REPowerEU and Fitfor55 science-based policy recommendations for achieving the Energy Efficiency First Principle

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sEEnergies

QUANTIFICATION OF SYNERGIES BETWEEN ENERGY EFFICIENCY FIRST PRINCIPLE AND RENEWABLE ENERGY SYSTEMS

REPowerEU and Fitfor55 science-based policy recommendations for achieving the Energy Efficiency First Principle

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Executive Summary

The current changes of the planet's biophysical dynamics, defining the current epoch of the Anthropocene, are becoming increasingly visible and intense, with 2021 being another record-breaking year of extreme weather. The urgency to respond is continuing to grow, as are efforts to limit global warming to well below 2°C, preferably 1.5°C, compared to pre-industrial levels, as mandated in the Paris Agreement. In addition, the war between Russia and Ukraine has put energy on the agenda and highlighted geopolitical elements of international fossil fuel trade and interdependence. The focus on **fast transition** away from parts of the European natural gas imports from Russia is pivotal.

A central measure towards a clean, smart and secure European energy system, is driven by significant **energy savings**, **energy efficiency** and **deployment of renewable energy**. The European Union has thus set ambitious objectives for the future of Europe's energy system, committed to developing a sustainable and decarbonised system and transitioning toward a low carbon economy in line with the Paris Agreement. Energy efficiency is seen as a cost-effective key to supporting the transformation of the energy system and achieving climate neutrality in combination with an acceleration of the deployment of renewable energy. The **Energy Efficiency First Principle** urges Member States to prioritise energy efficiency in planning processes and investments. The question is what energy efficiency measures have which effect and at what levels renewable energy is more cost effective than further end savings?

The call for action to transform Europe's energy system has been further amplified by the recent geo-political pressures instigated by Russia's invasion of Ukraine. The Commission's **REPowerEU Plan** thus outlines short-term measures for the twofold goal of ending the EU's dependence on Russian fossil fuels and addressing climate change, via energy savings, diversifying energy supplies and accelerating the deployment of renewable energy to replace fossil fuels in buildings, industry and the power sector.

REPowerEU has several elements and has been presented in steps. This report includes considerations presented on May 18th 2022 as well as all of the Fit for 55 measures. In sEEnergies, a cost effective 100% renewable energy and energy efficiency-based scenario is presented for EU27 and the United Kingdom in 2050. This vision gives a **full decarbonisation of the energy, buildings, industry and transport sectors** without exceeding sustainable bioenergy resources. SEEnergies utilises targeted and cost-effective energy efficiency measures combined with renewable energy in a re-designed European smart energy system.

sEEnergies addresses **REPowerEU** and the **European 2030 goals** by means of known technologies within energy efficiency and renewable energy. It is pivotal that REPowerEU and the decarbonisation targets in 2030 does not:

1) hinder the long term 2050 target and
2) provides short term energy security in Europe using known technology

This report aims to provide **sound science-based policy suggestions to support the Energy Efficiency First Principle and renewable energy targets**, based on the project's overall findings. First, an overview of the existing EU policies, targets, directives and regulations is provided as a starting point for the subsequent identification of policy gaps related to energy efficiency and renewable energy. The majority of the policies covered in this report are aimed at 2030. sEEnergies has created a more cost

and resource efficient system compared to the Commission's TECH1.5 scenario for 2050 (COM(2018) 773) meeting the climate neutrality target in 2050 called sEE 1.5. A sEE 2030 energy system scenario is presented based on the sEE 1.5 target. Existing EU targets are compared with the sEE 2030 energy system results and analysed in terms of their implications for policy, in order to ensure that the objectives for the energy system in 2030 do not present obstacles for achieving the recommended system redesign for 2050 and offer strategic insight for addressing the current energy market disruption caused by Russia's invasion of Ukraine and enhancing Europe's energy security. The comparisons and policy suggestions are discussed in terms of the energy system as a whole and its components as well as the building, industry, and transport sectors.

Based on the analysis, it was found that the overall energy efficiency targets set by the Commission's REPowerEU Plan for 2030 are in line with the sEE 2030 scenario, which achieves a **14% reduction** of the 2020 reference scenario projections for 2030, and subsequently the transition to the sEEnergies sEE 1.5 climate neutral system target. However, the concrete sector energy efficiency means to achieve the targets differ between REPowerEU and sEEnergies 2030. Furthermore, **targeted energy efficiency measures sector by sector** combined with an **energy system re-design** provides a **more efficient 2030 and 2050 energy system** comparing primary energy consumption and final energy consumption, as shown in Figure 1 below.

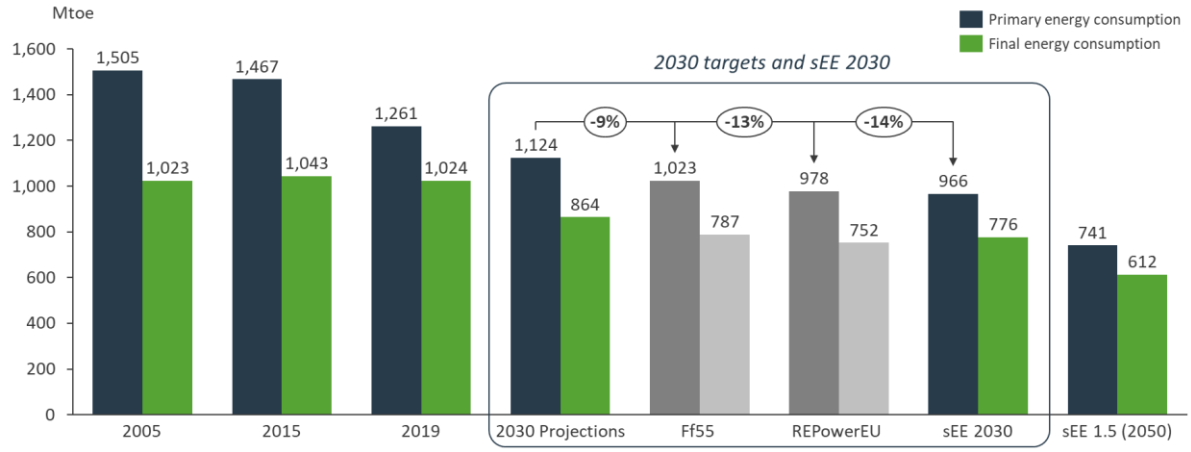

Figure 1 . Primary and final energy consumption for 2005, 2015, 2019, 2030 projections based on the EU 2020 reference scenario, EU policy targets for 2030 (Fit-for-55 and REPowerEU) and sEE 2030, and sEE 1.5

Careful consideration of each sector and prioritisation of a holistic system redesign towards a smart energy system is recommended. In particular, sEEnergies recommends more emphasis on efficient **supply systems for heating**, such as district heating, compared to the sole focus on very ambitious targets for end demand reductions in existing buildings and more focus on targeted policies to electrify transport and industry. A move away from the focus on Nearly zero-energy buildings (NZEBs) and on-site renewable energy production, as set out by the **Energy Performance of Buildings Directive**, toward stronger targets on the **building envelope** is suggested. The NZEB concept dilutes the demands linked to building envelope improvements, which will impede achieving the 2050 targets. A new **Heat Planning Directive** is further suggested to bring heating on the agenda as a part of the energy system and to enable zoning mechanisms for different types of heat supply.

SEEnergies has shown that the three sectors (buildings, transport and industry) have equally large energy efficiency potentials. Therefore, it is recommended that the European Commission develops a stronger and more holistic regulatory focus in transport and industry as well as buildings. On the supply side, sEE 2030 achieves **RES shares of 60% in buildings, 24% in transport, and 51% in industry**. For transport, a more systematic approach is needed for structuring energy efficient urban development and enabling modal shifts through the extensive development of cross-national public transport solutions. A **Sustainable Transport Infrastructure Directive** is recommended that frames long-term structural changes related to energy efficient infrastructures in transport across Europe, namely rail and e-road system developments. For industry, additional improvements to the Eco-Design, Energy Labelling and Fuel Quality Directives are recommended that support the phase-out of low efficiency combustion technologies, reward the use of excess heat for district heating, promote onsite use of concentrated solar and PV large roofs, and shift focus from measures promoting hydrogen use toward measures that support the electrification of industries by use of large-scale heat pumps and direct electricity use.

Regarding natural gas consumption, **sEEnergies 2030 shows 14 – 22% greater potential gas savings** compared to the total savings set out by Fit-for-55 and REPowerEU measures, which are shown in Figure 2. The largest gas savings in sEEnergies 2030 are achieved through the system effects of renewable energy and electrification measures as well as the delayed nuclear phase-out until 2030, which are quantified at a total of 83 bcm of natural gas. This likely shows a shortcoming of the EU Commission's model, which does not explicitly account for the system effects of increased levels of household heat pumps, district heating (large-scale heat pumps) and electric vehicles. The waterfall chart below (Figure 3) shows the full (22%) potential for gas savings of the energy efficiency and renewable energy measures achieved by sEEnergies 2030, including the imported hydrogen, behaviour and fuel price changes, as well as the fuel shift with coal and LNG, as set out by REPowerEU.

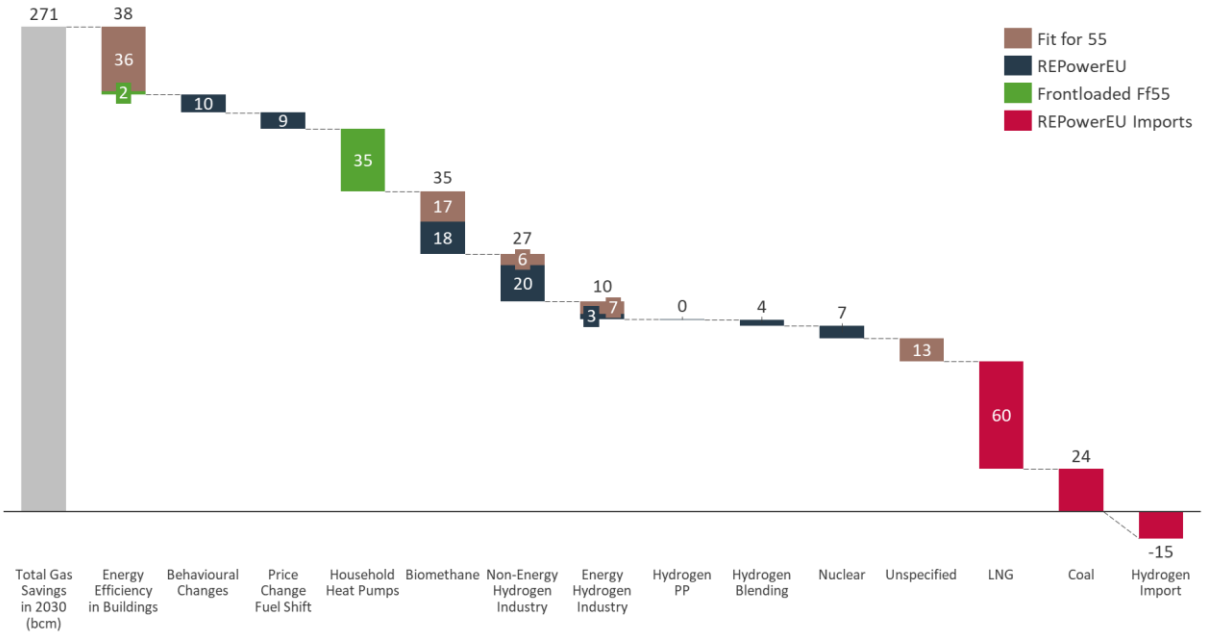

Figure 2. Disaggregated natural gas savings (bcm) by Fit-for-55 and REPowerEU measure

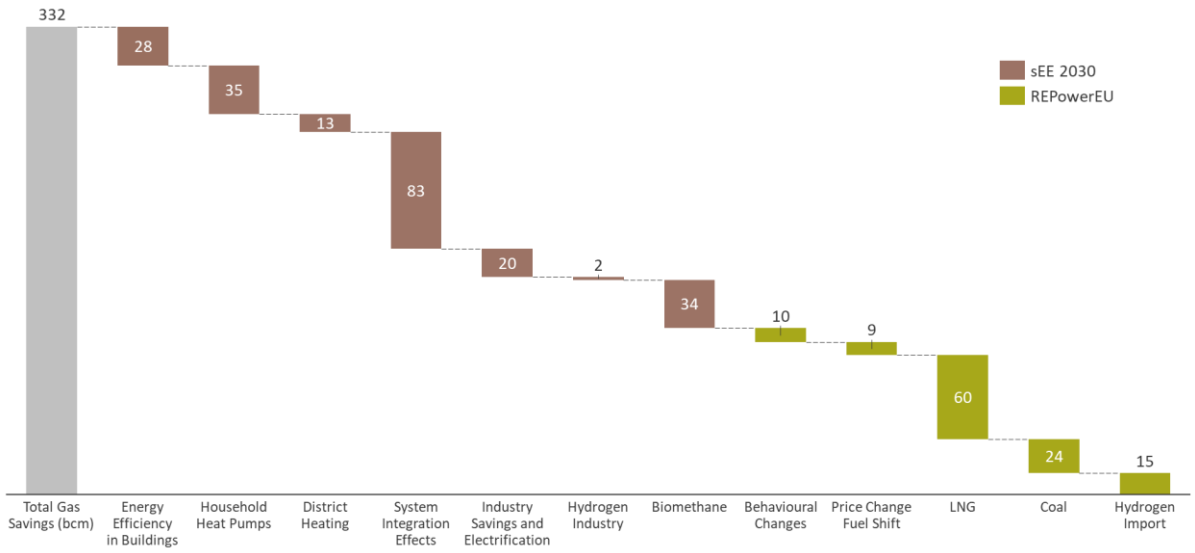

Figure 3. Breakdown of total natural gas savings in bcm achieved by sEEnergies 2030, including the imported hydrogen, behaviour and fuel price changes, and fuel shift with coal and LNG, as set out by REPowerEU.

On a system level, sEEnergies provides **reductions in CO_2 emissions of 58%** (compared to 1990 levels) and **biomass levels at 1790 TWh**, while reducing the natural gas consumption, in line with REPowerEU. Compared to the EU targets in REPowerEU and the EU 1.5TECH scenarios for renewable energy, higher levels of fluctuating renewables are also recommended for 2030 of **640 GW of solar PV, 490 GW of onshore wind,** and **95 GW of offshore wind energy**, and for 2050 of **1170 GW of solar PV, 920 GW of onshore wind,** and **250 GW of offshore wind energy**. The sEEnergies 2030 scenario achieves a slightly higher **RE share of 47%** compared to the REPowerEU 2030 target of 45%**.** The heightened ambition for hydrogen production, set out by REPowerEU, is discouraged as it creates new import dependencies, ultimately replacing imported natural gas with indirect import of green hydrogen or natural gas-based hydrogen. Instead, sEEnergies strongly suggests energy efficiency improvements and extensive electrification over the replacement of one gaseous fuel with another as well as a postponing of higher hydrogen use, as renewables have a stronger effect on energy security and climate mitigation in these first steps in the electricity sector. The following chart (Figure 4) shows the capacities of the sEEnergies EU27 energy system components for both 2030 and 2050.

