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The European Commission's 2050 Vision "A clean planet for all" – Implications for Sector Strategies and Climate Governance

Final report

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The European Commission's 2050 Vision "A clean planet for all" – Implications for Sector Strategies and Climate Governance

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by

Jakob Wachsmuth, Vicki Duscha, Johannes Eckstein, Andrea Herbst, Patrick Plötz
Fraunhofer Institut for Systems and Innovation Research ISI, Karlsruhe

Matthias Duwe, Nick Evans, Mona Freundt, Katharina Umpfenbach
Ecologic Institut, Berlin

Kjell Bettgenhäuser, Andreas Hermelink
Guidehouse, Köln

On behalf of the German Environment Agency

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Publisher
Umweltbundesamt
Wörlitzer Platz 1
06844 Dessau-Roßlau
Tel: +49 340-2103-0
Fax: +49 340-2103-2285
info@umweltbundesamt.de
Internet: www.umweltbundesamt.de

/umweltbundesamt.de
/umweltbundesamt

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Fraunhofer Institute for Systems and Innovation Research ISI
Breslauer Str. 48
D-76139 Karlsruhe

Ecologic Institut gemeinnützige GmbH
Pfalzburger Str. 43/44
D-10717 Berlin

Guidehouse Energy Germany GmbH
Am Wassermann 36
D-50829 Köln

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Publications underlying this report

This report is a summary of the following series of reports, working papers and fact sheets, which contain the same results in more detail:

- Duscha, V.; Lehmann, S.; Ittner, S. (2021): Revision der EU-Klimaschutz-Verordnung [Revision of the EU Effort-Sharing-Regulation]. Available at: https://www.umweltbundesamt.de/publikationen/revision-der-eu-klimaschutz-verordnung, last accessed on 22.11.2021.
- Duwe, M., Freundt, M. (2019): Fact Sheet: EU 2050 strategic vision "A Clean Planet for All". Brief Summary of the European Commission proposal. Available at: https://www.umweltbundesamt.de/en/publikationen/fact-sheet-eu-2050-strategic-vision-a-clean-planet, last accessed on 22.11.2021.
- Duwe, M. (forthcoming): Making EU climate governance fit for Net Zero – How to complete the current landscape of planning and review processes for targets and policies to align it with the climate neutrality objective. Discussion Paper. Umweltbundesamt, Dessau-Roßlau.
- Herbst, A., Fleiter, T., Neuwirth, M., Rehfeldt, M., Wachsmuth, J. (2021) Options for achieving a close-to climate-neutral EU industry and their implications. Fraunhofer Institute for Systems and Innovation Research ISI, Karlsruhe, 2021. Available at: https://www.isi.fraunhofer.de/content/dam/isi/dokumente/sustainability-innovation/2021/WP-S-08_2021_Options_for_achieving_a_close-to%20climate-neutral_EU_industry.pdf, last accessed on 22.11.2021.
- Hermelink, A., Bettgenhäuser, K. (2021): The European Commission's Renovation Wave Initiative for the Building Sector. Discussion Paper. Climate Change 53/2021. Umweltbundesamt, Dessau-Roßlau, 2021. Available at: https://www.umweltbundesamt.de/publikationen/the-european-commissions-renovation-wave-initiative, last accessed on 22.11.2021.
- Plötz, P., Wachsmuth, J., Gnann, T., Neuner, F., Speth, D., Link, S. (2021): Net-zero carbon transport in Europe until 2050 - Targets, technologies and policies for a long-term EU strategy. Fraunhofer Institute for Systems and Innovation Research ISI, Karlsruhe, 2021. Available at: https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cce/2021/EU_Transport_policybrief_long.pdf, last accessed on 22.11.2021.
- Wachsmuth, J., Eckstein, J., Held, A., Herbst, A., Plötz, P., Bettgenhäuser, K., Berg, T., Hardy, M., Schimmel, M., Duwe, M., Freundt, M., Frelih-Larsen, A., Hirschnitz-Garbers, M., Araujo, A. (2019): Assessment of the In-depth Analysis Accompanying the Strategic Long-term Vision "A clean planet for all" of the European Commission. Climate Change 35/2019. Available at: https://www.umweltbundesamt.de/en/publikationen/assessment-EU-vision-clean-plaent-for-all, last accessed on 22.11.2021.

One of the authors of each of the individual publications has been responsible its summary in this report.

Abstract

In November 2018, the European Commission published its Strategic Long-Term Vision entitled "A Clean Planet for all" calling for the target of net-zero greenhouse gas emissions by 2050. This proposal was subsequently agreed upon by EU heads of state and government, it features centrally in the European Green Deal and has now been made a legally binding objective in the EU Climate Law. The Strategic Long-Term Vision was supported by a detailed In-depth Analysis. The central objective of the work presented in this report was to assess the European Commission's Strategic Long-Term Vision and supplementary materials and reflect on them in light of state-of-the-art sector analyses.

The report is a summary of a series of publications. These publications provide insights on the In-depth Analysis along with an assessment of the role of the Strategic Vision and how it can be turned into an effective long-term strategy for the EU. In addition, sector analyses for the transport sector, the industry sector and the buildings sector provide insights on the action needed to reach long-term decarbonisation in those sectors. An assessment of the inception impact assessment to the Effort Sharing Regulation shed light on different options for a meaningful combination of CO_2 pricing (emissions trading) and regulation under the Effort Sharing Regulation. Lastly, a stocktake on the overall landscape of EU climate governance as of autumn of 2021 identified remaining weaknesses and recommends ways to strengthen the existing processes to ensure that they can get the EU on a path towards climate neutrality. A central recommendation is the call for an update to the EU long-term strategy as a central hub to provide oversight and guidance for sectoral and horizontal strategies as well as the next policy package (beyond 2030) that is due in 2024.

Kurzbeschreibung

Im November 2018 veröffentlichte die Europäische Kommission ihre Strategische Langzeit-Vision „Ein sauberer Planet für alle", welche Netto-Null-Treibhausgasemissionen als Ziel für die EU im Jahr 2050 vorschlug. Dieses Ziel wurde ein Jahr später von den EU-Staats- und Regierungschefs angenommen. Es ist auch eine zentrale Zielgröße im European Green Deal und durch das EU-Klimaschutzgesetz wurde es rechtlich verbindlich. Die Strategische Langzeit-Vision von 2018 wurde von einer detaillierten Folgenabschätzung begleitet. Das Hauptziel der in diesem Bericht vorgestellten Arbeit bestand darin, die Strategische Langzeitvision der Europäischen Kommission und die ergänzenden Materialien zu bewerten und sie im Lichte der neuesten Sektoranalysen zu reflektieren.

Der Bericht ist eine Zusammenfassung einer Serie von Publikationen. Diese Publikationen geben Einblicke in die Folgenabschätzung sowie eine Einschätzung der Rolle der Strategischen Vision und wie sie zu einer effektiven Langzeitstrategie für die EU entwickelt werden kann. Darüber hinaus geben Sektoranalysen für den Verkehrs-, Industrie- und Gebäudesektor Aufschluss darüber, welche Maßnahmen erforderlich sind, um eine langfristige Dekarbonisierung in diesen Sektoren zu erreichen. Eine Analyse der ersten Folgenabschätzung zur Effort-Sharing-Verordnung beleuchtet die verschiedenen Optionen für eine sinnvolle Kombination aus CO_2-Bepreisung (Emissionshandel) und Regulierung im Rahmen der Effort-Sharing-Verordnung. Schließlich wurden in einer Bestandsaufnahme des Gesamtbilds der EU-Klimagovernance im Herbst 2021 verbleibende Schwachstellen ermittelt und Wege zur Stärkung der bestehenden Prozesse empfohlen, um sicherzustellen, dass sie die EU auf den Weg zur Klimaneutralität bringen können. Eine zentrale Empfehlung ist die Forderung nach einer Aktualisierung der EU-Langzeitstrategie als zentraler Drehscheibe, um Übersicht und Orientierung für sektorale und horizontale Strategien sowie für das nächste Politikpaket (nach 2030), das 2024 ansteht, zu bieten.

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1.5LIFE	EC scenario with net-zero GHG emissions in 2050 focussing on a circular economy approach and lifestyle changes
1.5TECH	EC scenario with net-zero GHG emissions in 2050 focussing on technological approaches
AFID	Alternative fuel infrastructure directive
AFOLU	Agriculture, forestry, other land uses
BAT	Best-available technology
BECCS/DACCS	Bioenergy/Direct air capture with CCS
CCS	Carbon capture and storage
CCU	Carbon capture and utilisation
CDR	Carbon dioxide removal
CO_2	Carbon dioxide
EC	European Commission
ECL	EU Climate Law
EPC	Energy performance certificates
EPBD	Energy Performance of Buildings Directive
ESR	Effort Sharing Regulation
EU	European Union
GDP	Gross domestic product
GHG	Greenhouse gas emission
IDA	In-depth Analysis supporting the SV
IPCC	Intergovernmental Panel on Climate Change
IPCC SR1.5	The IPCC's Special Report on Global Warming of 1.5°C
LTS	Long-term climate strategy
LULUCF	Land use, land use change and forestry
MEPS	Minimum energy performance standards
MS	Member States of the EU
NDC	Nationally determined contribution to the Paris Agreement
NECP	National Energy and Climate Plan
NZEB	Nearly-zero energy buildings
PA	Paris Agreement
RES	Renewable Energy Sources
RRF	Recovery and Resilience Facility
SDG	Sustainable development goals
SV	Strategic long-term vision "A clean planet for all"
UNFCCC	United Nations Framework Convention on Climate Change
ZEV	Zero-emission vehicles

1 Introduction

1.1 Background

With the Paris Agreement (PA), the international community agreed on a set of ambitious climate goals—most prominently among these is the long-term temperature goal of holding global warming well below 2°C and to pursue efforts to further limit global warming to 1.5°C (UNFCCC 2016). Article 4 of the agreement frames these objectives around the requirement of reaching a global balance of greenhouse gas (GHG) emissions and sinks in the second half of the 21st century, also referred to as climate and GHG neutrality, with the former actually referring to human activity having no net impact on the climate system including for instance land use change (IPCC 2018a). Moreover, Article 4.19 requests all parties to prepare long-term low GHG development strategies consistent with the goals of the PA by 2020. The agreement's long-term perspective, combined with an iterative process of ever-increasing short-term contributions by all Parties, has emphasised the importance of the transformational nature of climate policy. The unequivocal message of the Special Report on Global Warming of 1.5°C, published by the Intergovernmental Panel on Climate Change (IPCC SR1.5), further substantiated this renewed attention on the long-term objective of GHG neutrality and its implications for current policy (IPCC 2018b). The middle of the century is a distant but rapidly approaching future, especially considering the magnitude of the challenge of transforming the world's economy to net-zero emissions.

