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IMPACT ASSESSMENT REPORT

Part 1

Accompanying the document

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

Securing our future

Europe's 2040 climate target and path to climate neutrality by 2050 building a sustainable, just and prosperous society

{COM(2024) 63 final} - {SEC(2024) 64 final} - {SWD(2024) 64 final}

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Glossary

Term or acronym	Meaning or definition
AFOLU	Agriculture, Forestry and Other Land Use, i.e., IPCC sectors 3 (Agriculture) and 4 (LULUCF) combined. The term 'land sector' is used as synonym.
BECCS	Bioenergy with Carbon Capture and Storage
BioCCS	Carbon capture and storage of biogenic CO2 emissions originated from the combustion of biomass to produce energy (BECCS) or from the processing of biomass in industrial applications
Biogenic carbon	Carbon Dioxide resulting from upgrade of biogas to biomethane
CAP	EU's common agricultural policy
Carbon capture	CO2 captured from industrial processes, power and heat production, biogas upgrade and direct air capture.
Carbon Pool	means the whole or part of a biogeochemical feature or system within the territory of a Member State and within which carbon, any precursor to a greenhouse gas containing carbon, or any greenhouse gas containing carbon is stored
CBAM	Carbon Border Adjustment Mechanism
CCS	Carbon Capture and Storage (permanently underground and in materials)
CCU	Carbon capture and usage
CH_4	Methane
Circular Economy	A circular economy moves away from the conventional consumption model and aims to decouple economic activity from the consumption of finite resources. Products, raw materials and resources are kept in circulation through maintenance, recycling, reuse or refurbishment. Thereby the generation of waste is minimized.
CO_2	Carbon dioxide
DACC	Direct Air Carbon Capture. The carbon captured can be stored (DACCS) or used.
DACCS	Direct Air Carbon Capture and Storage
EAF	Electric Arc Furnace
E-fuels	Electro-fuels, manufactured using captured carbon dioxide or carbon monoxide. Note that e-fuels are not the same as RFNBOs (see RFNBO definition in this glossary).
EJ	Exajoule
ESABCC	European Scientific Advisory Board on Climate Change ESABCC(2023). Scientific advice for the determination of an EU-wide 2040 climate target and a greenhouse gas budget for 2030–2050. DOI: 10.2800/609405
ESR	Effort Sharing Regulation
ETS	Emissions Trading System
ETS1	Existing ETS extended to also include maritime shipping
ETS2	New ETS covering buildings, road transport and fuels for additional sectors
EUR	Euro, unless specified otherwise, all monetary figures are expressed in constant 2023 prices ("EUR2023")
FEC	Final Energy Consumption: the total energy consumed by end users, such as households, industry and agriculture. It is the energy which reaches the final consumer's door and excludes that which is used by the energy sector itself
Fit-for-55 package	Package of legislation makes all sectors of the EU's economy fit to meet the 2030 climate target of a reduction of its net greenhouse gas emissions by at least 55% by 2030.
GAE	Gross Available Energy: the overall supply of energy for all activities of a country (defined as: Primary production + Recovered & Recycled products + Imports – Export + Stock changes).

GHG	Greenhouse gas(es)
GHG budget	Total volume of net greenhouse gas emissions that are expected to be emitted over a given period. The European Climate Law refers to the 2030-2050 period.
Greenhouse gases	Greenhouse gases from the Kyoto Protocol: Carbon dioxide (CO2); Methane (CH4); Nitrous oxide (N2O); Hydrofluorocarbons (HFCs); Perfluorocarbons (PFCs); Sulphur hexafluoride (SF6).
Gross Available Energy (GAE)	Overall supply of energy for all activities of a country.
Gross GHG emissions	Total GHG emissions excluding the contribution of industrial carbon removals and of net LULUCF removals.
HFCs	Hydrofluorocarbons
ICE	Internal Combustion Engine
Industrial Carbon Management	Technologies, infrastructures, policies and business models for the capture of carbon dioxide (CO_2), its transport, storage, and utilisation as feedstock in industrial processes. The CO_2 can be captured from process or energy emissions of industrial installations, also referred as point source emissions, or directly from the atmosphere with Direct Air Carbon Capture (DACC) installations.
Industrial Carbon Removals	BECCS, DACCS and biogenic carbon
IPCC	The Intergovernmental Panel on Climate Change
Land sector	Synonym for AFOLU sector.
Lignocellulosic Crops	Refers to a range of plants rich in cellulose, hemicelluloses, and lignin including wood from forestry, short rotation coppice, such as willow and poplar, and energy crops, such as energy grasses and reeds. The latter is produced to serve as biomass for the production of advanced / second-generation biofuels.
LNG	Liquefied Natural Gas
LRF	Linear Reduction Factors of the ETS
LULUCF	Land Use, Land Use Change and Forestry
LULUCF net removals	Aggregated emissions from and nature-based carbon removals in the LULUCF sector creates a net removal in the EU, as the sector absorbs more greenhouse gases than it emits.
MACC	Marginal Abatement Cost Curve, which shows the marginal cost of additional reductions in greenhouse gas emissions.
MFF	Multiannual financial framework
Mha	Million hectares
MIDAS	Modelling Inventory and Knowledge Management System of the European Commission
MRV	Monitoring, Reporting and Verification
N2O	Nitrous oxide
Nature-based removals	Nature-based removals are a collection of approaches using the potential of healthy ecosystems to both reduce and remove emissions. They are either enhancing the ability of healthy ecosystems to sequester carbon dioxide by making ecosystems more resilient whilst preserving or enhancing locally adapted biodiversity and the ecosystems’ wide range of ecosystem services or restore a degraded ecosystem so that it no longer emits harmful greenhouse gas emissions. Nature-based removals can be one of several functions of nature-based solutions.
Nature-based solutions	Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social, and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes, and seascapes, through locally adapted, resource-efficient and systemic interventions. Nature-based solutions must therefore benefit biodiversity and support the delivery of a range of ecosystem services.
NDC	Nationally Determined Contribution

NECP	National Energy and Climate Plans. This analysis uses the NECPs as submitted in 2019 by the Member States and analysed by the Commission in 2020. The current NECP update runs in parallel with the preparation of this Impact Assessment and could not be taken into account.
PFCs	Perfluorocarbons
RFNBO	"Renewable Fuels of Non-Biological Origin" are liquid or gaseous fuels, the energy content of which is derived from renewable sources other than biomass. This term designates renewable hydrogen but also its derivatives (e.g., e-fuels).
RRF	Recovery and Resilience Facility
SDG	Sustainable Development Goal
SF6	Sulphur hexafluoride
Sink / (carbon) removal	Means any process, activity or mechanism that removes a greenhouse gas, an aerosol, or a precursor to a greenhouse gas from the atmosphere via natural and technological solutions. It includes industrial carbon removals and certain nature-based carbon removals that remove carbon dioxide from the atmosphere (CO2).
Source / emission	Means any process, activity or mechanism that releases a greenhouse gas, an aerosol or a precursor to a greenhouse gas into the atmosphere
UNFCCC	United Nations Framework Convention on Climate Change

References to policy documents

Policy document	Reference
EU Biodiversity Strategy for 2030	COM/2020/380 final
2030 Climate Target Plan	COM(2020) 562 final
CO_2 standards for cars and vans	Regulation (EU) 2023/851
Critical Raw Materials Act (proposal)	COM(2023) 165 final
EU's Long-Term Strategy – A Clean Planet for all A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy	COM (2018) 773 final Complemented by: "In-depth analysis in support of the Commission Communication COM(2018) 773"
ETS Directive	Directive 2003/87/EC (amended by Directive (EU) 2023/958)
European Climate Law	Regulation (EU) 2021/1119
Farm to Fork Strategy	COM/2020/381 final
Fluorinated greenhouse gases Regulation (proposal)	COM/2022/150 final
Governance Regulation	Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action
Green paper for a 2030 framework for climate and energy policies	COM(2013) 169 final
Greening Freight Transport package	COM(2023) 440 final
Industrial Emissions Directive (proposal)	COM(2022) 156 final/3
Net Zero Industry Act (proposal)	COM(2023) 161 Final
Regulation of methane emissions reductions in the energy sector (proposal)	COM/2021/805 final
Urban waste-water treatment Directive (proposal)	COM(2022) 541 final
2023 State of the Energy Union Report	COM(2023) 650 final

1 INTRODUCTION: POLITICAL AND LEGAL CONTEXT

1.1 Legal obligation and approach

This report accompanies a Communication on the EU climate target for 2040 in view of implementing the European Climate Law, which enshrines in law the EU's commitment to become climate neutral by 2050 and the EU's 2030 climate target to reduce net greenhouse gas (GHG emissions) by at least 55% in 2030 relative to 1990. This initiative does not aim at developing and committing on the post-2030 policy framework implementing that 2040 climate target at this stage.

The Climate Law mandates the Commission to make a legislative proposal, as appropriate, for a Union-wide 2040 climate target within 6 months of the global stocktake under the Paris Agreement, which will be completed at the Conference of the Parties in December 2023. The 2040 target will also inform the EU's future post-2030 Nationally Determined Contribution (NDC) that all Parties must submit to the UNFCCC by 2025 (under Article 4(9) of the Paris Agreement).

The Climate law also calls on the Commission, when making the proposal for the Union 2040 climate target, 'at the same time, to publish in a separate report the projected indicative Union greenhouse gas budget for the 2030-2050 period' taking into account the advice of the European Scientific Advisory Board on Climate Change (see box).

The **European Scientific Advisory Board on Climate Change (ESABCC)**, set up under the 2021 European Climate Law (article 3), serves as an independent point of reference for the EU on the science of climate change. Its tasks include providing scientific advice and issuing reports on existing and proposed Union measures, climate targets and indicative greenhouse gas budgets. In June 2023, it published advice ([1]) recommending a **2040 target for the EU to reduce net GHG emissions in the range of 90-95% compared to 1990.**

The "**GHG budget**" for the EU for 2030 to 2050 is defined in the Climate Law as the total volume of EU net greenhouse gas emissions expected to be emitted in that period ([2]). It combines a "carbon" budget (cumulative CO2 emissions) with cumulative emissions of non-CO2 GHGs ([3]). The GHG budget is strongly dependent on the level of net GHG emissions reached in 2040, as the intermediate point between 2030 and 2050, and is used to assess the climate performance of the 2040 climate target and the fairness of the EU's contribution to global climate action ([4]).

([1]) ESABCC (2023). Scientific advice for the determination of an EU-wide 2040 climate target and a greenhouse gas budget for 2030–2050. DOI: 10.2800/609405.

([2]) European Climate Law, Article 4(4).

([3]) Non-CO2 GHG emissions defined in the Kyoto Protocol: CH4, N2O, SF6, PFCs and HFCs. They are converted into "CO2 equivalent" using the global warming potential for a 100-year time horizon from the IPCC Fifth Assessment Report ("AR5").

([4]) According to the IPCC, given the nearly linear relationship between cumulative CO2 emissions and increases in global surface temperature, cumulative CO2 emissions are relevant for understanding how past and future CO2 emissions affect global surface temperature. IPCC Sixth Assessment report (AR6), Working Group 1 "The physical science", Technical summary, Table TS.3 | Estimates of remaining carbon budgets and their uncertainties.

This impact assessment thus assesses different levels of net GHG emissions in 2040 and the associated sectoral pathways bridging 2030 to climate neutrality by 2050. It does not assess the post-2030 energy and climate policy framework, to be developed at a later stage.

The assessment of the 2040 climate target will largely be determined by two main dimensions: on the one hand the *GHG budget* measuring the climate performance of the target and the fairness of the contribution of the EU to the global climate agenda and, on the other hand *feasibility*, including costs, technological deployment and trade-offs.

1.2 Climate change and cost of inaction

Climate change will remain the defining challenge of the coming decades, shaping the future of the global society and economy through its impacts and our response. The harmful impacts of global warming are increasing in scale and frequency, with devastating effects on people, nature, and economic systems across the globe. Droughts, heatwaves, floods, wildfires and storms are becoming more frequent and severe, impacting wider areas and hurting more people, businesses, critical infrastructure, ecosystems, and affecting our ability to sustain prosperity and stability in the long run.

This is happening alongside interrelated challenges of biodiversity loss and natural resource depletion, unsustainable use of natural resources, including water, raw materials, and land, increasing the risk of crossing further planetary boundaries ([5])([6]) and decreasing the stability and resilience of natural and human systems. This reduces their capacity to both mitigate and adapt to climate change and leads to further negative impacts.

As recently confirmed by the work of the Intergovernmental Panel on Climate Change (IPCC) ([7]), the scientific evidence is unequivocal: emissions of greenhouse gases (GHG) from human activities are at the root of global warming observed since at least the 1950s. The scale of changes in the climate system is already unprecedented, but with every additional increase in warming, the risks for society and nature will increase and become more difficult to manage. The last eight years have been the warmest on record at global level and 2023 was the warmest year with several regions of the globe seeing record-

([5]) A safe operating space for societies is defined by planetary boundaries to man-made perturbation of nine critical Earth-system processes: climate change, ocean acidification, stratospheric ozone, global phosphorus and nitrogen cycles, atmospheric aerosol loading, freshwater use, land use change, biodiversity loss, and chemical pollution. Crossing such boundaries can lead to catastrophic impacts for societies. See Rockström J. et al., Planetary boundaries: Exploring the safe operating space for humanity. Ecol. Soc. 14, 32 (2009). http://www.ecologyandsociety.org/vol14/iss2/art32/

([6]) Richardson, Katherine, Will Steffen, Wolfgang Lucht, Jørgen Bendtsen, Sarah E. Cornell, Jonathan F. Donges, Markus Drüke et al. "Earth beyond six of nine planetary boundaries." Science Advances 9, no. 37 (2023): eadh2458.

([7]) IPCC, 2023: Sections. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 35-115, doi: 10.59327/IPCC/AR6-9789291691647 breaking temperatures ([8]). Globally, the year 2023 was 1.48°C warmer than the pre-industrial level[9]. According to the World Meteorological Organization ([10]), Europe is warming twice as fast as the global average, with annual average temperature reaching 2.3°C above pre-industrial (1850-1900) average in 2022, compared to the global average of 1.15°C.

With current NDCs and policies, the world is not on track to meet the Paris Agreement objectives of limiting the temperature increase to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels. Exceeding this threshold will result in additional adverse impacts, some of which will be irreversible, and further constrain our adaptation options. Accelerated action is essential to avoid the worst impacts of climate change and requires deep, rapid and sustained greenhouse gas emissions reductions in all sectors and regions, while stepping up adaptation efforts ([11]).

The experienced cost of climate change is continuously increasing, and with increasing global warming, the impacts are expected to become even more severe and widespread in the coming decades. Without urgent climate action globally, several parts of the climate system are increasingly likely to reach irreversible tipping points, with devastating consequences, leading to uncharted and high-risk conditions for human and natural systems. Heatwaves, floods, wildfires, and other climate-related factors are already adversely affecting human health and well-being. All countries and regions are concerned, but least developed regions and low-income population groups are particularly exposed and vulnerable to climate change.

It is estimated that global damages from climate change could reach 10-12% of GDP by the end of the century. However, such estimates are conservative, since they do not include the wider impacts on society and natural systems, notably in the most exposed countries and regions, with likely knock-on regional or global effects on geo-political stability and security. In addition, given the difficulty in doing so, most economic analyses do not represent the impacts of crossing climate tipping points, which are increasingly likely with every incremental increase in global warming, and which will significantly impact the global economy. Looking forwards, the cost of unmitigated climate change will greatly exceed the cost of reducing GHG emissions, both in magnitude and extent. A growing number of analyses and estimates point to the high costs already incurred now by our economies due to floods, droughts, heatwaves and other climate change related events. And this is without taking into account the human suffering caused by these events.

([8]) European State of the Climate 2022 | Copernicus
([9]) https://climate.copernicus.eu/global-climate-highlights-2023
([10]) World Meteorological Organization, 2023. State of the Climate in Europe. WMO-No. 1320.
([11]) IPCC. AR6 Synthesis Report: Climate Change 2023; AR6 Climate Change 2022: Impacts, Adaptation and Vulnerability; AR6 Climate Change 2022: Mitigation of Climate Change; AR6 Climate Change 2022: The Physical Science Basis.

1.3 International context

The urgent need for stronger action to tackle climate change comes at a time of multiple global crises. The COVID-19 pandemic severely hit the global economy, especially in 2020, and resulted in temporary GHG emissions reductions in the EU and across the globe. Global emissions rebounded in 2021-2022 and reached a new high in 2022[12]. Globally, the longer lasting impacts of the pandemic, including increases in extreme poverty, gender and social inequality, and impacts on health exacerbate vulnerability to climate change and lead to compound impacts. With the Fit-for-55 package, REPower EU, NextGenerationEU and the Multiannual Financial Framework for 2021-2027, the EU has developed a collective response to the economic crisis caused by the pandemic that allows it to continue to drive the twin green and digital transition.

The pandemic has also revealed global supply chain vulnerabilities. Increasing geo-economic and geopolitical tensions, together with Russia's illegal, unprovoked, and unjustified war of aggression against Ukraine, are further impacting global trade and investment flows, increasing the risk of trade restrictions and supply chain disruptions. These developments highlight the vulnerability that can result from dependencies in strategically important sectors, including access to critical raw materials, which are necessary for the twin transition ([13]). As other countries grasp the strategic importance of decarbonising their economies, there is intense competition for the materials, skills, technologies and investments needed to secure essential supply chains and for a share of the global market of the products and services of the future.

As a response, Europe is taking necessary steps towards open strategic autonomy to protect its strategic interests and collective security, and to strengthen the resilience of its supply chains to external shocks, including through stronger international cooperation with likeminded third countries and the proposed Net Zero Industry Act and European Critical Raw Materials Act. The EU is investing in European industrial capacity to manufacture net-zero technologies and in deploying these technologies to meet the EU's 2050 climate objective.

The high energy prices and geopolitical tensions following Russia's military aggression against Ukraine have exacerbated the need for the EU to ensure its energy security and robustness of its supply chains for raw materials and net-zero technologies. This has highlighted the economic and strategic vulnerabilities that come with dependence on fossil fuels, the main drivers of climate change. The energy crisis brought about by the war has made very clear the need to step up the transition to clean energy, energy

([12]) Total GHG emissions (without LULUCF) reached 53.8 GtCO2-eq in 2022. See JRC EDGAR database and report: GHG emissions of all world countries, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/953322, JRC134504.

([13]) 2023 Strategic Foresight Report: Sustainability and people's wellbeing at the heart of Europe's Open Strategic Autonomy.

efficiency and climate neutrality in the EU and globally ([14]) whilst avoiding the creation of new strategic dependencies.

The EU has intensified its Climate and Energy Diplomacy, guided by regular Council Conclusions from the EU Foreign Affairs and Environment ministers. The 2022 EU external energy engagement strategy as part of the REPowerEU Plan has been strengthened, outlining how the EU supports a global, clean, and just energy transition to ensure sustainable, secure and affordable energy. Meanwhile, however, in 2022 subsidies for fossil-fuel consumption reached a record $7 trillion globally (7.1% of world GDP) ([15]).

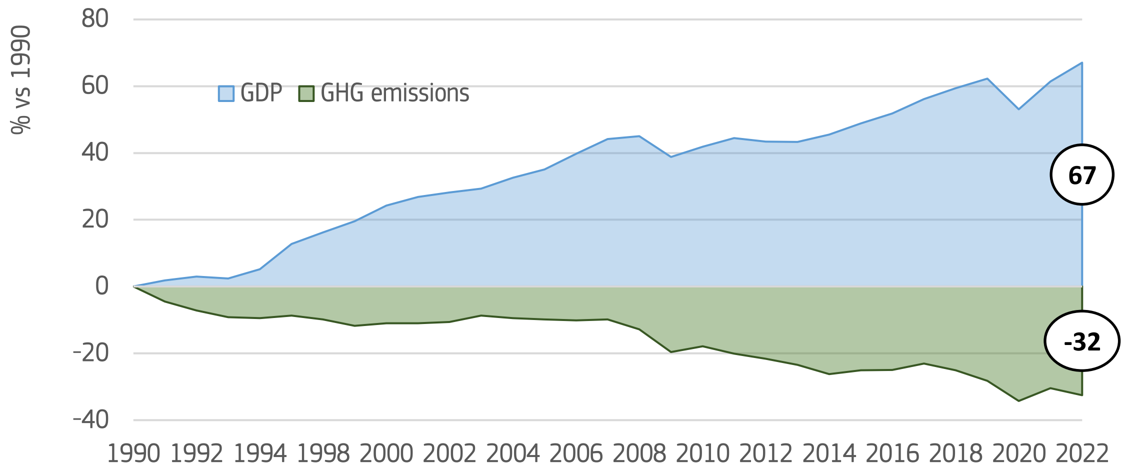
In December 2023 at COP28, the first Global Stocktake (GST) will assess ([16]) the progress towards the goals of the Paris Agreement.

1.4 Existing EU policy framework

1.4.1 Progress towards the 2030 climate target

Over the past decades, the EU has developed and regularly updated a comprehensive set of climate, energy, and other relevant enabling policies that have allowed a decoupling of economic activity from GHG emissions (Figure 1) and spurred the development of clean energy ([17]).

Figure 1: GHG emissions and GDP development in the EU since 1990



Source: GHG from EEA GHG data viewer (extracted 20/6/2023), GDP in real terms from AMECO and WB

([14]) State of the Energy Union 2022. Report from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions.
([15]) Black, Simon, Antung Liu, Ian Parry, and Nate Vernon (2023). "IMF Fossil Fuel Subsidies Data: 2023 Update." Working paper, IMF, Washington, DC.
([16]) [Placeholder for GST conclusions]
([17]) Annex 10 provides a summary of the evolution of GHG emissions under the different climate legislation instruments and of the energy system. A more detailed analysis can be found in the Climate Action Progress Report (GHG emissions) and in the State of the Energy Union Report (energy).

Provisional data ([18]) for 2022 show that total EU net GHG emissions decreased by around 3% compared to 2021, whilst EU GDP grew by 3.5%. 2022 emissions therefore continued their descending trend with reductions compared to 2019 of 5.6%. Emissions covered by the current ETS reduced by 0.2% compared to 2021 (and are 8% below the 2019 pre-COVID and pre-war level) while emissions under the ESR, decreased by 2.9%. Net removals from the Land Use, Land-use Change and Forestry (LULUCF) sector show a break In their recent declining trend, with an expected increase in carbon sinks of 6% compared to 2021.

Exceptional events over the last 3 to 4 years have made the assessment of GHG emission trends more complex and continue to have an impact on 2022 emissions. The COVID-19 lockdowns and restrictions led to an unprecedented but temporary drop in GHG emissions of 8% in 2020. In 2021, the economic recovery affected regions and sectors differently. Some sectors, such as the transport sector and travel-related emissions, recovered fully only in 2022. The energy crisis that started in 2021 continued in 2022, exacerbated by Russia's unprovoked and unjustified invasion of Ukraine, which drove energy prices to record highs, particularly gas prices.

Overall, the EU's domestic GHG net emissions are on a clear downward path, falling steadily over the last 5 years. The transformation of the energy sector has been the main driver of the decarbonisation of the EU economy over the last decades, through improvement of the energy intensity of the economic activity and decarbonisation of the energy mix ([19]).

Still, in view of meeting the 2030 climate target, the pace of emission reductions will need to pick up and almost triple the average annual reduction achieved over the last decade. Relative to past mitigation efforts, the most significant cuts in emissions are needed in buildings and transport, where the pace of decarbonisation has remained sluggish or even moving in the opposite direction. At the same time, action in the LULUCF sector is essential to enhance carbon removals. Although reaching the emissions cuts required from agriculture looks achievable when looking at the evolution over the past three decades, the lack of substantial progress in recent years is a concern, calling for a gear change. ([20])

The energy crisis highlighted how dependence on imported fossil fuels makes Europe vulnerable to geopolitical threats. The EU responded collectively and effectively to Russia's weaponisation of its energy supplies. A series of emergency legislative measures ensured that Europe avoided major energy supply disruptions and is now better prepared. However, deeper structural changes are needed to mitigate Europe's

([18]) The Governance Regulation ((EU) 2018/1999) requires Member States to report approximated GHG inventories annually by 31 July. Based on this reported data, the EEA compiles a Union approximated GHG inventory or, if a Member State has not communicated its approximated GHG emissions by that date, on the basis of EEA's own estimates. This provides an early estimate of GHG emissions ahead of the full GHG inventory.

([19]) Climate Action Progress Report 2023 accompanying SWD. Section 3.2

([20]) Climate Action Progress Report 2023 vulnerability. The EU needs to accelerate the energy transition to ensure affordable, reliable access to energy for households and businesses.

The "Fit for 55" package sets the EU on a path to reach its climate targets in a fair, cost-effective, and competitive way. Most of the key proposals in the package have been adopted by co-legislators and EU policies are now aligned with the updated 2030 target set in the European Climate Law. Implementing the new legislation under the Fit for 55 package will enable the EU and its Member States to reduce net GHG emissions by at least 55% compared to 1990 levels by 2030 ([21]).

1.4.2 The "Fit for 55" package and the European Green Deal

The European Climate Law enshrines the EU's commitment to become climate neutral by 2050 in law, providing a clear direction of travel for the transition. It expresses the EU's commitment to reduce net GHG emissions by at least 55% in 2030 relative to 1990, as the EU contribution to achieving the Paris Agreement goals. An essential part of the European Green Deal, the 'Fit for 55' legislative package provided the policy framework to meet the 2030 climate target, ensuring a just and socially fair transition, while strengthening innovation and preserving the competitiveness of EU industry ([22]).

The **Fit-for-55 package** includes the following adopted or agreed proposals: reform of the EU Emissions Trading System (ETS) and the Market Stability Reserve (MSR); a new, self-standing ETS for buildings, road transport and fuels for additional sectors (ETS2); revised Effort Sharing Regulation (ESR); the Carbon Border Adjustment Mechanism (CBAM); the Social Climate Fund (SCF); a revised Land Use, Land-Use Change and Forestry (LULUCF) Regulation; updated CO_2 emission standards for cars and vans; the Alternative Fuel Infrastructure Regulation (AFIR); FuelEU Maritime; ReFuelEU Aviation; the Energy Efficiency Directive (EED); Renewable Energy Directive (RED); the Regulation on methane emissions reduction in the energy sector; and the associated revision of the Regulation on Fluorinated Greenhouse Gases.

The Fit-for-55 and associated proposals that are still under negotiation with the co-legislators at the time of drafting this report are: the Energy Performance of Buildings Directive (EPBD); the Hydrogen and decarbonised gas market package; the proposal for a revised Energy Taxation Directive; and the revision of the Regulation on CO_2 emission standards for heavy-duty vehicles.

([21]) The legislation as adopted is estimated to result in a net domestic reduction of GHG emissions of 57% by 2030 compared to 1990. An overview of targets is presented in Chapter 1 of the staff working document – 'Technical information' accompanying the Climate Action Progress Report 2023.
([22]) This ambition has been mirrored by the EU's closest neighbours (Western Balkans, Moldova, Ukraine and Georgia) through the adoption of the 2030 climate targets, in line with the clean energy package, in the framework of the Energy Community Initiative.

REPowerEU plan, the EU's reply to the energy crisis derived from Russia's military aggression against Ukraine, stepped up EU's renewable energy and energy efficiency ambitions. Renewables and energy efficiency measures reduce both emissions and dependency on imported fuels: there is no contradiction between the Green Deal and REPowerEU. The forthcoming final updates of the National Energy and Climate Plans, to be submitted in June 2024, will also be a key instrument for Member States and the EU to achieve the 2030 climate target.

The EU enabling framework to support the transition to climate neutrality has been expanding. The EU Emissions Trading System (ETS) reduces emissions and generated more than EUR 150 billion in auction revenues ([23]), which Member States are to use to support climate action. At least 30% of the EU's multiannual financial framework' for 2021-2027 and of NextGenerationEU (potentially, over EUR 670 billion) are to be spent on climate related investments. Increasing provisions to address the needs of the most vulnerable include the Just Transition Fund for the most affected territories that must cease fossil-fuel related activities, transform and restructure carbon-intensive industries, and invest in future-proof jobs opportunities and training. The Social Climate Fund supports social cohesion and will mobilise EUR 86.7 billion from 2026 to 2032 using revenues from the ETS2, alongside the Modernisation Fund that supports clean energy investments in lower-income Member States and the Innovation Fund, one of the world's largest funds for the demonstration of innovative net-zero technologies, with revenues from the EU ETS.

The Green Deal Industrial Plan accelerates the transition to climate neutrality by reinforcing European industry's lead in the supply of clean technologies and products while ensuring global cooperation and making trade work for the green transition. It promotes a simpler and predictable framework for the skills and access to finance needed for the transition. This includes making best use of the Innovation Fund, simplified granting of State aid to accelerate the transition ([24]), the Net Zero Industry Act to strengthen and scale-up European manufacturing capacity for net-zero technologies and the Critical Raw Materials Act to ensure a secured and sustainable supply of raw materials important for the green and digital transition.

As a follow-up to the Farm to Fork Strategy and the Biodiversity Strategy for 2030, the EU has also made several proposals to enhance nature-based solutions that can mitigate climate change and enhance ecosystems' resilience to climate change. Relevant legislative and policy proposals include the Carbon Removal Certification Framework, the Nature Restoration Law, the Circular Economy Action Plan, the Framework for Sustainable Food Systems, and the Soil Monitoring Law.

([23]) Revenues from the ETS calculated in the period 2012-2022 and until 31 August 2023 (COM(2019) 557 final/2, COM(2020) 740 final, SWD(2021) 308 final, and EEX for most recent data).

([24]) There are possibilities for simplified granting of State aid under the Temporary Crisis and Transition Framework and the recently revised General Block Exemption Regulation. While State aid can help incentivise and accelerate the green transition by supporting relevant initiatives, it needs to comply with the applicable rules, which foresee among others, that it should be limited to the minimum amount necessary and that it should address situations where State intervention is needed, e.g. due to the presence of market failures.

This comprehensive framework should enable the EU to meet its commitments under the Paris Agreement. In doing so, it provides an important example to encourage other Parties to the United Nations Framework Convention on Climate Change (UNFCCC) to take more ambitious commitments and put in place the measures needed to implement these, driving the global transition to climate neutrality.

2 PROBLEM DEFINITION

The core problem this initiative aims to tackle is the absence of an EU-wide, economy-wide ambition level for 2040, in terms of net greenhouse gas emission reduction, as an interim target to climate neutrality in 2050.

An intermediate climate target for 2040 needs to be set to provide much needed predictability for Member States, stakeholders, investors, and EU decision makers for the decisions needed to achieve climate neutrality by 2050, including decisions taken in the coming years to meet the EU's 2030 target.

As set out in section 1.4 above, the EU needs to step up the existing pace of emissions reductions across all sectors to meet its 2030 target. The 'Fit-for-55" legislation' adopted in 2023 allows the EU to exceed the -55% reduction by 2030, when fully implemented, but requires a focus on implementation, including through the updated NECPs that Member States will submit to the Commission in June 2024.

Many decisions taken now by the EU, Member States and other actors have implications for EU greenhouse gas emissions that extend well beyond 2030.

This need for certainty is set out in the European Climate Law, which calls on the Commission to come forward with a proposal for a 2040 climate target within six months of the global stocktake. Implementation of the Climate Law requires an intermediate 2040 climate target to set the pace for EU-wide reductions of net GHG emissions over 2030-2050.

The 2040 climate target will provide essential information to allow the definition in the coming years of the future climate, energy, and wider enabling framework, to meet the 2040 target. The post-2030 policy framework will be designed during the next Commission mandate ([25]).

Finally, a 2040 target is needed that reflects the scale of the global challenge and that ensures that the EU continues to lead by example to push ambitious global action. Limiting global warming to the Paris Agreement temperature target of 1.5°C requires GHG emissions to be at net zero globally by the early 2050s ([26]). The remaining global

([25]) The approach of first agreeing the ambition level and then the policy framework to implement the target was also used in previous cycles to set the 2020 and 2030 climate and energy targets.
([26]) IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001

carbon budget compatible with this objective, estimated at 500 GtCO2 ([27]) from the start of 2020, is being depleted at a rate of above 40 GtCO2 per year ([28]). As global climate action is delayed and GHGs continue to accumulate in the atmosphere, climate change is accelerating and the risk of reaching irreversible tipping points in the climate system, with unknown and potentially catastrophic consequences for humans and ecosystems, is increasing.

The adoption of a 2040 climate target is needed for the definition of the new NDC that the EU will submit the UNFCCC by 2025 as required under the Paris Agreement. Its absence would compromise the EU’s contribution to the global climate agenda at a moment when new momentum for global climate action is urgently needed.

3 WHY SHOULD THE EU ACT?

3.1 Legal basis

According to Article 11 of the Treaty on the Functioning of the European Union (TFEU), environmental protection requirements must be integrated into the Unio'’s policies and activities, in particular with a view to promoting sustainable development. Articles 191 to 193 of TFEU further clarify that Union policy shall preserve, protect, and improve the quality of the environment; protect human health; and promote measures at the international level to deal with regional or worldwide environmental problems. Article 191 cites climate change as an example of this type of problem. This initiative responds to the legal requirement under the European Climate Law Article 4(3), which calls on the Commission to make a legislative proposal, as appropriate, for a Union-wide 2040 climate target within 6 months of the global stocktake referred to in Article 14 of the Paris Agreement ([29]).

3.2 Subsidiarity: Necessity of EU action

Climate change is a trans-boundary problem. For trans-boundary problems, individual action is unlikely to lead to optimal outcomes. Instead, coordinated EU action can effectively supplement and reinforce national and local action. Coordination at the European level enhances the effectiveness of climate action. EU action is justified on grounds of subsidiarity in line with Article 191 of the Treaty on the Functioning of the European Union.

3.3 Subsidiarity: Added value of EU action

A Union-wide climate target for 2040 will have implications across the entire EU economy. It is needed to guide a wide range of EU policies and will require EU level policy responses, beyond climate policy. The impacts on economic activity, employment,

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([27]) with 50% likelihood of limiting global warming to 1.5 degrees
([28]) Forster, P. M., et al. (2023). Indicators of Global Climate Change 2022: annual update of large-scale indicators of the state of the climate system and human influence, Earth Syst. Sci. Data, 15, 2295–2327, https://doi.org/10.5194/essd-15-2295-2023.
([29]) The first global stocktake taking place end of 2023.

cohesion, environment, energy, transport, food security, health, affordability, distributional effects, trade, and international relations are policy areas better considered at EU level.

Coordinated EU policies and support measures have a much bigger chance of leading to a true transformation via 2040 and towards EU climate neutrality by 2050. Through coordinated action it will be possible to take the different capabilities of Member States and regions to act into account and to use the power of the EU single market as a driver for cost-efficient change.

Coordinated climate action at EU level is also of importance for international climate action. Since 1992, the EU has worked to develop joint solutions and push for a global agreement to fight climate change. These efforts helped to reach the Paris Agreement in 2015. International climate policy and climate diplomacy are stronger due to climate policy coordination at EU level, even more crucial in a world in which the EU accounts for only around 7% of global GHG emissions ([30]). The assessment of pathways for setting a Union-wide climate target for 2040 will be a powerful example for the EU's closest neighbours and international community. It is also a necessary step for determining the EU's Nationally Determined Contribution under the Paris Agreement to be communicated in 2025. Without it, the EU and its Member States risk undermining their capacity to stimulate climate action at the global level.

4 OBJECTIVES: WHAT IS TO BE ACHIEVED?

4.1 General objective

The general objective of this initiative is to propose a Union-wide, economy-wide GHG target for 2040 that will put the EU on an effective, cost-efficient, and just trajectory towards climate neutrality by 2050, as called for under the European Climate Law.

What is not an objective of this initiative and Impact Assessment?

This initiative does not:

- Evaluate the suitability or coherence of the existing 2030 energy and climate policy framework (for an overview see Section 1.4) for the period 2031-2040;
- Develop a new post-2030 energy and climate policy framework to implement the 2040 GHG ambition level.

The objectives of this initiative are more like those of the 2013 Green paper for a 2030 framework for climate and energy policies or the EU's 2018 Long Term Strategy than like the 2030 Climate Target Plan of September 2020, as the latter already outlined possible updates of the then existing framework for 2030.

([30]) Data for year 2021, excluding international shipping and aviation. Source: EDGAR

4.2 Specific objectives

The adoption of a GHG target for 2040 aims at ensuring that the EU achieves its climate neutrality target in 2050 while respecting its other long-term priorities. The analysis in this impact assessment will evaluate the different target options according to their ability to deliver on the following seven specific objectives.

SO1: Ensure that climate neutrality is delivered
Reaching the emissions reduction target of 2030 will largely happen through fast emission reductions in sectors with low abatement costs, such as power generation.

Beyond this date, the contribution of hard-to-abate sectors (e.g., transport, some industrial processes) to the mitigation effort must significantly increase. Some sectors, such as agriculture and air travel, will not be able to cut their GHG emissions to zero in the coming decades, because they deliver goods and services that can only be partially substituted or there are inherent limits to the GHG mitigation options available to them. Science is clear that large amounts of compensating "negative" emissions ("carbon removals") will be needed in the EU and globally by the second half of the century ([31]) to meet the goals of the Paris Agreement, and, after 2050, the EU economy should generate net negative emissions ([32]).

This specific objective thus relates to the degree to which a given 2040 target level entails GHG abatement in the different sectors, including through the contribution of carbon removals, already in the first decade 2031-2040 to avoid delaying such actions to the last decade, which would jeopardize reaching the objective of climate neutrality by 2050.

