DEVELOPING THE EU LONG TERM CLIMATE STRATEGY

SPECIAL REPORT

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Developing the EU Long-Term Climate Strategy

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List of Abbreviations

€/kWh – Euro per kilowatt hour

2011 Transport White Paper – The White Paper, called "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system"[4], issued in 2011 by the European Commission

2016 Reference Scenario – The European Commission's "EU Reference Scenario 2016"[5]

2017 proposed Combined Transport Directive – The "Proposal for a Directive of the European Parliament and of the Council amending Directive 92/106/EEC on the establishment of common rules for certain types of combined transport of goods between Member States"[6]

2050 Energy Roadmap – The roadmap, called "Energy Roadmap 2050"[7], issued in 2011 by the European Commission

2050 Roadmap – The roadmap, called "A Roadmap for moving to a competitive low carbon economy in 2050"[8], issued in 2011 by the European Commission

BECCS – Bio-energy with carbon capture and storage

BP – British Petroleum

CAPRI model – Common Agricultural Policy Regionalised Impact model

CCS – Carbon Capture and Storage

CEFIC – The European Chemical Industry Council

CO2 – Carbon dioxide

COP21 – Twenty-first session of the Conference of the Parties

COP24 – Twenty-fourth session of the Conference of the Parties

DG CLIMA – Directorate-General for Climate Action

EEA – European Environmental Agency

ECF – European Climate Foundation

EFTA – European Free Trade Association

EIB – The European Investment Bank

[4] COM(2011) 144 final.
[5] https://ec.europa.eu/energy/sites/ener/files/documents/20160713%20draft_publication_REF2016_v13.pdf.
[6] COM/2017/0648 final - 2017/0290 (COD).
[7] COM(2011) 885 final.
[8] COM(2011) 112 final

ESR – Effort Sharing Regulation

EU – European Union

EU ETS – EU Emissions Trading System

EUA – European Union emission allowance

EUR – Euros

EUROFER – European Steel Association

G4M model – Global Forest model

GAINS model – Greenhouse Gas and Air Pollution Interactions and Synergies model

GDP – Gross Domestic Product

GEM E3 model – General Equilibrium Model for Economy-Energy-Environment model

GHG – Greenhouse gas

GLOBIOM model – Global Biosphere Management model

GW – Gigawatt

IPCC – The Intergovernmental Panel on Climate Change

IRENA – The International Renewable Energy Agency

JRC – The Joint Research Centre

JRC–IDEES – The Integrated Database of the European Energy Sector

LDS – Long-term low greenhouse gas emission development strategy, as in the Paris Agreement[9]

LLES – Long-term low emission strategy, as in the proposed Governance of the Energy Union regulation[10]

LTCS – The long-term climate strategy to be issued in 2019

LULUCF – Land use, land-use change, and forestry

MS – Member State

Mtoe – Million tonnes of oil equivalent

NDC – Nationally determined contribution

NECP – National Energy and Climate Plan

NET – Negative emission technologies

[9] https://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf .
[10] COM(2016) 759 final/2.

NGO – Non-governmental organization

PA – Paris Agreement

POTEnCIA model – Policy Oriented Tool for Energy and Climate Change Impact Assessment model

PRIMES model – Price-Induced Market Equilibrium System energy system model

PV – Photovoltaic

SET plan – Strategic Energy Technology plan

TFEU – The Treaty on the Functioning of the European Union

TWh – terawatt hours

UK – United Kingdom

UNFCCC – United Nations Framework Convention on Climate Change

USD – United States Dollar

Glossary

1.5 to 2-degree target – The commitment under the Paris Agreement to limit the global temperature rise this century to well-below 2°C above pre-industrial levels, and pursue efforts to limit the increase to 1.5°C.

2018 Talanoa Dialogue – A mandated process requested by the Parties to the Paris Agreement to take stock of the global progress towards the long-term goal of the Paris Agreement.

Carbon budget – The maximum amount of greenhouse gases that can be emitted during a specific period. Global carbon budgets typically reflect which emission volumes allow to keep the global temperature increase below a certain threshold, while more granular carbon budgets distribute this global budget between different actors.