The sense of urgency that accompanies integrating long-term objectives more directly into current policy has also influenced policy-making in the European Union (EU). The European Commission (EC) had developed a basis for a long-term climate strategy (LTS) for the EU as early as 2011 with its "Roadmap to a low-carbon economy by 2050" (EU COM 2011). While the 2050 Roadmap was never formally adopted due to resistance by some Member States (MS), it has been formative for the discussion on long-term mitigation pathways for the EU, especially pertaining to EU energy and mobility roadmaps. Although the target formally adopted by the EU was an 80-95% GHG emissions reduction by 2050 (from 1990 levels), the scenarios underlying the 2050 Roadmap focussed on achieving the lower end of this range, i.e., an 80% reduction. Importantly, a reduction of the EU's GHG emissions by only 80% in 2050 has been found to be inconsistent with the PA's long-term temperature goal (cf. Wachsmuth, Schaeffer and Hare 2018), especially considering the IPCC SR1.5 (IPCC 2018b). Hence, the 2050 Roadmap was outdated, not only in regards to the PA's more ambitious long-term perspective but also recent technological developments (cf. Graichen 2016 and Wachsmuth et al. 2018).

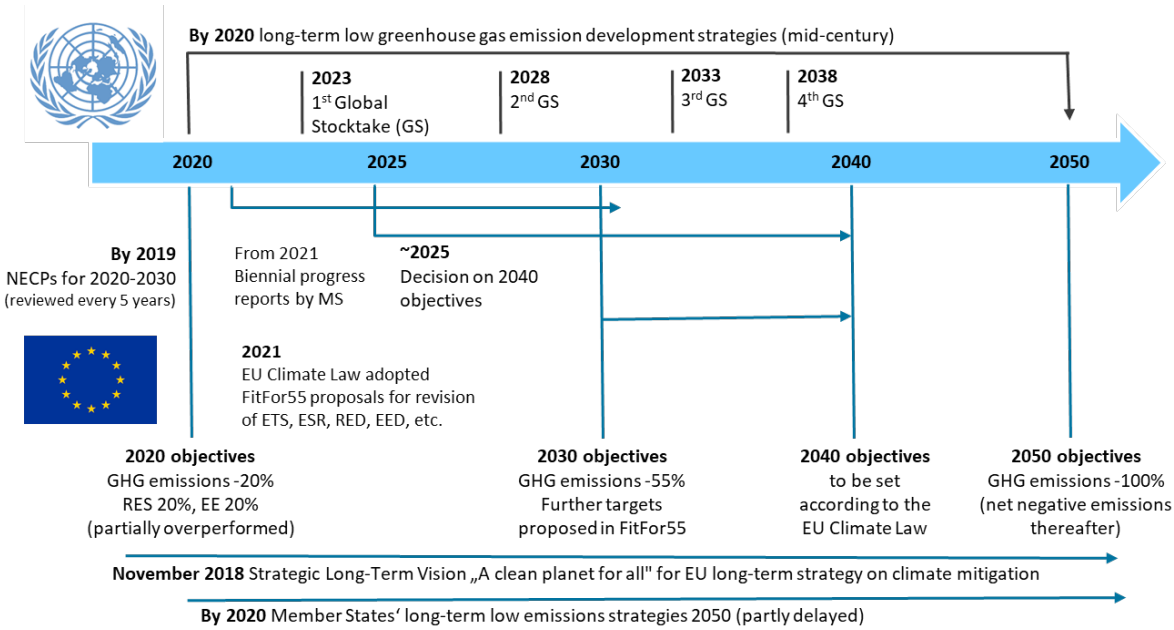
Therefore, in March 2018, heads of state and government requested the EC to prepare a "proposal for a strategy for long-term EU greenhouse gas emissions reduction in accordance with the Paris Agreement" (European Council 2018). This demand, echoed by the European Parliament, was then enshrined as EU law in Art. 15 of the Regulation on the Governance of the Energy Union and Climate Action (EU COM 2018a), also known as the Governance Regulation. The legislation stipulated that the EC should develop a scenario for net-zero GHG emissions in 2050 in order to explore the PA's requirement of reaching a balance of GHG emissions and sinks. Accordingly, the Commission developed analytical material and crafted a policy summary in response to this obligation. On 28 November 2018, the EC published a Communication entitled "A Clean Planet for all. A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy" (EU COM 2018b) referred to here as the "Strategic

Vision" (SV), supported by a detailed In-depth Analysis (EU COM 2018c) (IDA). In conjunction, the SV and IDA form the EU's draft long-term climate strategy (EU LTS).[1]

With the SV, the EC suggested climate neutrality by 2050 (defining it as a domestic balance of GHG emissions and removals) as an increased long-term target for the EU. This proposal was met with largely positive reactions from different quarters. Ursula von der Leyen made it a central pillar of the programme for her tenure as Commission President in July 2019, and declared it the core guiding objective of the European Green Deal a few months later. The subsequent adoption of climate neutrality by EU heads of state and government made it possible to include it in the EU Climate Law, proposed in March 2020 and agreed in April 2021. The scope was even extended in the ECL to net "negative emissions thereafter" (Article 2.1 ECL).

The development of the EU LTS is one element in a set of ongoing processes in international and European energy and climate policy (cf. Figure 1). In a first step, it already resulted in the formal submission of a long-term low GHG development strategy to the UNFCCC in 2020, as requested in the PA. This document states the objective of the EU to achieve climate neutrality by 2050. In parallel, all parties to the PA, including the EU, are expected to update their Nationally Determined Contributions (NDC). The EU's 2021 NDC update took into account the recent revision of the EU's 2030 framework, in particular the increased overall GHG target of 55% reduction by 2030.

Figure 1: Time axis for the processes of international and European climate policy relevant to the EU long-term climate strategy



Source: own representation

[1] Henceforth, any mention of an "EU LTS" or "EU strategy" refers to both the SV and IDA in conjunction.

1.2 Objectives and structure of the report

The central objective of the work presented in this report was to assess the European Commission's Strategic Long-Term Vision and supplementary materials and reflect on them in light of state-of-the-art sector analyses. The main results were published in following individual reports, working papers and fact sheets: Duscha et al. (2021), Duwe and Freundt (2019), Duwe (forthcoming), Herbst et al. (2021), Hermelink and Bettgenhäuser (2021), Plötz et al. (2021), Wachsmuth et al. (2019). The results contained in these documents are summarised in this report and reference is provided to the related documents. This allows the reader to gain an overview of the main findings and provides links for further reading.

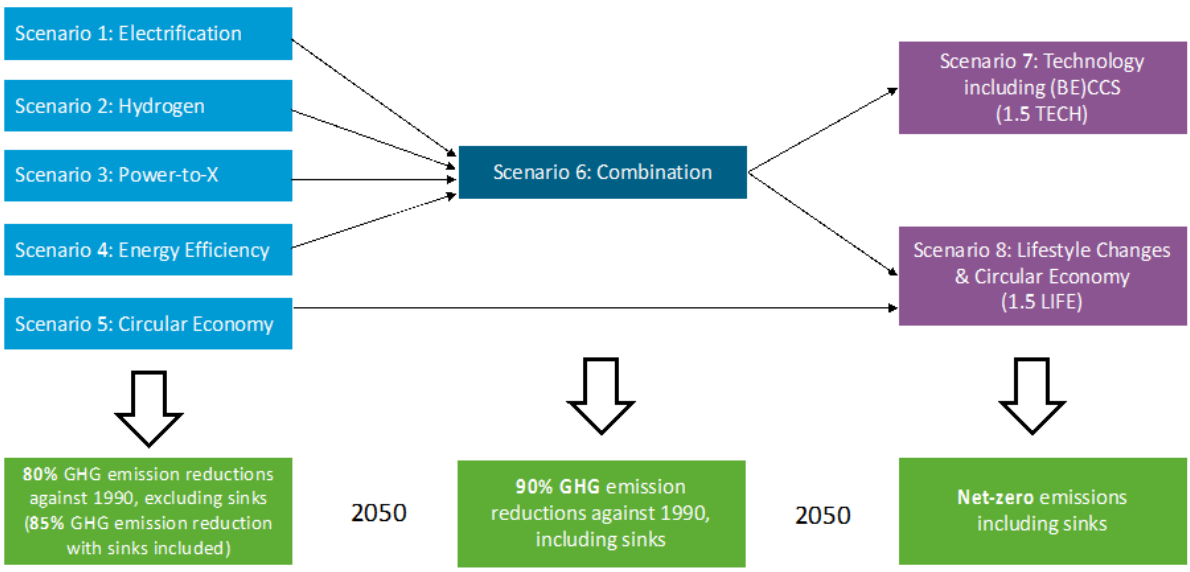
This report is structured as follows: Section 2 provides a summary of the analysis of the IDA in Wachsmuth et al (2019). Section 3 concentrates on the in-depth sector analyses developed within Herbst et al. (2021), Plötz et al. (2021) as well as Hermelink and Bettgenhäuser (2021) (Section 3.1: industry, Section 3.2: transport, Section 3.3: buildings). Section 4 summarises findings on the inception impact assessment to the effort sharing regulation published in Duscha et al. (2021). Section 5 provides a stocktake on the political level as developed by Duwe (forthcoming) and Section 6 concludes. Given the high dynamics of the EU climate policy, some of the presented results were obtained without knowledge of the most recent developments. In particular, Section 2 presents pre-European-Green-Deal results, Section 3 and 4 include considerations of activities under the European Green Deal results, while only the results in Section 5 already reflect the Fit-for-55 legislation package published in July 2021.

2 Summary of the strategic long-term vision "A clean planet for all" of the European Commission and assessment of the In-depth Analysis accompanying the strategic vision

In November 2018, the European Commission presented its long-term Strategic Vision "A clean planet for all" (EU COM 2018b), which presents its analysis of options for long-term climate policy in the European Union. In the strategic vision, the European Commission lays out a pathway for a transition to a climate neutral economy by 2050 - meaning the EU's net greenhouse gas emissions will be zero in that year. The strategic vision states that a GHG-neutral EU is technologically feasible and achievable in a socially fair and cost-efficient manner. A brief summary of the strategic vision is provided in a factsheet by the German Environment Agency (Duwe and Freundt 2018).

The Strategic Vision was accompanied by an In-depth Analysis document (EU COM 2018c) containing a detailed impact assessment based on a scenario analysis. The In-depth Analysis builds on one baseline scenario and eight mitigation scenarios (see Figure 2) , which meet the EU's at that time implemented 2030 targets, but differ in their ambition and mitigation focus afterwards. Only two of these scenarios (1.5TECH and 1.5LIFE) achieve net-zero GHG emissions by 2050 - the target defined in the strategic vision. In addition, there is one further variant with limited biomass (1.5LIFE-LB), and one more detailed industry scenario (Mix95) that are both compatible with net-zero GHG emissions in 2050. This group of scenarios is called net-zero scenarios in the following.