SO2: Minimise the EU's GHG budget
According to IPCC AR6 report there is a near-linear relationship between cumulative anthropogenic CO2 emissions and the global warming they cause. The remaining global "carbon budget" (i.e., the cumulative CO2 emissions) corresponding to the Paris Agreement temperature goals is decreasing every year (see Annex 14).

The Climate Law refers to the "GHG budget" as the cumulative net GHG emissions over 2030-2050, which is used in this impact assessment to measure the climate performance of the different 2040 target options and the corresponding contribution of the EU to the global climate agenda.

SO3: Ensure that the transition is just
The transition towards climate neutrality will need to be socially just and fair in order to succeed.

The pace of action will have important implications for households, as consumers, investors, and workers. Economic and social inequalities mean that many households do not have the resources or incentives to make the necessary investments in low-carbon

([31]) IPCC (2018). Special Report on 1.5°C. Frequently Asked Questions Chapter 4 (FAQ 4.2).
([32]) European Climate Law, article 2

goods (e.g., electric vehicles, building renovations) that would allow them to reduce their energy costs and GHG emissions without measures to support action. Achieving climate neutrality will lead to the disappearance of jobs in fossil fuel extraction and GHG-intensive sectors, but also to the diversification of existing sectors and jobs and the emergence of new ones. The level of ambition for 2040 affects the investments that need to be made already before 2030, for example in manufacturing capacity of net-zero technologies, in building renovations, and in servicing of net zero equipment, which all require additional skilled workers.

Determining the ambition level for 2040 has implications for planning and funding of social, redistributive, education, training, and employment policies, and can serve as an opportunity to address social and employment inequalities.

SO 4: Ensure that the long-term competitiveness of the EU economy is maintained

The transition to climate neutrality will engender deep economic transformations that have important implications for the competitiveness of the EU economy. Some historical European industries, such as car manufacturing and energy intensive manufacturing, will have to invest in new low-carbon production processes and products. The transition will also lead to investment in innovations that drive productivity and competitiveness.

The EU's partners and other key players have understood the strategic importance of investing in the industries and technologies needed for the transition to climate neutrality ([33]). The global demand for materials, skilled people, technologies, and investments in clean industries will increase steadily as other major economies embark on the climate transition. There is strong competition to seize market shares and first-mover advantages ([34]) in the growing global market clean products and services. The post-2030 policy framework will need to build on the Green Deal Industrial Plan and the Net-Zero Industry Act.

SO 5: Provide predictability for the deployment of best-available, cost-effective, and scalable technologies

Climate neutrality by 2050 and negative net emissions after 2050 hinge on the very important deployment of several climate-neutral technologies that are not currently deployed at scale. The faster these become affordable for companies and households, the easier the path to climate neutrality. This requires removing barriers to innovation, deployment, and finance for key technologies and to develop new skills for new jobs. New supply chains are needed to ensure that affordable and effective clean solutions are available to all, including for sustainable lifestyle choices.

([33]) Annex 3 of the Staff Working Document on investment needs assessment and funding availabilities to strengthen EU's Net-Zero technology manufacturing capacity (SWD(2023) 68 final: the US Inflation Reduction Act of 2022provides major investments to reduce US GHG emissions (USD 370 billion estimated by Congress. In China, support to New Energy Vehicle manufacturers over the past decade (including consumer subsidies and rebates, exemption from sales tax, R&D and public procurement) is estimated at more than USD 100 million.

([34]) Strategic Perspectives (2023). Competing in the new zero-carbon industrial era. Assessing the performance of five major economies on key decarbonisation technologies.

SO 6: Ensure the security of supply of energy and resources

The COVID pandemic and Russia's military aggression against Ukraine demonstrated how supply chain disruptions and energy crises can negatively affect the EU economy. A sharp decrease in the EU's reliance on imported fossil fuels will be an important co-benefit of the transition towards climate neutrality. However, supply disruptions (e.g., of clean energy technologies, raw materials, water, or components) have the potential to slow the green transition and make it more expensive and the EU needs to avoid replacing one strategic dependence, for example on Russian fossil fuels, with another. The EU's reliance on imports of many critical raw materials and components necessary for the low-carbon transition can lead to vulnerabilities if supply is too concentrated.

SO 7: Ensure environmental effectiveness

The pathway to climate neutrality needs to be one that protects and enhances biodiversity, water resources, air quality, food security, and other essential natural services needed for our sustainable development. It should also reduce the risk of climate disasters and support adaptation to climate change to ensure an adequate response to the increasing impacts of climate change. Setting a 2040 target and pathway from 2030-2050, allows anticipation and exploitation of synergies between climate neutrality, biodiversity, and other environmental objectives.

Table 3 maps these seven specific objectives to Article 4(5) of the Climate Law. The consideration (h) "fairness and solidarity between and within Member States" will depend on the future framework.

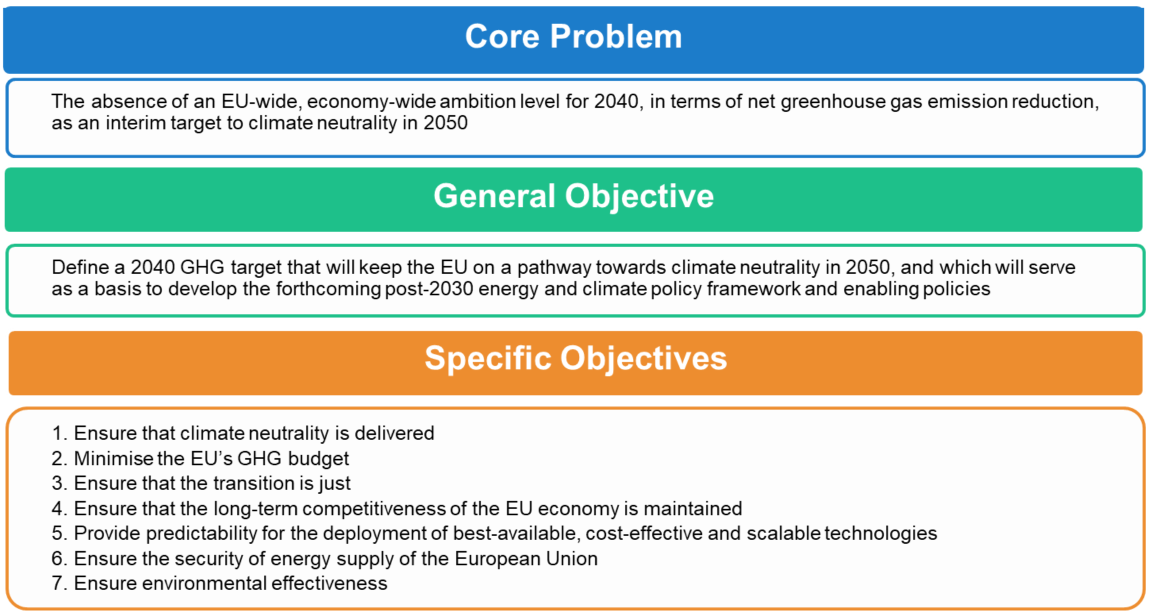
Table 1: Mapping of the Specific Objectives to Article 4(5) of the Climate Law

Specific Objectives	**Climate Law Article 4(5)** *"When proposing the Union 2040 climate target […], the Commission shall consider the following:"*
SO 1: Ensure that climate neutrality is delivered	(Climate Law article 2)
SO 2: Minimise the EU's GHG budget	(a) "the best available and most recent scientific evidence, including the latest reports of the IPCC and the Advisory Board" (b) "the [..] costs of inaction" (l) "international developments and efforts undertaken to achieve the long-term objectives of the Paris Agreement and the ultimate objective of the UNFCCC" (m) "existing information on the projected indicative Union greenhouse gas budget for the 2030-2050 period"
SO 3: Ensure that the transition is just	(b) "the social […] impacts" (c) "the need to ensure a just and socially fair transition for all" (g) "energy affordability"
SO 4: Ensure that the long-term competitiveness of the EU economy is maintained	(b) "the economic impacts, including the costs of inaction" (d) "cost-effectiveness and economic efficiency" (e) "competitiveness of the Union's economy, in particular small and medium-sized enterprises and sectors most exposed to carbon leakage"
SO 5: Provide predictability for the deployment of best-available, cost-effective and scalable technologies	(k) "investment needs and opportunities" (f) "best available cost-effective, safe and scalable technologies" (g) "energy efficiency and the 'energy efficiency first' principle, […] and security of supply"
SO 6: Ensure the security of energy supply of the European Union.	(g) "energy [..] security of supply"
SO 7: Ensure environmental effectiveness	(b) "the environmental impacts, including the costs of inaction" (i) "the need to ensure environmental effectiveness and progression over time" (j) "the need to maintain, manage and enhance natural sinks in the long term and protect and restore biodiversity"

4.3 Intervention logic

Figure 2 summarises the intervention logic, mapping the core problem to the general objective and the seven specific objectives.

Figure 2: Intervention logic



5 WHAT ARE THE AVAILABLE TARGET OPTIONS?

5.1 Current policy framework

5.1.1 The Climate Law and the Fit-for-55 package

This impact assessment aims to identify the most appropriate 2040 target level to bring the EU to climate neutrality by 2050. This 2040 target level is framed by the two existing climate targets, as defined in the European Climate Law: the 2030 climate target and the climate neutrality objective by 2050. The "Fit-for-55" package is the policy framework that implements the 2030 climate target.

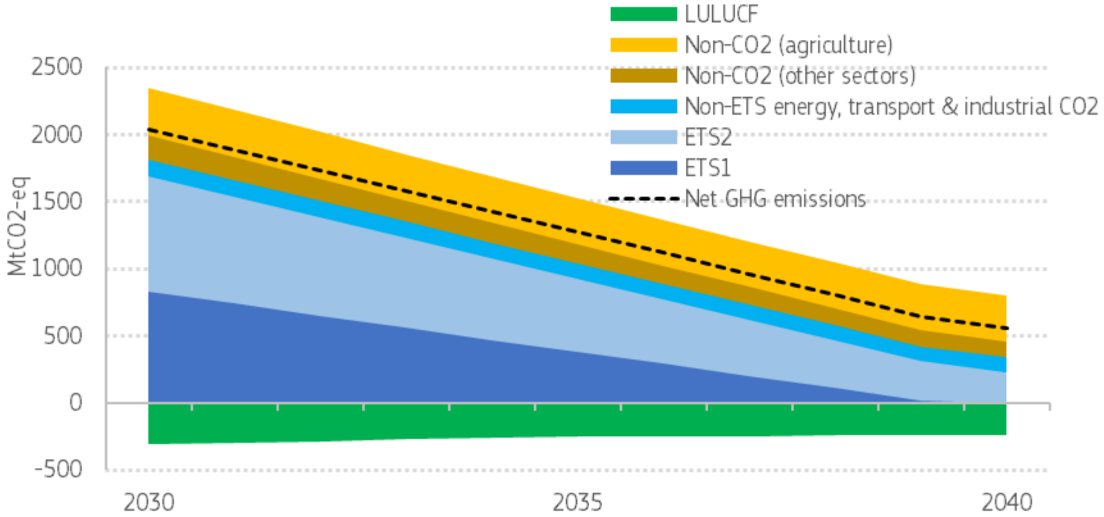
5.1.2 What would happen to the net GHGs emissions by 2040 with a continuation of the current policy framework?

With the "Fit-for-55" policy framework, the EU economy meets its 2030 climate target of a domestic reduction of net ([35]) GHG emissions of at least 55% compared to 1990 levels. While the "Fitfor-55" policy framework is designed for the period up to 2030, a limited part of the legislative package includes explicit, sectoral, post-2030 GHG emissions targets. In the absence of a review, the current design of the EU ETS Directive also applies beyond 2030.

This section looks at the net GHG emissions reductions that would theoretically be reached in 2040 with a continuation of this framework. Figure 3 ([36]) depicts the GHG trajectories for 3 main categories: (1) LULUCF net removals, (2) non-CO2 emissions, (3) CO_2 from energy, transport and industrial processes, a large part of which are covered by the ETS.

([35]) GHG emissions after deduction of carbon removals
([36]) A further description of the implied emission reductions under the prolongation of the current policy framework, including unchanged "linear reduction factors" in the ETS, can be found in Annex 6, section 4.

Figure 3: Theoretical 2030-2040 GHG emissions with the current policy framework



Note: ETS1 and ETS2 apply their respective linear reduction factor in 2030 onwards (corresponding to yearly reductions of about 90 MtCO2 in ETS1 and 63.2 MtCO2 in ETS2), "Rest energy, transport & industrial CO2" is derived from the EU Reference Scenario 2020 ([37]), non-CO2 is from GAINS model (assuming no specific mitigation), LULUCF is from GLOBIOM (assuming no mitigation post-2030).

(1) In the absence of a policy for LULUCF beyond 2030, modelling shows that (1) LULUCF net removals would be limited to -220/-230 MtCO2-eq.

(2) About half of current non-CO2 emissions ([38]) currently come from agricultural activities (e.g., enteric fermentation, use of fertilisers and manure management). Without any dedicated post-2030 GHG mitigation policy objective, the agricultural activities would still be significant emitters by 2050. Legislative initiatives such as the review of the fluorinated greenhouse gases Regulation, the Regulation of methane emissions reductions in the energy sector, the revision of the Industrial Emissions Directive, or the revision of the urban waste-water treatment Directive will reduce the "other" non-CO2 emissions by a third over 2030-2040. By 2040, total non-CO2 emissions with still be too large (around 460 MtCO2-eq, 10-15% lower than in 2030), notably in agriculture.

(3) A small part of *CO_2 emissions from energy, transport and industrial processes* are not under the ETS ([39]). The revised ETS will cover sectors which currently represent more than 90% of CO2 emissions from energy, transport, and industrial processes. In the absence of any new post-2030 legislation, the emissions outside the ETS would decrease only very little over time, reaching together around 100 $MtCO_2$ in 2040. The ETS sets an emissions cap reducing every year by a "Linear Reduction Factor" (LRF) both for "ETS1" (the existing ETS extended to cover also maritime shipping) and for "ETS2" (the new system covering buildings, road transport and the remaining energy-related CO_2

([37]) https://energy.ec.europa.eu/data-and-analysis/energy-modelling/eu-reference-scenario-2020_en

([38]) Excluding non-CO2 emissions from the LULUCF sector and the very small share of non-CO2 GHGs covered by the ETS that will follow the same pattern as discussed in the related paragraph.

([39]) Part of CO2 emissions from industrial processes, as well as CO2 emissions from fossil fuel combustion in the agriculture sector (2.6% of total 2021 CO2 emissions included in GHG inventories categories 1 and 2), inland waterways transport (0.6%) and rail transport (0.1%).

from industry). Without a change to the current LRFs after 2030, the cap under ETS1 reaches almost zero in 2040 ([40]), and the cap under ETS2 reaches zero in 2044.

In addition, *the transport-related emissions under the ETS* are also covered by specific instruments with explicitly defined post-2030 targets: CO2 standards for vehicles in road transport, limits on the GHG intensity on energy used in the maritime sector and shares of sustainable advanced fuels in aviation emissions.

The resulting theoretical net GHG emissions under an unchanged policy framework would amount to -88% in 2040 compared to 1990. This reduction level is therefore considered as the "baseline" climate target for 2040 to which other target levels are compared.

This "baseline" target level goes beyond the reductions of net GHGs corresponding to the "linear" trajectory linking the 2030 climate target and climate neutrality in 2050 referred to in the Climate Law (Article 8)([41]), which translates into a reduction of net GHG emissions compared to 1990 of 78% (77.5% if starting from 55% reduction in 2030 or 78.5% in 2040 considering the estimated EU-wide net domestic GHG emissions cut by 57% by 2030 compared to 1990 under the Fit-for-55 legislation as adopted ([42])).

5.1.3 Approach for the assessment of the 2040 climate target

The impact assessment is framed by the 2030 climate target and by the objective of climate neutrality by 2050. Up to 2030, the impact assessment reflects and fully implements the Fit-for-55 policy framework and associated targets.

Table 2 shows all explicitly defined and impact-assessed policies with concrete impacts on GHG emissions beyond 2030. These policies are included in all 2040 climate target options and accompanying analytical scenarios (see section 5.3), but these policies alone are neither sufficient to meet the 2040 target options considered nor climate neutrality by 2050.

([40]) While the cap in Article 9 of the EU ETS Directive (stationary and maritime) would reach close to zero already in 2039 and zero in 2040, the allowances issued due to Art 3c (aviation) of the Directive are above 0 until 2044 included, getting to zero from 2045.
([41]) The Climate Law Article 8(1) refers to an indicative linear trajectory which sets out the pathway for the reduction of net emissions at Union level on which the Commission shall base its assessments on Union progress and measures and national measures.
([42]) See the Climate Action Progress Report 2023.

Table 2: Pieces of legislation considered in the default post-2030 framework

GHG and sector	Legislation	Status at the time of the analysis
CO_2 emissions in transport	CO2 emission standards for cars and vans	Adopted
	CO2 emission standards for heavy-duty vehicles	Proposal
	TEN-T Regulation	Agreed
	Alternative Fuel Infrastructure Regulation	Adopted
	Intelligent Transport Systems Directive	Adopted
	Greening Freight Package	Proposal
	ReFuelEU Aviation	Adopted
	FuelEU Maritime	Adopted
CH_4 from the energy sector	Regulation on methane emissions reduction in the energy sector	Agreed
F gases	F-Gas Regulation	Proposal
Methane from waste	Landfill Directive	Not recently reviewed
	Waste Framework Directive	Not recently reviewed
	Urban Wastewater Treatment Directive	Proposal
Methane from agriculture	Industrial Emissions Directive	Proposal
GHG emissions from the energy sector	Energy Taxation Directive	Proposal

Note: "Adopted" means formally adopted by the European Parliament and European Council. "Agreed" means that a political agreement between the co-legislators has been reached. "Proposal" means proposed by the European Commission. "Not recently reviewed" means that this legislation is in force and has not been reviewed in recent years.

The rest of the post-2030 policy framework is still to be defined, or to be reviewed so that it can be aligned with achieving climate neutrality by 2050 and with the 2040 climate target once that target has been set. This applies to the ETS Directive, which already foresees a review ([43]) in view of being compliant with the 2040 climate target. As a result, this assessment of the 2040 target does not assume a prolongation of unrevised ETS provisions after 2030 within the default post-2030 policy framework.

The impact assessment uses economic modelling to analyse the evolution of sectoral emissions and the contribution of technologies that are necessary to meet different 2040 target levels and climate neutrality by 2050.

5.2 Target options

This impact assessment aims to identify the most appropriate 2040 target level to bring the EU to climate neutrality by 2050 and to contribute to international action to fight climate change. The different target options considered in this impact assessment are therefore focused on different levels of net GHG emissions reduction in 2040 compared to 1990.

([43]) Including the EU ETS Directive, which foresees a review in 2026, including in view of being in line with the Union's 2040 climate target (Article 30(3) of Directive 2003/87/EC).

5.2.1 *Discarded target levels*

The assessment discards target levels below 75%. A target lower than 75% has the lowest support in the Public Consultation, from citizens, civil society organisations, businesses, and academic institutions alike, with less than 10% of support across all replies. A target lower than 75% is below the linear trajectory and would imply a complete break in the trend of GHG emission reductions compared to 2021-2030 and even a slowdown compared to the average 2011-2030 (see Table 3). It would also mean that steeper emissions reductions would be needed between 2041–2050, with a substantial risk, due to postponing more of the decarbonisation effort to the last decade, that the EU does not reach its legal objective of net climate neutrality by 2050. This option has the highest corresponding GHG budget (at least 23 GtCO2-eq), so the lowest climate performance, and is thus not consistent with the EU commitments to global climate action.

The assessment also discards target levels above 95%. In its analysis for the recommendation on the 2040 target, the ESABCC concludes that all scenarios with 2040 emissions reductions above 95% exceed one or more of the environmental risk levels or limits used to rule out pathways not considered feasible, based on levels of carbon capture deployment, carbon removals from the land sink or bioenergy use. No other recently published scientific publication on a 2040 climate target for the EU to get to climate neutrality by 2050 has analysed or projects reductions of above 95% by 2040 (see Annex 13).

5.2.2 *Considered target levels*

The assessment therefore focuses on target levels between 75% and 95%. It looks at three climate target levels articulated around (i) the linear trajectory between 2030 and 2050 and (ii) the 85-95% range for an EU 2040 climate target compatible with the 1.5°C long-term temperature goal that is analysed in the scientific literature, including the ESABCC (see Annex 13).

- <u>Target Option 1: a net GHG reduction target in 2040 of up to 80%</u>

This target option is compatible with a linear trajectory of net GHG emissions between the existing 2030 climate target and the 2050 climate neutrality objective referred to in the Climate Law (Article 8), which would lead to a reduction level of 78% (see section 5.1.2). This option is significantly lower than the “baseline” target level of 88% (see section 5.1.2).

Among the three options assessed, this option gets the largest share of responses to the public consultation from businesses (nearly 30%) and public authorities (37%), but the lowest share among research organisations (15%), individuals (11%) and civil society organisations (8%).

In view of the comparison with the other target options, target option 1 is analysed through scenario S1 described in Section 5.3 and Table 4 and further described in Annex 6.

- Target Option 2: a net GHG reduction target in 2040 of at least 85% and up to 90%

This target option is compatible with the level of net GHG reductions that would be reached in the case of a prolongation of the current policy framework (-88%).

It matches the lower half of the 85-95% range provided by recent scientific literature on 1.5°C-compatible trajectories to bring the EU to climate neutrality by 2050, including the lower end of the range *analysed* by the ESABCC considering the challenges of short-term technological scale-up by 2030 (88-92%). It remains lower than the range *recommended* by the ESABCC (90-95%).

This option gets a large share of responses to the public consultation by research organisation (35%), and some support by businesses (22% for SMEs and 24% for large businesses) and individuals (24%).

In view of the comparison with the other target options, target option 2 is analysed through scenario S2 described in Section 5.3 and Table 4 and further described in Annex 6.

- Target Option 3: a net GHG reduction target in 2040 of at least 90% and up to 95%

This option corresponds to the range *recommended* by the ESABCC. It also matches the higher half of the 85-95% range analysed by recent scientific literature on 1.5°C-compatible trajectories to bring the EU to climate neutrality by 2050.

A target above 90% is the clear preferred option for individuals (46%) and aggregated across all organisations (30%). It is, in particular, favoured by civil society organisations (63%) and is supported by research institutions (35%) as much as option 2. SMEs support this option (21%) as much as the target option 2. It gets 19% of support from public authorities and 13% from large businesses that participated to the public consultation.

In view of the comparison with the other target options, target option 3 is analysed through scenario S3 described in Section 5.3 and Table 4 and further described in Annex 6.

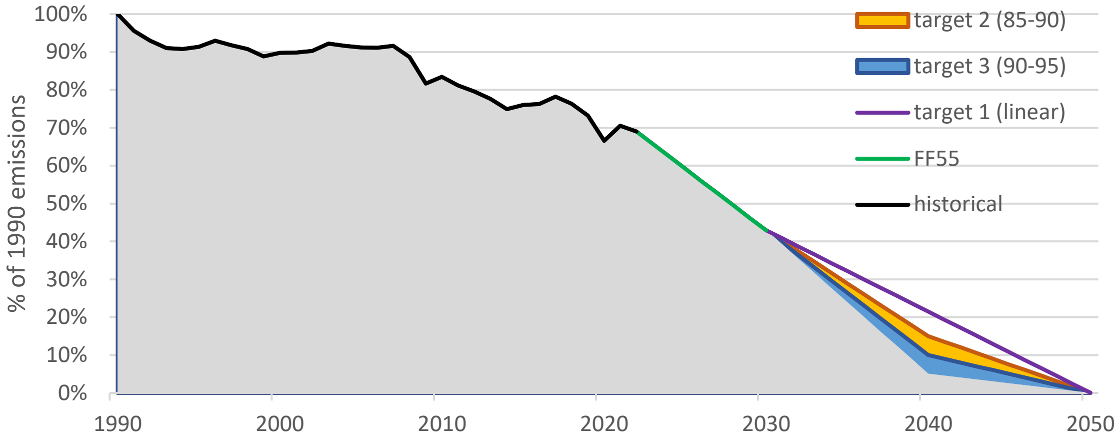
5.2.3 Emission profiles and cumulative GHG emissions under the different target options

Table 3 and Figure 4 allow to compare the different target options in terms of their net GHG reduction profiles and their associated cumulative net GHG emissions of 2030-2050 (the “GHG budget”). Each target option corresponds to a level of net GHG reductions in 2040. For each target option, **the “GHG budget” is calculated assuming net GHG emissions reaching zero in 2050 and linear trajectories of net GHGs between 2030 and 2040 and between 2040 and 2050**.

Table 3: GHG budget and annual reduction of GHG emissions of each target option

	GHG budget 2030-2050 (GtCO2-eq)	Yearly reductions (% 1990 levels)				
		1991-2010	2011-2030	2021-2030	2031-2040	2041-2050
Target level below 75%	More than 23				-1.8%	-2.5%
1 (linear, 78%)	21	-0.9%	-2.0%	-2.8%	-2.2%	-2.2%
2 (at least 85%)	Up to 18				-2.8%	-1.5%
3 (at least 90%)	Up to 16				-3.3%	-1.0%

Figure 4. Profile of the net GHG emissions over 1990-2050



Note: The net GHG emissions reflect the scope of the European Climate Law, i.e., all domestic net emissions (as under the UNFCCC inventories), international intra-EU aviation, international intra-EU maritime, and 50% of international extra-EU maritime from the MRV scope. 2022 values are based on EEA proxies. The intra-EU / extra-EU international aviation split is estimated based on air transport activity data (passenger-kilometres). The intra-EU / extra-EU international maritime split is based on MRV information for recent years and applied backwards to 1990.

Source: EEA, Eurostat.

5.3 The policy scenarios behind the target options ([44])

The quantitative assessment of the target options is done through analysis based on economic modelling, building on three "representative" scenarios (S1, S2, S3), which all reach climate neutrality in 2050 but through different net GHG levels in 2040. These scenarios allow to assess the reduction of GHG across sectors and the contribution of different technologies, like carbon capture, to the different 2040 target levels. Each of these scenarios directly correspond to the three target options assessed, i.e. target option 1, 2, and 3, respectively. They are used to carry out the comparison of the impacts of the

([44]) The model-based analysis is a technical exercise based on a number of assumptions that are shared across scenarios. Its results do not prejudge the future design of the post-2030 policy framework three target options assessed (section 7) and the choice of the preferred target option (section 8).

Another variant (LIFE) allows an assessment of the sensitivity of the analysis to assumed societal trends that can change the future evolution of GHG emissions. This variant serves to open the debate on the role of such trends in the context of meeting climate neutrality by 2050. In practice for the analysis, the LIFE scenario is set to be compatible with target option 3. However, the associated conclusions are relevant for and can be applied to all the target options.

5.3.1 Scenarios S1, S2 and S3

To ensure comparability across target options, the three scenarios (S1, S2, S3) share the same key assumptions on: 1/ socio-economic assumptions (in terms of population, economic activity, industrial production, and food production), 2/ technology costs (described in Annex 6, section 2.4), and 3/ common "default" policy elements applying post-2030 (described in Annex 6, section 3).

All three scenarios build on the continuation and upscaling of the current trends driving decarbonisation towards 2030, notably electrification of energy demand, deployment of renewables, and improvements in energy efficiency. Specific assumptions on more sustainable lifestyle (see 5.3.2) are not implemented.

The scenarios mainly differ with respect to the uptake over 2030-2040 of novel technologies to meet different levels of net GHG emissions in 2040. These technologies include, among others, advanced biofuels and the development of lignocellulosic bioenergy crops, precision agriculture, e-fuels, or the development of a carbon management industry.

- S1: up to 2040, this scenario relies essentially on the Fit-for-55 **energy trends,** which allow it to deliver a target in 2040 that is the "linear" reduction path of net GHGs between 2030 and 2050. It does not assume specific mitigation of non-CO2 emissions beyond their default evolution within the current framework, for instance in agriculture, or in the LULUCF sector.
  Beyond 2040 though, all sectors need to drastically reduce GHG emissions in view of meeting the climate neutrality objective by 2050 and all technologies need to be deployed.
- S2: to reach a reduction of at least 85% by 2040, this scenario **combines** the energy trends reflected in S1 with a further deployment of carbon capture and e-fuels as well as substantial reductions of GHG emissions in the land sector, including non-CO2 emissions in the agriculture sector and carbon removals in the LULUCF-sector.
- S3: to reach a reduction of at least 90% by 2040, this scenario builds on S2 and relies on a **fully developed carbon management industry** by 2040, with carbon capture covering all industrial process emissions and delivering sizable carbon removals, as well as higher production and consumption of e-fuels than in S2 to further decarbonise the energy mix.

Table 4 provides a detailed overview of the building blocks of the scenarios S1, S2 and S3. The analysis is based on the 2019 NECPs, and specific national policies until March 2023 are included. More elements can also be found in Annex 6 (section 3).

5.3.2 LIFE – more sustainable lifestyles

In addition to the three core scenarios that are used to compare the 2040 target options, a complementary variant (LIFE) looks at the sensitivity of the analysis to key societal trends related to more sustainable lifestyles, resulting from changes in the consumer preferences, from circular economy measures related to the use of energy and materials, as well as from changes in mobility and the food system ([45]). **"LIFE" is not attached to a specific target option and is not used to compare the different target options. It serves to illustrate how these demand-side driven actions can complement the supply-side technology deployment analysed in the core scenarios.**

LIFE assesses the impact of a shift in consumption patterns to more sustainable alternatives leading to a more efficient use of natural resources. For example, consumers use products longer, repair more goods, shift to a "sharing economy" and products as a service, reduce energy consumption by controlling heating and cooling temperature settings, and adopt more sustainable mobility patterns led by shared mobility and active transport modes such as increased bike use. For the food system, LIFE assumes that consumers gradually shift to healthier and more sustainable diets ([46]), while production follows the Farm to Fork Strategy and Biodiversity Strategy objectives, in particular reducing nutrient surplus and fertilisers needed to bring nature and biodiversity back to a healthy state and reducing food waste ([47]). The analysis does not make assumptions on the drivers for these shifts in consumption patterns, which can be the result of societal trends, changing social norms and preferences, voluntary actions, or incentivising policies.

Table 4 describes the main building blocks of LIFE; detailed assumptions are described in section 3 of Annex 6. In practice in this analysis, the LIFE variant is set so that it aims at reaching net GHG reductions of at least 90% compatible with target option 3, in other words providing a different GHG mitigation picture that allows a direct comparison with the overall level of reductions in the core scenario S3. The results provide an indication of the order of magnitude of the reduction in the costs and technological investment needed to reach the 2040 GHG ambition level in the default common set of assumptions used in the three core scenarios, and that can instead be achieved through these demand-

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([45]) The food system means the actors and activities involved from the production to the consumption of food products from agriculture and forestry, fisheries, and aquaculture, including food governance actors and institutions and the interactions with neighbouring systems (economic, ecological, social, etc.).
([46]) The right food environment can create and accelerate the shift towards healthier, less resource intensive and more plant-based diets. See for instance: European Commission Group of Chief Scientific Advisors, Scientific Advice Mechanism (SAM), 'Towards Sustainable Food Consumption – Promoting healthy, affordable, and sustainable food consumption choices', Scientific Opinion No.14, 2023
([47]) The food waste proposal (COM (2023) 420 final) was not adopted in time to be factored in the core scenarios and is therefore only reflected in "LIFE".

side changes. The conclusions from the analysis of the LIFE variant are relevant for and can be applied to all the target options.

Table 4: Overview of the scenario building blocks by 2040

<table>
<tr><th></th><th>S1</th><th>S2</th><th>S3</th><th>LIFE</th></tr>
<tr><td>Rationale</td><td>Continuity of existing decarbonisation trends up to 2040: improvement of energy efficiency, electrification of energy demand, deployment of renewables in the power system</td><td>Similar as S1, but S2 also includes a wider diffusion of novel technologies by 2040 (carbon capture, e-fuels)</td><td>Similar as S2, but S3 assumes a faster and wider uptake of novel technologies over 2031-2040 (carbon capture, e-fuels)</td><td>Assumes more sustainable lifestyles and a move towards a more circular and shared economy. It translates into a different evolution of demand patterns for energy use in buildings, transport, in relation with materials management towards or in the food system</td></tr>
<tr><td rowspan="2">Industry</td><td colspan="2">Electrification of energy consumption, some development of e-fuels by 2040</td><td>More e-fuels by 2040 than in S2</td><td rowspan="2">Enhanced circularity entails comparatively lower needs for primary production of materials, and so lower needs for carbon capture</td></tr>
<tr><td>Very limited carbon capture in industrial processes</td><td>Deployment of carbon capture</td><td>Further deployment of carbon capture</td></tr>
<tr><td rowspan="2">Buildings</td><td colspan="3">Further electrification through sustained deployment of heat pumps</td><td rowspan="2">Lower thermostat settings for heating and cooling temperature deliver additional energy savings</td></tr>
<tr><td>Low average annual renovation rate in 2031-2040 and high in 2041-2050</td><td>Similar average renovation rate in 2031-2040 and 2041-2050</td><td>High average annual renovation rate in 2031-2040 and low in 2041-2050</td></tr>
<tr><td>Transport</td><td colspan="4">EU Sustainable & Smart Mobility Strategy and Action Plan: milestones achieved (particularly with regard to rail, inland waterways and short-sea shipping)</td></tr>
<tr><td rowspan="2">Road transport</td><td>CO2 standards for cars and vans: -100% vs 2021 from 2035 onwards</td><td colspan="2">CO2 standards for cars and vans as in S1 + Higher car occupancy & some shift from car to active modes (walking, cycling) and public transport, driven by a shift towards shared and collaborative mobility services and multimodal travel</td><td>As in S3 plus stronger shift towards shared and collaborative mobility services and multimodal travel, including sustainable urban transport; ‘smart’ charging</td></tr>
<tr><td colspan="2">CO2 standards for HDVs: -90% vs 2019 from 2040 (-100% for buses), more efficient operation of freight vehicles and delivery of goods by optimising multi-modal delivery solutions, higher use of intermodal freight transport</td><td>CO2 standards for HDVs: -100% vs 2019 from 2040, more efficient operation of freight vehicles and delivery of goods by optimising multi-modal delivery solutions, higher use of intermodal freight transport</td><td></td></tr>
<tr><td rowspan="2">Maritime transport</td><td colspan="4">FuelEU Maritime GHG intensity targets: -31% in 2040 and -80% in 2050 (vs 2020)</td></tr>
<tr><td>Lower end of the IMO GHG reduction target range (-70% in 2040 vs 2008)</td><td>Mid-point of the IMO target range (-75% in 2040 vs 2008)</td><td colspan="2">Higher end of the IMO target range (-80% in 2040 vs 2008)</td></tr>
<tr><td>Aviation</td><td>ReFuelEU Aviation SAF mandates (34% in 2040 and 70% in 2050; including a sub-mandate for synthetic aviation fuels and H2: 10% in 2040 and 35% in 2050)</td><td>Slightly more ambitious fuel mandates than in S1 (SAF: 36% in 2040 and 72.5% in 2050; synthetic aviation fuels and H2: 12% in 2040 and 37.5% in 2050), incentives for the deployment of zero-emissions aircraft</td><td>Slightly more ambitious fuel mandates than in S2 (SAF: 38% in 2040 and 75% in 2050; synthetic aviation fuels: 14% in 2040 and 40% in 2050), incentives for the deployment of zero-emissions aircraft</td><td>As in S3 plus fewer business trips and long trips compared to scenarios, modal shift to rail (particularly for short trips)</td></tr>
</table>

	S1	S2	S3	LIFE
Power system	Limited remaining CO2 emissions in 2040, share of renewables in total electricity production increases compared to 2030	Close to decarbonised in 2040, larger deployment of renewables	Fully decarbonised in 2040, the system operates mostly with renewables	
	The deployment of renewables is facilitated by system optimisation (interconnections, storage and demand-side response). Nuclear according to MS policies until March 2023; plays a comparable role in all scenarios.			
Bioenergy	Moderate increase by 2040 compared to current, stabilises over 2041-2050	Larger increase by 2040 compared to current, and slightly declines after 2040		
H2 & e-fuels	Some increase in 2040 above 2030 levels	Stronger increase than in S1, notably in the transport sector	Stronger increase than in S2 in all sectors	
Carbon capture	Limited uptake in 2031-2040 and large deployment in 2041-2050	Deployment in 2031-2040, in particular in industrial processes, maintained in 2041-2050	Further deployment in 2031-2040 to cover remaining energy and industrial process emissions	
Carbon removals	Very limited uptake of BECCS by 2040	Some deployment of BECCS and DACCS by 2040	Higher deployment by 2040 of both BECCS and DACCS	
Circularity				Circular economy trends limiting raw materials needs
Food system	Continuation of current trends based on the Agricultural Outlook 2022			Change towards more sustainable food diets, reduction of food waste objectives leading to additional reduction of agriculture GHG
	Very limited GHG reductions in agriculture	GHG in agriculture decrease further thanks to larger deployment of technological options	GHG in agriculture decrease further thanks to full deployment of technological options	
LULUCF	Small increase of forest land and decrease in grassland	Policy intensity to cover mitigation costs equivalent to meeting the 2030 target		
		Higher land-use change with bigger increase of forest land, additional wetland and cropland while stronger decrease of grassland		More available land for carbon farming and high-diversity elements such as set aside and fallow land with natural vegetation through land-use change in grassland and cropland
Non-land-related non-CO2 GHG emissions	Non-land-related non-CO2 emissions slowly decline, combining current policy framework and transformation of the energy system	Non-land-related non-CO2 emissions decline further thanks to additional mitigation		

6 WHAT ARE THE IMPACTS OF THE TARGET OPTIONS?

The impacts of the different 2040 target options are illustrated by the three scenarios S1, S2 and S3 ([48]) presented in the previous section. Section 6 shows the impact of these scenarios and complements the analysis by quantifying the impact of changing lifestyles as shown by the LIFE sensitivity analysis.

