electricity Ten-Year Network development Plan process (TYNDP)[100].

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[97] European Commission, 2020, An EU-wide assessment of National Energy and Climate Plans Driving forward the green transition and promoting economic recovery through integrated energy and climate planning (COM/2020/564). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:564:FIN.

[98] This also includes EU funding, mainly from the Connecting Europe Facility, which has a budget of 5.84 billion EUR for the period between 2021 and 2027. See European Commission, 2020, Connecting Europe Facility 2021-2027 adopted. Available at: https://cinea.ec.europa.eu/news/connecting-europe-facility-2021-2027-adopted-2021-07-20_en.

[99] European Commission, 2020, Communication A EU-wide assessment of National Energy and Climate Plans Driving forward the green transition and promoting economic recovery through integrated energy and climate planning (COM/2020/564). Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:564:FIN.

[100] ENTSO-E, 2021, Planning the future grid. Available at: https://tyndp.entsoe.eu/.

Since the TYNDP concerns the transmission infrastructure, its main focus is on the development of cross-border electricity interconnections and national transmission projects with a cross-border relevance. However, the system integration aspect is considered as well, exploring the potential synergies between electricity and gas systems that can deliver investment savings.

In the scenarios developed for the 2020 TYNDP[101], the share of variable RES in electricity production is predicted to reach between 41% and 43% in 2030, depending on the scenario.

The assessment of power system needs for 2030[102] shows that 35 GW of additional cross-border interconnection capacity is planned to be finished by 2025. However, adding further 50 GW of interconnection capacity in the period between 2025 and 2030 would be necessary to cost-effectively meet the forecasted variable RES deployment. This additional 50 GW of cross-border capacity is partially covered by existing projects included in the TYNDP, but almost half the additional capacity would have to be covered by new projects that are beyond the current plans of network operators. The construction of additional 50 GW of interconnection would require around 17 billion EUR in investments. However, this investment is only planned to cover the addition of renewable energy sources in a volume that would lead to 40% emission reduction in 2030. To meet the increased emission reduction target, the effort would have to be increased.

The assessment methodology is based on increasing the "social-economic welfare" at the EU level. The basic premise is that the increased cross-border capacities will enable trading larger volumes of energy between countries, thus reducing the curtailment of variable RES generation, reducing overall power system costs (by increasing competition, efficiently using generation assets and reducing overall load variability, among others), and integrating the EU internal electricity markets (leading to higher electricity price convergence among others). The TYNDP cost-benefit assessment shows that the planned investments would lead to avoiding the curtailment of 47 TWh of renewable electricity[103] by 2030, and to a net reduction of the generation cost by 3 billion EUR annually, in comparison to a situation where no new investment in the cross-border capacities is made after 2020.

The ENTSO-E Assessment of Power System Needs does not address the need for internal (national) grid reinforcements resulting from the increased cross-border capacities. Since the above mentioned sum of 17 billion EUR covers only the additional investment needs, the estimate of total investment needs can be best complemented by adding the historical figures. The latest survey of European network costs shows that 9.5 billion EUR was invested in the EU27 transmission networks[104] in 2018.

b. TSO investments in other innovative solutions

While there are other possible measures to adapt transmission grids for increased variable RES production (notable projects are for example the integration of day-ahead and balancing markets), the level of investment is hard to assess since there is little publicly available data. A potential reason for this is that the level of investment needed is substantially lower than the cost of building physical

101 ENTSO-E and ENTSOG, 2020, TYNDP 2020 Scenario report. Available at: https://www.entsos-tyndp2020-scenarios.eu/wp-content/uploads/2020/06/TYNDP_2020_Joint_ScenarioReport_final.pdf.

102 ENTSO-E, 2021, Completing the map: Power system needs in 2030 and 2040. Available at: https://eepublicdownloads.blob.core.windows.net/public-cdn-container/tyndp-documents/TYNDP2020/Foropinion/IoSN2020MainReport.pdf.

103 In 2020, the total renewable electricity production in EU was 1048 TWh.

104 Trinomics, 2020, Energy costs, taxes and the impact of government interventions on investments: Final Report on Network Costs. Available at: https://op.europa.eu/en/publication-detail/-/publication/06abcbec-1740-11eb-b57e-01aa75ed71a1/language-en.

infrastructure. For example, most of the RD&I projects monitored by the ENTSO-E have a budget lower than 20 million EUR[105].

c. Distribution system development progress and delivery gap

According to the results of a survey of 51 DSOs undertaken for this study (the results are presented in Annex B3), only a minority (29%) of distribution grid operators are expecting major constraints to connecting the expected additional renewable electricity producers to their grid. On the other hand, 65% of surveyed DSOs are expecting only partial, minor challenges in their grid.

The survey also shows that the impacts of the new renewable energy targets are not being analysed yet at the level of individual DSOs. In fact, the majority of DSOs (at least 57% of respondents) are waiting for the EU ambition to be translated into national policies, which will result in delaying the planning process of grid development. Of the DSOs surveyed, 61% expect that the increased ambition of Fit for 55 package will require additional actions from their side.

A more high-level perspective is needed to quantify the impacts of the policy package, which is presented in a recent study published by E.DSO and Eurelectric[106]. The study anticipates 70% of the newly connected renewable electricity sources will be connected at the distribution level by 2030. This presents a substantial challenge for distribution networks' operations, as the networks were designed according to the centralised production paradigm, which is based on unidirectional energy flows from production located at the transmission level to consumption sites. The decentralised nature of renewable electricity production, however, requires multidirectional flows of energy in the electric networks and can cause problems with network stability (voltage quality), or overload power lines, transformers and other equipment. Investments in network reinforcements and better network management tools are therefore necessary to accommodate widespread and decentralised renewable electricity sources connections.

The challenge facing the network operators is three-fold:

1. Integration of renewable energy:
    a. Controlling imbalances caused by variable renewable production;
    b. Integrating distributed production;
    c. Enabling demand-side participation and supplying growing demand in new applications, such as electromobility and household heating;
2. Optimisation of necessary investments:
    a. Better monitoring of grid and proper network planning;
    b. Deploying smart network management tools;
3. Security of supply and automation:
    a. Modernising grid equipment and deploying smart meters;
    b. Enhancing grid stability and resilience; and

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105 ENTSO-E, 2019, Monitoring report 2018: Research, development and innovation projects. Available at: https://rdmonitoring.entsoe.eu//wp-content/uploads/2019/05/entso-e_RDnI_MR_2019_Main_Report_190510.pdf.

106 Monitor Deloitte, 2020, Connecting the dots: Distribution grid investment to power the energy transition. Available at: https://www.edsoforsmartgrids.eu/wp-content/uploads/Deloitte-Study-connecting-the-dots-full-study.pdf.

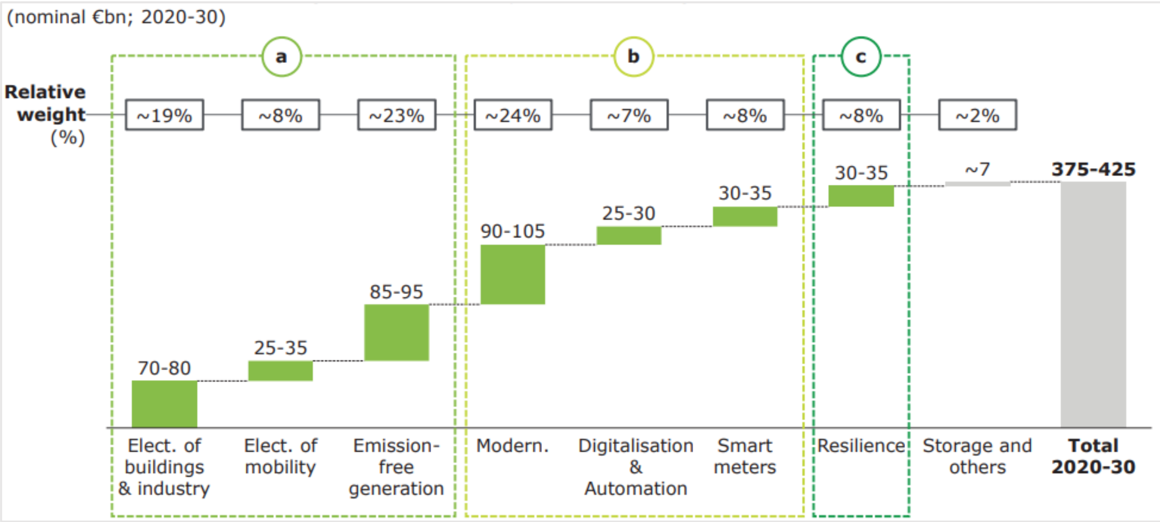
c. Enhancing data management and cyber security.

Based on estimates provided by a selected number of electricity Distribution System Operators (DSOs), the cost of adapting all these measures in the EU27 and UK grids could reach 375-425 billion EUR in the period between 2020-2030[107]. The annual investment needed would therefore be 50-70% higher than the historical investment rates. Hitting the emissions reduction target for 2030 (50-55% emission reduction) could also increase the cost of renewable energy integration by 8% compared to currently planned investment.

As shown in Figure 9 below, the largest share of the investment needed will be for the modernisation of existing equipment (24%), connecting "emission-free generation" (23%) and electrification of buildings and industry (19%)[108].

Investment in emission-free generation, electrification of buildings and industry, and investment in integration of electromobility would be the main drivers of the 8% investment increase needed to reach the 55% reduction target.

Figure 9: Estimate of EU27+UK planned investments in DSO networks in the period 2020-2030



Source: Deloitte, 2020.

d. Conclusions

The main characteristics and results of the scenarios analysed above are summarised in Table 14in the Annex B1. It is clear that the scenarios are not fully comparable, since they differ in assumptions and scopes. The E.DSO scenarios estimate a lower level of investment needed than the EC scenarios, which however include a wider scope of investment covering transmission networks, heating & cooling and energy storage. The ENTSO-E scenario estimates only additional investment needs up to 2030, but it can be complemented with the historical investment levels. When the transmission and distribution operators' estimates of investment needs are combined, they are approximately equivalent to the sum estimated in the EC scenarios. Therefore, from a high-level perspective, the scenarios seem to be relatively aligned.

[107] Ibid.

[108] Ibid.

The comparison of the scenarios also reveals that the amount of investment in transmission networks is lower than for investments in distribution networks, which is in line with historical trends[109]. The predictions also confirm the long-term trend of increasing network investment.

A deeper look into the scenarios' assumptions shows that they differ in the composition of investment between transmission and distribution level. While the main investment component on the TS level is on building new power lines (cross-border or also internal grid reinforcements), the distribution-level investments are dispersed into a wider group of measures.

Finally, all the scenarios show that additional actions are needed beyond the currently planned policies (on the national level) to integrate the renewable energy production necessary to achieve the Fit for 55 package goals. The ENTSO-E scenario only assumes a 40% emission reduction target by 2030, so additional investment will be needed and should be considered in future planning.

3.2.2. Progress in renewable sources grid integration

Although the findings of the previous chapter show that the need for grid investment is increasing, it is worth noting that grid operators have so far been successful in integrating renewable energy sources without endangering the functioning of the networks. For example, the SAIDI index (System Average Interruption Duration Index), representing how often the power supply to consumers is interrupted, has been decreasing or staying at a similar level in most European countries over the past years, despite the significant increase in variable renewable electricity production[110]. However, in areas with high variable RES penetration, the adequate level of security of supply sometimes has to be achieved at the cost of curtailing the renewable energy production[111]. Moreover, curtailment of RES either reduces the returns on investment of RES operators, or has to be reimbursed by the network operators, which increases the network costs for all grid users.

a. Progress on TS level

As explained in the section assessing TSOs plans for integrating renewables, the largest share of investments is geared towards developing new power lines that reduce network constraints and can therefore transport larger volumes of renewable electricity.

The most prolific case of negative impact of network constraints on RES integration is the situation in Germany[112]. The amount of curtailed renewable energy production has been rising continuously since 2013, reaching 6.48 TWh in 2019. This is equivalent to 2.9% of the total renewable energy produced in Germany in that year. This phenomenon is mostly related to the situation in transmission networks, as TSOs were responsible for requesting the curtailment of 83% of the curtailed energy. However, it is worth noting that 81% of the total volume was curtailed by installations connected to distribution networks[113].

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[109] Trinomics, 2020, Energy costs, taxes and the impact of government interventions on investments: Final Report on Network Costs. Available at: https://op.europa.eu/en/publication-detail/-/publication/06abcbec-1740-11eb-b57e-01aa75ed71a1/language-en.

[110] CEER, 2018, CEER Benchmarking Report 6.1 on the Continuity of Electricity and Gas Supply. Available at: https://www.ceer.eu/documents/104400/-/-/963153e6-2f42-78eb-22a4-06f1552dd34c.

[111] Clean Energy Wire, 2018, Interconnectors & blockages – German grid at odds with EU power market. Available at: https://www.cleanenergywire.org/factsheets/interconnectors-blockages-german-grid-odds-eu-power-market.

[112] Ibid.

[113] BnetzA, 2021, Monitoring report 2020. Available at: https://www.bundesnetzagentur.de/SharedDocs/Downloads/EN/Areas/ElectricityGas/CollectionCompanySpecificData/Monitoring/MonitoringReport2020.pdf?__blob=publicationFile&v=2.

A large portion of the key transmission grid projects currently being developed is included in the current list of Project of Common Interest (PCI list)[114]. Since all the candidate projects for the PCI list have to prove their positive impact on renewable energy integration, it can also be argued that these projects are the most relevant for progress assessment in this study. ACER is tasked with annual monitoring the implementation progress of these projects, collecting valuable data on the overall progress of transmission networks adaptations.

i. PCI monitoring report

The conclusions of the ACER monitoring process of the PCIs are published in the annual PCI monitoring report. According to the latest version[115], 18 projects out of the 106 electricity projects in the current list of PCIs reported advancements in their status in the last year (2020). However, 21 projects did not advance their status at all since 2015 and no activities were reported for seven projects in the last year.

According to the project promoters, 70% of the PCIs are expected to be finished by 2025, although ACER finds this number overly optimistic[116]. Only 7% of the projects are currently implemented ahead of time. Around 25% of the projects experienced delays in comparison to previous schedule in 2020. Out of all the electricity projects on the current PCI list, 30% are delayed and completion of further 8% had to be rescheduled by the project promoters. The main reason was delays in permit granting (especially environmental permitting), followed by delays caused by COVID-19 pandemics.

The duration of the reported delays varies for the electricity projects from three months up to three years (with an average of 15 months), while the duration of rescheduling is typically longer (from four months up to five years).

b. Progress at DS level

While the progress on transmission level can be characterised to a great extent by the build-up of missing grid interconnections that will facilitate the function of domestic markets as well as of the European Internal Energy Market, on the distribution level the development in recent years sees mainly the shift of focus from investment in new lines to a much wider group of measures aimed at accommodating the emerging challenges.

ii. Main DS challenges in integrating variable RES

- Implementation delays

The results of the survey conducted for this study show that half of the DSOs (49%) think that the progress of grid adaptation is well under way, and only 20% expressed concerns about the pace. A significant portion of operators cannot say whether the progress of adaptations is sufficient, presumably due to uncertainty around the policy targets.

Over half of the DSOs also indicated that they are not experiencing significant delays in project implementation. The DSOs experiencing delays indicated that they are mostly caused by the delays in permitting process, lack of human resources and by impacts of COVID-19 pandemics. The average reported delay of a project was 1.15 years.

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114 European Commission, 2019, Key cross border infrastructure projects. Available at: https://ec.europa.eu/energy/topics/infrastructure/projects-common-interest/key-cross-border-infrastructure-projects_en.

115 ACER, 2021, ACER report on the progress of electricity and gas projects of common interest. Available at: https://documents.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/2021_ACER%20Consolidated%20Report%20on%20the%20progress%20of%20electricity%20and%20gas%20Projects%20of%20Common%20Interest.pdf.

116 Ibid.

- Identification of barriers for DSOs

According to a study from the Renewables Grid Initiative[117], the grid operators (both at TS and DS levels) are facing barriers in the development of the grid reinforcements needed to integrate new renewable electricity generation.

The operators indicated that those are mainly concerning the regulatory framework:

- Complicated project permitting process;
- Pressure from the regulators to decrease the costs, while also pushing for increased renewables integration;
- Lack of regulatory cost recognition for additional environmental and social mitigation and compensation work to improve acceptance rates (of grid expansion);
- Lack of consideration by regulators of the costs of not developing the grid (e.g. re-dispatch costs);
- Lack of regulatory foresight to incentivise system flexibility in order to integrate larger quantities of renewables in the near future.

Compared to transmission system operators, **distribution grid operators view public opposition as a less significant issue** (presumably because lower voltage lines are easier to bury underground and are therefore not so visible to the public). The DSOs however cite some additional specific issues to the list above:

- There is a lack of internal knowledge and capacity at the local regulatory level to make the correct decisions on investment and to develop the right regulatory framework;
- Larger customers do not always plan accurately their future demand, making the DSO plans less useful;
- Overly cautious privacy rules for customer data hamper their effective use for grid analyses, making optimisation of existing infrastructure more difficult.

These barriers were validated by the results of the DSO survey, which shows that the biggest challenges identified by the operators are 1. Difficulties in setting appropriate network tariffs; 2. Availability of adequate human and institutional resources and 3. Availability of sufficient financing to conduct the necessary investment. The public opposition was indicated as a significant challenge mainly by smaller DSOs with less than 100,000 customers, while larger DSOs were highlighting more the lack of human resources and the long duration of permitting process.

iii. DSOs' actions to integrate the additional RES generation

The results of the DSO survey show that the most commonly undertaken grid adaptation action is reinforcing the capacity of existing lines, currently deployed or planned (78% of surveyed operators). Upgrading grid control systems (63% of DSOs) is the second most common measure, while building new power lines is substantially less common. The survey has also shown that the focus on investment in new grid lines is more common for small DSOs with fewer than 100,000 customers, while larger companies tend to focus more on alternative solutions, such as upgrading monitoring and prediction tools and integrating flexibility services. This suggests that larger DSOs are currently in the centre of the challenge of deploying alternative solutions for renewables grid integration. The following section draws on further literature research to investigate these actions further.

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[117] RGI, 2018, European Grid Perspectives: How system operators see the future. Available at: https://renewables-grid.eu/fileadmin/user_upload/Files_RGI/RGI_Publications/RGI_European_Grid_Perspectives_2018.pdf.

A JRC report on DSO activities[118], surveying the activities of large DSOs with over 100,000 customers illustrates the trend by analysing the involvement of DSOs in various activities. Given the focus on large DSOs, these results have to be read with caution, as the extent of proliferation of these measures will be probably more limited for operators managing smaller grids.

DSOs are using (non-frequency) ancillary services

DSOs are increasingly involved in managing the demand in their networks, through Demand-side management (DSM) or Demand response (DR). DSOs can procure in a non-discriminatory manner (non-frequency) ancillary services and congestion management from a number of flexibility resources connected to their networks, among which demand response. According to the JRC report, 38.5% of the DSOs reported having a DSM or DR program to help manage their grid. Over one third of the DSOs estimated that the use of demand-based ancillary services would lead to CAPEX or OPEX savings. Around half the DSOs reported that they have some active consumers[119], but **only 13% are actively managing them** (although another 40% of DSOs reported that they have some kind of pilot programme in place).

DSOs are managing distributed energy generation, electromobility

There are significant differences in the level of distributed generation connected to the distribution networks in Europe. In the JRC study, the DSOs reported an installed capacity in the range from 10 MW to 20 GW (mean value reaching around 2.7 GW). The variable nature of the production is illustrated by the fact that only 25% of DSOs reported over 2,000 full load hours of production and 25% of DSOs only reported fewer than 118 full load hours.

With regards to the charging points, 75% of DSOs reported fewer than 176 connections in their networks. However, as the JRC report points out, this is also because DSOs do not have a clear picture of the situation, missing for example charging points connected beyond the meter (in office buildings for example). Half of the DSOs also reported that there is no reporting obligation on charging points for their consumers.

Over a fifth of DSOs own an energy storage assets. Use of this storage is limited by law to ensure the secure functioning of the network.

[118] JRC, 2021, Distribution System Operator Observatory 2020: An in-depth look on distribution grids in Europe. Available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC123249.

[119] Customers who might consume or store electricity, sell self-generated electricity, or participate in flexibility or energy efficiency schemes.

Box 6: Ancillary services procurement by DSOs

A number of flexibility resources can provide non-frequency ancillary services, such as congestion management, voltage control and islanded operation to DSOs. While relatively low, utilisation of demand response for management of congestion in distribution grids is relatively advanced compared to the procurement of other ancillary services.

Several projects in the EU aim at increasing the participation of consumers and using demand response to provide services[120]. For example, the German demonstrator project of the Interflex H2020 project, implemented in the network of Avacon Netz, seeks to develop a platform (directly linked to the DSO's distribution management syste

m) for the DSO to directly control smart meters of 60 households and therefore leverage flexibility resources. This allowed the DSO to better monitor and identify critical network conditions, curtail load or behind-the-meter renewable generation if necessary, and gradually phase electrical heating loads in and out (instead of activating all heating loads simultaneously when low energy price periods began)[121].

This enables the DSO to source ancillary service from consumers and to avoid additional investments. It also illustrates many of the new roles of electricity DSOs in Europe, who increasingly not only manage demand response through implicit and explicit incentives, but also manage distributed renewable generation.

Source: Author's own elaboration.

iv. DSOs are using more advanced monitoring and asset control tools

One of the most important tools for the advanced monitoring of grids is the deployment of smart meters. According to the DSOs surveyed in the JRC report, 63% of connections were equipped with them in 2020, missing the EU target of 80% for that year. The distribution of smart meters varies significantly across the networks. While around 25% of DSOs have already equipped all their customers with smart meters, 25% of them have installed them in less than 12% of connections.

In terms of asset management tools, the DSOs are commonly using remote control of substations high voltage/medium voltage interface (HV/MV), but this practice is not common for the medium/low voltage (MV/LV) substations (three quarters of DSOs use remote control for fewer than 10% of substations on this level). More commonly, DSOs are using SCADA (Supervisory Control And Data Acquisition) systems for asset management. These can be used for voltage and load control at substations and for end-user load control, and 36% of DSOs reported the ability to perform this.

Some other advanced network monitoring and management tools used by DSOs are power flow simulations (used by 25% of DSOs on a 15-minute basis), data analytics for asset planning or sensor technology for outage detection. 41% of DSOs reported having pilot projects for advanced load and storage management and 38% DSOs reported having DER visualisation and management tools.

[120] Several are listed in: INTENSYS4EU, 2021, Working groups Consumer and Citizen engagement. Available at: https://www.h2020-bridge.eu/working-groups/customer-engagement/.

[121] Interflex, 2019, Interflex project summary: January 2017 – December 2019. Available at: https://interflex-h2020.com/interflex/project-demonstrators/germany/.

Box 7: Advanced distribution management systems innovation in the EU

Advanced distribution management systems (ADMS) are used to improve the operation of the distribution system but are often also a requirement for other innovative approaches to enable the integration of variable renewables, such as the non-discriminatory procurement of flexibility services from all market actors. Therefore, DSO actions related to improving TSO-DSO coordination or procuring congestion management services, for example, often depend on the existence of an ADMS which allows for the monitoring and control of distribution networks in real time.

ADMS systems such as remote monitoring and control of substations and network devices are a mature technology offered by a number of vendors. According to the Commission, "Europe has the highest penetration of ADMS [advanced distribution management system] technologies globally. This is due to several factors, including high rates of substation and feeder automation, carbon and energy efficiency targets, adoption of renewables, smart metering initiatives, and more. Most Western European utilities are expected to have one or more ADMS modules deployed while Eastern Europe shows lower rates of ADMS penetration regionally"[122].

Therefore, while innovation in ADMS software and hardware continues, one of the most relevant research fields is the improvement of ADMSs support for the integration of variable RES. This aspect is being addressed directly or indirectly by a number of initiatives. For example, the Flexgrid project aims to combine advanced grid models and tools with flexibility management, data analytics and forecasts tools in order to facilitate the integration of variable RES[123]. The project highlights the relevance of advanced modelling of distribution networks (supported by real time remote monitoring of network conditions) as a pre-condition for identifying the flexibility needs of the network and procuring the necessary services in the appropriate timeframe.

Source: Author's own elaboration.

v. DSOs are coordinating with TSOs

According to the DSOs' survey responses, most (67%) of the mid-sized (between 100,000 and 1 million customers) and all large DSOs are planning increased cooperation with other grid operators, in particular with TSOs. Only 21% of smaller DSOs indicated the same intention.

The future TSO-DSO coordination challenges can be categorised in several ways. Power sector associations suggest one way to classify the challenges is[124]:

- Cooperation in network operation;
- Cooperation in planning;
- Exchange in all necessary information regarding long-term planning;
- Exchange in all necessary information regarding generation and demand-side response for daily operation;
- Cooperation to achieve coordinated access to resources; and
- Cost-efficient, secure and reliable development and operation of networks.

[122] European Commission, 2020, SWD 953 Clean Energy Transition – Technologies and Innovations. Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52020SC0953&rid=1.

[123] Flexgrid, 2021, Flexgrid project. Available at : https://flexgrid-project.eu/.

[124] Geode et al, 2021, Smart Grid Key Performance Indicators: A DSO perspective.

The DSOs are sharing data with TSOs in order to improve the management of the whole electricity network. DSOs are sharing demand and generation forecasts mostly on a daily, monthly or yearly basis, while the real-time measurements (from substations) are shared on a 15-minutes basis. In the other direction, at least 25% of the surveyed DSOs are receiving data on network conditions from the TSOs on an hourly or 15-minutes basis. The survey results also suggest that ex-post data sharing is a more common practice so far.

Box 8: Electricity TSO/DSO coordination

Regulation 2017/1485 on a guideline on electricity transmission system operation requires the coordination of TSOs and DSOs in a number of issues, including on remedial actions, balancing, voltage control and data exchange. TSOs and DSOs therefore already regularly interact and cooperate on these (and other) issues. However, there is significant room for improvement for integrated management of the electricity system – with associations representing market participants and network operators recently developing recommendations on integrated balancing and congestion management[125].

For example, the Coordinet H2020 project includes ten pilot projects in Spain, Greece and Sweden to foster the cooperation of TSOs and DSOs, while at the same time enabling the non-discriminatory participation of network users in energy markets and non-market based ancillary service procurement[126]. In the Spanish pilots, the systems will be developed to enable the procurement of services for congestion management, balancing, voltage control and controlled islanding from various flexibility resources (renewable generation units at all voltage levels as well as demand response resources at low and medium voltage levels)[127].

Source: Author's own elaboration.

c. Conclusions

The grid operators are facing different challenges at transmission and distribution system levels.

At TS level, the main challenge is building cross-border interconnectors and internal transmission lines to avoid grid congestion and curtailment of variable RES production. When implementing grid development/reinforcement projects, public opposition and permitting are one of the main issues that are causing delays in project implementation.

At DS level, the role of grid operator is changing to a more active system manager. This requires a higher level of investment and enhanced capabilities, new business models, digitalization, or cooperation with other actors, such as TSOs.

Issues such as long permitting procedures and public opposition make building new power lines even harder and prolong the project implementation time. Alternative solutions aimed at limiting expenses and use of flexibility are more suitable options to accommodate the changes in production and consumption patterns.

3.2.3. Overview of grid development financing mechanism

Given the different investment priorities at transmission and distribution system level, this section will primarily focus on distribution networks.