Figure 2: Overview over the scenarios in the EC 's 2050 vision

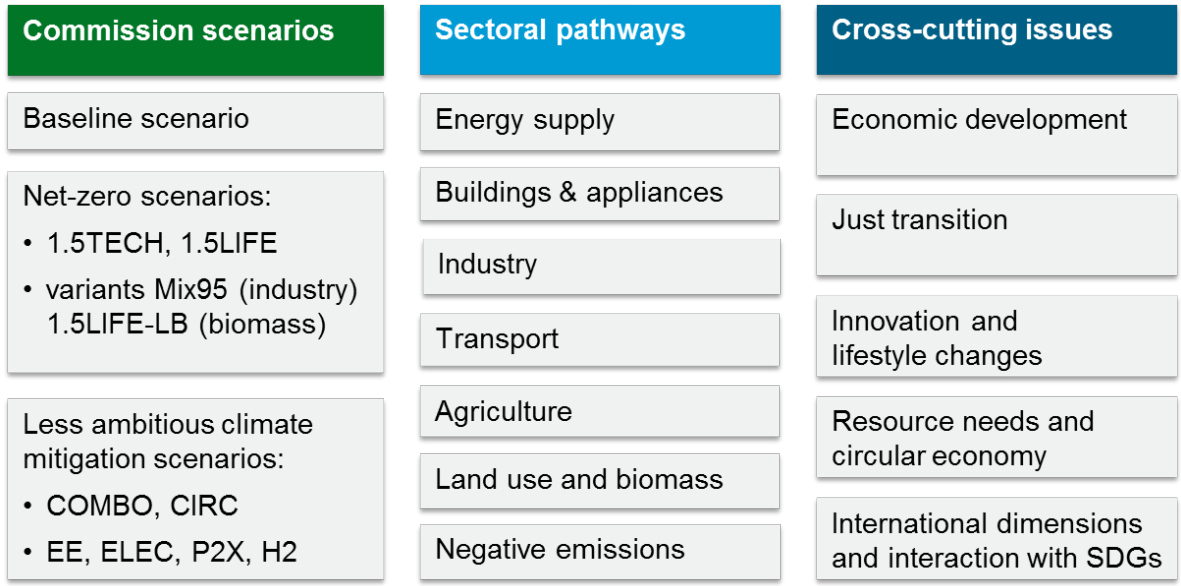


Source: Duwe and Freundt 2018

The report "Assessment of the In-depth Analysis Accompanying the Strategic Long-term Vision "A clean planet for all" of the European Commission" (Wachsmuth et al. 2019) presented the findings of an assessment of the In-depth Analysis, in particular its suitability as the analytical input for the Strategic Vision. The report flags key issues with regard to three areas: (1) the net-zero scenarios in comparison to the baseline scenario, (2) the corresponding sectoral pathways

(energy supply, buildings, transport, industry, agriculture, land use and negative emissions) and (3) cross-cutting issues (economic development, just transition, innovation and lifestyle changes, resource needs and circular economy as well as international dimensions including the sustainable development goals (SDGs)) (see Figure 3).

Figure 3: Focus areas for the assessment of the In-depth Analysis underlying the European Commission's long-term strategic vision "A clean planet for all"



Source: Wachsmuth et al. 2019

Sectoral pathways

The sectoral pathways of the scenarios were assessed using a common set of criteria, which led to the following central findings (see Section 2 of Wachsmuth et al. 2019):

- **In general, all sectors have to pursue very ambitious GHG emission reductions early on in the net-zero scenarios.** 1.5LIFE differs from 1.5TECH by including circular economy approaches and lifestyle changes in addition to technological approaches. Nevertheless, some GHG emissions remain in both scenarios, in particular CO_2 emissions from international transport, energy-intensive industries as well as non-CO_2 emissions from agriculture and waste. These emissions are compensated by both natural carbon sinks from land use and artificial sinks based on carbon capture and storage (CCS), with triple the amount of negative emissions in 1.5TECH than in 1.5LIFE.
- **With regard to energy supply, all scenarios are characterised by the vastly increasing relevance of renewable energy sources.** The power sector has to reduce emissions particularly rapidly to enable strong emission reductions via electrification. In both net-zero scenarios, there is also a substantial use of electricity-based fuels and gases. Nonetheless, none of the scenarios maximises the use of renewable energy sources (RES) in combination with strong energy demand reductions. The renewable share could be increased to limit negative emissions more stringently. Furthermore, nuclear capacity increases after 2030, which is highly debatable given social acceptance concerns and the adverse financing environment for new nuclear power plants.
- **For the buildings sector, the presented pathways appear plausible when compared to other studies.** The renovation rates in the net-zero scenarios are moderate, although still

ambitious when compared to the current empirical rates. In contrast, the assumptions about energy savings due to renovations are very high, and imply that nearly all renovations have to meet the highest energy efficiency standards. Due to the high level of electrification, there is a substantial increase in electricity demand in spite of greater efficiency measures.

- **For industry, the sectoral pathways show that it is possible to transform industry to close to CO_2-neutrality by the middle of the century.** However, the technologies available today are not sufficient because it is often not possible to switch from fossil fuels to RES due to the high temperature levels required and the competition for biomass with other sectors. Therefore, early development of CO_2-neutral production processes such as the direct reduction of steel with hydrogen and new kinds of low-carbon cements need to be part of the strategic considerations. At the same time, the potentials for material efficiency and circularity are not yet fully covered in the modeling and should be explored in more detail in future long-term scenario modelling.

- **For the transport sector, the scenario results appear plausible when compared to other studies.** A reduction in demand is required due to strong technology shifts. International aviation is responsible for the major share of remaining CO_2 emissions in 2050. Almost all scenarios exhibit a mixture of technologies for road transport including electrification, hydrogen, biofuels, e-liquids and natural gas. As many of these technologies require their own infrastructure, scenarios with only one or a few dominant technologies may be more plausible. These infrastructure feedback loops require additional attention in future long-term scenario modelling.

- **For agriculture, the analysis highlights the key areas with mitigation potential (methane and nitrous oxide emissions) as well as the need to address systemic issues of reducing food waste and the consumption of animal products. However, the list of included measures is limited.** The most obvious omissions are improved crop rotation and improving soil management to reduce soil compaction. In addition, the analysis does not sufficiently consider the trade-offs between the proposed mitigation options and other impacts, e.g. with biodiversity and animal welfare. The analysis does not mention the transformation of the food system and it is unclear if it accounts for the full potential on the demand side. Only the 1.5LIFE scenario assumes a change in consumer preferences.

- **With regard to land-use, mitigation in the net-zero scenarios is primarily achieved in the land-use change and forestry sector. One of the assumptions subject to the greatest doubt is the large role that energy crops are expected to play for bioenergy.** Only in 1.5TECH is mitigation achieved by implementing agricultural practices that improve soil carbon sequestration and turn cropland from a carbon source into a carbon sink. To avoid concerns about the sustainability of biomass, the scenarios assume that nearly all the biomass required for bioenergy is produced within the EU. Moreover, an alternative low-biomass scenario, 1.5LIFE-LB, was created specifically for the land-use category to demonstrate a decarbonisation pathway with a limited use of biomass.

- **With regard to the role of negative emissions, the only artificial sinks considered are bioenergy and direct air capture with CCS (BECCS/DACCS).** Other options such as bio char and enhanced weathering are not considered. 1.5TECH assumes ambitious carbon removal, while 1.5LIFE assumes much lower carbon capture with marginal BECCS. Compared to other studies on the geological storage potential for CO_2 in the EU, the In-depth Analysis relies on a moderate use of underground storage in the scenarios. A range of costs is presented for CDR technologies, but it is not clear which values are ultimately used for the

modelling. These assumptions can strongly influence the level of negative emissions realised in the scenarios.

Cross-cutting issues

Cross-cutting issues were addressed qualitatively, with the following findings (see Section 3 of Wachsmuth et al. 2019):

- **From an economic point of view, a shift is required from consumption to an investment in GDP of roughly 1%, resulting in a substantial increase in the required capital mobilisation**. Economic development is considered relative to a baseline and assumes an increase in GDP of 68-71% by 2050 relative to 2015. Decarbonisation has a relatively minor influence on this figure (-1.3% to +2.2% depending on the model). The implications for the EU's multi-annual financial framework for 2021-2027 are not assessed.
- **With respect to a just transition, decarbonisation has only a low influence on labor, and long-term developments are dominated by demographic change, digitalisation and automation.** Regions in risk of being left behind are those which depend on contracting or energy-intensive economic sectors. The focus is on labor and reskilling within the EU. The international dimension is not considered. Citizen engagement is seen as important, but the required rise in awareness is assumed to take place in society in general, and is merely supported by labelling and standards.
- **With regard to innovation and lifestyle changes, the In-depth Analysis sees the need to make the corresponding investments in innovation, but identifies a lack of funding here compared to other economies worldwide**. Social innovations are also regarded as important, but measures to bring about changes in behavior are not described. With respect to technological innovations, the In-depth Analysis describes neither the necessary market diffusion and corresponding upscaling of key innovative technologies nor possibly disruptive transitions.
- **The In-depth Analysis associates two major benefits with a circular economy: (1) GHG emissions can be strongly reduced if raw materials are increasingly recycled; (2) the dependency on the respective imports is reduced.** Resource needs and the circular economy constitute a recurring theme throughout the In-depth Analysis although there is no section dedicated specifically to this topic. The required regulatory framework for a circular economy is not described in any detail. Nor is there any discussion of possible rebound effects, i.e. increased use overcompensating the increased supply from recycling.
- **With respect to international dimensions and the interaction with SDGs, the In-depth Analysis sees international collaboration as essential to tackling global problems, including those related to climate change.** A deeper dialogue with countries in financial straits is addressed; in particular, it is proposed to pursue a dialogue with fossil-fuel exporting nations to encourage them to diversify their economic portfolio in the direction of renewable energies. Overall, climate action is seen to have many co-benefits with other SDGs, especially internationally and considering health benefits and the eradication of water shortages and poverty.

Methodological considerations

The assessment of the sectoral pathways included methodological considerations and produced the following central findings (see Sections 2 and 3 of Wachsmuth et al. 2019):

- While technology assumptions have been reviewed and published, key **input and output parameters** such as sectoral activities and energy demands are **only partially available**.
- The techno-economic assumptions in the power sector seem to be in line with assumptions in other studies. In particular, the widely criticised **risk premiums for renewable electricity generation are no longer used**.
- In the buildings sector, the modeling still applies **relatively high discount rates on private investments**, which may have limited the efficiency gains.
- In the agricultural sector, it is **unclear whether yield stability is considered**, for which additional soil management measures would be needed.
- In the LULUCF sector, a crucial factor that is **not sufficiently discussed is the CO_2 removal rate**. Given the strong use of biomass in 1.5TECH/1.5LIFE, it is important to reflect that CO_2 is only re-sequestered gradually at a rate that depends on the type of land and biomass.
- With regard to negative emissions, **carbon capture and negative emissions are used almost interchangeably** so that it remains unclear how carbon is accounted in the model.
- Results for the **economic development** are **based on a reduced set of scenarios** that includes 1.5TECH but excludes 1.5LIFE. This is a drawback for the comparison of the net-zero scenarios.

Summary

In summary, the analytical input provided in the In-depth Analysis covers the key aspects for building an adequate long-term climate strategy and is thus a strong foundation for the Strategic Vision, in spite of certain limitations:

- **The In-depth Analysis is comprehensive** in the way that it covers mitigation pathways for all relevant sectors and GHGs as well as economic and social implications. The sectoral pathways to net-zero GHG emissions are plausible **and in accordance with the ranges resulting from other studies**.
- The In-depth Analysis serves as a basis for the discussion of a long-term GHG development strategy only for the EU. Nevertheless, its **extensive efforts on assessing the feasibility of net-zero GHG emissions may be helpful to a lot of other countries as well.**
- It is positive that **the net-zero scenarios 1.5TECH and 1.5LIFE show the trade-off between behavioral changes and higher negative emissions** rather explicitly, but there is almost no discussion of the political implications, in particular no prioritisation of measures.
- While the set of scenarios with 80% GHG reduction in 2050 explore many different options, the set of only two full net-zero scenarios is rather limited. For instance, **it is unclear why there is no scenario that maximises the use of RES**.
- The analysis is not fully transparent, because important input and output data are not provided for all scenarios and they are therefore difficult to assess. **Greater transparency is important to foster its acceptability by the relevant stakeholders**.
- The In-depth Analysis also contains detailed considerations of economic and social implications and projects a minor impact of decarbonisation relative to other developments. However, **a strong shift of capital from consumption to investment is needed**.