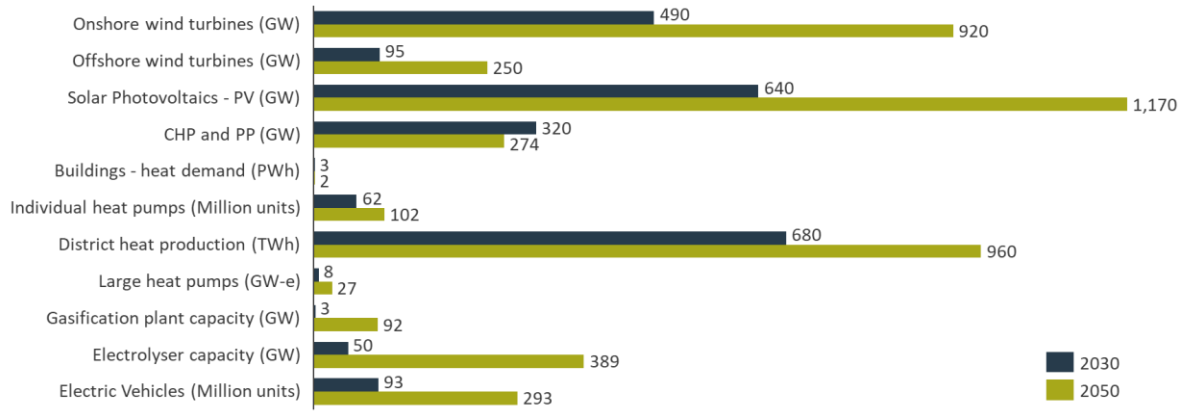

Figure 4. Total capacities of the sEEnergies 2030 and 2050 models for EU27.

The policy recommendations based on the analyses and findings of the sEEnergies 2030 and 2050 models are visually presented below, providing key considerations for Europe's energy transition.

ENERGY SYSTEM POLICY RECOMMENDATIONS

Overall, EU policies have an explicit focus on energy demands and not enough emphasis on **energy system re-design** and conversion. A systemic approach to **sector integration** is suggested in order to avoid suboptimal system design.

Energy Efficiency and Renewables

- The EE targets set by REPowerEU Plan for 2030 are in line withthe sEE 2030 scenario, which achieves a **14% reduction** of 2020 reference scenario projections for 2030 of **966 Mtoe of primary energy** and **776 Mtoe of final energy consumption**.
- sEE 2030 achieves a **58% cut in CO_2 emissions from 1990 levels**, which is in line with the heightened ambitions set out by the European Green Deal.
- sEEnergies achieves a more efficient system using less biomass and hydrogen compared to the REPowerEU ambitions and achieves a slightly higher RE share of 47% in the EU's gross final consumption.
- Compared to the EU targets in REPowerEU and the EU 1.5TECH scenarios set for renewable energy, sEEnergies recommends greater levels of fluctuating renewables for 2030 and 2050
  - 2030 targets: **640 GW of solar PV, 490 GW of onshore wind**, and **95 GW of offshore wind energy.**
  - 2050 targets: **1170 GW of solar PV, 920 GW of onshore wind**, and **250 GW of offshore wind energy**.
- sEEnergies recommends geothermal and solar targets for 2050 **of 0.04 PWh/year geothermal** and **0.03 PWh/year solar thermal energy**.

Hydrogen

- A target of **5 Mt of hydrogen in 2030** is considered sufficient, as set by Fit for 55.
- A target of **50 GW of electrolyser capacity** is considered sufficient for 2030.
- Strongly suggest energy efficiency improvements and **extensive electrification** over the replacement of one gaseous fuel with another.
- Avoid additional hydrogen production and all new direct and indirect gas consumption.

Sustainable Bioenergy

- Current target on **sustainable biomethane production of 35 bcm** by 2030, as set by the REPowerEU plan, is considered appropriate.
- Measures should **limit the use of biomass** to the extent possible, given long-term concerns related to **resource scarcity** and **land use**, with sEE2030 capping **biomass use at 1790 TWh**.
- Measures should emphasise the development and roll-out of **Power-to-X technologies** and **electrification**, as well as the replacement of coal in industry with biomass.

BUILDING POLICY RECOMMENDATIONS

Energy Performance of Buildings Directive

- Better balance between **end savings and supply** is recommended, with more realistic and ambitious **targets for end consumption**.
- A reduction in **heat demand of 40%** for existing residential and service buildings is needed from 2020 to 2050, which is equivalent to **1.3-1.4% absolute heat reduction per year**.
- Rather than having a higher target, directive should focus on implementation of existing targets and measures.
- Stronger **monitoring** and **knowledge-sharing** between Member States on best practices is suggested.
- A move away from the focus on NZEB and on-site renewable energy production toward stronger targets on the **building envelope** is suggested, as the NZEB concept dilutes the demands linked to building envelope improvements.

New Heat Planning Directive

- Focus on **heating as a part of the energy system** and zoning mechanisms for different types of heat supply.
  - Support the systematic identification of **spatial potentials for district heating** in the Member States in order to prioritise between district heating and individual heating solutions, such as electric heat pumps.
  - A heightened ambition for individual heat pumps, from the current Fit-for-55 package of 30 million units, is recommended to **45 million newly installed individual heat pumps by 2030**.
- Support framework for **district heating** with mandatory demand to have **local ownership** and **governance models** and to use of state-of-the-art technology for EE and DH.

District Heating and Individual Heat Pumps

- A higher ambition to decarbonize the building stock by 2030 is recommended by **increasing district heating from 13% (2019) to 20%** and **increasing heat pumps share from 5% (2019) to 26%**, instead of a sole focus on end demand reductions in existing buildings and individual heat pumps.
- A **financial infrastructure support mechanism** for establishment of new district heating systems is recommended as well as ensuring that access **to low interest rate public loans** if ownership is local and that no profit is taken out of the system.
- Mandatory planning procedures and private economic conditions are recommended that favour long-term investments in EE and DH.
- **Demand assessments** should be **based on socio-economic cost** and a subsidy (national or EU) should be based on **local valuation** (a kind of CBA system).
- The establishment of a **democratic infrastructure** is also suggested that demands full disclosure of financial elements in tariff structure.

TRANSPORT POLICY RECOMMENDATIONS

Electrification and Emissions

- Measures promoting the **acceleration of electrification**. sEEnergies model finding at least **93 million electric vehicles** necessary on the roads by 2030, an increase by more than 200% than the European Green Deal target of 30 million zero-emission cars.
- Only allow the registration of **zero-emission vehicles** (cars, vans, motorbikes, mopeds, etc.) by 2030.
- Separate targeted policies for **all modes of transport** are recommended, including light-duty vehicles and heavy-duty transport.
  - For example, the Sustainable and Smart Mobility Strategy target on the number of zero-emission vehicles should **cover other forms of transport**, in addition to cars.
- **Financial support mechanism** for the **electrification** of trucks, navigation, and aviation by battery-electric propulsion systems, e-road systems, and charging stations.

Alternative Fuels

- Eliminate targets that allow for biofuels, biogas and LNG in transport.
- Clear targets to support **alternative fuel infrastructure** developments, e.g., methanol for trucks and ammonia and methanol for navigation. sEE 2030 gives the possibility to have blend-in demands for aviation and navigation of 10% (measured in terms of the energy content), which is not directly comparable to EU volumetric blend-in demands, nevertheless, sEEnergies targets are higher than EU targets.
- Electrofuels should be prioritized for **aviation** and **navigation**.
- The focus on CO_2 emissions of **heavy-duty vehicles** should be reduced, since this promotes the use of biofuels and biogas.

Urban Spatial and Infrastructure Development

- Targeted policies to promote **urban densification** and **efficient demand growth**, whereby Member States are encouraged to develop local planning mechanisms for limiting continued urban sprawl and sharing platforms for energy efficiency urban development knowledge and best practices are established.
- A **Sustainable Transport Infrastructure Directive** is recommended that frames long-term structural changes in transport, primarily energy efficient infrastructures across Europe, supporting rail and e-road system developments (not only charging points).
- Refocus **TEN-E** to stop the support of road infrastructure (motorways), and instead support the development of **local public transport** infrastructure (e.g., metro, tram) as well as **trans-European high-speed rail**.

INDUSTRY POLICY RECOMMENDATIONS

New Industry EE Directive

- Shift focus from measures that promote the use of hydrogen, toward measures that support the **electrification of industries** by use of **large-scale heat pumps** and **direct electricity use**.
- Hydrogen and bioenergy should be reserved for hard to abate processes.
- Reward the use of **excess heat for district heating**.
- Push **industrial symbiosis**.
- Phase out low efficiency combustion technologies (Eco-design).
- Promote **onsite use of concentrated solar** and PV on large roofs, **geothermal heating**.
- Measures for **flexible demand, operation**, and **consumption**.
  - Flexible consumption can be incentivised through **adjusted fuel** and **electricity cost structures** based on **peak load and connected capacity** in addition to a volumetric measure of energy.

Electrification and Renewables

- A heightened ambition is suggested for the **RES share in industry in 2030 of at least 50%.**
- Clear **electrification** of industry targets are also recommended of at least **38% in 2030** and **65.5% in 2050**.
- EU wide financial support mechanism for **large-scale electrification** of industry targeted at vulnerable sectors.
- Electrification of **low-temperature processes** can be further prioritised as a short-term means of reducing **natural gas consumption**.

Socio-economic Potentials

- Set targets that ensure **high costs on greenhouse gas emissions**.
- Set lower boundary targets for **levies on combustion**.
  - A levy to promote electricity and halt increased bioenergy use .

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Acronyms & Abbreviations

Term	Description
BAT	Best Available Techniques
bcm	Billion cubic meters of natural gas
BREF	BAT Reference Document
CHP	Cogeneration of heat and power
CO_2	Carbon dioxide
EE	Energy efficiency
EED	Energy Efficiency Directive
EEFP	Energy Efficiency First Principle
ELD	Energy Labelling Directive
EPBD	Energy Performance of Buildings Directive
ESD	Effort Sharing Directive
EU ETS	European Union Emissions Trading Scheme
EU	European Union
Ff55	Fit for 55
gCO_2eq/MJ	Grams of CO_2 equivalent per megajoule
GHG	Greenhouse gas
GW	Gigawatt
H_2	Hydrogen gas

IED	Industrial Emissions Directive
KW	Kilowatt
LNG	Liquefied natural gas
Mt	Million tonnes
Mtoe	Million tonnes of oil equivalent
MW	Megawatt
NECP	National Energy and Climate Plan
NZEBs	Nearly zero-energy buildings
PCI	Project of Common Interest
RE	Renewable energy
RED II	Renewable Energy Directive
SAF	Sustainable aviation fuel
TEN-E	Trans-European Networks in Energy
TSI	Technical specification for interoperability
TWh	Terawatt hour

1 Introduction

This handbook describes the EU policy related to energy efficiency within the energy system and based on the findings in the report: Energy Efficiency Roadmap Europe: A cost-effective and energy efficient strategy for decarbonizing Europe (Deliverable 6.3). The aim is to identify policy gaps and possible overlaps related to energy efficiency.

Policy gaps were identified by following three main methodological steps

1. Developing a sEEnergies 2030 (sEE 2030) scenario based on the sEEnergies scenario addressing the 1.5 degree 2050 target (sEE 1.5), using backcasting to compare to policies.
2. Reviewing all policy related to energy efficiency in the EU, as shown in Table 1 below.
3. Comparing sEE 2030 results with EU targets to identify gaps and develop policy recommendations for Europe's energy system, building, transport and industry sectors.

Table 1. EU policies, directives, strategies, and measures reviewed

Energy System	REPowerEU
	European Green Deal - Energy System Integration Strategy - Offshore Renewable Energy Strategy - Hydrogen Strategy
	Energy Efficiency Directive
	Renewable Energy Directive
	Energy Union Strategy
	National Energy and Climate Plans
	Trans-European Networks in Energy
Buildings	Energy Efficiency Directive
	European Green Deal - Renovation Wave Strategy
	Energy Performance of Buildings
	Eco-Design Directive
	Energy Labelling Directive
	Heating and Cooling Strategy
Transport	European Green Deal - Sustainable and Smart Mobility Strategy - ReFuelEU Aviation and FuelEU Maritime Initiatives
	CO_2 emissions regulations of new vehicles and new heavy-duty vehicles
	Fuel Quality Directive
	Renewable Energy Directive
	Alternative Fuel Infrastructure Regulation
	Clean and Energy Efficient Road Transport Vehicle
	Directive on the Interoperability of the Rail System
Industry	European Green Deal – Hydrogen Strategy
	Industrial Emissions Directive
	Eco-Design and Energy Labelling Directives
	Heating and Cooling Strategy
	Fuel Quality Directive
	EU Emissions Trading Scheme

Based on the gap analysis, sound science-based policy suggestions are presented to address those gaps. In particular, given the geo-political tensions instigated by Russia's invasion of Ukraine, the policy gap analysis and recommendations presented in this report are in dialogue with the most recent developments of the European Commission's REPowerEU Plan, which outlines short-term measures for the twofold goal of ending the EU's dependence on Russian fossil fuels and addressing climate change. In this way, we show that sEEnergies addresses REPowerEU and the European 2030 goals by means of known technologies with energy efficiency and renewable energy, without increasing coal consumption.

Overall, sEEnergies addresses long-term 2050 decarbonisation targets without exceeding our sustainable bioenergy resources by using targeted and cost-effective energy efficiency measures combined with renewable energy in a re-designed European energy system in 2050. Based on the analysis, it was found that the overall energy efficiency targets set by the EU's REPowerEU Plan for 2030 are in line with the sEEnergies sEE 2030 scenario and subsequently the transition to the sEEnergies sEE 1.5 climate neutral system target.

However, the concrete sector energy efficiency means to achieve the targets differ between REPowerEU and sEEnergies. In particular, sEEnergies recommends more emphasis on efficient supply systems for heating, such as district heating, compared to the sole focus on very ambitious targets for end demand reductions in existing buildings and more focus on targeted policies to electrify transport and industry. Furthermore, targeted energy efficiency measures sector by sector combined with an energy system re-design provides a more efficient 2030 and 2050 energy system comparing primary energy consumption and final energy consumption, as shown in Figure 1 above.

sEEnergies has a higher ambition to decarbonise the building stock by 2030, with a more cost-effective system for buildings by increasing district heating from 13% (2019) to 20% and increasing heat pumps share from 5% (2019) to 26%, instead of a sole focus on end demand reductions in existing buildings and individual heat pumps. A better balance between end savings and supply is recommended, along with a shift away from the focus on Nearly Zero-Energy Buildings (NZEBs) and onsite renewable energy production toward stronger targets on the building envelope combined with strong targeted measures for renewable energy. Furthermore, a new Heat Planning Directive is suggested that places emphasis on heating as a part of the energy system and establishes zoning mechanisms for different types of heat supply.

For transport, sEEnergies foregrounds primarily the acceleration of the electrification rate as well as energy-efficient urban development. Consequently, an elimination of targets allowing for biofuels, biogas and LNG transport is recommended, such that fuel cell vehicles remain a niche technology given their reliance on hydrogen and lower energy efficiency and electrofuels are reserved for hard to electrify modes, i.e., aviation and navigation. Furthermore, a refocus of the TEN-E is suggested such that support for continued road infrastructure developments, i.e. motorways, is replaced with support for the development of local public transport infrastructure and trans-European high-speed rail.

Concrete measures targeting improved energy efficiency in industry are needed that shift the focus from hydrogen centred toward electrification via large-scale heat pumps and direct electricity use. The phase out of low efficiency combustion technologies is also supported as is the promotion of industrial symbiosis, the use of excess heat for district heating and the onsite use of concentrated solar and PV

on large roofs. Furthermore, sEEnergies recommends an alignment of socio-economic potentials with business economic payback times, such as targets that ensure high costs on greenhouse gas emissions.