[125] CEDEC et al, 2019, TSO – DSO Report – An Integrated Approach to Active System Management.

[126] CoordiNET, 2019, The CoordiNET Project Pilots. Available at: https://coordinet-project.eu/.

[127] Comillas et al, 2020, CoordiNet Deliverable D3.1 - Report of functionalities and services of the Spanish demo.

The investment in DS deserves more scrutiny because of the substantially higher level of funds needed than for the transmission networks. The distribution network charges for consumers are also substantially higher than transmission network charges and therefore have a more significant impact on consumers.

However, the general principles of regulation described in this section can be applied on transmission networks as well (especially the regulatory frameworks supporting innovation).

a. Key principles of efficient investment in energy infrastructure

The investment in network infrastructure, as well as the cost recovery via network tariffs, is explained in Annex B2 to the report. There are three general ways to promote efficient financing of networks. Firstly, the planning of network investment should be improved by integrating the energy efficiency first principle, by introducing consideration of alternative and innovative investment and by increasing the coordination of DSO and TSO plans. Secondly, a regulatory framework for the operators can be applied to encourage them to lower their overall expenditure (e.g. by lowering operational costs; pursuing innovative solutions instead of CAPEX investments). Thirdly, the regulator can promote the use of cost-reflective network tariffs that will influence the behaviour of network users, in a way that will help reduce investment and operational costs of the electricity grid.

i. Planning of network development

From a long-term perspective, integration of distributed energy resources (DER) needs to be considered in network plans. The DSOs are currently mandated to prepare network development plans on a biannual basis, although MSs can decide not to apply the obligation to DSOs serving fewer than 100,000 connected customers or serving small isolated systems. However, according to the JRC survey[128], 77% of DSOs are preparing an investment plan, so the coverage is already substantial.

Nevertheless, the experience from MSs suggests that the network development plans at distribution level currently focus primarily on ensuring security of supply[129]. More work needs to be done on the integration of the cost-efficiency perspective (there is no consolidated cost-benefit analysis methodology for distribution network planning), and on new generation capacity and other flexibility sources[130].

ii. Regulatory incentives for efficient grid development

Historically, the regulation of network revenues was based on remunerating all approved costs incurred by the network operators (cost-based regulation). The most commonly used models are cost-plus regulation or rate-of-return regulation. However, these regulatory models might incentivise the network operators to increase their expenditure in order to increase their revenues (gold-plating).

Incentive-based approaches, focusing on achieving a wider goals of network regulation, are therefore being developed and implemented in an increasing number of Member States.

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[128] JRC, 2021, Distribution System Operator Observatory 2020: An in-depth look on distribution grids in Europe. Available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC123249.

[129] CEER, 2020, CEER webinar on DSO development plans and network planning. Available at: https://www.ceer.eu/documents/104400/-/-/0540f675-934d-b039-b913-dd5727d42e07.

[130] Eurelectric, 2020, Recommendations on the use of flexibility in distribution networks. Available at: https://www.eurelectric.org/media/4410/recommendations-on-the-use-of-flexibility-in-distribution-networks_proof-h-86B1B173.pdf.

The main goals of the regulation are listed by the Council of European Energy Regulators (CEER) (specifically for the DSOs)[131]:

- Ensuring a level playing field for all stakeholders (e.g. non-discriminatory network access);
- Promoting cost efficiency;
- Ensuring financial viability of the network operation business;
- Facilitating innovation;
- Improving the quality of service;
- Ensuring security of supply;
- Facilitating the improvement of sustainability, including the promotion of energy efficiency; and
- Ensuring a coordinated whole system approach.

Reaching all these goals at the same time is a challenging task, as they can be contradictory and complex. For example, investing heavily in network reinforcements to ensure a high level of security of supply might lower cost effectiveness. Various elements of regulatory design can help find the required balance between such differing priorities.

Generally, there is significant room for improvement of regulatory frameworks for electricity networks and actions by network operators concerning innovation. A 2019 study for the European Commission found that "innovation is in many MS not explicitly incentivised or recognised in the regulatory framework. This is an issue where the gains from innovative approaches are uncertain or hard to quantify. Moreover, where innovative approaches over time would reduce the asset base or do not directly benefit the TSO, TSOs have less to gain from pursuing innovative approaches. Our analysis also shows that TSOs only pursue projects that they expect will be accepted by the regulator, while novel approaches that are not certain to be accepted often do not pass the stage of an idea[132]". While the study was focused on the transmission level, the findings are applicable to electricity distribution, where the challenges indicated are arguably more important.

The study identifies five main recommended measures to improve regulatory frameworks for energy infrastructure in EU Member States:

- Introduce requirements to consider innovative solutions when planning investments;
- Perform Social Cost Benefit Analysis for larger projects;
- Mitigate CAPEX bias by encouraging a balanced consideration of OPEX-based solutions;
- Consult national development plans/investment plans with relevant stakeholders; and
- Require consideration of OPEX-based solutions when planning investments.

These and other measures are considered below.

The first, high-level aspect is the degree of incentivisation. Different regulatory designs provide varying incentives for cost reduction and offer different level of risk-exposure for DSOs. A reasonable rate of return for the DSO has also to be set by the regulatory framework. As the context in which DSOs operate vary significantly across Member States, the adequate level of efficiency incentives and rate of return vary, but in general some level of incentivisation is welcome.

[131] CEER, 2018, Incentives Schemes for Regulating Distribution System Operators, including for innovation. Available at: https://www.ceer.eu/documents/104400/-/-/1128ea3e-cadc-ed43-dcf7-6dd40f9e446b.

[132] Ecorys, 2019, Do current regulatory frameworks in the EU support innovation and security of supply in electricity and gas infrastructure? https://ec.europa.eu/energy/studies_main/final_studiesdo-current-regulatory-frameworks-eu-support-innovation-and-security-supply_en.

In electricity distribution, 21 National Regulatory Authorities (NRAs) apply incentive regulation[133]. Price caps are used by seven NRAs and 14 NRAs use revenue caps[134].

A second classification of regulatory frameworks can be established according to whether the capital and operational expenditures are treated separately or together (in revenue cap approaches, or when setting price caps). Approaches treating capital and operational expenditures can remove perverse incentives for gold-platting by network operators, but increase the complexity of the revenue setting process. Five NRAs in the EU (in Germany, Lithuania, the Netherlands, Portugal and Sweden) apply a so-called TOTEX[135] approach[136].

Another related aspect of favouring OPEX-based solutions is the requirement that DSOs do not discriminate against non-network based solutions (for example consideration and non-discriminatory procurement of flexibility or congestion management services instead of deployment of DSO-owned solutions).

Whether CAPEX/OPEX or TOTEX revenue setting mechanisms are employed, regulators can apply an efficiency requirement to allowed revenues (so-called X-factor) in order to gradually reduce allowed revenues within or between regulatory periods, thus providing a regulatory pressure for operators to reduce expenditures. Alternatively, a profit-sharing mechanism may be used, where operators are entitled to keep a certain percentage of any savings they are able to achieve (with the remainder leading to lower network tariffs).

Regulatory frameworks can also allow and provide incentives for DSOs to develop measures to address specific challenges. This includes for example premia to rate of returns for specific projects related to integrating distributed energy resources, energy storage, EVs, smart grids and others.

Box 9: Incentive mechanisms for DSO efficiency and innovative solutions in the EU

Profit sharing mechanisms are sometimes used in the regulation of allowed revenues or tariffs for network operators in the EU, both for electricity and gas. In the electricity sector CEES lists profit sharing mechanisms for DSOs in Lithuania (for the roll-out of smart meters) and Portugal (for smart grid investments)[137].

In Austria, the NRA authorises a 'WACC adder' (i.e. a risk premium to the standard cost of capital used to remunerate investments) for investments related to the integration of distributed renewable energy, EVs and smart charging, development of smart grids and smart metering, among others. However, the application of this and other incentive mechanisms needs to be adequately assessed, to ensure they actually foster the increase deployment of innovative solutions – as the NRA itself indicates that the effectiveness of the risk premia is not clear[138].

Source: Author's own elaboration.

[133] In Belgium, there are 3 regional regulators (for Flanders, Wallonia and Brussels) that are included in these figures.

[134] CEER, 2020, Report on Regulatory Frameworks for European Energy Networks 2020. Available at: https://www.ceer.eu/documents/104400/-/-/5947b3af-5643-1411-02c9-b5d009b7b748.

[135] Under the TOTEX approach, the grid operators are given a single expenditure allowance, in opposition to setting separate allowances for OPEX and CAPEX. This approach was successfully pioneered by the UK regulator.

[136] CEER, 2020, Report on Regulatory Frameworks for European Energy Networks 2020. Available at: https://www.ceer.eu/documents/104400/-/-/5947b3af-5643-1411-02c9-b5d009b7b748.

[137] Ibid.

[138] Ibid.

While the use of regulatory sandboxes is still the exception in the EU, the practice is growing. Regulatory sandboxes provide well-defined exemptions from specific regulatory provisions (not only to DSOs but also market participants or other infrastructure operators). Sandboxes are not supposed to be permanent solutions but rather to enable experimentation by energy sector actors and regulatory learning by NRAs in fast-evolving challenges such as distributed procurement of flexibility services, OPEX-based solutions for congestion management, and increasing participation in energy markets for new energy technologies. Therefore, regulatory sandboxes may not only affect revenues of DSOs, but also the design of network tariffs and non-network related aspects of energy regulation.

Box 10: Energy regulatory sandbox in Germany

At least seven regulators in Europe have already implemented regulatory sandboxes (Austria, France, Germany, Italy, Lithuania, the Netherlands and the UK) and others are in preparatory stages[139].

In Germany, the federal government has adopted the SINTEG ordnance (Ordnance creating a legal framework for collection practical experience in the SINTEG programme) to provide a regulatory framework for experimentation projects taking place under the funding programme Smart Energy Showcases – Digital Agenda for the Energy Transition (SINTEG).

The ordnance defines the process for claiming the German NRA BnetzA compensation due to economic disadvantages incurred in the participation in the SINTEG programme. For example, electricity consumers testing load shifting solutions (contributing to grid stability and flexibility) may be subject to higher network charges due to the changes in the consumption pattern, and may request compensation for the network charge increase.

Source: Author's own elaboration.

iii. Design of network tariffs

Network tariffs can incentivise consumers' behaviour to reduce the network operation costs if they are properly designed. In addition to ensuring equal treatment of all consumers, regulatory oversight should therefore also facilitate the design of more dynamic tariffs that can reflect the actual conditions in the grid. ACER provides an overview of electricity distribution tariffs in the EU[140], which serves as a basis for the following section.

The network tariffs are set by the NRAs in 21 EU countries. In another three countries the methodology is approved by the NRA (only in Finland and Sweden are the tariff methodologies set by the DSOs without NRA approval).

Tariffs can be either energy-based (per kWh), power-based (per kW), paid in lump-sum or in some combination of these options. Different tariff structures can be applied for different cost types (e.g. metering charges can be a lump-sum, while the tariff part related to investment and operation in the network can be energy- and/or power-based). Table 5 below summarizes the current composition in EU Members States[141]. This shows that currently the distribution tariffs are predominantly energy-based, focusing on the total volume of energy withdrawn by the consumers. Moreover, in the majority of MSs the energy component represents over 50% of the withdrawal charges (usually reaching over 75% of the share).

139 CEER, 2021, CEER Approach to More Dynamic Regulation. Available at: https://www.ceer.eu/documents/104400/-/-/70634abd-e526-a517-0a77-4f058ef668b9.

140 ACER, 2021, Report on Distribution Tariff Methodologies in Europe.

141 Ibid.

Table 5: Composition of withdrawal tariffs for electricity distribution in the EU

	Tariff structure	Nr. Of MSs
All network users charged the same tariff (16 MSs)	Energy-based only	3
	Combination of energy-based and power-based	9
	Combination of energy-based and lump-sum	1
	Combination of energy-based, power-based and lump-sum	4
Different tariff basis for different user groups (10 MSs)	Mostly combination of energy-based and other components	10

Source: ACER, 2021.

Injection tariffs – charges for injecting energy into networks – are applied (on DS level) in 10 MSs. These charges are paid as a lump sum in four MSs, the rest being divided among other options. Germany is applying negative injection charges, remunerating the producers for avoided network costs.

A specific situation occurs for network users who both withdraw and inject energy into the grids. This might be energy storage operators (e.g. pumped hydro or batteries) or active consumers. In the case of energy storage in particular, this might result in double charging for the same energy, which is used mainly for balancing supply and demand in the network and may have actually reduce overall network costs. Therefore, as storage's utilisation of the networks may provide system benefits, it may be warranted to avoid double charging practices. An elegant solution may be the use of power-based charges, which would automatically avoid double charging – however such a choice should consider multiple other factors.

iv. Application of network tariffs for emerging technologies

The ACER report[142] investigated three emerging topics in distribution networks: power-to-X[143] facilities, charging points for electric vehicles and energy communities. Applying tailored network tariffs would facilitate the utilisation of the grid management potential of these concepts and technologies.

Currently, no NRA reports different tariff treatment for power-to-X facilities. A similar situation applies to operators of publicly accessible recharging points, with the exception of three MSs (Italy, Portugal and Spain). In these countries, the specific tariffs give more weight to the energy component than the general tariff (possibly to avoid disincentivising construction of new charging points that might initially see low utilisation rates). More concretely, in Italy and Portugal recharging infrastructure operators or the recharging service users can opt for a purely energy-based tariff, while in Spain the optional tariff has a higher energy component (but still contains a power component).

[142] Ibid.

[143] Transformation of electricity into another energy carrier, such as hydrogen (via electrolysis) or other low-carbon fuels.

Box 11: Network tariff incentives for citizen energy communities

In the case of citizen energy communities, a specific regulatory framework at national level has so far been designed only in Portugal. This is a specific tariff for self-consumption, effectively reducing the charges for the use of the public network to a minimal reimbursement of network costs the energy community is responsible for[144].

The following example from the Portuguese NRA is provided in the ACER report: if both the consumption and production units are connected to LV, distribution tariffs may only be due for the use of the LV grid, not for the use of higher voltage levels, such as MV and HV (as is applicable otherwise).

Therefore, the energy community is charged only for LV costs. However, this circumstance is conditional on the non-existence of reverse power flows (from lower to higher voltage levels). While Portugal is the only Member State with a framework for energy communities at national level, tariff adjustments are implemented (often for individual specific networks or on an experimental basis) or planned to be developed for energy communities in Belgium (Brussels region), Finland, France, Malta, and Italy.

Source: Author's own elaboration.

v. Temporal and spatial variations of network tariffs

In the case of injection charges, there are differences between the voltage level in seven MSs; Austria applies different charges in different geographical areas (irrespective of DSO network boundaries). In Finland and Sweden, the charges are based on the time of injection.

Withdrawal charges vary with the voltage level in all MSs. Austria is including spatial component, as in the case of injection charges. The time differentiation is not applied at all in 10 MSs, while nine MSs apply energy-based time differentiation and eight MSs apply combination of power- and energy-based time differentiation. The time-differentiated tariff is mandatory for all or some network users in seven MSs. The most used time differentiation is day/night (13 MSs), peak/off-peak (10 MSs) and seasonal (eight MSs). Dynamic tariffs are currently not applied in any MS.

ACER has investigated the possible correlation between the time-differentiated tariffs and deployment of smart-meters, but there was little evidence that these are connected (the deployment of smart-meters should enable implementation of time signals during 2021 only in the case of Ireland).

Time- or location-differentiated tariffs can be used to reflect the network conditions, including eventual congestions. However, further experience is required regarding the benefits of the use of such tariffs against the added complexity. Another important point of attention is the possibility for time-differentiated network and supply tariffs providing conflicting signals to consumers.

b. Conclusions

The network planning process is established on the distribution system level and the DSOs are cooperating to a certain extent with the TSOs to optimise the necessary level of investment. To integrate the expected variable RES additions in a cost-effective manner, this cooperation needs to be further widened.

[144] In the ACER report, a following example is provided: If both the consumption and production units are connected to LV: in that case distribution tariffs may be due only for the use of the LV grid, but not for the use of higher voltage levels, such as MV and HV (as is applicable to consumption-only units). However, this circumstance is conditional on the non-observation of reverse power flows (from lower to higher voltage levels).

However, the network development plans are focusing mainly on ensuring the security of supply and the consideration of energy efficiency or of the flexibility needs has not been widely integrated yet.

The regulatory frameworks for network operators are still largely orientated on CAPEX-based investments, and less attention is given to operational expenditures. Several trends could improve the cost-effectiveness of electricity grid operation if applied on a broader scale in more MSs:

- NRAs are moving towards incentive-based regulation, which rewards (financially) grid operators for achieving certain goals (like reducing network losses, operational expenditure);
- More NRAs are adopting the TOTEX approach, which gives the same priority to capital as well as operational expenditure; and
- NRAs are introducing regulation that allows and facilitates innovation, for example by introducing regulatory sandboxes.

The network tariff design remains so far relatively static, allowing only limited incentives for consumers to adapt their behaviour according to the network needs. Tariff structures are still predominantly energy-based, time of use components are not used broadly. In most countries, there are no specific tariffs tailored to active consumers and other new concepts, such as charging points for electromobility or citizen energy communities. This limits the potential of the demand side to contribute to network management and to lower the network operation costs.

3.3. Policy recommendations

c. Summary of problems and barriers identified in previous tasks

Based on the evidence gathered in previous chapters, the main problems in delivering the electricity grid ready for the 2030 level of renewable electricity production are:

i. Gaps in planned network development up to 2030

The increased ambition of Fit for 55 package is not yet reflected in the plans of transmission network operators, especially in the ENTSO-E scenarios.

The EDSO has undertaken a high-level analysis of the impacts of the increased targets on distribution networks. **The majority of the DSOs participating in our survey however indicate that they will wait for the resulting changes in national policies to adapt their plans** (although some indicate that they are actively taking steps to prepare for the increased ambition).

Given the usual length of legislative process at EU level and subsequent transposition periods into national frameworks, it will take several years before the national targets and policies are adapted to Fit for 55 ambition. This means that **the grid adaptations will be planned with some delays, limiting the time for implementation of the planned measures before 2030**.

ii. Gaps in implementation of grid adaptations

Many grid adaptation projects are facing delays in implementation. The average delay of electricity (transmission) PCI projects is 15 months. Similarly, the DSOs report an average implementation delay of 1.15 year, although only minority of them are actually facing significant delays. The most commonly cited reasons for delays are problems in permitting procedure, public opposition and, in the case of DSOs the lack of human and institutional resources. The COVID-19 pandemic also negatively impacted the project implementation, first by disrupting the works, but also by negatively impacting the delivery times and prices of necessary components and materials.

iii. Gaps in efficient network planning

The network development planning process has seen improvements in recent years, but the regulatory framework is still not fully adapted to facilitate cost-efficient network planning.

At EU level, the biggest gap is in the uncoordinated planning of energy sectors. Although the ENTSOs for electricity and gas are now developing common scenarios of future supply and demand, the lack of interlinked gas and electricity network model prevents optimising the investment in network adaptations.

At distribution system level, the focus is predominantly on ensuring the security of supply, while the efficiency and flexibility dimensions are yet to be fully introduced. This is also reflected in the fact that the most considered network adaptations are reinforced or new power lines and grid control measures, while lower number of DSOs are planning to invest in flexibility integration. This is especially the case for smaller DSOs, while larger operators indicate more progress in this aspect. Similarly, smaller DSOs also indicate the intention to cooperate with other network operators on network development coordination less often.

iv. Gaps in financing of the grid adaptations

Although there are great differences in the regulatory design between MSs, the regulatory frameworks currently favour the investment into new power lines and other infrastructure assets (CAPEX based), not taking into account other alternative solutions. Moreover, the regulatory frameworks do not incentivise innovative solutions for grid adaptations that could improve the efficiency of network operation.

The DSOs surveyed mentioned the reluctance of regulatory authorities to approve the necessary investment in network upgrades (and to allow the recovery of the costs via network tariffs).

In most cases, the NRAs have not yet implemented the appropriate network tariff structure that would incentivise the behaviour of consumers to minimise the network management costs. Dynamic network tariffs, as well as special tariffs for energy communities, active customers or electromobility are still largely missing.

The DSOs have also indicated that the rates of return on investment currently allowed are not sufficient to incentivise the necessary investment in variable RES integration. However, without a proper economic analysis, these claims should be taken with a degree of caution (since the same DSOs are the ones to profit from increasing the return rates).

b. Recommended policy measures to address the identified problems

Based on the assessment of the gaps in integrating renewables into electricity grids, the recommendations listed below should be taken at EU and national levels to help bridge the gaps and increase the chances for the EU to reach its carbon savings targets. These recommendations are classified into three categories:

- Implementation of existing EU policies: Before considering new EU policies, it is crucial to ensure that existing EU policies are properly implemented at MS level. The most relevant policy is the Electricity market reform, based on the Clean Energy for All Europeans package[145];
- Support of policy proposals: In the context of new policy proposals in the Fit for 55 package, some policies are highlighted as key elements that should be introduced; and

[145] European Commission, 2021, Electricity market design. Available at: https://ec.europa.eu/energy/topics/markets-and-consumers/market-legislation/electricity-market-design_en?redir=1.

- Additional policy recommendations: policies that have not yet been considered, but will be important to facilitate the modernisation of electricity grids and integration of additional renewable energy sources.

c. Implementation of existing EU policies

- Further work needs to be done on the implementation of updated electricity market design (in particular the Electricity Market Directive) at the national level:
- Introducing legislation that enables the establishment and functioning of citizen energy communities, and active customers;
- Introducing a regulatory framework that incentivises distribution system operators to use flexibility services;
- Introducing a regulatory framework for DSOs that will allow them to cooperate on the development of recharging points for electric vehicles;

Considering financial incentives for deploying alternative solutions to investment in new power lines, such as the use of flexibility (based on Article 32 of the Electricity Market Directive) This could be done by allowing the operator to keep part of the saved costs.

Network planning and investment

- Strengthening the requirements on the consideration of alternative types of investment;
- Introducing or strengthening incentives for expenses reduction for the network operators, by using TOTEX approach or efficiency-based remuneration;
- Including long-term estimates of flexibility service needs in Distribution Network development plans;
- Involving a wider group of stakeholders in the development of the network plans, including market participants providing innovative services, as well as energy communities.

Network tariffs

- Introducing dynamic price contracts for consumers.

d. Support of policy proposals

TEN-E Regulation revision

The views of distribution operators should be taken into account when developing the EU-wide TYNDP. The amendments of the TEN-E regulation, aiming at increasing the role of EU DSO entity in the TYNDP process should be adopted.

Fit for 55 package

Revision of the Renewable Energy directive

- MSs need to update their objectives with regards to renewable electricity generation deployment by 2030, so that grid operators have a clear view on the volumes of renewable energy that need integrating. Network operators need to take this into account when planning the future grid development in their Network Development plans.

Energy Efficiency Directive

- Supporting strengthening the requirements on adhering to energy efficiency first principle in network planning and tariff design.

e. Additional policy recommendations

- Introducing further regulation to streamline the permitting process for infrastructure projects other than the Projects of Common Interest and (such as setting one-stop-shops for distribution grid operators);
- Facilitating the cooperation between DSOs and TSOs. NRAs could be given a greater role in ensuring this, either by being the mediator or by overseeing the process;
- District heating and cooling network operators should also be involved in the cross-sectoral network planning process;

Facilitating regulatory support of innovation by introducing the dynamic regulation concepts:

1. Regulatory sandboxes;
2. Incentive regulation;
3. Pilot regulations and regulatory implementation;
4. Strengthened participation of and consultation with market participants.

4. THE POTENTIAL OF THE NEW RENOVATION WAVE ON BUILDINGS

4.1. Background

4.1.1. The Climate Target Plan and the role of decarbonising the EU building stock

Recent changes in the EU's climate ambitions have created more urgency in decarbonising the EU building stock. In the 2030 Climate Target Plan (CTP), the European Commission (EC) committed to cut net greenhouse gas (GHG) emissions in the EU by at least 55% by 2030, compared to 1990. Achieving this ambition will be crucial to keep to the Paris Agreement, especially given the Intergovernmental Panel on Climate Change's (IPCC) recent report indicating an urgent need to rapidly cut emissions to minimise the impacts of climate change.

Decarbonising[146] the building stock is one of the most significant and cost efficient ways to achieve the EU's targets, given that the EU building stock is responsible for 40% of the total energy consumption and 36% of energy-related GHG emissions in the EU[147]. **The building sector's GHG emissions need to decrease by 60%, final energy consumption by 14% and energy consumption for heating and cooling (H&C) by 18%[148].**

The building sector is also responsible for GHG emissions over the entire lifecycle of the building via the production of materials (i.e. embodied carbon) for its construction, renovation and end of life. In this context, on 14 October 2020, the EC published its Renovation Wave strategy, which aims to improve the energy and carbon performance of buildings.

4.1.2. The current state of renovations and energy efficiency improvements of the EU building stock

The current state of energy efficiency building renovations[149] in the EU is too slow and does not result in significant energy savings enough to reach the EU's climate ambitions. It is estimated that **75% of the current EU building stock will remain by 2050**[150], implying that energy renovations of the *existing* building stock in the next few decades will be crucial. The majority of the EU's building stock's floor area is residential (75%), while 25% is non-residential (commercial and public buildings)[151]. However, as commercial buildings are more energy intensive than residential buildings, about one-third of energy consumption in buildings occurs in non-residential buildings, while the remaining two-thirds occurs in residential buildings[152].

[146] Via energy efficiency improvements and replacement of fossil with renewables.

[147] European Commission, 2020, 2030 Climate Target Plan. Available at: https://ec.europa.eu/transparency/regdoc/rep/10102/2020/EN/SWD-2020-176-F1-EN-MAIN-PART-1.PDF.

[148] Compared to 2015 levels.

[149] Energy efficiency building renovations, or also called energy renovations, are renovation measures which improve the energy efficiency of a building. These measures include works such as window/door replacement, installation of thermal insulation, replacement of H&C systems.

[150] Esser, A. et. Al, 2019, Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU Final report, Publications Office of the European Union: Luxembourg.

[151] European Commission, n.d., EU buildings Factsheets. Available at: https://ec.europa.eu/energy/eu-buildings-factsheets_en.

[152] EASAC, 2021, Decarbonisation of buildings: for climate, health and jobs 2021.

Although 11% of the EU building stock undergoes some type of renovation each year, the weighted annual energy renovation rate[153] is only 1%[154] when looking at exclusively energy renovations. This renovation rate varies between MSs[155], as indicated in their Long-term Renovation Strategies (LTRS)[156]. These energy renovations typically do not result in large energy savings, with annual primary energy savings per renovation ranging from 9% to 17%[157]. Finally, in terms of reducing emissions in the building sector, embodied carbon over the building lifecycle is usually not addressed.

4.1.3. The Renovation Wave strategy

In this context, the Renovation Wave strategy (RWS) aims to at least double the annual energy renovation rate of residential and non-residential buildings by 2030 and to promote renovations that lead to significant energy savings, also known as *deep renovation*. This strategy sets up key principles, including the increase of energy efficiency, affordability, decarbonisation, circularity, health, and digitalisation of buildings, while maintaining the EU's architectural heritage.