Carbon capture and storage (CCS) – A process consisting of the separation of CO2 from industrial and energy-related sources, transport to a storage location, and long-term isolation from the atmosphere[11].

Carbon leakage – A situation in which emitting activities move to other countries with no, or less stringent, climate constraints. This can result in a net increase of emissions.

Carbon neutrality – When the amount of carbon dioxide emitted equals the amount removed from the atmosphere. In the context of the Paris Agreement this refers to anthropogenic emissions.

Decarbonisation pathway – A representation of a possible future development of carbon dioxide emissions based on a coherent, internally consistent and plausible set of assumptions about the future state of the world.

Proposed Governance of the Energy Union regulation – A proposal for a regulation that establishes a mechanism to oversee the implementation of the 2030 EU climate and energy policy objectives and targets and integrates the EU's climate and energy planning into a single framework. The proposal was issued by the European Commission on 30 November 2016 and was discussed by the Council and the Parliament. As of April 2018, it is still under trialogue negotiations.

Impact assessment – An analysis by the European Commission that examines whether there is a need for EU action and analyse the possible impacts of available solutions.

Integrated National Energy and Climate Plan – A document outlining a Member State's objectives, policies and measures in all areas of the Energy Union. The plan would cover the period 2021-2030 and would be renewed every ten years[12].

[11] Cited from https://www.ipcc.ch/pdf/special-reports/srccs/srccs_wholereport.pdf

[12] http://www.consilium.europa.eu/en/press/press-releases/2017/12/18/governance-of-the-energy-union-council-agrees-general-approach/pdf

Modelling tool – a model; a numerical representation of a system or state of affairs.

Overshoot pathway - Emissions, concentration or temperature pathways in which the metric of interest temporarily exceeds or overshoots the long-term goal before stabilizing to the desired level[13].

Nationally Determined Contributions (NDCs) – Represent each Party's contribution towards meeting the goal of the Paris Agreement, and stipulate the domestic mitigation measures that a Party intends to take to achieve the objectives of such contributions along with Adaptation efforts and identified needs for international support in terms of capacity (building), technology and finance.

Paris Agreement – A global response to climate change adopted on 12 December 2015 by 195 countries, that seeks to keep the increase in global temperature this century to well below 2°C above pre-industrial levels, while pursuing efforts to limit the increase to 1.5°C. The Agreement entered into force on 4 November 2016 and has (as of April 2018) been ratified by 175 Parties to the UNFCCC.

Ratchet-up mechanism – An established and regular process foreseen by the Paris Agreement in which countries increase their climate ambition by taking stock and submitting progressively more ambitious climate action plans every five years.

Reference scenario – A pathway given current trends and policies against which the results of decarbonisation scenarios can be compared.

Resilience – Being able to withstand or quickly recover from negative shocks.

Scenario – A coherent, internally consistent, and plausible description of a possible future state of the world[14].

Techno-economic – A techno-economic analysis that assesses the economic and technological possibilities to achieve a particular goal.

Transparency – The condition of being open to public scrutiny.

[13] Cited from: https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_Glossary.pdf
[14] Cited from: http://www.ipcc-data.org/guidelines/pages/definitions.html

1. Introduction

1.1. Background to the EU 2050 Roadmap

In general, a roadmap is a document that provides guidance on how to reach a specific objective. Depending on its scope and level of granularity, it might outline broad strategies and decarbonisation pathways, but also offer more granular operational tools, formulating instructions for strategy implementation. Roadmaps provide general direction but do not themselves set mandatory quantitative targets, which in the European Union context are generally decided by the European Council.

Issued in 2011, the 'Roadmap for moving to a competitive low carbon economy in 2050' (henceforth the '2050 Roadmap') is an important policy document. It provided a vision of how to deliver greenhouse gas (GHG) reductions of 80% to 95% by 2050 compared to 1990 levels. It also outlined milestones, which would show whether the EU was on course to reach its climate targets, and policy challenges, investment needs and opportunities in different sectors.

The 2050 Roadmap is a relatively short political document that sets out the general emission reduction target, determined beforehand by the Council, and breaks it down by sectors. It discusses several co-benefits of decarbonisation, such as economic growth, air quality improvements and new sources of sustainable employment. The 2050 Roadmap was accompanied by a very substantial impact assessment, providing a quantitative analysis.