On a system level, sEEnergies provides a lower greenhouse gas emissions and biomass level, while reducing the natural gas consumption, in line with REPowerEU. In fact, sEEnergies 2030 shows 22% greater potential in gas savings (331 bcm) compared to the total savings set out by Fit-for-55 and REPowerEU measures (271 bcm). The largest gas savings in sEEnergies 2030 are achieved through the system effects of renewable energy and electrification measures as well as the delayed nuclear phase-out until 2030, which are quantified at a total of 83 bcm of natural gas. Higher levels of fluctuating renewables are recommended for 2030 and 2050, compared to the EU targets in REPowerEU and the EU 1.5TECH scenarios for renewable energy. The heightened ambition for hydrogen production, set out by REPowerEU, is discouraged as it creates new import dependencies, ultimately replacing imported natural gas with indirect import of green hydrogen or natural gas based hydrogen. Instead, sEEnergies strongly suggests energy efficiency improvements and extensive electrification over the replacement of one gaseous fuel with another as well as a postponing of increased levels of hydrogen use, as renewables have a stronger effect on energy security and climate mitigation in these first steps in the electricity sector.

In the next section (section 2), the existing EU political and regulatory instruments in place connected to energy efficiency and energy system transition, including the most recent developments and proposals by the European Commission are described. Section 3 describes the policy gap results based on the sEE 2030 energy system and the review of the EU policies. Based on the comparisons, policy recommendations are provided for the energy system as well as for each sector. An overview and discussion of the results are then presented in Section 4.

2 EU Framework Regarding Energy Efficiency and Energy System Transition

This section provides an overview of existing EU political and regulatory instruments regarding energy efficiency and energy system transition, which will serve as the basis to identify whether existing and planned policies can support the energy efficiency measures proposed in the report: Energy Efficiency Roadmap Europe: A cost-effective and energy efficient strategy for decarbonizing Europe (Deliverable 6.3).

Energy efficiency measures are recognised as a technical means to achieve a sustainable energy supply, reduce greenhouse gas emissions, and improve security of supply, as well as a political means to promote the competitiveness of the EU. The EU's prioritisation of energy efficiency extends across numerous political instruments, which first emerged in the 1970s and have been continuously evolving in tandem with shifting international and EU agendas (Economidou et al., 2020). These multiple instruments carry direct and indirect implications across all sectors, including building, transport, industry as well as energy grids and system. The following sections give a general overview of the existing and planned EU policies, targets, directives, etc. discussed by sector level, starting with a brief review of the overarching directives, strategies and legal frameworks.

2.1 General Policies and Directives

In 2012, the EU established a set of binding measures through the **Energy Efficiency Directive (EED)** that required all EU countries to realise energy saving potentials across all stages of the energy chain, including generation, transmission, distribution and end-use consumption (Directive 2012/27/EU). This was subsequently amended as part of the 'Clean energy for all Europeans package' in 2018, updating the policy framework to 2030 and beyond and setting the headline EE target for 2030 of a reduction of at least 32.5% relative to the 2007 reference scenario projections for 2030 (EU 2018/2002). In (absolute) terms of primary and final energy consumption, the 2030 target mandates that EU energy consumption (excluding the UK) should be no more than 1128 Mtoe of primary energy and 846 Mtoe of final energy, which correspond respectively to 26% and 20% reductions compared to 2005 levels (ibid.).

More recently, in December 2019, the European Commission launched the **European Green Deal** – a package of policy initiatives that set an ultimate goal of reaching climate neutrality by 2050, thereby raising its 2030 climate ambition, which was set at 40% cut in GHG emissions from 1990 levels, to at least 55% compared to 1990 levels (COM/2019/640). In order to align current policies and laws with the tightened ambitions, the EU has set out the 'Fit for 55' package that revises climate, energy and transport-related legislation. It proposes an increase of the EE 2030 target to 39% for primary and 36% for final energy consumption (relative to the 2007 reference scenario projections for 2030), which translates to 1023 Mtoe and 787 Mtoe of primary and final energy, respectively (Proposal 10745/2/21). Compared to 2005 levels, the newly proposed target aims to reduce primary energy consumption by 32% and final energy consumption by 23% (ibid.). Under the EED, Member States are required to energy more efficiently across all stages of the energy chain by:

- Setting national energy efficiency targets [Article 1, 3]
- Establishing long term strategies to facilitate investments in the renovation of all buildings [Article 4]
- Carrying out energy efficient renovations on at least 3% of public buildings [Article 5]

- Large companies to make audits of their energy consumption to identify energy saving potentials [Article 8]
- Easy and free access to data on consumption through individual metering, in order to empower energy consumers to improve consumption management [Article 9-11]
- Promoting efficient heating and cooling and high efficiency cogeneration [Article 14, 15]

In addition to the explicit EE target set out by the EED, the EU has also established an Energy Union strategy, published in 2015, that aims for secure, sustainable, competitive and affordable energy across the EU (COM/2015/080). This strategy is built on five mutually-reinforcing dimensions, which emphasise the plural implications of energy efficiency measures on reducing energy imports and emissions, and driving jobs and growth, as well as the importance of diversifying Europe's energy sources and driving the energy transition (ibid).

The **Renewable Energy Directive (RED II)** further establishes a legal framework for the development of RE across all sectors (Directive EU 2018/2001). As with the EED, RED II has gone through several iterations, with the most recent proposal for revision based on the Fit for 55 package. Currently, the directive sets a binding target of 32% for the overall share of energy from renewable sources in the EU's gross final energy consumption in 2030, where 'energy from renewable sources' is explicitly defined as "energy from renewable non-fossil sources, namely wind, solar (solar thermal and solar photovoltaic) and geothermal energy, ambient energy, tide, wave and other ocean energy, hydropower, biomass, landfill gas, sewage treatment plant gas, and biogas" (ibid., Article 2). The proposed Fit for 55 revision raises this target to 40% of renewable energy sources in the overall energy mix in 2030 (COM/2019/640).

In light of Russia's invasion of Ukraine and the geo-political implications inherent to energy system regulation, the European Commission proposed, in March 2022, the **REPowerEU** plan to make Europe independent from Russian fossil fuels, seeking to diversify gas supplies, accelerate the roll-out of renewable gases and replace gas in heating and power generation (COM/2022/108). On 18 May, 2022, the Commission presented an updated REPowerEU Plan (COM(2022) 230), which if approved and successfully implemented should end Europe's reliance on Russian energy by 2027, along with the implementation of all Fit-for-55 measures, which were estimated to reduce gas consumption by 116 bcm. The efforts outlined in this plan aim to boost energy efficiency gains, increase the share of renewables, increase LNG imports and pipeline imports from non-Russian suppliers, address infrastructure bottlenecks, and, most notably, to scale up renewable hydrogen and biomethane.

The updated REPowerEU plan proposes a further increase to the binding Energy Efficiency Target from 9% to a 13% reduction of primary and final energy consumption by 2030 compared to the 2020 reference scenario projections, which corresponds to a new target of 978 Mtoe of primary and 752 Mtoe of final energy consumption (ibid.). The Plan also proposes a recast of RED II, increasing the total renewable energy generation target from 1067 GW to 1236 GW by 2030, as well as a new target of over 320 GW of solar photovoltaics newly installed by 2025, and 585 GW by 2030. As part of the increased ambition for solar, the Commission also presents the **EU Solar Strategy** and the **European Solar Rooftop Initiative**, aiming to accelerate rooftop installation such that by 2025, 58 TWh of additional electricity is generated (COM(2022) 221). The Plan also proposes to double the current deployment rate of individual heat pumps, corresponding to a cumulative 10 million units over the next 5 years.

Table 2 below summarises the policy instruments discussed above, in terms of overall policy objectives and specific quantified targets.

Table 2. Overview of policies and related targets connected to all sectors

Policy Instruments	Aims	Quantified Goals
Paris Agreement 2015	Legally binding international treaty on climate change to limit global warming well below 2, preferably to 1.5°C, compared to pre-industrial levels.	GHG emissions 2030 target: at least 40% cuts in GHG emissions from 1990 levels. RE 2030 target: at least 32% share for renewable energy (from 2007 reference scenario projection for 2030).
European Green Deal 2019 Fit for 55, 2021	Climate neutral European Union in 2050; reviews and proposed improvements to existing laws re. climate merits.	2030 target: 40% RE share in EU's gross final energy consumption = 1067 GW total renewable energy generation capacity by 2030. 2030 target: Reduce EU gas consumption by 116 bcm. 2030 target: 40 GW of electrolysers in Europe; 5.6 Mt of renewable hydrogen. 2030 target: 469 GW installed wind capacity. 2030 target: 530 GW installed solar PV capacity.
REPowerEU 2022	Make Europe independent from Russian fossil fuels; diversify gas supplies; accelerate the roll-out of renewable gases; replace gas in heating and power generation.	2030 target: lower EU gas consumption by 155 bcm (the breakdown of this total is detailed in section 3.1.2 below) 2030 target: 45% share of renewables = 1236 GW of total renewable energy generation by 2030. 2030 target: 510 GW of wind capacity (450 GW onshore and 60 GW offshore), 592 GW of solar photovoltaic installed by 2030. 2030 target: EU energy consumption (excluding the UK) at most 978 Mtoe of primary and 752 Mtoe of final energy. 2030 target: 10 Mt of domestic renewable hydrogen production and 10 Mt imported. 2030 target: 35 bcm of sustainable biomethane production by 2030. 2027 target: double current deployment rate of individual heat pumps = cumulative 10 million units over the next five years.
Energy Efficiency Directive (EED II) 2018	Sets rules and obligations for achieving the EU's 2020 and 2030 energy efficiency targets.	2030 target: EU energy consumption (excluding the UK) should be no more than 1023 Mtoe of primary energy and 787 Mtoe of final energy.
Renewable Energy Directive (RED II) 2018	Development of renewable energy across all sectors.	2030 target: 32% RE share in EU's gross final energy consumption.
Fit for 55 recast of REDIII 2022	Revise existing directives to heighten ambitions as part of Fit-for-55 package	2030 target: 40% RE share in EU's gross final energy consumption.
Energy Union Strategy 2015	Secure, sustainable, competitive and affordable energy across the EU.	--

2.2 Building Sector Policies and Directives

Buildings are considered central to the EU's energy efficiency and climate agendas, accounting for nearly 40% of final energy consumption and 36% of energy-related direct and indirect greenhouse gas emissions (COM/2021/802), with the majority of policies and strategies focused on the "particular challenge related to the renovation of the EU building stock" (SWD 2020 176), as well as carbon pricing and building codes.

Along with the EED that sets out specific targets for the building sector, the EU has also established the **Energy Performance of Buildings Directive** (EPBD) (2010/31/EU), with the ultimate aim to promote policies that can achieve a highly energy efficient and decarbonised building stock by 2050. Specifically, the EED establishes a binding requirement for EU countries to renovate each year at least 3% of the total floor area of publicly owned buildings and further improves requirements to identify and lift barriers relevant to the split incentives dilemma (EU 2018/2002). The obligated implementation of energy savings, as outlined in Article 7 of the EED, can be achieved via policy measures, e.g., energy efficiency obligation schemes, focusing on building renovations and boiler replacement (IEA, 2020).

The EPBD requires member states to establish long-term renovation strategies, which form part of each countries' integrated national energy and climate plans (NECPs) and "support the renovation of the national stock of residential and non-residential buildings, both public and private,…facilitating the cost-effective transformation of existing buildings into nearly zero-energy buildings" (ibid., Article 2a). These strategies must include measures and measurable progress indicators, milestones for 2030, 2040, and 2050, and an estimate of the expected energy savings and wider benefits as well as its overall contribution to the EU's EE target (ibid.).

Member states are further required to set cost-optimal minimum energy performance requirements "for building elements that form part of the building envelope and that have a significant impact on the energy performance of the building envelope when they are replaced or retrofitted" (2010/31/EU, Article 4) based on a common general framework for the calculation of energy performance of buildings established in the EPDB (2010/31/EU, Annex I). The EPBD also requires all new buildings to be nearly zero-energy buildings (NZEB), defined by "a very high energy performance [with] the nearly zero or very low amount of energy required…covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby" (ibid., Article 2).

The European Green Deal proposes further increases of ambitions regarding Europe's building stock, such that by 2030 buildings' GHG emissions are reduced by 60%, their final energy consumption by 14% and energy consumption for heating and cooling by 18% compared to 2015 levels (COM/2021/802). In addition, the European Green Deal's **Renovation Wave strategy** further builds on the national long-term building renovation strategy, setting the aim to double annual energy renovation rates and identifying three focus areas, namely tackling energy poverty and worst-performing buildings, renovation of public buildings, and the decarbonisation of heating and cooling (COM/2020/662). Further revisions propose to move from the current NZEB to zero-emission buildings by 2030.

The EU identifies heating and cooling as "the most significant energy end-use sector, accounting for about 50 % of total energy demand in the EU, [with] buildings represent[ing] 80% of this consumption" (C/2019/6625). Thus, EU countries are also requested to carry out comprehensive assessments every five years on efficient heating and cooling, in line with Article 14 of the EED (Directive 2012/27/EU), aiming "to set clearer requirements for the gathering and processing of data, and to allow Member

States to focus their analysis on locally relevant ways of heating and cooling in a technologically neutral way" (C/2019/6625). Based on their extensive review of EU energy efficiency policies for buildings, Economidou et al. (2020) identify the EPBD, EED, the **Eco-design Directive** (ED) and the **Effort Sharing Decision** (ESD) as the key contributors to promoting energy efficiency. Early requirements on construction products and boilers gradually transformed into a set of standards for individual building elements, under the ED, energy labelling requirements for space and water heaters, under the Energy Labelling Directive (ELD), and energy performance requirements for entire buildings, under the EPBD, which banned the sale of inefficient boilers and have since contributed to a decline in heating energy consumption (ibid.).

In fact, according to the Commission's **Heating and Cooling Strategy**, presented in 2016, the ELD and ED for boilers is estimated to bring energy savings of 600 TWh and CO_2 emission reductions of 135 million tonnes over the period 2015 – 2030 (COM(2016) 51). The strategy also places emphasis on the potential for district heating (DH) and combined production of heat and power to provide secure and renewable energy and produce significant energy and CO_2 savings, however it does not provide explicitly defined or quantified goals (ibid.).

Table 3 below summarises the EU policy instruments related to buildings discussed above, identifying the relevant objectives and measures of each as well as any related quantified goals.

Table 3. Overview of policies and targets connected to building sector

Policy Instruments	Aims and Measures	Quantified Goals
Energy Efficiency Directive (EED II) 2018	- EE obligation schemes - Address split incentives dilemma	Each year, renovate at least 3% of the total floor area of publicly owned buildings.
Energy Performance of Buildings Directive (EPBD) 2010	- Long-term renovation strategies - Energy performance requirements - Nearly zero-energy buildings	--
European Green Deal: Renovation Wave Strategy 2020	- Tackle energy poverty and worst-performing buildings - Renovation of public buildings - Decarbonise heating and cooling of buildings	2030 target: reduce final energy consumption by 14% from 2015 levels. 2030 target: double annual energy renovation rate of buildings. 2030 target: reduce energy consumption for heating and cooling by 18% from 2015 2030 target: reduce GHG emissions of buildings by 60% from 2015 levels.
European Green Deal: Fit-for-55 2020	--	2030 target: 49% RES share in buildings in 2030.
REPowerEU 2022	--	2030 target: 60% RES share in buildings.
Eco-Design Directive 2009	Set EU-wide rules for environmental performance of individual energy-related building element (e.g. boilers).	2030 projected goal (boilers): energy savings of 600 TWh and CO_2 emission reductions of 135 million tonnes by 2030 (from 2015).
Energy Labelling Directive 2009	Set energy labelling requirements for space and water heaters.	
Heating and Cooling Strategy 2016	Integrate efficient and sustainable heating and cooling in EU energy policies. - Stop energy leakage from buildings - Decarbonise electricity and district heating - Intensify EE and RE efforts in buildings	--

2.3 Transport Sector Policies and Directives

Policies regarding transportation and mobility are considered central elements of Europe's sustainability agenda and centre around objectives linked to e.g., transport-related emissions, multimodal transport, infrastructure, and intelligent transport systems. As the transport sector contributes to nearly a quarter of Europe's GHG emissions and is the major cause of air pollution in cities, the Commission's Strategy for Low-Emission Mobility was adopted in 2016, supporting the deployment of low-emission alternative energy for transport, such as advanced biofuels, renewable electricity and renewable synthetic fuels, the transition to zero-emission vehicles, and improvements in the efficiency of the transport system via e.g., digital technologies and smart pricing (COM/2016/0501). More recently, the **European Green Deal** has proposed to heighten ambitions for EU's transport sector, raising the 2050 target for reductions in GHG emissions from 60% to 90% compared to 1990 levels, which correspond to 268.9 Mtonnes CO_2eq and 67.2 Mtonnes CO_2eq in 2050, respectively (COM/2019/640).