4.1.4. Embodied carbon of the building sector

As mentioned, buildings not only produce emissions during their operation, but also during the production, construction, renovation process and demolition. To address this embodied carbon, alternative new building and renovation methods must be adopted to reduce the lifecycle emissions of buildings. There are two main ways to reduce lifecycle emissions during the renovation process: circular renovation methods and carbon sequestration via bio-based building materials (e.g. timber and bamboo instead of cement; wool, hemp or straw insulation instead of fossil- or mineral-based insulation).

a. Circular renovation

The EU building sector is responsible for 50% of all extracted raw materials[158] (via the production of building material) and contributes to 36% of the EU's waste generation[159] (via construction, renovation and demolition processes). Increasing the energy renovation rate could increase the construction sector's burden on raw material extraction and landfills. However, the use of recycled materials and using building materials more efficiently could mitigate these negative impacts. Circular building solutions therefore play an important role in decreasing (life-cycle) emissions of buildings.

With this in mind, circularity is one of the main principles of the RWS, which prescribes making buildings more resource efficient and circular. The EC also announced in the Circular Economy

153 The annual energy renovation rate is the percentage of buildings, out of the entire building stock, renovated annually.

154 European Commission, 2020, A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives. Available at: https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1835.

155 European Commission, 2021, Preliminary analysis of the long-term renovation strategies of 13 Member States. SWD(2021) 69 final.

156 LTRS are required MS strategy plans to support the energy renovation of the national building stock and decarbonising the building stock by 2050.

157 Residential and non-residential, respectively; Esser, A. et. al, 2019, Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU Final report, Publications Office of the European Union: Luxembourg.

158 European Commission, 2020, A new Circular Economy Action Plan. Available at: https://ec.europa.eu/environment/strategy/circular-economy-action-plan_en.

159 Eurostat, 2021, Waste statistics, 2021, available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics#Total_waste_generation.

Action Plan (CEAP) that a new Strategy for a Sustainable Built Environment will be introduced, which will promote circularity principles throughout the building lifecycle.

Other policy frameworks relevant for promoting and informing about the use of recycled and resource efficient building materials are Level(s), the Construction Products Regulation (CPR) and the Sustainable Products Initiative (SPI) of the Ecodesign Directive.

b. Carbon sequestration through the renovation of the existing building stock

The RWS goes beyond just reducing GHG emissions in the building sector by introducing ambitions to turn the EU's built environment into a carbon sink through the promotion of green infrastructure and the use of bio-based building materials that can store carbon[160]. As the majority of the EU's current building stock is expected to remain in the long-run, implementing bio-based material in renovations could be a way to make the building stock a carbon sink. However, the impact of bio-based material use in renovations is relatively small compared to the impact of using bio-based materials in new building construction, as more bio-based solutions can be implemented in the construction process.

4.2. Assessment of key challenges of the EU's building renovation wave strategy

This section seeks to assess the key barriers to the EU's building renovation wave strategy. The potential of the renovation wave to reach the EU's climate ambitions is analysed in Section 4.2.1, the key barriers are identified in Section 4.2.2, the existing EU policies addressing these barriers are mapped out in Section 4.2.3, the major gaps in the EU policies in addressing these barriers are identified in Section 4.2.4 and several case studies of innovative energy renovation policies are presented in Section 4.2.5.

4.2.1. The potential of the renovation wave to reach the EU's climate ambitions

Overall, the renovation wave does have the potential to reduce energy consumption and GHG emissions. However, the current legislative framework is not on track to bring about the renovation wave needed to reduce the building sector emissions by 60%, compared to 2015 levels. The main obstacle is the lack of alignment between the MS Long-term Renovation Strategies and the EU ambitions. There is also contention as to whether the goals set by the Renovation Wave strategy (RWS) are sufficient to meet the EU's climate ambitions. Finally, there is an investment gap in the building sector, which needs to be addressed in order to increase the rate and depth of renovation.

a. Energy savings via increasing renovation rate and depth

In order to reach the CTP targets, the RWS aims to at least double (to 2%) the annual energy renovation rate by 2030, leading to 35 million building units renovated by 2030. The strategy also aims to *foster* deep energy renovations, but does not provide a quantifiable goal.

However, the Member State LTRS do not always align with these estimates (Table 196 in Annex0). The varying base years and lack of explicit renovation rate ambitions makes the comparison incomplete[161].

[160] Bio-based building materials store carbon since bio-based materials are composed of carbon, which has been captured from the atmosphere via photosynthesis.

[161] Some MSs provide a renovation ambition in terms of number of renovated buildings instead of a specific rate.

There is also huge uncertainty around the capacity of MSs to reach the written level of ambition set by their LTRS, given the weak link with policy measures and financial means. There are also concerns about the inconsistencies between the actual energy consumption trends and the reported current energy savings, making monitoring of the actual progress challenging, and not comparable between MSs.

Based on studies and stakeholder views, the renovation rate target (2%) prescribed by the RWS is not sufficient to reach the target energy savings and emissions reduction. Based on the EUCalc model[162], the Buildings Performance Institute Europe (BPIE) estimates that the RWS's ambition to increase the renovation rate would lead to GHG emissions reduction of 42%, compared to the expected 60% and energy consumption in H&C would be reduced by 8%, compared to the expected 18%. To meet the emissions reduction proposed in the RWS, BPIE suggests that the annual renovation rate would have to triple (from 1% to 3%), with 70% being deep renovations (renovation that results in energy savings of at least 60%). A study by the European Academies Science Advisory Council (EASAC)[163] based on EC studies concludes that an average renovation rate of 3% is necessary to address 85%-95% of the existing EU building stock by 2050.

Other studies estimating the impact of increasing the renovation rate on energy savings and emissions also indicate a need for a higher renovation rate (i.e. >2%). However, varying methodologies (base/projection year, renovation rates, type of building and renovation, etc.) make comparisons between results difficult. A study by Pohoryles et al. (2020)[164] estimates the impact of the renovation rate on emissions and primary energy consumption, based on combined retrofitting schemes (energy and seismic). They find that a 1% (3%) annual renovation rate by 2030 would lead to a GHG emissions reduction of 10-20% (27-38%), compared to 2020 levels. Another study by Fraunhofer Institute for Systems and Innovation Research (ISI) (2019)[165] estimates the potential energy savings from renovating the building envelope and heating system of residential and commercial/public buildings by 2050. These type of investments in residential would lead to a 38% decrease in final energy consumption by 2050, compared to the baseline 2050 scenario. These measures would also lead to around a 40% decrease in final energy consumption by 2050 in service buildings.

b. Financing the renovation wave

There is a significant investment gap in the EU building sector, which can be filled by proposed EU funding, although the mobilisation of funds will be crucial, especially in the long term. From 2012 to 2016, it is estimated that about 282 billion EUR were spent annually on energy renovations in the EU[166]. Roughly 75% of this investment went towards residential buildings, while the remaining 25% was invested in private and public non-residential buildings[167].

[162] The EUCalc model is a model which forecasts the impact of European-level climate-related policy on several outcomes (e.g. energy use, GHG emissions, social/environmental impacts). The model allows differentiation of ambition levels in different sectors.

[163] EASAC, 2021, Decarbonisation of buildings: for climate, health and jobs.

[164] Pohoryles, D. et al, 2020, Energy performance of existing residential buildings in Europe: A novel approach combining energy with seismic retrofitting. Energy and Buildings, 223, 110024.

[165] Fraunhofer Institute for Systems and Innovation Research ISI, 2019, Energy Savings Scenarios 2050.

[166] Esser, A. et. al, 2019, Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU Final report. Publications Office of the European Union: Luxembourg.

[167] Ibid.

In addition to the current public and private investments, the EC suggests that around **275 billion EUR** of additional investment in building renovation is needed every year[168] to achieve climate targets, indicating an investment gap.

The EC mentions several financial instruments to finance the renovation wave (Table 6). From 2021 to 2027, an estimated **1,851 billion EUR** of funding is available for energy renovation of building from various EU sources. The Recovery and Resilience Facility (RRF), which the European Council agreed to endow with 672.5 billion EUR, can support MSs with renovation investment and energy efficiency related reforms. Even if 37% of the RRF must be targeted towards climate-related expenditure, there is not a specific obligation on MSs to dedicate a certain amount of the RRF to renovation and upskilling. Other EU financial instruments are suggested, such as InvestEU, the European Initiative for Building Renovation by the European Investment Bank (EIB), and possibly revenues from the EU Emission Trading System (ETS) (via the new Social Climate Fund).

Table 6: Estimated EU funding for Energy Renovation of Buildings 2021 to 2027

Type of funding	Funding Source	Responsible EU institution	Funding (billion EUR)
Direct EU funding	Multi-annual Financial Framework	DG REGIO	995
	Recovery and Resilience Facility	Secretary General DG REFORM	672
	React EU	DG REGIO	47
	Just Transition Fund	DG ENER	17.5
	Modernisation Fund	DG CLIMA	14
Leveraging private financing	InvestEU	EIB	9.1
	LIFE	DG ENVI	2.4
Research and innovation	Horizon Europe	DG RESEARCH	94
Total			**1851**

Source: Renovation Europe Campaign, Funding for Energy Renovation, n.d., available at: https://www.renovate-europe.eu/funding-for-energy-renovation/.
Note: Numbers based on the EU Commission Staff Working Document: SWD (2020) 550 final, October 2020.

Given the funding available, mobilising and targeting existing public funds will be crucial. However, depending exclusively on public funding is not sustainable, and triggering private investments is therefore also important[169].

[168] European Commission, 2021 Questions and Answers on the Renovation Wave. Available at: https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_1836.

[169] Bukarica V. et al, 2017, Renovation in Buildings, Odyssee-Mure. Available at: https://www.odyssee-mure.eu/publications/policy-brief/renovation-building-policy-brief.pdf.

4.2.2. Key barriers to achieving the renovation wave

There are four key barrier types to the Renovation Wave: lack of vision and targets, technical barriers, financial barriers and social barriers. Table 7 provides an overview of these barriers and of the type of building it primarily affects. For each barrier, the type of building it affects is identified. Lack of vision/targets impacts both residential and service buildings.

Financial barriers impact both the renovation of residential and service buildings, though some barriers are specific to vulnerable households in residential buildings. Technical barriers impact both building types. Social barriers are focused on primarily households in residential buildings.

Table 7: Overview of barriers to the renovation wave

Barriers		Type of building	Sources
Lack of a stable vision	EU ambitions are insufficient	Residential and service	BPIE (2021a); EU (2021d); interviews
	MS long term strategies are insufficient and not harmonised across MS	Residential and service	BPIE (2021b); Remeikienė et al. (2021); interviews
	Lack of integrated planning (*Silo thinking*)	Residential and service	Enefirst (n.d. a); BPIE (2020c); interviews
	Lack of political stability	Residential and service	Beillan et. al (2011); interviews
Financial	Lack of economic attractiveness	Residential and service	Bertoldi et. al (2021); Sunderland et. al (2020a); Esser et. al (2019); Fraunhofer ISI et. al (2017); D'Oca et. al (2018); Alam et. al (2019); Artola et. al (2016); Meyer et. al (2014)
	Difficulty for low-income households to access financial resources	Residential	D'Oca et. al (2018); Azizi et. al (2019); interviews
	Low investor/owner/ financial institution confidence in investments	Residential and service	D'Oca et. al (2018); Sunderland et. al (2020a); Beillan et. al (2011); interviews
	Split incentive problem	Residential and service (rental)	EASAC (2021); Bertoldi et. al (2021); Sunderland et. al (2020a); Esser et. al (2019); Alam et. al (2019)
Technical	Lack of sufficient labour	Residential and service	Brucker et. al (2021); Material Economics (2018); Artola et. al (2016); interviews
	Skills gap	Residential and service	Bertoldi et. al (2021); Sunderland et. al (2020a); Beillan et. al (2011); Alam et. al (2019); Esser et. al (2019); D'Oca et. al (2018); interviews
	Lack of data on actual energy savings	Residential and service	BPIE (2020c); interviews
Social	Lack of awareness amongst owners/ end users	Residential	Bertoldi et. al (2021); Sunderland et. al (2020a); Alam et. al (2019); Azizi et. al (2019); D'Oca et. al (2018); Fraunhofer ISI et. al (2017); Meyer et. al (2014); Beillan et. al (2011); interviews
	Lack of technical assistance	Residential	Sunderland et. al (2020a); D'Oca et. al (2018); Fraunhofer ISI et. al (2017); interviews
	Renovation complexity and disruptions	Residential	Sunderland et. al (2020a); Alam et. al (2019); D'Oca et. al (2018); Artola, I. (2016)

Source: Authors' own elaboration.

a. Lack of a stable vision

There is a concern that the EU's current policy framework and strategies (including the Renovation Wave) do not have a sufficient long-term and stable vision or strategy to adequately decarbonise the EU building stock by 2050. Stability over the long term is essential to build confidence along the value chain, to properly build capacities, invest in workforce, in R&D, and in assets.

The Renovation Wave's long-term renovation rate and depth targets are considered insufficient. As discussed in Section 4.2.1, studies have concluded that the (deep) renovation rate needs to be greater than 2% in order to reduce GHG emissions by at least 60% in the building sector. Additionally, several MS LTRS indicate that the renovation rate needs to be greater than 2%, keeping in mind these LTRS were based on the previous 40% GHG emissions reduction target[170].

Member States' long term renovation strategies (LTRS) are also criticized for not providing a sufficient or harmonised long-term vision for the Renovation Wave. A study by BPIE[171] pointed out that national LTRS do not provide a long-term vision up to 2050[172] and fail to meet several legal requirements of EPBD article 2a. The study concludes that most of the examined LTRS do not have set goals to fully decarbonise the building stock, energy reduction targets tend to be too low, and the LTRS provide insufficient details to analyse the adequacy of the policies, funding and other measures. However, a preliminary analysis of the available LTRS by the JRC[173] found the LTRS to be generally complete, despite raising concerns that the strategies do not provide sufficient details, i.e. lack of sufficient measures and concrete instruments to illustrate their ability to reach their ambitions. This creates concerns about the effective implementation of MS LTRS. The JRC study also pointed out that the national strategies are not harmonised in terms of types of data and policy measures, making a comparison of ambition levels difficult. Additionally, several MSs did not submit their LTRS on time[174]. This delay is partly recognised as a lack of prioritisation of the renovation wave[175].

Plans for decarbonising the building sector tend to think of solutions in silos. EE improvements and renewable H&C systems are intricately linked. Depending on the renewable supply available, improvements in energy performance can have a profound impact by decreasing the overall energy need of a building. In this way, EE improvements need to be cohesive and balanced with RES solutions. In practise, however, EU legislation is not sufficiently integrated[176]. For instance, the decarbonisation of the building sector is tackled separately within the Renewable Energy Directive (RED), Energy Efficiency Directive (EED) and Energy Performance in Buildings Directive (EPBD) without adequate synergies concerning EE improvements and transition to renewables. There also needs to be sufficient coherence between EU-driven national plans, such as the National Recovery and Resilience Plans (NRRPs), LTRS and the National Energy and Climate Plans (NECPs). For instance, the NRRP will accelerate renovation over the next six years, but plans such as the NECP by 2030 and LTRS by 2050 need to ensure that there is a sufficient (financial) strategy to continue after six years,

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170 European Commission, 2021, Preliminary analysis of the long-term renovation strategies of 13 Member States. SWD(2021) 69 final.

171 BPIE, 2021, The Road to Climate Neutrality. Are the national Long-Term Renovation Strategies fit for 2050? Available at: https://www.bpie.eu/wp-content/uploads/2021/03/BPIE_LTRS-_10-1.pdf.

172 Particularly in terms of ensuring financing up until 2050.

173 European Commission, 2021, Preliminary analysis of the long-term renovation strategies of 13 Member States. SWD(2021) 69 final..

174 Also partly due to the COVID-19 crisis.

175 BPIE, 2020, A review of EU Member States' 2020 Long-term renovation strategies. Available at: https://www.bpie.eu/wp-content/uploads/2020/09/LTRS-Assessment_Final.pdf.

176 Enefirst, 2021, Fabric first approach: main barriers and solution pathways. Available at: https://enefirst.eu/wp-content/uploads/Implementation-map-D4.2_DRAFT-Buildings_fabric-first.pdf.

to avoid a *stop-and-go* trend. At MS level, plans for decarbonising H&C need to be integrated with the national plans for decarbonising the building stock[177].

The lack of policy stability can create major disruptions in the renovation wave. The lack of certainty about regulation, triggered by cuts in public funding or fast pace of policy change, gives investors, including residential and commercial building owners, mixed signals on whether to invest in energy renovation[178] and causes instability across the entire value chain.

b. Financial barriers

As mentioned in section 4.2.1, an additional 275 billion EUR will need to be invested in building renovation every year to achieve the EC's climate targets. The main barriers to filling this investment gap are the lack of economic attractiveness of building renovations, the lack of investor/owner confidence, the lack of accessible financing and the lack of social safeguards.

Potential investors/property owners lack confidence in energy renovation and do not find the investment in decarbonising buildings attractive. The long payback time for energy renovation investments lowers investors'/property owners' confidence. This is partly due to the fact that the payback time often exclusively considers the benefit of lower energy bills and not additional benefits, such as indoor air quality and thermal comfort improvements. Low (fossil) energy prices[179], limited savings compared to other investments as well as a lack of guarantee of real savings also make energy renovation economically unattractive. Additionally, an overall lack of knowledge about energy efficiency renovation reduces financial institutions' confidence.

Homeowners and property owners, particularly those with a low income, do not have the financial means or accessible incentives to initiate energy renovations. According to 74% of consumers from an EC study[180], energy renovations are too expensive. A major concern is the high upfront costs of energy renovations, especially deep energy renovations and renewable H&C deployment[181,182]. Long payback times and insufficient guarantee of high efficient performance contribute to owners' reluctance to borrow funds for energy renovation[183,184], considering 78% of surveyed consumers in an EC study[185] prefer not to take out loans or mortgages for energy renovation. Additionally, low-income households, who generally are not eligible for (low interest)[186]

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177 BPIE, 2020, A guidebook to European Building Policy: Key legislation and initiatives. Available at: https://www.bpie.eu/wp-content/uploads/2020/08/BPIE_Guide-on-Building-Policy_Final.pdf.

178 Beillan, V. et al., 2011, Barriers and drivers to energy-efficient renovation in the residential sector: Empirical findings from five European countries. ECEEE Report, 2011.

179 Artola I. et al, 2016, Boosting Building Renovation: What potential and value for Europe? Available at: https://www.europarl.europa.eu/RegData/etudes/STUD/2016/587326/IPOL_STU(2016)587326_EN.pdf.

180 Esser, A. et. al, 2019, Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU Final report. Publications Office of the European Union: Luxembourg.

181 Fraunhofer ISI et al, 2018, Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables). Work package 5: Barriers, Best Practices and Policy Recommendations. Edited by European Commission Directorate-General for Energy.

182 D'Oca, S. et al., Technical, financial, and social barriers and challenges in deep building renovation: Integration of lessons learned from the H2020 cluster projects. Buildings, 8(12), 174.

183 Ibid.

184 Meyer, N. I. et al., 2014. Barriers and Potential Solutions for Energy Renovation of Buildings in Denmark. International Journal of Sustainable Energy Planning and Management, 1, 59-66, 2014. Available at: https://doi.org/10.5278/ijsepm.2014.1.5.

185 Esser, A. et. al, 2019, Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU Final report, Publications Office of the European Union: Luxembourg.

186 Azizi, S. et al., 2019, Analysing the house-owners' perceptions on benefits and barriers of energy renovation in Swedish single-family houses. Energy and Buildings, 198, 187-196, 2019.

bank loans, are insufficiently targeted in terms of funding[187]. As low-income households usually live in worse performing buildings, providing targeted financial means is important.

There is also the *split incentive problem*, where conflicting incentives between landlords and tenants prevent energy renovations from occurring. According to an EC study[188], 68% of tenants are concerned that energy renovations would only benefit landlords, as landlords may increase rent prices before renovations have resulted in lower energy bills for tenants, leading to less affordable housing. On the other hand, landlords may perceive the benefits only to impact the tenants in terms of lower energy bills. A balanced business case should be found between landlord and tenant.

c. Technical barriers

Technical barriers (i.e. lack of skilled workforce, lack of knowledgeable professionals, lack of knowledge (sharing), lack of accessible, metered data on energy consumption and savings) are another obstacle for the renovation wave.

The labour shortage in the EU construction sector is a significant bottleneck for the renovation wave[189]. From 2011 to 2020, the job vacancy rate[190] in the EU construction sector more than doubled to 2.9% with a peak at 3.5% in 2019[191]. The renovation wave is expected to create an additional 160,000 jobs in the EU construction sector[192], further increasing the importance to fill this labour gap and prevent an even greater labour shortage. Working conditions in the construction sector are seen as poor and unstable[193], with over 20% of all fatal work accidents in the EU in 2018 were in the construction sector[194]. This contributes to making the sector unattractive to the potential workforce, particularly the youth. Policies which create a stable demand for energy renovation could create more job security[195] and digitalisation and industrialisation of the sector could improve working conditions.

There is a skills gap in the building sector. Properly trained, local EE contractors and other professionals (architects and designers)[196,197,198] are in short supply. This can further create

[187] D'Oca, S. et al., 2018, Technical, financial, and social barriers and challenges in deep building renovation: Integration of lessons learned from the H2020 cluster projects. Buildings, 8(12), 174.

[188] Esser, A. et. al, 2019, Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU Final report. Publications Office of the European Union: Luxembourg.

[189] Brucker Juricic, B. et. al, 2021, Review of the Construction Labour Demand and Shortages in the EU. Buildings. 11(1), 17, 2021.

[190] Job vacancy rate is the proportion of total vacancy posts that are vacant. (number of job vacancies/(number of occupied posts + job vacancies))/100. This statistic provides information about labour shortages.

[191] Eurostat, 2021, Job vacancy rate by NACE Rev. 2 activity – annual data (from 2001 onwards). Available at: https://ec.europa.eu/eurostat/databrowser/view/JVS_A_RATE_R2__custom_1236766/default/table?lang=en.

[192] European Commission, 2020, A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives. Available at: https://ec.europa.eu/energy/sites/ener/files/eu_renovation_wave_strategy.pdf.

[193] The construction sector is highly impacted by business cycles, which creates an unstable workforce

[194] Eurostat, 2021, Accidents at work statistics, 2020. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Accidents_at_work_statistics.

[195] Bukarica V. et al, Renovation in Buildings. Odyssee-Mure, 2017, Available at: https://www.odyssee-mure.eu/publications/policy-brief/renovation-building-policy-brief.pdf.

[196] D'Oca, S. et al, 2018, Technical, financial, and social barriers and challenges in deep building renovation: Integration of lessons learned from the H2020 cluster projects. Buildings, 8(12), 174.

[197] Beillan, V. et al, 2011, Barriers and drivers to energy-efficient renovation in the residential sector. Empirical findings from five European countries, ECEEE Report.

[198] Alam, M. et al, 2019, Government championed strategies to overcome the barriers to public building energy efficiency retrofit projects. Sustainable Cities and Society, 44, 56-69.

complexity across the value chain, such as difficulty for architects to find enough competent installers available[199].

Professionals are also not always aware of the available energy efficiency[200] and holistic[201] solutions. This lack of expertise and confidence in the construction sector not only reduces the supply of trained professionals but leads to scepticism amongst consumers.

There is a lack of adequate communication and coordination between professionals in the building sector[202]. Local authorities often lack the necessary knowledge on the technical characteristics of the building stock and current renovation actions to create targeted energy renovation support[203]. Local authorities also lack expertise to plan heating and cooling decarbonisation, considering the energy supply and related infrastructure. On the supply side, the variety of professionals involved in the renovation process can create confusion for consumers. This lack of knowledge and coordination creates a complicated process for local authorities, which makes energy renovations unattractive[204].

Measuring the actual outcomes of energy performance improvements (i.e. metered data) is still a challenge. Lack of proper equipment and data management systems (e.g. building automation and control systems in service buildings) to measure energy performance makes it difficult for owners to estimate the results of their own renovation projects. It also makes it difficult for national and local authorities to estimate the actual impact of policies. There is also a lack of significant and systematic data collection.[205] Monitoring the progress of national targets and strategies is hindered by the inability to analyse the actual impact of EE policies.

d. Social barriers

On top of the complexity and inconvenience of renovation, owners' and tenants' lack of awareness of the benefits of energy renovation deters them from renovating.

Most households/owners are unaware of the EE solutions available as well as the potential energy savings and additional benefits of energy renovation. Households tend to have limited access to information about the potential energy savings from (deep) renovation[206] and underestimate its benefits, such as additional comfort and quality of life[207,208]. Additionally, not only do end users and owners lack trust (as mentioned in the technical barriers), they also lack technical

199 Esser, A. et al, 2019, Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU Final report. Publications Office of the European Union: Luxembourg.

200 D'Oca, S. et al, 2018, Technical, financial, and social barriers and challenges in deep building renovation: Integration of lessons learned from the H2020 cluster projects. Buildings, 8(12), 174, 2018.

201 Professionals in the construction sector tend to be specialised and not knowledgeable of buildings as a holistic system, which hinders the ability to take a holistic approach to building renovations.

202 Ibid.

203 Beillan, V. et al, 2011, Barriers and drivers to energy-efficient renovation in the residential sector. Empirical findings from five European countries. ECEEE Report.

204 Ibid.

205 BPIE, 2020, A guidebook to European Building Policy: Key legislation and initiatives. Available at: https://www.bpie.eu/wp-content/uploads/2020/08/BPIE_Guide-on-Building-Policy_Final.pdf.

206 Beillan, V. et al, 2011, Barriers and drivers to energy-efficient renovation in the residential sector. Empirical findings from five European countries. ECEEE Report.

207 Ibid.

208 Meyer, N. I., et al, 2014, Barriers and Potential Solutions for Energy Renovation of Buildings in Denmark, International Journal of Sustainable Energy Planning and Management, 1, 59-66, 2014. Available at: https://doi.org/10.5278/ijsepm.2014.1.5.

expertise in EE and renewable technologies[209], making the decision-making process more overwhelming (in terms of comparing options and making the right choice). According to an EC study, 66% of EU consumers consider the complexity of selecting the right technical measures a barrier to energy renovation and 65% think that the complexity of calculating the costs and benefits is a barrier[210].

Energy renovations can be inconvenient. Energy renovations are usually delayed until major renovations are required[211]. According to an EC survey study, necessary maintenance or inspections are the trigger for energy renovations for over 30% of EU consumers[212]. The decision making process is complex and long, especially in the case where approval is needed in multi-owner buildings[213]. Additionally, renovations can be a practical nuisance for residence in terms of creating disruptions and possibly requiring vacating the building[214].

4.2.3. Existing EU policy on energy renovation

In this section, we mapped existing EU level policies to the key energy renovation barriers described above; this exercise was designed to inform the gap analysis. Table provides an overview of how EU policy addresses energy renovation. Relevant amendments to existing EU policies from the Fit for 55 package are identified at the end of this section.

209 Fraunhofer ISI et al., 2017, Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables). Work package 5: Barriers, Best Practices and Policy Recommendations. Edited by European Commission Directorate-General for Energy.

210 Esser, A. et al, 2019, Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU Final report. Publications Office of the European Union: Luxembourg.

211 Meyer, N. I., et al, 2014, Barriers and Potential Solutions for Energy Renovation of Buildings in Denmark. International Journal of Sustainable Energy Planning and Management, 1, 59-66, 2014. Available at: https://doi.org/10.5278/ijsepm.2014.1.5.