Member States built, and continue to build, on both these documents during the drafting of their national long-term strategies. The Council of the EU, however, did not reach a consensus on the Roadmap, which was unexpected, as Council conclusions would not have directly implied obligations for Member States.

Much has changed since the 2050 Roadmap was published in 2011. Although the timing is still unclear, the European Commission will publish a new Long-Term Climate Strategy (LTCS). The European Council, in its conclusions of 22 March 2018[15], asked the European Commission to publish the new LTCS in 2019.

Our project provides a 'roadmap' for the development and delivery of the LTCS. It has two outputs. This Technical Paper describes the main issues that need to be addressed, the potential choices that can be made in the design of the new strategy and an analysis of the implied trade-offs.

An accompanying Policy Paper presents different bundles of consistent choices from the Technical Paper, resulting in different architectures, and may serve as a basis upon which to build the new LTCS.

1.2. Impact of the 2050 Roadmap

Although the 2050 Roadmap was not formally endorsed, it has turned out to be an innovative planning

[15] European Council conclusions on Jobs, Growth and Competitiveness, as well as some of the other items (Paris Agreement and Digital Europe), 22 March 2018, http://www.consilium.europa.eu/media/33430/22-euco-intermediary-conclusions-en.pdf

tool and a widely cited policy document, which gave the European Commission significant influence over the structure of energy and climate debates.

At the EU level, the 2050 Roadmap set out a framework and targets for future legislative proposals and texts. The Energy Efficiency Directive (2012) thus explicitly states it *"contributes to meeting the goals set out in the Roadmap"*[16]. The 2050 Energy Roadmap explores how the energy sector needs to transition in order to reach the 2050 targets included in the 2050 Roadmap[17]. Member States documents similarly use the 2050 Roadmap as a reference document, including for the development of their own national roadmaps[18].

Finally, the 2050 Roadmap was also influential because of the sectoral decarbonisation pathways that it proposed. This sectoral focus encouraged industrial sectors to develop their own mid-century roadmaps, setting out how they intend to decarbonise[19].

1.3. The need for a new EU long-term climate strategy

Three major legislative developments have taken place since the publication of the 2050 Roadmap, and contribute to making the publication of a new EU LTCS a necessity: at the international level, the Paris Agreement has been said to have "changed everything"[20].

At the EU level, the two significant developments have been the Governance of the Energy Union, which is in the process of finalisation, and the 2030 Climate and Energy Framework, which sets climate change targets for 2030.

The Paris Agreement entered into force in November 2016, much earlier than predicted. It created a new global framework for the fight against climate change, and increased the ambition through its provisions.

The Paris Agreement goal is to hold the increase in the global average temperature to well below 2°C above pre-industrial levels, and to pursue efforts to limit the temperature increase to 1.5°C. This goal is to be achieved by a global peaking of emissions as soon as possible, and subsequent rapid emission reductions. In the second half of this century, anthropogenic carbon emissions and carbon sequestration are to be bought into balance.

This new level of ambition in the Paris Agreement is significant and needs to permeate the spirit and

[16] Other European Commission proposals widely cite the 2050 Roadmap as a reference document, including "A policy framework for climate and energy in the period from 2020 to 2030" (2014), or the impact assessment accompanying the "Proposal for a Directive on the energy performance of building" (2016).

[17] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0885&from=EN

[18] An example of such roadmaps that take EU's Low-Carbon Economy Roadmap as reference, is the Portuguese "National Low Carbon Roadmap 2050" (2012). Other examples of Member States documents citing the EU 2050 Roadmap include the 'Update of the sectoral analyses of the CGEDD report (…) on the 4-fold division of greenhouse gas emissions by 2050" (2017), from the French Ministry of the Environment, Energy, and the Sea, or the "Long term budget forecast: Report of the Federal Government" (2016) of the Austrian Federal Ministry of Finance.