A more detailed analysis on the sectoral GHG evolution and associated technological deployment attached to each scenario can be found in Annex 8.

6.1 GHG emissions

6.1.1 Net GHG emissions

The net GHG emissions analysed in this impact assessment correspond to the Union-wide GHG emissions and removals regulated in Union law ([49]).

Table 5 shows the sectoral net GHG emissions in the different scenarios serving to analyse the 2040 target options. All scenarios achieve climate neutrality in 2050.

([48]) The model-based analysis is a technical exercise based on a number of assumptions that are shared across scenarios. Its results do not prejudge the future design of the post-2030 policy framework.
([49]) European Climate Law, Article 2. They cover all domestic emissions, LULUCF, international intra-EU aviation, international intra-EU maritime, and 50% of international extra-EU maritime from the MRV scope.

Table 5: Sectoral net GHG emissions

	2015	2040			2050
		S1	S2	S3	S3**
Reduction vs 1990 – %	**-24%**	**-78%**	**-88%**	**-92%**	**-101%**
Net GHG Emissions (target scope)*	**3592**	**1051**	**578**	**356**	**-38**
Power and district heating[A]	1031	120	8	-10	-39
Other energy sectors[B]	237	71	45	11	-19
Industry[C]	605	267	181	89	16
Residential & services[D]	519	119	92	75	19
Other non-energy sectors[E]	130	33	26	25	22
Domestic transport	780	190	143	120	7
Agriculture[F]	385	351	302	271	249
Waste management	120	65	52	52	28
LULUCF net removals	-322	-218	-316	-317	-333
International transport (target scope[G])	107	52	46	41	11
International Transport (memo items)					
	233	124	113	106	27

*Note: *Calibration residuals to GHG inventory 2023 are allocated to relevant sectors. A: Includes removals from BECCS. B: Includes removals from DACCS. C: includes CO2 from fossil fuel combustion in industry and CO2 from industrial processes. D: Includes fossil fuel combustion CO2 emissions in agriculture. E: CO2 fugitive emissions and non-CO2 emissions from direct use or specific products. F: GHG inventory "category 3". G: international intra-EU aviation, international intra-EU maritime (MRV) and 50% of international extra-EU maritime (MRV).*
***S1 and S2 values for 2050 are similar to S3 and represented in more details in Annex 8.*

Source: PRIMES, GAINS, GLOBIOM.

Scenario S1 projects emissions following a linear trajectory between 2030 and climate neutrality 2050, reaching around 1050 MtCO2-eq in 2040. This requires limited development by 2040 of advanced mitigation options like carbon capture or e-fuels. A higher uptake under S2 of e-fuels, carbon capture, further abatement in agriculture and dedicated mitigation actions in the LULUCF sector lead to stronger emission reductions of 88%, with net GHG emissions reaching around 580 MtCO2-eq. S3 achieves a steeper reduction of around 92% (around 350 MtCO2-eq), compared to S2, based on rapid deployment and scale up of novel technologies by 2040.

LULUCF net removals have experienced rapid changes of the past years, and the future evolution of this sector is uncertain. The level can vary depending on the effect of policies or climate change impacts (see section 1.8 in Annex 8). When this uncertainty is included in the calculation of the net GHG emission reduction in 2040, each scenario still remains within the range of their respective target option, namely S1 corresponding to target option 1 (up to 80%), S2 corresponding to target option 2 (85-90%) and S3 corresponding to target option 3 (90-95%).

The importance of net removals from LULUCF was confirmed in the public consultation, where nearly 50% of citizens asked for a stronger reliance on the LULUCF sink given uncertainty about the deployment of industrial removals. Among organisations, views were more divided between civil society organisations demanding a stronger reliance on the LULUCF sink, research institutions and public authorities favouring a balanced approach, and business associations and companies favouring either a balanced approach or a stronger reliance on industrial removals. However, when asked about the most relevant solutions for fighting climate change, citizens and all stakeholder groups uniformly indicated nature-based solutions for the LULUCF sector (afforestation, reforestation, and forest restoration, as well as peatland restoration) as being the most important solutions.

Energy supply emissions ("power and district heating", as well as "other energy sectors") remain positive (180 MtCO2-eq) in the case of S1 but get close to zero in S2 (about 50 MtCO2-eq) and reach zero in S3 in 2040. The decarbonisation of the energy sector is possible thanks to the availability of a broad set of technologies to generate carbon-free electricity (notably renewables) and to the development of carbon capture and carbon removals in S2 and S3 (see 6.1.2), as well as to the reduction of methane emissions from the decreased use of fossil fuels. Emissions in industry are cut by 56-84% compared to 2015, due to electrification, implementation of new manufacturing technologies, innovation in processes, use of alternative materials or sources such as RFNBOs and cleaner supply chains. Contribution of the gradual uptake of hydrogen and development of carbon capture to industrial emission reduction is seen in S2 and goes further in S3, where solid fossil fuels virtually disappear, and all process CO2 emissions are captured. Residential and service emissions decrease by 77-85% compared to 2015, depending on the scenario, driven by a sustained deployment of heat pumps and renovation of building envelopes.

Transport emissions drop by 69-78% compared to 2015, primarily due to large-scale deployment of electric vehicles in road transport in all scenarios, along with a further switch from fossil fuels to e-fuels and advanced biofuels in maritime, aviation and road transport in S2 and S3.

In the agricultural sector, where GHG emissions remained relatively stable over the last 10 years, GHG emissions decrease by around 10% compared to 2015 in S1 and by between 22% and 30% with more ambitious reductions in S2 and S3, driven by technological improvements in breeding, mitigation of enteric emissions, manure management and fertiliser application. The waste management sector reduces CH_4 emissions in all scenarios by more than half compared to 2015. These results are broadly in line with the public consultation results, which show that energy supply, agriculture and transport are expected to be the sectors most affected by the green transition after 2030 ([50]).

[50] In the energy supply sector, the public consultation respondents expect a strong decrease in fossil fuel consumption coupled with a transition to renewable energy sources. In the agriculture sector, respondents expect significant changes in production methods, land management practices and consumer behaviour. Finally, in the transport sector, they expect a transition to electric vehicles and alternative fuels, along with a modal shift to the lowest carbon-intensive modes.

6.1.2 Carbon capture and carbon removals

The role of **carbon capture** and **carbon removals** is an important differentiating factor for the 2040 climate ambition, which is in general also acknowledged by stakeholders in the public consultation. While civil society organisations, research institutions and citizens largely agree on the need for separate targets for GHG emissions, nature-based removals and industrial removals, businesses and public authorities' views are more evenly divided between three separate targets and one single target. The nature of this divergence lies in different opinions on the potential and challenges to scale up industrial removals and to which extent removals should be used to compensate for residual GHG emission reduction.

The modelling results in Table 6 show that while annual capture remains lower than 100 MtCO2 in S1, it reaches around 220 MtCO2/year in S2, and around 350 MtCO2/year in S3, where most emissions from the power system and industrial processes are captured and industrial carbon removals technologies are well deployed. The crucial role of carbon capture to reach high levels of decarbonisation of the industrial system by 2040 is a common finding across the various models used for the detailed analysis (see Annex 8) and in line with the public consultation, where all stakeholder groups would prioritise capturing CO2 from non-energy industrial processes over other applications. The captured carbon is used to produce e-fuels (the consumption of which varies across scenarios – see section 6.1.3) or stored, with injection rates for storage in 2040 close to 150 MtCO2/year in S2 and 240 MtCO2/year in S3. CO2 implemented in materials is projected to develop mostly in the 2041-2050 decade.

Table 6: Industrial carbon capture and use

	2040			2050
Carbon Captured – MtCO2/year	**S1**	**S2**	**S3**	**S3***
By Source	**86**	**222**	**344**	**452**
Industrial Processes	37	123	137	136
Power (fossil fuels)	26	41	32	55
Power (biomass) and DACC**	16	54	153	232
Biogenic (upgrade of biogas into biomethane)	7	4	22	30
By Application (use and storage)	**86**	**222**	**344**	**452**
E-fuels	43	75	101	147
Synthetic materials	0	0	0	59
Underground storage	42	147	243	247

Note: *S1 and S2 values for 2050 are similar to S3 and represented in more details in Annex 8. **Includes carbon for storage (DACCS) and use.

Source: PRIMES.

As described in the results of the public consultation ([51]), alongside deep reductions of **gross GHG emissions**, **carbon removals** are expected to play an important role in the coming decades to get to climate neutrality by 2050 and negative emissions thereafter (Table 7).

Table 7: Industrial removals and net LULUCF removals

	2040			2050
	S1	**S2**	**S3**	**S3****
Gross GHG emissions (MtCO2-eq)	**1273**	**943**	**748**	**411**
Total Removals (MtCO2-eq)	**-222**	**-365**	**-391**	**-447**
Industrial Removals (MtCO2)	-4	-49	-75	-114
LULUCF net removals (MtCO2-eq)	-218	-316	-317	-333

*Note: **S1 and S2 values for 2050 are similar to S3 and represented in more details in Annex 8.*

Source: PRIMES, GAINS, GLOBIOM.

Gross GHG emissions ([52]) are projected to reduce by between 75% (S1) and 85% (S3) in 2040 and around 92% in 2050 compared to 1990, providing the biggest contribution to

([51]) 61% of the position papers analysed, commented on carbon removals, with many of them indicating removals would be instrumental to reach climate neutrality, if complementary to GHG emission reduction at source.

([52]) Gross GHG emissions are defined as the actual GHG emissions excluding the contribution of industrial removals and LULUCF net removals, that are included of the calculation of "net GHG" emissions as measured for the EU's climate objectives in 2030 and by 2050.

climate neutrality, but still leaving residual GHG emissions. This result, in line with the lowest gross GHG emissions by 2050 of 390 MtCO2-eq presented by the ESABCC ([53]), shows that removals are required to compensate emissions that cannot be abated due to extremely high abatement costs or technical unfeasibility. Carbon removals can either be achieved through the LULUCF sector as nature-based removals or technically as industrial carbon removals derived from carbon capture.

LULUCF net removals are projected to contribute significantly over 2030-2050 in scenarios S2 and S3 with net removals of around -320 MtCO2-eq (see Table 7).

The role of industrial removals remains much more limited in the short run, given the need to fully develop some aspects of the technology to ensure large-scale deployment ([54]). They become significant by 2040 to meet higher climate targets, with about -50 MtCO2 in S2 and -75 MtCO2 for S3, representing close to 25% of the total carbon capture. To reach climate neutrality by 2050, the analysis projects industrial removals of more than -100 MtCO2, complementing land-based removals in the LULUCF sector. All pathways modelled therefore need a strong LULUCF net removal complemented by industrial removals to put the EU on the path towards climate neutrality.

Table 8 provides an overview of the GHG emissions from agriculture, forestry and other land use ("AFOLU", combining net emissions from agriculture and LULUCF) across the different scenarios. Emissions in the sectors reach net zero ahead of 2040 in S2 and S3, later in case fossil fuel related CO2 emissions in agriculture are included in S1.

Table 8: Emissions from the agriculture sector and LULUCF net removals

	2040				2050			
	S1	S2	S3	LIFE	S1	S2	S3	LIFE
Agriculture (category 3) + LULUCF net removals	133	-14	-46	-150	-92	-83	-84	-195
Agriculture (categories 3 & 1) + LULUCF net removals	165	15	-19	-122	-73	-64	-66	-175

Note: Category 3 refers to the UNFCCC agricultural sector; category 1 to energy use in agriculture.

Source: GAINS, GLOBIOM, PRIMES.

6.1.3 GHG emissions in the LIFE sensitivity case

Table 9 summarises the impact of the LIFE sensitivity analysis on GHG emissions. The case achieves the same reductions in net GHG emissions as S3, but through a different distribution of emissions across sectors.

The difference of emissions in LIFE compared to S3 results from a more sustainable food system and associated land use, which reduces the net emissions from the land sector by about 100 MtCO2-eq, combining a cut in emissions from agriculture of about 60

([53]) ESABCC, Figure 37.
([54]) Key barriers for the roll-out of carbon capture are investment and operating costs, regulatory implementation, complexity of full chain infrastructure projects, as well as public acceptance.

MtCO2-eq and significant additional removals from the LULUCF sector of around 40 MtCO2-eq in 2040. This lowers the need for carbon capture and industrial carbon removals. In parallel, an increased Circular Economy and more sustainable mobility contribute to limiting the emissions in the energy and industry sector, which are intermediate between S2 and S3.

Table 9: Comparison of GHG in the LIFE case with the core scenarios

MtCO2-eq	**2040**			
	S1	**S2**	**S3**	**LIFE**
Net GHG emissions	**1051**	**578**	**356**	**353**
of which from the land sector*	133	-45	-46	-150
of which from agriculture	*351*	*302*	*271*	*209*
of which from energy and industry**	918	593	402	503
Carbon capture	**86**	**222**	**344**	**278**
Carbon removals	**-222**	**-365**	**-391**	**-387**
of which industrial removals	-4	-49	-75	-27
of which LULUCF net removals	**-218**	**-316**	**-317**	**-360**

*Note: *Emissions from agriculture and net removals from the LULUCF sector. **Includes other non-land sectors like waste management, as well as industrial carbon removals*

Sources: PRIMES, GAINS, GLOBIOM

6.2 Evolution of the energy system and associated raw material needs

6.2.1 The energy system

Climate policy and energy security go hand in hand as the decline of fossil fuels has profound consequences for the EU's energy dependence. Import dependency (the share of imports in GAE), decreases from 61% in 2019 to 34% in S1, 29% in S2 and 26% in S3 in 2040. Due to the decline of domestic production and a continued need for oil imports, a large decrease in import dependency requires deeper decarbonisation. In 2050, the dependency is reduced to only 15%, more than half associated with non-energy uses of fuels. High demand for renewables, storage and novel technologies may lead to new dependencies for raw materials or technology imports from non-EU countries.

Table 10 summarises the main results for the evolution of the energy system from the PRIMES model. These results are validated by the findings of four other energy system models that have been used in the context of this impact assessment (i.e., POTEnCIA, METIS, EU-TIMES and POLES – see Annex 6). More details on the evolution of the energy system can be found in Annex 8.

Deep changes in the energy mix underpin the decarbonisation of energy supply. Continued energy efficiency improvements reduce the need for energy. Gross available energy (GAE) decreases from approximately 1450 Mtoe (or 61 EJ) in 2021 to around 1020 Mtoe (43 EJ) in 2040 (around 30% reduction), with limited differences across scenarios S1, S2 and S3. LIFE entails further reduction of GAE by 24 Mtoe (1 EJ). After 2040, GAE remains practically constant as energy savings are compensated by the additional energy required for renewable hydrogen production by electrolysis, and direct air capture.

Fossil fuels use decreases and renewable energy increases (in particular, wind and solar power). By 2040, fossil fuel supply for energy use will decrease by more than 70% compared to today. The measures foreseen in LIFE reduce fossil fuel use by an additional 10 Mtoe (0.4 EJ); by 2050 only small amounts of fossil fuel remain (approximately 150 Mtoe or 6.2 EJ), in large part used for non-energy purposes and long-distance transport. More than half of all fossil fuels used in the EU in 2050 are used in the non-energy sector as feedstock for chemical processes (plastic, fertilisers, etc.). The phase out of fossil natural gas imports from Russia accelerates the transition trajectory. The consumption of natural gas, biomethane and biogas reaches approximately 105 – 155 Mtoe by 2040 (4.5 – 6.5 EJ). In 2050, the consumption of those gaseous fuels in the EU is still between 70 and 80 Mtoe for all scenarios (3.0 – 3.5 EJ). Oil is the last fossil fuel to reduce, and consumption in 2050 is estimated at approximately one fourth of that in 2020. Coal is almost completely phased out by 2040.

Climate policy and energy security go hand in hand as the decline of fossil fuels has profound consequences for the EU's energy dependence. Import dependency (the share of imports in GAE), decreases from 61% in 2019 to 34% in S1, 29% in S2 and 26% in S3 in 2040. Due to the decline of domestic production and a continued need for oil imports, a large decrease in import dependency requires deeper decarbonisation. In 2050, the dependency is reduced to only 15%, more than half associated with non-energy uses of fuels. High demand for renewables, storage and novel technologies may lead to new dependencies for raw materials or technology imports from non-EU countries.

Table 10: Summary of key energy indicators

	2030	2040			2050
		S1	S2	S3	S3**
Policy relevant indicators					
Energy-related CO2 reductions vs 2005	-58%	-83%	-90%	-94%	-103%
RES share in Gross FEC	42.4%	65%	72%	75%	89%
FEC reduction vs 2015 (55)	-19%	-34%	-34%	-36%	-40%
Energy indicators - Supply					
Gross Available Energy (Mtoe)	1160	1022	1021.	1018	1032
- Fossil fuels	663	375	311	275	150
- of which for non-energy use	*96*	*96*	*96*	*96*	*80*
- of which captured	*1.8*	*11.5*	*13.2*	*13.3*	*24*
- Nuclear	139	129	129	129	142
- Renewables	328	482	544	613	691
Net imports (Mtoe)	572	347	298	267	153
Import dependency (%)	50%	34%	29%	26%	15%
Hydrogen production (Mtoe)(56)	9	60	76	100	185
e-Fuels production (Mtoe)	2	15	27	37	60
Energy indicators – Power generation					
Gross electricity generation (TWh)	3362	4563	4899	5212	6922
Net installed power capacity (GW)	1617	2181	2377	2525	3256
- Fossil fuels	238	172	164	156	142
- Nuclear	94	71	71	71	71
- Renewables	1285	1939	2142	2298	3027
Storage and flexibility options (GW)	172	213	254	275	238
Final Energy					
Final Energy Consumption (Mtoe)	764	622	614	604	555
Electricity share in FEC	33%	48%	50%	51%	62%
e-Fuels share in FEC	0%	1%	3%	5%	7%

*Note: GAE does not include ambient heat from heat pumps. E-Fuels include power-to-liquid and power-to-gas fuels but not hydrogen. Storage technologies include only battery and pumped-hydro storage, whose decline between 2040 and 2050 is due to the projected increased use of power-to-X technologies. The analysis is based on the 2019 NECPs and national legislation as of March 2023. **S1 and S2 values for 2050 are similar to S3 and represented in more details in Annex 8.*

Source: PRIMES.

([55])Note that the 2030 energy efficiency is expressed as % reduction compared to the projection of the 2020 Reference scenario (not compared to 2015).

([56]) Renewable hydrogen is a rapidly evolving technology and sector. The modelling results for 2030 in this table reflects the EU RFNBO targets, and associated hydrogen production, as per the revision of the Renewable Energy Directive under the Fit-for-55 package. However, the modelling for the future design of the post-2030 policy framework will take into account the updates of the National Climate and Energy Plans due in June 2024.'

Renewables gradually become the backbone of the EU energy system. The share of renewables in GAE grows from 17% in 2021 to 50% – 60% in 2040. The share of wind and PV in GAE increases to 27% – 34% in 2040. The use of biomass and waste is also projected to increase by 30% in S2 and S3 representing approximately 20% of the GAE share in 2040 ([57]). This evolution is mostly driven by advanced liquid biofuels and biomethane, while direct consumption of solid biomass is projected to decrease. The future role of bioenergy will have to be integrated into a sustainable circular bioeconomy, following the cascading principle. The conviction of renewables becoming the backbone of the EU energy system is shared throughout the public consultation, where across all stakeholder groups and citizens renewable energy from wind, solar or hydro was consistently rated as the most relevant solution for the energy transition towards carbon neutrality. This notion was also supported in many position papers arguing for an enhanced use of renewable energies. Stakeholders, in particular from science, civil society, and EU citizens identified the expansion of renewable energies as among the most important challenges for the EU to reach its climate ambition.

Renewable **hydrogen** as energy vector appears as a key technology of the future EU energy system, including to produce e-fuels (both gaseous and liquid) and to contribute to decarbonise the hard-to-abate sectors (such as aviation and maritime transport, among others). In the next two decades, there are large differences in hydrogen scale-up across scenarios. In 2040, the S3 scenario projects more than 60% more hydrogen production than S1, with most of the difference related to demand for e-fuels. LIFE reduces demand for renewable hydrogen by around 15 Mtoe with circular economy measures and consumption patterns (that reduce the need for certain materials). In 2050, hydrogen consumption reaches up to 185 Mtoe (7.7 EJ). Imports of RFNBOs pick up after 2035, but in low amounts due to still relatively high costs. Hydrogen and the development of clean fuels are regarded as particularly important for the EU's energy transition towards climate neutrality by business associations and companies (both SME's and large industries).

([57]) In the scenarios considered, the "gross available energy" from biomass is capped at 9 EJ, the environmental risk level for "primary bioenergy use" indicated by the ESABCC – see Annex 6. Future analyses may assume other supply levels of biomass to stay within the sustainability boundaries, in view of the on-going scientific debate.

Member States revision of their nuclear energy policy

Recent announcements by several Member States show a renewed interest in nuclear energy. A "nuclear alliance" has been set up by some Member States and is led by France. Among other policy changes, France has adopted a law in June 2023 that abolishes the objective of reducing the nuclear power share in the electricity mix to 50%, as well as the capping of nuclear production capacity at 63.2 GW. In addition, several operators have either already obtained licence or announced plans for further lifetime extensions of nuclear plants. Other changes include life extension of nuclear plant in Hungary and Finland. These legal changes added approximately 18 GW of capacity to the European nuclear fleet in 2040 (of which France accounts for about 17 GW), compared to the assumptions Section 2.5.2.2 of Annex 6 (that already include the plans adopted up to March 2023 and in particular additional nuclear capacity in Bulgaria, Czechia, Finland, Hungary, Netherlands, Poland, Romania, Slovenia and Slovakia). Due to the lead time of new nuclear plants, nuclear capacity in 2030 is unchanged compared to the original policy assumptions.

This scenario variant discusses how this legal revision changes the energy system and GHG emissions compared to the results in the S3 scenario.

With the new French legislation of June 2023, the installed capacity of nuclear plants in France reaches 54 GW by 2040 (an increase compared to 37 GW projected before the change of the law). In 2040, the share of nuclear energy in the power mix of France reaches 38% of total electricity generated compared to 27% before the June 2023 change of the law. (This compares to a share of nuclear in power generation in 2020 of 72%. This difference between 2020 and 2040 is mainly due to the electricity consumption increasing considerably - which is partly matched by more renewables). With the new French policy, the installed capacity of nuclear plants in Europe reaches 88 GW by 2040 (compared to 71 GW in the previous S3 scenario and 94 GW in 2030).

Compared to the results shown in Climate policy and energy security go hand in hand as the decline of fossil fuels has profound consequences for the EU's energy dependence. Import dependency (the share of imports in GAE), decreases from 61% in 2019 to 34% in S1, 29% in S2 and 26% in S3 in 2040. Due to the decline of domestic production and a continued need for oil imports, a large decrease in import dependency requires deeper decarbonisation. In 2050, the dependency is reduced to only 15%, more than half associated with non-energy uses of fuels. High demand for renewables, storage and novel technologies may lead to new dependencies for raw materials or technology imports from non-EU countries.

Table 10 for the S3 scenario, the additional nuclear plants increase the share of nuclear power in the energy mix from 13% of GAE to 15% in 2040 (or approximately 160 Mtoe). This increase of nuclear energy leads to a slightly slower growth of renewables that reach 600 Mtoe in 2040 (or 10 Mtoe difference). Net installed capacity follows a

The coming decades require a significant increase in electricity supply, mainly due to the increasing electrification of end-use sectors, but also to the power needed for the production of RFNBOs and DACC. Electricity generation increases from 2905 TWh in 2021 to about 4565 TWh in S1, 4900 TWh in S2 and 5210 TWh in S3 in 2040.

In 2040, S1 requires around 13% less electricity than S3. This is explained by substantial differences in production of RFNBOs and in industrial removals by DACC. In 2040, electrolysers, RFNBO synthesis and DACC combined consume approximately 600 TWh more electricity in S3 than in S1. In S2 consumption is approximately 270 TWh more than S1 for the same purposes. Due to the lower hydrogen production (thanks to circular economy measures and consumption patterns) LIFE allows to save almost 390 TWh of total electricity production in 2040. Projections for electricity, hydrogen and RFNBOs consumption in 2050 are similar across all scenarios.

The share of fossil-fired power generation steadily decreases by 2040, from 36% in 2021 to 8% in S1 and 3% in S3. Residual fossil-fired generation consists almost solely of gas-fired power plants (equipped with CCS or used for peak demand). Renewables increase their contribution to total electricity generation from about 40% in 2021 to 81%-87% in 2040 (wind and solar accounting for the largest shares of renewable capacity). The analysis results in nuclear power generation decreasing from 730 TWh in 2021 to around 495 TWh in 2040 with nuclear capacity assumptions in line with the Member State policies as in 2019 National Energy and Climate Plans and national policies as of March 2023([58]). Net imports of electricity from outside the EU remain very small (around current levels).

As wind and solar PV generation have relatively low full load hours, replacing fossil fuels with renewables requires higher installed power capacity. Total installed capacity grows more than two times faster than electricity generation between 2015 and 2040. There are large differences in renewable capacity across scenarios. In 2040, S3 and S1 requires 6% more and 8% less capacity than S2, respectively (2300 GW in S3, 1940 GW in S1 and 2140 GW in S2). The circular economy measures and behavioural changes in LIFE significantly decrease the amount of generation capacity, by around 200 GW in 2040.

Balancing the high share of variable renewable electricity generation requires a flexible power system. Flexibility needs are increasingly met by storage solutions (mainly pumped hydro storage and batteries) reaching 275 GW in S3 in 2040 and by demand side measures including demand management technologies such as the production of hydrogen with electrolysers and – to a lower extent – the production of other RFNBOs. There is a marked difference with scenarios S1 and S2 requiring significantly less storage and electrolyser capacity than S3 in 2040.

([58]) These assumptions reflect the situation until March 2023. In June 2023, France has adopted a law which removes the objective of reducing the share of nuclear power in the electricity mix. additional 3.3 GWe nuclear capacity was officially announced for deployment by mid-2030s. See Annex 8 for more details. Future analysis will take the revised policies into account, as reflected in the updated National Energy and Climate Plans which are currently being drafted.

Final energy consumption (FEC) shows a large reduction already this decade, reaching 765 Mtoe in 2030 (32 EJ: the Energy Efficiency Directive target), further reducing in 2040 to 622 Mtoe (26 EJ) in S1, 614 Mtoe (25.7 EJ) in S2 and 604 Mtoe in S3 (25.3 EJ). The share of renewable energy in gross FEC increases from 42% in 2030 (in line with the Renewable Energy Directive target) to 65% in S1, 72% in S2 and 75% in S3 in 2040.

The share of fossil fuels in total FEC decreases from above 60% in 2015 to 30% in S1, 25% in S2 and 23% in S3 in 2040, and further down to only 5% in 2050. Electricity becomes the dominant energy vector in final energy sectors. The share of electricity in FEC increases from 23% in 2015 to above 45% in 2040 (approximately 280-290 Mtoe across scenarios or 11.7 – 12.1 EJ) and up to 57% (320 Mtoe – 13.4 EJ) in 2050. This increase is mainly driven by the uptake of electric vehicles, the penetration of heat pumps and electrification of low and medium temperature industrial processes. Fossil fuels start to be partially replaced by hydrogen and other RFNBOs in industry and transport (representing more than 10% and 20% of sectoral demand in S2 and S3 in 2040), while the consumption of RFNBOs in the building sector remains limited throughout the period. Across all sectors, RFNBOs account for approximately 5-10% of total FEC in 2040 and 16% in 2050.

Under existing energy efficiency policies, all end-use sectors are expected to reduce energy consumption significantly in the current decade. Energy consumption continues to decrease in the decade 2031-2040 albeit at a slower pace (except for the transport sector that sees considerable improvements after 2030 thanks to accelerated electrification). Compared to 2021, energy consumption decreases by 42% in 2040, in the transport sector ([59]), 45% in the residential sector, approximately 30% in the services and industrial sectors and by 25% in agriculture. Only small additional reductions in final energy consumption occur by 2050 in all sectors.

6.2.2 Raw materials needs

The manufacturing and deployment of net-zero technologies will increase the needs for Critical Raw Materials (CRMs).

With scenario S3, the deployment of five net-zero technologies (wind turbines, solar PV, batteries, electrolysers, and heat pumps) would imply a need for up to 500 000 tonnes of copper each year in the decade 2031-2040, including 125 000 tonnes for wind alone. This compares with a global copper demand of 26 million tonnes in 2022 according to the IEA, including 370 000 tonnes for electric vehicles and 1.2 million tonnes for wind and solar ([60]). The global supply for copper is expected to exceed 30 million tonnes in 2030 ([61]).

([59]) Including international aviation but excluding international maritime transport.
([60]) IEA (2023), Critical Minerals Data Explorer, IEA, Paris https://www.iea.org/data-and-statistics/data-tools/critical-minerals-data-explorer. Accessed on 05 December 2023.
([61]) IEA (2023), Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach, IEA, Paris https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach

Batteries for electric vehicles and stationary batteries would create needs of up to 80 000 tonnes of lithium and 60 000 tonnes of cobalt per year in 2040. As a comparison, global lithium demand in 2022 was 130 000 tonnes, including 69 000 tonnes for electric vehicles, and cobalt demand was around 200 000 tonnes ([60]). By 2030, global supply for lithium and cobalt are expected to be as high as 721 000 and 380 000 tonnes, respectively ([61]).

In S1 and S3, raw material needs would be lower and higher than in S2, respectively, as in 2040 net installed renewable power capacity is lower by 8% in S1 and higher by 6% in S3 compared to S2.

6.3 Environmental and health impacts

6.3.1 Benefits of climate change mitigation

It is estimated that climate damages could cost EU GDP by up to 1% annually already in the next few years, with damages strongly increasing afterwards, reaching up to 2.3% of EU GDP by mid-century, and possibly getting much higher in only a few decades in case of uncontrolled climate change with estimates for the EU in this analysis reaching 7% by the end of the century. Such estimates are conservative since they do not include the wider impacts on society and natural systems (see Annex 7).

To compare the avoided cost of climate change across options, Table 11 below provides a comparison of the monetisation of the externalities associated to GHG emissions. It considers the difference across target options in cumulative emissions over 2030-2050 and a "cost of carbon" capturing these externalities.

Table 11: Difference across options in cumulative GHG emissions and cost of climate change

		Comparison to target option 2					
		2031-2040		2041-2050		2030-2050	
		Option 1	Option 3	Option 1	Option 3	Option 1	Option 3
Cumulative GHGs* (GtCO2-eq)		1.7	-1.3	1.4	-1.1	3.1	-2.4
*Climate change cost** [Bn EUR 2023 per year]*	*(Lower valuation)*	*26*	*-20*	*31*	*-24*	*29*	*-22*
	(Higher valuation)	*49*	*-38*	*58*	*-44*	*53*	*-41*

*Note: *Considering 2040 reductions of 85% for T2 and 90% for T3. **Cost calculations based on the "Handbook on the external costs of transport (Version 2019 – 1.1)" following the avoidance cost approach. The cost of carbon is interpolated from the Handbook: EUR 155 per tonne of CO2 in 2030-2040 and EUR 224 per tonne in 2041-2050 (central value of the handbook, used for the "Lower" valuation) and EUR 291 per tonne in 2031-2040 and EUR 416 per tonne in 2041-2050 (high value of the handbook, used for the "Higher" valuation), in EUR 2023.*

Note that the methodology used for the monetisation of the external costs of climate change is subject to discussions and that there is a high level of uncertainty associated with such estimates and their use. Some studies conclude that the costs used are (significantly) underestimated. In some other organisations ([62]), a cost of carbon of above €800/ tCO2 is suggested by 2050.

In addition, given the difficulty in doing so, analyses, including this one, do not represent the impacts of crossing climate tipping points, which are increasingly likely with every incremental increase in global warming. Looking forward, the cost of unmitigated climate change will greatly exceed the cost of reducing GHG emissions, both in magnitude and extent.

6.3.2 Health impacts

The transformations required to reduce GHG emissions in the EU have positive impacts on air quality because they lead to lower energy consumption and a shift to non-emitting renewable energy sources and to less polluting combustion fuels. According to projections produced using the GAINS model ([63]), the S1, S2 and S3 scenarios have very similar impacts, with primary air pollutant emissions in the EU decreasing by 16%-77% (depending on the pollutant) between 2015 and 2040 (see Table 12). This results mostly from the projected strong decline in fossil fuel use in the energy system and lower consumption of solid biomass in residential buildings, combined with clean air policies. Consequently, the impacts on public health also decline. In general, the most harmful air pollutants for human health are PM2.5, tropospheric ozone and NO2([64]). Between 2015 and 2040, the number of premature deaths per year caused by PM2.5 and ozone exposure in the EU dropped by 58% ([65]) and the costs associated to premature mortality caused by PM2.5 and ozone exposure decreased by 55% or 61%, depending on the valuation method employed.

LIFE yields additional co-benefits in terms of lower air pollutant emissions and a greater reduction in premature mortality, mainly as a result of lower air pollutant emissions from agricultural activities, in particular lower NH3 emissions, which has been found to result in economic benefits from improved health ([66]). Additional indirect air quality benefits also stem from reduced methane emissions as a precursor of ozone emissions. In addition to improved air quality, a shift in diet as in LIFE would deliver significant health

([62]) EIB, France, Germany, UK for example
([63]) The methodology used is similar to the one used in the Third Clean Air Outlook (COM(2022) 673).
([64]) According to the Third Clean Air Outlook. Note that tropospheric ozone is not emitted directly into the air. It is created by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOC), in the presence of sunlight. The analysis of clean air impacts will be presented in more details in the COM 4th Clean Air Outlook report (forthcoming, 2024).
([65]) The analysis considers the direct effects of PM2.5 (full exposure range) and ozone on human health, together with the indirect effects of NOx as precursors of particulate matter and ozone. However, the direct effects of NO2 are not considered to avoid the risk of double counting, since there is conflicting scientific evidence on the extent to which the health impacts of PM2.5 and NO2 overlap.
([66]) Shift to flexitarian diets could reduce ammonia emissions by 33% in the EU. Through avoided premature mortality, economic losses in the agricultural sector from dietary shifts could be mitigated by 39% in the EU in such a scenario. Himics et al. ‘Co-benefits of a flexitarian diet for air quality and human health in Europe’, 2022

benefits, reducing for example the risk of cardiovascular diseases ([67]), cancer ([68]), diabetes, and obesity ([69]).

Table 12: Primary air pollutant emissions, impacts on premature mortality and costs associated to premature mortality

	2015	2040				Change 2015-2040			
		S1	S2	S3	*LIFE*	S1	S2	S3	*LIFE*
Primary air pollutant emissions (kt)									
SO2	2316	525	529	529	*529*	-1791 (-77.3%)	-1787 (-77.1%)	-1787 (-77.1%)	*-1787 (-77.1%)*
NOx	7392	2140	2140	2114	*1913*	-5252 (-71.1%)	-5252 (-71.1%)	-5277 (-71.4%)	*-5478 (-74.1%)*
PM2.5	1380	521	524	521	*517*	-859 (-62.2%)	-857 (-62.1%)	-859 (-62.2%)	*-863 (-62.5%)*
VOC	6362	4503	4501	4497	*4259*	-1860 (-29.2%)	-1861 (-29.3%)	-1865 (-29.3%)	*-2103 (-33.1%)*
NH3	3690	3086	3090	3091	*2346*	-604 (-16.4%)	-600 (-16.3%)	-599 (-16.2%)	*-1345 (-36.4%)*
Premature mortality caused by PM2.5 and ozone exposure									
Expressed in 1000 death cases per year	466	197	198	196	*188*	-268 (-57.6%)	-268 (-57.6%)	-269 (-57.8%)	*-277 (-59.5%)*
Expressed in 1000 life years lost per year	5977	2667	2668	2650	*2544*	-3309 (-55.4%)	-3309 (-55.4%)	-3326 (-55.7%)	*-3432 (-57.4%)*
Costs associated to premature mortality caused by PM2.5 and ozone exposure (EUR 2023 billion/year)									
Higher valuation method (VSL*)	1724	677	677	673	*646*	-1047 (-60.7%)	-1046 (-60.7%)	-1051 (-61.0%)	*-1077 (-62.5%)*
Lower valuation method (VOLY*)	686	306	306	304	*292*	-380 (-55.4%)	-380 (-55.4%)	-382 (-55.7%)	*-394 (-57.4%)*

*Note: * The valuation follows the same methodology used in the Third Clean Air Outlook. The "higher valuation" is done using the value of a statistical life (VSL) methodology (where the VSL is assumed to be EUR 4.36 million, in EUR 2023), and the "lower valuation" is done using the value of a life year (VOLY) methodology (where the VOLY is assumed to be EUR 114 722, in EUR 2023). Note that, in the Third Clean Air Outlook, these values are expressed in EUR 2015.*

Source: GAINS.

In addition to direct effects, climate action should mitigate the increasing negative effects that climate change has on air quality and human health, due notably to heatwaves and wildfires ([70]) and the climate-induced spread of vector-borne diseases.

([67]) Koch et al. (2023) Vegetarian or vegan diets and blood lipids: a meta-analysis of randomized trials. European Heart Journal
([68]) Chan, Doris SM, Rosa Lau, Dagfinn Aune, Rui Vieira, Darren C. Greenwood, Ellen Kampman, and Teresa Norat. "Red and processed meat and colorectal cancer incidence: meta-analysis of prospective studies." *PloS one* 6, no. 6 (2011): e20456.
([69]) Tukker et al. (2011) Environmental impacts of changes to healthier diets in Europe. Ecological Economics
([70]) World Meteorological Organization, *WMO Air Quality and Climate Bulletin*, No 3, September 2023.