212 Esser, A. et al, 2019, Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU Final report. Publications Office of the European Union: Luxembourg.

213 Alam, M. et al., 2019, Government championed strategies to overcome the barriers to public building energy efficiency retrofit projects. Sustainable Cities and Society, 44, 56-69.

214 Ibid.

Table 8: Mapping of existing EU policies relating to energy renovation barriers

	Barriers	EPBD	EED	RED	Other legislation	Financial instruments	EU databases and programmes
Lack of a stable vision	EU ambitions for the building sector are insufficient	LTRS	Energy savings target, energy savings obligation	Benchmarks and binding targets			
	MS long term strategies are insufficient and not harmonised across MS	LTRS (long term roadmap)			NECPs (GR)		Concerted Action EPBD
	Lack of integrated planning (*Silo thinking*)	LTRS (long term roadmap)		Integrated planning	EEF principle (GR)		
	Lack of political stability	Long-term development strategy					
Financial	Lack of economic attractiveness	LTRS (provide support & mobilise investments), EPCs, BRPs	Energy savings obligation, public sector exemplary		NECPs (mobilise investments), Ecodesign (Min. efficiency standards for building technologies)	Multi-annual Financial Framework, RRF, React EU, JTF, etc.	
	Difficulty for low-income households to access financial resources	LTRS (mobilise investments for energy poverty actions)	Energy performance contracting		NECPs (mobilise investments)	Multi-annual Financial Framework, RRF, React EU, JTF, etc.	EU Energy Poverty Observatory
	Low investor/owner/ financial institution confidence in investments	EPCs and BRPs	Energy performance contracting		Technical screen criteria (EU Taxonomy)	InvestEU and LIFE	DEEP
	Split incentive problem	LTRS (requirements)					
Technical	Lack of sufficient labour and skills gap	LTRS (requirements), upskilling programmes		Upskilling programmes, train installers			Pact for Skills, LIFE: Build up skills and European Alliance for Apprenticeships
	Lack of data on actual energy savings	Building stock observatory				Horizon Europe & New European Bauhaus	National EPC databases
Social	Lack of awareness amongst owners/end users and renovation complexity and disruptions	EPCs, LTRS (optional BRPs), consumer rights	Energy audits, consumer rights, Public sector exemplary	Consumer rights	NECPs (GR), consumer rights (ETD, Energy Labelling Directive)	Horizon Europe	National EPC databases Technical assistance (e.g. ELENA)

Additional action is needed

Source: Author's own elaboration.

a. Lack of a stable vision

EU legislation provides a (long-term) vision for the renovation wave in the form of energy savings/RES targets. It is intended to guide MS to make long-term goals and plans, but the regular changes are compromising the stable framework required by MS and economic actors. Also, some targets are not binding and ambitions are insufficiently implemented at MS level.

The **Energy Efficiency First principle**, established by the Governance Regulation (Art. 2), ensures that throughout energy planning, policy and investment decisions, MS should consider cost-optimal, alternative energy efficiency measures which could achieve the same objectives. In principle, this can be seen as a clear signal that heat planning tackling both energy efficiency and renewable supply should be integrated and stimulated. However, the EEF principle remains a high-level principle, without concrete implications.

EU Directives set the vision for increasing energy efficiency and phasing out fossil fuels in the building sector. The EED set targets for energy savings, although they are not binding. The RED sets a benchmark on RES in buildings and binding targets for RES in H&C. However, there are concerns that these targets are not sufficient to meet the EU's ambitions to cut emissions by 55% by 2030. Under the EPBD, Member States must submit Long Term Renovation Strategy (LTRS) (EPBD Art. 2a), which are intended to provide a long-term vision for MS to decarbonise their building stock. Although MS are expected to fix long-term clear goals up to 2050 in their LTRS, most of the MSs do not adequately address the requirement to create a comprehensive roadmap to 2050, especially regarding the final goal to decarbonize the sector[215]. Additionally, some MS National Energy and Climate Plan (NECP), established in the Governance Regulation, are not ambitious enough in terms of energy efficiency targets.

Overall, the EU legislative framework (i.e. EPBD, EED, RED) is intended to create policy stability by creating long-term developments of energy efficiency and renewable technologies and solutions. However, several elements reduce this confidence, such as the uncertainty around MS implementation of EU regulations and future changes to EU ambitions and regulations.

To improve the implementation of EPBD legislation at MS level, a joint initiative between the EC and MSs, called the **Concerted Action EPBD**, was initially launched in 2005. The Concerted Action EPBD is a platform to encourage sharing of best practises and related information between national ministries and agencies and also external stakeholders, such as researchers and experts[216].

b. Financial barriers

Several EU policy instruments exist to tackle financial barriers. These mainly address the mobilisation of investments, mitigating risk perception, energy poverty and affordable housing.

MSs are required to mobilise investments for energy renovation. However, most MSs do not adequately address these LTRS requirements (EPBD (Art. 2a(3))) and the LTRS are not detailed enough on how renovation agendas will be financially supported in the long term[217].

[215] BPIE, 2021, A review of EU Member States' 2020 Long-term renovation strategies. Available at: https://www.bpie.eu/wp-content/uploads/2020/09/LTRS-Assessment_Final.pdf.

[216] BPIE, 2020, A guidebook to European Building Policy: Key legislation and initiatives. Available at: https://www.bpie.eu/wp-content/uploads/2020/08/BPIE_Guide-on-Building-Policy_Final.pdf.

[217] BPIE, 2020, A review of EU Member States' 2020 Long-term renovation strategies. Available at: https://www.bpie.eu/wp-content/uploads/2020/09/LTRS-Assessment_Final.pdf.

NECPs should also include policies and measures to mobilise investment, however, most MS NECP policies and measures are too vague and incomplete, potentially leading to missed opportunities for financing and investment[218].

Several direct EU funding programmes will be utilised to finance the Renovation Wave, including the Multi-annual Financial Framework, the Recovery and Resilience Facility (RRF), React EU, the Just Transition Fund (JTF), and the Modernisation Fund. InvestEU and LIFE will be used to leverage private financing. Additional support schemes include the Smart Finance for Smart buildings initiative, the European Energy Efficiency fund (private-public partnership), and Horizon Europe. Mobilising and mainstreaming these financial resources will be key to maximise the full potential of the EU financial resources.

Financing barriers could also be tackled by reliable energy performance certificates (EPCs) (as outlined in EPBD (Art. 11)). The EPC is a tool to compare and assess the energy performance of buildings. It also provides recommendations for cost-optimal energy performance improvements, which can be used to certify the energy performance of a building. This creates an economic incentive to improve energy performance in buildings for owners as it can be used to increase the rental price.

The EED includes several provisions to mobilise national funds towards energy efficiency measures, including the renovation requirements on central government buildings (Art. 5) and the obligation for national funds towards energy efficiency measures (Art. 20)[219]. Additionally, the EED has greatly contributed to the development of energy performance contracting (EED Art. 18), where a specialised company (i.e. energy service company (ESCO) or Third Party Financing company) is responsible for EE improvements with performance guarantee for a specific duration of time and costs covered by the savings achieved. The EED also contributes to increasing the uptake of energy performance contracting (EED Art. 27)[220]. However, as of now, energy performance contracting is only used in the context of large commercial buildings. A good set up of Energy Performance Contracting or even Third-Party Financing schemes with an enabling framework (e.g. support instrument to reach an average payback time of 15 to 20 years for EE and RES investments) could leverage financial means.

Other EU instruments exist to attract investment into EE renovation: the EU Taxonomy includes a technical screening criteria for the building sector to direct private capital towards sustainable investments in energy renovation; and the De-risking Energy Efficiency Investment Platform (DEEP) reduces risk perception, although it could be improved by MS engaging all market players[221].

There are several requirements on MSs and EU support schemes to address energy poverty and housing affordability. MSs are obliged to address energy poverty and the split incentives problem under LTRS requirements (EPBD Art. 2a(1d)) and the Energy savings obligation (EED Art. 7(11)). However, most MSs do not adequately address or only meet the minimum LTRS requirement to outline national policies related to energy poverty and split-incentives[222]. This would need to be coupled with financing to ensure housing affordability.

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[218] Ecologic, 2019, Planning for net zero: assessing the draft national energy and climate plans. Available at: https://www.ecologic.eu/sites/default/files/publication/2019/2149-necp-assessment-ecologic-institute-climact_20190516.pdf.

[219] Economidou, M. et al., 2019, Accelerating energy renovation investments in buildings, EUR 29890 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-12195-4, doi:10.2760/086805, JRC117816.

[220] European Commission, 2021, Proposal for a directive of the European Parliament and of the Council on energy efficiency (recast). COM(2021) 558 final, 2021e.

[221] BPIE, 2020, A guidebook to European Building Policy: Key legislation and initiatives. Available at: https://www.bpie.eu/wp-content/uploads/2020/08/BPIE_Guide-on-Building-Policy_Final.pdf.

[222] BPIE, 2021, A review of EU Member States' 2020 Long-term renovation strategies. Available at: https://www.bpie.eu/wp-content/uploads/2020/09/LTRS-Assessment_Final.pdf.

The EU Energy Poverty Observatory, launched in 2018, focuses on promoting public engagement, enabling networking and knowledge sharing and providing technical assistance to combat energy poverty and could be involved.

c. Technical barriers

EU policies addressing technical barriers focus on closing the skills gap, encouraging knowledge sharing and funding research and development of innovative energy renovation technologies and solutions.

EU requirements on MSs and EU programmes address the skills gap in the construction sector directly and indirectly. MSs are required to outline national policies to promote skills and education in the construction and EE sectors (EPBD (Art. 2a(1f))). However, most MSs do not adequately address or only meet the minimum requirement to outline national policies related to skills and education[223]. A number of EU programmes promote knowledge sharing and skills development to address the skills gap in the construction sector, including: Pact for Skills[224], LIFE: Build Up Skills[225] and the European Alliance for Apprenticeships[226].

Several EU databases promote more knowledge sharing and make information more accessible to market players across the value chain, including: Building Stock Observatory (BSO), National EPC databases and the De-risking energy efficiency investment platform. However, there is still a lack of significant and systematic data collection[227]. Online platforms, such as Build-up and RenoWiki, exist to share best practices across MS. However, these existing databases have differing collection methodologies, which hinders comparability and comprehensiveness[228].

EU funding programmes, such as Horizon Europe and New European Bauhaus (in development) are financially supporting R&D for innovative energy renovation technologies and solutions. However, more funding needs to be directed towards industrialisation[229], digitalisation, and the relevant training and upskilling, to encourage the adoption of EE/RES technologies in the construction sector.

d. Social barriers

EU policy instruments seek to increase consumer knowledge and awareness, providing technical assistance and creating incentives for energy renovation.

EU Directives provide MSs with several policy instruments to increase consumer awareness and knowledge. Under the EPBD, there are Energy Performance Certificates (EPCs). However, EPCs in their current state are of low quality and are not easily accessible for owners[230]. There is also still a lack of awareness of the value of EPCs amongst intermediaries (architects, main contractors, installers, etc.).

223 Ibid.

224 The Pact for Skills is a networking/knowledge hub to support skills development.

225 Set up national qualification platforms and roadmaps for training the building workforce and facilitate the introduction of new qualification and training schemes.

226 Improve quality and supply of apprenticeships.

227 BPIE, 2020, A guidebook to European Building Policy: Key legislation and initiatives. Available at: https://www.bpie.eu/wp-content/uploads/2020/08/BPIE_Guide-on-Building-Policy_Final.pdf.

228 Steuwer et al, 2020, Lessons learned to inform integrated approaches for renovation and modernisation of the built environment, European Commission.

229 Ibid.

230 European Commission, 2021, Preliminary analysis of the long-term renovation strategies of 13 Member States. SWD(2021) 69 final, 2021c.

Furthermore, the implementation of EPCs at MS level varies greatly in terms of comprehensiveness and quality[231]. MSs also have an optional scheme for Building Renovation Passports (BRPs) in their LTRS (EPBD (Art. 2a(1c)), which is a digital instrument that provides a long-term, tailored plan for (deep) renovation for a specific building. However, only a few MS are implementing this tool and they are only in the early stages of the implementation phase. The LTRS requirements outlined in EPBD Art. 2a(1g) require MS to collect information on the potential energy savings and wider benefits of energy renovation. However, very few MS estimated wider benefits of energy renovation, and of those who did, only a couple of benefits were quantified. [232] This makes it difficult to perform a cost-benefit analysis. In addition, NECPs include information/awareness programmes. Energy audits, as mandated in the EED (Art. 8) for large companies every four years, are also a tool to increase awareness.

EU regulation protects EU consumer rights to information concerning energy in buildings. The EED includes requirements on billing and consumption information rights direct consumers. The information is important for final users to be informed about their energy consumption. Additionally, under the Energy Taxation Directive (ETD), electricity consumer rights are established in terms of customers' ability to choose their electricity supplier, access to information concerning the share of each energy source, environmental impact, etc[233]. In the Energy Labelling Directive, the obligation for MSs to use energy efficiency labelling schemes for products, such as those used in buildings, provides consumers information rights about the energy performance of their building products.

Databases, such as EPC databases, also trigger interest in energy renovation. However, the national EPC databases are not always easily accessible to the public.

EU instruments promoting technical assistance exist. The European Local Energy Assistance (ELENA) provides technical assistance for EE and RES investments. One-stop-shops are promoted, as indicated in the EPBD and RED. Horizon Europe is funding one-stop-shop projects such as OpenGela, for instance. Other EU instruments for technical assistance include the Recovery Plan: Technical Support instrument, EU City Facility and LIFE: Project Development Assistance Facility.

e. Fit for 55: Adapting the current EU policy framework to the Renovation Wave

Many EU policy revisions are currently under discussion to align policy with the EU's climate ambitions established in the CTP and to advance the vision set by the RWS. Most of these amendments are under the Fit for 55 package. It will be crucial to create synergies between all these legislative frameworks.

One of the key legislative drivers of the RWS is the revision of the Energy Performance of Buildings Directive (EPBD)[234]. One of the possible new EPBD measures driving energy renovations in the EU building stock may be the phased introduction of mandatory minimum energy performance standards (MEPS)[235], which would require some buildings to increase energy efficiency to certain standards and potentially drive better-performing buildings towards nearly Zero Energy Buildings (nZEBs).

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[231] BPIE, 2017, Building Renovation Passports: customised roadmaps towards deep renovation and better homes. Available at: https://www.bpie.eu/wp-content/uploads/2017/01/Building-Passport-Report_2nd-edition.pdf.

[232] BPIE, 2021, A review of EU Member States' 2020 Long-term renovation strategies, 2020b. Available at: https://www.bpie.eu/wp-content/uploads/2020/09/LTRS-Assessment_Final.pdf.

[233] Odyssee-Mure, Mure Database, n.d., Available at: https://www.measures.odyssee-mure.eu/energy-efficiency-policies-database.html.

[234] European Commission, 2021, Energy efficiency – Revision of the Energy Performance of Buildings Directive, 2021a. Available at: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12910-Energy-efficiency-Revision-of-the-Energy-Performance-of-Buildings-Directive_en.

[235] European Commission, 2021, Inception Impact Assessment. Available at: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12910-Energy-efficiency-Revision-of-the-Energy-Performance-of-Buildings-Directive_en.

Additionally, the update of the Energy Performance Certificates' (EPCs) framework could increase the quality and availability of building performance information.

Other possible measures include introducing Building Renovation Passports (BRPs), implementing deep renovation standards and addressing resource efficiency, circularity principles, digitalisation, climate resilience, health and environmental standards. The revision of the EPBD is planned to be adopted by the EC in the last quarter of 2021[236].

The revised Renewable Energy Directive (RED), published in July 2021, sets a new benchmark of 49% renewable energy sources (RES) in buildings. The H&C 1.1 percentage point annual increase target has become binding and RES in district H&C[237] should increase to 2.1 percentage points every year. These revisions encourage the phasing out of fossil fuels and support the adoption of RES in buildings.

The revised Energy Efficiency Directive (EED), published in July 2021, sets higher targets for energy savings (39% for primary; 36% for final), puts legal requirements on implementing EEF in planning and investment decisions, requires that MSs increase the renovation rate of public buildings to 3%, encourages the public sector to use Energy Performance Contracts for renovation, prioritises energy efficiency measures for vulnerable and energy poor households and empowers final consumers with basic contractual rights on heating, cooling and hot water.

The revision to the EU ETS, published in July 2021, includes a proposed separate emissions trading system (ETS) for the buildings sector, which will incentivise decarbonisation by putting a price on fossil fuels and by generating revenues for MSs to support the decarbonisation of buildings.

4.2.4. Gap analysis

The previous exercise revealed the major gaps in EU policy to reach the EU's previous and new climate ambitions in how it addresses barriers to energy efficiency improvements in buildings. Table outlines these policy gaps. Although some existing EU policies address these barriers, they are not always sufficiently implemented at MS level. Therefore, the policy gaps have been categorised as concerning: gaps due to insufficient EU policies/measures (EU level) or due to insufficient MS action/implementation of EU policies (MS level). Note that gaps at MS level are general and the situation varies per MS.

[236] European Commission, 2021, Energy efficiency – Revision of the Energy Performance of Buildings Directive. Available at: https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12910-Energy-efficiency-Revision-of-the-Energy-Performance-of-Buildings-Directive_en.

[237] District heating and cooling is a system where heat/cold is distributed to building through insulated pipes.

Table 9: EU policy gaps for tackling energy renovation barriers

Barriers	Policy gap	MS level	EU level	MS level
Lack of a stable vision	Insufficient MS long-term vision and implementation	MS NECPs are not ambitious enough in terms of EE targets		X
		MSs LTRS lack sufficient detail to create an adequate long-term vision		X
		Uncertainty about MS implementation of EU regulations		X
	Lack of integrated planning	Lack of adequate synergies between EU legislative frameworks	X	
Financial	Lack of MS long-term financial planning and implementation	Lack of coordination between EU and national/local level government	X	X
		MSs LTRS insufficiently address requirements to support mobilisation of investments and lack detail on how renovation agendas will be financially supported in the long-term		X
		MS NECP policies and measures are vague and incomplete and lead to missed opportunities for financing and investment		X
	Lack of accessible funding and instruments	EU funding programmes need to be mobilised and mainstreamed	X	
		Energy performance certificates are not easily accessible	X	
		Energy performance contracting is only used in the context of large, commercial buildings	X	
	Insufficiently addressing energy poverty and split incentives	MSs LTRS insufficiently address energy poverty and split-incentives		X
Technical	Insufficiently addressing need for labour capacity and upskilling	MSs LTRS insufficiently address skills and education		X
		Lack of sufficient funding towards industrialisation and digitalisation of the sector and the relevant training/upskilling	X	X
	Lack of accessible data and monitoring	There is a lack of significant, systematic data collection	X	X
		Insufficient publicly accessible data and monitoring of actual energy consumption	X	X
Social	Insufficient accessibility of information	Energy Performance Certificates (EPCs) are of low quality and not easily accessible for owners and intermediaries (e.g. architects, installers, etc.) lack awareness of the value of EPCs.	X	X
		Implementation of EPCs at MS level varies greatly	X	X
		Very few MSs have implemented Building Renovation Passports	X	X
		Lack of estimation of wider benefits of renovation at MS level (in LTRS)		X
	Lack of technical assistance programmes on a large scale	Need for sufficient funding to scale-up technical assistance programmes	X	X

Source: Authors' own elaboration.

4.2.5. Case studies

To illustrate policies which address the barriers identified in Section 4.2.2, innovative energy renovation policies implemented by MSs or other countries identified in the course of the literature review and interviews were further developed into nineteen case studies. Table 10 provides an overview of the case studies (further information in the Annex provides the details of each case study). Policies were chosen based on: relevance (effectively addressing renovation barriers), success (policy resulted in energy/carbon savings, boosting renovation) and innovation (using new, innovative mechanisms to trigger innovation). These case studies, showcasing the approach taken at national or regional level to tackle these barriers, can guide EU policy. However, it is important to keep in mind that successful policies at country level do not necessarily translate to similar outcomes in another country. Some level of flexibility at EU level to allow MS to apply tailored solutions based on local needs is important.

Table 10: Overview of innovative energy renovation policy case studies

Type of policy	Country, Policy
Integrated planning	Germany (Baden-Wurttemberg), Climate Protection Law: Heat Planning Denmark (Sonderborg), ProjectZero
Financing	Belgium (Gent), Knapt Op – Recurring Fund Germany, KfW Energy-efficient construction and refurbishment programmes France, MaPrimeRénov Austria, Residential building subsidy Ireland, Heat pump grants Italy, Superbonus scheme
Digitalisation	Germany, Energy savings meter
Information/ awareness	Belgium (Flanders), Woningpas and EPC+ Germany, Individueller Sanierungfahrplan France, Passeport Efficacité Energétique Denmark, Better Home France (Alsace), Oktave Belgium (Brussels), HomeGrade
Regulation/ standards	England & Wales, Minimum Energy Efficiency Standards Scotland, Minimum Energy Efficiency Standards Belgium (Flanders), Flemish Renovation Pact – Minimum requirements for roof insulation and glazing The Netherlands, Office building MEPS

Source: Authors' own elaboration.

4.3. Additional potential for emissions reductions and costs from circular and bio-based renovation methods in existing buildings

This section assesses the additional potential of circular and bio-based renovation methods in decarbonising the existing EU building stock, the potential for emissions reduction and costs from circular/bio-based energy renovation methods. Several case studies of innovative circular/bio-based energy renovation policies are also presented below.

4.3.1. Estimated potential and cost of circular/bio-based renovation methods in achieving emissions reduction in buildings and districts

The potential energy and carbon savings from circular and bio-based renovation methods in buildings and districts has been estimated based on literature review and expert interviews. Overall, there is some evidence that these renovation methods provide reductions in both energy consumption and emissions. However, a lifecycle approach taking into account embodied and sequestered carbon emissions is necessary to realise this potential. However, this evidence is limited, particularly for renovation. There are also some concerns about the sustainability of slow-growing bio-based building materials due to the increased pressure it puts on resources.

a. Estimated potential of circular renovation methods

As buildings become more energy efficient and use low-carbon energy, embodied carbon[238] in building material will become a more important factor, as it becomes a greater portion of a building's lifecycle carbon footprint. Reducing the burden of extracting raw materials through circular renovation methods therefore reduces the embodied carbon in buildings. A study by Material Economics[239] estimated the impact of circular construction methods on emissions in the EU construction sector (Table 11).

[238] Embodied carbon is the sum of all carbon emissions from the process of producing a good or service, in this case, building materials.

[239] Material Economics, 2018, The Circular Economy: A powerful force for climate mitigation.

Table 11: Impact of circular building opportunities on carbon emissions in 2050 circular scenario

Circular building opportunities	Carbon emissions reduction (Mt CO2 per year)	Impact on building material carbon emissions per year, 2050 circular scenario compared to 2050 baseline (%)
Cement recycling	13	6%
Reduce material waste	10	4%
Reuse of building components	20	9%
Materials efficiency[240]	24	10%
Circular construction activities subtotal	**67**	**29%**
Sharing[241]	13	5%
Prolonging lifetime of buildings[242]	43	19%
Total	**123**	**53%**

Source: Material Economics, The Circular Economy: A powerful force for climate mitigation, 2018.

According to the Material Economics study, a gradual adoption of circular building opportunities is estimated to reduce annual carbon emissions of building materials by 53% by 2050 (-123 Mt CO2 per year, and when considering circular construction activities alone, carbon emissions would be reduced by 29% (-67 Mt CO2 per year), compared to the scenario in 2050 where none of the circular actions are taken. This scenario is ambitious, but the authors note that it is still incremental. Of the circular construction activities, material efficiency and reuse of building components would have the most impact. It is important to note that these estimates make a distinction between the emissions reduction from renovation and those from new construction.

Additionally, some case studies show the climate potential of circular renovation methods. The Horizon2020 project DRIVE0[243] developed and implemented seven circular renovation cases in seven EU MSs. Some of these projects indicated a 25% to 50% cost reduction compared to current deep renovation strategies based on a high level of prefabrication using locally mined existing materials, while also indicating energy savings (125-315 kWh/m^2) greater than the EU average for deep renovation (112 kWh/m^2). However, the use of prefabrication and bio-based materials makes it difficult to know to what extent circular methods attributed to these results. A series of Swedish case studies of reuse projects found that about 30 tons of CO_2 were saved[244] per project.

240 Use less material per building via less over-specification, improved design and high-strength materials.

241 E.g. office sharing, more communal spaces.

242 Via adaptation/renovation of existing buildings.

243 Driving decarbonisation of the EU building stock by enhancing consumer centred and locally based circular renovation process.

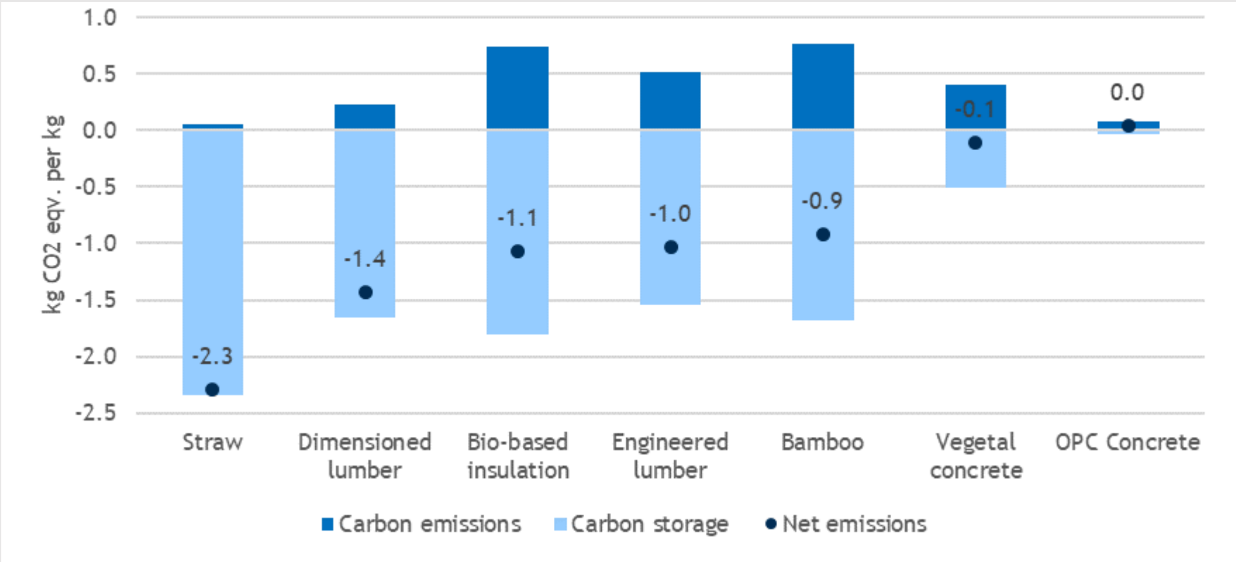
244 Andersson J. et al, 2021, Potential, effects and experiences from recycling in the construction and real estate sector from the local collaboration arena in the Gothenburg region "Recycling West". Available at: https://www.ivl.se/download/18.182a90c917b9f528bf17f31/1631266000401/FULLTEXT02.pdf.