[19] These sectoral roadmaps include, but are not limited to, CEFIC's "European chemistry for growth: unlocking a competitive, low carbon and energy efficient future" (2013), or EUROFER's "A steel roadmap for a low carbon Europe 2050" (2013)

[20] E.g. Patricia Espinosa Executive Secretary, UN Framework Convention on Climate Change on 23 November 2016 on http://www.climateactionprogramme.org/climate-leader-papers/the_game_has_changed_for_good

ethos of the LTCS, as well as upcoming revisions to the EU National Determined Contribution (NDC). This is well illustrated by examining the UNFCCC targets under three different agreements – the Kyoto Protocol first commitment period, the Kyoto Protocol second commitment period and the Paris Agreement.

Table 1: From Kyoto to Paris

	Coverage	Reduction of all covered countries	EU reduction
Kyoto	18% of global emissions	4-5% from 1990 to 2012	2012: 8%
Doha	11% of global emissions	18% from 1990 to 2020	2020: 20%
Paris	100% of global emissions	Carbon neutrality in second half of 21st century	2030: 40% 2050: tbd

Source: Own representation.

Provisions in the Paris Agreement have also created the need for coordination with the UNFCCC process and cycle. Parties to the Agreement are invited to communicate, or update, their NDCs by 2020 and every five years thereafter, as well as to communicate their mid-century, Long-term low GHG emission Development Strategies (LDSs) by 2020.

Whether or not the LTCS will in fact be the long-term strategy that the EU will communicate to the UNFCCC remains to be seen, but there is no doubt that the LTCS will inform its provisions, while the LTCS itself will be informed by the Paris Agreement's level of ambition and process.

The 2018 Talanoa dialogue, which will take stock of collective efforts and progress, will be an important moment for the EU to examine its level of ambition, and with it the provisions in the upcoming LTCS. Moreover, as the EU is expected to be at the forefront of the fight against climate change, the EU LTCS could play an important role as an international benchmark. The EU also has to submit to the UNFCCC annual inventories and biennial reports[21].

The LTCS might also play a coordination role for the 2030 Climate and Energy Framework and the Energy Union, to help ensure the consistency of climate policy and targets. The proposed Governance of the Energy Union regulation, which is currently under discussion, foresees that Member States will submit national Long-term Low Emission Strategies (LLESs) to the European Commission. It is currently unclear how the European Commission will assess the consistency of those strategies with EU commitments. In addition, a new decarbonisation pathway with more ambitious targets might be inconsistent with the current emissions-trading system (ETS) cap and effort-sharing regulation (ESR) targets. The new EU LTCS could serve as the benchmark for comparison.

In addition to these changes in the climate policy field, climate science itself is also under continued review and improvement. The LTCS should take scientific conclusions into account, such as the IPCC's Fifth Assessment Report (published in 2014), the forthcoming IPCC Special Report on 1.5°C and the

[21] Decision 2/CP.17 establishes the guidelines for the submission these biennial reports by Annex I Parties.

annual UNEP Emission Gap Reports, among others.

1.4. Assumptions for the EU 2050 Roadmap have changed

The 2050 Roadmap was built on assumptions and expectations that largely reflected the consensus at the time. However, just as climate science and international commitments have changed, some of these assumptions have changed significantly in the past seven years.

To illustrate this, Table 2 compares some of the assumptions and expectation of relevant EU documents in 2011 and 2016/2017.

Table 2: Change in expectations

		2050 Roadmap, 2050 Energy Roadmap, or 2011 Transport White Paper Reference Scenario *2020 Forecast*	**2016 Reference Scenario**, or the 2017 proposed Combined Transport Directive *2020 Forecast*	**Change in expectation**
GDP (in Million 2005 EUR)		14,164[a]	13,483[d]	**-8%**
CO2 emissions, energy related (Mt)		3,511[a]	3,281[d]	**-7%**
Discount rates	**Power Generation**	9%[a]	7.5 – 8.5%[d]	**-1pp**
	Private Individuals	17.5%[a]	11% – 14.75%[d]	**-4.5pp**
Oil price (in 2008 dollars)		88[a]	80[d]	**-9%**
EUA Price		16.5[b]	15[d]	**-9%**
Coal (gross consumption in mtoe)		263[a]	251[d]	**-5%**
Natural Gas (gross cons. in mtoe)		413[a]	385[d]	**-7%**
Renewables (gross cons. in mtoe)		258[a]	267[d]	**+3%**
Wind (net generation capacity in GW)		231[a]	207[d]	**-10%**
Solar (net generation capacity in GW)		53[a]	136[d]	**+155%**
CCS (net generation capacity in GW)		*2050 Forecast* 101[a]	*2050 Forecast* 19[d]	**-81%**
Battery cost in €/kWh		*2050 Forecast* 560-780[c]	*2050 Forecast* 160[e]	**-75%**