6.3.3 Environmental impacts

Air pollution causes acidification and eutrophication, damaging ecosystems and crops. As shown in Table 13, in the S1, S2 and S3 scenarios, the decrease in SO_2, NO_x and NH_3 emissions reduces the total area affected by severe acidification in the EU by around 80% between 2015 and 2040. Moreover, the total area affected by severe eutrophication decreases by around 23.5% over the same period, mainly as a result of the decrease in nitrogen-related emissions. LIFE brings complementary co-benefits in terms of reduced acidification and eutrophication because of the lower NO_x and NH_3 emissions from agricultural activities.

Table 13: EU ecosystem area where acidification or eutrophication exceed critical loads

	2015	2040				Change 2015-2040			
		S1	S2	S3	LIFE	S1	S2	S3	LIFE
Acidification (1000 km2)	157	31	31	31	19	-126 (-80.4%)	-126 (-80.4%)	-126 (-80.4%)	-137 (-87.7%)
Eutrophication (1000 km2)	1164	891	892	890	742	-273 (-23.5%)	-272 (-23.4%)	-274 (-23.5%)	-422 (-36.3%)

Source: GAINS.

S2 and S3 show a higher demand for bioenergy compared to today. Due to the higher reliance of S3 on industrial carbon removals (including DACCS) and e-fuels than S1 or S2, S3 may involve greater need for bioenergy if BECCS and liquid biofuels were to substitute a limited deployment of these technologies.

The future demand for biomass in 2040 compared to today is driven by an increased demand for advanced/ second generation biofuels, and is satisfied through a higher supply of lignocellulosic crops, which to a large extent substitute crops for first generation biofuels ([71]). In 2040 total cropland remains unchanged in S1 compared to today and increases by 1.2 Mha in S2 and S3. In S2 and S3, forest land increases by about 4.9 Mha compared to 3.3 Mha in S1 and (rewetted) wet- and peatlands increase by about 1.4 Mha from a conversion of grassland in S2 and S3 (compared to 0 Mha in S1).

The impacts on biodiversity resulting from land use change are very limited across scenarios and remain between -1% (S1) and +4% (S2) of average suitable habitat increase in 2040 compared to 2020. The practices put in place to increase LULUCF net removals can actually positively impact biodiversity: reforestation, polyculture afforestation under close-to-nature practices and rewetting of peatlands play out more favourably for habitats and ecosystems than monocultures. Different biomass demand does not significantly alter biodiversity across scenarios, however, for lignocellulosic crops to be fully environmental beneficial, impacts on land-use and water-use should be minimised, by showing higher yields and lower water use than feed crops and through applying limitation in their use.

([71]) In 2040 total cropland remains unchanged in S1 and increases by 1.2 Mha in S2 and S3, because around 80% of the required area for lignocellulosic crops comes from crops for first generation biofuels or other crops.

Building on a shift to healthier diets and more sustainable practices, LIFE leads to complementary changes in the agricultural land area, where allowing part of the land to be freed up from livestock, fodder activities and intensively grazed land and converted into extensive grassland, high diversity landscape features with – in comparison to S2 and S3 – more natural vegetation (+6.8 Mha), forest land (+4 Mha) and rewetted organic soils (+0.3 Mha). This change in land use is accompanied by a reduction in nutrient surplus and use of pesticides, and an increase of organic farming in line with the Farm to Fork Strategy. The land use change has a positive effect on LULUCF net removals, which can be expected to create additional income opportunities for farmers through carbon farming, as well as significant co-benefits for biodiversity: the likelihood to find agricultural areas with a high value for biodiversity and ecosystems improves by 14% within the EU ([72]) compared to S2 and S3.

Biodiversity is also affected by climate change. High-latitude and freshwater ecosystems, the prevailing domains in southern European and Boreal areas, are particularly vulnerable to climate change (see Annex 7). Climate change mitigation reduces the likelihood of larger climate change impacts on biodiversity and natural systems and, in so doing, helps to increase resilience and adaption to climate change. More biodiverse ecosystems (e.g., biodiverse forests), are more resilient, multifunctional, deliver more ecosystem services and may function better to remove carbon ([73]) ([74]).

6.4 The socio-economic implications of mitigation ([75])

6.4.1 Macro-economic impacts

The impact assessments for the 2030 Climate Target Plan and the long-term strategy for 2050 concluded that the respective objectives were projected to have limited impacts on broad macro-economic aggregates, including GDP and total employment. These conclusions were reached while assessing impacts relative to a baseline with significantly lower climate ambition. The benchmark used for the comparison of the macro-economic modelling in this impact assessment is the S2 scenario.

At aggregate level, the three models used in this impact assessment consistently show that a higher level of mitigation in 2040 only has a slightly negative, transitory impact on GDP, while a lower level of mitigation yields a minor positive effect. In 2040, GDP for S3 is at worst 0.8% lower than in S2 under the E-QUEST model (see Table 14 and

([72]) Using the ‘Biodiversity Friendly Practices’ (BFP), a biodiversity indicator capturing the likelihood to find High Nature Value farmland in a region. The total index is an area weighted average of the partial indices for arable crops, permanent crops, grassland and set aside / fallow land. Partial indices for different land use categories are therefore weighted according to their proportion of total utilised agricultural area.
([73]) Mori, Akira S., Laura E. Dee, Andrew Gonzalez, Haruka Ohashi, Jane Cowles, Alexandra J. Wright, Michel Loreau et al. "Biodiversity–productivity relationships are key to nature-based climate solutions." Nature Climate Change 11, no. 6 (2021): 543-550.
([74]) Liang, Jingjing, Thomas W. Crowther, Nicolas Picard, Susan Wiser, Mo Zhou, Giorgio Alberti, Ernst-Detlef Schulze *et al.* "Positive biodiversity-productivity relationship predominant in global forests." Science 354, no. 6309 (2016): aaf8957.
([75]) All figures quoted in this section are expressed in constant EUR 2023.

Annex 8) while output is at best 0.6% higher in S1 than in S2 (JRC-GEM-E3 model). By 2050, GDP levels almost converge for the three scenarios.

However, the limited impacts on broad aggregates do not reflect the transformations that the economy will undergo, and the required reallocation of capital and employment in the coming decades across sectors and actors. The macro-economic models indicate that a higher GHG ambition in 2040 shifts the composition of GDP from consumption towards investment (consistent with the investment needs identified in section 6.4.2). Nevertheless, the impacts on private consumption remain small across models and levels of ambition. In addition, the composition of consumption should evolve over time, with a gradual decrease in the share of energy consumption and an increase in the share of other goods in total consumption. This compositional shift would be positive from a welfare perspective, as energy-related services would not be negatively affected by lower energy consumption (*e.g.*, a better insulated house provides the same – or likely better – level of comfort than a poorly insulated one, with a lower energy consumption).

In terms of sectoral output, a higher level of climate ambition in 2040 is associated with a faster decline in the output of fossil fuel industries, though all scenarios reach broadly similarly low levels of output by 2050 (see Table 14 and Annex 8). The impact on the output of energy intensive industries is also somewhat larger with more ambition, even though the effect under S3 is limited with a decline of 0.2% relative to S2 in 2040 and 2050, both under a scenario where the rest of the world implements policies in line with the current NDCs (fragmented action setting) and under a scenario where the rest of the world acts in line with the 1.5°C objective (global action setting).

Table 14: Sectoral output and GDP in 2040, deviation vs. S2 (% change)

	S1 fragmented	S3 fragmented	S1 global	S3 global
GDP (*)	0.5%	-0.2%	0.6%	-0.2%
Fossil fuel industries	10.2%	-5.6%	15.0%	-5.2%
Energy intensive industries	1.4%	-0.2%	-0.3%	-0.2%
Transport equipment	0.7%	-0.5%	0.6%	-0.4%
Other equipment goods	0.5%	0.2%	-1.3%	0.3%
Consumer goods industries	0.7%	-0.6%	-0.8%	-0.8%
Transport	2.0%	-1.0%	1.0%	-1.1%
Construction	0.0%	0.5%	0.0%	0.6%
Market services	0.5%	-0.2%	1.1%	-0.2%
Non-market services	0.2%	-0.2%	0.4%	-0.2%
Agriculture	2.0%	-1.0%	1.0%	-1.1%
Forestry	-10.9%	0.5%	-13.1%	-1.4%

(*) The GDP impacts reported in this table are only those from the JRC-GEM-E3 model.

Source: JRC-GEM-E3.

While the output of energy intensive industries is somewhat larger under S1 than under S2 in 2040 under a fragmented action setting, it is actually lower in a global action setting. This is driven by the earlier adoption of decarbonised technologies in EU industry relative to the rest of the world under S2, which results in an increase in its competitiveness in a setting where the rest of the world also needs to invest in low-carbon processes. It must be noted also that the output of energy intensive industries is projected to continue growing across all scenarios in future decades. The growth rate between 2015 and 2040 is projected to range between 25.5% and 27.6% (fragmented action setting).

A higher level of ambition in 2040 (S3) would entail somewhat lower private consumption, which would affect notably road and air transport, equipment goods and consumer goods industries. However, under a global action setting, these sectors could actually be positively impacted by 2050 as global demand for equipment goods and technological know-how linked to decarbonisation increases and as the EU gains competitiveness and export market shares, thereby also driving up transport activity.

Overall, the difference in the evolution in the EU's global export market shares across scenarios is marginal, which points to limited differences in competitiveness impacts across target options (Table 15). While the EU is expected to represent a gradually declining share of global exports in the coming decades, this is driven mainly by the smaller relative size of its population and economy and not by the level of climate ambition. As indicated above, a more relevant factor for the impacts on competitiveness is the level of ambition in mitigation policies in the rest of the world, with a higher level of ambition susceptible to increase market shares for EU companies.

Table 15: EU share in global exports (% of world trade)

	2040			2050		
	S1	S2	S3	S1	S2	S3
Fragmented action						
All exports	16.4%	16.2%	16.1%	15.9%	15.9%	15.9%
Energy intensive industries	17.4%	17.1%	17.1%	16.9%	16.8%	16.8%
Transport equipment	25.3%	25.1%	25.0%	24.1%	24.1%	24.1%
Other equipment goods	17.5%	17.3%	17.1%	16.7%	16.7%	16.7%
Consumer goods industries	12.6%	12.5%	12.3%	12.0%	12.0%	12.0%
Market services	22.7%	22.8%	22.7%	21.5%	21.5%	21.5%
Agriculture	7.2%	7.0%	7.0%	6.2%	6.3%	6.3%
Forestry	4.4%	4.3%	4.3%	3.1%	3.1%	3.1%
Global action						
All exports	16.9%	16.7%	16.6%	16.9%	16.9%	16.8%
Energy intensive industries	17.9%	17.6%	17.6%	17.6%	17.5%	17.5%
Transport equipment	25.3%	25.2%	25.0%	24.4%	24.4%	24.3%
Other equipment goods	18.1%	17.9%	17.8%	18.7%	18.7%	18.7%
Consumer goods industries	13.3%	13.2%	13.0%	13.6%	13.6%	13.6%
Market services	21.7%	21.7%	21.7%	19.1%	19.1%	19.1%
Agriculture	7.8%	7.6%	7.5%	6.4%	6.5%	6.9%
Forestry	4.4%	4.3%	4.3%	3.1%	3.1%	3.2%

Source: JRC-GEM-E3.

The transition to climate neutrality and the level of ambition for 2040 will also impact the EU's main trading partners. While the level of total EU imports is similar across scenarios, the composition of imports and their carbon intensity will change with the transition. Imports of fossil fuels will decline sharply in the coming decades, with an even sharper and faster decline under S3. For market services and agro-forestry goods, the share of EU imports is expected to grow during the transition. A broad-based assessment suggests that the share of EU imports coming from Africa and Asia (excluding China and India) will increase.

The extent to which public finances could be affected by the transition itself and by the scenarios in this impact assessment will depend on a multiplicity of factors, many determined at Member State level. On the revenue side, environmental taxes play a key role in decoupling economic growth and environmental impacts. In 2021, environmental taxes represented about 2.2% of GDP or 5.5% of the total revenues of EU Member States from taxes and social contributions, the bulk linked to energy taxes for fossil fuels. The base of carbon taxes will erode as the EU progresses towards climate neutrality. Revenues from carbon pricing or other taxes aiming at reducing emissions should increase over the transition before declining as the EU economy moves towards climate neutrality. In that context, phasing out fossil fuel subsidies will be all the more important. These trends will have implications for the design of tax and revenue systems.

On the expenditure side, the impact will be affected, among others, by the extent to which Member States directly fund or support investment in climate change mitigation and adaptation. In turn, the risks to government finances arising from fossil fuel price shocks, as recently experienced following Russia's war of aggression in Ukraine, would be much lower under a higher target for 2040. Simulation with the JRC-GEM-E3 model of a stylised shock resulting in doubling of fossil fuel prices (coal, oil and gas), without knock-on effects on electricity prices, shows that the negative impact on GDP, private consumption and employment is halved if it takes place in an economy with a largely decarbonised energy system projected for 2040, compared to the same shock taking place in 2025 (GDP impact of -0.4% vs. -0.8% and private consumption impact of -1.3% vs. -2.6%).

The risks from climate-related hazards for public finance are becoming increasingly obvious, though these will be determined by the success of global mitigation efforts and the extent to which private insurance can provide adequate coverage ([76]). Insurance cover for climate-related natural catastrophes is low - at about 25% at EU level, with large disparities among Member States ([77]).

Finally, it is critical to assess the potential impacts of the climate transition alongside its co-benefits (section 6.3) and the costs of inaction. Co-benefits in terms of human health, strategic independence, quality of life and environmental sustainability cannot all be adequately measured in financial terms or as economic impacts; however they are large and affect welfare in many ways. In addition, the damaging impacts of global warming are becoming increasingly stark and immediate, both for our economies and people. Short-term costs are soaring due to the occurrence and intensity of extreme weather-related events. While estimates of long-term economic losses are shrouded with

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([76]) The Commission's Fiscal Sustainability Report 2021 highlights that extreme weather and climate-related events already pose risks to fiscal (debt) sustainability in several countries, while further stressing that the assessment is based on an incomplete view of risks and is therefore likely to underestimate the negative fiscal impacts.
([77]) Based on the dashboard on insurance protection gap for natural catastrophes from the European Insurance and Occupational Pensions Authority.

uncertainty and will depend to some extent on our ability to adapt to a changing climate, they all point to impacts that are several times the estimated impacts of mitigation policies.

6.4.2 Investment needs

The EU energy system needs to be decarbonised to a large extent by 2040 in all scenarios. This requires the modernisation of many facets of our economy. All scenarios imply an intensification of efforts to replace fossil fuels with renewable and carbon-free sources of energy, achieving higher energy efficiency across the economy, and increasing innovation. Existing capital assets (*e.g.*, fossil-based power plants, heating and cooling systems or industrial processes) will be progressively replaced with renewable technologies, carbon-free or electricity-based assets, whose capital intensity may be larger than fossil-based assets. New industrial capacities such as critical raw material processing or clean steel, will be built, to supply the decarbonisation needs. The transition of the energy system will require sustained investment including in research, industry, and supply chain capacities. This will trigger innovation.

All scenarios require similar significant investment needs for the energy system over the period 2031-2050, although with different time profiles over the two decades, and different sectoral composition. This highlights the necessity to ensure enabling conditions that make such a level of investment feasible and that avoid investment decisions that are not compatible with the transition.

The three scenarios imply annual energy system investment needs (excluding transport) above 3% of GDP for the period 2031-2050 (Table 16). This amounts to an additional 1.5 percentage points of GDP compared to average energy system investment in 2011-2020, a period during which overall investment levels in the EU were historically low (see Annex 8). It is also comparable to the level of investment that will be needed in the current decade to achieve the objectives of the Fit-for-55 package. The resulting evolution of investment as a proportion of GDP is not exceptional in historical terms, though the increase would need to be sustained over a prolonged period of time: the ratio between gross fixed capital formation (GFCF) and GDP in the EU has fluctuated between 20-23% since the mid-90s, dropping to a 20% low between 2010 and 2020 before bouncing back in more recent years towards the average of 22% seen in 2000-2010. In the 1970s and 1980s, the average ratio was at 25.8% and 23.1%, respectively.

The electricity sector (generation and grid) dominates investment needs on the supply side given the increasing electrification in the economy. On the demand side, the residential sector accounts for the largest share of investment needs at about two-thirds of the total (excluding transport).

Table 16: Average annual energy system investment needs (billion EUR 2023).

	S1			S2			S3			ΔLIFE		
	2031-2040	2041-2050	2031-2050	2031-2040	2041-2050	2031-2050	2031-2040	2041-2050	2031-2050	2031-2040	2041-2050	2031-2050
Supply	236	377	306	289	328	308	341	281	311	-59	-14	-36
Power grid	79	88	84	88	81	85	96	75	85	-15	-2	-9
Power plants	97	187	142	128	157	142	151	133	142	-28	-6	-17
Other	59	102	81	72	90	81	94	73	83	-16	-6	-11
Demand excl. transport	332	377	354	355	357	356	372	338	355	-23	1	-11
Industry	38	31	35	46	24	35	48	22	35	-7	-3	-5
Residential	225	250	237	237	242	239	248	230	239	-12	4	-4
Services	49	78	63	53	73	63	57	67	62	-4	1	-2
Agriculture	19	19	19	19	19	19	20	18	19	0	0	0
Transport	866	875	870	861	885	873	856	882	869	-80	-85	-82
Total	1433	1629	1531	1505	1570	1537	1570	1501	1535	-162	-97	-129
Total excl. transport	567	754	661	644	685	664	713	619	666	-82	-12	-47
Memo:												
Real GDP (period average)	19444	22369	20906	19444	22369	20906	19444	22369	20906	19444	22369	20906

Note: "ΔLIFE" compares the cost of the LIFE scenario to the S3 scenario, which both meet the same overall net GHG reductions by 2040.

Source: PRIMES.

More ambition in 2040 (S3) requires higher annual investment needs in 2031-2040 and a faster deployment of decarbonisation technologies on the supply and demand side, but also comparatively lower investment levels in 2041-2050. The opposite is true for scenario 1, relative to scenario 2, with a significant delay in the deployment of investment that would entail a great deal of catching up with annual investment (excluding transport) of EUR 755 billion in 2041-2050, i.e. 6% higher than what is required under scenario 3 in 2031-2040. The difference across scenarios takes place notably in energy supply (+18% and -18% compared to S2, respectively). A higher level of ambition in 2040 also requires industry to shift faster towards the manufacturing of net-zero technologies and the use of carbon capture, and to expand the associated supply chains that enable the decarbonisation of other sectors. Compared to S2, investments in 2031-2040 to decarbonise industry are 4% higher in S3, and 16% lower in S1. In services, the differences are +8% and -7%, respectively, and in the residential sector +5% and -5%, respectively. In agriculture, the difference between the scenarios is very small, at +0.4% and -1.2% relative to S2.

LIFE shows that demand-side action, including shifts to a more sharing economy, more circular use of materials or more sustainable mobility can reduce the need for investment across the entire period. The reduced energy demand results in lower investment requirements across the board. In aggregate, average annual investment needs (excluding transport) in 2031-2050 are almost EUR 50 billion or 7.1% lower with LIFE than under S3. They are about EUR 36 billion per annum (12%) lower on the supply side and about EUR 5 billion (15%) lower in industry.

Investment in transport ([78]) is projected at about EUR 870 billion per annum (4.2% of GDP) in 2031-2050 and varies little across scenarios. About 80% of the average annual investment in 2031-2050 is projected in road transport, mainly to purchase private cars (about EUR 510 billion per annum and 60% of the total) ([79]). Investment needs for recharging and refuelling infrastructure account for a small proportion of the total, at about EUR 15 billion per annum. Changes towards more sustainable mobility patterns (LIFE) reduce the average annual transport-related investments in 2031-2050 by around EUR 80 billion (9%).

These investment needs will be met by both private actors and the public sector. Private businesses are likely to be the main source of investment on the supply side and in industry. Public support via State aid has been instrumental in the past for the deployment of renewable energy generation. It will likely remain critical in the future deployment of innovative decarbonisation technologies in the energy system (e.g. renewable hydrogen) and industry (e.g. innovative production processes and carbon capture, storage, and use). Investment by SMEs largely depends on the sector where they operate (see Annex 4). Households will face large investment needs for the renovation of the building stock and the acquisition of zero tailpipe emission vehicles. How up-front investment costs for renovation and heating/cooling will be borne will depend on ownership structure (homeowners, tenant vs. landlord) and on the extent of public support.

The early push on investment under S3 enables the achievement of a higher mitigation target by 2040, with associated benefits in terms of a lower overall carbon budget, reduced fossil fuel imports and lower negative impacts of GHG emissions. In turn, the delay in investment effort under S1 comes at the cost of lower mitigation, higher fossil fuel imports and higher negative impacts from emissions.

The early push under S3 is most significant on the supply side, where the economic agents responsible for the investment consist mainly in private businesses with good access to finance, backed by collateral in terms of assets and predictable long-term revenue streams (Table 17). Industry would also need to anticipate investment under S3 to some extent, and it is likely to have solid access to finance. In the residential sector, where access to finance is likely more challenging for low- and middle-income households the need for an early push under S3 is less significant. Overall, average annual investment (including transport) under S3 is 4% higher than under S2 in 2031-2040. This amounts to 0.3% of GDP, most of which on the supply side.

([78]) These figures represent the full acquisition cost of new vehicles, not only the incremental cost related to the decarbonisation of transport. In addition, it should be noted that investment in transport here reflect the expenditures on vehicles, rolling stock, aircraft and vessels plus recharging and refuelling infrastructure. They do not cover investments in infrastructure to support multimodal mobility and sustainable urban transport. They factor in a higher number of vehicles sold as well as any potential increase in the average size/class of vehicles.
([79])The figure factors in a higher number of vehicles sold as well as any potential increase in the average size/class of vehicles.

Table 17: investment profiles across options and financial feasibility (annual averages, 2031-2040)

	Billion EUR 2023		% change vs. S2		% GDP		Deviation vs. S2 (% GDP)	
	2011-2020	S2	S1	S3	2011-2020	S2	S1	S3
Total	863	1505	-4.8%	+4.3%	5.8%	7.7%	-0.37%	+0.33%
Total excl. transport	248	644	-11.9%	+10.8%	1.7%	3.3%	-0.39%	+0.36%
Supply	80	289	-18.4%	+18.0%	0.5%	1.5%	-0.27%	+0.27%
Industry	7	46	-15.7%	+4.4%	0.0%	0.2%	-0.04%	+0.01%
Residential	116	237	-5.1%	+4.7%	0.8%	1.2%	-0.06%	+0.06%
Services	29	53	-7.1%	+8.3%	0.2%	0.3%	-0.02%	0.02%
Agriculture	17	19	-1.2%	+0.4%	0.1%	0.1%	0.00%	0.00%
Transport	616	861	0.5%	-0.5%	4.2%	4.4%	+0.02%	-0.02%

Source: PRIMES.

A sensitivity analysis on investment costs has been done for electricity production from solar and wind energy, new fuels, and heat pumps, *i.e.* technologies at the core of the Commission proposal on a Net Zero Industry Act (NZIA) and that will be critical as enablers of the EU's decarbonisation objectives. Over the past decades, the cost of low carbon technologies has decreased sharply as a result of technological progress and learning-by-doing. However, as demand for renewable technologies and electrification - and for the raw materials needed for their production - are set to increase globally, these sectors could potentially be subject to price shocks or sustained price pressures. This would depend on the capacity of global markets to respond to that demand, on the ability of circular economy policies to create a resource base for "secondary" materials production in the EU, and on the capacity of the EU to create a domestic value chain for primary materials. A 20% increase in investment costs for the four NZIA-covered technologies would increase annual energy system investment needs (excluding transport) in 2031-2040 by 5.5%, 6.1% and 6.3%, respectively under S1, S2 and S3. However, such a cost increase would only affect newly installed capacity during the period of the price shock, and not the entire stock of assets. In this regard, a price shock on renewable technologies (or raw materials needed for their production) is fundamentally different from a price shock on fossil fuels.

Net-zero technologies are at the centre of strong geostrategic interests and at the core of the global technological race, as exemplified by the United States' Inflation Reduction Act and China's dominance in manufacturing of some cleantech. In this context, the Net-Zero Industry Act is part of the actions announced in the Green Deal Industrial Plan of February 2023, aiming at simplifying the regulatory framework and improving the investment environment for the Union's manufacturing capacity of technologies that are key to meet the Union's climate neutrality goals and energy targets. The investments needed to build EU-based manufacturing capacity for five key net-zero technologies (wind, solar PV, electrolysers, batteries and heat pumps) are estimated at approximately billion EUR 23 for the decade 2031-2040. Two thirds of total investments are for battery manufacturing, one fifth to one quarter are for manufacturing of wind technologies, and electrolysers, solar PV and heat pumps each represent between 2 and 6% of the total. This level of investment needs takes into account that investments in manufacturing capacity already take place by 2030.

6.4.3 Energy system costs and other mitigation costs

Energy system costs ([80]) are one of the important factors driving the competitiveness of EU businesses. This Impact Assessment is based on model results, reflecting adopted legislation under the FF55 package (see Section 1.4.1), existing National Energy and Climate Plans ([81]) and understanding of the possible evolution of technologies and costs.

6.4.3.1 Energy system costs for the whole economy

The total energy system–costs - including capital costs and energy purchase costs for both the supply and demand sectors –[82])([83]) - that result from the modelling are projected to be only slightly higher for the more ambitious scenarios in 2031-2040. System costs are 1.5% higher under S3 than under S2, while they are only 2.1% lower under S1 than under S2. The moderate increase in system costs that parallels increases in mitigation targets in 2040 are driven by higher investment needs in 2031-2040, which translate into higher annual capital costs. A higher cost of energy purchases under S3 than under S2 also contributes to the increase in overall energy system costs.

When contrasted with the situation in 2011-2020, however, the shift in the composition of total energy system costs from energy purchases to capital costs is very clear under all three scenarios. Total energy system costs (including carbon revenues) in 2031-2040 range from 12.4% of GDP under S1 to 12.9% under S3. This is around the 2021-2030 average and represents a moderate increase from an average of 11.9% of GDP in 2011-2020. While energy purchases represented 9.2% of GDP in 2011-2020, they are projected to amount to 7.8% of GDP in 2031-2040 under S2. In contrast, capital costs are projected to increase from 2.7% of GDP in 2011-2020 to 4.9% in 2031-2040 (Table 18). The benefits of higher investment levels in terms of lower energy purchase are therefore very clear.

([80]) While energy system modelling captures the energy system costs well, the costs associated with the transition are broader. Rapid structural change will lead to the devaluation of equipment and other assets in several industrial sectors, notably in fossil fuels extraction and processing.

([81]) "Current" at the time of publication, i.e. the NECPs submitted in 2020. Future climate and energy assessments will take into account the final NECPs updates (2024), including for nuclear capacity.

([82]) The total energy system costs considered here includes capital costs (for energy supply installations such as power plants and energy infrastructure, as well as investment in buildings for energy efficiency related renovation, purchase of end-use equipment and appliances as well as energy related equipment for transport) and energy purchase costs. For transport, the "capital cost" covers only additional capital costs for improving energy efficiency or for using alternative fuels, including alternative fuels infrastructure.

([83]) Capital cost is computed as the annualisation of overnight investment considering a weighted average cost of capital of 10%, which reflects both financing and opportunity cost.

Table 18: Energy system costs profiles across options (2031-2040, annual average)

	Billion EUR 2023		% change vs. S2		% GDP		Deviation vs. S2 (% GDP)	
	2011-2020	S2	S1	S3	2011-2020	S2	S1	S3
Total energy system costs	1766	2472	-2.1%	+1.5%	11.9%	12.7%	-0.27%	+0.19%
Industry*	270	410	-3.4%	+2.3%	1.8%	2.1%	-0.07%	+0.05%
Tertiary**	312	397	-0.5%	+0.5%	2.1%	2.0%	-0.01%	+0.01%
Residential	620	850	-1.4%	+1.0%	4.2%	4.4%	-0.06%	+0.04%
Low-income households	221	316	-1.5%	+1.0%	1.5%	1.6%	-0.02%	+0.02%
Transport	564	815	-3.1%	+2.0%	3.8%	4.2%	-0.13%	+0.08%
Road transport	467	485	-1.5%	+1.9%	3.2%	2.5%	-0.04%	+0.05%
Capital costs	407	956	-1.8%	+1.7%	2.7%	4.9%	-0.09%	+0.08%
Industry*	17	85	-3.2%	+1.6%	0.1%	0.4%	-0.01%	+0.01%
Tertiary**	51	137	-2.1%	+2.4%	0.3%	0.7%	-0.02%	+0.02%
Residential	251	490	-1.9%	+1.6%	1.7%	2.5%	-0.05%	+0.04%
Low-income households	78	176	-2.2%	+1.7%	0.5%	0.9%	-0.02%	+0.02%
Transport	87	243	-1.1%	+1.6%	0.6%	1.3%	-0.01%	+0.02%
Road transport	56	152	+0.9%	-1.3%	0.4%	0.8%	+0.01%	-0.01%
Energy purchases	1359	1516	-2.3%	+1.3%	9.2%	7.8%	-0.18%	+0.10%
Industry	253	325	-3.4%	+2.5%	1.7%	1.7%	-0.06%	+0.04%
Tertiary**	261	259	+0.3%	-0.5%	1.8%	1.3%	0.00%	-0.01%
Residential	369	360	-0.7%	+0.3%	2.5%	1.8%	-0.01%	+0.01%
Low-income households	143	140	-0.6%	+0.2%	1.0%	0.7%	-0.00%	+0.00%
Transport	476	572	-3.9%	+2.1%	3.2%	2.9%	-0.11%	+0.06%
Road transport	412	334	-2.5%	+3.4%	2.8%	1.7%	-0.04%	+0.06%

*Note: *includes cost to abate industrial process CO_2 emissions. ** includes energy related costs in services and in agriculture.*

Source: PRIMES.

Total energy system costs as a share of GDP are projected to gradually decreases under all three scenarios after 2040 as energy purchases continue to decline in relative terms, while capital costs remain broadly constant at around 4.8% of GDP. Total energy system costs are projected at around 11.3% of GDP in 2041-2050 under all three scenarios, lower than the level in 2011-2020. The LIFE setting shows that circular economy actions and more sustainable lifestyles can limit the costs associated with investments and fuel use by up to 0.2 percentage points in 2031-2040, and 0.5 percentage points in 2041-2050.

An important driver is the cost of net fossil fuels imports, which represented about 2.2% of GDP in 2010-2021 and 4.1% during the energy crisis in 2022[84]. The EU's climate and energy policies by 2030 and the pathways to climate neutrality considerably reduce the exposure of the energy system to fossil fuel price shocks. As the energy system decarbonises, fossil fuel imports decrease over time ([85]) to 1.4% of GDP over 2031-2040 and down to 0.6% in 2041-2050, contributing directly to limiting the energy system cost

([84]) Based on Eurostat's trade data for CN code 27, with the exclusion of codes 2712, 2714, 2715 and 2716.
([85]) Despite assuming growing international fossil fuel prices over time – see Annex 6.

(Table 19). On the other hand, it increases the EU demand for raw materials and, possibly, the EU dependence on imports from other countries for low-carbon technologies.

Table 19: Average annual economy-wide energy system costs (billion EUR)

	2011-2020	2021-2030	2031-2040			2041-2050		
			S1	S2	S3	S1	S2	S3
Total energy system costs								
Billion EUR	1766	2130	2419	2472	2508	2508	2527	2530
% GDP	11.9%	12.5%	12.4%	12.7%	12.9%	11.2%	11.3%	11.3%
Fossil fuel imports								
Billion EUR	336	427	293	277	265	150	142	133
% GDP	2.3%	2.5%	1.51%	1.42%	1.36%	0.67%	0.63%	0.59%

Source: PRIMES.

The EU's future energy system will be characterised by a growing use of electricity, largely based on renewables. Electricity production costs are expected to be comparable across all scenarios in 2040. The cost structure will evolve towards a capital-based system, albeit at a different pace depending on the scenario: the share of fuels (fossil fuels, biomass, nuclear fuel) in total costs decreases to 22-13% depending on the level of decarbonisation and of associated remaining fossil fuels in 2040.

Table 20: Average electricity production cost

	2040				2050
EUR23/MWh	**S1**	**S2**	**S3**	**Δ LIFE**	**(S3)**
Average production cost, of which	97	96	94	-0.7%	87
Fuels (incl. taxes and ETS payments)	22%	16%	13%	-0.6%	13%
Capital cost	47%	51%	54%	+0.5%	53%
O&M cost	32%	33%	32%	+0.1%	34%

Source: PRIMES

6.4.3.2 Energy costs and prices for businesses

Energy system costs for the demand sectors (sectors others than those of energy or electricity production) are similar across scenarios for industry and tertiary sectors. As a share of gross value added and in comparison, with the level of the current decade, these costs are projected to decline over time for tertiary sectors, on account of lower energy purchases in relative terms.

As far as industry is concerned, the implementation of low-carbon processes, particularly carbon capture and storage, leads to higher capital-related costs for the scenarios with higher ambition. Capital-related costs under S3 are 1.6% higher than under S2 in 2031-2040 while energy purchases increase by 2.5%, in line with the level of decarbonisation and the role of e-fuels to substitute remaining fossil fuels. In turn, the lower ambition under S1 than S2 enables a reduction in capital costs and energy purchases of only about

3%. Overall, the limited increase in energy purchases across scenarios leads to a moderate increase in energy system costs as a share of gross value added in 2031-2040 compared to earlier periods, before a stabilisation thereafter.

In the tertiary sector, the increase in total energy system costs resulting from higher climate ambition is more limited (+0.5% in S3 compared to S2 and -0.5% in S1 compared to S2, for 2031-2040). Higher levels of investment in energy-efficient equipment and to renovate buildings result in lower energy purchases under S3 than under both S2 and S1. Capital-related costs in 2031-2040 are 2.4% higher under S3 than S2, but this is partly compensated by a reduction of 0.5% in energy purchases. Given that the largest part of companies in the tertiary sector are SMEs (62% of the gross value added of the sector, nearly 70% of employment by the sector) and that 65% of SMEs are in services, the effects on this sector are well representative of the impact on SMEs.

Table 21: Average annual energy system costs for businesses (billion EUR)

	2031-2040				2041-2050			
	S1	**S2**	**S3**	**Δ LIFE**	**S1**	**S2**	**S3**	**Δ LIFE**
Industry & Tertiary	791	807	819	-20	881	885	886	-52
Capital-related cost*	224	234	241	-7	277	281	285	-14
Energy purchases	567	574	578	-14	604	603	601	-38
Industry	397	410	420	-16	462	467	470	-41
Capital-related cost	83	85	87	-3	114	116	117	-9
Energy purchases	314	325	333	-13	348	350	352	-31
Tertiary**	394	397	399	-4	419	418	417	-11
Capital-related cost*	134	137	141	-3	150	151	153	-3
Energy purchases	260	259	258	-2	269	267	264	-8

*Note: * includes investment in energy efficient renovation of services buildings. ** includes energy-related cost in "services" and in agriculture. "ΔLIFE" compares the cost of the LIFE scenario to the S3 scenario, which both meet the same overall net GHG reductions by 2040.*

Source: PRIMES.

Table 22 shows the average electricity prices for industry and services in 2040 and 2050. They remain fairly stable in the long run with very similar patterns across scenarios, reflecting electricity production system costs shifting to lower operating costs and higher capital-related costs. Low carbon capacity progressively substitutes CO_2-emitting assets driving the system to a more capital-based structure which is less exposed to fossil fuel prices.

Table 22: Average final price of electricity for businesses

EUR23/MWh	2040	2050
Industry	130-131	131-133
Services	249	255

Note: The electricity prices shown here reflect the evolution of the average electricity production costs to supply these sectors (i.e., considering their load profile) as well as the taxes applied to the sectors.

Source: PRIMES.

Table 23 shows the share of energy related costs in total production costs for the different scenarios for all industries and differentiated between energy intensive and non-energy intensive industries (EIIs and non-EII) ([86]). For the industrial sector as a whole, the difference across scenarios in 2031-2040 is limited, with higher climate ambition translating into only mildly higher energy related costs.

Table 23: Share of energy-related costs in total production costs in industry

		2031-2040				2041-2050	
		S1	**S2**	**S3**	***ΔLIFE***	**S3**	***ΔLIFE***
All	Energy related cost	3.8%	3.9%	4.0%	*-0.15pp*	4.0%	*-0.34pp*
	fuel expenses	3.0%	3.1%	3.2%	*-0.12pp*	3.0%	*-0.26pp*
	capital and other costs	0.8%	0.8%	0.8%	*-0.03pp*	0.9%	*-0.08pp*
EIIs	Energy related cost	10.2%	10.7%	11.0%	*-0.55pp*	11.5%	*-1.31pp*
	fuel expenses	7.9%	8.3%	8.5%	*-0.44pp*	8.6%	*-1.01pp*
	capital and other costs	2.3%	2.4%	2.5%	*-0.11pp*	2.9%	*-0.30pp*
non-EIIs	Energy related cost	1.63%	1.62%	1.63%	*-0.02pp*	1.48%	*0.02pp*
	fuel expenses	1.36%	1.35%	1.36%	*-0.02pp*	1.13%	*-0.02pp*
	capital and other costs	0.27%	0.27%	0.27%	*0.00pp*	0.35%	*-0.01pp*

Note: "ΔLIFE" compares the cost of the LIFE scenario to the S3 scenario, which both meet the same overall net GHG reductions by 2040.

Source: PRIMES.