They concluded that most of the reused building materials were non-renewable, meaning reused material potentially have a bigger environmental value than climate value.

b. Estimated potential of bio-based renovation methods

Using bio-based construction materials has the potential to reduce net carbon emissions by storing carbon. For instance, while traditional construction material, such as concrete and aluminium, produce embodied emissions, wood produces net negative emissions thanks to its carbon storing properties[245]. However, not all bio-based building materials have the same carbon storing capabilities and some bio-based materials emit more emission than others. Straw, bio-based insulation and lumber in buildings have high potential to reduce net emissions when looking at net emissions per kg of material ($\leq$-1. Kg CO2e/kg net emissions) (Figure 10)[246,247].

Figure 10: Carbon storage potential of bio-based building materials



Source: Pomponi, Francesco, et al., 2020 and Arehart, J. et. al., 2020.
Note: Straw can be used in the building envelope as a structural and insulative material; OPC= ordinary Portland cement.

The estimates for emissions reduction vary from study to study[248], depending on several factors, such as the method of estimation, the building type studied, the compared material as well as the metrics used. Table 22 in Annex 0 provides an indicative overview of the range of estimates of emissions reduction from using wood-based building materials.

In terms of turning the EU building stock into a carbon sink, fast growing bio-based building materials (e.g. straw, hemp) are considered to have more potential in the short term (to 2050) than slower growing bio-based material, such as timber. However, there are additional technical constraints which discourage the use of fast-growing bio-based solutions. This is due both to sustainability and feasibility concerns[249].

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245 van Dam J. et al, 2019, Catalogus biobased bouwmaterialen 2019, available at: https://www.biobasedeconomy.nl/wp-content/uploads/2019/02/GG-22-Catalogusbouwmaterialen-site.pdf.

246 Pomponi, Francesco, et al, 2020, Buildings as a global carbon sink? A reality check on feasibility limits., One Earth 3.2 (2020): 157-161.

247 Arehart, J. et al, 2020, How much carbon can construction materials store?, Poster from AscUS (un) Conference 2020. Available at: https://ascus.metabolismofcities.org/presentations/18283/.

248 Hill, C. A. S., 2019, The environmental consequences concerning the use of timber in the built environment. Frontiers in Built Environment, 5, 129.

249 Churkina, G. et al, 2020, Buildings as a global carbon sink. Nature Sustainability. 3(4), 269-276.

There are concerns that increased demand of timber could lead to the intensification of deforestation and illegal logging, which would also reduce forest carbon stocks in the short-term[250]. However, this is a less of a concern for fast-growing bio-based materials, such as straw and hemp for insulation[251]. Additionally, fast-growing bio-based materials are found to have greater capacity to store carbon in the short term[252]. However, in the long term, the difference in potential between slow and fast growing bio-base materials disappears[253]. Additionally, there are technical constraints to bio-based insulation, as bio-based insulation is less performant than synthetic insulation products.

There are also concerns that the environmental consequences of the maintenance of wood building materials outweighs the benefits from carbon sequestration. For instance, specific chemical preservative treatments are needed for wood that is implemented in buildings and these chemicals can have significant environmental impact. This aspect on the maintenance and treatment of bio-based building materials is currently not considered in lifecycle assessments.

4.3.2. Case studies

Innovative renovation policies, which promote the use of circular/bio-based renovation methods, implemented by MSs or other countries identified in the course of the literature review and interviews, were further developed into case studies. We built four case studies, which are documented below. Note that some policies only currently cover new constructions, not renovations. The case studies consist of:

- Green Deals – Circular buildings, the Netherlands;
- Recycled Construction Materials Ordinance, Austria;
- Dutch Decree – Environmental Performance Calculation for Buildings, the Netherlands; and
- LCA Center Denmark, Denmark.

A detailed description of each case study is in Table 21 in Annex 1.

4.4. Policy evaluation and recommendations

Based on the assessment of policy gaps and case studies, the recommendations listed below are suggested to be taken at EU level to help bridge the policy gaps and increase the chances for the EU to reach its carbon savings targets. These recommendations are classified into three categories:

Implementation of existing EU policies: Before considering new EU policies, it is crucial to ensure that existing EU policies are properly implemented at MS level, which is far from being the case, as some of them have only been recently introduced[254];

Support of policy proposals: In the context of new policy proposals in the Fit for 55 package, certain policies are highlighted as key elements that should be introduced; and

Additional policy recommendations: policies which have not yet been considered, but will be important to boost energy renovations.

[250] Pomponi, F., et al, 2020, Buildings as a global carbon sink? A reality check on feasibility limits. One Earth 3.2, 157-161.

[251] Pittau, F. et al, 2018, Fast-growing bio-based materials as an opportunity for storing carbon in exterior walls. Building and Environment, 129, 117-129.

[252] Göswein, V. et al, 2021, Influence of material choice, renovation rate, and electricity grid to achieve a Paris Agreement-compatible building stock: A Portuguese case study. Building and Environment, 195, 107773, 2021.

[253] Ibid.

[254] For instance the revised EPBD (2018) and RED II (2018).

Based on our findings, the recommendations are:

Implementation of existing EU policies

1. **EU guidance on and monitoring of implementation of existing EU policies**: Not all existing EU policies are effectively implemented at MS level yet. It is crucial to ensure that these policies are realised at MS level first;
2. **Integration of existing planning:** there is a need for EU and national planning to be more integrated (e.g. LTRS, EED National Comprehensive Assessment[255], RED II renewable potential assessment[256] and the NECPs). These synergies ensure policy stability for actors across the value chain and provide confidence to owners/investors;
3. **EU guidance on MS LTRS updates**: In order for the EU to meet its carbon savings targets, MSs must be aligned in their ambitions and MSs must adequately meet all requirements for LTRS set up in the current EPBD. It is also important that MSs' calculation and monitoring of progress is cohesive; and
4. **Promote energy services**: Stimulate energy services via guidance and financial and/or de-risking instruments. Energy service companies (ESCOs) should be promoted because they are able to address financial, technical and social barriers through their services. This will expand the contribution of Energy Performance Contracts to the renovation wave. In particular, encouraging digitalisation in energy services (e.g. metering and grid flexibility) can improve data collection and monitoring of actual energy savings.

Support of policy proposals

5. **Strengthen Energy Performance Certificates (EPCs)**: improve the quality of EPCs and encourage the use of them, which will make energy renovation more attractive, and link EPCs with (or even evolve towards) Building Renovation Passports. This will provide owners/renovation professionals more useful and accessible information and drive renovation via financial incentives during trigger points (selling and rental). EPC should be reconciliated with real final energy consumption data and EPC databases should be made publicly available (after aggregation and anonymisation) to trigger interest in energy renovation amongst owners[257];
6. **Minimum Energy Performance Standards (MEPS)**: Oblige MS to set up MEPS, in line with their LTRS, or replace with equivalent measures making the progressive renovation of each single building compulsory to reach full decarbonisation, and linked with financing, to drive renovation while ensuring enough financial capacity. A timeline constraint should be made for MS to ensure timely implementation, but there should also be some MS flexibility, as some MSs already have some type of MEPS set up. MEPS should be linked with existing EPCs and mainstreamed in LTRS; and
7. **Financial support, with special attention to low-income households:** grants and subsidies with the intensity of funding, depending on the depth of renovation and the level of performance and level of income, to encourage deep and/or progressive renovation to reach full decarbonisation, and improve accessible financing to low-income households.

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[255] Member States shall carry out and notify to the Commission a comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling, namely the National Comprehensive Assessment (NCA) (under Article 14 of EED - Directive 2012/27 on Energy Efficiency).

[256] Member States shall carry out an assessment of their potential of energy from renewable sources and of the use of waste heat and cold in the heating and cooling sector (under Article 15(7) of REDII - Directive 2018/2001 on renewable energy).

[257] BPIE, 2020, A guidebook to European Building Policy: Key legislation and initiatives.

Additional policy recommendations

8. **Integrated local planning**: Empower local authorities and oblige them to plan H&C decarbonisation. For many EU measures, administration at local level is crucial. However, local authorities need the financial and knowledge capacity at all levels (e.g. planners, architects, workers, etc.) in order to implement these measures. Local authorities should be obliged to plan H&C decarbonisation, integrating EE and RES solutions, to avoid future lock-in effects;
9. **Stable and long-term financial incentives via LTRS**: Enforce MS to integrate LTRS and financial strategy, and link all policy instruments with long-term financial support (especially NRRP), to ensure long-term financial planning to create financial certainty for owners, investors, and all economic actors across the value chain;
10. **Adequate long-term funding for technical assistance instruments/tools:** Ensure that local technical assistance instruments/tools (e.g. one stop shops, BRPs, etc.) are adequately funded (via EU or MS funds) on the long term to ensure stability and scale-up of services;
11. **EU guidance on skills development and attract labour to the construction sector:** Provide guidance to MS to develop/improve skills of all building professionals and to improve the perception of the construction sector to attract new workers via digitalisation and industrialisation. Digitalisation and industrialisation of the sector are key elements to incorporate in upskilling as well as to improve the perception of the construction sector for high skilled workers;
12. **Encourage MS to integrate the Life Cycle Approach (LCA):** The EU should suggest MS to integrate LCA and require MS to consider a future expansion of the scope of existing measures (e.g. MEPS, EPCs) to account for the life cycle of buildings;
13. **Encourage MS to investigate circular renovation opportunities:** The EU should encourage MS to study further into balancing the requirements of the renovation wave (increasing the workforce and achieving real savings) and consider where possible to promote circular construction; and
14. **Encourage MS to investigate bio-based renovation opportunities:** The EU should recommend MS to further study and consider the costs and benefits of using bio-based materials in the renovation process, taking into the viability of the resource in the context of the bio-economy and bioenergy.

Table 23 in Annex 1 maps out the policy recommendations with the policy gaps that they address.

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ANNEX

Industry

Interviews

We conducted seven 60-minute interviews with 10 industry stakeholders. The purpose of the interviews was to update, augment, contextualise, and test information gained in the literature review.

Table 12: Industry stakeholders interviewed

	Name	Organisation
1	Rob van der Meer	The European Cement Association (CEMBUREAU)
2	Malgosia Rybak	Confederation of European Paper Industries (CEPI)
3	Cillian O'Donoghue	Eurometaux
	Nikolaos Bitsios	
	Nikolaos Keramidas	
4	Adam Pawelas	Danone Waters (FMCG sector)
5	Bernard Gilmont	European Aluminium association
	Christian Leroy	
	Sandro Starita	
6	Catherine Cooremans	University of Lausanne

The interviews were semi-structured, meaning that interviewees received questions ahead of time, but the interviewers also asked follow-up questions during interviews. Notes were sent to interviewees for review and validation and are included in the Annex. The **interview questions** are listed below.

1. What is your role at your organisation?
2. How aware or involved are you in your industry's decisions about energy efficiency?

<u>Historical energy efficiency</u>

3. Energy efficiency is defined as the ratio of the useful output to a process to the energy input to the process. What measures or actions were taken in recent years by your industry to improve energy efficiency?
4. How effective were these measures or actions in reducing energy consumption and consequently GHG emissions?
5. Why were these measures undertaken? What were the main drivers to adopt these measures?
6. Is it common to have energy management systems (e.g., ISO 50001) and regular energy audits in your industry?
7. Are there any interesting benchmarking reports (publicly published) in your industry that relate to energy efficiency?

Impact of current EU/govt policy

8. What impact did EU policy have?
9. What impact did Member State policy have?

EU/Govt policy gaps

10. How much more energy savings potential would you say there is in your industry in the near-medium term? It's ok to use terms like low, med, high, approximate %s
11. What are the barriers to achieving this potential?
12. How could EU policy better address these barriers?

Digitalisation

13. To what extent have processes in your industry been digitalised?

Circular economy

14. To what extent have processes in your industry been adopting circular economy measures?

Analysis of how EU policy addresses obstacles to energy efficiency in industry

Table 13: How current and proposed EU policy address key barriers to energy efficiency

Policy		High uncertainty about the long-term value of energy efficiency investments	Organisational ineffectiveness	Lack of clarity on decarbonisation pathways
EU Emissions Trading System	**Current policy**	Current pricing schemes contribute to organisational ineffectiveness because they result in market signals that undervalue energy efficiency investments compared to other decarbonisation or operational excellence projects. Updated schemes under Fit for 55 today only worsen this ineffectiveness because business managers know less about what fuel prices look like as a result of new policies.	The EU ETS sets a carbon price and a cap on emissions for certain economic sectors every year. The cap and free allowances and being reduced gradually every year. The current ETS incentivised EIIs to invest in EE by adding the cost of carbon to that of energy use. However, in some cases, waste heat recovery is not valorised through ETS, thus, discourages investments in this space. Regulatory compliance costs negatively affected industry's competitiveness, resulting also in carbon leakage and investments leakage.	The combined uncertainty of the ETS, CBAM, and ETD, under Fit for 55 makes it hard for industry to develop business cases for decarbonisation pathways, including energy efficiency projects because the resulting impacts on energy prices is unknown. Price uncertainty is compounded by uncertainty around which fuels will actually be relied on, which will vary depending on how the RED II and LULUCF elements of the package are finalised, in addition to how infrastructure and markets for hydrogen develop. Investments in plant to improve energy efficiency need to be for equipment that uses fuels the infrastructure and prices for which can be relied upon and forecasted with reasonable certainty.

Policy		High uncertainty about the long-term value of energy efficiency investments	Organisational ineffectiveness	Lack of clarity on decarbonisation pathways
	Fit for 55 proposed update		Lowers the overall emissions cap and increase the annual linear reduction factor (LRF). The likely outcome is an increase in energy prices which should stimulate additional investment in EE, though only if it is seen as more strategic than renewables. Yet, it is still worth mentioning that investments leakage may take place, since regulatory compliance costs will be higher.	
	Proposed Carbon Border Adjustment Mechanism (CBAM)		The CBAM would put a carbon price on imports of a targeted selection of products / electricity to protect industry from carbon leakage, by encouraging industries outside Europe to align with the EU's climate neutrality goals and disincentivising carbon intensive products. If the CBAM is watertight it should stimulate further investment in EE to help industry lower long-term operational costs.	

Policy		High uncertainty about the long-term value of energy efficiency investments	Organisational ineffectiveness	Lack of clarity on decarbonisation pathways
Energy Taxation Directive (ETD)	**Current policy**		Disincentivises EE investment by artificially lowering the cost of energy avoided (fossil fuel costs); new, less carbon-intensive fuels are taxed based on volume and so at rates similar to their fossil equivalent if the new fuel emerged since the 2003. Many exemptions for fossil fuel taxes (*de facto* taxes, or "tax expenditures").	
	Fit for 55 proposed update		Energy taxation based on the energy content of energy products and electricity, and their environmental performance. Phases-out exemptions for fossil fuel taxes. The result should incentivise energy efficiency by helping correct and stabilise energy prices.	
Land use, land use change, and forestry (LULUCF) regulation	**Current policy**		The current regulation sets rules for the accounting of biomass use as bioenergy, given that it meets sustainable forest management criteria	
	Fit for 55 proposed update		Sustainability criteria for the use of biomass to produce bioenergy will be strengthened in a way that respects the principle uses of woody biomass. Therefore, the types of biomass that will be allowed to be used and the amounts that will be allowed to be used will impact energy prices and therefore the financial value of energy efficiency. Also, the emissions of biomass used in energy will be recorded and accounted towards each MS's climate commitments.	It is unclear to industries whether biomass use will be/not be encouraged in the future, which affects investment decisions in shifting towards alternative fuels use.

Policy		High uncertainty about the long-term value of energy efficiency investments	Organisational ineffectiveness	Lack of clarity on decarbonisation pathways
Updated Renewable Energy Directive (RED)	**Current policy**	NA	Current renewable energy targets combined with MS policies, and the ETS have made investment in renewables a preferred decarbonisation pathway for industry. By securing purchased power agreements and similar contracts for renewables, industry hedges on energy prices, therefore making the value of energy efficiency investments more stable.	Current policy has renewables target of 32.5% for the EU but lacks specific direction for industry
	Fit for 55 proposed update	NA	The proposed updates (at right) would further incentivise investment in renewables by setting specific targets and benchmarks. This could help secure energy efficiency investments by making the fuel sources and prices more stable.	The update aims to "mainstream" renewables into industry by setting minimum annual target increases of 1.1%/year with the goal of 50% renewables by 2030. Sets benchmark for use of renewables of non-biological origin (RFNBOs) to 50% if hydrogen use
Updated Energy Efficiency Directive (EED)	**Current policy**	Energy auditors sometimes lack experience on the industry itself, and they focus more on meeting the requirements of the management system itself rather than improving the energy management system at the facility. Furthermore, there is no obligation on enterprises to implement the recommendations resulting from the energy audit.	The current policy does not directly incentivise industry to invest in energy efficiency and there is no support granted to EE projects to protect investments in these types of projects in the future.	The current policy sets EU and national savings targets (32,5% by 2030, 2007 base) and obligations (0,8%/year), and requires industry to undergo energy audits. But industry is not required to follow-up on audits by implementing energy efficiency projects identified.
	Fit for 55 proposed update	No change in key metrics	The updated policy does not directly incentivise industry to invest in energy efficiency, unlike the RED which requires "mainstreaming" renewables into industry.	The proposed update increases national targets to 40% and doubles savings obligations. Industry would forgo free allocation under the ETS if audits not performed. Still no specific energy savings or energy intensity targets, unlike the RED.

Policy		High uncertainty about the long-term value of energy efficiency investments	Organisational ineffectiveness	Lack of clarity on decarbonisation pathways
Innovation Fund, Horizon 2020, etc.	**Current policy**	Administrative difficulties in accessing and applying to the innovation fund represent a big constraint, especially for small innovative firms.	Assessment of the funding applications takes into account the degree of innovation, which will give the chance for front runners (1st in line) to receive the funds but may not give the same opportunity for second and 3rd in line. More demonstration projects are needed to provide proof of concept. The scope of innovation funding is dedicated to innovative technologies (beyond the state of art), but not on understanding the benefits of EE and addressing weakness points that hinder innovation (e.g., supporting digital skills and digital infrastructure)	
	Fit for 55 proposed update		Positive impact: More funding (now €20 billion for 2020-2030) is allocated to the Innovation Fund in the new Fit for 55 package	

Source: Authors' own elaboration.

Grid

Detailed comparison of grid investment scenarios

Table 14: Overview of grid investment estimates for 2020-2030

Actor	Scenario	Emission reduction in 2030	Electricity demand	RES Total production	variable RES generation share	RES Installed capacity	Annual investment needs	What portion is additional investment over planned expenses?	Type of investment considered
			TWh/a	TWh/a	%	GW	billion EUR		
EC	Reference	40%	2996	1767	41	853	50	-	Electricity transmission and distribution networks, heating and cooling, transport, and energy storage.
	MIX 55	55%	3154	2051	48	1007	59	According to the Commission assessment of the NECPs, reaching the 55% emission reduction target would require approximately 7 billion EUR more of annual investment in power grids.	Electricity transmission and distribution networks, heating and cooling, transport, and energy storage.

Actor	Scenario	Emission reduction in 2030	Electricity demand	RES Total production	variable RES generation share	RES Installed capacity	Annual investment needs	What portion is additional investment over planned expenses?	Type of investment considered
			TWh/a	TWh/a	%	GW	billion EUR		
ENTSO-E	National trends	40%	3237	~2100	41-43	926	9.5 (historical figure[258]) + additional 3.4 billion between 2025-30	17 billion EUR (3.4 billion annually) to invest in additional interconnections between 2025 and 2030.	EU27+UK coverage Cross-border interconnections.
E.DSO	Central	46%	3530			940	34-39	50-70% higher investment than in the 2015-20 period (cca 23 billion EUR annually).	EU27+UK coverage Investment in distribution networks.
	Increased ambition	50-55%	3680			1050 (emission-free generation)	37-42	25-30 billion EUR (8% more investment needed than in the central scenario).	EU27+UK coverage[259] Investment in distribution networks.

Source: Authors' own elaboration.

[258] Ibid.

[259] This means that some of the values are larger than in the EC scenarios. For example, the annual electricity demand in UK is currently 330 TWh/a, explaining some of the differences in estimates for 2030. (for the electricity demand figures, see: Government of the UK, 2021, Digest of UK Energy Statistics (DUKES): electricity. Available at: https://www.gov.uk/government/statistics/electricity-chapter-5-digest-of-united-kingdom-energy-statistics-dukes.

Description of network investment remuneration and tariffication mechanisms

As energy networks are considered to be a natural monopoly, the business of grid operators is usually regulated, with allowed revenues and tariffs either defined or approved by the regulatory authority. The grid operators recover the investments in grid development, including the cost of capital for equity and debt, via network tariffs charged from the network users. The general principles for setting network tariffs are set in the Electricity directive[260]. The main principles are that the tariffs should be non-discriminatory (applying same rules to all consumers or group of similar customers) and cost-reflective (customers should pay only for the costs they are responsible for).

ACER notes that a suitable tariff design can support overall system efficiency through adequate price signals to network users. Since network charges constitute a significant portion of total energy costs to the users, the way they are set can provide the incentive for efficient investment and operational decisions from a system perspective[261].

Network tariff design aims at recovering the costs incurred by a system operator (including capital remuneration) while stimulating economic efficiency[262]. According to ACER, the following costs are allowed to be recovered:

CAPEX: Return on capital, depreciation of investments;

OPEX, including also:

- Costs of distribution[263] losses;
- Metering costs; and
- Non-network-related policy costs: (non-VAT) taxes, levies, costs of support schemes (RES, stranded power generation, etc.);

Residual system services costs (i.e. those that cannot be allocated to the responsible network users), such as e.g. capacity reserves, congestion management, voltage control and reactive power support, black-start capability and system balancing.

Results of the DSOs survey

With the help of the EU DSO entity, we have reached out to European electricity distribution system operators to collect their views on the topic. The survey was conducted between 13 September and 5 October 2021. In total, we received 51 responses.

Country of origin

The responses came from DSOs in 15 EU countries, with largest proportion of the responses coming from Germany and Sweden (each representing 25% of the total), followed by Spain (14% responses) and Finland (8%).

Figure 11: Country of DSO origin

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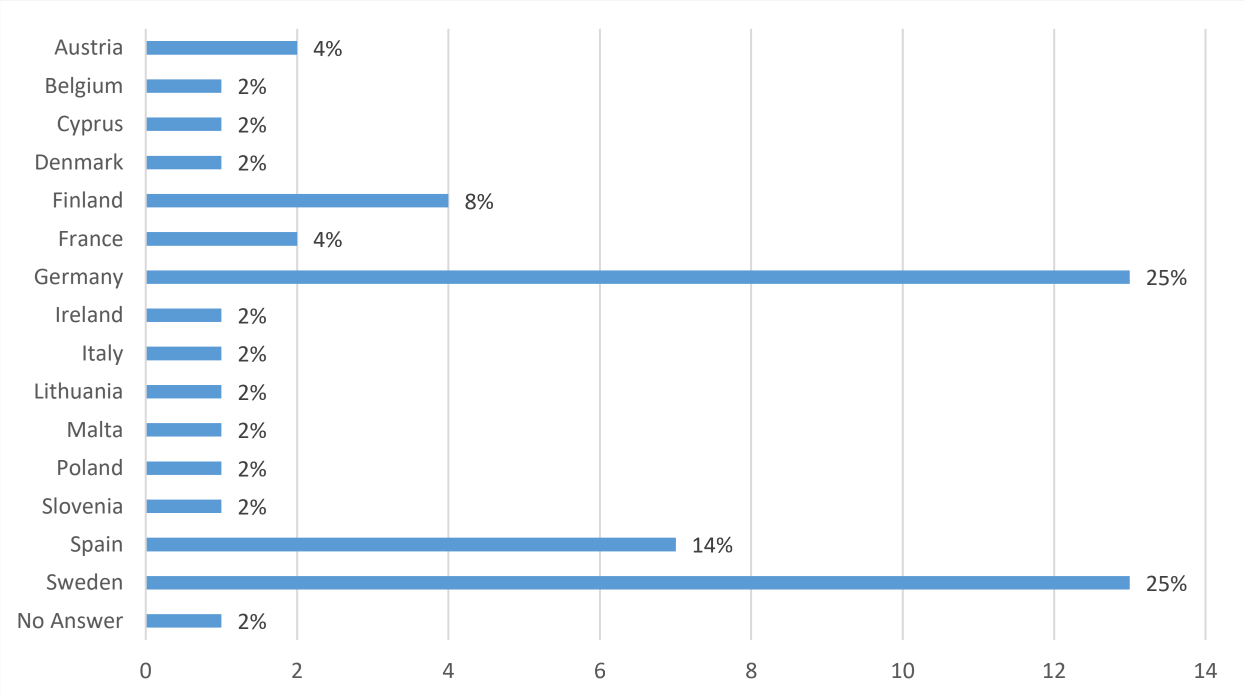
[260] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity. Available at: http://data.europa.eu/eli/dir/2019/944/oj.

[261] ACER, 2021, Report on Distribution Tariff Methodologies in Europe. Available at: https://documents.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/ACER%20Report%20on%20D-Tariff%20Methodologies.pdf.

[262] Next to network tariffs, there are several less significant revenue streams for network operators, aiming at covering specific expenditure, such as connection charges for new users or covering some network control operations (specifically on distribution level, this covers reactive power injection or withdrawals). Part of the costs can be also covered by national or local financing mechanisms.

[263] Or transmission losses, although this is a less significant issue on TS level.



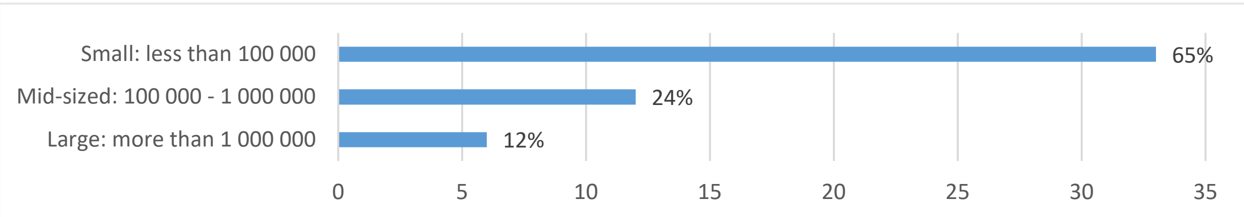
Source: authors' own elaboration.

Information on DSO business

The survey has managed to cover a diverse group of DSOs, in particular collecting the views of 33 (65% of the total) small businesses with less than 100 000 customers. Views of larger DSOs are however also represented.

Accordingly, the amount of annually supplied energy varied significantly, with the lowest supplied volume of 410 MWh and the highest of 125 TWh. The average energy supplied for DSOs with less than 100 000 customers was 277 GWh, 2 761 GWh for DSOs with 100 000 – 1000 000 customers and, for DSOs with more than 1 million customers, the average was 52.55 TWh.

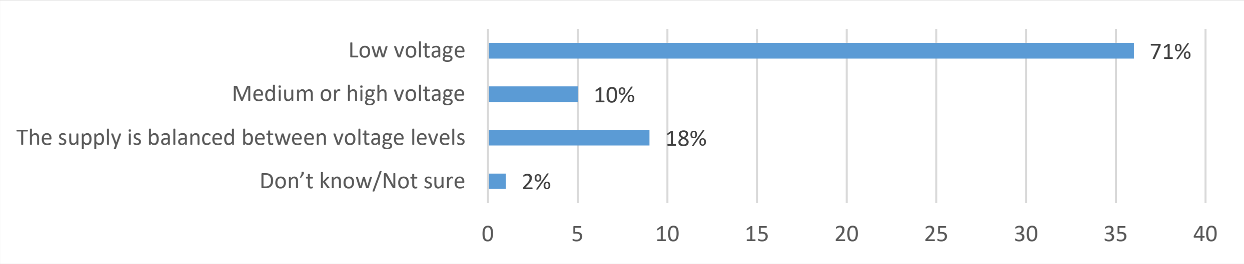
Figure 12: Size of DSOs by number of customers



Source: Authors' own elaboration.