- **The variety of models used underpins the robustness of the findings**, in particular the economic feasibility of a transformation to net-zero GHG emissions. However, the restricted set of scenarios for the macro-economic assessment is a shortcoming.
- **There is detailed information on the role of technical and also social innovations, including the current status of the EU's innovation framework, but future requirements remain vague**. The role of lifestyle changes is also only touched upon briefly.
- **While resource efficiency is addressed** throughout, there is no section dedicated specifically to this important issue so that its **implications are not clear**.
- **International cooperation is seen as having multiple benefits and as being key to fostering the transformation to net-zero GHG emissions.**

3 In-depth Sector Analyses

Based on the findings from the Strategic Vision and the IDA, in-depth sector analyses were conducted in the context of the project to provide further scientific assessment of the Strategic Vision and the Commission's underlying quantitative analyses. Three sectors were analysed in detail, which face significant challenges when looking at net-zero emission scenarios: industry, transport and buildings. The following is a summary of the findings from the different sector papers, all of which have been published (cf. Herbst et al. 2021, Hermelink and Bettgenhäuser 2021, Plötz et al. 2021).

3.1 Deep Decarbonisation of Industry

Background and Motivation

In 2019, industry accounted for about 26% of EU-27 final energy demand and its dominant energy carriers are gas, electricity, coal, and oil (Eurostat 2021). This means the sector is critical for the achievement of European climate goals. The high share in final energy demand mainly stems from energy-intensive industries such as the iron and steel, non-metallic mineral, or the chemical sector. Within these industries, specific energy-intensive products/processes are particularly relevant for the future achievement of European climate targets. Even though some sectors already use a high share of electricity and biomass, industry, in general, still needs to make substantial further efforts to reduce the use of fossil fuels in the next decades and the transformation of the industrial sector towards CO_2-neutral production is facing major challenges. In terms of end-uses, most industrial GHG emissions are from high-temperature process heat, either in the form of steam or hot water, or from the direct firing of various types of furnaces. The high temperatures and the specific requirements of furnaces limit the use of renewable energies to biomass or secondary energy carriers (e.g. electricity or synthetic fuels). Process-related emissions account for about one fifth of all direct emissions. At present, it is technically difficult or even impossible to mitigate them with market ready technologies.

Consequently, a reduction target of over 90% for industry by 2050 requires a wide variety of reduction options. While the EU Low-Carbon Roadmap 2011 for the industry sector was still limited to energy efficiency, biomass and CCS, the new long-term climate strategy (EU COM 2018) includes further options such as electrification, renewable synthetic energy sources, ambitious recycling management, material efficiency along the value chain and innovative manufacturing processes. As the concept of material efficiency and the circular economy is gaining momentum in the policy debate across all stakeholders (e.g. EU LTS, EU Green Deal, Circular Economy Action Plan, sectoral approaches for example EU Battery Alliance, New Bauhaus, etc.), there are synergies between the policy agendas of decarbonisation and the circular economy. The EU Commission's 2020 Environmental Services Action Plan makes environmental services an important element in industrial transformation.

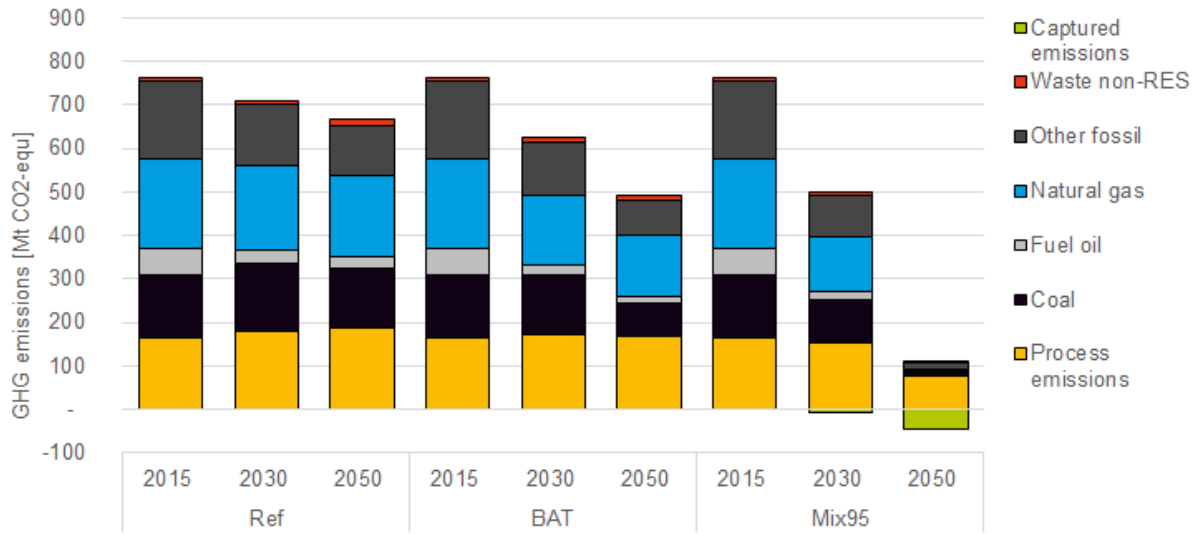
The working paper on industrial transformation discusses options for achieving a close-to climate-neutral EU industry and their implications (Herbst et al. 2021).

Main Findings

Ambitious changes to the entire industrial production system and a profound transformation in many sectors and value chains is necessary to achieve near climate neutrality in the industry sector. The most important abatement levers are energy and material efficiency or circular economy, process change to secondary production routes and innovative CO_2-neutral processes, as well as extensive use of CO_2-neutral secondary energy carriers such as electricity and hydrogen (Fleiter et al. 2019). The transformation needs a rapid speed of change which targets a

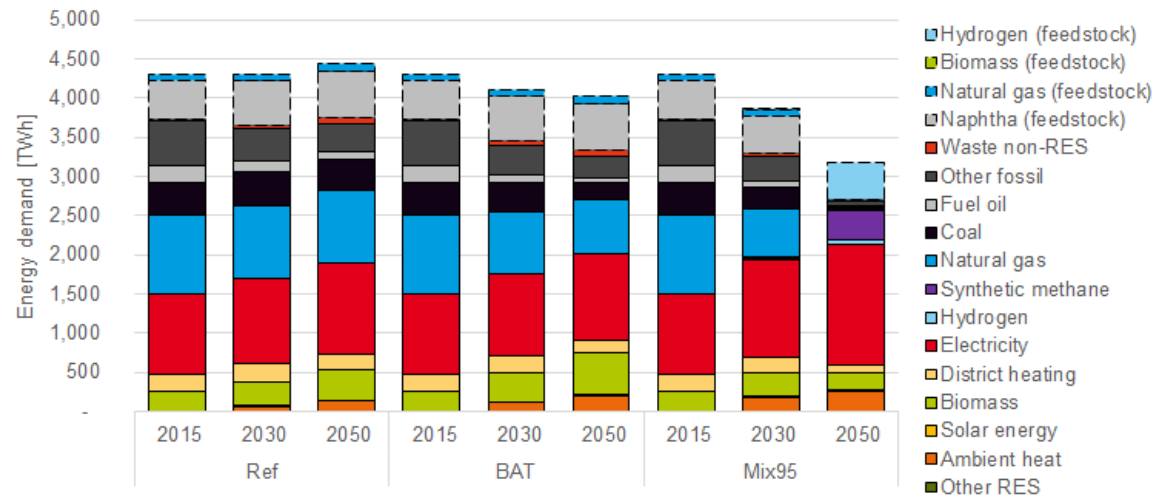
nearly 100% transition by 2050 (see Mix95 scenario in comparison to a reference and a Best Available Technology (BAT) Scenario in Figure 4 and Figure 5)

Figure 4: Industrial GHG emissions by scenario and energy carrier



Source: Fleiter et al. (2019)

Figure 5: Industrial final energy demand plus feedstock by scenario



Source: Fleiter et al. (2019)

The processes currently used to produce energy-intensive basic material products have been optimised over many decades. Consequently, the remaining energy efficiency potentials due to applying the BAT are limited (see Figure 4 and Figure 5). Nevertheless, an ambitious increase in energy and material efficiency in all applications and sectors is a prerequisite for CO_2-neutral industrial production. It reduces the final energy demand and thus lowers the costs for the expansion of renewable energies, grid expansion and the import of secondary energy sources.

Switching to CO_2-neutral or low-CO_2 energy sources for the generation of process heat is a central lever for reducing industrial CO_2 emissions. This includes the generation of process

steam, but also heat generation by means of industrial furnaces. In basic materials industries, temperatures of more than 1000°C are necessary in many cases. Here, only biomass and biogas as well as the use of renewables via secondary energy sources such as electricity, hydrogen or synthetic gas come into question. The conversion of process heat generation to biomass or renewable electricity is in many cases associated with fundamental conversions or the replacement of furnaces and steam generators. Besides economic considerations, the change of energy source in many processes depends on technical restrictions. For example, a minimum use of coke or coal is required in the blast furnace for steel production. In these areas, a comprehensive change of energy sources is only feasible if it is accompanied by a fundamental process change. In some cases, this also requires early replacement of technologies before they reach their ordinary end-of-life, which increases overall investment needs and costs.

The purely energetic use of synthetic methane to generate process heat in industrial furnaces and for steam generation is associated with low conversion costs on the demand side, because the equipment for firing natural gas can be used further. Starting from an established technological and economic basis for the use of natural gas in the existing energy system, synthetic gas can maintain and expand in industrial furnaces and process steam generation. However, the use of synthetic methane is strongly dependent on the blending of synthetic gas in the gas grid, which is not assumed to take place in substantial amounts before 2030. Furthermore, the generation efficiency has to be taken into account when comparing the use of synthetic methane to direct electrical or green hydrogen-based solutions.

Especially in the steel and basic chemicals industry, the use of hydrogen from renewable-based electrolysis (in the following 'green hydrogen') seems to be a promising option for decarbonisation. The chemical industry already uses fossil hydrogen as feedstock in the ammonia and methanol production, which leads to the assumption that a conversion to green hydrogen would be relatively easy to realise from a technical perspective, given the availability of the necessary quantities of green hydrogen. The production of ethylene could be carried out via the Methanol-to-Olefines (MtO) route, which uses green hydrogen based methanol as an intermediate and is much more energy-intensive than the conventional production. However, this would lead to a significant increase in methanol demand. Furthermore, this makes the supply of carbon necessary and offers a starting point for CCU concepts. For energy uses, however, only the contribution of hydrogen is relevant.