Several policies are in place regarding road transport as it accounts for the majority of transport-related emissions. The **CO_2 emissions regulation of new passenger vehicles** (Regulation (EU) 2019/631) and of **new heavy-duty vehicles** (Regulation (EU) 2019/1242) establishes CO_2 emissions performance requirements for new cars, vans, and lorries, setting targets for 2020, 2025 and 2030 and incentives for the uptake of zero- and low-emission vehicles, as shown in Table 4 below. Recently, in June 2022, lawmakers in the European Parliament plenary voted to mandate that all new car and van sales should be zero emissions from 2035 as a key part of the Fit for 55 package, thereby amending the CO_2 emissions regulation of new passenger vehicles (Regulation (EU) 2019/631). The proposed amendment (COM(2021) 556) sets new targets for emissions performance of cars and vans, which are included in the two last columns in the table below.

Table 4. EU CO_2 emissions performance targets for cars, vans, and lorries

	2020	2025	2030	2030 (proposal)	2035 (proposal)
Cars	95 g CO_2/km*	15% reduction**	37.5% reduction**	55% reduction**	100% reduction**
Vans	147 g CO_2/km*	15% reduction**	31% reduction**	50% reduction**	100% reduction**
Lorries	-	15% reduction***	30% reduction***	-	-

* target levels refer to the NEDC emission test procedure

** defined as a percentage reduction from the 2021 starting points defined in Annex I of Regulation (EU) 2019/631

*** defined as a percentage reduction of emissions compared to EU average in reference period (1 Jul 2019–30 Jun 2020)

The **Fuel Quality Directive** further sets strict quality requirements for petrol, diesel and biofuels used in road transport and gasoil used in non-mobile machinery, in terms of greenhouse gas intensity that is calculated on a life-cycle basis, covering emissions from extraction, processing and distribution (Directive 2009/30/EC). The directive's most recent iteration in 2016 set a target for 2020, obliging Member States to require fuel suppliers to reduce GHG intensity by 6% by the end of 2020, compared to the fuel baseline standard for 2010 of 94.1 gCO_2eq/MJ, which translates to a 2020 target of 88.5 gCO_2eq/MJ. The latest data provided by the Member States shows that the average GHG intensity of fuels and energy supplied in 2019 was 90 gCO_2eq/MJ, confirming that EU fuel suppliers were on average behind the 2020 target (COM(2021) 961 final).

In addition, the **Alternative Fuel Infrastructure Directive**, adopted in 2014, "sets out minimum requirements for the building-up of alternative fuels infrastructure, including recharging points for electric vehicles and refuelling points for natural gas (LNG and CNG) and hydrogen, to be implemented

by means of Member States' national policy frameworks" (Directive 2014/94/EU). The most recent development, responding to the European Green Deal, proposes an Alternative Fuels Infrastructure Regulations (COM(2021) 559 final) to replace the current Directive and complement the infrastructure goals set in the Sustainable and Smart Mobility Strategy of the Commission. These goals include:

- By 2030, for each battery electric and plug-in hybrid car registered in a Member State, a total power output of at least 1 kW and 0.66 kW, respectively, is provided through publicly accessible recharging points.
- By 2025, 1 million recharging points are installed.
- By 2030, 3.5 million recharging points are installed.

The **recast of the Renewable Energy Directive** (REDII) sets a transport sub-target for 2030 that obligates Member States to require fuel suppliers to supply a minimum of 14% of the energy consumed in road and rail transport as renewable energy. Regarding biofuels and biogas, the RED II also sets a target for 2030 that establishes a minimum share of the contribution of biofuels and biogas produced from feedstock to final consumption of energy in transport at 3.6%. In this way, the directive can promote emerging low-carbon alternative fuel technologies. The Commission adopted a proposal for a further revision of the REDII, as part of the Fit for 55 package, that proposes an increased ambition level of renewables in transport by setting a 13% GHG intensity reduction target for 2030 (COM(2021) 557).

To promote and stimulate the market for clean and energy-efficient vehicles, the **Clean and Energy-Efficient Road Transport Vehicles Directive** sets out requirements for Member States to ensure that lifetime energy and environmental impacts are taken into account when procuring road vehicles and establishes a methodology for calculating operational lifetime costs (Directive 2009/33/EC). The European Green Deal further proposes to extend the ETS to road transport and building fuels from 2026 and emphasise action on upstream fuel suppliers, rather than car drivers and households (COM/2019/640).

The European Commission's Communication on the **2030 Climate Target Plan** further places emphasis on the importance of taking action in the aviation and maritime sectors, regarding efficiency improvements of aircraft, ships and their operations as well as sustainable renewable and low-carbon fuels (COM/2020/562). Subsequently, the **ReFuelEU Aviation** and **FuelEU Maritime** initiatives were established with the aim to increase the production and uptake of sustainable alternative fuels. Regarding aviation, the initiative proposes EU-wide targets for fuel suppliers and airline operators in order to boost the supply and demand of sustainable aviation fuels (SAF) in the EU. It obliges fuel suppliers to include more SAF into jet fuel: 2% by 2025; 5% by 2030; 20% by 2035; 32% by 2040; 38% by 2045; 63% by 2050, promoting advanced biofuels and synthetic fuels produced from green electricity (COM(2021) 561).

For marine transport, the FuelEU Maritime initiative proposes a common maritime regulation given the cross-border and global dimension of maritime transport, in an effort to avoid a patchwork of national measures that set diverging targets (COM(2021) 562). Specifically, the initiative calls for a 75% reduction of GHG intensity of the energy used onboard by ships by 2050 and the following targets regarding the share of renewable and low-carbon fuels of the international maritime transport fuel mix, based on the policy scenarios assessed in the 2030 Climate Target Plan and the **Sustainable and Smart Mobility Strategy** (ibid.):

- By 2030, renewable and low-carbon fuels should represent 6-9% of the maritime fuel mix,
- By 2050, renewable and low-carbon fuels should represent 86-88% of the maritime fuel mix.

In addition to the FuelEU Maritime initiative, the European Green Deal also proposes to extend the **European Emissions Trading System** (EU ETS) to include the maritime sector, starting in 2023, further ensuring cost-effective emission reductions in the sector (COM/2019/640). It is important to note here that the above-mentioned proposals set out by the European Green Deal have not, as of yet, entered into force and remain to be assessed, negotiated and adopted as legislation by the European Parliament and Member States.

Existing EU legislation regarding European rail systems focus on system interoperability as a means of increasing the competitiveness of rail transport (Directive (EU) 2016/797). The directive aims to establish technical specifications for interoperability (TSIs) concerning the design, construction, service, renewal, operation and maintenance of national rail networks (ibid.).

Table 5 below summarises the EU policy instruments related to transport discussed above, identifying the relevant objectives and measures of each as well as any related quantified goals.

Table 5. Overview of policies and targets connected to transport sector

Policy Instruments	Aims and Measures	Quantified Goals
European Green Deal 2019	Support the transition to cleaner, greener and smarter mobility.	2050 target: 90% reduction in transport related GHG emissions (compared to 1990 levels) = 67,235 thousand tonnes in 2050. 2030 target: 1 KW in charging capacity installed for each battery electric car registered in a Member State. 2030 target: 3.5 million recharging points.
European Green Deal: Sustainable and Smart Mobility Strategy 2020	Implement green and digital transformation of EU transport system and increase its resilience to future crises.	2030 target: At least 30 million zero-emission cars in operation on European roads. 2050 target: Nearly all cars, vans, buses as well as new heavy-duty vehicles will be zero-emission.
European Green Deal: ReFuelEU Aviation Initiative 2020	Set common EU regulatory framework to increase the share of sustainable aviation fuels in aviation fuel mix.	2030 target: fuel suppliers to include 5% more SAF into jet fuel. 2050 target: fuel suppliers to include 63% more SAF into jet fuel.
European Green Deal: FuelEU Maritime Initiative 2021	Set common EU regulatory framework to increase the share of renewable and low-carbon fuels in maritime fuel mix.	2030 target: renewable and low-carbon fuels represent 6-9% of the maritime fuel mix. 2050 target: renewable and low-carbon fuels represent 86-88% of the maritime fuel mix. 2050 target: 75% reduction of GHG intensity of the energy used onboard by ships.
CO_2 emissions regulations of new vehicles and new heavy-duty vehicles 2019	Set EU fleet-wide CO_2 emission targets and incentivise the uptake of zero- and low-emission vehicles.	2030 targets: Cars: 37.5%; Vans: 31%; Lorries: 30% reduction in CO_2 emissions performance (from the 2021 starting points).
Fit for 55 recast of CO_2 emissions regulations 2022	Amend CO2 emissions regulations of new vehicles and new heavy-duty vehicles to phase out ICE cars and vans by 2035	2030 targets: Cars: 55%; Vans: 50% reduction in CO_2 emissions performance from 2021. 2035 targets: Cars and vans: 100% reduction from 2021 starting points.

Policy Instruments	Aims and Measures	Quantified Goals
Fuel Quality Directive 2009	Set common fuel quality rules to reduce GHG and air pollutant emissions, establish a single fuel market, and ensure fuel compatibility for vehicles across the EU.	2020 target: 6% reduction from 2010 baseline = 88.5 gCO2eq/MJ.
Renewable Energy Directive (REDII) 2018	Regulate the share of energy from renewable sources used for transport.	2030 target: Member States must supply a minimum of 14% of the energy consumed in road and rail transport as renewable energy. 2030 target: Contribution of advanced biofuels and biogas produced from feedstock as a share of final consumption of energy in the transport sector to be at least 3.5%.
Fit for 55 recast of REDII (REDIII) 2022		2030 targets: - 13% GHG intensity reduction. - 2.2% share of advanced biofuels (single counted). 2.6% share of RFNBOs (single counted).
Alternative Fuel Infrastructure Regulation 2014	Set framework of common measures for the deployment of alternative fuels infrastructure in the EU.	--
Clean and Energy-Efficient Road Transport Vehicles 2009	Promote and stimulate the market for clean and energy-efficient vehicles by establishing a methodology for calculating operational lifetime costs.	--
Directive on the Interoperability of the Rail System 2016	Increase the competitiveness of rail transport by establishing TSIs to achieve system interoperability.	--

2.4 Industry Sector Policies and Directives

EU policy engagement with the industry sector centres around three focal points, namely competitiveness, digital transformation and a climate-neutral, circular economy. With respect to the EU goal of reaching climate-neutrality by 2050, political and regulatory instruments aim to support the transformation of EU energy-intensive industries as they account for more than half of the energy consumption of the EU industry (EC, n.d.). Several measures under the EED apply to the industry sector such as the EE obligation schemes whereby Member States are required to achieve cumulative end-use energy savings each year (from 2021 to 2030) equivalent to 0.8% of annual final energy consumption (averaged over the most recent three-year period prior to 2019), by designating energy savings requirements to obligated parties (Article 7 of the EED). In addition, Article 14 of the EED sets out measures for industrial waste heat recovery, requiring Member States to carry out cost-benefit analyses of industrial installations with a total thermal input exceeding 20MW (Directive 2012/27/EU).

The **Industrial Emissions Directive** (Directive 2010/75/EU) is the central EU instrument regulating emissions from the industrial sector, primarily through the improved application of Best Available Techniques (BAT). The Commission organises expert exchanges, resulting in BAT Reference Documents (BREFs), which form the basis for setting permit conditions. The BREF on Energy Efficiency establishes EE indicators for industry with the aim to assist self-analysis and monitoring, and the comparison of the energy efficiency of industrial units, activities or installations (EC, 2009). These political instruments thus do not set explicit targets for industries, but rather provide the tools for Member States to achieve greater energy savings and emission reductions in industry. Similarly, the **Eco-Design and Energy Labelling Directives** also provide Member States the tools to improve the environmental performance of energy-related products and increase their uptake. Emphasis is also placed on cogeneration of heat and power (CHP), in the EU Strategy on Heating and Cooling, as a means of producing significant energy and CO_2 savings in the industry and services sector (COM(2016) 51).

As mentioned above, the **Fuel Quality Directive** also applies to industrial fuels, namely gasoil used for non-mobile machinery, however the explicit targets set out in the directive apply to transport fuels. The Green Deal's **Hydrogen Strategy**, on the other hand, proposes an explicit target for a 50% share of renewables in hydrogen consumption in industry by 2030 (COM(2020) 301).

The targets set out by the **EU Emissions Trading** (EU ETS) include an overall emission reduction in ETS sectors of 43% by 2030 compared with 2005 levels, while the Fit for 55 package proposes to increase the target to 61% by 2030. The Effort Sharing Directive establishes binding annual GHG emission targets for those sectors of the economy not covered by the ETS, setting a 2030 target of at least 40% reduction in domestic emissions compared to 1990 levels.

Regarding energy efficiency measures for industry, there is no binding EU framework specifically assigned to EE in industry (see Malinauskaite et al. (2019) for an in-depth review of EU policies on EE in industry). Although there are several measures imposed by the EED, they are not specifically designed to industrial activities and thereby overlook particular features of industrial sectors (ibid.).

Table 6 below summarises the EU policy instruments related to industry discussed above, identifying the relevant objectives and measures of each as well as any related quantified goals.

Table 6. Overview of policies and targets connected to industry sector

Policy Instruments	Aims and Measures	Quantified Goals
Industrial Emissions Directive (IED) 2010	Regulate emissions from industrial sector, primarily improved application of Best Available Techniques (BAT).	--
Eco-Design Directive 2009	Improve the environmental performance of energy-related products and increase their uptake in industry.	--
Energy Labelling Directive 2009		
Heating and Cooling Strategy 2016	Support significant energy and CO_2 savings in the industry and services sector.	--
Fuel Quality Directive 2009	Reduce GHG and air pollutant emissions from fuels used in industry.	--
European Green Deal: Hydrogen Strategy 2020	Support the replacement of fossil fuels with hydrogen in industry sectors that are difficult to decarbonise and the contribution of hydrogen to climate neutrality.	2030 target: 50% share of renewables in hydrogen consumption in industry.
EU Emissions Trading Scheme (EU ETS) 2021	Establish a carbon market to reduce GHG emissions cost-effectively.	2030 target: 43% reduction of emissions in ETS sectors compared to 2005 levels.
European Green Deal: EU ETS recast 2022	Support the transformation of industry sector to become greener, more circular and more digital, while remaining competitive.	2030 target: 61% reduction of emissions in ETS sectors compared to 2005 levels.
RePowerEU 2022		2030 targets: - 1.9% RES share in industry, average yearly increase for 2020-2030. - 78% of hydrogen consumed in industry is renewable.
Effort Sharing Decision (ESD) 2016	Establish binding annual GHG emission targets for non-ETS sectors to support the transition to a low-carbon economy and increase energy security.	2030 target: 40% reduction in domestic emissions compared to 1990 levels.

2.5 Energy System Policies and Directives

Alongside EU policy efforts that focus on buildings, transport and industry, policies supporting energy systems are an integral part of achieving climate neutrality and current energy efficiency and renewable energy targets. The Clean Energy Package, proposed in response to the Energy Union Strategy, sets a new governance mechanism to ensure that the EU-wide targets will be collectively met (IEA, 2020). A key part of these efforts includes the **National Energy and Climate Plans** (NECPs), whereby each Member State is required to submit its plan to the European Commission, outlining their climate and energy goals, policies, and measures from 2021 to 2030 (Regulation (EU) 2018/1999).