The DSOs also varied by the voltage level they supply their customers at. The majority (71%) of the surveyed DSOs supply their customers on low voltage level, but there are some that also work predominantly on medium voltage or have the supply balanced between those levels.

Figure 13: What is the voltage level you predominantly supply your customers?



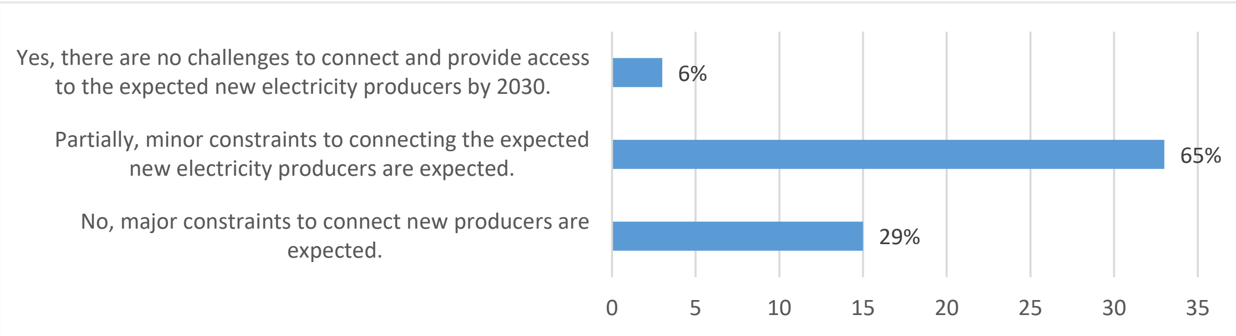
Source: Authors' own elaboration.

1. In your view, is your electricity grid ready to accommodate significantly higher levels of renewable electricity production predicted for 2030 (e.g. being able to connect the renewable sources and supply securely the demand from consumers)?

Only 3 DSOs indicated that their electricity grid is ready for significantly higher levels of renewable electricity production. However, 65% of the DSOs are expecting only "minor" constraints for additional renewable electricity connections. 30% of the DSOs are expecting major hurdles for new connections. When asked to explain the source of major constraints, the DSOs mentioned in particular:

- The generally high (perceived) policy ambition of new renewable electricity generation;
- Need for additional grid expansion;
- Need to secure adequate investment;
- The growing ratio of RES to network load;
- One DSO mentioned that they are already experiencing problems with additional grid connections.

Figure 14: View on variable RES integration

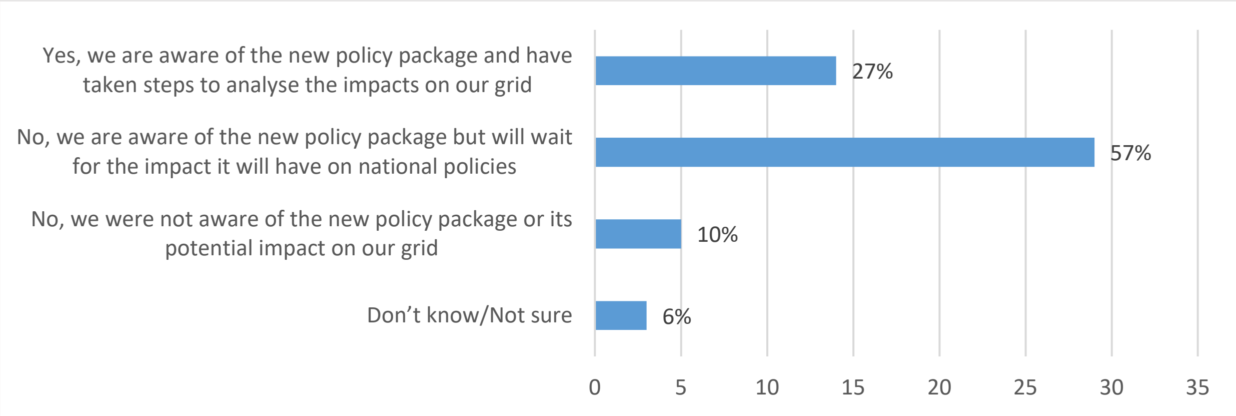


Source: Authors' own elaboration.

2. Have you analysed the impact of the newly proposed objectives in the European Green Deal and the Fit for 55 package on your grid? (such as increased national renewable energy production or the increased electrification of end-use sectors like mobility or heating via heat pumps)

The responses to this question show that DSOs are generally aware of the existence of the Fit for 55 package, but are mostly planning to wait until it will be implemented on national level. This might result in delaying of the translation of the Fit for 55 ambitions into practical grid development plans. However, 27% of the DSOs are actively analysing the impacts of the proposed legislation. Interestingly enough, 5 out of the 6 large DSOs with over 1 million customers are also planning to wait on the impacts on national policies (while the logical assumption would be that larger DSOs have more capacity to analyse such policy impacts).

Figure 15: Awareness about new RES targets



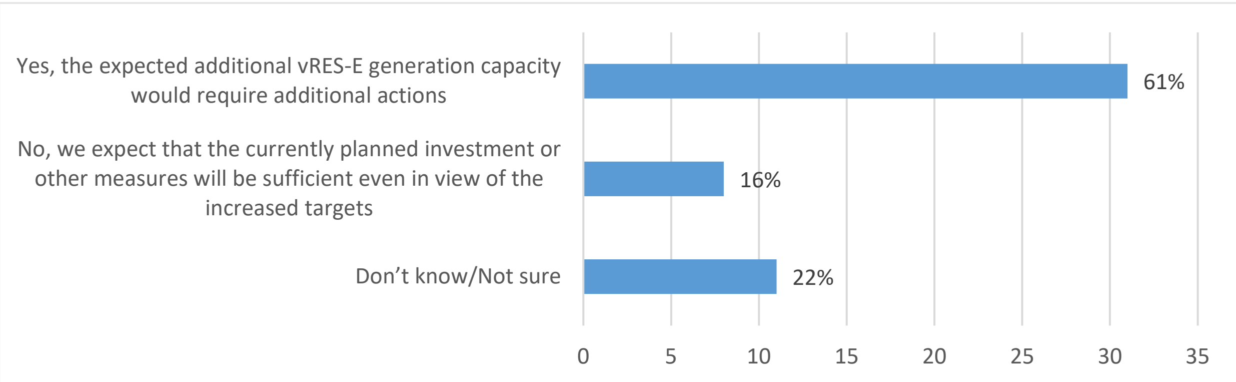
Source: Authors' own elaboration.

3. Do you foresee a need for additional actions to prepare the grid for reaching these targets (beyond currently planned investments or other measures)?

Almost two thirds of the DSOs are expecting that more actions and measures will be necessary to achieve the increased target of the revised RED directive. Only 16% of DSOs indicated that they expect that the currently planned investments and measures will be sufficient even for the increased renewable energy production.

When comparing the answers of DSOs categorised by their size, it is apparent that the perceived need got additional action is more prevalent among the larger operators. While only 52% of DSOs with less than 100 000 customers replied yes, the share has grown to 75% for medium-size DSOs with 100 000 – 1 million customers and to 83% of the largest DSOs.

Figure 16: Implications of increased RES ambition



Source: Authors' own elaboration.

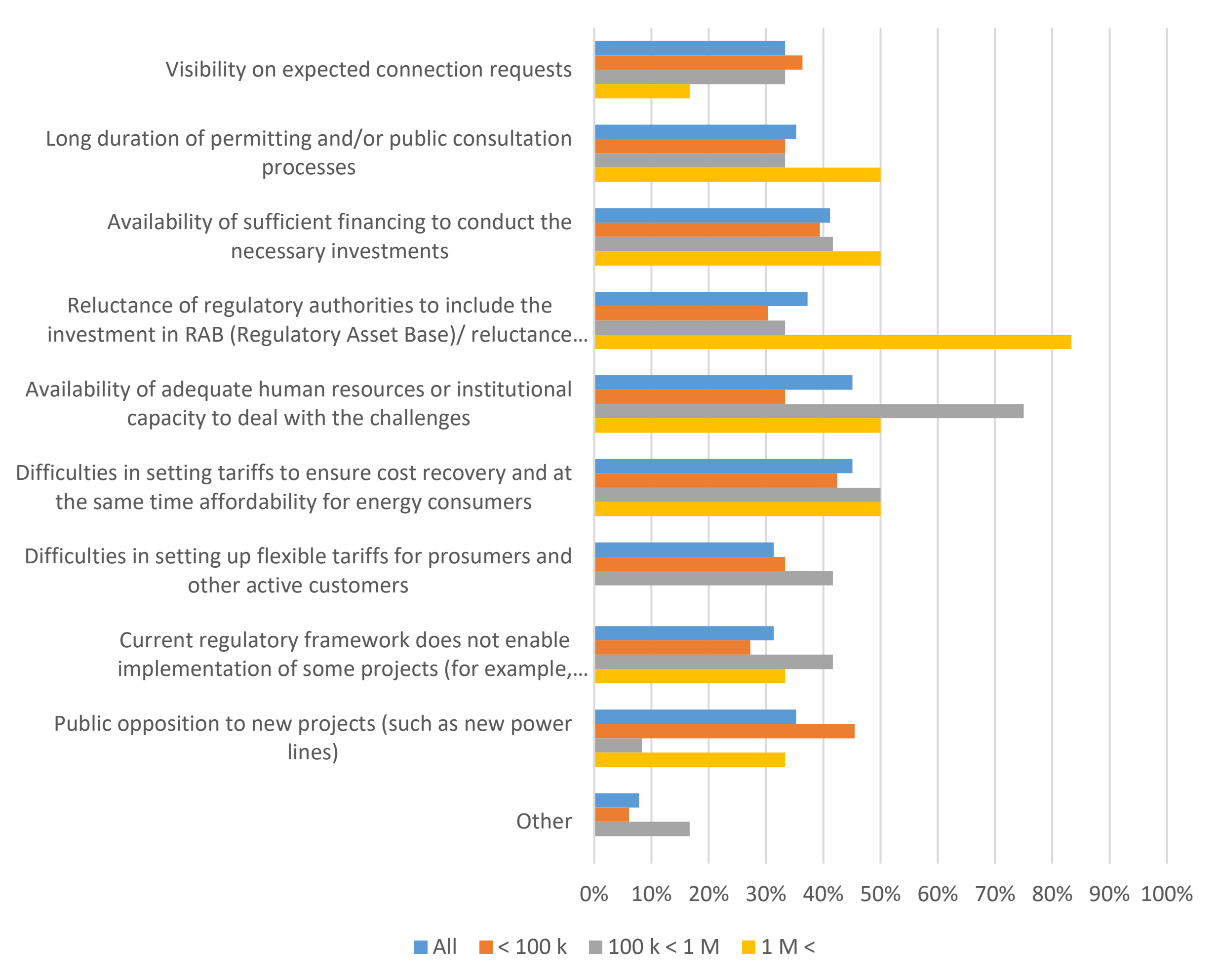
4. Which of the following is the biggest challenge to integrating significantly higher renewable electricity production?

The question was aiming at discovering what are, in the view of the DSOs, the biggest challenges to integrate the additional renewable electricity production. In general, most DSOs reported that the challenges lie in "difficulties in setting tariffs to ensure cost recovery and at the same time affordability for energy consumers", as well as in "availability of adequate human resources or institutional capacity to deal with the challenges" (both challenges indicated by 45% of all DSOs). 41% of all DSOs also indicated that there is a challenge in "availability of sufficient financing to conduct the necessary investments".

A more detailed analysis shows some differences in the perceived challenges according to the size of the DSOs. For small DSOs, Public opposition is actually the most mentioned challenge, while problems with availability of human resources are less prevalent. In contrast to that, all mid-sized DSOs indicated the availability of human and institutional capacities as a significant problem. 67% of them also reported that current regulatory frameworks do not enable implementation of some (innovative) projects). For large DSOs, the most mentioned challenge was the "reluctance of regulatory authorities to include the investment in RAB (Regulatory Asset Base)/ reluctance to increase network charges for consumers".

When asked what other challenges are the DSOs facing, the operators mentioned a lack of coordination of local and regional distribution network planning or the absence of regulatory framework for new market players, such as storage operators or flexibility providers.

Figure 17: Main challenges of RES integration



Source: Authors' own elaboration.

5. What additional EU and Member State policy or regulatory measures (or changes to existing ones) would be needed to address these barriers?

The replies to the open question on additional EU or national policies are summarized in the table below. The measures mentioned multiple times are simplifying the regulatory framework, simplification of the permitting procedures and enabling higher returns on investments.

Table 15: Other RES integration challenges

Proposed measure	Nr. of occurrences
Simplifying and unifying the regulatory framework	7
Simplification of permitting procedures	5
Enabling higher returns on investments	4
Regulatory incentives for network investments and innovation	3
Incentives for deployment of energy storage	2
Faster implementation of EU policy on national level	1
Ensuring access to metering information	1
Enable to pass on the RES connection cost to customer	1
Regulatory framework for flexible tariffs	1
Regulatory incentives for the use of flexibility	1
Enable the access to EU funding (e.g. covid recovery funds)	1
Income incentives in the regulatory framework for integrating additional RES production	1
Reduce the pressures of NRAs to reduce network tariffs	1
Enable more freedom in managing the renewable energy generation	1
More focus on the total system end cost for the customers	1
Regulatory framework for vulnerable customers	1

Source: Authors' own elaboration.

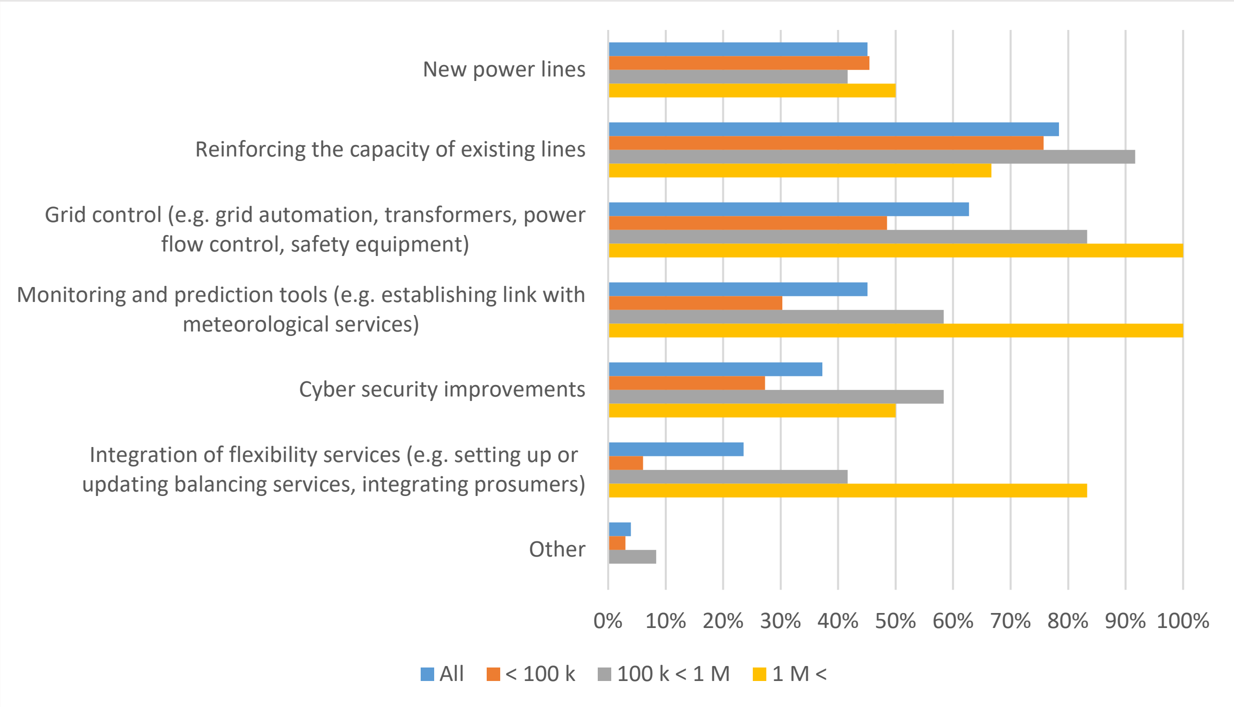
6. Which, if any, actions or measures primarily focused on integrating new renewable electricity generation capacity, are you currently undertaking, or planning to?

The responses show that reinforcing the capacity of existing lines is the most common measure, currently deployed or planned by 78% of surveyed operators. The second most common measure is upgrade of grid control systems, such as remote/automatic control or investment in flow control measures, being deployed by 63% of DSOs. In contrast, only 45% DSOs are developing new power lines and only 24% are planning to integrate flexibility services.

There are significant differences in the planned measures depending on the size of the DSO. In case of largest DSOs with over 1 million customers, all the respondents have indicated that they plan to upgrade the grid control as well as the network monitoring and prediction tools. 83% of the large DSOs also plan to integrate more flexibility services. Reinforcing or development of new power lines is, on the other hand, less prevalent measure. Small DSOs Indicate mostly plans to reinforce existing power lines (92% of respondents) and to upgrade the grid control equipment, but show less interest in alternative measures. Most remarkably, only 6% of small DSOs (2 companies) indicated plans to develop flexibility services.

This suggests that the conventional focus on CAPEX investments is prevailing more on among the smaller companies, while larger DSOs are more advanced in deploying alternative solutions.

Table 16: Main DSO grid adaptation investments



Source: Authors' own elaboration

The other measures mentioned by DSOs are deploying volt-var (reactive power) control of PV inverters, centralised reactive power control or upgrading to OLTC (On-Load-Tap-Change) transformers.

DSOs were also asked to specify the flexibility services they are working on. The results are summarized in the table below:

Table 17: Flexibility deployed by DSOs

Type of action/flexibility solution deployed	Nr. of occurrences
Flexibility market development	2
Studies on flexibility integration	2
DSM by utilizing dynamic tariffs	2
EV charging management	1
Redispatching	1
Peak shaving incentives	1
Deployment of battery systems	1

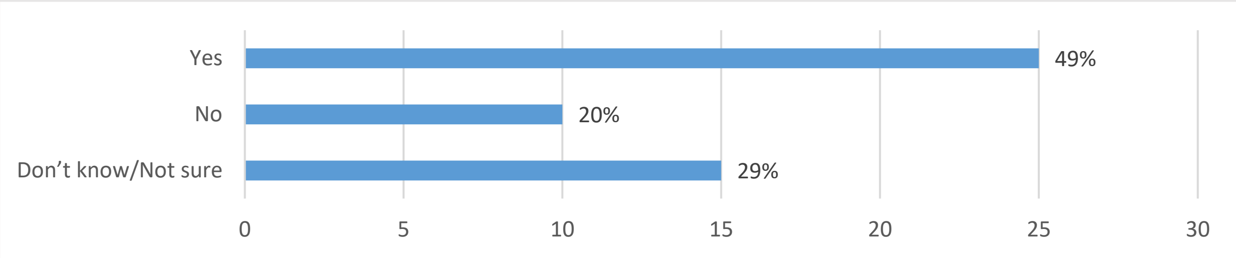
Cooperation with TSO (on delivery of flexibility services to the TSO)	1
Real-time power flow control	1

Source: Authors' own elaboration

7. Do you think that the adaptation of your electricity grid is well under way to accommodate – by 2030 - anticipated levels of renewable electricity production?

Moving on to the implementation of grid upgrades, 49% of the DSOs indicate that the progress of adaptations is well on the track to accommodate the anticipated renewable electricity production in 2030 and only 20% of them disagree with this statement. Some DSOs also provided further explanation to their answers, which suggests that those not sure about the progress are mainly uncertain about the future policy framework and targets, while (some of) those replying "no" indicated that significant additional investment in expansion of grid capacities are needed.

Figure 18: Progress of grid adaptation

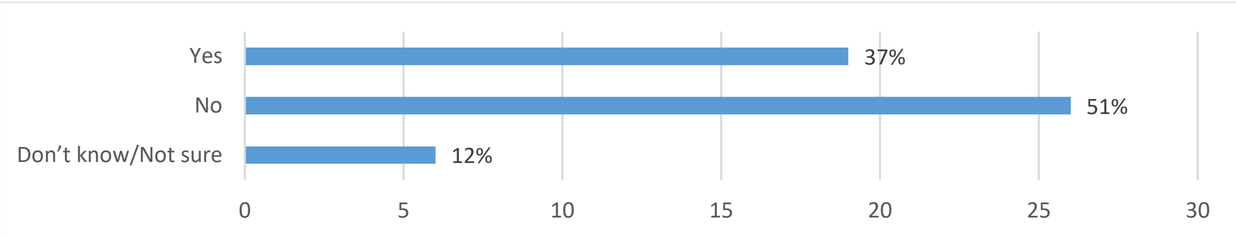


Source: Authors' own elaboration

8. Are you currently facing delays in implementing grid upgrade projects?

While over a half of the DSOs answered that they are not facing significant delays in implementation of grid upgrade projects, 37% of the DSOs are also experiencing delays.

Figure 19: Delays in grid adaptation



Source: Authors' own elaboration.

The indicated reasons for the delays are:

Table 18: Causes of grid adaptation delays

Cause of delay	Nr. of occurences
Scarcity of human resources	3
COVID-19 pandemics - delays in materials and components delivery	2
Long permitting procedures	2
Complexity of permitting process	2

Lack of public acceptance	1
Organisational challenges	1

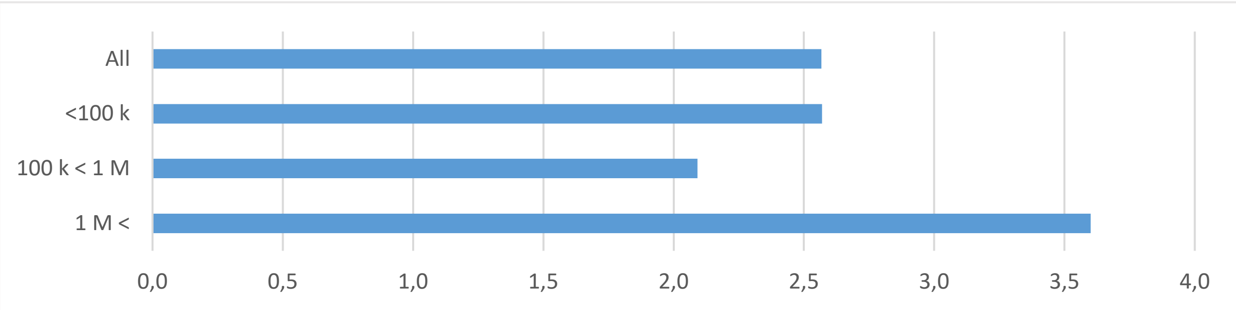
Source: Authors' own elaboration.

This indicates that scarcity of human and institutional resources are indeed an issue. Furthermore, The COVID pandemics has impacted also the delivery of renewables grid integration targets.

9. What is the average duration of a project for a new line (from final investment decision to commissioning, in years?

According to the surveyed DSOs, the average duration of a new power line project is around 2.5 years. However, the largest DSOs report on average one year longer implementation period.

Figure 20: Average project duration in distribution grids

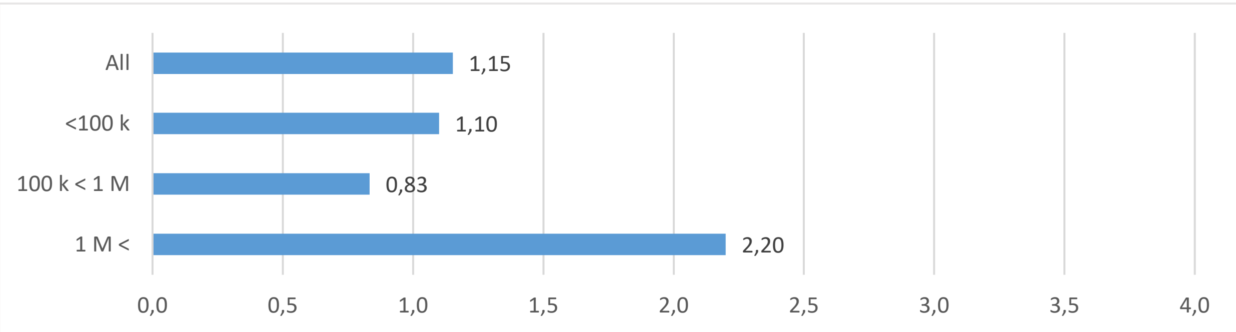


Source: Authors' own elaboration.

10. What is the average delay of your projects (in years), where delay is the difference between the planned duration and actual time to completion?

The reported average delay of project implementation is around one year. Again, largest DSOs are on average reporting circa one year longer delays.

Figure 21: Average delay of grid adaptation projects

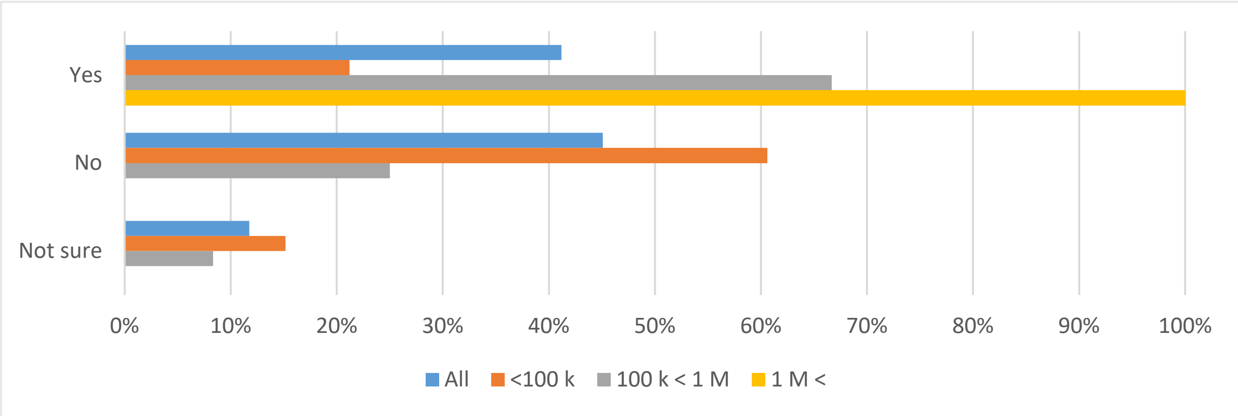


Source: Authors' own elaboration.

11. Are you planning or considering to increase cooperation with other grid operators (including on the transmission system level), possibly across national borders?

There is a significant difference between smaller and larger DSOs in the intention to increase cooperation with other grid operators. While the larger DSOs are predominantly planning to do so, the majority of small DSOs (61%) indicated they do not intend to take further actions to strengthen the cooperation. The DSOs mentioned mostly the TSO-DSO cooperation as the key one.