Sources: Own calculations based on the impact assessments of the [a] 2050 Energy Roadmap, [b] 2050 Roadmap, [c] 2011 Transport White Paper, [d] 2016 Reference Scenario, [e] 2017 proposed Combined Transport Directive.

On the macro-economic level, the unexpectedly long recession led to an 8% lower GDP forecast for 2020 in 2016, compared to the 2011 forecast. Accordingly, expected 2020 CO2 emissions were also corrected downward from 2011 to 2016. The crisis also led to significantly lower discount rates resulting from the European Central Bank's monetary policy reaction.

Despite substantial volatility in the oil market, the 2011 and 2016 assumptions for oil prices in 2020 are not significantly different. The same holds for emission allowance prices. Fossil fuel consumption expectations fell in line with GDP expectations. However, the expectation for the contribution of carbon

capture and storage to the decarbonisation of the power sector in 2050 was down by 80% in 2016 compared to 2011.

Rapid technological development since the publication of the 2050 Roadmap has reduced the price of renewable energy and battery storage much faster than anticipated, which has led to an increase in expected renewable generation capacity. This is mainly due to the massive expansion in solar power[22], with today's installed capacities (107 GW) more than double what the 2050 Energy Roadmap expected for 2020[23]. In 2017[24] the European Commission expected battery costs in 2050 to be a quarter of what they projected only six years earlier[25].

The political environment has also changed considerably, and not only because of the Paris Agreement and Energy Union processes. A phase-out of coal and of combustion engines was not deemed politically feasible[26] in 2011 but is now becoming a reality in many EU Member States or is under discussion[27].

The energy balances of neighbouring regions also evolved. For example, energy demand in the southern Mediterranean countries and Turkey is up compared to 2011 (in Algeria, for example, by 33% by 2016, according to BP, 2017).

The economic, technological, and political situation has changed substantially in comparison to 2011. Hence decarbonisation pathways that were not taken into account in 2011 can now be considered.

1.5. About the project

This Technical Paper is a deliverable of the project 'Developing the EU long-term climate strategy'. The project is a joint initiative of Bruegel and the European Roundtable Climate Change and Sustainable Transition (ERCST/ICTSD). It aims to provide a roadmap for the development and delivery of the new EU LTCS.

The Technical Paper describes key choices that can be made in the new LTCS, with an in-depth analysis of the trade-offs implied. This includes the main elements that will need to be considered in reviewing the current roadmap leading up to 2050, and also covers the process that should be used in the development and the delivery of the new roadmap.

In the development of this Technical Paper, a strong interaction with stakeholders throughout the EU was sought. Many Member States have developed their own roadmaps, as have many industrial sectors.

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[22] The expectations for wind changed much less. At the 2017 installation volume of 16 GW and a current installed capacity of 169 GW, the EU will have 217 GW – falling between the higher 2011 projections and the lower 2016 projections WindEurope, (2018).

[23] The two biggest drivers of this unexpected development where the quickly falling cost (both technology and capital) and the strong support schemes.

[24] Impact Assessment on 2017 Transport White Paper (Directive 92/106/EEC) (p.86): https://ec.europa.eu/transparency/regdoc/rep/10102/2017/EN/SWD-2017-362-F1-EN-MAIN-PART-1.PDF

[25] 2011 Transport White Paper Impact Assessment: http://ec.europa.eu/smart-regulation/impact/ia_carried_out/docs/ia_2011/sec_2011_0358_en.pdf

[26] A coal phase out was possibly also not considered that necessary in 2011, as expectations surrounding CCS were still high.

[27] Coal phase out has been announced in 11 Member States: Austria, Belgium (already completed), Denmark, Finland, France, Ireland, Italy, The Netherlands, Portugal, Sweden and the UK (Europe beyond Coal, 2017).