There is a more marked difference across scenarios for EIIs. For these industries, which account for about 25% of total manufacturing value-added ([87]), the share of energy-related costs in total production costs is 0.3 percentage points higher (corresponding to a 3% increase in energy system costs) in 2031-2040 in S3 than in S2. A lower level of ambition under S1 generates leads to a moderately lower energy system cost by 0.5 percentage points of total production costs compared to S2 (corresponding to a 4.4% decrease). The bulk of the difference comes from fuel expenses, while capital costs remain fairly similar across scenarios. Novel low-carbon technologies replace conventional processes, allowing a reduction in the purchase of fossil fuels, while, at the

([86]) "EIIs" covers iron & steel, non-ferrous metals, chemicals, non-metallic minerals, paper & pulp.
([87]) Estimate based on a wide definition of the EII ecosystem, economy-wide gross value added and gross valued added in the manufacturing sector (NACE 2 code C)

same time, in scenarios with higher emission reductions by 2040, larger quantities of e-fuels are used. The EU put in place the Carbon Border Adjustment Mechanism (CBAM)([88]) to avoid carbon leakage by ensuring that the carbon price of imports in key EIIs is equivalent to that paid by producers in the EU.

In non-EIIs, which represent the majority of total manufacturing value-added and include many SMEs (see the SME test Annex), the share of energy-related costs in total production costs is much smaller and scenario S3 shows virtually no difference compared with S2 in 2031-2040, even though there is a 1% increase in energy system costs in absolute terms.

The LIFE setting shows how circular economy, material and energy efficiency actions contribute to limiting the share of energy related costs in EIIs. Among others, decrease of scrap export and increased recycling allows for a larger secondary production share, and significant savings in the more expensive e-fuels necessary for the decarbonisation of primary processes.

6.4.3.3 Costs related to mitigation of GHG emissions in the LULUCF sector and non-CO2 GHG emissions

Table 24 provides an overview of the average annual costs in the LULUCF sector and for non-CO2 emissions in the different scenarios. The costs are related to the implementation of abatement technologies or nature-based removal solutions. The technical available potential for nature-based removals and mitigation measures differs between the two decades, leading to varying annual costs across decades, as the entire potential up to the respective maximum carbon value is implemented.

Table 24: Costs related to mitigation of GHG emissions in the LULUCF sector and non-CO2 GHG emissions by decades

Average annual costs [EUR 2023 billion/year]	**2031-2040**			**2041-2050**			**2031-2050**		
	S1	**S2**	**S3**	**S1**	**S2**	**S3**	**S1**	**S2**	**S3**
Mitigation of LULUCF GHG emissions	1.1	2.5	2.5	1.6	2.8	2.8	1.3	2.7	2.7
Mitigation of non-CO2 GHG emissions	0.0	0.7	3.4	3.9	4.1	5.0	2.0	2.4	4.2
- of which in the agriculture sector	0.0	0.4	3.2	3.8	3.9	4.8	1.9	2.2	4.0

Source: GLOBIOM, GAINS.

S1 does not assume specific LULUCF and non-CO2 policies in 2040, showing smaller mitigation costs for the 2031-2040 period. Both sectors have to contribute to meeting climate neutrality in 2050 also in that scenario, which entails some mitigation action and associated costs in the last decade 2041-2050.

([88]) CBAM covers cement, iron and steel, aluminium, fertilisers, as well as electricity and hydrogen.

For LULUCF, additional nature-based removals such as improved forest management, afforestation or rewetting are applied in S2 and S3 by 2040. The associated average annual cost in these scenarios amount to EUR 2.5 billion in 2031-2040 and EUR 2.8 billion in 2041-2050.

The average annual costs associated to mitigation of non-CO2 emissions over the 2031-2040 period are around EUR 0.7 billion per year in S2 and around EUR 3.4 billion per year in S3. Over the 2041-2050 period, the average annual costs are higher than in the previous decade: EUR 3.9 billion in S1, EUR 4.1 billion in S2, and EUR 5 billion in S3. Most of the annual mitigation costs take place in the agriculture sector, which represents the bulk of the unabated non-CO2 GHG emissions post-2030. The sectoral mitigation costs of the sector are reflected in the macro-economic analysis presented in section 6.4.1.

6.4.4 Social impacts and just transition

6.4.4.1 Fuel expenses, energy and transport poverty

Energy-related expenses represent a significant share of total expenditure for a large proportion of EU households, in particular middle- and low-income households. The recent increase in energy prices has had strong negative social impacts and increased the rates of energy (and transport) poverty. Assessing the implications of this initiative on energy system costs for households is therefore of critical importance.

The following assessment is based on modelling results, reflecting the current legislation, and understanding of the possible evolution of technologies and costs. This assessment will feed into the development of the future policy framework and support measures in the coming years to meet the 2040 target, which will determine the actual costs and how they impact individuals, regions, and society.

The cost structure is characterised by an increase of capital-related costs due to the purchase of more efficient appliances and the investment for enhancing the insulation of dwellings. This allows avoiding an increase in energy purchases despite the assumed increase in international fossil fuels prices over time, the impact of carbon pricing and the diffusion of new non-fossil fuels.

The relative importance of energy-related costs for households in private consumption is projected to decline in 2031-2040 compared to 2021-2030, due to the decreasing importance of fuel purchases in all scenarios. Early action in S3, driven by larger direct efficiency investments (see Section 6.4.2), also translates into a slightly higher share of energy-related costs in S3. It then represents 8.2% of private consumption as opposed to 8.0% in S1 and 8.1% in S2 (see Table 25). Energy purchases and electricity price are projected to be very similar across scenarios.

Table 25: Average annual energy system costs as % of private consumption and average final price of electricity for households in the residential sector

Average Annual Energy System Cost								
EU27 – Average across all income categories	**2031-2040**				**2041-2050**			
	S1	**S2**	**S3**	**ΔLIFE**	**S1**	**S2**	**S3**	**ΔLIFE**
Total (% of private consumption)	8.0%	8.1%	8.2%	-0.12pp	7.1%	7.1%	7.1%	-0.14pp
*Capital related costs**	*4.5%*	*4.6%*	*4.7%*	*-0.08pp*	*4.1%*	*4.1%*	*4.1%*	*-0.01pp*
Energy purchases	*3.4%*	*3.5%*	*3.5%*	*-0.04pp*	*3.0%*	*3.0%*	*3.0%*	*-0.13pp*
EU27 – Low Income Categories	**S1**	**S2**	**S3**	**ΔLIFE**	**S1**	**S2**	**S3**	**ΔLIFE**
Total (% of private consumption)	14.0%	14.3%	14.4%	-0.20pp	12.0%	12.0%	12.1%	-0.25pp
Capital related costs	*7.8%*	*7.9%*	*8.1%*	*-0.13pp*	*6.5%*	*6.5%*	*6.6%*	*-0.01pp*
Energy purchases	*6.3%*	*6.3%*	*6.3%*	*-0.07pp*	*5.5%*	*5.5%*	*5.4%*	*-0.25pp*
Electricity Price (EUR/MWh)**								
Residential	288	288	288	-0	289	290	290	-0

*Note: * includes purchase of appliances and cost of renovation. "ΔLIFE" compares the cost of the LIFE scenario to the S3 scenario, which both meet the same overall net GHG reductions by 2040. ** Average final price of electricity. The electricity price shown here reflects the evolution of the average electricity production cost to supply the sector (i.e., considering its load profile) as well as the taxes applied to the sector.*

Source: PRIMES.

Modelling projections also show that capital related cost (including the purchase of appliances and cost of renovation) as a share of private consumption are higher for low-income households than for the average household (8.1% in low-income households compared to 4.7% on average over 2031-2040 in scenario S3, which is a relative increase with respect to S2 of 0.13 percentage points in low-income households and 0.07 percentage points on average). Low-income categories often live in relatively less well insulated homes, in most need of renovation. For low-income households, the capital-related costs as a share of private consumption are 0.2 percentage point higher in S3 than in S2 for 2031-2040. Specific social measures are needed to ensure a just and fair transition (see Annex 9).

Table 26: Average annual energy system costs of road transport (% of total private consumption), and average final price of electricity in private transport

Average Annual Energy System Cost								
EU27 – Average across all income categories	**2031-2040**				**2041-2050**			
	S1	**S2**	**S3**	**ΔLIFE**	**S1**	**S2**	**S3**	**ΔLIFE**
Total	3.7%	3.8%	3.8%	-0.19pp	2.3%	2.3%	2.3%	-0.23pp
*Capital related costs**	*1.3%*	*1.2%*	*1.2%*	*-0.04pp*	*1.1%*	*1.1%*	*1.1%*	*-0.10pp*
Energy purchases	*2.4%*	*2.5%*	*2.6%*	*-0.15pp*	*1.2%*	*1.2%*	*1.2%*	*-0.13pp*
Electricity Price (EUR/MWh)**								
Private transport	*223*				*223*			

*Note: "ΔLIFE" compares the cost of the LIFE scenario to the S3 scenario, which both meet the same overall net GHG reductions by 2040. * This covers only the additional capital costs for improving energy efficiency or for* *using alternative fuels. ** Average final price of electricity. The electricity price shown here reflects the evolution of the average electricity production cost to supply the sector (i.e., considering its load profile) as well as the taxes applied to the sector.*

Source: PRIMES.

Similarly, a higher degree of mitigation ambition is also linked to slightly higher total energy system costs in road transport[89], which represent 3.7%, 3.8% and 3.8% of private consumption respectively in S1, S2 and S3 (see Table 26) and correspond to a relative increase of 0.07 percentage points in S3 compared to S2 and a 0.10 percentage point decrease in S1. A limited decrease of capital costs from S1 to S3 is observed, and a moderate increase of energy purchase linked to a larger consumption of e-fuels in S3. The LIFE analysis shows that a more sustainable mobility can reduce energy purchases, by an order of magnitude of about 0.2 percentage points of private consumption in 2031-2041 and in 2041-2050.

The more ambitious the scenario, the quicker the dependence to fossil fuels is reduced, allowing households in Europe to be better protected from future fossil fuel price shocks.

6.4.4.2 Distribution

Section 6.4.4.1 assesses the impact of changes in energy and transport related expenses on households. Beyond this, impacts on relative prices throughout the economy are susceptible to affect households in differentiated manners. The JRC-GEM-E3 model and micro-data from the household budget survey were used to assess the potential impacts.[90] (A macro-economic model is better suited to capture the full effects and interactions across sectors that affect relative prices). Changes in relative prices are projected to differ relatively little across scenarios, though the relative price of housing is likely to be higher under S2 and S3 than under S1, as higher levels of renovation increase costs for homeowners and renters alike (see Annex 8 for details). Similarly, energy purchases for transport by households are projected to increase with a higher level of mitigation in 2040.

Linking these estimated changes in relative prices to micro-data from the household budget survey, the JRC estimated distributional impacts per expenditure and income decile. This shows that lower income households will be more affected than higher income households, as measured in terms of compensating variation, i.e. the monetary transfer that would be necessary to maintain the same level of utility as under the past set of relative prices. Assuming that none of the additional revenues from ETS are redistributed to households to temper impacts, the welfare impact of S2 would amount to less than -0.5% (% of total expenditure) for the lowest expenditure deciles, and about -

[89] The details of the total transport expenditures of households (including total capital costs) are provided in Annex 8.

[90] The analysis benefited from inputs from two joint projects between Directorate-General Employment, Social Affairs and Inclusion (DG EMPL) and the Joint Research Centre (JRC) of the European Commission: "Assessing and monitoring employment and distributional impacts of the Green Deal (GD-AMEDI)" and "Assessing distributional impacts of geopolitical developments and their direct and indirect socio-economic implications, and socio-economic stress tests for future energy price scenarios (AMEDI+)". See https://ec.europa.eu/social/main.jsp?langId=en&catId=1588.

0.3% for the highest expenditure decile. The effects would be larger under S3 at about -1.2% and -0.8%, respectively. Redistributing some of the additional carbon revenues at national or EU level would sharply reduce this negative impact on the lower expenditure deciles.

6.4.4.3 Employment

The aggregate employment impacts of S2 and S3 differ only slightly from S1, which already factors in the transformation of the EU economy to climate neutrality by 2050, with a lower 2040 target. The labour market and social implications of the transition itself, however, will be concentrated in some specific sectors. It will entail opportunities but also challenges, particularly in terms of skills availability and reallocation of the labour force across sectors and occupations. This analysis focuses on the implications of the transition for the most affected sectors more than on the comparison of impacts across scenarios. In parallel to decarbonisation, other factors will also impact the labour market: ageing of the population, decline in the working age population and other trends fully independent from climate policy, including technological changes and the uptake of artificial intelligence.

Modelling under JRC-GEM-E3 projects that recent trends in sectoral employment (increase in the share of services in employment and decrease in the share of industry and manufacturing), are set to continue across the different scenarios, which display very similar patterns by 2040 (Table 27). The flipside of the increase in the share of service sector jobs is a gradual decrease in the share of employment in energy intensive industries, consumer goods industries and transport equipment. The share of employment in other equipment goods, however, is projected to remain stable as the transition should increase EU and global demand for the type of equipment needed for decarbonisation. While output in energy intensive industries, consumer goods industries and transport equipment are projected to grow significantly between 2015 and 2040, they will be outpaced by overall GDP growth. However, in the context of a declining aggregate level of employment, driven by a shrinking labour force, these sectors' share of employment (and absolute employment) are projected to decline over the coming decades.

Employment in fossil fuel industries is expected to be at negligible levels in 2040 and 2050. In contrast, market and non-market services together represent more than 60% of total employment. Given the downward trend in employment in sectors where men are more represented alongside an upward trend in services, the transition is expected to have a limited or positive impact on women's employment. Annex 8 further assesses the implications of the transition for the labour market and skills requirements by considering the potential opportunities arising from investment needs. Employment opportunities should be particularly significant in areas related to the renovation of the building stock, the transition to decarbonised sources of heating and cooling (heat pumps) and the electrification of the economy, including the large-scale installation of renewable sources of electricity.

Table 27: Sectoral employment, share in total employment (%)

	2020	2030	2040			2050
			S1	S2	S3	S3
Fossil fuel industries	0.13%	0.11%	0.07%	0.06%	0.05%	0.05%
Energy intensive industries	6.7%	6.5%	6.2%	6.1%	6.2%	5.9%
Transport equipment	2.1%	2.0%	1.9%	1.9%	1.9%	1.8%
Other equipment goods	6.3%	6.1%	6.1%	6.1%	6.1%	6.1%
Consumer goods industries	4.4%	4.2%	4.1%	4.1%	4.0%	3.9%
Transport	3.6%	3.9%	3.7%	3.7%	3.7%	3.7%
Construction	7.8%	7.6%	7.6%	7.7%	7.7%	7.7%
Market services	34.0%	34.6%	35.0%	34.9%	34.9%	35.3%
Non-market services	26.6%	27.1%	27.3%	27.3%	27.3%	27.5%
Agriculture	3.5%	3.3%	3.1%	3.1%	3.1%	2.8%
Forestry	0.4%	0.3%	0.4%	0.5%	0.5%	0.4%
Other	4.4%	4.3%	4.5%	4.6%	4.6%	5.0%

Note: In this table, "transport" does not include storage.

Source: JRC-GEM-E3 model.

Further, major opportunities for employment creation should arise from the development of manufacturing capacity for green technologies, mainly solar photovoltaic and solar thermal, wind power generation, battery and storage facilities, heat pumps, electrolysers and fuel cells, sustainable biogas and biomethane, carbon capture and storage and grid technologies. Boosting the EU manufacturing capacity in these sectors is at the core of the Net Zero Industry Act proposal, and it will necessitate corresponding efforts to ensure that the skills needs are developed among the EU's labour force. The transition will require accompanying policies at the regional and sectoral levels to ensure that reskilling and retraining opportunities are available for workers who need them.

6.4.4.4 Regional impacts

The transition to a low-carbon economy will have heterogenous impacts on regions within the EU. The decarbonisation of production capacities, the transformation of the energy system, the need to develop an industrial carbon management system and the evolution of the land sector will all affect regions differently.

Regions with a relatively high share of employment in sectors most impacted by the transition are more exposed to the transition (see details in Annex 8). This includes the regions with a high share of employment in sectors that are being phased out in several countries (mining of coal, lignite and oil shale; extraction of crude petroleum, natural gas and peat; refining of petroleum products), in energy intensive sectors, as these will have to produce the same goods differently (manufacturing of chemicals and chemical products, manufacturing of other non-metallic mineral products, manufacturing of basic metals), and in sectors that will have to produce different goods (manufacturing of motor vehicles, trailers and semi-trailers) ([91]). In 2020, only two EU regions (NUTS-2 level) had employment shares of more than 1% of direct employment in coal and lignite mining, crude petroleum, and natural gas extraction, with potential wider local impacts due to indirect employment The employment and social consequences of the decline in extraction activities needs to be mitigated, in line with the European Green Deal's objective of leaving no region behind (see Annex 9). When considering energy intensive industries or industries that will have to produce different goods (e.g. automobile sector), more regions will be affected. In these regions and territories, the employees from these sectors will have specific reskilling needs. In regions where the automobile sector represents a high share of the economic activity, the move to the manufacturing of electricity vehicles requires companies in the supply chain to adjust their business models. The transition will be faster in S3 than in S2 and faster in S2 than in S1. Regions that are particularly impacted by the transition need to be accompanied and supported (see examples of EU and national measures and programmes in Annex 9).

All scenarios require a decrease of fossil fuels and a strong growth of renewable energy for electricity production. This will entail different opportunities and challenges for regions: reconversion of fossil fuel producing regions, opportunities to develop local resources and create jobs where the renewable energy potential is the largest, and infrastructure development challenges to connect electricity producing centres with consuming centres. These opportunities and challenges will be more acute in S3, which has the largest increase of electricity production needs, 6% higher than in S2, while S1 is 7% lower than S2. The development of an industrial carbon management system will require the development of a full supply chain and of the necessary infrastructure to link CO2 emitting energy supply and industrial sites to carbon storage or usage sites (notably to produce e-fuels). The territories with strong presence of energy intensive industries (e.g., cement production, chemicals industries, etc) will have to anticipate and develop the corresponding capacities. The scenarios show a very different picture in 2040: while projections for S1 are around 80 MtCO2 of capture, S2 exceeds 200 MtCO2 and S3 gets close to 350 MtCO2, where virtually all regions hosting CO2 emitting industrial process sites would be concerned.

The need to maintain and enhance LULUCF net removals and to curb GHG emissions from the agriculture sector will mostly affect rural regions. Territories where agriculture plays a major role and where associated emissions are currently the highest will have to achieve a larger deployment of technologies and practices to reduce GHG emissions in S2 or S3 than in S1. A shift in society towards a healthier and more sustainable food system, as in LIFE, means a higher uptake of more extensive farming practices with opportunities to generate revenues from nature-based removals activities.

Innovation capacity, the level of instruction and the quality of infrastructure contribute to the preparedness of regions for the transition. Annex 9 provides examples of EU and national measures and programmes that can support regions for the transition. The EU's cohesion policy plays an important role.

([91]) See also OECD (2023), Regional Industrial Transitions to Climate Neutrality, OECD Regional Development Studies, OECD Publishing, Paris.

7 HOW DO THE TARGET OPTIONS COMPARE?

The different target options are compared based on the results of the analysis of the different representative scenarios shown in section 6. The target Option 2 serves as the "baseline" target level (see section 5.1).

7.1 Effectiveness

7.1.1 Specific objectives

The effectiveness of the different target options is assessed against the different specific objectives defined in section 4.

The capacity to secure the delivery of climate neutrality by 2050 (specific objective SO1) is measured in terms of overall and sectoral progress of required GHG reductions between 2030 and 2050 achieved by 2040 for the different target options. Option 1 covers only half the necessary overall reductions throughout the period, with sectoral progress ranging from 9% to 68% only. Compared to the baseline Option 2, Option 1 delays to the last decade significant sectoral reductions, including in the hard-to-abate sectors, and the development of carbon removals (see sections 6.1.1 and 6.1.2), putting at risk the achievement of climate neutrality by 2050. Conversely, Option 3 anticipates the importance to implement reductions in all sectors and to deploy carbon removals, with 77% of the overall needed reductions over 2030-2050 achieved by 2040, ranging from 58% to 93% across sectors, thus securing a higher capacity to deliver climate neutrality by 2050 than Option 2.

In terms of climate performance and importance to minimise the GHG budget (SO2) to contribute to the global Paris Agreement temperature goals, Option 3 leads to a lower GHG budget over 2030-2050 of at most 16 GtCO2-eq (11% lower than option 2), against 18 GtCO2-eq for option 2, and 21 GtCO2-eq for option 1 (17% higher than option 2).

Table 28: Effectiveness: Delivering climate neutrality and GHG budget

Specific objective		Assessment criteria		Option 1	Option 2	Option 3
SO1	Delivering climate neutrality	GHGs reductions achieved in 2040 as a % of needed over 2031-2050	Total net GHGs	*50% (-15 pp vs Option 2)*	*65%*	*77% (+ 12 pp vs Option 2)*
			Sectors* (min / max)	*9% / 68%*	*55% / 88%*	*58% / 93%*
SO2	Minimising GHG budget	Cumulative GHG emissions over 2030-2050 (GtCO2-eq)		*21 (+17% vs Option 2)*	*18*	*16 (-11% vs Option 2)*

*Note: *Sectors described in section 6.1.1. **Assuming net zero being reached in 2050 and linear interpolation of net GHGs between 2030 and 2040 and between 2040 and 2050.*

In terms of just transition (SO3), the difference in energy costs for households is limited compared to Option 2. Option 1 is lower by 1.4% in the residential sector (1.5% for low-income households) and by 1.5% in road transport. Energy costs for households under Option 3 are 1% higher in the residential sector (also for low-income households) and 1.9% higher in road transport.

The effect of competitiveness (SO4) is measured by the overall energy system cost, the economic output (total GDP and Energy intensive industries) and by the shares on global trade. Overall, the difference between options is limited on all these criteria, and even more so between option 3 and the baseline target option 2.

The overall energy system cost over 2031-2040 is 1.5% higher in option 3 than in option 2, while it is 2.1% lower in option 1 (Table 29).

For industry, total energy system costs in 2031-2040 are 2.3% higher in option 3 than in option 2, and 3.4% lower in option 1 (see Annex 8). For the tertiary sector, they are 0.5% higher in option 3 and 0.5% lower in option 1. For the time period 2041-2050, these differences are smaller and even reverse: for industry, total energy system costs are then 0.6% higher in option 3 than in option 2, and 1.1% lower in option 1. For the tertiary sector, they are 0.3% lower in option 3 and 0.2 higher in option 1. For energy intensive industries, the share of energy-related costs in total production costs vary between 10.2% in option 1 and 11% in option 3 for the time period 2031-2040.

This translates into very limited difference in terms of overall macro-economic impact, with option 3 showing a very minor negative deviation in GDP of -0.2% compared with option 2, and option 1 showing a slight positive deviation of 0.5% compared to option 2. By 2050, there is no difference in GDP levels across scenarios as the impacts are transitory.

The options also differ little in terms of economic output of key EU sectors. For example, for energy intensive industries, it is projected to be 0.2% lower under option 3 than option 2, and 1.4% higher under option 1. As also highlighted by certain stakeholders, what matters more for these industries and other export-oriented sectors than the EU target per se, is the extent to which the industrial sector decarbonises in the rest of the world, both in terms of processes and power supply. In the context of higher mitigation ambition in the rest of the world, output under option 1 is 2.3% lower than under option 2. In option 3, it is almost at the same level as in option 2. This is due to first-mover advantages that benefit EU industries.

Finally, the EU share in global exports varies little across options, with long-term trends dominated by other factors such as regional trade dynamics and trade agreements, or the declining relative share of the EU's population and GDP globally. Higher ambition under Option 3 generates a marginal 0.1 percentage point decrease in the EU's share in global exports compared to Option 2, with Option 1 yielding only a 0.2 percentage point increase.

Section 7.1.2 discusses the financial feasibility for the different actors.

Table 29: Just transition and Competitiveness

Specific objective		Assessment criteria			Option 1 vs 2	Option 3 vs 2
SO3	Just transition	Cost for households (2031-2040)	Residential	Average	-1.4%	+1.0%
				Low income	-1.5%	+1.0%
			Road transport	Average	-1.5%	+1.9%
SO4	Competitiveness	Total system cost (annual average 2031-2040)			-2.1%	+1.5%
		Economic output* (2040)	GDP		+0.5%	-0.2%
			EIIs		+1.4%	-0.2%
		EU shares in global exports (% of world trade, 2040)			+0.2 pp	-0.1 pp

*Note: *Considering fragmented climate action in the rest of the world.*

In terms of deployment of technologies (SO5), option 3 already deploys more than half (54%) of the investment needs to get to climate neutrality by 2050 by 2040, against 48% in Option 2. With only 43% of the investment needs by 2040, Option 1 delays the technological effort towards the last decade (Table 30).

Option 3 leads to the deployment by 2040 of almost two thirds of the renewable electricity capacity compatible with climate neutrality by 2050 (against 56% for option 2), more than half the needed renewable hydrogen production capacity (41% for option 2) and almost three-fourths of the needed carbon capture capacity (against about half for option 2). Conversely, Option 1 delays the deployment of these key technologies to the last decade 2041-2050 (less than half of the renewable capacity installation needs, only about a third of the needed hydrogen production capacity and less than 20% of the carbon capture capacity by 2050 are installed by 2040), thus putting the achievement of climate neutrality by 2050 at risk.

Section 7.1.2 discusses the technological feasibility for the different actors.

In terms of security of energy supply (SO6), in 2040 Option 3 has a lower dependence on fossil fuel imports than Option 2 (26% versus 29%). Option 1 still has a dependence on fossil fuels of 34%. This translates into lower fossil fuel import costs for the EU of about EUR 12 billion (annual average over 2031-2040) in Option 3 compared to Option 2, while Option 1 shows about EUR 16 billion higher costs.

Option 3 shows higher deployment of new technologies, which will lead to a higher consumption of rare and raw materials. However, the nature of these materials allows to a stock to be built up, making the system more resilient than with the combustion of fossil fuel. Moreover, it creates a resource base that can be recycled and reused, which is not possible for fossil fuels. The coherence section (7.3) discusses the interplay with the security of raw materials supply.

Table 30: Effectiveness: Deployment of technologies and security of energy supply

Specific objective		Assessment criteria		Option 1	Option 2	Option 3
SO5	Deployment of technologies	Investment	Progress achieved in 2040 (% 2031-2050)	43%	48%	54%
		RES deployment	Progress achieved in 2040 (% 2031-2050)	47%	56%	64%
		H2 production	Progress achieved in 2040 (% 2050)	32%	41%	54%
		Carbon capture	Progress achieved in 2040 (% 2050)	19%	49%	76%

Specific objective		Assessment criteria	Option 1 vs 2	Option 2	Option 3 vs 2
SO6	Security of energy supply	Energy dependence (2040) (Fossil fuels imports / GAE)	+5pp	29%	-3pp
		Fossil fuel imports costs (2040) (bn EUR 2023)	+6%	277	-4%

Regarding environmental effectiveness (SO7), Option 3 is very similar to Option 2 on all accounts, while Option 1 shows a slightly lower use of bioenergy by 2040 compared to Option 2. The differences in terms of biodiversity impact are expected to remain very limited across all target options (see sections 6.3.3) - the coherence section (7.3) discusses the risks of trade-offs associated to bioenergy use. Finally, the three target options also yield strong and very similar benefits in terms of improved air quality for ecosystems and health (see sections 6.3.3 and 6.3.2).

Table 31: Environmental effectiveness

Specific objective		Assessment criteria	Option 1 vs 2	Option 2	Option 3 vs 2
SO7	Environmental effectiveness	Gross available energy from biomass (EJ)	-1.0	8.8	+0
		Biodiversity	Differences smaller than 0.2% on biodiversity indicators		
		Air quality	Very limited differences across target options, which all show benefits for ecosystems and health compared to current		

7.1.2 Financial and technological feasibility

Financial feasibility

The up-front investment needs and the associated capital costs are the two key indicators of financial feasibility. Most of the early push in investment in 2031-2040 under S3 compared to S2 or S1 that lower the risk of missing 2050 climate objective takes place on the energy supply side, where investors are mainly large private and/or public utilities with good access to finance due to secure and relatively predictable revenue streams. The increase compared to historical investments and the difference across options is much less significant in industry, and takes place in sectors where large companies dominate and where access to long-term finance is likely to be good as well, especially considering a context where industrial policy might be strengthened to maintain a globally competitive industrial base in EU. For buildings the level of investment differs little across options, though the push for gains in energy efficiency will require an increase in the investment to GDP ratio of about 0.4 percentage points in 2031-2040 compared to the level in 2011-2020. A wide range of actors, from individual homeowners to real-estate investors or public authorities (social housing), will be responsible for these investments, with different abilities to access low-cost finance.

Table 32 shows that the annual energy system investment needs (excluding transport) are projected to increase under S2 to 3.3% of GDP in 2031-2040, compared to 1.7% in 2011-2020 (Table 32). Average energy system investment in 2011-2020 was historically low, however, and the increase in the investment to GDP ratio is well within the variability experienced over the past decades. A higher level of climate ambition under S3 in 2040 leads to non-negligible, though macro-economically limited, increases in investment needs (excl. transport) during the first decade, i.e., an increase of 0.4 percentage points compared to S2, while S1 leads to a similar decrease of 0.4 percentage points compared to S2. Over the whole period 2031-2050, the three scenarios require a similar level of investment (excluding transport) of 3.2% of GDP.

Table 32: Average annual investment needs in 2031-2040 (% of GDP and deviation vs. S2)

	% GDP		Deviation vs. S2 (% GDP)	
	2011-2020	S2	S1	S3
Investment needs				
Total	5.8%	7.7%	-0.37%	0.33%
Total excluding transport	1.7%	3.3%	-0.39%	0.36%
Supply	0.5%	1.5%	-0.27%	0.27%
Industry	0.0%	0.2%	-0.04%	0.01%
Residential	0.8%	1.2%	-0.06%	0.06%
Services	0.2%	0.3%	-0.02%	0.02%
Agriculture	0.1%	0.1%	0.00%	0.00%
Transport	4.2%	4.4%	0.02%	-0.02%

Source: PRIMES.

The supply side accounts for the largest differences between the scenarios (+/- 0.27 percentage point of GDP lower or higher than S2 for S1 and S3, respectively). While SMEs and households will play a role in the deployment of renewables, the vast majority of investment on the supply side will be carried out by large private and/or public utilities. The latter have good access to finance on favourable terms, including because their financial flows are relatively secure and predictable, which makes them good candidates to access long-term finance from players like insurance companies or pension funds. The development of green finance instruments will nevertheless be important to ensure that funding is indeed available. In industry, large businesses will bear a significant share of the increase in investment needs. They are likely to have good access to long-term finance and other supports to enhance their competitiveness, and the difference in investment needs across options is quite limited, at +0.05 percentage points of GDP between S1 and S3.

After energy supply, the residential sector is the sector where investment needs increase the most across options (+/- 0.06 percentage point of GDP lower or higher for S1 and S3, respectively). While the range between S1 and S3 is relatively limited at 0.12 percentage points of GDP, it comes on top of a 0.4 percentage point increase between the average for 2011-2020 and the average under scenario 2 for 2031-2040. The feasibility of the increase in renovation investments will hinge upon a range of factors that go well beyond financial issues, some of which are independent from the level of climate ambition, for example, the level of awareness or information on renovation options among households, knowledge about and confidence in contractors. In terms of financial feasibility, the situation will also differ widely according to household type and income level, and whether renovations are driven by individual homeowners or larger companies or public authorities owning real estate assets. In any case, a strong enabling framework will be needed to ensure access to finance at affordable costs for homeowners, or direct support from public budgets.

Table 33: Average annual investment needs (excluding transport) and capital costs (billion EUR 2023 and deviation from S2)

	S2			S1 vs. S2 (bn EUR)			S3 vs. S2 (bn EUR)		
	2031-2040	2041-2050	2031-2050	2031-2040	2041-2050	2031-2050	2031-2040	2041-2050	2031-2050
Up-front investment									
Supply	289	328	308	-53	+49	-2	+52	-46	+3
Demand	355	357	356	-23	+20	-2	+18	-19	-1
Industry	46	24	35	-7	+7	0	+2	-2	0
Residential	237	242	239	-12	+8	-2	+11	-12	0
Services	53	73	63	-4	+5	+1	+4	-6	-1
Agriculture	19	19	19	0	0	0	0	0	0
Total	644	685	664	-76	+69	-4	+69	-66	+2
Annual capital costs *									
Industry	85	116	101	-3	-2	-2	+1	+1	+1
Residential	137	151	144	-3	-1	-2	+3	+2	+2
Tertiary	490	507	499	-9	-5	-7	+8	+4	+6
	S2			**S1 vs. S2 (%)**			**S3 vs. S2 (%)**		
	2031-2040	**2041-2050**	**2031-2050**	**2031-2040**	**2041-2050**	**2031-2050**	**2031-2040**	**2041-2050**	**2031-2050**
Up-front investment									
Supply	289	328	308	-18%	+15%	-1%	+18%	-14%	+1%
Demand	355	357	356	-7%	+6%	0%	+5%	-5%	0%
Industry	46	24	35	-16%	+28%	0%	+4%	-7%	+1%
Residential	237	242	239	-5%	+3%	-1%	+5%	-5%	0%
Services	53	73	63	-7%	+6%	+1%	+8%	-8%	-1%
Agriculture	19	19	19	-1%	+2%	+1%	0%	-1%	0%
Total	644	685	664	-12%	+10%	-1%	+11%	-10%	0%
Annual capital costs *									
Industry	85	116	101	-3%	-2%	-2%	+2%	+1%	+1%
Residential	137	151	144	-2%	-1%	-1%	+2%	+1%	+2%
Tertiary	490	507	499	-2%	-1%	-1%	+2%	+1%	+1%

** includes financing and opportunity costs.*

Source: PRIMES.

This impact assessment considers a target at EU level only and therefore does not assess specific aspects at the level of Member States. National budgets will nevertheless need to contribute to the investment needs either via direct public sector investment, or via support for private investment, subject to the State aid rules where applicable, e.g., to support renovation in the residential sector as described above or to support industrial decarbonisation. The extent to which the public sector will support the transition will vary widely across Member States, depending on national policy choices. The extent to which Member States have fiscal space to fund the transition also varies significantly, depending on their current level of indebtedness and the level of indebtedness that they will have by the start of the next decade. Such factors will impact, among others, their room for manoeuvre under the EU fiscal rules that will prevail at the time and their financing costs on the financial markets. None of this can be predicted at this stage, and this goes well beyond the scope of this impact assessment.

Finally, the difference in investment needs across options in the tertiary sectors and transport sectors are negligible and do not raise issues in terms of the comparison in the financial feasibility across scenarios.

Technological feasibility

All the target options remain within the technology feasibility indicators thresholds used by the ESABCC: primary energy biomass of 20 EJ/year in 2050, a maximum amount of carbon capture of 500 Mt CO2/year, hydrogen production capacity of 150 GW in 2030 and a 20% decline of final energy demand between 2020 and 2030. They also remain lower than the technological deployment challenges identified by the ESABCC for wind and solar installed capacities in 2030, (respectively 900 and 623 GW) ([92]), which considered the implication of conservative potential estimates.

Reducing energy and industry CO2

Any of the options considered will require increasing the rate of deployment of mature technologies such as wind and solar power. Already by 2030, the deployment of wind and solar will increase considerably compared to both the historical average and the highest historical level of deployment reached in 2022 (see Section 1.2.2 of Annex 8). Option 1 leads to a lower level of effort between 2031 and 2040 compared to the 2021–2030 decade but, to reach carbon neutrality by 2050, it requires after 2040 by far the highest growth of wind and solar across all options and periods, with an average annual installation rate over the decade 2041-2050 more than twice the level achieved in 2022. This trend (a reduction in ambition followed by a very steep acceleration) appears counterintuitive and might put the climate neutrality target at risk. Option 3 anticipates decarbonisation of the power sector in the years 2031-2040 with lower effort required up to 2050. The trajectory of Option 3 is safer as it leaves more flexibility in the last years to cope with delays and unexpected developments. Option 2 lies in between Option 1 and Option 3. The growth of wind and solar power is also described in position papers collected during the public consultation, where the deployment rate for these two

([92]) ESABCC report Table 5 and Table 6.

technologies is projected to increase several times in the 2020-2040 period. Each of the options considered will increase the need for critical raw materials. In the 2031–2040-decade, Option 3 will require more raw materials than the other options considered. However, the increase in global supply for raw materials such as Cobalt, Copper and Lithium is expected to be considerably larger than the amount needed for the energy transition in the EU ([93]).

A clear distinctive feature of the target options is the importance of **novel technologies** to reduce CO_2 emissions in energy, transport and industry such as CCS, BECCS, DACC, production of hydrogen by electrolysis and e-fuels and low-carbon processes for energy-intensive industries. The maturity of technologies is an important driver of the projected portfolio of net-zero technologies. In recent years, innovation resulted in significant improvements of the technology readiness. For the main bulk of net-zero technologies needed to reach the 2040 targets, the Technology Readiness Level (TRL) is already at least 8 (out of 9) which means that they are in an advanced deployment stage ([94]). DACC (TRL of 7) and BECCS (TRL of 5.5) are less mature today, and need to be further developed over the coming years, as highlighted by stakeholders during the public consultation. Subsequently. these two technologies will come into play only between 2030 and 2040.