The **Trans-European Networks in Energy (TEN-E)** regulation is a fundamental instrument to the EU's regulatory framework for energy infrastructure. Its objectives are to ensure the functioning of the internal energy market and security of supply in the Union, to promote energy efficiency, energy savings, the development of new and renewable forms of energy, and the interconnection of energy networks (Regulation (EU) No 347/2013). A central element in the TEN-E regulation is the Project of Common Interest (PCI) concept that defines infrastructure projects aiming at the completion of the European internal energy market. Currently, the PCI list includes 98 projects, 67 of which relate to electricity transmission and storage, 20 gas projects, six CO_2 network projects and five smart grid projects (ibid.). The TEN-E regulation also establishes a methodology for system-wide cost-benefit analysis, based on which projects can apply for the PCI status.

More recently, the European Green Deal has proposed several strategies to further support the green transformation of Europe's energy system and infrastructure. In particular, the **Energy System Integration Strategy** calls for a transition toward an energy system that links the various energy carriers (electricity, heat, cold, gas, solid and liquid fuels) with each other and with end-use sectors (buildings, transport, industry) (COM/2020/299). Under this strategy, three main characteristics of an integrated EU energy system are identified, namely efficiency and circularity, cleaner power system, and cleaner fuel system (ibid.).

The **Offshore Renewable Energy Strategy** proposes explicit targets for the EU energy system, such that, by 2030, an installed capacity of at least 60 GW of offshore wind and at least 1 GW of ocean energy should be achieved, and by 2050, 300GW of offshore wind and 40GW of ocean energy (COM/2020/741). Regarding onshore wind, in 2018, the European Commission launched its communication on the Long-Term Decarbonisation Strategy, stating that Europe will need up to 1200 GW of wind capacity to reach an energy system compliant with the Paris Agreement by 2050 (COM(2018) 773). According to the Commission's 1.5 TECH 2050 scenario, 451 GW of offshore wind and 759 GW of onshore wind capacity will be needed by 2050 (ETIPWind et al., 2020).

In light of Russia's invasion of Ukraine and the geo-political implications inherent to energy system regulation, the European Commission proposed, in March 2022, the REPowerEU plan to make Europe independent from Russian fossil fuels, seeking to diversify gas supplies, accelerate the roll-out of renewable gases and replace gas in heating and power generation (COM/2022/108). The Commission places emphasis on the promise of fully implementing the Fit for 55 proposals as well as the relevancy of the EEFP and proposes further heightening of ambitions – as shown in Table 7 below from COM/2022/108.

Table 7. REPowerEU proposals for boosting the Fit for 55 proposals with higher or earlier targets for renewable energy and energy efficiency (from COM/2022/108)

REPowerEU Track	Focus	Ff55 2030 Ambition	REPowerEU Measure	Replaced by end of 2022 (bcm equiv.)	Additional to Ff55 by 2030 (bcm equiv.)
Gas diversification	Non-Russian Natural Gas		LNG diversification	50	50
			Pipeline import diversification	10	10
	More Renewable Gas	17 bcm of biomethane production, saving 17 bcm	Boost biomethane production to 35bcm by 2030	3.5	18
		5.6 million tonnes of renewable hydrogen, saving 9-18.5 bcm	Boost hydrogen production and imports to 20mt by 2030	-	25-50
Electricity Europe	Homes	EE measures, saving 38bcm	EU-wide energy saving (e.g. by turning down thermostat for buildings' heating by 1°C, saving 10 bcm)	14	10
		Counted under overall RES figures below	Solar rooftops front loading – up to 15TWh within a year	2.5	frontloaded
		30 million newly installed heat pumps installed in 2030, saving 35 bcm in 2030	Heat pump roll out front loading by doubling deployment resulting in a cumulative 10 million units over the next 5 years	1.5	frontloaded
	Power Sector	480 GW of wind capacities and 420 GW of solar capacities, saving 170bcm (and producing 5.6 Mt of Green Hydrogen)	Wind and solar front loading, increasing average deployment rate by 20%, saving 3bcm of gas, and additional capacities of 80GW by 2030 to accommodate for higher production of renewable hydrogen.	20	Gas savings from higher ambition counted under green hydrogen, the rest is frontloaded
Transform Industry	Energy-Intensive Industries	Front load electrification and renewable hydrogen uptake	Front load Innovation Fund and extend the scope to carbon contracts for difference	Gas savings counted under the renewable hydrogen and renewables targets	

The new targets clearly identify the increased use of biomethane and renewable hydrogen as key measures to eliminate the EU's dependency on Russian gas. In particular, the new hydrogen target aims to double production to 10 million tons of renewable hydrogen by 2030, which according to the European Clean Hydrogen Alliance, would require an installed electrolyser capacity of 90-100 GW_{LHV} in terms of hydrogen output (up to 140GW in terms of electricity input, assuming an average electrolyser utilisation factor of 43% and electrolyser efficiency of 70%) (European Clean Hydrogen Alliance, 2022).

A recent study, released in April 2022 by the University of Cambridge, presents novel results regarding the atmospheric implications of increased hydrogen use, assigning a Global Warming Potential value of 11 for H_2 (Warwick et al., 2022). Thus, in tandem with measures that boost hydrogen production, assessment efforts analysing the impacts of hydrogen use in terms of climate change must also be fast-tracked in order to ensure that the Commission's proposals remain in line with EU climate and GHG emission ambitions.

Table 8 below summarises the EU policy instruments related to the energy system discussed above, identifying the relevant objectives and measures of each as well as any related quantified goals.

Table 8. Overview of policies and targets connected to the energy system

Policy Instruments	Aims and Measures	Quantified Goals
REPowerEU 2022		2030 targets: - 510 GW installed wind capacity - 592 GW installed solar PV capacity - 65 GW hydrogen installed electrolyser capacity - 12.3 Mtoe biogas used in power plants - District Heating and Cooling: average yearly increase of 2.3% for 2020-2030 - 35 bcm of sustainable biomethane production.
National Energy and Climate Plans 2018	Set new governance mechanism to ensure that EU-wide targets will be collectively met. - require Member States to submit plan outlining their climate and energy goals, policies, and measures from 2021 to 2030.	--
Trans-European Networks in Energy 2013	Ensure the functioning of internal energy market and security of supply in the Union; promote energy efficiency, energy savings, the development of new and renewable forms of energy, and the interconnection of energy networks. - Projects of Common Interest - Priority thematic areas: smart grids deployment, electricity highways, cross-border CO_2 network.	--
European Green Deal: Energy System Integration Strategy 2020	Support the optimisation and modernisation of the EU's energy system as a whole; achieve cost-effective decarbonisation of EU economies.	--
European Green Deal: Offshore Renewable Energy Strategy 2020	Boost uptake of offshore renewable energy sources to support the clean energy transition in the EU.	2030 target: installed capacity of at least 60 GW of offshore wind and at least 1 GW of ocean energy. 2050 target: 300GW of offshore wind and 40GW of ocean energy.
European Green Deal: Hydrogen Strategy 2020	Explores the potential for renewable hydrogen in decarbonising the EU economy.	2030 target: 40 GW of electrolysers in Europe by 2030.

3 Policy Gap Analysis: Results and Recommendations

Based on the above overview of EU policies, targets, directives and regulations related to energy efficiency, this section compares these with the sEE 2030 energy system results, in order to identify any policy gaps and to inform the investment strategy for developing the sEE 1.5 energy system in the report "Energy Efficiency 2050 Roadmap for Europe: A cost-effective and energy-efficient strategy for decarbonising". The objective is to provide science-based recommendations for policy makers to support the implementation of the EEFP. The comparisons and policy suggestions are discussed by the same topics presented above related to existing EU policy objectives.

3.1 Energy System and Natural Gas Policy Gaps and Recommendations

The application of the energy efficiency first principle makes it possible to achieve a highly efficient decarbonised European energy system by 2050. Transformative action and policy that influences short-term implications needs to be developed to reach the envisioned scenario for 2050. In addition, given the current political developments threatening Europe's energy security, a shorter-term perspective is also necessary in informing decisions in the coming months and years. In this section, the policies analysed and suggestions provided are related to the energy system as a whole, followed by sector-specific analyses and recommendations.

3.1.1 Primary and Final Energy Consumption

The primary and final energy consumption targets from the EU policy are:

- EED 2030 target: EU27 energy consumption no more than 1128 Mtoe of primary energy and 846 Mtoe of final energy.
- Ff55 2030 target: EU27 energy consumption no more than 1023 Mtoe and 787 Mtoe of primary and final energy (9% reduction of 2020 reference scenario projections for 2030)
- REPowerEU 2030 target: EU27 energy consumption should be no more than 978 Mtoe of primary and 752 Mtoe of final energy consumption (13% reduction of 2030 projections).

The results for the sEE 2030 transition energy system compared to the EU policies are presented in Figure 5 below.

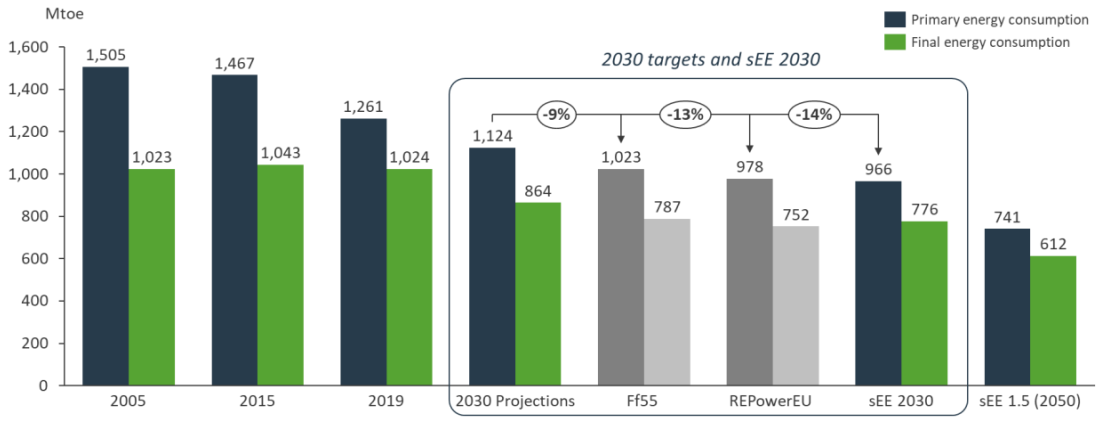

Figure 5. Primary and final energy consumption for 2005, 2015, 2019, 2030 projections based on the EU 2020 reference scenario, EU policy targets for 2030 (Fit-for-55 and REPowerEU) and sEE 2030, and sEE 1.5

The overall energy efficiency targets set by the Commission's REPowerEU Plan for 2030 are in line with the sEE 2030 scenario that achieves a 14% reduction of 2020 reference scenario projections for 2030 of 966 Mtoe of primary energy consumption and 776 Mtoe of final energy consumption and subsequently the transition to the sEEnergies sEE 1.5 climate neutral system target, which achieves 741 Mtoe and 612 Mtoe of primary and final energy consumption, respectively. Furthermore, by comparing the primary and final energy consumption, it can be seen that the sEEnergies energy system re-design provides a more efficient 2030 and 2050 energy system. The means by which these targets are achieved are elucidated in the sections below, which delve into further detail regarding the sEEnergies 2030 energy system and its components.

3.1.2 Natural Gas Consumption

The role of fossil fuel exports in supporting the Russian aggression has turned the EU's attention on taking decisive action to cut Europe's dependence on Russian gas. Current targets regarding natural gas consumption, as set out by Fit for 55 and REPowerEU Plan, are:

- Ff55 2030 target: reduce natural gas demand by 116 bcm (30% reduction from 2020).
- REPowerEU 2030 target: reduce natural gas demand by an additional 155 bcm of natural gas, on top of the Ft55 goals.

Based on COM(2022) 108, SWD(2022) 230, and COM(2022) 230, the natural gas savings from the Fit-for-55 measures amount to a total of 116 bcm, while a total of 155 bcm of natural gas is displaced from REPowerEU measures (including recent related political decisions, such as the abandoned phase-out of nuclear plants in Belgium and France). The following waterfall chart (Figure 6) presents the disaggregated natural gas savings per Ff55 and REPowerEU measure. Some of the REPowerEU measures proposed by the Commission are to frontload Fit-for-55 measures (see Table 1 in COM(2022) 108), thus these savings have been categorically separated ('frontloaded Ff55') in order to avoid double counting. Furthermore, the amount of gas displaced by hydrogen was interpreted from the data available in Table 8 in SWD(2022) 230 that shows the hydrogen use by sector in 2030, of which 15 bcm of gas savings are achieved through imported hydrogen, which is also highlighted in the chart.

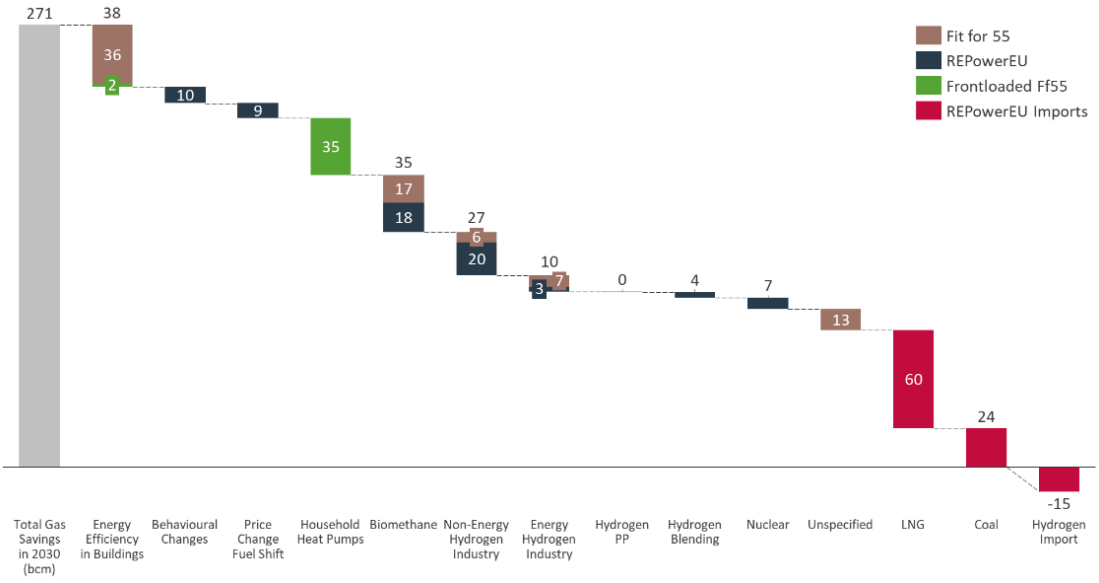

Figure 6. Disaggregated natural gas savings (bcm) by Fit-for-55 and REPowerEU measure

The sEEnergies 2030 model achieves a total of 213 bcm gas savings, as shown in the chart below (Figure 7). In order to be able to accurately compare the natural gas savings from Fit for 55 and REPowerEU measures with the estimated savings in the sEEnergies 2030 model, the waterfall chart shown in Figure 8 was created for the EU measures where the fuel shift measures, namely LNG and coal, are removed. Figure 8 thus represents the point of reference for comparing the total and disaggregated natural gas savings from EU policies with the estimated savings from sEE 2030.