Updating the EU LTCS thus requires careful attention to all sectors in Member States with different profiles.

The process leading up to this Technical Paper began with a stakeholder meeting in June 2017, in which the fundamental elements of a new roadmap were discussed. Based on this meeting and the existing national and sectoral roadmaps, a draft outline of a new roadmap was developed by Bruegel and ICTSD.

The draft outline was presented to relevant stakeholders in five separate workshops held in Berlin, Copenhagen, Częstochowa, Paris and Rome in January 2018. The aim of the workshops was to gather input on the draft outline and to identify the main elements to consider in developing a new roadmap. About 25-30 stakeholders, including Member States, the European Commission, climate organisations, and the private sector, attended the workshops. To the greatest extent possible, the workshops were held in collaboration with national governments.

The draft outline was updated and finalised based on the input from the workshops. The revised outline was used to guide the development of this Technical Paper and to ensure that all pertinent issues and options that emerged during the workshops were included. The Technical Paper is accompanied by a Policy Paper which presents different bundles of inherently consistent set of choices that can serve as basis for building the new roadmap.

A draft of the Technical Paper and a draft outline of the Policy Paper were presented to a selected group of reviewers in Brussels in March 2018. Based on the feedback from this meeting and on subsequent comments from stakeholders, the two papers were finalised.

In April 2018, the Technical Paper and Policy Paper were presented at a launch event in Brussels.

Both papers were made possible by grants from the governments of France, Germany, Denmark, Sweden, and from the European Climate Foundation, Climate-KIC, ENEL, EdF and Shell.

2. Purpose, need and audience

2.1. What needs does the LTCS aim to fulfil?

Issue

As part of its domestic policy process, and international commitments, the EU has to:

i. Develop guidance for EU climate policy and related Member State policy, in line with the goal of the Paris Agreement
ii. Deliver a long-term low GHG emission development strategy (LDS) to the UNFCCC
iii. Ensure synchronisation with the proposed Governance of the Energy Union regulation
iv. Inform industry in its investment decisions
v. Provide a vehicle for engaging EU citizens and stakeholders in decisions over the decarbonisation of society

These deliverables are complementary. It would create confusion and undermine credibility if, for example, the submission to the UNFCCC differed in substance from the general policy direction of the EU.

The LTCS is therefore likely to meet several of these needs, and possibly even, to some extent, all of them. The issue is how the LTCS will interact with these other EU deliverables, as each may have a slightly different angle and a different audience.

It is unlikely that the LTCS can meet all of these aims simultaneously and satisfactorily. However, it is important that there is coordination to guarantee consistency of the message to all audiences, and to provide internal coherence. However, one document aiming to meet all needs risks becoming unfocused, and politically more difficult to approve. It is difficult to be everything to everyone.

The LTCS might therefore have a particular focus and/or might then also serve as a basis and be used to focus on other needs, in order to develop other products that the EU needs to deliver. Depending on this focus, it might give priority to certain elements or audiences, and some of these needs might receive greater emphasis. The options set out below are therefore not meant to be mutually exclusive. The choice is not between options, but one of focus, prioritisation and emphasis.

2050 Roadmap

The 2050 Roadmap provided guidance for EU and related Member State policy and was as such quoted in several important EU and Member State texts[28]. In terms of investment decisions, its sectoral breakdown of decarbonisation pathways was influential. It was the starting point of several sectoral long-term decarbonisation strategies[29]. To some extent it also communicated with citizens, through the publication of a citizens' summary[30].

[28] See 1.1 Impact of the 2050 Roadmap.
[29] See 1.1 Impact of the 2050 Roadmap.
[30] https://ec.europa.eu/clima/sites/clima/files/summary/docs/roadmap_2050_en.pdf.

Option 1: Focus on developing guidance for EU policy and related Member State policy

One of the important purposes of the LTCS is to help justify and guide future energy and climate policy. It can provide a benchmark, help set future national and sectoral targets, and in general contribute to the coordination of European, national and sectoral policies to ensure that they are consistent with optimal decarbonisation pathways. The LTCS could also highlight the priorities of the European Commission to other EU institutions.