Figure 22: Planned cooperation with other operators

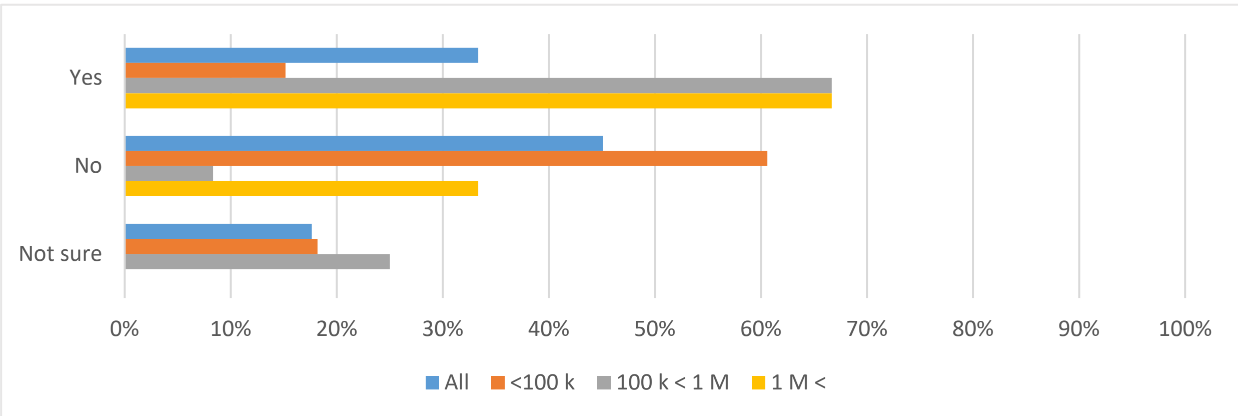


Source: Authors' own elaboration.

12. Are you planning or considering to cooperate (or further cooperate) with gas or district heating grid operators (e.g. on network planning, integration of hydrogen)?

The DSOs have answered in a similar way the question whether they plan to strengthen the cooperation with network operators across sectors. Although the numbers are slightly lower than in Question 11, 33% of the DSOs still intend to increase this kind of cooperation as well (mostly medium-sized and large DSOs). DSOs mentioned facilitation of hydrogen use as one of the examples of cooperation. Moreover, one DSO pointed out that the coordination is going on within a single company that operates gas and district heating network.

Figure 23: Planned cross-sectoral cooperation



Source: Authors' own elaboration.

Renovation Wave

Approach and Methodology

Approach

This analysis is founded on a literature review and expert interviews to provide an overview of the discussed objections. Based on these data/knowledge collection methods, the key barriers to energy renovation in buildings is analysed in the framework of five steps:

1. The potential of the renovation wave to reduce energy consumption and emissions;
2. Documentation of market barriers;
3. Mapping existing EU policy framework against barriers;
4. Gap analysis; and
5. Case studies.

For the additional potential for energy and carbon savings due to circular/bio-based renovation methods in existing buildings, the analysis is structured in two steps:

1. Estimation of the additional contributions (energy/carbon savings) and costs; and
2. Case studies.

The analysis is concluded with a policy evaluation and recommendations. The work done under each step is set forth below.

Methodology

The analysis conducted in the study is based on a literature review, expert interviews as well as our expertise from recent related studies and impact assessment. The methodology and output of this research is explained below.

Literature Review

The main purpose of the literature review was to collect and assess information on the barriers to decarbonise buildings and potential for additional contributions from circular/bio-based renovation methods, document how existing EU policy addresses those barriers, and research additional policy options based on those taken by MSs or other countries that accelerate the rate and depth of energy renovations. The literature includes official EU and MS publications, academic publications, and grey literature. In total we researched 60 sources, such as:

1. 25 journal publications, 19 reports, 7 EU publications; 6 policy briefs; 1 article; 1 academic publication and 1 conference paper;
2. Publications concerning the following topics: renovation barriers (21), renovation policy (e.g. MEPS, LTRS, EPCs, etc.) (16), bio-based renovation (16), renovation rate (8), circular renovation (4);
3. Publications cover all 27 Member States, as well as USA, UK, Canada, Australia, Norway, Switzerland and New Zealand;
4. Publications concerning the following main renovation barriers: lack of a stable vision (7), lack of integrated planning (3), lack of economic attractiveness (e.g. high costs) (11), low confidence in energy renovation investment (6), insufficient access to finance (7), split incentives problem

(4), lack of sufficient (skilled) labour (13) lack of awareness (12), and complexity/nuisance of renovation (8).

Table 19: Literature review for building renovation

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
Ajayi, S. O., Oyedele, L. O., & Ilori, O. M., Changing significance of embodied energy: A comparative study of material specifications and building energy sources. Journal of Building Engineering, 23, 324-333, 2019.	2019	Journal publication	This study estimated the impact of different building materials on embodied carbon of buildings.	Commercial	UK
Alam, M., Zou, P. X., Stewart, R. A., Bertone, E., Sahin, O., Buntine, C., & Marshall, C., Government championed strategies to overcome the barriers to public building energy efficiency retrofit projects. Sustainable Cities and Society, 44, 56-69, 2019.	2019	Journal publication	This study reviews literature on the barriers to retrofitting public buildings as well as ways to address these barriers. They find that a government top-down approach is required.	Public	Australia
Andersson J. et. al, Potential, effects and experiences from recycling in the construction and real estate sector from the local collaboration arena in the Gothenburg region "Recycling West", 2021.	2021	Report	(In Swedish) The report overviews the results of pilot projects of circular construction and demolition projects. They found that per project, about 30 tons of CO2e were saved. They concluded that most of the reused building materials were non-renewable, meaning reused material potentially have a bigger	Buildings (general)	Sweden

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
			environmental value than climate value.		
Artola I., Rademaekers K., Williams R., & Yearwood J., Boosting Building Renovation: What potential and value for Europe?, 2016.	2016	Report	This report analyses literature concerning the state of the EU building stock and assesses policy options and their potential to accelerate energy renovation in the EU building sector.	Buildings (general)	EU
Azizi, S., Nair, G., & Olofsson, T., Analysing the house-owners' perceptions on benefits and barriers of energy renovation in Swedish single-family houses. Energy and Buildings, 198, 187-196, 2019.	2019	Journal publication	This study analyses the benefits and barriers to energy renovation in Swedish residential buildings based a survey of single-family house homeowners.	Residential	Sweden
Bauer P. et. Al, Productivity in Europe. Trends and drivers in a service-based economy. JRC Technical Report, 2020.	2020	Technical report	This study analyses the trends and driving forces of the productivity growth in Europe.	n/a	EU (general)
Beillan, V. E. A. I. A., Battaglini, E., Goater, A., Huber, A., Mayer, I., & Trotignon, R., Barriers and drivers to energy-efficient renovation in the residential sector. Empirical findings from five European countries. ECEEE Report, 2011.	2011	Report	This study documents the barriers to energy efficiency renovation, and finds the following conclusions: owners are not motivated mainly and exclusively by energy savings; lack of skilled workforce to meet the requirements of energy efficient	Residential	France, Germany, Spain, Italy, Switzerland

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
			retrofitting; public support schemes for renovation measures are very important; and local embedding of projects is important.		
BEIS, Evaluation of the Domestic Private Rented Sector Minimum Energy Efficiency Standard Regulations: Interim Report., 2019.	2019	Report	The report evaluates the impact of the minimum energy efficiency standard regulation in the UK residential private sector.	Residential	UK
BPIE, A guidebook to European Building Policy: Key legislation and initiatives, 2020.	2020	Report	This report provides an overview of EU legislation concerning building policy, identifying best practises, barriers and providing recommendations.	Buildings (general)	EU, Portugal, Italy, Poland, France, Lithuania, Ireland, Austria, Germany, Belgium, Sweden, Denmark
BPIE, A review of EU Member States' 2020 long-term renovation strategies, 2020.	2020	Policy brief	An assessment of the compliance of 14 national LTRS against Article 2a of the EPBD. Only Spain is fully compliant, the rest of the available strategies are not completely in line with the EPBD requirements. Notably, more than half of the MS have missed the deadline to submit their LTRS.	Buildings (general)	Austria, Belgium, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Luxembourg, Netherlands, Spain, Sweden
BPIE, Building Renovation Passports: customised roadmaps towards deep renovation and better homes, 2017.	2017	Report	Based on literature review and interviews, the report provides an overview of developments of building renovation passport	Buildings (general)	EU, Germany, Belgium, France

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
			schemes in EU Member States and identifies the main issues and provides recommendations.		
BPIE, On the way to a climate-neutral Europe: contributions from the building sector to a strengthened 2030 climate target, 2020.	2020	Report	This study estimates that the current deep renovation rate needs to increase from 0.2% to 2% to reach the EU's climate ambitions, which exceeds the Renovation Wave Strategy's goal to increase the general renovation rate from 1% to 2%.	Buildings (general)	EU (general)
BPIE, The Renovation Wave Strategy and Action Plan: Designed for Success or Doomed to Fail? A review and gap analysis of the Renovation Wave, 2021.	2021	Policy brief	This gap analysis of the Renovation Wave Strategy considers how the action plan needs to be adjusted during the implementation phase in terms of: aligning measures with EU climate ambitions, ensure coherence and adjust sequencing. The Renovation Wave Strategy should aim to reach an annual deep renovation wave of 3% by 2030; suggested measures should have specifications on their contribution to increasing the deep renovation rate and reducing GHG emissions by 2030; it should be clarified what is meant by resilience and adaptation in the buildings sector; EC should aim at a	Buildings (general)	EU (general)

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
			comprehensive revision of EPBD, going beyond the action plan; EC should assess when measures would begin to take effect and how important the impact will be.		
BPIE, The Road to Climate Neutrality. Are the national Long-Term Renovation Strategies fit for 2050?, 2021.	2021	Policy brief	The available national LTRS are not aligned with 2050 climate ambitions and need to be revised, including an amendment to EPBD Art. 2a.	Buildings (general)	Belgium, Czechia, Estonia, Finland, France, Germany, Netherlands, Spain
BPIE, Whole-life carbon: challenges and solutions for highly efficient and climate-neutral buildings., 2021.	2021	Report	Embodied carbon contributes to 10-20% of the EU building stock's carbon footprint. As legislation drives down operational carbon, embodied carbon has increased in both relative and absolute terms, as high performance buildings require more materials and services. Suggest that there should be a common European policy taking whole-life carbon into consideration. Both energy and carbon metrics as well as policies targeting both embodied and operational emissions are necessary. A few MS have already have whole-life carbon policies.	Buildings (general)	EU (general), Denmark, Netherlands, Finland, Sweden, France, Germany, Switzerland, UK

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
Brucker Juricic, B., Galic, M., & Marenjak, S., Review of the Construction Labour Demand and Shortages in the EU. Buildings, 11(1), 17, 2021.	2021	Journal publication	Literature review of skills/labour shortage in the EU labour market with specific attention to the construction sector. Most MS are facing a labour/skills shortage.	Buildings (general)	EU (general)
Bukarica V., Loncarevic A.K., Pesut D., & Zidar M, Renovation in Buildings. Odyssee-Mure, 2017.	2017	Policy brief	This policy brief provides an overview of MS policies to stimulate energy renovation and briefly cover the main challenges to upscaling building renovation.	Buildings (general)	EU
CE Delft, Zero carbon buildings 2050, 2020.	2020	Report	This report estimated the impact of EU building measures on GHG emissions as well as identify the main barriers to decarbonising the building stock.	Buildings (general)	EU, Poland, Spain, Netherlands
Chastas, P., Theodosiou, T., Kontoleon, K. J., & Bikas, D., Normalising and assessing carbon emissions in the building sector: A review on the embodied CO2 emissions of residential buildings. Building and Environment, 130, 212-226, 2018.	2018	Journal publication	Literature review of case studies of embodied carbon emissions in residential buildings.	Residential	
Chen, Z., Gu, H., Bergman, R. D., & Liang, S.,Comparative life-cycle assessment of a high-rise mass timber building with an equivalent reinforced concrete alternative	2020	Journal publication	This study conducted a whole building LCA to estimate the environmental impact of building materials.	Residential	North America

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
using the Athena impact estimator for buildings. Sustainability, 12(11), 4708, 2020.					
Churkina, G., Organschi, A., Reyer, C. P., Ruff, A., Vinke, K., Liu, Z., ... & Schellnhuber, H. J., Buildings as a global carbon sink. Nature Sustainability, 3(4), 269-276, 2020.	2020	Journal publication	This study estimates the potential of using engineered timber to provide carbon storage in building materials.	n/a	Global
D'Oca, S., Ferrante, A., Ferrer, C., Pernetti, R., Gralka, A., Sebastian, R., & Op't Veld, P., Technical, financial, and social barriers and challenges in deep building renovation: Integration of lessons learned from the H2020 cluster projects. Buildings, 8(12), 174, 2018.	2018	Journal publication	The report summarises the barriers and challenges of the building renovation process based on H2020 workshops and interactive discussions. The main barriers in the deep renovation process were technical, financial and social.	Buildings (general)	EU (general)
Dodoo, A., Lifecycle impacts of structural frame materials for multi-storey building systems. Journal of Sustainable Architecture and Civil Engineering, 24(1), 17-28, 2019.	2019	Journal publication	This study estimates the impact of different structural frame materials in multi-storey buildings on lifecycle primary energy and GHG emissions.	Residential	Norway
Dorizas P.V., De Groote M., & Fabbri M., How can Member States implement iBRoad?, BPIE, 2019.	2019	Report	The report analyses the barriers and enablers to the design and implementation of iBroad (individual building renovation roadmap).	Residential	Portugal, Poland, Bulgaria, Belgium, Denmark

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
EASAC, Decarbonisation of buildings: for climate, health and jobs, 2021.	2021	Report	The report provides policy advice for decarbonising the EU building stock from 2020 to 2050.	Buildings (general)	EU
Ecologic, Planning for net zero: assessing the draft national energy and climate plans, 2019.	2019	Report	This study assessed the MS NECP drafts and analyses the adequacy of the national targets and the completeness of the policy descriptions. Overall, the plans do not have adequate targets nor credibility. Good practises are identified.	Buildings (general)	EU
Economidou, M., Todeschi, V. and Bertoldi, P., Accelerating energy renovation investments in buildings, EUR 29890 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-12195-4, doi:10.2760/086805, JRC117816, 2019.	2019	EU publication	The report summaries the most important public funding schemes for each MS and investigates new private financial tools to stimulate more energy efficiency investments in buildings. The primary financial instruments are grants and subsidies (61%) followed by soft loans (19%) and tax incentives (10%) targeted to residential, commercial and public buildings. About 15 billion euros are spent by public resources annually across the EU, though higher levels of funding are required to meet the EU's climate ambitions. Identified 129 ongoing public financial and fiscal	Residential, commercial and public	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, The Netherlands, Poland, Portugal, Romania, Slovakia,

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
			schemes supporting energy renovations in buildings.		Slovenia, Spain, Sweden, UK
Enefirst, Implementation map on barriers and success factors for E1st in buildings, 2021.	2021	Report	The report does an analysis of the barriers and success factors for policy approaches for the energy efficiency first principle.	Buildings (general)	EU
Esser, A. et. al, Comprehensive study of building energy renovation activities and the uptake of nearly zero-energy buildings in the EU Final report, Publications Office of the European Union: Luxembourg, 2019.	2019	EU publication	The current renovation rate (1%) is not sufficient to decarbonise the EU building stock. The most common triggers for energy renovation were: necessary maintenance, replacement of defective components, budget becoming available, alignment of energy renovations with comfort and health aspects Education on energy efficiency measures is needed for intermediaries (architects, main contractors and installers) The main roadblocks to energy renovation are financial and administrative barriers.	Buildings (general)	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, The Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, UK
European Commission, Preliminary analysis of the long-	2021	EU publication	LTRS vary in terms of completeness and ambition level.	Buildings (general)	Austria, Cyprus, Czechia,

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
term renovation strategies of 13 Member States, 2021.					Denmark, Estonia, Finland, France, Germany, Ireland, Luxembourg, Netherlands, Spain and Sweden
Fabbri M., Volt J., & de Groote M., The Concept of the Individual Building Renovation Roadmap, BPIE, 2018.	2018	Report	This study provides case studies on individual building renovation roadmaps in several EU countries.	Residential	Denmark, Belgium, France and Germany
Fraunhofer Institute for Systems and Innovation Research ISI, Energy Savings Scenarios 2050, 2019.	2019	Report	This study estimates the possible energy savings by 2050 from different techno-economic advances (incl. renovation). Renovation of building envelope and heating system of residential and commercial/public buildings is expected to decrease final energy consumption by 40%.	Residential, commercial	EU
Fraunhofer ISI; Fraunhofer ISE; IREES; Observ'ER; TU Wien; TEP Energy, Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables). Work package 5: Barriers, Best Practices and Policy	2017	Report	The aim of the study is to provide a detailed overview of the heat and cold supply as well as use in Europe in 2012. The study covers all 28 EU Member States plus Iceland, Switzerland and Norway. It is composed of five reports and a complete dataset. The reports are:	Heating and Cooling	EU, Iceland, Switzerland, Norway

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
Recommendations. Edited by European Commission Directorate-General for Energy, 2017.			The report on work package 5 covers barriers, best practices and policy recommendations. In the centre of the analysis are the identification of factors and bottlenecks (economic aspects, behavioural issues, decision making routines, financing conditions, subsidy programs among different stakeholders) influencing the diffusion of renewable heating and cooling technologies and might be overcome with suitable policies.		
Göswein, V., Silvestre, J. D., Monteiro, C. S., Habert, G., Freire, F., & Pittau, F., Influence of material choice, renovation rate, and electricity grid to achieve a Paris Agreement-compatible building stock: A Portuguese case study. Building and Environment, 195, 107773, 2021.	2021	Journal publication	This study estimates the environmental impact of using bio-based renovation materials.	Residential	Portugal
Hafner, A., & Schäfer, S., Comparative LCA study of different timber and mineral buildings and calculation method for substitution factors on building	2017	Journal publication	This study estimated the environmental impact of different construction materials.	Residential	Germany

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
level. Journal of cleaner production, 167, 630-642, 2017.					
Hart, J., D'Amico, B., & Pomponi, F., Whole-life embodied carbon in multistory buildings: Steel, concrete and timber structures. Journal of Industrial Ecology, 25(2), 403-418, 2021.	2021	Journal publication	This study estimates the environmental impact of timber alternatives in different building structures.	Residential	UK
Hill, C. A. S., The environmental consequences concerning the use of timber in the built environment. Frontiers in Built Environment, 5, 129, 2019.	2019	Journal publication	This study compares literature on the use of timber in buildings and its impact of the environment.	n/a	n/a
Hinge, A., Minimum Energy Standards for Rented Properties: an international review, 2020.	2020	Report	This study provides an overview of minimum energy performance standards in different countries to improve energy efficiency in rented properties. The study finds that there is minimal data available concerning the effectiveness of the policies as most have been implemented recently.	Residential, commercial	US, UK, Netherlands, New Zealand, Belgium, Australia
IEA, Case Study: Energy Savings Meter Programme in Germany, 2019.	2019	Article	This case study analyses the German energy savings meter programme. The case study covers the impact,	Residential, commercial	Germany

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
			barriers and opportunities of the programme.		
Jan van Dam & Martien van den Oever, Catalogus biobased bouwmaterialen 2019, 2019.	2019	Academic publication	Catalogue of bio-based building material and specific uses.	n/a	n/a
Lupíšek, A.; Trubaˇcík, T., Holub, P., Czech Building Stock: Renovation Wave Scenarios and Potential for CO2 Savings until 2050. Energies 2021, 14, 2455, 2021.	2021	Journal publication	This study estimates the potential decarbonisation of the Czech building stock. The implementation of most ambitious scenario would result in a reduction of annual carbon emissions by 43% by 2050. Namely, the scenario based on the current national LTRS would lead to emissions above 2050 emissions targets.	Buildings (general)	Czechia
Material Economics, The Circular Economy: A powerful force for climate mitigation, 2018.	2018	Report	This study estimates the impact of a circular economy on emissions in the EU by 2050. Five different aspects of circular economy are analysed: steel, aluminium, plastics, mobility and buildings and cement.	Buildings (general)	EU (general)
Meyer, N. I., Mathiesen, B. V., & Hvelplund, F., Barriers and Potential Solutions for Energy Renovation of Buildings in Denmark.	2014	Journal publication	Current Danish policies are too slow and inefficient to decarbonise the existing building stock. Overall, the current Danish policies do not efficiently address private	Buildings (general)	Denmark

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
International Journal of Sustainable Energy Planning and Management, 1, 59-66, 2014.			households. The paper proposes policy recommendations which would reduce energy consumption of existing buildings by more than 40%.		
Moschetti, R., Brattebø, H., & Sparrevik, M. Exploring the pathway from zero-energy to zero-emission building solutions: A case study of a Norwegian office building. Energy and Buildings, 188, 84-97, 2019.	2019	Journal publication	This study analyses alternative design solutions to achieve zero-energy/emissions in office buildings.	Commercial	Norway
Nabitz, L., & Hirzel, S., Transposing the requirements of the energy efficiency directive on mandatory energy audits for large companies: A Policy-Cycle-based review of the national implementation in the EU-28 member States. Energy Policy, 125, 548-561, 2019.	2019	Journal publication	This study analyses the implementation process of energy audit obligations on large companies, as introduced in Art. 8 of EED. The study finds that interlinkages of policy cycles are important for a smooth policy process at MS level (to prevent different MS interpretations of requirements).	Commercial	EU
Olaussen, J. O., Oust, A., & Solstad, J. T., Energy performance certificates–Informing the informed or the indifferent?. Energy Policy, 111, 246-254, 2017.	2017	Journal publication	This study estimates the price premium of Energy Performance Certificates using data from the Norwegian housing market.	Residential	Norway

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
P. Bertoldi, B. Boza-Kiss, N. Della Valle, M. Economidou,The role of one-stop shops in energy renovation - A comparative analysis of OSSs cases in Europe, Energy & Buildings, 2021.	2021	Journal publication	This study analyses 63 case studies of one-stop-shops in across Europe.	Buildings (general)	Austria, Belgium, Spain, Portugal, Italy, Netherlands, Bulgaria, Cyprus, Czechia, Germany, Denmark, Estonia, Finland, France, Hungary, Norway, Sweden, Slovakia, UK
Petersen, A., and Solberg, B., Environmental and economic impacts of substitution between wood products and alternative materials: a review of micro-level analyses from Norway and Sweden. For. Policy Econo. 7, 249–259. doi: 10.1016/S1389-9341(03)00063-7, 2005.	2005	Journal publication	This study estimates the environmental impact of using wood instead of concrete and steel in buildings.	n/a	Norway, Sweden
Pierobon, F., Huang, M., Simonen, K., & Ganguly, I., Environmental benefits of using hybrid CLT structure in midrise non-residential construction: An LCA based comparative case study in the US Pacific Northwest. Journal	2019	Journal publication	This study estimates the environmental impact of a specific type of timber in commercial buildings.	commercial	United States

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
of Building Engineering, 26, 100862, 2019.					
Pittau, F., Krause, F., Lumia, G., & Habert, G., Fast-growing bio-based materials as an opportunity for storing carbon in exterior walls. Building and Environment, 129, 117-129, 2018.	2018	Journal publication	This study estimates the potential for the EU housing stock to become a carbon sink with the use of bio-based materials in energy renovations of residential buildings. The study compares five different construction solutions and finds that ones with fast-growing bio-based solutions have the most potential.	Residential	EU (general)
Pohoryles, D. A., Maduta, C., Bournas, D. A., & Kouris, L. A., Energy performance of existing residential buildings in Europe: A novel approach combining energy with seismic retrofitting. Energy and Buildings, 223, 110024.; Fraunhofer ISI (2019). Energy Savings Scenarios 2050, 2020.	2020	Journal publication	The study analyses the potential energy performance improvement of combining energy and seismic retrofitting in the renovation of existing residential buildings, investigating 20 European cities using a building energy model. The study finds that with a renovation rate of 3%, there could be a 30% reduction in primary energy use and GHG emissions reduction with 10 years.	Residential	EU
Pomponi, Francesco, et al. "Buildings as a global carbon sink? A reality check on feasibility limits."	2020	Report	This paper summarises the potential of buildings becoming a global carbon sink.	Buildings (general)	Global

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
One Earth 3.2 (2020): 157-161, 2020.					
Remeikienė, R., Gasparėnienė, L., Fedajev, A., Szarucki, M., Đekić, M., & Razumienė, J. (2021). Evaluation of Sustainable Energy Development Progress in EU Member States in the Context of Building Renovation. Energies, 14(14), 4209.	2021	Journal publication	The study compares EU MS in terms of energy usage, renewable resources, energy efficiency and emissions as a result of energy usage, in the context of building renovation. Latvia, Sweden, Portugal, Croatia, Austria, Lithuania, Romania, Denmark and Sweden are found to be the most advanced Member States in terms of energy efficiency, renewable usage and minimising emissions.	Buildings (general)	EU
Sathre, R., & O'Connor, J., Meta-analysis of greenhouse gas displacement factors of wood product substitution. Environmental science & policy, 13(2), 104-114, 2010.	2010	Journal publication	This study estimates the environmental impact of using wood building materials based on an average of 21 studies.	Residential, commercial	n/a
SEAI, Encouraging heat pump installations in Ireland, 2020	2020	Policy brief	This policy brief reviews the heat pump grant in Ireland to encourage heat pump installation. The paper provides recommendations.	Residential	Ireland
Steuwer et. al, Lessons learned to inform integrated approaches for renovation and modernisation of	2020	EU publication	This study develops lessons learned from existing policy instruments in MSs and other countries concerning	Buildings (general)	Belgium, Germany, Denmark, Greece,

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
the built environment, European Commission, December 2020.			decarbonising the building stock. The study recommends: aligning policies with long-term objectives; introducing regulatory and market-based instruments for the transformation of the European building stock; enhancing the gathering availability and harmonisation of building data and information, facilitating the market penetration of innovative financial mechanism, accelerating renovation and flexibility in the built environment by utilising digitalisation and automation, achieving policy integration exchange hubs and integrated urban planning.		Spain, France, Hungary, Ireland, Italy, Lithuania, the Netherlands, Poland, Portugal, Romania and Sweden, Norway, UK, US
Sunderland, L. & Santini, M., Case Studies: Minimum energy performance standards for European buildings, 2020.	2020	Report	This case studies briefing presents six case studies of European introductions of MEPS.	Residential, commercial	Belgium, England/Wales, France, Netherlands, Scotland,
Sunderland, L. & Santini, M., Filling the policy gap: Minimum energy performance standards for European buildings, 2020.	2020	Report	This report analyses how MEPS can increase the rate and depth of renovation while avoiding negative	Residential, commercial	Netherlands, Poland, Germany, UK, France, Belgium, US,

Full citation	Year of publication	Source type	Summary	Sectors addressed	Countries covered
			consequences on low-income households.		Canada, Australia, New Zealand
Tisov, A., Kuusk, K., Escudero, M. N., Assimakopoulos, M. N., Papadaki, D., Pihelo, P., ... & Kalamees, T., Driving decarbonisation of the EU building stock by enhancing a consumer centred and locally based circular renovation process. In E3S Web of Conferences (Vol. 172, p. 18006). EDP Sciences, 2020.	2020	Conference paper	This report summarises the results of the H2020 project DRIVE0, which aims to decarbonise the EU building stock and accelerate deep renovation through circular renovation processes. The project covers seven MS and provides best practises based on the project results.	Buildings (general)	Netherlands, Spain, Ireland, Italy, Estonia, Slovenia, Greece
Trinomics, Quantifying the benefits of circular economy actions on the decarbonisation of EU economy, 2018.	2018	Report	A meta-analysis of literature on the impact of circular economy actions on GHG emissions.	Buildings (general)	EU (general)

Source: Compiled by Trinomics

Expert interviews

The purpose of the interviews was to augment, contextualise, and test information gained in the literature review on the key barriers and policies on building decarbonisation and circular/bio-based renovation methods with experts on energy renovation in buildings. We conducted **eight 45-minute interviews** with people representing a range of voices, including research institutions, architects, construction sector, EE industry, building owners and financial sector. The interviewees are:

1. Oliver Rapf, Executive Director of Building Performance Institute Europe (BPIE);
2. Jan Rosenow, Principle and European Programme Director of The Regulatory Assistance Project (RAP);
3. Adrian Joyce, Secretary General of European Alliance of Companies for Energy Efficiency in Buildings (EuroACE);
4. Eugenio Guintieri, Secretary General, and Spyros Mathioudakis, Policy Officer, at European Builders Confederation;
5. Luigi Petito, Head of Secretariat and Memberships, and Antoan Montignier, Policy and Advocacy Advisor, of The European Alliance to Save Energy (EU-ASE);
6. Christophe Sykes, Director General of Construction Products Europe;
7. Emmanuelle Causse, Secretary General, and Nataša Vistrička, Policy Director at the International Union of Property Owners) (UIPI);
8. Ralf Goldmann, Head of Division, Energy Efficiency Projects Directorate at the European Investment Bank (EIB).