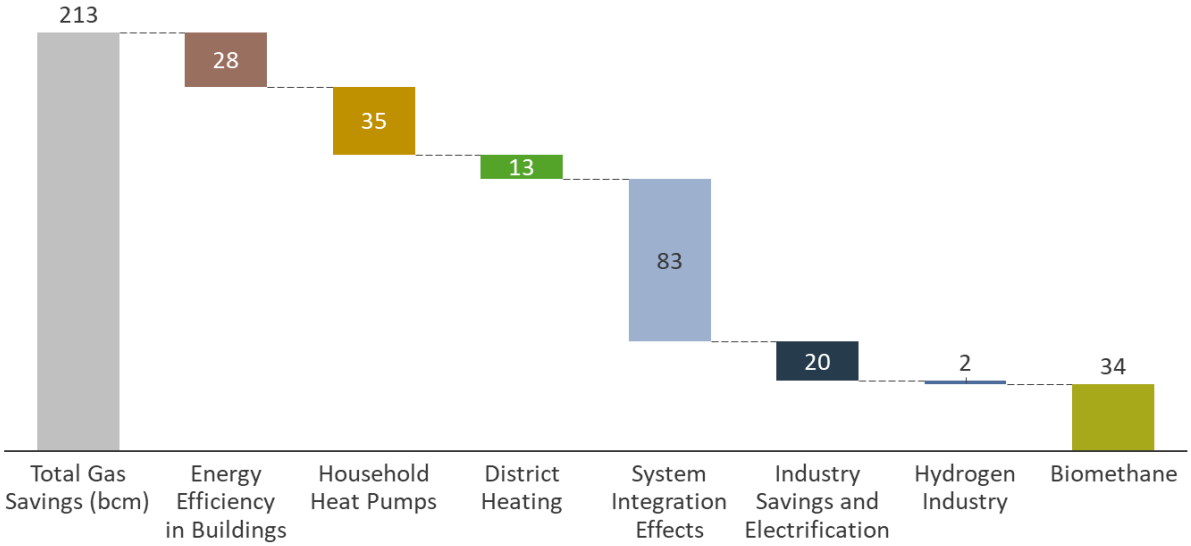

Figure 7. Disaggregated natural gas savings (bcm) achieved by sEEnergies 2030

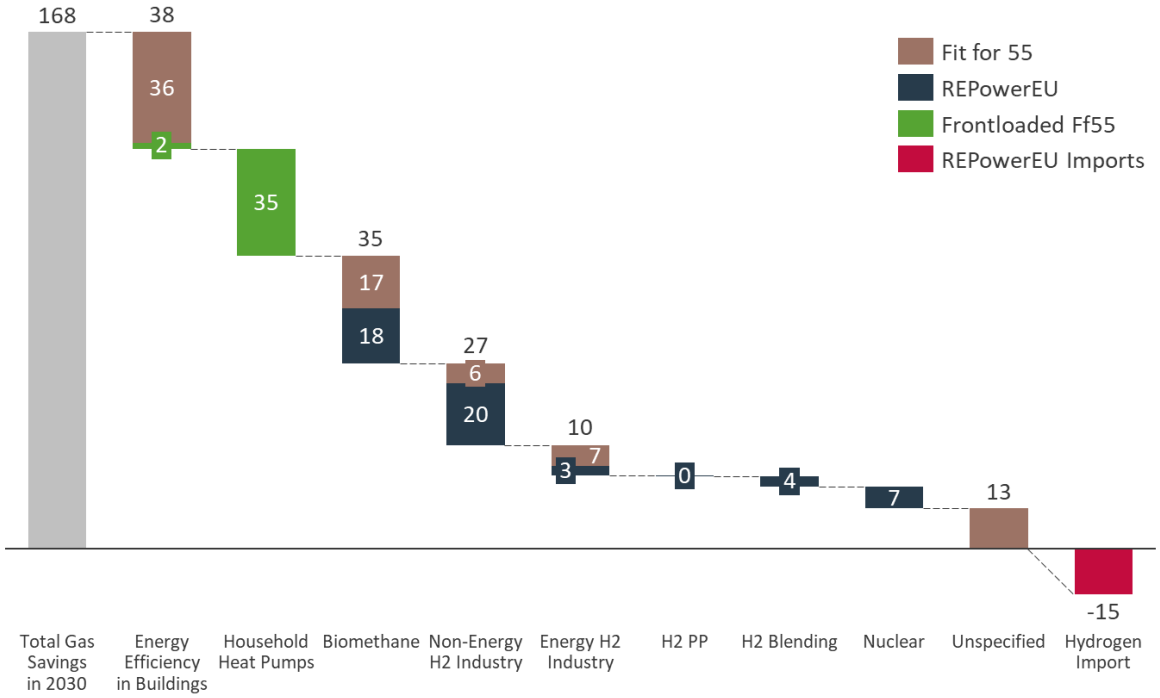

Figure 8. Disaggregation of natural gas savings (bcm) achieved by Fit for 55 and REPowerEU for comparison with sEEnergies 2030

By comparing the charts in Figure 7 and Figure 8, the sEEnergies measures show greater potential for displacing natural gas by 2030 by 26 bcm, equivalent to a 14% increase in potential gas savings. The gas savings induced by measures related to household heat pumps and biomethane are similar between sEEnergies and EU policy. A clear difference can be seen in terms of the natural gas savings owing to energy efficiency measures in buildings, where the heat savings achieved in sEEnergies 2030 are lower compared to the EU targets, as this is considered a more realistic and achievable target for Europe in 2030. Based on a bottom-up modelling of the EU building stock, sEEnergies 2030 assumes an average heat demand of 11,000 kWh per building and achieves a general 10% reduction in heat demand by 2030, where a total of 62 million[1] individual heat pumps will be needed by this year. According to the targets set out by the European Green Deal, an additional 30 million heat pumps are needed by 2030 (starting from about 17 million in 2021), while heat savings are estimated to be higher in 2030 (compared to sEE 2030). Yet, the gas saved due to individual heat pumps is estimated to be at the same level as sEEnergies 2030. In other words, it is unclear how the Commission estimates the additional 30 million heat pumps given that their targeted heat savings in buildings are higher and their estimated gas savings are the same (35bcm) compared to sEEnergies 2030. A reassessment of these estimations is therefore recommended.

Furthermore, sEEnergies achieves additional gas savings of 13 bcm due to large-scale heat pumps for district heating, for which the EU Commission has not accounted. The sEEnergies 2030 model also achieves approximately 20 bcm of gas savings via energy efficiency and electrification measures implemented in industry, with only 2 bcm of gas displaced by hydrogen in industry. Compared to sEEnergies, the Commission places much greater, and likely overly optimistic, emphasis on hydrogen, which they estimate to displace a total of 27 bcm of natural gas (with 8 Mt of hydrogen).

Furthermore, the largest gas savings in sEEnergies 2030 are achieved through the system effects of renewable energy and electrification measures as well as the delayed nuclear phase-out until 2030, which have been quantified at a total of 83 bcm of natural gas. This likely shows a shortcoming of the EU Commission's model, which does not account for the system effects of increased levels of household heat pumps, district heating (large-scale heat pumps) and electric vehicles. Nevertheless, based on Table 1 in SWD(2022) 230 some savings are acknowledged, as 21 bcm of natural gas can be saved through PV and wind, of which 12 bcm is achieved through hydrogen production and 9 bcm through additional substitution of gas in the power system. Furthermore, the 13 bcm in Fit for 55 that is not specified could be counted as part of the structural changes effectuated by increased levels of renewable energy.

The natural gas savings that can be achieved through fuel shift measures as well as behavioural and price changes can be further added to the sEEnergies 2030 savings to show the full potential for gas savings beyond the energy efficiency and renewable energy measures achieved by sEEnergies 2030. The fuel shift with coal and LNG can be added as well as a hydrogen import to replace hydrogen in the non-energy industry hydrogen demand. This is shown in Figure 9 below, where the yellow segments on the right represent the measures added, showing a total of 332 bcm of gas that can be saved in 2030, which is 22% greater than the saving potential (271 bcm) set out by the European Commission’s Fit for 55 and REPowerEU measures.

[1] sEEnergies estimates a total of 11 million heat pumps in 2019, assuming a heat demand of 13,000 kWh per building.

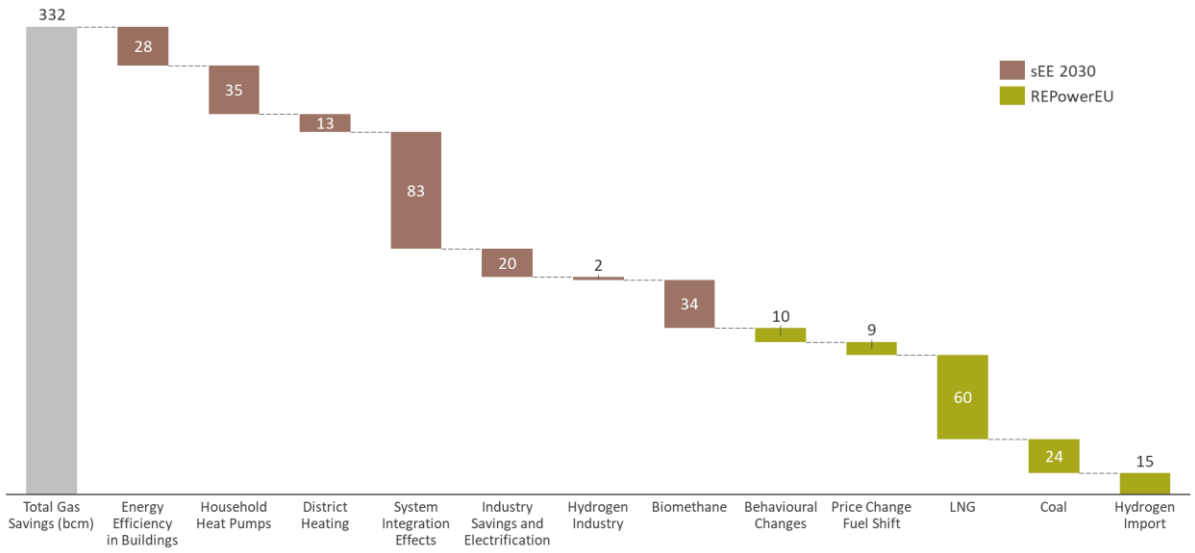

Figure 9. Disaggregation of total natural gas savings that can be achieved by sEEnergies 2030, including fuel shift measures, behaviour changes, and price changes

The following sections dive deeper into the details of each of these measures, providing explicit policy recommendations and targets based on the sEEnergies 2030 results in terms of renewable energy, hydrogen, heat pumps, bioenergy, etc.

3.1.3 Renewable Energy Generation

The renewable energy targets from the EU policy are:

- REDII 2030 target: 32% RE share in EU's gross final energy consumption.
- Ff55 2030 target: 1067 GW total renewable energy generation capacity by 2030 (40% RE share in EU's gross final energy consumption).
- REPowerEU 2030 target: 1236 GW of total renewable energy generation by 2030 (45% RE share in EU's gross final energy consumption).
- Fit for 55 2030 target: 530 GW of solar PV capacity and 469 GW of wind capacity (409 GW onshore and 60 GW offshore) and at least 1 GW of ocean energy by 2030.

sEEnergies achieves a more efficient system using less biomass and hydrogen compared to the REPowerEU ambitions and achieves a slightly higher RE share of 47% in the EU's gross final consumption. Figure 10 below compares the renewable energy targets for onshore and offshore wind, solar PV, and ocean energy of EU policies (including Fit for 55, REPowerEU, and 1.5 TECH) with the results of the sEE 2030 and sEE 1.5 models. The Fit-for-55 2050 targets are based on the Offshore Renewable Energy Strategy (COM/2020/741), which does not explicitly define targets for onshore wind and solar PV, these segments are therefore left blank in the chart. As the chart shows, the sEEnergies 2030 energy system achieves higher installed capacities of wind and solar energy compared to both Ff55 and REPowerEU measures.

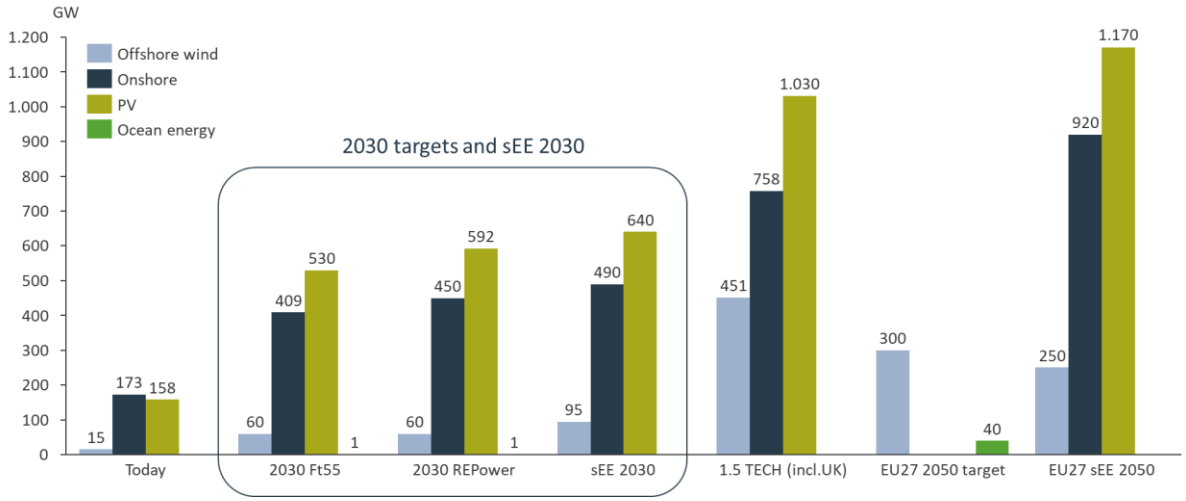

Figure 10. Renewable energy EU27 targets for 2030 and 2050 compared with sEE 2030 and sEE 1.5.

sEEnergies therefore recommends greater levels of fluctuating renewables for 2030: 640 GW of solar PV, 490 GW of onshore wind, and 95 GW of offshore wind energy; and for 2050: 1170 GW of solar PV, 920 GW of onshore wind, and 250 GW of offshore wind energy.

Ocean energy was not considered in the sEEnergies model. However, sEEnergies takes into consideration geothermal and solar thermal energy for district heating, for which the EU has not defined any targets, and recommends annual potentials of 0.04 PWh geothermal and 0.03 PWh solar thermal energy.

3.1.4 Greenhouse Gas Emissions

The targets regarding greenhouse gas emissions from the EU policy are:

- EED 2030 target: at least 40% cut in GHG emissions from 1990 levels in 2030.
- Ff55 2030 target: at least 55% cut in GHG emissions from 1990 levels in 2030.

The emissions accounted for in sEEnergies are related to CO_2 levels. A direct comparison with EU targets is therefore not possible since the emission levels of other greenhouse gases were not accounted for in sEEnergies. Instead, a discussion of the relative changes in emission levels is provided. The EU27 1990 levels of CO_2 emissions were estimated based on available Eurostat data, excluding emissions from the sub-sectors and processes that have not been included in sEEnergies, such as fuel combustion in petroleum refining, manufacturing industries and construction, and agriculture. Based on this estimation, sEEnergies 2030 achieves a 58% cut in CO_2 emissions from 1990 levels, which is in line with the heightened ambitions set out by the European Green Deal. The 55% target is therefore deemed achievable; however, it requires more careful consideration on what energy efficiency means in the concrete sectors as well as on implementation in terms of energy efficiency and deployment of renewables. In order to cost-effectively do this, sEEnergies illustrates that a system redesign towards a smart energy system can create a better platform for achieving significant reductions in GHG emissions.

In policy, CO_2 levies should not be mobilised as the single most important measure, but instead be implemented as an element of a more holistic package, one that is tailored to each sector, based on their own financial and technical contexts. If carried out in this manner, a tightening of the EU ETS mechanism is strongly suggested, by which more sectors are included, however with the regulations taking context into account.