European and Member State public investment policies, in particular, need a framework to ensure their consistency with optimal pathways. These investment policies include direct public investment and incentives put in place to foster private investment. The LTCS can also highlight where European and national Research and Development (R&D) public support is most needed, and give guidance on the balance between deployment and R&D investment and the timing of these instruments.

In addition to developing guidance for internal EU and Member State policy, the LTCS can also provide guidance for non-Member States. EU energy policy is indeed integrated with, and has a significant impact on, non-EU countries such as Norway, Morocco, Russia and members of the Energy Community[31]. These countries need to understand the long-term EU decarbonisation strategy, which will assist them in the planning of their own climate strategies and energy plans for the transition.

Option 2: Focus on providing the UNFCCC and the international community with a long-term strategy

The EU must deliver to the UNFCCC an LDS: Decision 1/CP.21 invites *"Parties to communicate, by 2020, to the secretariat mid-century, long-term low GHG emission development strategies"*[32]. The LTCS could itself be this document, or could instead form the starting point (in terms of ambition and targets) for another long-term strategy prepared specifically for UNFCCC submission.

The UNFCCC document, however, while having no set format, will have a certain emphasis, and must address particular elements that will emerge from the UNFCCC process and the Talanoa dialogue.

Were the LTCS to be submitted to the UNFCCC, it would need to address these elements specifically, while for internal purposes, the EU document might have a different (e.g. sectoral) focus, or have a horizon that goes beyond mid-century. Addressing the EU LTCS to the UNFCCC could therefore mean that it will become overly complex or less able to respond to other important EU needs, such as the need to provide direction to different sectors.

[31] Members of the Energy Community, such as Ukraine or Moldova, have agreed to implement the EU's energy sector rules.
[32] Decision 1/CP. 21, Para. 35

Option 3: Focus on the Governance of the Energy Union process

i. At Member State level

As part of the proposed Governance of the Energy Union regulation, which is under discussion at time of writing, Member States will need to submit Integrated National Energy and Climate Plans. The LTCS can serve as an input and coordination tool for these short-term plans.

Member States also have to submit long-term low emission strategies (LLES) as part of the proposed Governance of the Energy Union regulation. The European LTCS can serve as a reference point for the drafting of these LLES, by sharing modelling tools and data for their drafting, and by helping achieve coherence between national and European long-term targets.

ii. At European Commission level

The proposed Governance of the Energy Union regulation states that the *"Commission shall assess the integrated national energy and climate plans and their updates"*, and in particular whether *"the targets, objectives and contributions are sufficient for the collective achievement of the Energy Union objectives"*[33]. The LTCS can provide the European Commission with the benchmark necessary to assess these national plans and to propose legislation if appropriate. It can also serve to outline the long-term goal and to identify the actions required in the short-to-medium term to reach that goal.

Option 4: Focus on helping inform investment decisions

The EU has a strong interest in having industrial sectors at the forefront of technological change. An LTCS that provides direction on climate and energy strategy will help guide investment that can contribute to that objective.

Although it does not create legal certainty, a climate strategy can be a soft-policy tool, providing industry with indicative guidance about decarbonisation pathways. The LTCS will indicate a general direction, a more or less granular perspective on future policy-making, which sectors can take into account in their investment strategies.

Depending on the chosen policy instruments, industry and workers can be among the first players affected by climate policies. The LTCS can provide them with more clarity on likely future policies and, if sectoral decarbonisation targets are included, on the share of effort each sector will have to take responsibility for.

[33] European Commission, 2017, "Proposal for a Regulation of the European Parliament and of the Council on the Governance of the Energy Union" (Corrigendum), p. 32.

Option 5: Focus on providing a vehicle for engaging EU citizens and stakeholders in decisions over the decarbonisation of society

Citizens will be affected by both climate change and climate policies, through:

i. The impact of climate change on living standards;
ii. The transformation of the labour market during the transition;
iii. The pass-through of carbon costs, for instance in energy bills;
iv. The health benefits of cleaner air;
v. The internalisation of GHG costs at the consumer level and the availability of more sustainable consumer products, etc.

Voters ultimately legitimise policy, and as such citizens need to buy into the LTCS. The LTCS can also collect input, and citizens and civil society should get an opportunity to share their views on the level of ambition of EU policies, and on how the EU intends to achieve these targets.