The interviewees were provided the following questions in advance of the interview:

Introduction

The task of this study involves identifying the key challenges to the EU's building renovation wave to decarbonise the EU building stock and provide policy recommendations. In the process of our research, we have identified the following key barriers to energy renovation:

1. Lack of vision: insufficient EU ambitions and long-term strategies; lack of integrated planning;
2. Financial: lack of attractiveness; high upfront costs; aversion to loans; difficulty accessing financial resources (for low-income households); low confidence in investments; split incentive problems;
3. Technical: lack of sufficient, skilled labour; lack of R&D and innovation;
4. Social: lack of awareness amongst owners/end users; lack of attractive incentives (complex, long decision making process); practical disruptions (noise, need to vacate the building during renovation process).

Based on these barriers and a mapping of the existing EU policy framework, we have compiled a *preliminary* list of policy recommendations:

5. EU guidance on MS LTRS updates and ensure MS actions and ambitions are aligned with EU's ambitions to decarbonise the EU building stock;
6. Strengthen Energy Performance Certificates (EPCs) to improve quality, encourage use and make energy renovation more attractive and link with (or even evolve towards) Building Renovation Passports;
7. Enforce MS to integrate LTRS and financial strategy, link all policy instruments with financial support;
8. Oblige MS to set up MEPS, in line with their LTRS, or replace by equivalent measure;
9. Empower local authorities and oblige them to plan H&C decarbonisation;

10. Target financial support, with the intensity of funding depending on the depth of renovation, the level of performance and level of income;
11. Provide guidance to MS to develop skills of all building professionals.

In the context of this research, we ask you to consider the following question, in addition to the topic questions below: ***What 10 EU policy recommendations for the 2030 timeline would you propose to fully decarbonise the building stock by 2050?***

Short term & long term vision / targets

1. What (key) elements are missing from the EU framework to conduct/guide MS towards the (full) decarbonisation of their building stock? ;
2. What role should the EU play in setting a vision for the decarbonisation of the EU building stock? ;
3. What should be done at EU level to incentivise MS to establish long term integrated energy planning?.

Phasing the renovation wave

Long term renovation strategies (LTRS)

1. How efficient/far are the MS LTRS setting their national vision, roadmap, concrete policy measures, and dedicated financing mechanisms to decarbonise their building stock? ;
2. How could MS LTRS better address these elements?

Mandatory minimum energy performance standards (MEPS)

1. Can MEPS support MS to phase the renovation wave and the decarbonisation of the building stock? If so, how? What alternative instrument could replace MEPS? If possible, please provide examples/best practises.

Decarbonising heating and cooling

1. How will/can the decarbonisation of the supply (moving to RES) be mainstreamed in the renovation wave implementation? If possible, provide examples/best practises.

Upskilling workers

1. Do you think that the skills-related programmes[264] suggested by the EC in the renovation wave strategy will address the skills gap sufficiently? Why/why not?;
2. If not, what other regulatory/non-regulatory measures do you think are necessary to address the need for professionals and upskilling of professionals in this sector? If possible, provide examples/best practises.

Financing and risk mitigation

1. What needs to be done to ensure EU financial instruments for building renovation are appropriate for accelerating the rate and depth of energy renovations? Should energy services be stimulated?

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[264] The Pact for Skills, Build up Skills, and the European Alliance for Apprenticeships as key EC programmes to support upskilling in the construction sector (as well as the European Social Fund+ and the Just Transition Fund for financial support).

2. For the residential building sector, lack of financial incentives and mainstreaming of financing are key barriers to energy renovation investments. How can the current EU and national financing instruments be better used in terms of more effectively targeting end-users and local authorities as well as better mitigate the risk (perception) of energy renovation? How can synergies with market-based mechanisms be better promoted?;
3. Which financial incentives are most appropriate to mobilise a greater share of private funds towards energy renovations? If possible, provide examples/best practises.

Sustainable renovation: carbon life cycle and circularity

1. Do you have references demonstrating the interest for bio-based or circular renovation?;
2. What would incorporating circular and/or bio-based renovation methods in the renovation of the *existing* EU building stock translate to in terms of additional energy and carbon savings and additional costs, relative to energy renovations without circular/bio-based methods? Please provide references to best practises or quantitative examples on energy savings/costs form circular or bio-based renovation if possible;
3. If possible, please elaborate on best practise case studies of policies which promote circularity or bio-based renovation.

LTRS Member State targets

Table 19: Summary of LTRS targets

Member State[265]	Current renovation rate		Projected renovation rate		Base year	Energy savings by 2050	Emissions reduction by 2050	Investment needs	
	year	%	year	%	year	%	%	by year	bn EUR
Austria	2020	1.5%	2050	3%	2020	n/a	64%	2050	10
Belgium (Flanders)					2005	33-70%	74-100%	2050	200
Belgium (Wallonia)					2017	22-27%	22-43%	2050	150-180
Cyprus			2030	1%	2020	20%	24%	2030	0.8
Czechia	2014	1.9%	2030	2-3%	2020	23.5%	40%	2050	33
Denmark					1990		70%	2050	5.4-10.2
Estonia					2020	60%	90%	2050	22
Finland					2020	55%	90%	2050	24
France	2010-14	10.3%			2015	41%	94%	2032	15-25
Germany	2010-14	0.7%	2030	1.3-2%	1990/2008	50%	67%		
Ireland	2020	1.3-1.5%	2030	2%	2030[266]		40-45%		
Latvia					2017		80%	2050	19
Luxembourg					2020	58%	62%		
Netherlands	2014	8.6%			1990		95%	2030	56-75
Romania			2030	1.6-3.4%	2017	10-25%	6-9%		
Spain	2014	0.1%			2020	36-37%	99%	2030	143[267]
Sweden	2020	2.3%			2016	10-38%	100%		

By 2030

This table has been compiled using the following sources: BPIE, 2020, A review of EU Member States' 2020 Long-Term Renovation Strategies; European Commission, n.d., Long-term renovation strategies. Available at: https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings/long-term-renovation-strategies_en; European Commission, 2021, Preliminary analysis of the long-term renovation strategies of 13 Member States. SWD(2021) 69 final.; Enerdata, n.d., Zebra 2020 – Data tool : Energy efficiency trends in buildings.

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265 English translations of LTRS are not available for: Bulgaria, Croatia, Greece, Hungary, Italy, Lithuania, Malta, Poland, Portugal, Slovakia and Slovenia.

266 Comparison to projections.

267 Residential sector only.

Case Studies

Table 20: Case studies of innovative energy renovation policies

Type	Country, Policy	Year active	Description	Building type	Relevant public bodies/ministries	Barriers addressed	Key results
Integrated planning	Germany (Baden-Wurttemberg), Climate Protection Law: Heat Planning[268]	2020	Requires 103 cities, based on size, to develop a roadmap for their CO2-neutral heat supply by 2050 for both residential buildings and industry. It requires consumption data to be shared between local authorities to encourage effective energy management; provides financial support from the region to cover the mandatory municipal planning process; and includes the development of a tool to foster sustainable construction.	Residential and industry	State of Baden-Wurttemberg (Regional)	Knowledge sharing (amongst local authorities), technical assistance, local financing	Too early in implementation phase to identify results.
	Denmark (Sonderborg), Project Zero[269]	2007	Public-private partnership to decarbonise Sonderborg, Denmark by 2029. The initiative is based on EE and RES solutions and incorporates several aspects, including education and energy advice	Residential and commercial	City of Sonderborg	Knowledge sharing, integrated planning, energy advice	By 2015, carbon emissions lowered 25%, compared to 2007 levels. 1,200 homeowners received free energy advice.

268 DBDH, 2021 Large and Growing Markets, 2021, International Magazine on District Heating and Cooling.

269 ProjectZero, n.d., available at: http://brightgreenbusiness.com/toppages/about-projectzero-2.

Type	Country, Policy	Year active	Description	Building type	Relevant public bodies/ministries	Barriers addressed	Key results
Financing	Belgium (Gent), Knapt Op - Recurring fund[270]	2021 (pilot)	Innovative financial system, which provides 30K EUR per house to residents who co-design renovation works with technical experts. The financing returns to the fund when the building is sold, which is guaranteed by a mortgage on the building.	Residential	City of Gent	Financing for low-income homeowners, technical assistance	Too early in implementation phase to identify results.
	Germany, KfW Energy-efficient construction and refurbishment programmes[271]	2009	The KfW, the state-owned investment and development bank, enables long-term financing for energy efficient construction and renovation through loans and grants.	Residential, services (commercial and public)	Ministry of Economic Affairs and Energy, KfW	Long-term financing for renovations	Reducing CO2 emissions by 9 mil. tonnes per year; 33% reduction in energy use.[272]
	France, MaPrimeRénov[273]	2020	Grant scheme to finance insulation, heating, ventilation and energy audit renovation works. The funding intensity is based on income and energy saving. The works must be carried out by RGE-labelled companies (guarantors for the environment).	Residential	French Government, National Housing Agency	Financing for low-income households	Too early in implementation phase to identify results, but about 190,000 requests were submitted in 2020.

[270] Giannakopoulou M., 'From House to Home' The Recurring Fund: A sustainable future for low-income housing renovations?, 2021, available at: https://www.uia-initiative.eu/en/news/house-home-recurring-fund-sustainable-future-lowincome-housing-renovations.

[271] Bukarica V. et al., Renovation in Buildings, Odyssee-Mure, 2017, available at: https://www.odyssee-mure.eu/publications/policy-brief/renovation-building-policy-brief.pdf.; KfW, KfW's programmes for energy-efficient construction and refurbishment have positive impacts on the climate and public coffers, 2018, available at: https://www.kfw.de/KfW-Group/Newsroom/Latest-News/Pressemitteilungen-Details_472512.html.

[272] Steuwer et. al, Lessons learned to inform integrated approaches for the renovation and modernization of the built environment, Annex III: Good practice examples, European Commission, 2020.

[273] European Commission, Proposal for a Council Implementing Design on the approval of the assessment of the recovery and resilience plan for France, 2021f.

Type	Country, Policy	Year active	Description	Building type	Relevant public bodies/ministries	Barriers addressed	Key results
	Austria, Residential building subsidy[274]	1982	Subsidies for increasing thermal quality and heating system efficiency in residential buildings. The programme is aimed at reducing heating energy consumption and switching to renewable heating. Households are able to be supported with up to 5K EUR for replacing fossil heating systems.	Residential	Austrian government	Financing heating system replacement	Based on impact evaluation: energy savings of 1.9 PH in 2014 1.76 PJ in 2015
	Ireland, Heatpump grants[275]	2018	Grant up to 3,500 EUR to install heat pump. The grant is based on the energy efficiency first principle by including prerequisites for minimum energy efficiency.	Residential	Ministry for Environment and Climate Change, Sustainable Energy Authority Ireland	Increase market competitiveness of RES H&C	>2,900 grant-aided heat pump installations between 2018 and Oct. 2020
	Italy, Superbonus scheme	2020-2021	The scheme intends to provide a tax credit which covers 110% of the costs of energy efficiency and structural improvements to buildings.	Residential and commercial	Italian government	Attract renovation investments	Too early in implementation phase to identify results.

274 Odyssee-Mure, Mure Database, n.d., available at: https://www.measures.odyssee-mure.eu/energy-efficiency-policies-database.html.

275 SEAI, Encouraging heat pump installations in Ireland, 2020, available at: https://www.seai.ie/publications/Heat-Pump-Adoption.-Maximising-Savings..pdf; Enefirst, Heat pump system grant by the sustainable energy authority of Ireland (SEAI), n.d., available at: https://enefirst.eu/wp-content/uploads/ID13_Heat-pump-subsidy_BPIE.pdf.

Type	Country, Policy	Year active	Description	Building type	Relevant public bodies/ministries	Barriers addressed	Key results
Information/awareness	Belgium (Flanders), Woningpas and EPC+[276]	2018	Building Renovation Passport linked to long-term targets for energy performance of the building stock, linked to EPCs, user friendly and tailored advise, includes digital logbook and customised measures and building owners are at the centre of the process. Additionally, there is consideration for setting up training for renovation advice auditors.	Residential	Flemish Energy Agency	Access to information, improve awareness, tailored financial/ technical advise, training of auditors	Too early in implementation phase to identify results.
	Germany, Individueller Sanierungsfahrplan[277]	2017	A publicly funded energy audit instrument, carried our by certified energy auditors. On-site energy audits can be up to 60% subsidised through this programme. This programme focuses on staged renovations.	Residential	Ministry of Economic Affairs and Energy	Technical advice	Regional roadmap (Baden-Wurttemberg): by mid-2018, 2,300 renovation roadmaps were developed, leading to 1.3Kt CO2 savings per year.

[276] Dorizas P.V. et al., How can Member States implement iBRoad?. BPIE, 2019, available at: https://www.bpie.eu/wp-content/uploads/2020/05/How-can-Member-States-implement-iBRoad.pdf.; Enefirst, Building Logbook – Woningpas: exploiting efficiency potentials in buildings through digital building file, n.d., available at: https://enefirst.eu/wp-content/uploads/12_BUILDING-LOGBOOK-WONINGPAS.pdf.

[277] Fabbri M. et al., The Concept of the Individual Building Renovation Roadmap, BPIE, 2018, available at: https://www.bpie.eu/wp-content/uploads/2018/03/iBRoad-The-Concept-of-the-Individual-Building-Renovation-Roadmap.pdf.

Type	Country, Policy	Year active	Description	Building type	Relevant public bodies/ministries	Barriers addressed	Key results
	France, Passeport Efficacité Energétique [278]	2017	A BRP via an online platform, which offers advice to owners, auditors and renovation professionals. The BRP is linked to long-term national energy performance targets, includes indicators for additional benefits (comfort), on-site audits and is linked to financing opportunities. The instrument was developed outside of existing systems.	Residential	French government	Technical advice	1172 passports carried out during testing phase; 68% of piloted passports triggered additional energy savings measures.
	Denmark, Better Home[279]	2014	Industry-driven one-stop shop model, which focuses on deep renovation, multiple benefits and innovative technologies. Better Home advisors are trained by the Danish Energy Agency. The scheme is now discontinued.	Residential, service (commercial)	Danish Energy Agency	Increase awareness, access to information; training advisors	About 700 plans registered; more than 400 trained advisors. It has been successful in boosting demand for holistic energy renovations.
	France (Alsace), Oktave[280]	2016	A one-stop-shop in the French region of Alsace, it provides tailored technical deep renovation advice, financial planning support, project management assistance and directory of qualified experts, trained via the programme.	Residential	Local government	Training professionals, access to information	Trained 250 professionals by 2017; included 180 projects, with 10.6 MWh of energy savings per year per project.

[278] Dorizas P.V. et al., How can Member States implement iBRoad?, BPIE, 2019, available at: https://www.bpie.eu/wp-content/uploads/2020/05/How-can-Member-States-implement-iBRoad.pdf.

[279] European Commission, European Construction Sector Observatory. Policy measure fact sheet. Denmark. Better Homes (BedreBolig) Scheme., 2018.; Dorizas P.V. et al., How can Member States implement iBRoad?, BPIE, 2019, available at: https://www.bpie.eu/wp-content/uploads/2020/05/How-can-Member-States-implement-iBRoad.pdf.

[280] Dorizas P.V. et al., How can Member States implement iBRoad?, BPIE, 2019, available at: https://www.bpie.eu/wp-content/uploads/2020/05/How-can-Member-States-implement-iBRoad.pdf.

Type	Country, Policy	Year active	Description	Building type	Relevant public bodies/ministries	Barriers addressed	Key results
	Belgium (Brussels), HomeGrade [281]	1996	The aim of the programme is to improve the energy performance of buildings and mobilise owners, occupants and buildings managers. It provides services such as: information/advice, technical, administrative and financial support as well as subsidises local associations.	Residential	Energy agencies, local government	Information campaign	Based on impact evaluation: final energy savings of 2.1 GWh in 2015 and 3.5 GWh in 2016.
Regulation/standards	England & Wales, Minimum Energy Efficiency Standards[282]	2018	Mandatory MEPS based on EPC class (E). Originally only for the privately rented sector and triggered by tenancy transaction, but as of 2020, extended to all privately rented residential buildings and as of 2023, to all non-residential privately rented buildings. The requirement only applies to buildings where an EPC is required. EPCs are triggered by changes in tenancy or ownership. Enabling funding is limited.	Residential and commercial (privately rented)	UK Government	Address energy poverty, trigger renovation via mandates, split incentives	Expected emission savings are 4.3 MtCO2-eq.[283]

[281] Odyssee-Mure, Mure Database, n.d., available at: https://www.measures.odyssee-mure.eu/energy-efficiency-policies-database.html.

[282] Sunderland L. & Santini M., Case Studies: Minimum energy performance standards for European buildings, 2020 b, available at: https://www.raponline.org/wp-content/uploads/2020/07/rap-ls-ms-meps-case-studies-2020-july-28.pdf.; BEIS, Evaluation of the Domestic Private Rented Sector Minimum Energy Efficiency Standard Regulations: Interim Report, 2019.

[283] Steuwer et. al, Lessons learned to inform integrated approaches for the renovation and modernization of the built environment, Annex III: Good practice examples, European Commission, 2020.

Type	Country, Policy	Year active	Description	Building type	Relevant public bodies/ministries	Barriers addressed	Key results
	Scotland, Minimum Energy Efficiency Standards[284]	2020	Mandatory MEPS based on EPC class (E, but by 2022, D). This applies to all privately rented homes under new tenancy, but will be extended to all privately rented homes by 2022. The MEPS only applied to homes where EPCs are mandatory. There is a strong enabling framework. Home Energy Scotland provides free advice. There are interest-free loans up to €42,789 for homeowners and grants are available for low-income/fuel-poor households for energy efficiency/heating renovations. There are area-based schemes to identify hard-to-reach households.	Residential (privately rented)	Home Energy Scotland	Address energy poverty, trigger renovation via mandates, split incentives	Too early in implementation phase to identify results

284 Sunderland L. & Santini M., 2020, Case Studies: Minimum energy performance standards for European buildings. Available at: https://www.raponline.org/wp-content/uploads/2020/07/rap-ls-ms-meps-case-studies-2020-july-28.pdf.

Type	Country, Policy	Year active	Description	Building type	Relevant public bodies/ministries	Barriers addressed	Key results
	Belgium (Flanders), Flemish Renovation Pact - Minimum requirements for roof insulation and glazing[285]	2015/ 2020	Rental housing without minimum insulation (since 2015) and glazing (since 2020) cannot be rented out based on a penalty point system. Standards are enforced at municipal level. This policy has been supported by information campaigns and renovation grants.	Residential, privately rented	Flanders government	Address energy poverty, trigger renovation via mandates, split incentives	Too early in implementation phase to identify results, but there is new pressure on small, private landlords to initiate improvements before compliance is mandatory[286]
	The Netherlands, Office building MEPS[287]	2018	From 2023, all office buildings will need to be of EPC class C, otherwise they can not be used as an office building. This measure includes cost thresholds, where renovation measures to meet requirements must be taken up to that threshold. RVO provides technical info. to support compliance (via online tool). There are tax incentives to offset some of the costs of EE measures.	Service (commercial)	Dutch government, Netherlands Enterprise Agency (RVO)	Trigger renovation via mandates, access to information	Though compliance is not yet mandatory, the policy has already had an impact on commercial real estate [288]

[285] Ibid.

[286] Hinge, A., 2020, Minimum Energy Standards for Rented Properties: an international review. Available at: https://www.energy.gov.au/sites/default/files/BEET%2010%20Minimum%20Energy%20Standards%20for%20Rental%20Properties%20-%20An%20International%20Review.pdf.

[287] Sunderland L. & Santini M., 2020, Case Studies: Minimum energy performance standards for European buildings. Available at: https://www.raponline.org/wp-content/uploads/2020/07/rap-ls-ms-meps-case-studies-2020-july-28.pdf.

[288] Hinge, A., 2020, Minimum Energy Standards for Rented Properties: an international review, Available at: https://www.energy.gov.au/sites/default/files/BEET%2010%20Minimum%20Energy%20Standards%20for%20Rental%20Properties%20-%20An%20International%20Review.pdf.

Type	Country, Policy	Year active	Description	Building type	Relevant public bodies/ministries	Barriers addressed	Key results
Digitalisation	Germany, Energy savings meter[289]	2016-2018 (pilot) extended to 2022	Eligible ESCOs that generate energy savings for their clients are able to receive funding to cover the cost of developing innovative digital energy services, where 75% of funding depends on the actual energy savings achieved based on meter readings. The level of funding depends on the fuel type. Additional funding is available for measures which enable grid flexibility.	Services (commercial)	Ministry of Economic Affairs and Energy	Financing innovation	The pilot phase ran from 2016 to 2018. Due to its success, the programme has been extended until 2022.

Source: Compiled by Trinomics

[289] IEA, 2019, Case Study: Energy Savings Meter Programme in Germany. Available at: https://www.iea.org/articles/case-study-energy-savings-meter-programme-in-germany.

Table 21: Case studies of innovative circular and/or bio-based renovation policies

Country, Policy	Year active	Description	Relevant public bodies/ministries	Key results
The Netherlands, Green Deals - Circular Buildings	2015-2017	Private-public collaborative project of more than fifty parties which focused on minimising the use of virgin materials in the building construction and usage phases. Indicators of building circularity were established to produce a circular building passport, which is partly created using existing initiatives and buildings. The end result of the project is a digital platform, including the circular building passport, which can be used to assess the circularity of a building.	Ministry of Economic Affairs, Ministry of Infrastructure and the Environment, and Ministry of the Interior and Kingdom Relations	The creation of a circular building passport
Austria, Recycled Construction Materials Ordinance	2015-	Regulation to promote the recycling of construction and demolition waste. The ordinance applies to construction/demolition activities and the production and use of recycled building material and the regulation.	Federal Ministry Republic of Austria BMK	8.6 mio. Tons of recycling building materials were produced in 2019.
The Netherlands, Dutch Building Decree - Environmental Performance Calculation for Buildings	2013-	The regulation stipulated that buildings (offices and residential) must have material environmental performance calculated in the submission of the environmental building permit. The method of calculation is based on a life cycle analysis (LCA) approach. This requirement only holds for new buildings, but it is being investigated how this regulation can also cover renovations.[290]	Dutch government, The Dutch Environmental Database (independent organisation)	n/a
Denmark, LCA Center Denmark	2002-	The LCA Center is the official national knowledge centre for the dissemination and support of life cycle assessment and approaches. The centre supports companies with the implementation of LCA.	Danish Environmental Protection Agency	n/a

Source: compiled by Trinomics

[290] Dutch Government, 2021, Environmental performance for buildings will be tightened on 1 July 2021. Available at: https://www.rijksoverheid.nl/actueel/nieuws/2021/03/11/milieuprestatie-voor-gebouwen-wordt-1-juli-2021-aangescherpt.

Estimation of emissions reduction from bio-based building materials

Table 22: Estimates of emissions reduction from bio-based building materials

Study	Bio-based method	Emissions savings	Unit
van Dam et. al (2019)	Wood frame	60	% less CO_2 emissions per house
	Wood products	0.9	Carbon storage: tCO_2/m^3
Petersen and Solberg (2005)	Wood vs. steel	36-503	kg CO_2e/m^3
	Wood vs. concrete	96-1032	kg CO_2e/m^3
Sathre and O'Connor (2010) (meta-analysis)	Wood product substitution	0.8-4.6	tCO_2 emission reduction per tCO_2 of additional wood products used (Average based on 21 studies)
Hafner, A., & Schäfer, S. (2017)	Wood vs. Brick concrete	18-178	kg CO_2e/m^3
Chen, Z. et. al (2020)	Wood vs. concrete	53	kg CO_2e/m^3
Moschetti, R. et. al(2019).	Wood vs. concrete	2	kg CO_2e/m^3
Dodoo, A. (2019).	Wood vs. concrete	120-222	kg CO_2e/m^3
Chastas, P. et. al (2018)	Wood vs. steel and concrete	30-470	kg CO_2e/m^3
Ajayi, S. O. et. al (2019)	Wood vs. steel and concrete	105-626	kg CO_2e/m^3
Hart, J. et. al (2021)	Wood vs steel and concrete	121-460	kg CO_2e/m^3
Pierobon, F. et. al (2019)	Wood vs. concrete	117-123	kg CO_2e/m^3

Source: compiled by Trinomics

Mapping of policy recommendations and policy gap

Table 23: Mapping of policy recommendations and policy gaps

Barriers	Lack of vision/targets		Financial			Technical		Social	
Policy gaps	MS vision/ implementation	Integrated planning	MS financial planning	Accessible funding/ instruments	Energy poverty/ split incentives	Labour capacity and upskilling	Accessible data and monitoring	Accessible information	Technical assistance
Recommendations									
EU guidance on and monitoring of implementation of existing EU policies	✓		✓	✓	✓	✓	✓	✓	✓
Integration of existing planning		✓							
EU guidance on MS LTRS updates	✓		✓	✓	✓	✓	✓	✓	✓
Promote energy services				✓	✓		✓	✓	✓
Strengthen EPCs				✓			✓	✓	
Mandatory MEPS, linked with financing				✓	✓				
Targeted funding				✓	✓				
Integrated local planning	✓	✓							
Financial incentives via LTRS			✓	✓					
Adequate long-term funding for technical assistance tools/instruments			✓	✓	✓			✓	✓
EU guidance on skills development and attract labour via digitalisation and industrialisation						✓			
Encourage MS integration of LCA							✓	✓	
Encourage MS investigation into circular renovation opportunities	✓							✓	
Encourage MS investigation into bio-based renovation opportunities	✓							✓	

Implementation of existing policies
Affirmation of existing policy proposals
Additional policy recommendations

Source: Authors' own elaboration

This study provides an analysis of the gaps in EU policies aimed at increasing industrial energy efficiency, an assessment of the ability of the electricity grid to absorb large increases in renewables, and an evaluation of the energy efficiency potential of the Renovation Wave. Links to the proposed Fit for 55 package are also made for all three topics.

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