3.1.5 Hydrogen

The targets regarding hydrogen production from the EU policy are:

- Fit for 55 2030 target: 40 GW of renewable hydrogen electrolysers.
- REPowerEU 2030 target: 65 GW hydrogen of installed electrolyser capacity
- Fit for 55 2030 target: 5.6 Mt of renewable hydrogen produced in the EU.
- REPowerEU 2030 target: 10 million tonnes of renewable hydrogen produced in the EU and 10 million tonnes imported.

REPowerEU has further heightened ambitions for hydrogen production that greatly exceeds the modelled hydrogen production in sEEnergies 2030, which shows that 5 Mt of hydrogen are a sufficient target for 2030. The sEEnergies scenario also finds 50 GW of electrolyser capacity to be sufficient for 2030. Specifically, given the extensive electrification of the transport sector in sEEnergies, fuel cell vehicles remain a niche technology due to their reliance on hydrogen and lower energy efficiency and therefore not much hydrogen is needed for transport. Furthermore, hydrogen for heating buildings is not recommended, instead emphasis should be placed on district heating and heat pumps. Overall, two thirds of the 5 Mt of hydrogen in sEEnergies 2030 goes into the production of electrofuels, primarily for aviation, and the rest is used in industry.

3.1.6 Sustainable Bioenergy

The targets regarding sustainable bioenergy from the EU policy are:

- REPowerEU: 35 bcm of sustainable biomethane production (341 TWh).
- REPowerEU: 160 Mtoe of biomass (1860 TWh), included in renewable energy target.

As discussed above, sEEnergies reaches the same target for sustainable biomethane production as set by REPowerEU of 35bcm by 2030, but a slightly lower target for biomass of 1790 TWh. sEEnergies recommends measures that keep the use of biomass for energy at a minimum, with respect to the growing long-term concerns related to resource scarcity and land use. Specifically, the use of biomass for biofuel production should be limited as it presents an energy intensive and inefficient way of using biomass. Instead, measures should emphasise the development and roll-out of Power-to-X technologies and electrification, as well as the replacement of coal in industry with biomass. Figure 11 below shows the distribution of biomass use in sEEnergies 2030.

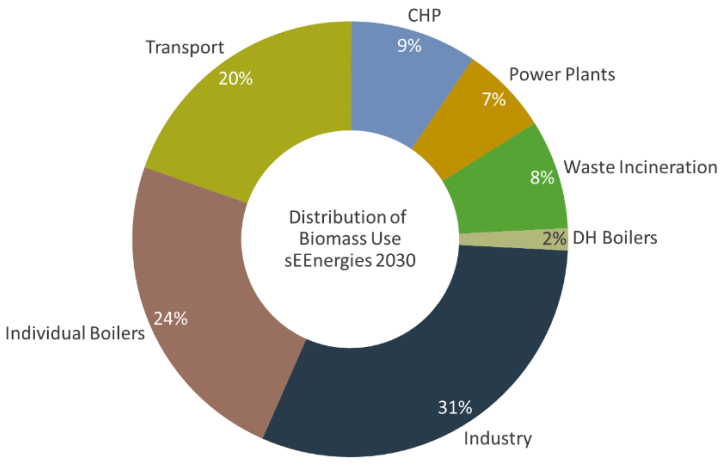

Figure 11. Distribution of biomass use in sEEnergies 2030

3.1.7 Policy Recommendations for Energy System

Energy Efficiency:

- The overall EE targets set by REPowerEU Plan for 2030 are in line with the sEE 2030 scenario that achieves a 14% reduction of 2020 reference scenario projections for 2030 of 966 Mtoe of primary energy consumption and 776 Mtoe of final energy consumption and subsequently the transition to the sEE 1.5 climate neutral system target.
- sEE 2030 achieves a 58% cut in CO_2 emissions from 1990 levels, which is in line with the heightened ambitions set out by the European Green Deal.
- More emphasis on efficient supply systems for heating such as district heating compared to sole focus on very ambitious targets for end demand reductions in existing buildings and more focus on targeted policies to electrify transport and industry.

Renewables:

- sEEnergies achieves a more efficient system using less biomass and hydrogen compared to the REPowerEU ambitions and achieves a slightly higher RE share of 47% in the EU's gross final consumption.
- Compared to the EU targets in REPowerEU and the EU 1.5TECH scenarios set for renewable energy, sEEnergies recommends greater levels of fluctuating renewables for 2030 and 2050.
    - 2030 targets: 640 GW of solar PV, 490 GW of onshore wind, and 95 GW of offshore wind energy.
    - 2050 targets: 1170 GW of solar PV, 920 GW of onshore wind, and 250 GW of offshore wind energy.
- sEEnergies recommends geothermal and solar targets for 2050 of 0.04 PWh/year geothermal and 0.03 PWh/year solar thermal energy.

Hydrogen:

- Strongly suggest energy efficiency improvements and extensive electrification over the replacement of one gaseous fuel with another.
- Avoid additional hydrogen production and all new direct and indirect gas consumption.
- A target of 5 Mt of hydrogen in 2030 is considered sufficient, as set by Fit for 55.
- A target of 50 GW of electrolyser capacity is considered sufficient for 2030.

Sustainable Bioenergy:

- Current target on sustainable biomethane production of 35 bcm by 2030, as set by the REPowerEU plan, is considered appropriate.
- Measures should limit the use of biomass to the extent possible, given long-term concerns related to resource scarcity and land use, with sEE 2030 capping biomass use at 1790 TWh.
- Measures should emphasise the development and roll-out of Power-to-X technologies and electrification, as well as the replacement of coal in industry with biomass.

Overall, EU policies have an explicit focus on energy demands and not enough emphasis on energy system re-design and conversion. In addition to the specific recommendations listed above, a systemic approach to sector integration is suggested in order to avoid suboptimal system design.

3.2 Buildings Policy Gaps and Recommendations

Buildings are considered central to the EU's energy efficiency and climate agendas, accounting for nearly 40% of final energy consumption and 36% of energy-related direct and indirect greenhouse gas emissions (COM/2021/802). In this section, the policy gaps identified and analysed are related to buildings in terms of both the supply system and the building envelope. Suggestions for the amendment of existing directives are suggested, as is the development of a new directive that brings forward heating as a key part of the energy system as well as zoning mechanisms for different types of heat supply.

3.2.1 Renovation Rate

The targets regarding the renovation rate of buildings from the EU policy are:

- Renovation Wave Strategy: at least double the annual energy renovation rate of buildings by 2030.
- Ff55 2030 target: annual renovation rate of 2% of entire housing stock in 2030; annual renovation rate (medium and deep renovation) of 1.9% of entire housing stock in 2030.
- REPowerEU 2030 target: annual renovation rate of 2.1% of entire housing stock in 2030.

A focus on heat demand reduction, rather than renovation rate is recommended. Specifically, based on the sEEnergies models, a reduction in heat demand of 40% for existing residential and service buildings is needed from 2020 to 2050, which is equivalent to 1.3 – 1.4% absolute heat reduction per year.

3.2.2 Energy Consumption and RES Share in Buildings

The targets regarding energy consumption and RES share in buildings in policy from the EU policy are:

- European Green Deal (Renovation Wave Strategy) 2030 target: reduce final energy consumption of buildings by 14% from 2015 levels.
- European Green Deal (Renovation Wave Strategy) 2030 target: reduce energy consumption for heating and cooling by 18% from 2015 levels.
- Ff55 2030 target: 49% RES share in buildings.
- REPowerEU 2030 target: 60% RES share in buildings.

sEEnergies 2030 achieves an RES share of 60% in buildings, (compared to 26% in 2019), which aligns with the heightened ambitions set out by REPowerEU. The sEEnergies model achieves approximately 2530 TWh in 2030 as maximum heat demand, which still places the EU on track to completely decarbonise the heating sector. This means that the target for heat reduction of heat demand in buildings can be decreased to 10% compared to 2015 levels, as this is considered a more realistic target for Europe's building stock. The sEEnergies 2030 model further shows a 6% reduction in individual fossil fuel boilers in 2030, compared to 2019. It is recommended that current targeted policies regarding on-site renewable energy production, as substantiated by the concept of Nearly Zero-Energy Buildings, are replaced by policies on diversifying heat supply in buildings with district heating as well as a concrete focus on building envelope refurbishments. This is because the NZEB concept dilutes the demands linked to building envelope improvements, which must be highly prioritised for Europe's building stock.

3.2.3 District Heating

The targets regarding district heating from the EU policy are:

- Ff55 District Heating and Cooling 2030 target: average yearly increase of 2.1% for 2020-2030
- RePowerEU District Heating and Cooling 2030 target: average yearly increase of 2.3% for 2020-2030

In total, sEEnergies has a higher ambition to decarbonize the building stock by 2030, with a more cost-effective system for buildings by increasing district heating from 13% (2019) to 20% and increasing heat pumps share from 5% (2019) to 26%, instead of a sole focus on end demand reductions in existing buildings and individual heat pumps. A new Heating Planning Directive is recommended, by which focus is placed on heating as a part of the energy system and zoning mechanisms can be established for different types of heat supply. A support framework is recommended for DH with mandatory demand to have local ownership and governance models and to use of state-of-the-art technology for EE and DH.

3.2.4 Individual Heat Pumps

The targets regarding individual heat pumps from the EU policy are:

- Ff55 2030 target: 30 million newly installed heat pumps installed in 2030.

Based on a bottom-up modelling of the EU building stock, sEEnergies 2030 assumes an average heat demand of 11,000 kWh per building and achieves a general 10% reduction in heat demand by 2030, where a total of 62 million individual heat pumps will be needed by this year. Starting from approximately 17 million heat pumps in 2021, sEEnergies recommends a heightened ambition of 45 million newly installed individual heat pumps by 2030.

Within the sEE 2030 scenario, heat pumps for private heating are implemented mostly before 2030 (left hand side in Figure 12), since private heat pumps are already growing at a fast rate from 2015 to 2019. If the rate is slowed down and there is an even split before and after 2030, then the total installed capacity required in sEE 1.5 may not be achieved (right hand side in Figure 12).

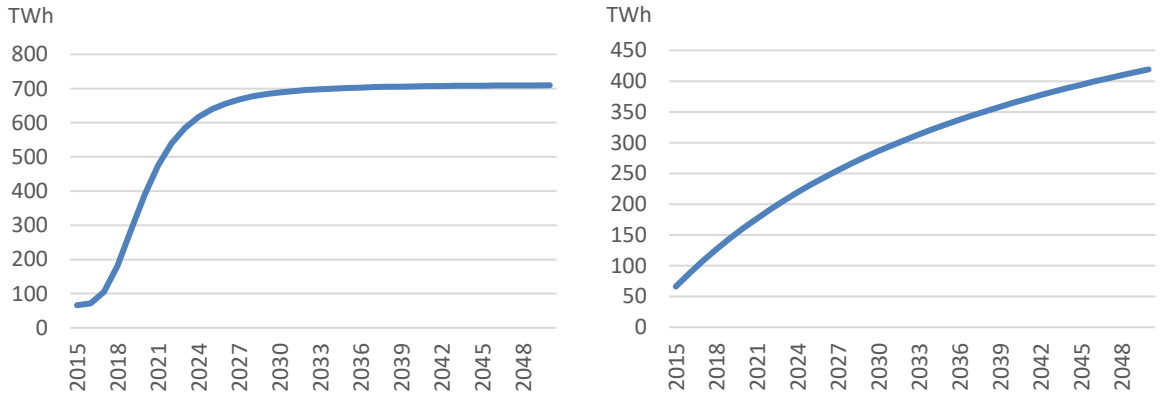

Figure 12. Implementation curve for private heat pumps towards sEE 1.5 in the sEE 2030 scenario (left) and an example of a slow implantation towards sEE 1.5 (right)

Furthermore, in terms of the impact on the energy system, when installing private heat pumps mostly before 2030 the primary energy demand is lower in 2030 than if the heat pumps are delayed until after 2030. This is even if electricity demand increases.

Heat pumps for private heating should continue their acceleration and mostly be installed by 2030 to 2035 which benefits the energy system. Implementation of heat pumps requires that there is a reduction of heat demand as well. Measures targeting the acceleration of the installation of heat pumps should therefore be implemented in tandem with measures focused on heat demand.

3.2.5 Policy Recommendations for Energy Efficiency in Buildings

Energy Performance of Buildings Directive:

- Better balance between end savings and supply is recommended, with more realistic and ambitious targets for end consumption.
    - A reduction in heat demand for existing residential and service buildings of 40% is needed from 2020 to 2050, which is equivalent to 1.3-1.4% absolute heat reduction per year.
- Rather than having a higher target, the directive should focus on implementation of existing targets and measures.
- Stronger monitoring and knowledge-sharing between Member States on best practices is suggested.
- A move away from the focus on NZEB and on-site renewable energy production toward stronger targets on the building envelope is suggested, as the NZEB concept dilutes the demands linked to building envelope improvements.

New Heat Planning Directive:

- Focus on heating as a part of the energy system and zoning mechanisms for different types of heat supply.
    - Support the systematic identification of spatial potentials for district heating in the Member States in order to prioritise between district heating and individual heating solutions, such as electric heat pumps.
    - A heightened ambition for individual heat pumps, from the current Fit-for-55 package of 30 million units, is recommended to 45 million newly installed individual heat pumps by 2030.
- Support framework for DH with mandatory demand to have local ownership and governance models and to use of state-of-the-art technology for EE and DH.

District Heating and Individual Heat Pumps:

- A higher ambition to decarbonize the building stock by 2030, with a more cost-effective system for buildings is recommended by increasing district heating from 13% (2019) to 20% and increasing heat pumps share from 5% (2019) to 26%, instead of a sole focus on end demand reductions in existing buildings and individual heat pumps.
- A financial infrastructure support mechanism for establishment of new district heating systems is recommended as well as ensuring that access to low interest rate public loans if ownership is local and that no profit is taken out of the system.
- Mandatory planning procedures and private economic conditions are recommended that favour long-term investments in EE and DH.
- Demand assessments should be based on socio-economic cost and a subsidy (national or EU) should be based on local valuation (a kind of CBA system).
- The establishment of a democratic infrastructure is also suggested that demands full disclosure of financial elements in tariff structure.

3.3 Transport Policy Gaps and Recommendations

The transport sector contributes to nearly a quarter of Europe's GHG emissions and is the major cause of air pollution in cities (COM/2016/0501). EU policies regarding transportation and mobility primarily centre around objectives linked to transport-related emissions and the uptake of zero-emission vehicles. In this section, these policies are compared to the sEE 2030 results related to transport and policy suggestions are provided in terms of electrification, emissions, alternative fuels, modal shifts, and urban spatial and infrastructure developments.

3.3.1 Electric Vehicles and Transport Emissions

The targets regarding electric vehicles and transport emissions from the EU policy are:

- Sustainable and Smart Mobility Strategy 2030 target: At least 30 million zero-emission cars in operation on European roads.
- Ff55 (recast of CO_2 emissions regulations of new vehicles and new heavy-duty vehicles) 2030 targets: Cars: 55%; Vans: 50% reduction in CO_2 emissions performance from 2021 starting points.
- Ff55 (recast of REDII) 2030 target: 13% GHG intensity reduction.

The electrification rate must be accelerated, with the sEEnergies model finding at least 93 million electric vehicles necessary on the roads by 2030 – an increase of more than 200% than the European Green Deal target of 30 million zero-emission cars. The sEEnergies model also achieves a share of 30% electric vehicles of the total cars and vans. To reach this share, measures supporting the phase-out of fossil fuel cars and incentivising the uptake of electric vehicles are needed, such as the CO_2 emissions regulations of new vehicles and new heavy-duty vehicles. Stricter policies are also recommended that only allow the registration of zero-emission vehicles (cars, vans, motorbikes, mopeds, etc.) by 2030. Furthermore, separate targeted policies for all modes of transport are recommended, including light-duty vehicles and heavy-duty transport. For example, the Sustainable and Smart Mobility Strategy target on the number of zero-emission vehicles can be amended to cover other forms of transport, in addition to cars.