Target Option 3 goes in hand with a stronger deployment of these technologies over 2031-2040 compared to Target Option 2, while Option 1 largely delays these developments to the last decade 2041-2050. For example, carbon capture is projected to amount in 2040 to close to 350 MtCO2 (including 155 MtCO2 for DACC and BECCS) in Option 3, against only 86 MtCO2 (16 MtCO2 for DACC and BECCS) in Option 1, while a total of about 450 MtCO2 is projected to be needed to reach climate neutrality in 2050. More details on the deployment of carbon capture technologies and their implication can be found on the Industrial Carbon Management Communication.

The use of these novel technologies will affect total electricity production needs and entail the development of hydrogen and carbon removal infrastructure. The implications across the energy system thus go beyond what is captured by cost estimates alone, including on availability of these technologies for large-scale industrial projects, public acceptance of CCS or large amounts of renewables, availability of raw materials or geological storage sites. Finally, a slower deployment of novel technologies would increase the recourse to other (mature) technologies, including for instance biomass (see section 7.3). These different aspects are more relevant for Option 3 by 2040, which will require an adequate policy framework to secure the needed technological uptake while limiting trade-offs and addressing public acceptance. Conversely, delaying these deployments to the last decade, Option 1 also delays the design and implementation of the action and measures and thus risks missing the climate neutrality objective.

([93]) See for instance the expectations on future supply in: IEA (2023), Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach, IEA, Paris https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach
([94]) The TRL evaluation is based on the EU’s Clean Energy Technology Observatory (CETO).

Non-CO2 and LULUCF

All technologies to mitigate non-CO2 GHG emissions considered in the analysis already exist and they are available for implementation, although in some cases there is ongoing research to improve them. There is, however, some uncertainty regarding the mitigation effectiveness and costs of some technologies that have not yet been applied on a large scale (for instance, feed additives and precision farming). Nature-based solutions that can increase the LULUCF net removals (e.g. forest management, rewetting, afforestation, agroforestry, soil carbon management) are all at a fully developed technological stage Future evolution of the LULUCF net removals bears still some uncertainty due to natural impacts such as droughts, high variation between regions and vegetation, and variation on the implementation level (e.g. forest management or agroforestry).

7.2 Efficiency

The assessment of the efficiency of the target options through a comparison of their overall mitigation costs and a monetisation of their environmental benefits, shown in Table 34. This table is computed based on the cost analysis in section 6.4.

Table 34. Comparison of the monetised costs and benefits across the different target options

Average annual cost (bn EUR2023/year)		Comparison to Target 2					
		2031-2040		2041-2050		2031-2050	
		Target 1	Target 3	Target 1	Target 3	Target 1	Target 3
MITIGATION COSTS *(see Table 19 and Table 23 in section 6.4.3)*							
Energy system cost		-53	+36	-19	+3	-36	+20
(% of energy system cost)		*-2.1%*	*+1.5%*	*-0.8%*	*+0.1%*	*-1.5%*	*+0.8%*
Non-CO2 and LULUCF costs		*-2*	*+3*	*-1*	*+1*	*-2*	*+2*
Total GHG mitigation cost		*-55*	*+39*	*-20*	*+4*	*-38*	*+21*
ENVIRONMENTAL BENEFITS *(see Table 11 and Table 12 in section 6.3)*							
Climate change (1)	*Lower*	0	+1	0	+1	0	+1
	Higher	0	+2	0	+2	0	+2
Air pollution (2)	*Lower*	-26	+21	-31	+25	-29	+23
	Higher	-49	+40	-58	+46	-53	+43
Climate change + Air pollution	*Lower*	0	+1	0	+1	0	+1
	Higher	0	+2	0	+2	0	+2
NET BENEFITS (Environmental benefits - Mitigation costs)							
« Lower » valuation of externalities		+29	-18	-11	+21	+9	+3
« Higher » valuation of externalities		+6	+1	-38	+42	-15	+22

Note: (1) Calculations based on the Handbook on the external costs of transport (Version 2019 – 1.1) following the avoidance cost approach. The cost of carbon is interpolated from values of the Handbook. The "lower valuation" uses the "central" value of the handbook EUR 155 per tonne of CO2 in 2031-2040 and EUR 224 per tonne in 2041-2050. The "higher" valuation uses the "high" value of the handbook of EUR 291 per tonne in 2031-2040 and EUR 416 per tonne in 2041-2050 in EUR 2023. (2) The valuation methodology is similar to that used in the Third Clean Air Outlook: the "lower" number uses the Value of a Life Year (VOLY) approach, while the "higher" value uses the Value of Statistical Life (VSL) approach.

Target Options 1 and 3 show a limited deviation of mitigation cost compared to target 2 by 2040, with annual mitigation cost being respectively EUR 56 billion lower and 36 billion higher. The difference in mitigation cost is largely dominated by the energy system cost, which is -2.1% lower for Option 1 than for Option 2, and +1.5% higher for

Option 3. Over the entire period 2031-2050, the difference is even smaller (-1.4% and +0.8%, respectively).

The difference of monetised environmental costs across options are of the same order of magnitude as the difference in mitigation costs. In the 2031–2040 decade, Option 1 shows net benefits compared to Option 2, driven by lower mitigation costs. However, in the second decade 2041-2050 target Option 3 clearly outperforms Option 2 and Option 1, leading to net benefits over the entire period 2031-2050 compared to the "baseline" option 2 with the two valuations of climate change externalities. It must be noted that the methodology used for the monetisation of the external costs of climate change is subject to discussions and that there is a high level of uncertainty associated with such estimates and their use. Some studies conclude that the costs used are (significantly) underestimated.

7.3 Coherence

The assessment of the target options looks at the coherence and risks of trade-offs in terms of environmental impact, strategic autonomy notably with respect to raw materials and manufacturing needs.

Environmental risks

The analysis shows that all the target options in 2040 remain close or below the environmental risk levels identified in the ESABCC report ([95]), namely carbon capture (425 Mt CO2 annually), the LULUCF net removals (400 Mt CO2 annually) and "gross available energy" from biomass (9 EJ annually). However, Option 3 relies on a higher level of industrial carbon removals and of e-fuels in 2040 than the other options: a limited deployment of these technologies may be compensated by a higher recourse to biomass-based solutions (BECCS, liquid biofuels). Depending on the size of these additional volumes, this in turn may negatively affect the LULUCF net removals or biodiversity, making this option more at risk of environmental trade-offs. This risk is also highlighted in some position papers published by stakeholders, which support an ambitious climate target together with other environmental priority goals. The adoption of more sustainable lifestyles as in the LIFE analysis limits the environmental risks of higher demand for bioenergy feedstocks observed in Option 3, due to a lower need for industrial carbon removals and e-fuels, while simultaneously delivering strong land-use related environmental co-benefits.

Strategic autonomy

[95]) ESABCC (2023). Scientific advice for the determination of an EU-wide 2040 climate target and a greenhouse gas budget for 2030–2050. DOI: 10.2800/609405, Table 6. Carbon capture use and storage (CCUS) includes fossil fuels, bioenergy, industry or direct air carbon capture (DACC). The level of the LULUCF net removals is currently declining and may further decline due to climate change. Therefore the risk level was set at 400 Mt CO2 annually, meaning that scenarios should not rely on even higher carbon removal levels. Future analyses may assume other supply levels of biomass to stay within the sustainability boundaries, in view of the on-going scientific debate.

Specific Objective 6 (in Effectiveness) shows that target Option 3 has the highest security of energy supply with the lowest dependence on external supply of fossil fuels, notably oil and natural gas.

However, the resilience of future energy systems will also be measured notably by a secure access to the technologies that will power those systems. Demand for raw materials (including critical raw materials) and the domestic manufacturing needs (Cfr. NZIA) to build these capacities will be proportional to the deployment of technologies such as renewables and storage, which is lower in Option 1 than in Option 2 in 2040 (renewables capacity is 8% lower) and higher in Option 3 (renewables capacity is 6% higher). The three target options all display a similar pattern of growing needs of raw materials in the coming decades in line with global trends ([96]), which highlights, in line with the opinion of several stakeholders, the importance of securing supply chains and anticipating the creation of a resource base within the EU economy in view of developing secondary supply.

A more sustainable economy

The analysis done with the LIFE case highlights the important contribution resource efficiency can make to meeting to climate objectives, while reducing the effort required in key sectors. It shows that strong synergies are possible between a more efficient use of resources in the economy and GHG mitigation objectives. The greater the reductions in 2040, the more valuable these synergies will be. This view is also shared by stakeholders, which are in favour of better implementation of resource efficiency strategies in climate action.

LIFE also shows that an increased uptake of demand-side options and more sustainable lifestyles would reduce the need to deploy the most novel abatement technologies such as carbon capture and hydrogen technologies and lower the amount of green electricity required. More generally, LIFE improves energy efficiency and significantly reduces the need for electricity consumption, installed renewable capacity, and storage, while providing opportunities in the land sector. It makes the pathways less dependent on novel technologies, while still reaching the highest target levels and the corresponding net GHG budget.

7.4 Subsidiarity

Climate change is a trans-boundary problem. For trans-boundary problems, individual action is unlikely to lead to optimal outcomes. Instead, coordinated EU action can effectively supplement and reinforce national and local action. Coordination at the European level enhances the effectiveness of climate action. This is particularly true in view of meeting the EU climate neutrality objective by 2050 and is valid for all 2040 climate target options assessed in this impact assessment.

([96]) IEA (2023). "Net Zero Roadmap. A Global Pathway to Keep the 1.5°C Goal in Reach"

7.5 Proportionality

The different target options differ substantially in terms of level of progress to the climate neutrality and in terms of cumulative GHG emissions (the “GHG budget”), with Option 3 outperforming the other two target Options. This option secures best the deployment of the needed technologies to meet climate neutrality by 2050. Its additional mitigation cost to bring the EU towards climate neutrality remains limited compared to the baseline Option 2 (+1.5% over 2031-2040, +0.8% over the entire period 2031-2050). The cost-benefit analysis shows a positive outcome for Option 3 compared to Option 2, including with a conservative valuation of the cost of climate change, while Option 1 shows a more uncertain outcome dependent on the valuation.

Target Option 3 is thus assessed to be the most proportional to the objective of this initiative, namely bringing the EU economy to climate neutrality by 2050 and for the EU to contribute to the global climate action in view of meeting the Paris Agreement temperature goals of limiting the temperature increase to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels.

The post-2030 climate, energy and wider policy framework will need to ensure that the social and industrial policies and support required is in place to deliver the clean technologies needed by 2040, including for carbon management.

7.6 Summary

Table 35 presents a summary of the comparison of the different options to the "baseline" Option 2. The assessment is done in the absence of the future policy framework post-2030, which will need to be designed to ensure a just transition and coherence with other policies.

Table 35: Summary of the comparison of options

	Opt.1 vs Opt. 2	**Opt. 3 vs Opt. 2**	**Source**	**Scoring methodology**
Effectiveness				
SO1 Delivering climate neutrality	– – –	+++	Table 27, section 7.1.1.	Quantitative comparison: "=" means a deviation up to 1%, "+" or "-" a deviation up to 3%, "++" or "--" a deviation up to 10%, "+++" or "---" a deviation higher than 10%
SO2 Minimising GHG budget	– – –	+++	Table 27, section 7.1.1.	
SO3 Just transition	+	–	Table 28, section 7.1.1.	
SO4 Competitiveness*, *cost* *GDP, trade*	+ =	– =	Table 28, section 7.1.1.	
SO5 Deployment of technologies	– –	++	Table 29, section 7.1.1.	
SO6 Security of energy supply	– –	++	Table 29, section 7.1.1.	
SO7 Environmental effectiveness	=	=	Table 30, section 7.1.1.	
Financial feasibility (annual capital cost)	+	–	Table 32, section 7.1.1.	
Technological feasibility, 2031-2040 2041-2050	+ –	– +	Based on section 7.1.2	Qualitative comparison*
Efficiency				
Lower valuation of externalities	+	=	Table 33 in section 7.2.	Quantitative comparison: "=" means a deviation of annual net benefit up to 5 bn EUR "+" or "-" net benefit up to 10 bn EUR "++" or "--" net benefit up to 20 bn EUR "+++" or "---" net benefit above 20 bn EUR
Higher valuation of externalities	– –	+++		
Coherence				
Environmental risks (land use)	+	–	Based on section 7.3	Qualitative comparison*
Strategic autonomy (excl. security of energy supply)	+	–		Qualitative comparison*
Subsidiarity	=	=	Based on section 7.4	
Proportionality	–	+	Based on section 7.5	Qualitative comparison*

*Note: *Qualitative comparison: "+" means that the Option performs better than Option 2, "-" means that the Option performs worse than Option 2, "=" means that the Option performs as Option 2.*

8 PREFERRED OPTION AND ITS IMPACTS

Target Option 3 with a range of 90-95% is the preferred option. This range is consistent with that recommended by the ESABCC and ensures the lowest GHG budget of all options. It provides the best balance between climate ambition and contribution to a fair share of the global carbon budget to meet the Paris Agreement temperature goals on the one hand, and feasibility on the other. 72% of the individuals and 66% of the organisations who responded to the public consultation consider that an ambitious climate target by 2040 will ensure that the EU does its part in protecting the planet and fulfilling its duty towards future generations. Several position papers analysed during the public consultation also call for an ambitious climate target, with some stakeholders explicitly targeting ranges at 90% or above.

Target Option 3 is **the most effective** in terms of bringing the EU to climate neutrality by 2050. With the lowest GHG budget, it also provides the strongest leadership from the EU and the most credible push to the EU's partners worldwide on the need and opportunities for accelerating climate action. Stakeholders largely agree on the positive influence that an ambitious EU climate target can trigger at global level. By encouraging early action, Target Option 3 is expected to have the **most impact on reducing global emissions**, and on increasing the prospect of keeping 1.5 degrees warming within reach, so as to limit the worst climate impacts and disruptions to all economies, including the risk of reaching irreversible climate tipping points.

Target Option 3 is also the **most effective in ensuring the EU's security of energy supply and strategic autonomy**, with an energy import dependency ratio 3 percentage points lower than the "baseline" Option 2 and a reduction in fossil fuel imports of 4%. It is also the option that best protects the EU against the negative socio-economic impacts of potential fossil fuel price shocks in future.

In terms of **financial feasibility**, all target options require a similar increase in average annual energy system investment over the period 2031-2050 and imply a moderate increase in energy system costs as a share of GDP compared to the average for 2011-2020. Target Option 3 entails a moderate early push in investment in 2031-2040 compared to the "baseline" Option 2, mostly on the energy supply side, where investors have good access to finance due to secure and relatively predictable revenue streams. The anticipation of investment under Target Option 3 is very limited in industry and in the residential sector.

Ensuring a just transition requires an even greater focus for Target Option 3 than for less ambitious target options, as the transition is somewhat accelerated. However, the **increase in costs for households compared to the "baseline" Option 2 is small**, **and this assessment does not account for any policy measures and redistributive instruments that can be expected to address this impact**; for example, the assessment of impacts does not include the use of carbon revenues to support households.

In terms of the **competitiveness**, Target Option 3 will lead to a greater impact for fossil fuel sectors, and a small negative impact on the output of energy intensive sectors compared to the "baseline" Option 2. However, the higher ambition of Option 3 can further showcase the EU's climate leadership. Target Option 3 will also lead to earlier investments in novel technologies, an important opportunity to develop the expertise and skills in the EU to supply the equipment and infrastructure that will be needed worldwide over decades to come for carbon dioxide removals to ensure global carbon neutrality. By supporting a higher development of low-carbon technologies, Option 3 would thus increase the positioning of the EU in the global race to clean technologies and solutions. Finally, in addition, the increased energy independence mentioned below is a strong advantage for the competitiveness of the EU industry, in reducing its exposure the international markets volatility.

Target Option 3 is also **the most efficient** to meet climate neutrality by 2050, showing the **highest net benefits in terms of avoided climate change and air pollution compared to the mitigation cost**. It shows slightly higher mitigation cost overall (+1.5% over 2031-2040 compared to the "baseline" Option 2, but only +0.8% over 2041-2050), which differs across sectors: while the cost increase in industry and transport are close to 2%, they are limited in services and the residential sector to 1% and 0.5%, respectively. Most SMEs are in sectors for which the impacts are very limited.

A greater push will also be required under Target Option 3 to ensure the availability of novel technologies such as carbon capture, including for DACC and BECCS, or e-fuels, which will need the setting up a dedicated policy. The implications above and other impacts or **trade-offs** identified, for example for avoiding new dependencies on imports of critical raw materials or pressure on biodiversity from the use of biomass associated with a more ambitious climate target option, can and must continue to be addressed and mitigated through dedicated policy measures, as part of the design of the future climate and energy policy framework, and wider enabling framework (e.g. financing, land-use and biodiversity, supply of critical raw materials, competitiveness).

Finally, the Impact Assessment further shows the potential for demand-side actions, such as behavioural changes in food, circularity and mobility (as in LIFE) to complement the energy and industrial transition (as shown in the scenarios) and to reduce the costs to society of reaching the 2040 target, lowering energy system costs, the need for investment in (novel) technologies, and environmental risks (e.g. of higher demand for bioenergy). However, lifestyle choices depend to a large extent on personal choice and positive incentives.

9 HOW WILL ACTUAL IMPACTS BE MONITORED AND EVALUATED?

The key EU legislation for planning, monitoring and reporting of progress towards the EU's climate targets and its international commitments under the Paris Agreement is the Regulation on the **Governance of the Energy Union and Climate Action** ('Governance Regulation') ([97]).

The Governance Regulation requires EU Member States to communicate and implement integrated **National Energy and Climate Plans** (**NECPs**) and to regularly report on

([97]) In accordance with Article 45 of the Governance Regulation, the Commission should review the Regulation with six months of each global stocktake. The evaluation of the Governance Regulation is planned in Q1 2024.

their progress in implementing them. It lays out the detailed reporting obligations on GHG emissions, policies and measures, projections, adaptation actions and support provided to developing countries. Every two years, Member States need to take stock of the progress achieved towards the objectives, targets and contributions set out in their NECPs, which are updated to reflect the countries' contributions to the EU climate and energy objectives ([98])([99]).

With the adoption of the **European Climate Law** in July 2021, the Commission should also provide an assessment of the progress made by all Member States towards the EU 2050 climate-neutrality objective ([100]). The first Climate Law assessment was undertaken in October 2023, together with the assessment of progress provided for under the Governance Regulation. The Climate Law assessment is to be carried out every five years, aligned with the global stocktake under the Paris Agreement. The Climate Law provides that the Commission base its assessment on an indicative, linear trajectory, which sets out the pathway for the reduction of net emissions at Union level, linking the Union 2030 climate target, **the Union 2040 climate target, when adopted**, and the 2050 EU climate-neutrality objective. The assessment of progress includes data derived from the European Earth Observation Programme Copernicus.

Under the annual **State of the Energy Union Report** ([101]), the Commission adopts the EU **Climate Action Progress Report** where it reports each year on EU-wide climate progress and delivers on obligations set out in the Governance Regulation, including to assess progress with the EU's climate targets. The Climate Action Progress Report is an opportunity to inform a wide audience about recent developments in EU climate action.

([98]) Based on guidance to MS issued by the European Commission issues, like the one for the updated NECPs 2021-2030 in view of contributing to "fit-for-55" objectives.
([99]) Final NECPs, in view of meeting the "fit-for 55" objectives, are due in June 2024.
([100]) The European Climate Law also requires the Commission to assess the collective progress made by all Member States on adaptation, the consistency of Union and national measures with climate neutrality and with progress on adaptation.
([101]) Under Article 29 of the Governance Regulation, where the Commission has to assess progress at Union and Member State level towards meeting the objectives of the Energy Union.

Annex 1: Procedural information

1. LEAD DG, DECIDE PLANNING/COMWORKPROGRAMME REFERENCES

The lead DG is DG CLIMA, Unit A2: Foresight, Economic Analysis & Modelling. The co-lead DG is DG ENER.

DECIDE reference number is: PLAN/2023/220.

It shows in the Commission Work Programme 2024 as item 2 in Annex I.

2. ORGANISATION AND TIMING

The impact assessment started in 2023, with the call for evidence published on 31 March 2023.

The impact assessment on the EU 2040 climate target was coordinated by an Inter-Service Group (ISG).

The Inter-Service Steering Group met 3 times: on 20 January 2023, 30 June 2023 and 18 September 2023. It was consulted throughout the different steps of the impact assessment process, notably on all the stakeholder consultation material and on the draft Impact Assessment.

The Commission Services participating in the ISG were: Secretariat-General, SJ, DG AGRI, DG BUDG, DG CNECT, DG COMM, DG COMP, DG DEFIS, DG ECFIN, DG EMPL, DG ENV, ESTAT, DG GROW, DG INTPA, JRC, DG MOVE, DG NEAR, DG RECOVER, DG REFORM, DG REGIO, DG SANTE, DG RTD, DG TAXUD, DG TRADE. The EEAS was also consulted.

3. CONSULTATION OF THE RSB

An upstream meeting between the lead DGs and the RSB took place on 24 April 2023.

The draft report was submitted to the RSB on 16 October 2023 and was discussed by the RSB on 15 November 2023.

On 17 November 2023, the RSB issued a negative opinion. A revised Impact Assessment has been submitted on 6th December 2023, fully addressing the recommendations provided by the Board in its first opinion.

On 22 December 2023, the RSB issued a second, positive opinion with reservations.

Table 36 and Table 37 show the RSB findings and the changes made to respond to the first and the second opinion respectively, which have been shared with the Inter-Service group.

Table 36: How the RSB findings of the 1st opinion have been addressed

Findings	How findings were addressed
(1) The problem, its drivers and its potential consequences are not clearly identified. The report does not adequately define the specific objectives and criteria based on which the performance of alternative 2040 target options would be assessed in line with the requirements of the EU Climate Law.	Following the recommendation by the RSB, the problem definition (section 2) has been simplified and aligned with the legal obligation stemming from the European Climate Law. The specific objectives (section 4) have been better defined, based on the elements under its article 4(5) for the Commission to take into consideration when proposing the 2040 target. The intervention logic has been streamlined. A set of criteria is used to compare the performance of the target options in terms of effectiveness according to these different specific objectives (section 7).
(2) The description of the dynamic baseline is underdeveloped and not sufficiently clear. The report fails to establish an appropriate benchmark for comparison. The rationale behind, the content of and the interaction between the options and the scenarios lack clarity. The report does not bring out clearly enough all available target and pathway choices and the trade-offs between them.	A more detailed section was added on what would happen to the net GHGs emissions by 2040 with a continuation of the current policy framework (section 5.1). On that basis the report establishes a clear "baseline" target level (section 5.1) against which the other target options are compared in terms of effectiveness, efficiency, coherence and trade-offs (in section 7). The relationship with the linear trajectory set out in Article 8 of the European Climate Law is described in the text. The choice of the target options is informed by the analysis by the ESABCC and other scientific publications on the EU 2040 target and their description reflects the responses of stakeholders to the public consultation (section 5.2). The methodology to calculate the cumulative GHG emissions over 2030-2050 (the "GHG budget") for each target option is described (section 5.2). Finally, the description of the target options and the relation to their representative scenarios have been simplified (sections 5.2 and 5.3), which allows a clearer comparison of the target options and the trade-offs between them (section 7). The scenarios are described in terms of very broad sectoral mitigation mix (section 5.3, which is completed by Annex 6). The detailed analysis (section 6, Annex 8) provides the details on the reductions of GHG per sector and the associated technology deployment, investment needs and costs for the scenarios associated to the target option. The LIFE scenario has been clarified as a "sensitivity" case to societal assumptions, whose conclusions can apply to the different target options. The assumptions for each sector under LIFE are drawn from and benchmarked to external studies, and are referenced in a new table in Annex 6 (section 3) and in the sector-specific sections of

	Annex 8
(3) The level of uncertainty of the modelling, including in terms of the remaining CO_2 budget, and the robustness of the results is not clearly identified and analysed.	To complement the more detailed description of the analytical framework that can be found in Annex 6, Annex 1 section 4 on "evidence, sources and quality" provides a description of the different economic models used for this impact assessment and the underlying key assumptions. The impact assessment is backed by a detailed analysis (Annex 8) that makes use of a multi-model approach that provides a cross-model comparison for a number of indicators to cross-validate the results of the analysis. A summary comparison across models for selected key indicators on energy and CO_2 as well as on macro-economic modelling has also been added to Annex 1 section 4. The convergence of results shows that the conclusions are robust and not biased by the internal logic and parameters of each model. Finally, the different sensitivity analyses undertaken are now presented in a clearer manner. This includes the sensitivity analysis to test how different costs for key energy technologies affect total investment costs, the LIFE variant to show the impact of a more sustainable materials and production, mobility, and food system, as well as an additional variant to analyse the effect on the energy mix of the recent review of the nuclear legislation in some Member States.
(4) The costs and benefits of each option are not clearly presented. The report is neither clear on the total costs and benefits due to frontloading investments in the 2031- 2040 period nor on the related financial and technological feasibility.	The presentation of costs and benefits of each option and how they compare has been clarified and extended in section 6. A new section (6.3.1) on the cost of the climate change externality has been added, which allows to compare the benefits of a lower 2030-2050 GHG budget (option 3) compared to a higher GHG budget (option 1) and compared to the "baseline". This complements the monetisation of the environmental benefits related to air quality improvement on health (section 6.3.2). These costs and benefits inform the comparison of target options in the new sections related to effectiveness along the different specific objectives, financial feasibility (including considering the financing cost associated to the investment needs) and overall efficiency (section 7). The assessment of competitiveness is also clearer, with some more detail on SME impacts. Further details are added in the main report on the views expressed by stakeholders in the public consultation. On technological feasibility, a new section has also been introduced (in section 7) that compares with the ESABCC analysis and assesses the Technology Readiness Levels

	(TRL) of technologies needed to reach the 2040 targets. As a result, the IA now presents the technological feasibility of the options. A new variant has also been added to illustrate the changes to the energy mix of the recent nuclear plans in some Member States (section 6.2).
(5) Options are not adequately compared as regards effectiveness, efficiency, coherence and proportionality. The choice of the preferred option is not sufficiently justified.	Criteria for the assessment of options (based on the European Climate Law article 4 (5)) have been defined to allow a clearer description of comparative impacts of the target options in terms of efficiency, coherence and proportionality. In addition, new sections have been introduced that look in detail at how the options compare according to each of these dimensions. The effectiveness assessment is done for each specific objective through specific quantitative indicators and is complemented by an analysis of the financial feasibility and the technological feasibility (see point above). Efficiency is assessed through the comparison of mitigation costs with benefits in terms of saved externalities, notably related to GHG emissions. Coherence is assessed in terms of environmental trade-offs and strategic autonomy. Proportionality compares the net benefits of each 2040 target option to achieve climate neutrality by 2050 and puts this in perspective with the limited mitigation cost difference and the possible trade-offs. This comprehensive comparison of the different target options motivates the choice of the preferred target option.

Table 37: How the RSB findings of the 2nd opinion have been addressed

Findings	**How findings were addressed**
(1) The report is not clear on how sustainable lifestyle changes are reflected in the dynamic baseline scenario. The policy choices regarding the inclusion of sustainable lifestyle changes (via the LIFE variant) are not brought out clearly and their interaction with the three scenarios is neither comprehensively assessed nor compared.	The 2040 target IA compares different 2040 target levels under a set of common key assumptions related to socio-economics and technology costs and performance. It does not aim at assessing policy choices that could influence such assumptions. However, as complementary dimension, the IA provides a sensitivity analysis on different socio-economic developments, including lifestyle choices, via the "LIFE" variant. Following the feedback by the RSB, the report makes clearer the role of this variant. The variant is built to meet the target option 3, and thus by design reaches in 2040 the same overall net GHGs

	reductions levels as the core scenario S3. The assumptions used are described in detail in Annex 6 (section 3.1.5) and further in the sectoral sections of Annex 8 (in section 1). This variant leads to a different sectoral composition of the abatement of net GHGs, as well as different costs in relation with mitigation of CO2 emissions from fossil fuel combustion and industrial processes. The conclusions of this sensitivity analysis are not exclusive to target option 3 and can be applied to all target options.
(2) The scoring of options is not convincingly demonstrated, the key trade-offs between options not clearly presented and the choice of the preferred option not sufficiently justified.	The methodology behind the scoring of options has been clarified, demonstrating its link with the full analysis in terms of effectiveness, efficiency, coherence, subsidiarity, and proportionality. For each of these aspects, the data sources (in case of quantitative comparison), the relevant sections for the analysis (in case of qualitative comparison) and the detailed scoring methodology, have been included in the summary table (Table 35). The comparison of the options has been further detailed in Section 7, including elements that guide the reader in the understanding of the key trade-off between the options. In particular, the key trade-off between fast technological deployment (and associated challenges) to secure climate neutrality and delayed action that would put at risk the net-zero target have been explained in section 7.1. Additional arguments in support of the preferred option in line with the extended analysis of section 7 and relevant views of stakeholders collected during the public consultation have been introduced in section 8.
(3) The report is not sufficiently clear about the risks related to financial and technological feasibility.	More detailed elements have been included in the financial and technological feasibility section (section 7.1.2). The financial feasibility analysis makes clearer the comparison across options in terms of investment needs and derived annualized capital cost, for energy supply, industry and households. The technological feasibility section adds an analysis on capacity deployment needs and more elements on raw materials needs to the Technology Readiness Level assessment.

4. EVIDENCE, SOURCES AND QUALITY

The impact assessment relies on a wide range of state-of-the art and proven modelling tools that ensure the quality of the analysis. The models have been used by the European Commission ([102]), Member States and a variety of stakeholders in the past decades to assess the impact of climate and energy policies. The models are continuously improved with cutting edge features and periodically peer-reviewed ([103]) by the scientific community. The models have also been used as basis for numerous publications in scientific peer-reviewed journals and conferences ([104]). They are managed by teams of highly experienced staff who have been working alongside the European Commission for many years in policy analysis, and therefore understand the scientific, technical and policy requirements to carry out modelling exercises. Their methodological underpinnings are explained in detailed descriptions available publicly for peer review, for instance in the Modelling Inventory and Knowledge Management System of the European Commission (MIDAS)([105]).

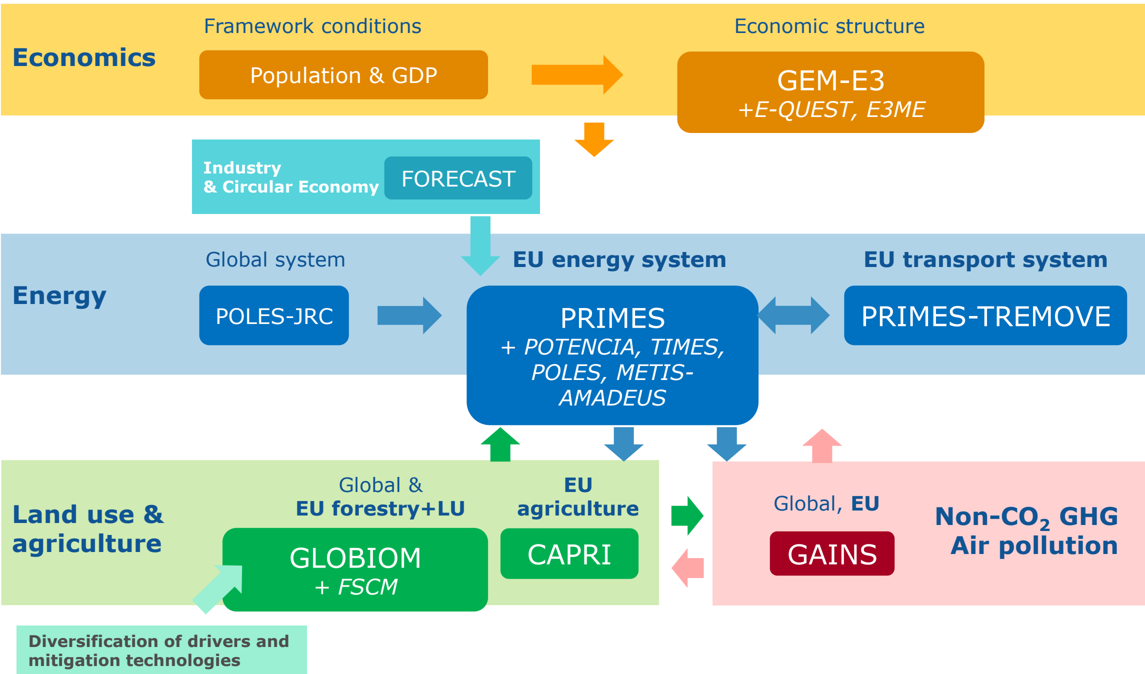
The underlying exogenous assumptions and the modelling scenarios are shared across models. Exogenous assumptions on population and GDP projections are based on the work of Eurostat (population projections) ([106]) and DG ECFIN (Ageing Report) ([107]). The methodology underpinning these projections are subject to regular review among Member States. Assumptions on technological costs and abatement costs are based on recent scientific literature review carried out by external consultants in collaboration with

([102]) For instance, the main modelling suite of Impact Assessment was used for the Commission's proposals for the Long-Term Strategy (COM (2018) 773), the 2030 Climate Target Plan (SWD (2020) 176 final), and the Fit for 55 package (COM (2021) 550 final).
([103]) See POTEnCIA peer-review in SORIA RAMIREZ A., POTEnCIA technical peer-review – Related documents, European Commission, Seville, 2017, JRC108360, and METIS peer-review in Ahlgren, E.O., et al. (2020). The METIS model review, EUR 30388 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-76-22744-1, doi:10.2760/28916, JRC118638.
([104]) Description and selected publication for the models used in the impact assessment:
PRIMES https://e3modelling.com/publications/,
POTEnCIA https://joint-research-centre.ec.europa.eu/potencia/potencia-publications_en,
EU-TIMES https://www.i2am-paris.eu/detailed_model_doc/eu_times,
POLES https://www.enerdata.net/solutions/poles-model.html
METIS: https://web.jrc.ec.europa.eu/policy-model-inventory/explore/models/model-metis/references/
AMADEUS https://www.engie.com/decarbonation-scenario-engie
GLOBIOM https://iiasa.github.io/GLOBIOM/index.html
CAPRI https://www.capri-model.org/doku.php?id=capri:capri_pub
JRC-FSCM https://data.europa.eu/doi/10.2760/244051
GAINS http://gains.iiasa.ac.at/models/gains_peer_reviewed.html
JRC-GEM-E3 https://joint-research-centre.ec.europa.eu/gem-e3/gem-e3-publications_en
E3ME https://www.e3me.com/how/papers/
NEMESIS https://web.jrc.ec.europa.eu/policy-model-inventory/explore/models/model-nemesis/references/
QUEST (E-QUEST) https://economy-finance.ec.europa.eu/economic-research-and-databases/economic-research/macroeconomic-models/quest-macroeconomic-model_en
([105]) MIDAS: https://web.jrc.ec.europa.eu/policy-model-inventory/
([106]) EUROPOP2019 (proj_19n) and short-term update of the projected population (2022-2032) (proj_stp22), which was the latest available projection at the time the key assumptions were adopted as a framework for all models used in the impact assessment.
([107]) DG ECFIN. Autumn 2022 Economic Forecast: The EU economy at a turning point.

the JRC and were validated by a dedicated stakeholders consultation prior to the modelling exercise. In particular, a stakeholder workshop on technology assumptions on land-sector-related and non-CO2 GHG emissions took place with national authorities, researchers and businesses in October 2022 and energy- and mobility-related techno-economic assumptions were discussed with several stakeholders in February 2022, and subsequently updated in February 2023.

The models are interconnected in multiple ways, as represented in Figure 5. For the energy system and the macro-economic analysis of this impact assessment, multiple independent models have been used in parallel to evaluate and assure the robustness of the results. The PRIMES model is the main energy system modelling tool for this impact assessment. The robustness of the results was assessed by comparing results from other energy system models, mainly the JRC's POTEnCIA and POLES, METIS-AMADEUS and TIMES. The GLOBIOM/G4M model suite (called "GLOBIOM" in this impact assessment) was used to cover all LULUCF-related GHG emissions in this impact assessment, and the results were tested with the JRC forest sector carbon model (FSCM). The CAPRI model was used to assess impacts from agricultural, trade and environmental policies on agriculture as well as biodiversity aspects linked to agriculture. The GAINS model was used as the main modelling tool to estimate air pollutant emissions and their impacts on human health and the environment, as well as non-CO2 GHG emissions. Three macro-economic models with distinct methodological underpinnings were used to assess the socio-economic impact of the target options and assess the robustness of the key findings. The JRC's GEM-E3 was used as the core model and is a recursive dynamic computable general equilibrium model, and DG ECFIN's E-QUEST and the Cambridge Econometrics' E3ME macro-econometric models complemented the analysis.

Figure 5: Modelling tools used for the impact assessment



The results of the independent modelling analyses are cross-checked across models, indicating a level of uncertainty for the different figures, and validating the robustness of the conclusion. While high-level results across models are well aligned (see Annex 8), uncertainty increases for more disaggregated results. Detailed modelling results are highly dependent on the design of the energy and climate policy framework (which is not the subject of this Impact Assessment) and the improvement and deployment of different technologies. The dependence of projections on the choice of model can be estimated comparing values obtained from models using the same assumptions and closely calibrated to the same statistical data: this is the case for the PRIMES and POTEnCIA energy models and for the JRC-GEM-E3, E3ME and E-QUEST macro-economic models.

Table 38 shows a summary of the cross-model uncertainty levels for the key high-level indicators of this Impact Assessment. Projections for the main emissions and energy indicators are closely aligned in PRIMES and POTEnCIA models (with deviations of few percentage points in 2040).

Table 38: Uncertainty level for key high-level energy and CO2 indicators.

Indicators	Uncertainty level		
	S1	S2	S3
2030-2050			
EU CO2 budget 2030-2050 (energy & industry CO2)	9%	1%	2%
2040			
Net Energy & industry CO2	8%	4%	8%
GAE	0%	3%	4%
FEC	4%	3%	3%
Share of RES in GFEC	6%	2%	1%

Note: Uncertainty level is defined as the dispersion between the max and min value obtained across models (max/min-1).