CCU/S for remaining clinker and lime production seems to be necessary, as conventional measures (e.g. fuel switch) would not suffice to decarbonise this sub-sector. E.g. two third of the emissions in cement production stem from chemical reactions in the production process. Consequently, a potential application of CCU/S is the non-metallic minerals industry, where process emissions are difficult to mitigate. The large-scale introduction of CCS might be related to substantial lock-ins and is a highly controversial subject regarding social acceptance and the distribution of costs (infrastructure, transport and storage). It might, however, play a certain role in scenarios that aim at industrial CO_2-neutrality. CCU for the unavoidable process emission from cement and lime might be able to provide the needed carbon to produce basic chemicals from green hydrogen. Capture from other processes (e.g. waste incineration plants) or other technical solutions, such as direct air capture of CO_2, are an additional option. However, long-term CO_2 neutrality must be taken into account as an important condition, which may require the CO_2 cycle to be closed at the end of the product's life.

Elements of a successful industrial transformation in Europe

In order for the transition to CO_2-neutral industrial production by 2050 to succeed, the time horizon until 2030 is crucial. By then, CO_2-neutral processes need to be scaled up from pilot and

demonstration scale to industrial level and made economically viable. Without a substantial use of new low CO_2-neutral production processes such as the production of steel via direct reduction or green-hydrogen-based basic chemicals, the transformation cannot be achieved. Accordingly, the regulatory framework must provide a clear perspective for CO_2-neutral production. This particularly concerns the availability and role of CO_2-neutral hydrogen, gas and electricity. Green lead markets can also accelerate the transformation. Beyond the basic industry, CO_2 price signals down to the consumption sectors are crucial to align value chains with the goal of CO_2 neutrality and support the transformation towards a circular economy.

3.2 Net-zero Carbon Transport in Europe until 2050

Background and Motivation

The European Union are committed to the ambitious target of climate neutrality by 2050 and to keeping global warming well below 2°C and efforts to limit it to 1.5°C. The long-term target of climate neutrality and the ambition of the Paris Agreement imply climate-neutral transport by 2050 unless large-scale negative emissions in other sectors are assumed. Transport is currently responsible for about one quarter of energy-related greenhouse gas emissions in the EU.[2]

The recent European agreement to reduce GHG emissions by 55% until 2030 (compared to 1990 emission levels) and the Green New Deal make a reconsideration of EU transport policies very timely. Furthermore, the European Commission published its Sustainable and Smart Mobility Strategy in December 2020 (EU COM 2020a) and the year 2021 will see new legislative proposals to meet the more increased -55% target for GHG emissions in 2030 (compared to 1990). Most importantly for transport, both the CO_2 fleet targets for newly sold passenger cars and light commercial vehicles for 2030 and the alternative fuel infrastructure directive (AFID) will be reviewed or revised in 2021. The current year thus provides a unique opportunity to re-think and re-align European transport policies to meet the EU's contribution to the Paris Agreement.

The policy brief "Net-zero carbon transport in Europe until 2050" (Plötz et al. 2021) derives domestic transport emission budgets for the EU-27 until 2050 and presents implications for transport policies in Europe.

Main Findings

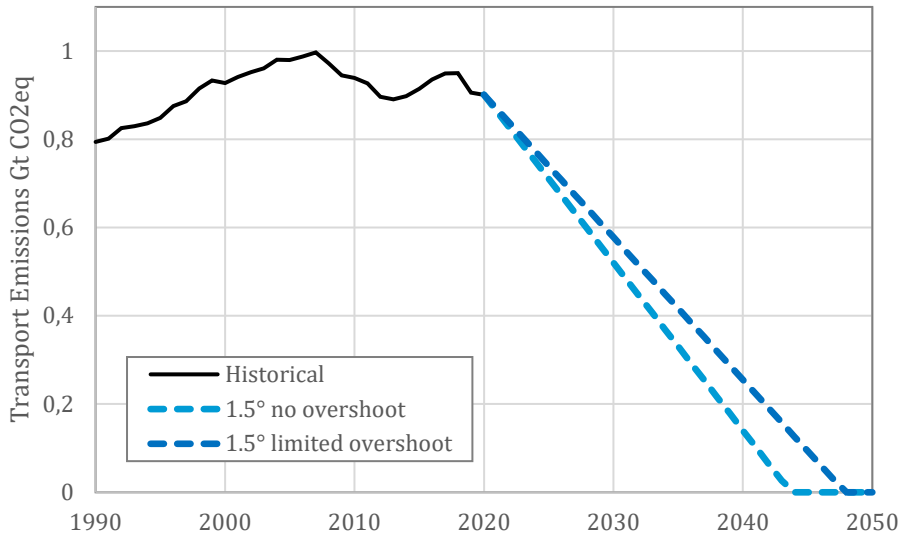
A Paris compatible greenhouse gas budget for Europe requires zero carbon transport before 2050. Domestic emission budgets for energy- and process-related GHG emissions of the EU-27 in line with 1.5°C of global warming indicate further 37 – 44 Gt CO_2e to be emitted until 2050. Deriving a share for transport either based on abatement costs or on transport's current share in greenhouse gas emissions leads to 10.2 – 12.1 Gt CO_2e, or about one quarter of the total GHG budget, while the range depends on whether limited overshoot of the 1.5°C target is allowed or not. Current GHG emissions from transport in Europe are 0.9 Gt CO_2e annually (excluding international bunkers for international navigation and aviation). At current annual emissions, Europe's transport carbon budget would be used up in 11 – 13 years and all further emissions would contribute to global warming permanently above 1.5°C.

The EU is not on track for zero carbon transport consistent with the Paris agreement. To remain within the GHG emission budget, transport emissions have to be reduced by 41 – 47% from current levels until 2030 (or 36 – 42% compared to 2005) and go to zero until 2044 – 2048, if a linear emission reduction path is assumed. The more ambitious reduction path is for a scenario

[2] See EU (2020), these numbers exclude international maritime traffic departing from the EU 28 but include international aviation departing from the EU 28.

with overshoot of the 1.5°C target and the less ambitious scenario with limited overshoot. For 2030, this linear reduction path is consistent with Europe's current goal of –55% in total GHG emissions until 2030 (compared to 1990 levels), if a similar reduction level is assumed for transport. However, the current EU sustainable mobility strategy aims at 90% GHG emission reduction from today's levels until 2050 (compared to today) whereas a 1.5°C carbon budget for transport requires a 90% reduction already until 2042 – 2045. The historical emissions since 1990 and the two linear reduction paths are shown in Figure 6. The required percentage emission reductions are summarised in Table 1.

Figure 6: Historical and required future transport GHG emissions within 1.5°C emission budgets



Source: Plötz et al. 2021

Table 1: Percentage change of transport GHG emissions for linear emission reduction

Scenario	1.5° no overshoot			1.5° limited overshoot		
Until\Compared to ...	1990	2005	2020	1990	2005	2020
2030	-34%	-47%	-42%	-27%	-41%	-36%
2035	-58%	-66%	-63%	-48%	-57%	-54%
2040	-82%	-86%	-84%	-68%	-74%	-72%
2045	-100%	-100%	-100%	-88%	-90%	-90%
2050	-100%	-100%	-100%	-100%	-100%	-100%

Source: Plötz et al. 2021

Net-zero carbon transport before 2050 is feasible but existing policies need to be tightened. Several studies have already discussed the path to net-zero carbon transport until 2050. The current fast market uptake of plug-in electric vehicles and the statements of several major global vehicle manufacturers to phase out combustion engine sales in cars until 2035 and in trucks until 2040 show that fast transition in road transport is possible. Policy makers can seize the current momentum to tighten existing CO_2 fleet targets for passenger cars and trucks. High speed rail and night trains offer the possibility to reduce future demand growth in aviation and

rail transport is already mostly electrified. Yet, additional action is needed to achieve zero carbon aviation and shipping. Demand reduction and sustainable zero carbon fuels appear as the main options that should be quickly implemented.

CO_2 fleet targets for passenger cars and trucks need to be much more ambitious. For passenger cars, the 2030 targets will be reviewed this year and a reduction of 80% until 2030 compared to 2021 as well as a transition to 0 gCO_2/km for cars no later than 2033 are consistent with a 1.5°C carbon budget for transport. Several major European manufacturers have already announced that more than two third of the newly sold vehicles will be electric in 2030 (Plötz et al. 2021). For trucks, the currently required 30% reduction until 2030 is too slow as the slow stock turnover requires a 100% reduction target for newly sold trucks already in 2034 or 2038 (depending on the state of zero carbon fuels and the possibility of temporal overshoot). Accordingly, a 55 – 67% reduction until 2030 compared to 2020 for newly trucks would be needed. This appears possible as many technical options for energy efficiency improvements are available, e.g., for diesel engines, tires, and aerodynamics, as well as a fast transition to zero-emission trucks (the manufacturers have announced the target of 100 % ZEV trucks by 2040).

Infrastructure and low-carbon fuel policies support the transition in road transport and reduce GHG emission from combustion engines. Fast infrastructure roll-out for electric cars and alternative fuel trucks are required. The existing AFID offers a suitable framework and should set ambitious infrastructure targets for the EU Member States for electrification of both light and heavy-duty vehicles. Ambitious low-carbon fuel standards will reduce the emissions of the existing combustion engine vehicle fleet.

New policies can accelerate the uptake of electric vehicles and ensure emission reduction of vehicles with combustion engines. A high share of zero-emission vehicles (ZEVs) allows highly emitting conventional vehicles (both cars and trucks) to enter the market and emit more CO_2 than expected from the fleet reduction targets. Ideally, a CO_2 emission reduction of newly sold combustion vehicles and the market uptake of ZEVs take place simultaneously in the next decade as the efficiency of both electric or combustion engine vehicles is relevant. The combination of CO_2 fleet targets purely for combustion engine vehicles and ZEV mandates, i.e., fixed ZEV sales quotas for vehicle manufacturers offers this possibility. Such an approach is already laid out in the Chinese dual-credit policy as well as in the Californian ZEV mandates (Axsen et al. 2020). The EU should carefully assess the benefits and draw backs of such a policy combination in Europe.

Pricing and mode shift can support the transition to zero carbon transport. Deep GHG emission reduction targets can be supported by a shift to low-carbon modes and by travel demand reduction. Carbon pricing can play an important role in both aspects as high road transport prices reduce car and truck travel activity and make train and active travel by foot and bike more attractive. This could be supported by light electric vehicles. Likewise, high taxation and carbon prices for aviation could shift transport to more sustainable high-speed and night trains. The targets for tripling passenger rail transport and doubling rail freight transport until 2050 are strong indicators for Europe's ambitious commitment to shift transport from road and air to railways. Infrastructure roll-out, a comprehensive night train network and strong pricing policies need to support this shift to the more sustainable rail transport.

A transition to sustainable zero carbon fuels is needed for aviation and navigation. Direct electrification of aviation and navigation even for domestic European transport is very unlikely in large stock shares until mid of the century for aviation and navigation despite already existing small scale electric ferries and first electric and hydrogen plane concepts. Strong carbon pricing can reduce additional growth of future travel activity and the introduction of quotas for

sustainable zero carbon fuels allow a step-by-step pathway to carbon neutral navigation and aviation. However, more research is required on how to tackle non-CO_2 global warming effects of aviation in high altitudes.

Elements of a Policy Roadmap for a Future Low Carbon Transport Policy Mix in Europe

The following points can provide guidelines for designing a policy mix that fosters zero-carbon transport in line with Europe's commitment towards zero carbon transport that is compatible with Europe's commitment to the Paris Agreement, i.e. to pursue efforts to limit global warming to 1.5°C.