Based on sEE 2030, a 20% reduction in CO_2 intensity from 2019 levels is found. This reduction is mainly due to an overall reduction in fuels, the decarbonisation of electricity production, the extensive electrification of transport as well as a reduction of losses in ICE vehicles. However, the EU focus on CO_2 emissions of heavy-duty vehicles promotes the use of biofuels and biogas. This should be compensated with concrete measures that support the electrification of vehicles as well as the decarbonisation of electricity production.

3.3.2 Renewable Energy, Biofuels and Biogas

The targets regarding renewable energy, biofuels, biogas, RFNBOs (renewable fuels from non-biological origin) and recycled carbon fuels (RCF) in transport from the EU policy are:

- REDII 2030 transport sub-target: Member States must require fuel suppliers to supply a minimum of 14% of the energy consumed in road and rail transport as renewable energy.
- REDII 2030 transport sub-target: The contribution of advanced biofuels and biogas produced from the feedstock as a share of final consumption of energy in the transport sector – at least 3.5% in 2030.
- Ff55 (recast of REDII) 2030 target: 2.2% share of advanced biofuels (single counted); 2.6% share of RFNBOs (single counted).

- ReFuelEU 2030 targets: sustainable aviation fuels (SAF) blending obligation from 5% in 2030 with sub-target for synthetic aviation fuels (e-kerosene) 0.7% in 2030.
- FuelEU Maritime 2030 target: renewable and low-carbon fuels represent 6-9% of the maritime fuel mix in 2030.

sEE 2030 achieves an RES share of 24% in transport for 2030, compared to a 5% share in 2019, with a 9% share of biofuels and a 3% share of electrofuels. SEEnergies therefore achieves a greater RES share in transport than set out by the REDII sub-target of 14%. SEEnergies prioritises the direct and battery electrification of the transport sector, recommending the reliance on hydrogen to be kept to a minimum.

The transition to electrofuels should be reserved for hard to electrify modes, i.e. aviation and shipping, thus, clear targets are recommended to support alternative fuel infrastructure developments. For trucks, heavy electrification targets are needed combined with specific blend-in targets for methanol. For aviation and navigation, concrete blend-in targets for methanol and ammonia are also recommended, whereby emphasis is initially placed on aviation given the greater difficulty in producing jet fuel.

Our proposal in sEE 2030 gives the possibility to have blend-in demands for aviation and navigation of 10%, which is measured in terms of the energy content. This is not directly comparable to the EU volumetric blend-in demands, nevertheless, the sEEnergies targets are higher than the EU targets. Furthermore, holistic plans to align infrastructure developments with fuel switch developments are strongly recommended. Regarding FuelEU Maritime, there are potential issues with the current formulation of the initiative that can allow for an extended period of LNG ships in the transition away from fossil fuels.

In order to fully support the extensive electrification of transport, the elimination of targets that allow for biofuels, biogas and LNG in transport is also suggested as well as the establishment financial support mechanisms that support the electrification of trucks, navigation and aviation by battery-electric propulsion systems, e-road systems and charging stations.

3.3.3 Energy Efficient Urban Spatial and Infrastructure Development

Currently, there are no clear EU policies that promote energy efficient spatial development as a promising measure for maintaining accessibility, while reducing transport volumes and promoting a shift from energy-demanding travel modes to modes requiring less energy per person kilometre travelled or ton kilometre of freight. In particular, the spatial characteristics that are considered to contribute the most to these aims are high population density, residential location close to the main centre of the city or metropolitan area, and location of specialised, labour-intensive or visitor-intensive jobs close to centre. It has been estimated that should energy efficient urban development be followed, passenger car transport demand will peak in 2030 in most of Western and Central European countries.

Therefore, targeted policies to promote urban densification and efficient demand growth are strongly recommended, whereby Member States are encouraged to develop local planning mechanisms for limiting continued urban sprawl and sharing platforms for energy efficiency urban development knowledge and best practices are established. A Sustainable Transport Infrastructure Directive is also recommended that frames long-term structural changes related to energy efficient infrastructures in

transport across Europe, namely rail and e-road system developments. Additionally, a refocus of the TEN-E regulation is suggested such that support for continued road infrastructure developments, i.e. motorways, is replaced with support for the development of local public transport infrastructure and trans-European high-speed rail.

3.3.4 Policy Recommendations for Energy Efficiency in Transport

Electrification and Emissions:

- Measures promoting the acceleration of electrification – sEEnergies model finds at least 93 million electric vehicles necessary on the roads by 2030, an increase by more than 200% than the European Green Deal target of 30 million zero-emission cars.
- Only allow the registration of zero-emission vehicles (cars, vans, motorbikes, mopeds, etc.) by 2030.
- Separate targeted policies for all modes of transport are recommended, including light-duty vehicles and heavy-duty transport.
    - For example, the Sustainable and Smart Mobility Strategy target on the number of zero-emission vehicles should cover other forms of transport, in addition to cars.
- Financial support mechanism for the electrification of trucks, navigation, and aviation by battery-electric propulsion systems, e-road systems, and charging stations.

Alternative Fuels:

- Eliminate targets that allow for biofuels, biogas and LNG in transport.
- Clear targets to support alternative fuel infrastructure developments, e.g., methanol for trucks and ammonia and methanol for navigation.
- sEE 2030 gives the possibility to have blend-in demands for aviation and navigation of 10% (measured in terms of the energy content), which is not directly comparable to EU volumetric blend-in demands, nevertheless, sEEnergies targets are higher than EU targets.
- Electrofuels should be prioritized for aviation and navigation.
- The focus on CO_2 emissions of heavy-duty vehicles should be reduced, since this promotes the use of biofuels and biogas.

Urban Spatial and Infrastructure Development:

- Targeted policies to promote urban densification and efficient demand growth, whereby Member States are encouraged to develop local planning mechanisms for limiting continued urban sprawl and sharing platforms for energy efficiency urban development knowledge and best practices are established.
- A Sustainable Transport Infrastructure Directive is recommended that frames long-term structural changes in transport, primarily energy efficient infrastructures across Europe, supporting rail and e-road system developments (not only charging points).
- Refocus TEN-E to stop the support of road infrastructure (motorways), and instead support the development of local public transport infrastructure (e.g., metro, tram) as well as trans-European high-speed rail.

3.4 Industry Policy Gaps and Recommendations

As shown in Johannsen et al. (2022), the implementation of energy efficiency measures for the industry sector energy transition requires a consortium of efforts including Best Available Technologies (BAT), electrification, recycling and innovative measures. In particular, it is recommended that hydrogen fuel shifting measures and the use of solid biomass should be strictly prioritised for high-temperature processes within, e.g., the chemicals and iron and steel sub-sectors (ibid.). The electrification of low-temperature processes can be further prioritised as a short-term means of reducing natural gas consumption and thereby eliminating Europe's dependence on Russian fuels.

3.4.1 Hydrogen

The targets specifically addressing hydrogen in the industry sector from the EU policy are:

- Hydrogen Strategy 2030 target: 50% of hydrogen consumed in industry is renewable
- RePowerEU 2030 target: 78% of hydrogen consumed in industry is renewable

The sEEnergies model achieves a 100% share of renewable hydrogen of the hydrogen consumed in industry. It is important to highlight, however, that the amount of hydrogen the EU proposes for 2030 is significantly higher than the amount of hydrogen modelled in sEEnergies (as discussed in Section 3.1.5). It is therefore recommended that a shift of focus away from hydrogen should be established via measures incentivising instead the electrification of industry.

3.4.2 Renewables Share and Electrification Rate

The targets regarding the share of renewable energy sources and electrification rates in industry from the EU policy are:

- RePowerEU 2030 target: average yearly increase of 1.9% RES share in industry, for 2020-2030.

In 2020, the RES share in industry was 17% for EU27. An annual increase of 1.9% therefore gives an RES share of approximately 21% in 2030, whereas the sEEnergies model achieves an RES share of 51% in industry in 2030. Transitioning away from fossil fuels toward the use of renewable electricity is a key mechanism for decarbonising the industry sector and responding to resource scarcity. Explicit measures and targets for the electrification of the industry sector are needed that promote the use of large-scale heat pumps and direct electricity use. More ambitious electrification rates combined with energy savings can offset the estimated increase in industrial energy demand. Specifically, the sEEnergies model achieves an electrification rate of 38% in 2030 and 65.5% in 2050 for industry.

Furthermore, currently, there are no binding EU policies that explicitly define targets or measures regarding future technologies and flexibility needs in industry. Although it has not been included in the developed models, technologies such as geothermal heating and concentrated solar heating can be relevant for the future renewable transition of industries, particularly for temperatures up to approx. 200°C. Johannsen et al. (2022) estimate that such technologies could potentially supply over 30% of the total industrial energy demand, especially in lower-temperature sub-sectors, such as paper and pulp.

Given the fluctuating nature of renewable energy sources, it is also important to consider the future needs of the industry sector to add flexibility to the overall energy system. This can be implemented via measures for flexible demand, operation, and consumption. For example, flexible consumption can

be incentivised through adjusted fuel and electricity cost structures based on peak load and connected capacity in addition to a volumetric measure of energy.

3.4.3 Waste Heat Recovery

The policies that are currently in place, namely the Heating and Cooling strategy and the EED, do not provide explicit targets for industrial waste heat recovery. Nevertheless, the Heating and Cooling strategy emphasises the promising potential of using industrial excess heat to reduce fossil fuel import and ensure energy supply security; while Article 14 of the EED requires Member States to identify the potential for high-efficiency cogeneration and efficient district heating and cooling.

sEEnergies recommends the development of a new directive that explicitly targets improved energy efficiency in industry, including a reward system for the use of excess heat for district heating. The sEEnergies 2030 model achieves an annual potential of 0.083 PWh from industrial excess heat, however targets can be set to more ambitious levels and can further take into consideration the potential of using waste heat from heat pumps in addition to industrial processes.

3.4.4 Policy Recommendations for Energy Efficiency in Industry

New directive targeting improved energy efficiency in industry:

- Shift focus from measures that promote the use of hydrogen, toward measures that support the electrification of industries by use of large-scale heat pumps and direct electricity use.
- Hydrogen and bioenergy should be reserved for hard to abate processes.
- Reward the use of excess heat for district heating.
- Push industrial symbiosis.
- Phase out low efficiency combustion technologies (Eco-Design and Energy Labelling Directives).
- Promote onsite use of concentrated solar and PV on large roofs.
- Measures for flexible demand, operation, and consumption.
    - Flexible consumption can be incentivised through adjusted fuel and electricity cost structures based on peak load and connected capacity in addition to a volumetric measure of energy.

Align socio-economic potentials with business economic payback times:

- Set targets that ensure high costs on greenhouse gas emissions.
- Set lower boundary targets for levies on combustion (a levy to promote electricity and halt increased bioenergy use).

Electrification and Renewables:

- A heightened ambition is suggested for the RES share in industry in 2030 of at least 50%.
- Clear electrification of industry targets are also recommended of at least 38% in 2030 and 65.5% in 2050.
- EU wide financial support mechanism for large-scale electrification of industry targeted at vulnerable sectors.
- Electrification of low-temperature processes can be further prioritised as a short-term means of reducing natural gas consumption.

4 Conclusions

In sEEnergies, a cost-effective 100% renewable energy and energy efficiency-based scenario was presented for EU27 and the United Kingdom in 2050. This vision gives a full decarbonisation of the energy, buildings, industry and transport sectors without exceeding sustainable bioenergy resources. SEEnergies utilises targeted and **cost-effective energy efficiency measures combined with renewable energy in a re-designed European smart energy system**. This report aimed to describe the EU policy related to energy efficiency within the energy system, and to identify policy gaps and possible overlaps related to energy efficiency, based on the findings in the report: Energy Efficiency 2050 Roadmap for Europe: A cost-effective and energy-efficient strategy for decarbonising (Deliverable 6.3), in which the sEE 2030 energy system scenario was presented based on the sEE 1.5 target.

In this report, existing EU targets were compared with the sEE 2030 energy system results and analysed in terms of their implications for policy, in order to ensure that the objectives for the energy system in 2030 do not present obstacles for achieving the recommended system redesign for 2050 and to offer strategic insight for addressing the current energy market disruption caused by Russia's invasion of Ukraine and enhancing Europe's energy security. Based on the gap analysis, sound science-based policy suggestions were presented to address those gaps and discussed in terms of the energy system as a whole and its components as well as the building, industry, and transport sectors, with an additional emphasis on short-term strategies that address the growing energy security concerns raised by Russia's invasion of Ukraine. In particular, the findings showed that **sEEnergies addresses REPowerEU and the European 2030 goals by means of known technologies with energy efficiency and renewable energy, offering a 14 – 22% greater potential in natural gas savings by 2030**. The largest gas savings in sEEnergies 2030 are achieved through the system effects of renewable energy and electrification measures as well as the delayed nuclear phase-out until 2030, which were quantified at a total of 83 bcm of natural gas. Based on the review of existing policies and strategies, the European Commission's model does not seem to explicitly account for the system effects of increased levels of household heat pumps, district heating (large-scale heat pumps) and electric vehicles. This is a shortcoming that the Commission must address in order to be able to strategically plan and implement measures for ending Europe's dependence on Russian gas.

Careful consideration of each sector and prioritisation of a **holistic system redesign** towards a smart energy system is recommended. In particular, sEEnergies recommends **more emphasis on efficient supply systems for heating**, such as district heating, compared to the sole focus on very ambitious targets for end demand reductions in existing buildings and more focus on targeted policies to electrify transport and industry. A move away from the focus on Nearly zero-energy buildings (NZEBs) and on-site renewable energy production, as set out by the **Energy Performance of Buildings Directive**, toward stronger targets on the **building envelope** is strongly suggested. The NZEB concept dilutes the demands linked to building envelope improvements, which will impede achieving the 2050 targets. A new **Heat Planning Directive** is further suggested to bring heating on the agenda as a part of the energy system and to enable zoning mechanisms for different types of heat supply.

Furthermore, sEEnergies has shown that the three sectors (buildings, transport and industry) have equally large energy efficiency potentials. Therefore, it is recommended that the European Commission develops **a stronger and more holistic regulatory focus in transport and industry as well as buildings**. On the supply side, sEE 2030 achieved **RES shares of 60% in buildings, 24% in transport,**

and 51% in industry. For transport, a more systematic approach is needed for structuring **energy efficient urban development** and enabling **modal shifts** through the extensive development of cross-national public transport solutions. A **Sustainable Transport Infrastructure Directive** is recommended that frames long-term structural changes related to energy efficient infrastructures in transport across Europe, namely rail and e-road system developments. For industry, additional improvements to the **Eco-Design, Energy Labelling and Fuel Quality Directives** are recommended that support the phase-out of low efficiency combustion technologies, reward the use of **excess heat** for district heating, promote onsite use of concentrated solar and PV large roofs, and shift focus from measures promoting hydrogen use toward measures that support the **electrification of industries** by use of **large-scale heat pumps and direct electricity use**.

Overall, it has been shown that in EU policy more clear and targeted focus on the holistic redesign of a **European smart energy system** is needed. The targets set out by the **Fit-for-55** and **REPowerEU** measures are found to be realisable and are in fact achieved by sEEnergies through more cost-effective means. Lastly, taking into account the inherent complexity of supranational governance institutions as the EU and international policy-making processes, sEEnergies strongly suggests a heightened **emphasis on implementation** and the concrete steps that need to be taken within and across Member States in realising the transition toward a **clean, smart and secure European energy system**.

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