Table 39 shows a summary of the impacts on GDP, private consumption and investment for S1 and S3 (in percentage change vs. S2) for the JRC-GEM-E3, E3ME and E-QUEST models. All three models concur that the macro-economic differences across the three representative scenarios are very limited to less than 1%.

Table 39: Impacts on key macro-economic variables across models (% change vs. S2, 2040)

	S1 (fragmented action)			S3 (fragmented action)		
	JRC-GEM-E3	E3ME	E-QUEST	JRC-GEM-E3	E3ME	E-QUEST
GDP	0.5%	0.0%	0.4%	-0.2%	0.0%	-0.8%
Private consumption	0.7%	0.3%	0.3%	-0.5%	-0.2%	-0.5%

Source: JRC-GEM-E3, E3ME, E-QUEST.

Annex 6 provides a more detailed description of the modelling tools and the way they interact in the impact assessment. It also provides a detailed description of the modelling scenarios underpinning the target options, including assumptions, drivers, and rationale.

Furthermore, Annex 7 provides the analysis of the cost of climate inaction based on a review of the literature and dedicated macro-economic modelling carried out for this impact assessment with the NEMESIS macro-econometric model. The NEMESIS model has been designed by an EU consortium to assess socio-economic impacts of research and innovation policies and used in several peer-reviewed publications ([108]).

Annex 8 provides the detailed analysis of the sectoral transformations towards different 2040 target levels and to climate neutrality by 2050, and a cross-model comparison for a number of additional indicators. A comprehensive literature review, including the advice by the European Scientific Advisory Board on Climate Change ([109]), complements throughout the documents the use of economic modelling.

([108]) NEMESIS, Selected publications: https://web.jrc.ec.europa.eu/policy-model-inventory/explore/models/model-nemesis/references/

([109]) ESABCC (2023). Scientific advice for the determination of an EU-wide 2040 climate target and a greenhouse gas budget for 2030–2050. DOI: 10.2800/609405.

Annex 2: Stakeholder consultation (Synopsis report)

Synopsis report on the stakeholder activities for setting an EU climate target for 2040

1. INTRODUCTION

In the framework of proposing an intermediate climate target for 2040 within the European Climate Law, the European Commission conducted consultation activities aimed at gathering views of different identified stakeholders: citizens, public authorities, businesses, etc. The current synopsis report is a summary of the results of the consultation activities. These will inform the impact assessment prepared by the EC.

The consultation activities included the following elements:

- **Public consultation (questionnaire and position papers):** A public consultation was conducted over a 12-week period from the 31/03/2023 until the 23/06 2023. It included a questionnaire and the option to submit position papers. The questionnaire comprised of a general section (17 questions) and an expert section (18 questions). The general section was targeted at a wider group of stakeholders while the expert section was more technical and involved questions about specific policy domains relevant for the target setting. The consultation incorporated mainly closed questions (32) but also few open questions.
- **Call for evidence:** In addition to the public consultation, stakeholders had the opportunity to share general remarks and feedback on the policy initiative through a call for evidence. They had the opportunity to upload position papers which were analysed together with the position papers received in the public consultation.
- **Targeted stakeholder event:** A hybrid stakeholder event was hosted by the EC in Brussels. Participants were informed about the policy initiative for setting the EU climate target for 2040 and invited to share their views.

The current synopsis report is prepared by a contractor ([110]).

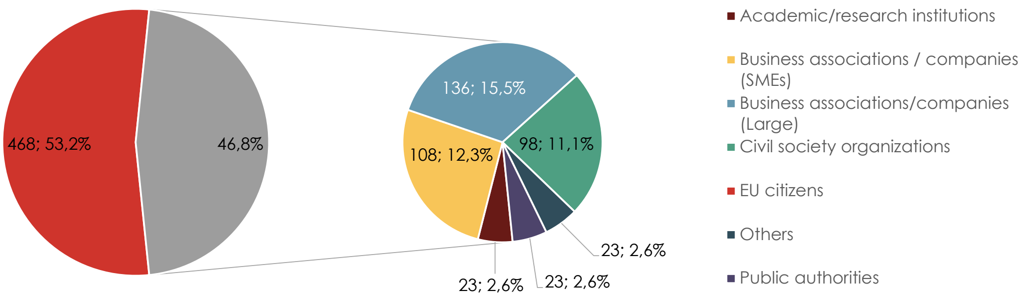
2. ANALYSIS OF PUBLIC CONSULTATION QUESTIONNAIRE

2.1. Overview of responses

In total, 903 responses to the public consultation were received. Among these, 23 (2.5%) responses were classified as part of a single campaign from private individuals in Slovakia (see Section 2.2). In addition, one response was identified as a duplicate, so that a total of 879 responses were included in the analysis. Out of these, 480 (54.6%) (EU citizen: 468, non-EU citizen: 12) were provided by private individuals, and 399 (45.4%) by organisations.

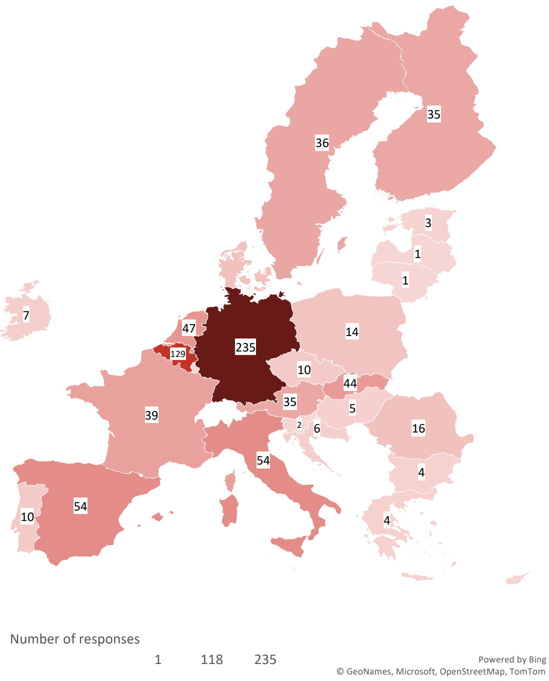
([110]) Technopolis Group in association with COWI A/S and Eunomia.

Figure 6: Responses by stakeholder group



Note: n = 879 (Number of responses to the public consultation questionnaire) (111)

Figure 7: Geographical distribution of responses by EU Member States



Note: n = 811 (Number of responses from EU27 Member States. The responses from Slovakia which are classified as a campaign are not included here. An additional 68 responses were received from non-EU countries.)

Most organisational responses came from companies and business associations: Small and medium-sized enterprises (SMEs) and business associations representing SMEs (108, 12.3%) or large companies (>250 employees) and associations representing them (136, 15.5%). An additional 98 (11.1%) responses came from civil society organisations. (112) Furthermore, 23 (2.6%) responses were received from

(111) The responses from Slovakia which are classified as a campaign are not included here. See Section on campaign identification for an overview of the campaign.

(112) Clusters the responses from NGOs (68), environmental groups (20), trade unions (9), and one consumer organisation (1).

academic/research institutions and an equal number of 23 (2.6%) responses from public authorities. Also, 23 (2.6%) responses were classified as “Other”. ([113])

The frequency of responses varied greatly between EU Member States (see Figure 7). The largest number of responses came from Germany (235, 26.7%), followed by Belgium (129, 14.7%) (also representing EU-level stakeholders).

2.2. Methodological approach and campaign identification

The data from closed questions was processed and cleaned to facilitate descriptive analysis and representation. Results are consistently presented as absolute numbers and percentage values. The latter indicate the proportion of responses within each respective stakeholder group. For Likert-scale questions, the share of (dis)agreement is supplemented by an average for all responses.

The methodology used for analysing open-text questions involved several steps. After eliminating invalid responses and identifying coordinated ones, a semi-automated thematic analysis was conducted, and themes were identified without preconceived notions.

Views from the public consultation are not statistically representative.

The strategy chosen to identify coordinated responses relied on clustering of closed question responses and a semi-automated analysis of similarities in open-text answers. The analysis of open-text answers led to the discovery of a distinct group of 23 (2.5%) responses from EU citizens from Slovakia, which were classified as a campaign, and analysed separately. The responses in the campaign showed the same narrative of urging political leaders to use sustainable transportation (Q11, open-text). Regarding climate ambition for 2040, most responses indicated that the EU should make its ambition dependent on other countries’ climate ambition (19, 83%). Overall, the answers in the campaign could be characterised as expressing climate-sceptical beliefs and attitudes.

2.3. Results from the general section of the questionnaire

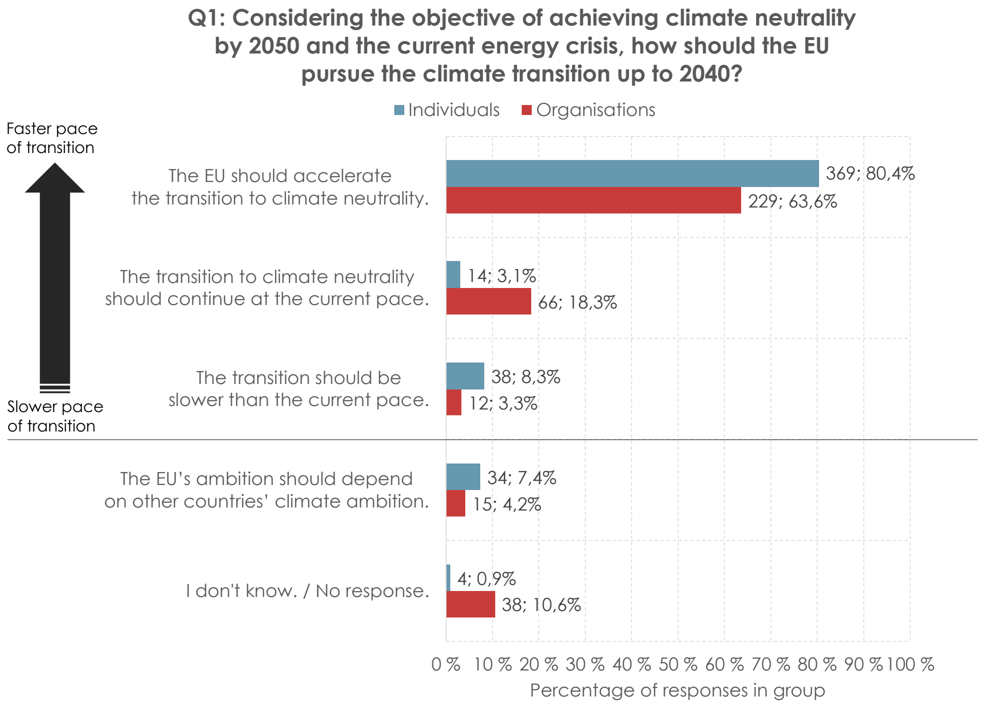
Overall opinion on the EU’s climate ambition for 2040

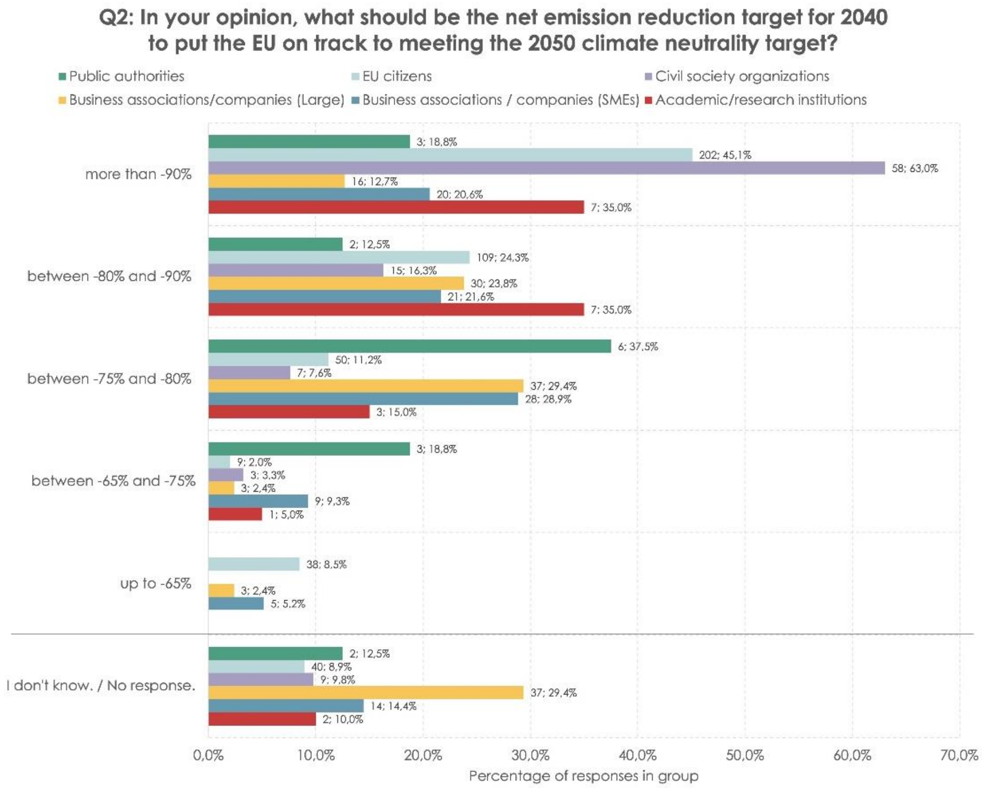
Overall, the responses to the level of ambition strongly endorse setting an ambitious EU climate target for 2040. A majority (598, 73%) of respondents (Individuals: 369, 80.4%; Organisations: 229, 63.6%) indicated that they want the EU to accelerate the transition to climate neutrality. Civil society organisations (84, 91.2%) and academic/research institutions (17, 85.0%) showed the highest levels of support, but also about half of SMEs (51, 52.6%) and large business associations or companies (60, 47,6%) favoured an acceleration of the transition. Regarding a specific net emission reduction target for 2040, more than half of the respondents supported a target of more

([113]) Includes the responses from non-EU citizens (12).

than -80% by 2040 (504, 61.5%). Again, more individuals (322, 70.2%) required a target of more than -80% than organisations (182, 50.5%). Stakeholder groups showed variation in ambition levels. A large majority of civil society organisations supported a net emission reduction target of more than -80%” (73, 79,3%), followed by academic/research institutions (14, 70,0%). Among business associations and companies, the responses dispersed more: 42,3% (41) of SMEs and linked associations advocated for more than -80 %, while among the group of large business and business associations 36.5% (46) advocated for more than -80%. Amon public authorities 31.3% (5) advocated for more than -80% reduction.

Figure 8: Responses on the pace of the climate transition (Q1) and the level of ambition (Q2)



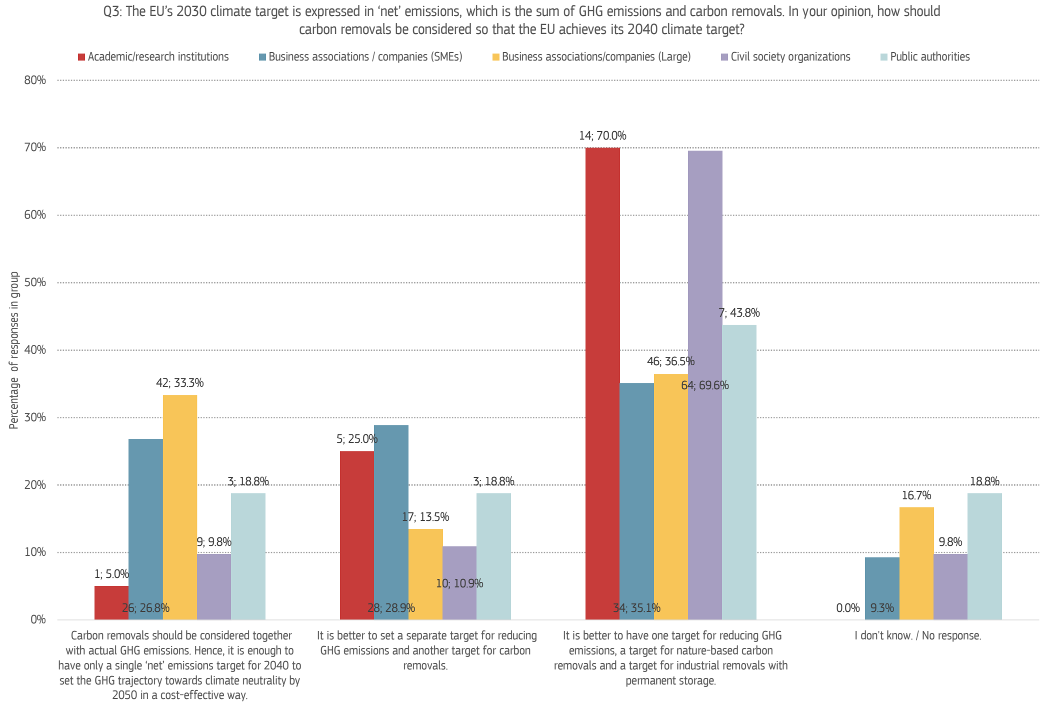


Note: n = 819 (Responses to the general section of the public consultation questionnaire)

In relation to the role of carbon removals in the EU's 2040 climate target, both individuals (272, 59.3%) and organisations (171, 47.5%;) favoured separate targets for

GHG emission reductions, nature-based carbon removals and industrial removals with permanent storage. Especially, civil society organisations (64, 69.6%) and academic/research institutions (14, 70.0%) believed that three separate targets are the best solution while public authorities (7, 43,8%) SMEs (34, 35,1%) and large business associations/companies (46, 36,5%) were less inclined to this option (see Figure 9).

Figure 9: Responses on the set up for the EU 2040 climate target



Respondents viewed most opportunities and challenges associated with ambitious EU climate targets as very relevant, mainly collective well-being (555, 67.8%) and taking responsibility for the planet and future generations (571, 69.7%). The most important challenges were ensuring a socially just transition for everybody (Avg.: 4.34, 52% rating 5), ensuring public support for climate ambition supported by EU policy (Avg.: 4.29, 56% rating 5) and improving energy efficiency (Avg.: 4.27, 56% rating 5). For SMEs associations/ companies, large business associations/ companies and for public authorities the most promising potentials were all related to economic factors, such as green jobs (58.8%, 57.1% and 75,0%), economic signals (57.7%, 73.0% and 75.0%) and energy security (55.7%, 58.7% and 81.3%).

The question of whether issues of gender should be of concern for climate policy created a stark divide, with most respondents being either strongly in favour (181, 22.1%) or strongly against it (162, 19.8%).

Contribution of individual sectors to the EU's climate ambition

Overall, a large majority of the respondents claimed that all sectors can and should do more to reduce emissions. The three most favoured sectors to increase their efforts were “Aviation & maritime transport” (Avg.: 4.42, 57% rating 5), “Road transport (passenger and freight transport)” (Avg.: 4.39, 59% rating 5) and “Industrial processes & waste” (Avg.: 4.25, 48% rating 5). “Production of electricity and district heating” was the sector that was expected to reach climate neutrality first, (442, 54%) and “Aviation & maritime transport” to be the last (393, 48%).

Personal contribution to protect the climate

Overall, respondents depicted a great awareness for climate change impacts and a willingness to make behavioural changes. (89% rating 4 and 5, Avg.: 4.66). They also declared to be ready to change their behaviour to reduce their carbon footprint (82% ratings 4 and 5, Avg.: 4.36).

The impacts of the climate crisis

Overall, respondents indicated that they are aware and concerned about the negative impacts of the climate crisis. At the same time, they point out that relevant actors must do more to prepare cities and countries for these impacts. “Loss of biodiversity and natural habitats” was of greatest concern for the respondents (Individuals: 355, 77.3%; Organisations 151, 41.9%; Total: 506, 61.6%). Additionally, in the open question on possible impacts of the climate crisis the themes climate refugees and migration; social and political conflicts; and health impact were mentioned most frequently.

On the societal level, natural disasters (338; 73.6%), negative impacts on food production (315; 68.6%) and migration or refugee movements (307; 66.9%) were most frequently selected by individuals as the most relevant climate-change related impacts.

Dealing with climate change-induced natural hazards, individuals indicated the highest level of fear for local vulnerability regarding heatwaves (322; 70.2%), droughts (310; 67.5%) and lack of water (306; 66.7%). Organisations feared the same hazards.

2.4. Results from the expert section of the questionnaire

General policy framework

Overall, respondents indicate that there is strong support for an extension of the scope of EU emissions trading to all fossil fuel uses and to cover non-CO_2 GHG emissions. For the other climate policy instruments, the results are less conclusive. Respondents most strongly agreed that all fossil fuel uses (Avg.: 4.27, 48% rating 5) as well as non-CO_2 GHG emissions (Avg.: 4.09, 46% rating 5) should be covered by EU emissions trading.

Regarding the future role of the Carbon Boundary Adjustment Mechanism (CBAM) and its scope, the strongest support is for the option that sectors with the highest absolute emissions should be prioritised for inclusion (Avg.: 3.90, 28% rating 5): transportation (appeared in 29 out of 151 responses), chemicals and polymers (24); and agriculture (20).

There are no significant majority opinions regarding the future development of the ESR. Especially large companies or business associations representing large companies favoured the idea that national targets should only cover emissions not covered by an ETS (37% rating 5), whereas they strongly disagreed with the idea that national targets should cover all GHG emissions from all sectors (7% rating 5).

Mitigation of GHG emissions from the land sector and policy options

In general, stakeholders demand more ambitious regulations to mitigate the GHG emissions in the land sector. They also indicate that if a carbon price were to be set for agricultural emissions, it should preferably be set for industry actors and then passed-on along the value chain - food companies and producers of fertilisers. Most respondents agreed that there is a need for regulatory approaches such as ambitious sectorial standards to drive the transition of the agricultural sector (Avg.: 4.23, 37% rating 5) and that focusing on aspects such as better information is not enough (Avg.: 1.75, 5% rating 5).

The role of carbon removals

Stakeholders' view on the general role of carbon removals was divided, with EU citizens and civil society organisations (52, 61.9%), in contrast to other stakeholder groups, arguing for a limited role of removals. EU citizens also argue for a stronger reliance on nature-based removals, while SMEs display a preference for a stronger reliance on industrial removals. Academic/ research institutions (10, 52.6%), public authorities (11, 61.1%) and SMEs (60, 62.5%) as well as large business associations/ companies (94, 72.9%) have a higher share of responses in favour of an important role of carbon removals. In contrast, civil society organisations (52, 61.9%) together with EU citizens (110, 50.2%), mostly prefer to limit the role of carbon removals.

Technologies

Overall, stakeholders identified technology costs as the most important barrier for the deployment of CCS. At the same time renewable energy sources are seen as the most relevant energy technology for the transition supplemented by energy efficiency, storage technologies, demand management, and innovation. T

Furthermore, the respondents rated that the most relevant technologies are wind, solar and hydropower. Energy efficiency and storage technologies are also considered as highly relevant. The open question confirmed the prominence of renewable energy with the addition of hydrogen (19 out of 156 responses) and nuclear power (15).

Engagement and social impacts

In general, stakeholders perceived the local and regional implementation of the European Green Deal as insufficient. They emphasised the importance of a just transition and agreed that the transition will affect and alter multiple sectors, including the energy, transport and agriculture sectors.

With regards to sectoral impacts of the transition, respondents specifically agreed that action to reskill and upskill the workforce due to structural shifts is required (Avg.: 4.45, 46% ranking 5) and that the green transition represents an opportunity for SMEs (Avg.: 4.14, 34% ranking 5).

Adapting to climate change

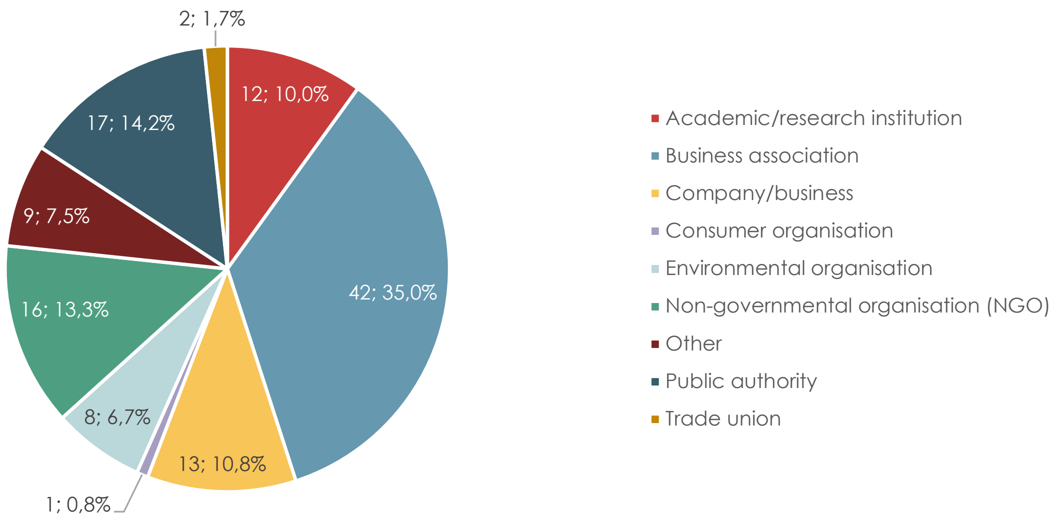
Overall, stakeholders agree that current EU regulations and policy are sufficient to guarantee the security of the mitigation efforts. Only 5.3% (31) of the respondents did agree that current EU regulations and policy are sufficient to guarantee the security of the mitigation efforts in face of climate impacts. The most favoured response was that the EU should draft new legislation to improve the climate resilience of mitigation efforts (167, 28.8%).

3. ANALYSIS OF POSITION PAPERS

3.1. Overview of position papers

A total of 237 position papers were received from the public consultation, and 146 through the call for evidence (63 were submitted to both). Out of these, two papers from national governments and one from the United Nations were submitted outside the formal consultation context. In addition, a couple of additional papers were identified through desk-research. Based on a preliminary review and a selection (removal of duplicates, relevance, type of stakeholder, previous contribution to IIA), 120 papers were thoroughly analysed.

Figure 10: Position papers by stakeholder group



Note: n = 120 (Number of position papers for in-depth analysis)

3.2. Methodological approach

The objective of the analysis was to identify the main views expressed in the position papers. A preliminary screening of all papers was conducted to identify the main characteristics and core idea of the papers. After selection, an in-depth review of all papers was conducted to identify the statements relevant for the analysis and the topics to which they belong. They were then associated with a unique identifier and basic information on the respondents which was subsequently used as variables for the analysis: stakeholder groups, country, sector etc. The main trends observed through this thematic analysis then explained and described.

3.3. Focus on position papers received from public authorities

Position papers received through the public consultation include contributions from the national governments of Denmark, Estonia, Poland, and Sweden. On a regional and local level, additional contributions from the Bavarian State Parliament, the Bavarian Ministry for the Environment and Consumer Protection, the Government of Flanders, the Cities of Amsterdam and Gothenburg were also received as part of the public consultation. On an international level, the United Nations also provided a contribution. Further relevant position papers from public authorities were identified based on desk research and provided by the EC. ([114])

The contributions by public authorities include recommendations and positions regarding the level of ambition and process for setting the EU climate target for 2040 and input on

([114]) These included position papers by the Dutch Ministry of Infrastructure and Water Management, the Irish Environmental Protection Agency, the German Environment Agency, the European Central Bank, and the Autonomous province Bolzano.

how this relates to national and regional progress of the transition and (sectoral/national) decarbonisation scenarios.

Most public authorities welcome the process of setting an EU-wide climate target for 2040. The Danish Ministry of Climate, Energy and Utilities, the Bavarian State Parliament, the United Nations, and the Autonomous province Bolzano call for an acceleration of the transition. The Danish Ministry of Climate, Energy and Utilities additionally advocates for setting an additional interim target for 2035, which would be aligned with the five-year timeframe for Nationally Determined Contributions (NDCs).

Contrarily, the Polish Ministry of Climate and Environment and the Government of Flanders express the view that the target setting for 2040 should be postponed as it is still too uncertain to predict the impact of an EU-wide climate target for 2040 and that the implementation of measures to achieve the 2030 climate targets should remain the primary objective.

4. ANALYSIS OF THE CALL FOR EVIDENCE

In addition to the public consultation, respondents were able to share feedback through a call for evidence. In total, 579 feedbacks were received. After the removal of 13 duplicate answers566 unique feedbacks remained. Most comments originated from Slovakia (126, 22.3%), Germany (100, 17.7%), Belgium (60, 10.6%), and Finland (50, 8.8%). Furthermore, a total of 146 position papers were collected, which were analysed together with the position papers obtained in the public consultation (see Section 3).

356 comments (62.9%) were received from **EU citizens**. Most opinions supported stringent GHG emission reduction targets by 2040, acknowledging that climate change is a serious threat to the EU. More radical opinions insisted on reaching climate neutrality by 2040. The second group of opinions came from climate change sceptics, insisting that climate change is not anthropogenic, and that climate action is a waste of resources. Most of opinions showed similarities with the campaign of Slovakian private individuals identified in the responses to the public consultation questionnaire.

98 submissions (17.3%) were made by **business associations** (55, 9.7%) and **companies** (43, 7.6%). Overall, companies and business associations were in favour of setting ambitious yet realistic 2040 GHG emission reduction targets based on the best available science.

55 submissions (9.7%) were made by CSOs, including NGOs (43, 7.6%), environmental organizations (9, 1.6%), trade unions (2, 0.4%), and one consumer organization (0.2%). The key messages from this stakeholder group underscored the importance to meet the requirements set by the Paris Agreement, generally, advocating for a more ambitious “net zero” transition.

14 submissions (2.5%) were made by **academic and research institutions**. The key messages from these responses related to the prevalent demand that the EU should integrate the latest scientific evidence when formulating the emission targets for the 2030-2040 period. Another important aspect was the EU's historical responsibility when it comes to carbon emissions.

Seven submissions (1.2%) were made by **public authorities**. The key messages from these responses related to the need for investments concerning the green transition for aspects such as green technologies and re-skilling. In this context, the submissions of public authorities highlighted the EU's crucial role as a supporting force that can facilitate the transition of other countries and thereby contribute to its global responsibility.

A further 36 responses (6.4%) came from **non-EU citizens** (4, 0.7%) or from stakeholders who classified themselves as "Other" (32, 5.7%). The topics of these responses largely mirrored the topics of the other stakeholder groups. Especially those stakeholder types that related strongly to their respective type.

4.1. Results from the analysis of position papers

<u>The 2040 target and associated opportunities, challenges and enabling factors</u>

Regarding the level of ambition for the net emission reduction target for 2040, 41 papers (34 % of the total) provided an opinion. Most papers (32) advocate for an acceleration of the transition and five prefer its current speed.

Many contributions favour a realistic transition pathway for industry, by undertaking a critical review of the practical feasibility of an ambitious 2040 target including impacts on competitiveness; the impact on energy prices; and the cost-effectiveness of a more ambitious target.

57 papers (48%) expressed an opinion about the opportunities related to higher climate ambition. More than a third of the papers consider that a higher climate ambition would benefit EU's economic competitiveness; the creation of new jobs; EU global leadership; innovation fostering or well-being. At the same time, most papers mention that the EU is facing multiple, technological, financial, social, regulatory and political challenges.

Only few papers discussed the impact of climate policies on SMEs, not expecting negative impacts provided that the administrative burden does not increase, and that support, and resources are provided to cope with the needed transition (fair transition).

<u>*The contribution of Individual sectors to the EU's climate ambition*</u>

Around 70 position papers (58% of all answers) provided opinions on the prioritisation of sectors and the following sectors were identified as priority for GHG emission reduction: transport (24), agriculture and forestry (14). Buildings (11) and industry (10).

<u>*The role of policy instruments*</u>

- EU Emission Trading System (EU ETS)

63 papers (53%) commented on the role of the ETS post-2030. An overwhelming majority considered the EU ETS as an instrument playing a key role in the mitigation of EU emissions. However, an evolution of the tool in relation to the 2040 target is needed.

The most widely discussed topic was the sectoral coverage, with a suggestion to extend to all, or to a restricted number of additional sectors. The interaction with other policies and instruments (ESR, LULUCF, CBAM) was addressed, with concerns expressed about the risk of double-coverage, relation between ETS- and CBAM-prices and scope coverage.

Most stakeholders supported an integration of carbon removal in the ETS.

The third most discussed topic concerned the international integration and potential linkages to other countries/regions.

- Carbon Border Adjustment Mechanism (CBAM)

39 papers (33%) provided elements on the role of CBAM. Most papers indicated that CBAM plays an essential role to avoid carbon leakage and to support carbon market internationalisation. However, more than a third considered that its efficiency is yet to be demonstrated.

22 papers discuss CBAM extension, with contradicting views. While two thirds of the papers considered that CBAM should be extended (to sector at most risk of carbon leakage, to cover the export part of the EU production, to integrate downstream sectors or cover all sectors covered by free allowances under the ETS), one third considered that a CBAM extension should be carefully considered.

- Effort Sharing Regulation (ESR)

23 papers (19%) expressed an opinion on the role of ESR. A bit less than half the papers expressed the need to adjust the ESR, notably given the broadening scope of the ETS.

Mitigation of GHG emissions from the land sector and policy options

44 of the analysed papers (37%l) commented on options to tackle agricultural emissions including sustainable farming/carbon farming (9) followed by dietary changes (7) and agriculture carbon removal role (7). Other options mentioned frequently were some form of market incentives and the non-inclusion of the agricultural sector in LULUCF.

The role of carbon removals

73 papers (61%) commented on the role of carbon removals to reach 2040 climate neutrality goals. Most papers acknowledged carbon removals as an important means, yet reservations and concerns were shared in 15 position papers, emphasising they should not be a substitute and offset for GHG emission reduction and should only be considered as a second-best option.

Carbon capture and storage/use

34 papers (28%) commented specifically on the role of different carbon capture and storage technologies. About half the papers, from business associations, public authorities and academia, encouraged the uptake of carbon capture and storage technologies, without assigning priority to one specific technology type.

Energy technologies

72 papers (60%) discussed the most relevant technologies for supporting the energy transition as well as opportunities and barriers of their uptake. 33 position papers (28%)

argued for enhancing the utilization of renewable energies and increasing their share in energy consumption. Moreover, 15 papers (13%) supported applying energy efficiency principles and taking into consideration the beneficial interaction between renewables, increased energy efficiency and GHG targets.

Engagement and social impacts

57 position papers (48%) discuss the social impact of future climate change policies. 28 (23%) make a comment on the need for a socially or economically just transition, where vulnerable groups, communities and Member States are protected from climate risks and poverty.

5. ANALYSIS OF THE STAKEHOLDER EVENT

On 9 June 2023, an all-day stakeholder event was held to gather further feedback and insights on the view of the EU's 2040 climate targets. It was attended in person by 34 stakeholder representatives, including ten from the energy sector, six from industry, six from think tanks, and six from NGOs, as well as representatives from transport, agriculture, SMEs, trade unions, and cities. In addition, a further 48 participants followed the meeting online.

The contents of the event are summarised in the following:

Climate impacts and cost of inaction: Stakeholders were convinced that natural hazards and biotic risks will impact the forestry, agriculture, and other land-use sectors, as well as renewables and waste management/recycling. They emphasised that cities and industries will be affected by employment and work-related risks. In this context, the communication of mitigation and adaptation measures should be linked with other environmental benefits to give a positive narrative, as well as to stress the costs of inaction.

Fair transition, employment, and social aspects: Stakeholders highlighted the skills gap regarding the required technologies and demographic factors as aspects that should be considered. It was stressed that financial support will be needed for green infrastructure (especially for smaller cities), as well as targeted support for lower/middle income groups for the switch of technologies (e.g., upfront costs of heat pumps and electric vehicles).

Energy – including storage, grids, and renewables: Stakeholders believed that aspects such as energy efficiency and contributions to energy security are key in the energy transition. There was disagreement on the role of hydrogen and e-fuels.

Carbon removals/storage: Participants demanded a clear differentiation between emission reductions and carbon removals, suggesting separate targets. The focus should be on emission reductions, with carbon removals reserved only for residual hard-to-abate emissions. In addition, two targets are also needed within the context of carbon removals: one for nature-based removals, and one for technological removal/storage.

Economic effects, competitiveness, industry, and SMEs: Most stakeholders approved the positive effects of having long-term targets and a more stable and predictable legal and regulatory framework is required for investments. More support for industry, such as Carbon Contracts for Differences (CCfD) will be needed for the transition. Additional claims included that the EU industry needs capital investment and reliable/available renewables as well as breakthrough technologies for key industries and lead markets for green technologies.

Agriculture, food security and land sectors (LULUCF, forests, biodiversity, and biomass): Agriculture stakeholders called for intensified food production within GHG boundaries. Forestry stakeholders emphasised the important role of wood-based raw materials and products, whereas civil society organizations called for agriculture to avoid energy crops and questioned the role of wood-based products.

International aspects, and non-EU climate action: Stakeholders emphasised that the EU should align with the UNFCCC 5-year policy cycles, such as setting a 2035 target. Additional claims included: assessing the EU's carbon footprint and the global contribution of EU-based companies in terms of behaviour and policies outside of Europe, as well as embedding carbon in trade flows.

Behavioural change and lifestyles: Stakeholders proposed to frame the green transition as "our well-being and lifestyles will be damaged if we fail to limit global warming to 1.5ºC". The focus should be on sufficiency principles, active mobility, new production models, and consumption-related emissions, as well as the green infrastructure and support for upfront costs that are needed to enable individual climate-friendly choices.

6. OTHER CONTRIBUTIONS

In 2023, the European Scientific Advisory Board on Climate Change (ESABCC) published an advice on the 2040 climate target and GHG budget ([115]). The ESABCC's advice is reflected throughout the Impact Assessment and comparisons with the ESABCC's analysis are made where appropriate.