- CO_2 fleet targets for newly sold cars in Europe have to be much more ambitious. An 80% reduction of the average emissions of newly sold vehicles until 2030 compared to 2021 is needed as well as a target of 0 gCO_2/km for cars no later than 2033. Similar targets hold for light-commercial vehicles.
- CO_2 fleet targets for trucks need to be tightened. A 55 – 67% reduction until 2030 compared to 2020 for newly trucks is needed followed by a 100% reduction target for newly sold trucks already in 2034 – 2038.
- Infrastructure for alternative fuel vehicles is required for a fast and successful transition to 100% ZEV in cars and trucks. Ambitious and single European standards are needed for fast charging of electric cars and trucks. The role of fuel cell vehicles and the amount of required infrastructure in road transport is still uncertain and requires adaptive planning and policies.
- Aviation and Navigation require sustainable zero carbon fuels. This transition can be ensured by introducing quotas for sustainable zero carbon fuels that start as soon as possible and reach 100 % by 2044 – 2048, compatible with the linear reduction path of a 1.5°C GHG emission budget for Europe.
- Carbon pricing, e.g., via taxation or an emission trading scheme in transport, can support the shift to low-carbon modes such as rail, public transit or bike, but will not alone deliver deep GHG emission reductions and should be seen as complement and not as substitute to ambitious CO_2 fleet targets and quotas.

3.3 Renovation Wave for Buildings

Background and Motivation

In the overall context of the Paris Agreement and its goal to limit global warming to well-below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels, the building sector has a shared responsibility. In the EU, it emits or is responsible for more than one third of the overall GHG emissions. This clearly shows the scale of the challenge given by the EU building sector target of climate neutrality by 2050. Since approximately 90% of today`s buildings will still be present by 2050, the energy renovation of existing buildings is a key challenge for the next decades. Therefore, the European Commission launched the Renovation Wave Initiative in the framework of the EU Green Deal (EU COM 2019a). Main goal of the initiative is to increase current energy renovation rates and at the same time depth of renovations, since current levels are insufficient to reach long-term energy and climate goals. Furthermore, it aims to create additional jobs, overcome energy-poverty due to lower energy bills for energy efficient buildings and addressing health and wellbeing in an appropriate way. In addition, financing elements like the Recovery and Resilience Facility (RRF) budgets play an important role, since significant

shares of funding (37% for the RRF) should be spent on climate friendly investments and reforms, such as energy efficient renovations in the EU building sector.

The "Renovation Wave" Paper (Hermelink and Bettgenhäuser 2021) gives an overview and an in-depth assessment of the EU Renovation Wave Initiative and puts it into perspective to the overall EU policy context and energy and climate targets.

EU policy context

Main elements of EU policy context are the European Green Deal in the first place as one of the priorities for the 2019-2024 European Commission, where the Renovation Wave is defined as a key action. In the field of EU climate action, the 2030 climate and energy framework with its updated 2030 targets is the central part, as well as the 2050 long-term strategy "A clean planet for all" together with national long-term strategies. The EU energy strategy adds the elements of the Energy Union from 2015, which is updated with an implementation focus by the "Clean energy for all Europeans package" in 2019. In this framework, also National Energy and Climate plans (NECPs) help to ensure that the EU is on a pathway in line with the targets. Finally, the Recovery and Resilience Facility (RRF) is supporting the transitions with a focus on sustainability and climate change as a consequence of the COVID-19 pandemic.

Main Elements of the Renovation Wave Initiative

The EC formulates the main objective of the Renovation Wave Initiative as follows (EU COM 2020a):

- At least double current renovation rates of public and private buildings by 2030 and foster deep renovations.

Why should that happen according to the EC? Originally two major reasons had been put forward, a third has been added as a consequence of the COVID-19 pandemic and the Recovery and Resilience Plans:

- Reach climate neutrality by 2050 and contribute to climate objectives for 2030;
- Alleviate energy poverty;
- Stimulate recovery of the EU economy.

Along with the Renovation Wave Communication an **annex** was published, called "The Renovation Wave: key Commission actions and indicative timelines", which is commonly referred to as the "**Renovation Wave Action Plan**". A broad set of initiatives is covered, whose launch is scheduled within a very ambitious timeframe, i.e. the bulk of actions is to be launched still in 2021. Actions are classified into several categories, reflecting the Renovation Wave Ccommunication's "*areas of intervention and lead actions critical to enable a step-change in the depth and scale of renovations*" (EU COM 2020a), which are meant to address all buildings plus the last three categories reflecting areas that "deserve specific attention".

Potential revision areas in Energy Performance of Buildings Directive and other Directives

A core set of directly effective regulatory measures is to be implemented by a targeted revision of the Energy Performance of Buildings Directive (EPBD). "Targeted revision" aims at changes to existing articles rather than a complete re-structuring of the directive. While the draft is expected in December 2021, the EC already published the Inception Impact Assessment (EU COM 2021), which provides further insight into the policy options the EC draws from the mandate given by the Renovation Wave Communication. Priority will be given to minimum energy performance standards (MEPS) and energy performance certificates (EPC).

The EC currently assesses different options for a phased introduction of mandatory minimum energy performance standards for different types of existing buildings. This is a change to previous editions of the EPBD that did not include mandatory improvements for existing buildings, except in cases where energy-related components were upgraded or replaced anyway or in case of major renovations. Options for MEPS vary by type of addressed buildings, ambition level, timeline, phasing and level of flexibility for MS. For example, MEPS could be first introduced in public and office buildings, then be extended to residential buildings with a view to addressing worst performing buildings and affordability of housing. It is also considered to include district and community approaches in defining minimum standards, to facility the development of zero or positive energy districts. In the context of EPC, the EC also ponders the definition and introduction of a certifiable deep renovation standard, mainly to de-risk investments in energy renovations for financial institutions.

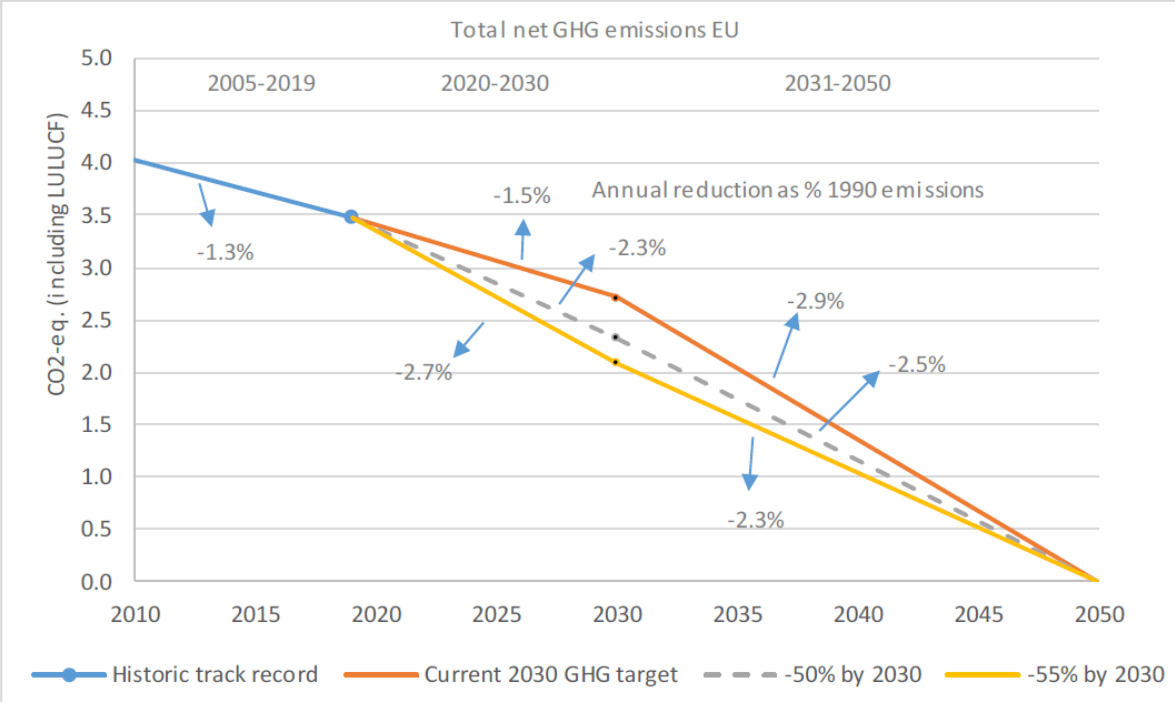
A revision of EPC is to strengthen their impact on creating a market pull for energy renovations. More accurate and reliable data for individual buildings on their energy performance, energy cost and share of renewable energy is envisaged for improving EPC quality. Under a so-called "new EPC framework", EPC shall be harmonised, be available in uniform EU machine-readable data format and linked to new metering technology. This kind of digitalisation shall also facilitate a higher availability and accessibility of EPC in databases, serving e.g. the purpose of identifying worst performing buildings. Digitalisation will also facilitate the introduction of Building Renovation Passports (BRP), which is proposed building on the results of the feasibility study of Article 19a (INIVE and BPIE, 2020).

Energy and Climate: Ambition vs. status

While being the natural focus of the Renovation Wave, also new buildings need to be put into focus in order to get buildings on the Climate Target Plan's -55% pathways. After a long transition period, since 1st January 2021 all new buildings need to be nearly-zero energy buildings (NZEBs). Yet, a study on energy renovation and the uptake of NZEBs (Esser et al., 2019) as well as the NZEB status the EC provided along with their State of the Energy Union report (EU COM 2020c) revealed less ambition than recommended by the EC in 2016 (EU COM 2016). Therefore, reviewing NZEBs, both for new and existing buildings, is needed, too, in the context of the upcoming EPBD impact assessment as part of the Renovation Wave Initiative.

The Climate Target Plan creates a new situation for evaluating the European building stock. Not only for the first time there is a 2030 milestone being in line with a reasonable pathway towards climate neutrality by 2050 as shown in Figure 7.

Figure 7: Stylised representation of future net GHG emission pathways compared to historic reduction rate since 1990



Source: own representation of EU COM 2020b

Figure 7 helps acknowledging the steep stepping-up of the ambition level. While still having in place the -40% GHG target in 2015/16 ("Current 2030 GHG target" in Figure 7), on December 2020 the EU adopted the "-55% by 2030" target with a view to realistically being able to achieve net-zero emissions by 2050. Looking at the details of policy scenarios "MIX" or "REG" reveals that (apart from power generation) the sectors "residential" and "services" - whose emissions to a large extent stem from buildings operation – by far need to have the highest reductions of around 54% to 64% only between 2015 and 2030. This ultimately highlights the urgent need for utilising both energy efficiency and renewable energy to a very significant extent within the upcoming regulatory and non-regulatory framework.

Conclusions

The analysis has shown that the Renovation Wave Initiative is a very ambitious and also a complex plan that has been put high on the political agenda of the EC. The defined goals are highly aspirational and the whole process is very dynamic. At the same time, the progress and activities on the ground and in the renovation market are not at all in line with what is defined as target-compliant within the strategy, neither with regard to the quality of renovations, nor the quantity of it. The implementation in the market will show whether the strategy can be successfully applied. In order to succeed with the Renovation Wave Initiative, the EC would need to take action in the activity fields shown above. But not only on EU level action is required, also the MS need to actively support the Initiative and need to implement it. Since the European level sets out the framework only, MS are in charge to apply the framework and requirements to their local context. Elements like for example better implementation and definition of NZEBs and the cost optimality framework, but also individual renovation plans and passports are key elements to the success of the Renovation Wave Strategy.

4 Medium-term Implications for the Effort Sharing Regulation

Increasing the EU-wide target to net-zero by 2050 has implications also for the medium-term targets in 2030 and the instruments implemented to reaching those targets. In light of the net-zero by 2050 target the Commission adopted an increased 2030 target of 55% reduction below 1990 levels (instead of 40%). Increasing the EU-wide GHG target for 2030 requires significant modifications for all relevant policy areas. The FitFor55 Package, published in July 2021 provided a first set of policy proposals and related impact assessments that shall allow the EU to reach its new target. Part of that package is a revision of the Effort Sharing Regulation (ESR). Within this project, an assessment of the inception impact assessment to the Effort Sharing Regulation was developed and published (Duscha et al. 2021).

The impact assessment to the climate target plan 2030 is a main source for the analysis of an extension of CO_2 pricing in the EU and served as the basis for the assessment of the inception impact assessment to the ESR. The following options for a revision of the ESR - based on the inception impact assessment document - were assessed in Duscha et al. (2021):

- **Option 1:** Phase out the Effort Sharing Regulation as a consequence of extending emissions trading and merging both the non-energy related ESR emissions from agriculture and the GHG emissions/removals under the LULUCF Regulation under a single climate policy instrument
- **Option 2:** Keep current ESR sectoral scope in parallel to extending emissions trading
- **Option 3**: Maintain in the ESR only the sectors not covered by emissions trading

Duscha et al. (2021) provide a description of the different options and discuss implications for emission reductions. In addition to a quantitative assessment of the options, an in-depth quantitative sector analysis is provided and effects on incentives for realising abatement options in the sectors under the ESR are being discussed.

Key findings

- In 2019, about 2.200 Mt CO_2e were covered under the ESR accounting for about 60% of the EU-wide emissions. Main sources for emissions under the ESR are road transport (35%) and the buildings sector including residential and non-residential buildings (21%).
- Increasing the EU-wide target for 2030 to 55% requires a significant increase in emission reduction ambition in the sectors currently covered under the ESR. The ambition for the ESR is heavily depending on the scope of the ESR but will likely remain under the ambition for the sectors covered under the EU emissions trading system (EU ETS). Under the current scope, the target under the ESR - based on the EU impact assessment on the 2030 target - would need to be increased from currently 30% to 39-40% below 2005 levels (the target under the EU ETS would need to be increased from 43% to 63% below 2005 levels). In case of a reduced ESR without road transport and the buildings sector, the target would need to be increased to "only" 34-36% below 2005 levels. In those scenarios emissions from road transport are reduced by 19-21% below 2005 levels, emissions in the buildings sector are reduced by 60-61% below 2005 levels.
- Under Options 1 and 2 from the inception impact assessment, there is either a regulatory gap (Option 1) or a double regulation of emissions under both the EU ETS and the ESR

(Option 2). Under Option 1, it cannot be guaranteed that the EU-wide target is being met. This is also the case under Option 2, although all sectors face emission reduction targets. The sectors - and emissions - newly included in the EU ETS would remain under the ESR. The EU-wide target would be missed if a significant amount of emission reductions would be realised in the sectors regulated under both instruments, the EU ETS and the ESR, but only a small amount of emission reductions in those sectors that are only regulated by one of the two instruments. This could be precluded if instead of including the sectors in the existing EU ETS a new emissions trading market would be implemented covering only those sectors that are also part of the ESR.
In contrast to Options 1 and 2, the design of the EU ETS and the ESR in Option 3 always allows for meeting the EU-wide emission reduction target if targets under the two instruments are being met. Here, the clear separation of emission budgets and instruments currently in place remains despite a possible extension of the EU ETS to new sectors. Precondition for meeting the targets under the EU ETS is the absence of a maximum price - even in case of heavy price increases.

- A moderate CO_2 price can be one component in a policy mix to reach the emission reduction required under the ESR, in particular for the road transport and buildings sector. A moderate CO_2 price alone, however, is very likely not sufficient due to the existence of other non-financial market barriers. Additional instruments are needed to reach the emission reductions needed if the CO_2 price is not meant to increase drastically. Therefore, keeping the ESR as one component in place (even if it only acts as a minimum emission reduction level for those sectors covered under the ESR as could be the case under Option 2) and introducing a separate emissions trading system for those sectors also covered under the ESR seems to be a promising way forward. This policy mix should allow reaching CO_2 prices needed in the sectors covered under the ESR (in particular road transport and buildings), while it prevents a significant increase in CO_2 prices under the current EU ETS, which could present a problem in particular for industry exposed to the international markets.

On a sector level:

- It is unlikely that a moderate CO_2 price in the road transport sector as well as the buildings sector is sufficient to incentivise the ambitious emission reductions required from these sectors until 2030 and thereafter. Additional policies are needed to reach net-zero carbon emissions in these sectors. The introduction of a CO_2 price in these sectors can present a meaningful component in the policy mix. Keeping the ESR in place in addition to the introduction of a CO_2 price can push the introduction of further instruments for the policy mix. In case the introduction of an ETS in these sectors includes a ceiling price, the existence of the ESR is necessary to ensure meeting the overall ESR target.

- Similarly, for non-ETS industry a regulation with a CO_2 price in a new sectoral ETS and the ESR targets provides a reasonable solution to ensure target fulfillment. At the same time, an integration of non-ETS industry in the existing EU ETS allows equal treatment of all industry installations. If non-ETS industry is integrated into the EU ETS a regulation under the ESR is no longer needed as the EU ETS - in combination with funding policies available to ETS as well as non-ETS industry - should be sufficient to incentivise the necessary transformational change. At the same time, non-ETS industry does not face additional burdens as could be the case if it is regulated under a newly created sector ETS together with road transport and buildings where CO_2 prices could be significantly higher. This can currently be seen under the national emissions trading system for fuels in Germany.

- The introduction of a new AFOLU instrument (agriculture, forestry, other land uses), which groups agriculture and the LULUCF sector with an individual target and individual rules, is seen in all three options named under the inception impact assessment to the ESR. In general, this attempt is positive if it is possible to introduce ambitious and binding national emission reduction targets for all emissions from agricultural activities and related land use. Compensation of emissions from agriculture through forestry and land-use sinks should not be allowed as long as agriculture has not realised its entire emission reduction potential. Similarly, linking between the EU ETS, a potential new sector ETS and the LULUCF sector is regarded critically.

5 Looking ahead: how to make EU Climate Governance fit for the Climate Neutrality Target

Targets, policies and an overarching legal framework are essential elements of a robust climate governance system. To check whether the existing system is up to the task of getting Europe on a path towards climate neutrality, this project took stock to help identify potential gaps and derive recommendations for how to address them (Duwe forthcoming).

The analysis built on a growing literature on climate governance and analyses of relevant regulatory frameworks[3] and on that basis defined eight key parameters for the assessment: 1. Overall context, legal framework, support; 2. Targets for both long- & short-term; 3. Strategic planning; 4. Policy cycle; 5. Progress monitoring; 6. Internal coordination; 7. Scientific advice; 8. Public participation.

The results are summarised in Table 2 below. They combine insights from an in-depth check for the EU level with a briefer analysis for the Member States' level specifically.

Table 2: Status quo climate governance for eight main elements and main weaknesses

Governance element	Status quo assessment	Main weaknesses and recommendations
1) Context, legal framework, political support	POSITIVE: Significant improvement since 2015, through GovReg and EU Climate Law (ECL). European Green Deal as the new guiding strategy. Political and public support is visible, and the pandemic could not stop the dynamic.	• Effectiveness of the overall framework will still need to prove itself. • Framework needs to be backed up by follow-up processes to monitor implementation.
2) Targets: long and short term	POSITIVE: 2030 and 2050 targets increased and legally enshrined. 2030 energy targets to follow accordingly. Binding national GHG targets remain. Adaptation goal in the ECL. Enhanced binding targets for natural sinks added at EU and national level. Process for interim targets and carbon budget established.	• Overall target in line with 1.5°C? • Next stop: proposal for 2040 target (2024) • Use carbon budget analysis for broader debate on EU fair share (2023-2024) • Net negative emissions may require further CDR discussion & quantification
3) Strategic planning	MIXED: EU LTS was influential in establishing climate neutrality goal – but is now outdated, with no update in sight. Adaptation strategies mandatory. A host of sectoral and horizontal strategies published, ECL mentions roadmaps. Individual Member States go further on CDR strategies.	• EU LTS needs regular updating, could act as hub and coordinate other sector strategies • Comprehensive CDR approach required in long run • Several national LTS not submitted yet. • LTSs and NECPs need alignment.

[3] The eight elements are taken from Duwe, M. & Evans, N. (2020): Climate Laws in Europe: Good Practices in Net-Zero Management. Berlin, Den Haag; Additional literature: Averchenkova, Fankhauser, and Finnegan (2020): The Impact of Strategic Climate Legislation: Evidence from Expert Interviews on the UK Climate Change Act. Climate Policy, p. 251 – 263; World Bank (2020) World Bank Reference Guide to Climate Change Framework Legislation. Equitable Growth, Finance & Institutions Insight. Washington, DC.

Governance element	Status quo assessment	Main weaknesses and recommendations
4) Policy cycle	MIXED: Review cycles for EU climate policy in place, "Fit For 55" package is an extraordinary one. Next revision: mid-2024. NECPs have forced integrated planning and established policy cycle in each Member State. ECL includes consistency checks	• No NECP equivalent at EU level, no process to identify need for EU policies – could be done via LTS update. • Revive ECCP for policy identification? • Second NECPs must be better – prepare now for mid-2023 draft updates • Need methodology for policy consistency.
5) Progress monitoring	MIXED: Established system, expanded. New climate neutrality progress assessment added by ECL, but without details on process or content. NECP progress gaps trigger Commission recommendations – but will they be adhered to?	• COM to develop net zero indicators. Member States also need them. To be used also in NECP updates and for assessments of NECPs and LTSs • Updates more frequently than every five years in annual State of the Energy Union. • Ensure follow-up of recommendations – stronger system possible?
6) Internal coordination	MIXED: All EU institutions have well-established mechanisms for climate policy, but few dedicated ones to provide ongoing coordination at meta level. Commission and Member States exchange on specific topics, have permanent committees.	• No inter-institutional coordination – create an annual forum for common status update and discussion on priorities. • All institutions need internal coordination. A dedicated European Parliament climate committee? A European Green Deal Supervisory Commission Working Group?
7) Scientific advice	POSITIVE: Many existing information providers among EU institutions. ECL includes a new independent European Scientific Advisory Board on Climate Change to be formed, modelled on national councils. Mandate is independent but unspecific.	• Advisory Board needs specific tasks to be effective in having impact on policy. Depends on individuals chosen for it. • Priority processes: climate neutrality progress monitoring, EU LTS update, 2040 target and carbon budget
8) Public participation	MIXED: Many formal options for input and good practice with consultations. EU Climate Pact launched. Additional language in ECL for national dialogues – but no checks on their implementation? Many Member States have stakeholder bodies. Climate assemblies being tried in several countries.	• Few interactive consultations, dialogue missing. Structured permanent forum warranted? • Climate assembly via EU Climate Pact? • National practices need improvement, NECP experience shows. • Add provision in revised GovReg for access to justice in national courts

Source: Duwe (forthcoming)

The analysis found a mix of strong elements and positive developments as well as remaining weaknesses. On the plus side, it can be stated that EU climate governance has been significantly expanded and strengthened since the adoption of the Paris Agreement – and at a remarkable speed. Moreover, political and public support have grown, which is evident in the higher targets adopted at EU level. However, the assessment reveals important gaps and shortcomings to address:

- Long-term planning (core topic of the project's focus) is not integrated sufficiently into the governance system, both at EU and at national level. A plethora of thematic strategies at EU level is not being connected and integrated into an overall framework other than reference to the Green Deal. At Member State level, a quarter of countries have not submitted their respective national long-term strategy and several Member States have no clear long-term target defined.
- Policy review cycles are regular, but not based on broad dialogue and do not amount to an EU level equivalent of the NECPs for Member States. NECPs and national LTSs are disconnected and may not be aligned. These processes cannot be challenged in national courts due to a lack of access under current rules.
- The analysis has also identified other areas of improvement that are of a more structural nature, such as the potential to enhance coordination inside and between EU institutions on the European Green Deal or a more permanent stakeholder dialogue dedicated to climate neutrality.