The outcomes of Horizon 2020 and Horizon Europe projects related to climate science and mitigation pathways provided important contribution and evidence base for this Impact Assessment.

([115]) ESABCC (2023). Scientific advice for the determination of an EU-wide 2040 climate target and a greenhouse gas budget for 2030–2050. DOI: 10.2800/609405.

Annex 3: Who is affected and how?

1. Practical implications of the initiative

The scope of the current initiative focuses on the ambition level of a 2040 GHG target only. The accompanying post-2030 policy implementation framework will be designed and proposed in a later stage. As such, in absence of this post-2030 policy implementation framework, it is not possible yet to calculate the administrative costs, regulatory fees and charges, and enforcements costs for businesses and citizens. All these elements of the 'one in, one out' approach will depend on the changes in the implementation of the post-2030 policy implementation framework, in comparison with the current 2030 policy framework.

The implementation of the current 2030 policy framework is supported by the 30% minimum climate mainstreaming in the MFF, and the 37% minimum climate requirement of the Recovery and Resilience Facility (RRF).

The preferred option for this initiative corresponds to a target range of 90-95% emission reduction compared to 1990.

2. Summary of costs and benefits

I. Overview of Benefits (total for all provisions) – Preferred Option		
Description	Amount	Comments
Direct benefits		
Avoided costs of climate change (section 6.3.1).	In option 3, in comparison with option 2, the average annual benefit from climate change mitigation is between EUR 20 and 38 billion for the time period 2031-2040, by EUR 24 and 44 billion for 2041-2050 and by EUR 22 and 42 billion over the entire period 2031-2050.	Avoiding costs of climate change is a general benefit for the whole society, including population, businesses, the public budget, and for nature and ecosystems. Such costs are generally thought to be underestimated, given the difficulty in predicting the impacts of climate change. This is specifically a benefit for all companies in sectors that are dependent on meteorological conditions and natural ecosystems (agriculture, fishery, etc). This is a benefit for companies as it reduces the risk of natural disasters

		and associated consequences on economic activities This is particularly true for SMEs which tend to have low insurance coverage for risks associated with extreme weather events. This is beneficial for public budgets as it reduces the risk that public money is needed to compensate losses associated with extreme weather events (for example losses in agriculture due to droughts). Finally, all citizens, whether workers in exposed sectors, inhabitants of potentially exposed accommodations, owners of exposed properties, or taxpayers benefit in consequences of the points mentioned above.
Higher energy independence and reduction of the risks associated with fossil fuel price shocks (see section 6.4.3.1)	In comparison with option 2, option 3 implies average annual savings of €22 billion for 2031-2040 due to reduced fossil fuel import. In 2041-2050, the annual savings amount to EUR 9 billion.	This is a benefit for the whole economy, large companies as well as SMEs, and, in fine, for the public budget as well. The higher energy independence reduces the risk of fossil fuel price shocks for companies, SMEs and all citizens. For all, it provides larger certainty to have access to energy at an affordable price.
Indirect benefits		
Reduction of air pollution and reduction of the associated premature mortality and morbidity (see Section 6.3.2)	Annually, the average benefit from air pollution reduction is between EUR 1 to 2 billion in option 3 compared to option 2 (in 2031-2040, as well as in 2041-2050).	This is a benefit for the whole EU population and for the public budget as a consequence of reduced health expenses. The health of all citizens benefits from reduced air pollution. This reduces health expenses, whether they are borne by public authorities or by private insurance companies. In turn, this benefits taxpayers and allows the public budget to be used for other needs.

II. Overview of costs – Preferred option							
		Citizens/Consumers		**Businesses**		**Administrations**	
		One-off	**Recurrent**	**One-off**	**Recurrent**	**One-off**	**Recurrent**
Action (a)	Direct adjustment costs		The figures for energy system costs provided below are annual averages. More details can be found in section 6. 4.3. of this document and in Section 2.3 of Annex 8. For the residential sector, the total energy system costs in 2031-2040 are EUR 9 billion (1%) higher in option 3 than in option 2. For 2041-2050, they are EUR 2 billion (0.2%) higher in option 3 than in option 2. The capital costs[116] are EUR 8 billion (1.6%) more in option 3 than in option 2 for 2031-2040 and EUR 4 billion (0.7%) more for 2041-2050. Energy purchases are EUR 1 billion higher in option 3 than in option 2 for 2031-2040 but EUR 2 billion lower for 2041-2050.		The figures for energy system costs provided below are annual averages. More details can be found in section 6. 4.3. of this document and in Section 2.3 of Annex 8. For industry the capital costs are EUR 2 billion (2%) higher in 2031-2040 in option 3 compared to option 2 and EUR 1 billion (less than 1%) higher in 2041-2050. Energy purchases are EUR 8 billion (2%) more in option 3 compared to option 2 for 2031-2040. They are EUR 2 billion (0.5%) more for 2041-2050. For the tertiary sector, capital costs are EUR 4 billion (3%) more in option 3 than in option 2 for the time period 2031-2040. They are EUR 2 billion (1%) higher for the time period 2041-2050. Energy purchases are EUR 1 billion (0.4%) smaller in option 3 than in option 2 for 2031-2040. They are EUR 1 billion (0.4%) smaller for 2041-2050.	*Will depend on the future post-2030 policy framework. It will also depend on the share of the costs for households and companies that can be borne by public funding. This partly depends on the national legislations (for example national or regional funding for improving energy efficiency in the residential sector).*	
		Energy systems costs for transport are borne partly by households, partly by businesses and public administrations. The corresponding capital costs are EUR 4 billion (1.6%) higher in					

[116] *Capital costs includes financing and opportunity cost for private actors through the application of a WACC at 10% in the annualization of overnight investment costs.*

		2031-2040 for option 3 compared to option 2, and EUR 6 billion (2%) higher in 2041-2050. Energy purchases for transport are EUR 12 billion (2%) higher in 2031-2040 but EUR 7 billion (1.4 %) lower in 2041-2050.					
	Direct administrative costs	*Will depend on the future post-2030 policy framework*					
	Direct regulatory fees and charges	*Will depend on the future post-2030 policy framework*					
	Direct enforcement costs	*Will depend on the future post-2030 policy framework*					
	Indirect costs						
Costs related to the 'one in, one out' approach							
Total	Direct and indirect adjustment costs		The figures for energy system costs provided below are annual averages. More details can be found in section 6. 4.3. of this document and in Section 2.3 of Annex 8. For the residential sector, the total energy system costs in 2031-2040 are EUR 9 billion (1%) higher in option 3 than in option 2. For 2041-2050, they are EUR 2 billion (0.2%) higher in option 3 than in option 2. The capital costs[117] are EUR 8 billion (1.6%) more in option 3 than in option 2 for 2031-2040 and EUR 4 billion (0.7%) more for 2041-2050. Energy purchases are EUR 1 billion higher in option 3 than in option 2 for 2031-2040 but EUR 2 billion		The figures for energy system costs provided below are annual averages. More details can be found in section 6. 4.3. of this document and in Section 2.3 of Annex 8. For industry the capital costs are EUR 2 billion (2%) higher in 2031-2040 in option 3 compared to option 2 and EUR 1 billion (less than 1%) higher in 2041-2050. Energy purchases are EUR 8 billion (2%) more in option 3 compared to option 2 for 2031-2040. They are EUR 2 billion (0.5%) more for 2041-2050. For the tertiary sector, capital costs are EUR 4 billion (3%) more in option 3 than in option 2 for the time period 2031-2040. They are EUR 2		

[117] *Capital costs includes financing and opportunity cost for private actors through the application of a WACC at 10% in the annualization of overnight investment costs.*

			lower for 2041-2050.		billion (1%) higher for the time period 2041-2050. Energy purchases are EUR 1 billion (0.4%) smaller in option 3 than in option 2 for 2031-2040. They are EUR 1 billion (0.4%) smaller for 2041-2050.		
		Energy systems costs for transport are borne partly by households, partly by businesses and public administrations. The corresponding capital costs are EUR 4 billion (1.6%) higher in 2031-2040 for option 3 compared to option 2, and EUR 6 billion (2%) higher in 2041-2050. Energy purchases for transport are EUR 12 billion (2%) higher in 2031-2040 but EUR 7 billion (1.4 %) lower in 2041-2050.					
	Administrative costs (for offsetting)	*Will depend on the future post-2030 policy framework*					

[1] *Capital costs includes financing and opportunity cost for private actors through the application of a WACC at 10% in the annualization of overnight investment costs.*

3. Relevant sustainable development goals

The initiative aims to assess the climate target for 2040, so goes beyond the time horizon of the UN sustainable development goals (SDG) for 2030. Nevertheless, it relates to a number of these goals and, by setting a clear direction beyond 2030, and will also contribute positively to these objectives by 2030 by providing long-term certainty for policy and investment decisions. The analysis also shows that there can be strong positive effects from some SDGs that play a role in reaching the 2040 climate target.

III. Overview of relevant Sustainable Development Goals		
Relevant SDG	Expected progress towards the Goal	Comments
SDG 3 – Good health and well being	Strong synergies in terms of air quality in all target options in EU and in countries that follow the EU lead and take more ambitious climate action.	

SDG 7 Affordable and clean energy	Clean and decarbonised energy is a key component of all target options. It shields consumer from shocks on the fossil fuel markets.	
SDG 8 Decent jobs and economic growth	The different 2040 target options display very limited difference in terms of overall macro-economic impact. They will contribute to mitigating the impacts of climate change, including for workers and on the economy. New markets and jobs to substitute fossil fuel-dependent economic activities and new opportunities in clean, technology manufacturing and deployment, land-use sector, service sector.	Skilling needs for new products and services in a low carbon economy. The new target and future framework are an opportunity to address labour market inequalities.
SDG 9 Industry, innovation and infrastructure	Reaching climate neutrality by 2050 represents an industrial and infrastructure challenge that will spur innovation. The most ambitious option (Option 3) builds on a larger deployment of low carbon solutions already by 2040, while the least ambitious one (Option 1) rather delays it during the last decade.	
SDG 13 Climate action	All target options are compatible with meeting climate neutrality by 2050.	However, the least ambitious target options rely heavily on deployment on novel technologies during last decade 2041-2050, which puts the climate neutrality target at risk.
SDG 15 Life on land / SDG 14 Life below water	Mitigate the adverse impacts of climate change on land, oceans and biodiversity.	Limited direct impact of climate action. The most ambitious climate target is at risk of trade-offs on land use due to potential bioenergy needs.
SDG 17 Partnerships for the goals	The preferred target option of 90-95% is much more likely to contribute positively to international climate action effort.	

ANNEX 4: SME TEST

Note: the "analytical framework" Annex appears as Annex 6, just ahead of the detailed analysis shown in Annex 7 (Cost of inaction) and Annex 8 (Detailed quantitative analysis of GHG pathways to climate neutrality).

Step 1/4: Identification of affected businesses

All segments of the EU economy are and will be affected by climate change, although some sectors are more exposed than others, notably agriculture, tourism, fisheries and forestry. SMEs have a more limited financial capacity and lower resources to adapt to climate change ([118]).

To contribute to limiting climate change globally through the implementation of the objective of climate neutrality by 2050, this initiative aims at assessing a 2040 EU-wide climate target covering the whole economy. It is thus relevant for all businesses and sectors since it will set the pace of the transition to 2050. The climate target is expressed as a reduction of net GHG emissions compared to 1990. It will directly affect GHG emitting sectors and those involved in the removal of CO2 from the atmosphere through natural or industrial means, but also, indirectly, other sectors consuming energy or providing goods and services to deliver a competitive and climate neutral EU economy by 2050.

This initiative does not specifically target or have specific provisions for SMEs. The objective of the current assessment is to compare various GHG ambition levels for 2040 to define the path between the established 2030 and 2050 objectives. This initiative and assessment come without the design of a new 2040 policy framework, which is expected in a later stage. The impact on SMEs depends on the sectors in which they operate. According to the 2022 Flash Eurobarometer "SMEs, green markets and resource efficiency" ([119]), about one in three (32%) SMEs in the EU offer green products or services, with a further 11% planning to do so in the next two years. For the largest share (43%) of SMEs selling green products and services, these products and services make up not more than 10% of their most recent annual turnover. About one in five (21%) reply that green products and services represent between 11% and 50% of their annual turnover and a slightly higher proportion (23%) answer that the sale of such products and services makes up more than 50% of their turnover. Just under 40% of SMEs surveyed have at least one full-time employee working in a green job some or all of the time: 33% say there are between one and five 'green' employees in their SME and 5% report that their number is higher than five.

According to this survey, most SMEs are taking measures to be more resource efficient. At the same time, the actual investment by SMEs in resource efficiency remains low. 35% of SMEs surveyed invested 1% or more of their turnover in this area in the two years before the survey. Saving energy is the second most common resource efficiency

([118]) Enabling business mitigation and adaptation to climate change Green policies and the role of Employer and Business Membership Organization. International Labour Organization. December 2022

([119]) Flash Eurobarometer 498 – SMEs, green markets and resource efficiency, March 2022.

action undertaken by SMEs. More than three-quarters (77%) of SMEs plan to implement additional measures to improve resource efficiency in their company. The most common resource efficiency action planned for the two years following the survey is saving energy (53%). A vast majority of SMEs (72%) do not (yet) have a concrete strategy in place to reduce their carbon footprint and become climate neutral; about a quarter of these SMEs reply they are planning to define one. One in five SMEs already have a concrete strategy in place to reduce their carbon footprint and 4% say they are already climate neutral. The most common actions undertaken to become carbon neutral (among SMEs with a carbon reduction strategy) include adopting or purchasing new technological solutions (49%).

To identify affected businesses,

Table 40 presents the share of each sector in the total number of SMEs and the share of employment by SMEs in each. About 66% of all SMEs are active in services. In this sector, many businesses will not be affected in any significant manner by the transition, while others may gain from business opportunities stemming from the need for innovative low carbon solutions. Agriculture represents almost a fourth of small and medium businesses and is a sector exposed to climate change. Given its hard-to-abate GHG emissions and its potential role to enhance LULUCF carbon removals, this sector is also very relevant for the transition. SMEs are also very present in construction, a sector that plays a major role to decarbonise the EU's building stock. Finally, SMEs are less present in other key sectors for the transition and where the assessment shows differences across target options in terms of deployment of new technologies and investment needs: electricity and clean fuels production, energy intensive industries and carbon capture and storage technologies.

Table 40: Indicators of SME activity by sector (2019)

	SME shares in the economy (% of total)		Sectoral split of SMEs (% of economy-wide SMEs)		
	Share in GVA	Share in employment	Number of companies	GVA	Employment
Fossil fuels	7.0%	6.6%	0.0%	0.1%	0.0%
Other mining and extraction	53.1%	59.2%	0.1%	0.3%	0.2%
Energy intensive industries	29.1%	34.4%	0.6%	2.9%	2.0%
Manuf. transport equipment (incl. parts and accessories)	7.9%	14.1%	0.1%	0.6%	0.6%
Manuf. electrical equipment and other machinery	32.0%	35.4%	0.5%	3.1%	2.0%
Other manufacturing	44.4%	65.0%	7.5%	14.3%	15.9%
Electricity, gas, steam and air conditioning supply	22.3%	29.0%	0.7%	1.4%	0.5%
Construction and architecture services	77.8%	89.1%	19.0%	16.4%	17.5%
Transport and storage	49.0%	43.6%	5.4%	5.2%	4.9%
Services	62.7%	69.5%	65.7%	54.3%	55.5%
Water, treatment and waste	46.7%	45.3%	0.3%	1.3%	0.9%
Total	52.9%	64.4%	100.0%	100.0%	100.0%
Memo:			Million	Billion EUR	Million people
All sectors above	52.9%	64.4%	23.1	3332	76.3
Agriculture	66.7%	95.6%	8.7	128	8.3

Source: Eurostat Structural Business Statistics; Farm Indicator by Legal Status of the Holding; and Detailed Breakdown of Main GDP Aggregates ([120]).

([120]) The data is calculated from the Structural Business Statistics (SBS), except for agriculture, which is not included in the dataset. For SBS sectors, the table is based on an aggregation of sectors by size class for special aggregates of activities (NACE 2). Fossil fuel sectors (B05, B06, C19); other mining and extraction activities (B07, B08, B09); energy intensive industries (C17, C20, C21, C23, C24); manufacturing of transport equipment (C29, C30); manufacturing of electrical equipment and other machinery (C27, C28); other manufacturing (all other C codes); electricity, gas, steam and air conditioning supply (D35); construction and architecture services (F41, F42, F43, M71); transport and storage (H49 to H53); services (all codes not listed in other sectors); water, treatment and waste (E36 to E39). The data for agriculture is not directly comparable and therefore provided separately. All farms under the holding of natural persons are considered SMEs, while all others are considered as not being SMEs. The gross valued added of SMEs in agriculture (and its share in total agricultural GVA) is estimated based on the percentage of hectares exploited by holdings under the ownership of natural persons, using total gross value added in

Step 2/4: Consultation of SME Stakeholders

The consultation of SME stakeholders includes the public consultation for this initiative, with the possibility to reply to a public questionnaire and to submit position papers, and a stakeholder event. The 2022 Flash Eurobarometer "SMEs, green markets and resource efficiency" also provides more general insights from SMEs.

The public consultation for the initiative was held from 31 March to 23 June 2023. The information about the public consultation was disseminated via 28 social media posts on the channels of the Commission (Twitter, Facebook, LinkedIn, Instagram). It was communicated to several Directorate Generals (DGs) of the Commission, Permanent Representations and stakeholders, some of which shared the information further to their own networks. The consultation was promoted in two intranet articles and multiple newsletters of the Directorate General for Climate Action ("Climate Pact" and "DG CLIMA monthly") and other DGs.

The questionnaire includes 13 general questions (e.g. on the level of ambition for the EU) and 18 more specific questions (e.g. on the role of carbon removal), including question 33 which covers the sectoral implications for SMEs. SMEs and representative organisations represent 12% of the responses to the public questionnaire. The diversity of SMEs (micro, small and medium-size enterprises) is represented, for example via the contribution of organisations such as SMEunited or Bundesverband Erneuerbare Energie e.V. (BEE). Respondent SMEs support for the different 2040 target levels assessed is split between reductions of 75%-80% (29%), 80%-90% (22%) and above 90% (20%). They consider that the green transition represents an opportunity for them (with a mark of 4.2/5), and agree with the following statements (sorted by decreasing support):

- The likely structural shift and changing skill requirements in the economy towards a green and circular economy will require EU action to reskill and upskill the workforce (4.4/5).
- The EU transition to a net-zero economy impacts differently the competitiveness of SMEs from those of large companies (4.1/5).
- The impact on competitiveness of micro-companies is likely to differ from the impact on small and medium-sized ones (4.0/5).
- After 2030, there will be a greater need to support SMEs to cope with the adaptation and costs associated with the green transition (3.9/5).

Only few position papers discuss the impact of climate policies on SMEs. These do not expect negative impacts provided that the administrative burden does not increase for SMEs, and that support and resources are provided to cope with the needed transition.

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agriculture (NACE code A01) as reporting in the national accounts. Similarly, SME employment in agriculture (and its share in total agricultural employment) is estimated based on the percentage of farms under the ownership of natural persons. SBS-based data is for 2019 to avoid the distortions due to the COVID pandemic. Figures for agriculture are for 2020 due to data availability.

Indications of possible support and resources are given in the paragraph 4/4 – Minimising negative impacts on SMEs (see below).

A stakeholder consultation event was held on 9 June 2023. 66 organisations were invited, including SMEs representatives (e.g. the European association of craft, small and medium-sized enterprises - SMEunited, or European Entrepreneurs - Confédération Européenne des Associations de Petites et Moyennes Entreprises - CEA-PME) or associations representing sector specific businesses including SMEs, for example the Committee of Professional Agricultural Organisations (COPA-COPEGA) or the Confederation of European Forest Owners (CEPF).

More generally, the 2022 Flash Eurobarometer evaluated the level of resource efficiency actions and the state of the green market among Europe’s SMEs. Among SMEs taking resource efficiency actions, 31% say that their production costs have increased, 26% that there has been no change in their production costs and 31% that there has been a decrease of their production costs over the two years before the survey as a result of the resource efficiency actions. Among SMEs that take resource efficiency actions, 64% rely on their own financial resources and 54% on their own technical expertise in their efforts to be more resource efficient. About a quarter of SMEs (24%) rely on external support. More than a third (36%) of SMEs relying on external support in their efforts to be more resource efficient say they receive public funding, such as grants, guarantees or loans. Over a quarter (28%) receive private funding from a bank, investment company or venture capital fund. More than one third of SMEs (36%) think that grants or subsidies would help their company the most to be more resource efficient.

The SMEs inputs from the public consultation and stakeholder event have been taken into consideration in this impact assessment, its in-depth analysis (see, for example, the competitiveness aspects in Section 8) and enabling framework annexes.

Step 3/4: Assessment of the impact on SMEs

The initiative does not set out measures that require specific compliance efforts from SMEs. Relevant impacts of this initiative on SMEs include the benefit from mitigating climate change (avoided cost of climate inaction and extreme climate-related events), investment needs and potential changes in energy prices, and change in specific markets. The understanding of the impacts on SMEs is important in view of better defining the enabling framework that will allow supporting and accompanying the transition for these actors.

First, contributing to mitigating climate change implies a benefit for SMEs. Small companies have started to experience the impact of climate change on their operation, as reported by the European Investment Bank in its 2022 overview on SMEs. Collier and Ragin ([121]) indicate that the higher frequency of extreme events due to climate change will imply higher costs for small businesses. In the worst cases of climate related extreme

([121]) Collier B. and M. Rajin, “As climate risk grows, so will costs for small businesses”. Harvard Business Review, August 2022.

events, exposed SMEs could lose up to 100% of their productive capacities. 38% of SMEs declare not to be covered for the risk of physical loss or damage from a natural disaster and 56% declare not to be covered for the risk of stopping business activities due to disaster related damage ([122]). In such circumstance, contributing to mitigating climate change is beneficial for all. According to the International Labour Organization, SMEs are less equipped than large companies to plan and invest in adaptation measures ([123]). A more ambitious 2040 target is more likely to lead to limiting climate change than a lower one.

Another benefit of the transition to a climate neutral EU economy is a reduction of the exposure of SMEs to fossil fuel price shocks, which can propagate through the entire energy system and all energy vectors. Due to the war in Ukraine, energy and their volatility have increased (180% increase in the gas price in the first two weeks of the war, reaching an all-time high of 320 €/MWh on 26 August 2022, while the average price was around 16, 47 and 123 €/MWh in 2015-2020, 2021 and 2022 respectively) ([124]) ([125]). Improving energy efficiency and independence from fossil fuel reduces the risk of such costs for SMEs. Simulations done with the JRC GEM-E3 model show that the economic impact of fossil fuel price shocks is smaller if the ambition for 2040 is larger.

In terms of cost of energy, the different target options display fairly similar impacts for most sectors relevant for SMEs (see Sections 2.2 and 2.3 in Annex 8). SMEs are expected to face very similar energy prices (including electricity prices) across target options. However, the most ambitious target entails a stronger reliance on new fuels, which are currently little deployed (for instance hydrogen to heat at high temperature) and which can concern large but also some smaller industrial actors (for instance the ceramic industry, where most manufacturers are SMEs).

Investments for electrification and energy efficiency improvement are required across all options, with a slightly higher level for the highest level of ambition than for the lower level. As presented in Table 40, around 66% of SMEs are active in services. For the majority of these SMEs, the impact of the transition is likely to be limited and the difference between options is small. For services sectors, average annual investment needs for all companies, including large businesses, range between EUR 49 billion (lower level of ambition) and EUR 57 billion (higher level of ambition) in 2031-2040. This is equivalent to a range of €800 to 940 per employee, keeping in mind that about 30 percent of employees in services work in large enterprises. On average over 2031-2050, investment requirements are very similar.

The impact of the three possible options on SMEs is rather dependant on the sectors. To some degree, the impact of the transition on SMEs depends on the ambition of the 2040

([122]) Flash Eurobarometer, SME insurance trends, European Insurance and Occupational Pensions Authority, 2022.

([123]) Enabling business mitigation and adaptation to climate change Green policies and the role of Employer and Business Membership Organization. International Labour Organization. December 2022

([124]) Adolfsen J. F., F. Kuik, E. M. Lis and T.Schuler, The impact of the war in Ukraine on euro area energy markets". ECB Economic Bulletin, Issue 4/2022.

([125]) Dutch Title Transfer Facility prices, Internal analysis based on S&P Global Platts.

target, in particular in the sectors that will need to contribute more or in which specific technologies will need to be applied more extensively. But the final impact will largely depend on the future design of policies and measures to be determined in the years to come in view of meeting the 2040 target.

Most SMEs are in sectors where the energy system costs for option 3 are limited in comparison with option 2 (see Table 41 below).

Table 41: Energy system costs for 2031-2040 and sectoral distribution of SMEs

	Sectoral split of SMEs (number of companies)	Sectoral split of SMEs (GVA)	Aggregate sector in the macro-economic analysis	Energy system costs for 2031-2040 (% change compared to option 2)
Services	65.7%	54.3%	Tertiary	+0.5%
Construction and architecture services	-19.0%	16.4%		
Water, treatment and waste	0.3%	1.3%		
Manuf. transport equipment (incl. parts and accessories)	0.1%	0.6%	Non-EIIs	+0.8%
Manuf. electrical equipment and other machinery	0.5%	3.1%		
Other manufacturing	7.5%	14.3%		
Electricity, gas, steam and air conditioning supply	0.7%	1.4%		
Transport and storage	5.4%	5.2%	Transport	+2%
Energy intensive industries	0.6%	2.9%	EIIS	+2.8%
Fossil fuels	0.0%	0.1%		
Other mining and extraction	0.1%	0.3%		

Note: the sectoral disaggregation used by the Structural Business Statistics does not exactly match the sectoral disaggregation used in PRIMES. The correspondence is indicative.

For the tertiary sector (services represent more than 65% of SMEs), the average investment needs over 2031-2050 are the same across options. It is their distribution over the two subperiods (2031-2040 and 2041-2050) which varies across options. The capital costs for the transition are higher in the most ambitious options (nearly +5% in option 3 compared to option 1 for 2031-2040 vs +2% in option 2 compared to option 1) but this is partly compensated by larger savings in energy purchases (nearly -1% in option 3 compared to option 1 vs -0,5% in option 2 compared to option 1).

For the construction sector (19% of SMEs in construction and architecture services), the transition is an opportunity as it requires the renovation of the building stock to improve energy efficiency. The need for renovation is high across options, but it is front-loaded with the most ambitious target (10% larger investment needs for 2031-2040 in option 3 compared to option 1, but equally smaller needs for 2041-2050). To avoid shortages, the transition will require to anticipate the needs with regards to skills and supply in general.

For the transport sector (5% of SMEs are in the transport and storage sector), the investment needs are comparable across options (see Section 6 of the main report). The most ambitious option implies a larger use of e-fuels and biofuels. The use of new energy carriers requires new types of engines and new activities (e.g. for their installation/maintenance). At the same time, new infrastructures need to be developed (for example, charging stations for electric vehicles). The reduced use of conventional vehicles with internal combustion engines ([126]) implies a reduction in corresponding activities, but, at the same time, new jobs are created for the supply, installation and maintenance of the new equipment and infrastructure, as well as for the development of new mobility services (e.g. shared cars).

In the manufacturing sectors that are not energy intensive (7.5% of SMEs in the manufacturing other than transport or electrical equipment), SMEs are most likely to decarbonise their production processes mainly via electrification and improvements in energy efficiency. For the sectors that are not energy-intensive, the options differ little in terms of investment needs in 2031-2050 at an average of around EUR 10 billion per annum, but options 3 and 2 imply a quicker transition than option 1. The risks associated with energy costs are limited even if they are higher with the most ambitious target (see Annex 8). The latter indeed relies more on relatively more expensive fuels. The transition brings opportunities in the markets for low-carbon technologies – for instance, in ocean energy ([127]) or sustainable advanced biofuels ([128]).

In the sectors that are most exposed to the transition (fossil fuel, other mining and extraction, energy intensive industries, electricity, gas and steam), SMEs only represent a very small share of the activity (less than 1.5% of SMEs). In these sectors, SMEs will have to adjust their activities. To give an example, the ceramic industry will have to rely on new fuels to heat at high temperature. Specific support programmes and measures exist to ensure a just and fair transition (see Annex 9).

Finally, the agriculture sector (23% of SMEs) is strongly exposed to climate change. The reduction of emissions implies opportunities and challenges. The intermediate and most ambitious options lead to strong GHG reductions in agriculture and a generalised uptake of new technologies. Agriculture is mildly affected by a higher level of ambition, with output 1% lower under S3 than under S2, which is itself 2% lower than under S1. In contrast, output in the forestry sector in 2040 is significantly higher under the higher ambition scenarios than under S1 as a result of the increased demand for biomass. By 2050, the differences are much less significant as biomass uses tend to converge across scenarios. The need to develop carbon removals is a source of opportunities and new revenues in the bioeconomy. The move to a more sustainable food system would contribute positively to the transition towards climate neutrality.

To conclude, the impact of the three possible options on SMEs is rather dependant on the sectors. In the sectors that are most exposed to the transition, SMEs have to anticipate

([126]) Less than 0.07% of SMEs in the EU are in the manufacturing of motor vehicles, trailers and semi-trailers; less than 0.06% are in the manufacturing of other transport equipment (Eurostat Structural Business Statistics). Around 3.4% are in the wholesale and retail trade and repair of motor vehicles and motorcycles. Other sectors involved in the supply chain of the automobile sector may be not impacted by the transition (e.g. textile manufacturing), negatively impacted (e.g. the manufacturing of compounds used in fossil fuel engines) or positively impacted (e.g. the manufacturing of batteries).

([127]) Ocean Energy – Technology Development Report. Low-carbon Energy Observatory, Joint Research Center, European Commission. EUR 30509 EN. 2020

([128]) Sustainable Advanced Biofuels– Technology Development Report. Low-carbon Energy Observatory, Joint Research Centre, European Commission. EUR 30502 EN. 2020 and adjust. This can be a challenge but also yield opportunities in terms of new markets for smaller businesses which tend to be more agile in developing innovative solutions. Across all target options, opportunities arise for green solutions and technical support including digitalisation, circular economy, and sustainable products. While the decarbonisation requires investments, it benefits SMEs by mitigating the risks associated with climate change and reducing the exposure of SMEs to fossil fuel price shocks.

Step 4/4: Minimising negative impacts on SMEs

The decarbonisation contributes to minimising climate change and hence to minimising the negative impact of climate change on SMEs.

Regarding the transition to a climate neutral economy, as the emission objectives for 2030 and 2050 have already been set, the options for intermediary ambition levels in 2040 are relatively close to one another. The analysis shows that there is limited difference between the target options assessed in terms of overall macro-economic impacts and costs for the sectors with more SMEs. While the decarbonisation of the EU economy will entail changes in business activities, it is also a source of opportunities given the role they play in innovation.

As the impact of the transition is strongly dependent on the sector in which SMEs operate, minimising the impact of the transition is achieved not only via programmes for SMEs but also by sector-specific measures. The EU has already put in place a number of measures and programmes dedicated to SMEs as well as those that are specifically targeted to sectors and regions exposed to the climate transition. As an example, the European programme for small and medium-sized enterprises (COSME) contributed to the climate mainstreaming objectives from 2014 to 2020. It included, among others, the Equity Facility for Growth (EFG) and the Enterprise Europe Network (EEN) which provides advice and support to SMEs. Based on the experience with COSME, other comparable programmes could be developed in the future. The European Investment Bank develops financing instruments that are particularly targeted to SMEs. The recent SME Relief Package (129) is expected to support SMEs in the transition to a low-carbon economy. Rules to ensure small businesses are paid in due time help them invest and innovate in sustainability and hire more employees. The Recovery and Resilience Facility makes unprecedented levels of funding available for greening, digitalisation, and upskilling in SMEs. It includes €44 billion of measures to support SMEs directly in 22 national plans. SMEs can benefit from broader measures worth €109 billion, such as loans or equity support open to all companies. InvestEU will help SMEs access loans and equity. It aims to mobilise over €370 billion in investment. This builds on the success of the European Fund for Strategic Investments where over 1.4 million SMEs benefitted from investment projects. It will also include guarantees for Solvency Support to tackle solvency risks. This will attract additional private investments to help SMEs scale-up and grow.

(129) COM(2023) 535 final

The actual impacts on SMEs will largely depend on the future design of policies and measures to be determined in the years to come in view of meeting the 2040 target once it has been agreed. These future policies, including enabling measures, need to take account of SME's ability to engage in climate action, from their ability to adapt to the impacts of climate change and invest in resilience, to their access to skills and finance for the investments needed to reduce their own emissions or to bring new technologies and solutions to market.

ANNEX 5: COMPETITIVENESS CHECK

This annex describes the competitiveness check of the preferred option (Option 3) of a target range of 90-95% reduction compared to 1990.

In terms of **cost and price competitiveness**, capital related costs for industry are 2% higher in Option 3 than in Option 2 for the time period 2031-2040. The difference between these two options falls to less than 1% for the time period 2041-2050. For the tertiary sector, capital related costs are 2.9% higher in 2031-2040 and 1.3% higher in 2041-2050. Energy expenditures for industry are 2.5% higher in Option 3 than in Option 2 in 2031-2040 and around 0.5% higher in 2041-2050. For the tertiary sector, energy expenditures are 0.3 lower in option 3 than in Option 2 in 2031-2040 and around 1% lower in 2041-2050.For energy intensive industries, this actually implies that the share of capital related costs in total production costs in 2031-2040 is only 0.1 percentage point higher in Option 3 than in Option 2 while the share of fuel expenses in total production costs is only 0.2 percentage point higher. In aggregate, total energy system costs are1.5% higher in Option 3 than in the "baseline" Option 2, partly due to higher financing costs. This difference corresponds to 0.19% of GDP. However this has a very limited impact on the EU share in global exports (see following paragraph). The price of electricity is very close in all the options considered. LIFE could reduce the total investment needs by 8%.

Regarding **international competitiveness**, earlier investment allows companies to position themselves earlier in the competition in low-carbon technologies. 52% of the organisations who responded to the public questionnaire agree that an ambitious target for 2040 will improve the competitiveness of the European economy and give EU industry a first-mover advantage on global markets. The EU share in global exports is comparable across options, with a difference of less than 0.1 percentage point between Option 3 and Option 2. The level of ambition in mitigation policies in the rest of the world actually has a higher impact on it: a higher level of global climate mitigation effort is susceptible to increase market shares for EU companies. In a setting where the rest of the world acts in line with the 1.5°C objective (global action setting), the EU share in global exports is 16.6% for Option 3, compared to 16.1% in the case of a more fragmented climate action (see Section 6.4.1). At the sector level, the differences between options are also very small. What matters more is international action. For example, for energy intensive industries, the EU share in global exports in 2040 is 17.1% for both Options 2 and 3 in a fragmented action setting, but 17.6% in a global action setting). For markets services, the EU share in global exports in 2040 is 22.7% in Option 3 compared to 22.8% in Option 2 in a fragmented action setting. It is 21.7% for both Options 2 and 3 in a global action setting. Option 3 for the EU is more likely to trigger more ambitious climate action in the rest of the world than the other target options. With more ambition domestically, the EU is in a stronger position to convince countries in the rest of the world to increase ambition of their own Nationally Determined Contributions within the UNFCCC. By showing that the transition is feasible at an acceptable cost, it can be an example to inspire from for climate policy development. By developing technologies to decarbonise the economy, it can also facilitate decarbonisation in other countries. Finally, it is also the option which reduces most the exposure to fossil fuel price shocks like the one induced by the war in Ukraine.

All options will have a positive impact on the **capacity to innovate** by triggering the development of new markets for products and services compatible with the 2050 climate neutrality objective. Option 3 accelerates this pull further already in 2031-2040 compared to the other options.

With regards to **SME competitiveness**, the preferred option shows no significantly higher energy-related cost for most sectors relevant for SMEs than the other options (see Annex 4). The impact depends on the sectors (see Annex 8). While the decarbonisation requires investments, it benefits SMEs by mitigating the risks associated with climate change and by providing an economic framework which is more resilient to potential energy price shocks.

Table 42: Overview of impact on competitiveness

Dimensions of Competitiveness	Impact of the initiative (++ / + / 0 / - / -- / n.a.)	References to sub-sections of the main report or annexes
Cost and price competitiveness	[0] Investment needs for 2031-2050 are very close across options. The preferred option implies more investment in 2031-2040 and less in 2041-2050 in comparison with Option 2. The difference in total energy system costs between options 3 and 2 corresponds to less than 0.2% of GDP.	Sections 6.4.2 and 6.4.3 Annex 8 Sections 2.2 and 2.3
International competitiveness	[0] The EU share in global exports is comparable across options, with a difference of around 0.1 percentage point between options 3 and 2. However, the preferred option is more likely to induce more ambitious mitigation action in the rest of the world, which, in turn, would have a positive impact on the EU share of global exports. The preferred option allows an earlier positioning of EU companies in the growing global market for innovative, low carbon technologies, clean products and services. The preferred option reduces exposure to fossil fuel import costs the quickest.	Section 6.4.1
Capacity to innovate	[++] The preferred option will spur innovation in a number of sectors by 2040 to deliver the reductions of net GHGs, including in energy, industry or the land sector.	Sections 6.1 and 6.2 Annex 8 Section 1
SME competitiveness	[0] The investment needs will depend on the sector. The preferred option shows no significantly higher energy-related cost than option 2 for most sectors relevant for SMEs.	Annex 4 Annex 8 Section 2.3

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