All of these points create the **risk that policy-making is not sufficiently informed by the long-term direction towards climate neutrality.**

Target processes in the next four years and key recommendations

While the focus for many EU climate policy experts in 2021-2022 will be on the "Fit For 55" negotiations, a set of upcoming processes in 2023 and 2024 are also key to success on climate neutrality and can address many current shortcomings:

- In **March 2023** national progress reports on NECP implementation are due (format to be adopted still by delegated act).
- In **June 2023** draft NECP updates are due, which need to be able to meet higher 2030 targets and should be better than the first set – final updates due a year later.
- In **September 2023** the Commission must present the first assessments regarding progress towards climate neutrality and policy consistency as established under the EU Climate Law. It will provide an initial answer to the question: "are we doing enough" to get to net zero?
- By **Mid-2024** at the latest (= six months after the Paris Agreement's Global Stocktake), the next review cycle of legislation *and* the proposal for the EU's 2040 target are due, plus the indicative EU carbon budget. The next package is thus looming on the horizon while the current one is being negotiated. It will be looking beyond 2030 – and beyond net zero.
- By the **end of 2024** national long-term strategies should be updated (Article 15.1 GovReg), a process that some Member States have already started – while others are yet to submit their first strategy altogether.

In considering these key processes, and based on the analysis of the existing governance landscape, the following actions would make climate policy "fit better" for net zero:

- A **revision of the Governance Regulation** to enhance NECPs and national LTSs, align them better, empower LTSs and clarify long-term targets. It also needs to specify access to justice at national level concerning both processes.
- A **transparent process for the development of a comprehensive methodology** for climate neutrality tracking and policy consistency, with net zero indicators that can also be used for NECP and LTS assessment – and to inform the national progress reports.

- An **update to the EU LTS** to inform the 2040 target proposal and the analysis on the next policy package in 2024 – and to coordinate the various parallel thematic strategies.
- A **dialogue with Member States** on where EU policies are needed most on the path to climate neutrality in preparation for that also gives visibility to national long-term strategies.

The EU LTS analysis and the dialogue with Member States would inform the next policy package and help shape an EU level policy overview for how to get to climate neutrality ("NECP style"). In parallel, broader engagement processes with stakeholders will be needed that could learn from the ECCP experience and be an actual exchange of ideas. At the same time, public participation options for citizens also need to be enhanced – through a possible expansion of the EU Climate Pact.

These changes to the existing governance system will require an investment from the Commission, but one that is largely non-additional and that could create synergies and save effort in the long run.

The ongoing negotiations on the **"Fit For 55" package are relevant in this context**. If a full revision of the GovReg would not be pursued by the Commission, amendments could be created also through the FitFor55 negotiations as a shortcut, i.e., through the review of the Effort Sharing Regulation. And as the timing for the extensive analysis needed for the next policy review may be too tight considering the need for changes being negotiated now to take effect and show results, the date could be pushed back by 6-12 months. A new "post-2030" package in 2025 would also leave time for a political decision to be taken on the EU's carbon budget and the 2040 target first.

6 Conclusions

The EC's Strategic Long-Term Vision (as the EU's long-term climate strategy under the Paris Agreement) has had a lasting impact on EU climate policy. The proposed target of climate neutrality was met with largely positive reactions from different quarters. Ursula von der Leyen made it a central pillar of the programme for her tenure as Commission President in July 2019, and declared it the core guiding objective of the European Green Deal a few months later. The subsequent adoption of climate neutrality by EU heads of state and government made it possible to include it in the EU Climate Law, proposed in March 2020 and agreed in April 2021. The scope was even extended in the ECL to net "negative emissions thereafter" (Article 2.1 ECL). Now the EU needs the means to deliver on this new objective.

As discussed in Section 2, the EU LTS (and similar studies) showed that **high investments need to be mobilised into technologies and infrastructures that are compatible with a climate-neutral economy**, while it remained open how this should be achieved. The recent Green Finance Taxonomy is meant to foster this, by directing private and public actors away from investments that will not be viable in a climate-neutral economy. There is already agreement on large parts of the taxonomy, but the ongoing debate about nuclear power and the role of gas makes clear that there is no accepted long-term vision in some areas. The diverse interests of the Member States can of course not be overwritten on the EU level. Nevertheless, some guardrails are necessary, e.g. in the context of the future design of pan-European energy infrastructures, in order to avoid stranded investments entailing high costs for the public. The negotiation of the Hydrogen and Decarbonised Gas Markets Package might provide orientation here.

Moreover, with its Strategic Vision, the EU also made clear that **the required large-scale transformation of the complete economy can only be achieved, if it is carried out in a manner that leaves no-one behind**, and coined the term just transition for this. Recently, this issue has become even more important in the context of both the COVID-19 pandemic and the rising prices of fossil fuels in autumn 2021. Both developments have led to some actors raising concerns that the transformation to climate neutrality is not feasible under these conditions, while a successful transformation could actually solve some important issues in this context. For instance, the currently debated Social Climate Fund addresses the issue of equality in this transformation. This underlines the need for a positive vision of the desired future pathway, which points out the multiple benefits of the transformation, for instance with respect to energy security, clean air and labour markets. While the EC addressed this already in its Strategic Vision, it still needs to be disseminated all over the EU, allowing the EU citizens to participate in its embodiment.

The review and increase of the interim target for 2030 from at least 40% to at least net 55% reductions from 1990 levels is a key step forward on the way to climate neutrality. The EC had to work hard to put together the FitFor55 Package of legislations to support implementation for the revised 2030 target. At the heart of the transformation, there is the need to defossilise the European energy system. While this is already happening rather quickly for electricity generation driven by the ETS and expansion of Renewables, the end-use sectors industry, buildings and transport have turned out to include hard-to-mitigate subsectors, in particular energy-intensive industries, the existing building stock and long-distance freight transport. To address these sectors, the EC has come up with individual sectoral strategies, namely the EU Industrial Strategy, the Renovation Wave, and the Strategy for sustainable and smart mobility, in order to provide the necessary guidance. The in-depth sector analyses summarised in Section 3 has reflected upon this in the long-term perspective.

The 2050 perspective on the industry sector shows that it will not be sufficient to implement best-available technologies across all the current production processes, but that a radical switch to new CO_2-neutral processes is needed, in particular in the production of steel, cement and basic chemicals. A strong CO_2 price signal from the EU ETS can be a key tool for enabling industrial transformation. However, even with a stronger reduction of emission allowances under the ETS as suggested in the FitFor55 package, it is uncertain whether the ETS is able to trigger these process switches early enough in view of the long-term upcoming investment cycles. Because by 2030, CO_2-neutral processes in industry must be able to be scaled up from pilot and demonstration scale to industrial level and operated economically. The EU Innovation Fund and similar national funding programs try to fill this gap by supporting the commercialisation of the relevant processes such as the use of low-carbon hydrogen, CCUS and circular economy approaches. While this is an important lever to address the long-term perspective, it is not clear how to track the progress in this regard. Moreover, the interplay of the ETS and such funding programs will become more important in the longer term. Here, additional instruments like the carbon contracts for difference may provide a promising approach to close the economic efficiency gap - if the CO_2 price is too low - while limiting the risk of over-funding. Equally important is an infrastructure expansion tailored to the needs of industry. Companies face a number of uncertainties in the context of the energy transition, this concerns in particular the (local) availability and the costs/prices of CO_2-neutral energy carriers such as electricity, hydrogen or PtG. A hydrogen backbone network connecting the major industrial sites could increase planning certainty and the willingness of companies to invest.

In addition to the overarching transport strategy, a clear long-term perspective still needs to be provided for long-distance freight transport. Clear targets have been proposed with the FitFor55 package for road transport, shipping and aviation. However, while electric mobility provides a clear long-term perspective for light-duty vehicles, there are still several competing options for freight transport, in particular battery-electric trucks, hydrogen-fuelled trucks and electrification of trucks via overhead lines. These options require different infrastructures, whose complete rollout require substantial investments and time. Against this background, the current strategy and the proposed Alternative Fuels Infrastructure Directive is not certain enough about which options to follow thoroughly and the CO_2 fleet targets for cars and trucks need to be more ambitious to reach the targets in an effective way.

For the defossilisation of the buildings sector, the EC's Renovation Wave provides an ambitious framework, which is an important guideline for the long-term pathway. However, reaching these ambitious targets requires substantial action early on in view of the long-term investment cycles. The current actions both on the EU and the Member States' level do not match up to the ambition of the Renovation Wave yet. The upcoming Energy Performance of Buildings Directive may be a first step in this direction. Elements like better implementation and definition of NZEBs and the cost optimality framework, but also individual renovation plans and passports are key elements to the success of the Renovation Wave Strategy.

The stocktake of the climate governance landscape as a whole in Section 5 has revealed important insights. Considering the positive impact of the EU's first LTS (the Strategic Visions document and the IDA), the lack of a mandate for an update is an obvious gap. There are several reasons, why **an update of the EU LTS should be considered**. First of all, the adoption of the 55% target for 2030, **the underlying calculations of the EU LTS are now out of date.** Long-term planning is not a one-off exercise but should be understood as continuous process – that is updated as new information becomes available (such as maturity and costs of technologies, lessons from implementation, etc.). Only then can long-term strategies properly inform near-term policy-making. The information from an updated EU LTS is needed to guide the setting of

the 2040 target and the review of the main policies, which are both due in 2024. An updated EU LTS would create added value for EU climate policy and most of the underlying analysis will need to be done anyway for the tasks the EC is already obliged to carry out.

Furthermore, a host of additional sectoral and horizontal strategies (some new initiatives and some that had been in the making for a while) have been published since the adoption of the European Green Deal. The ECL also includes an article on "sectoral roadmaps" (Article 10), obliging the Commission to engage with sectoral representatives about the drawing up of dedicated roadmaps towards climate neutrality. However, other than the loose framing of the European Green Deal, **there is currently no central policy framework for coordination between the sectoral and horizontal strategies**. A regular updating could help orchestrate the various sectoral and horizontal strategies. An **EU LTS could serve as a "master plan" or at least as a central hub for all efforts needed towards climate neutrality**.

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