Addressing the need to engage EU citizens, and thus having a broader audience, does not prevent the LTCS from being primarily a policy-making document, which could remain relatively technical. Different tools could be developed for different purposes and stakeholders. A sub-product for citizens, such as an online calculator to visualise the impact of policies on remaining carbon budgets, could be envisaged, for example.

3. Type of document

3.1. What is the political ownership of the LTCS?

Issue

The LTCS will be issued by the European Commission. Depending on the process, however, political ownership could lie with another institution or set of stakeholders. The legal status of the document and potential voting procedures to be followed during its approval process will be critical for the perception of the existing support for its goals and vision. This also affects the strength of any potential signals sent to Member States, civil society, business and international stakeholders.

As such, the political ownership of the LTCS is an important element, with serious consequences, that will need to be considered and understood.

2050 Roadmap

The 2050 Roadmap was published by the European Commission as a Communication to various EU institutions (the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions) and to national parliaments for their information[34]. The purpose was for each institution to define their own resolutions or conclusions based on this Communication, and take ownership of the vision of the 2050 Roadmap.

The 2050 Roadmap was discussed in the June 2011 Environment Council with Council *Presidency* conclusions published following the meeting[35]. One Member State opposed the inclusion of milestones in the Roadmap[36].

The European Parliament, however, did endorse the 2050 Roadmap[37]. If both the Council and the European Parliament had endorsed the 2050 Roadmap, this would have signalled that it had broad ownership at the highest level. However, it must be noted that, as environmental law-making only requires qualified majority voting in the Council, the absence of consensus on the Roadmap did not necessarily prevent further law-making based on the targets and milestones of the 2050 Roadmap.

Option 1: LTCS issued as a Communication

A Communication from the European Commission as a technical document[38] (e.g. with a headline document and supporting Impact Assessment) would serve to inform policy-makers and stakeholders.

[34] https://ec.europa.eu/clima/policies/strategies/2050_en#tab-0-3.
[35] http://www.consilium.europa.eu/uedocs/cms_data/docs/pressdata/en/envir/122956.pdf.
[36] https://www.reuters.com/article/us-eu-environment/poland-blocks-eu-efforts-on-carbon-limits-idUSBRE8281DV20120309.
[37] http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//NONSGML+TA+P7-TA-2012-0086+0+DOC+PDF+V0//EN.
[38] In this context, a document drafted by European Commission experts, that does not need political agreement from other institutions to be published.

It would also assist in the development of a mature and informed debate, both on the EU's long-term decarbonisation pathways, and on the formulation of new goals that take into account the Paris Agreement and the upcoming IPCC Special report on 1.5°C.

It would encounter less resistance from Member States and some stakeholders than a political document, while still creating visibility for the revisiting of the EU's climate targets and providing guidance for Member States in preparation of their own LLES[39].

Such a technical document could be drafted and published faster than a more political document. It would not itself be voted on by either the Council or the Parliament, but could be the start of a longer political process, which would entail the formulation of opinions, reports, resolutions and conclusions by appropriate EU institutions (Council, European Parliament, Committee of the Regions, European Economic and Social Committee).

Once the Communication is issued, it could be politically endorsed by European institutions. Alternatively, it could be followed by new legally binding documents from the co-legislators (such as new long-term decarbonisation targets voted on by the Council).

The publication of an initial technical document could also be helpful at the international level as part of the Talanoa dialogue at the UNFCCC. However, that would mean that the document should be published before the start of COP24 at the end of 2018, which may not be realistic.

This approach may also enhance the freedom of the European Commission to "think outside the box" during drafting, and promote more ambition. At the same time, this approach may also mean that the involvement of other institutions and stakeholders would not be subject to an equally strict procedure, as would be the case during the ordinary legislative process, resulting in less transparency.

Option 2: LTCS as a legally binding document

The European Commission may decide to propose a LTCS as a legally binding document. Depending on the legal basis, it would need to follow a strict procedure, and require agreement from other EU institutions.

If the LTCS should be binding, it would likely have to follow a similar process as the 2020 and 2030 targets, which were decided on in 2007 and 2014. The process encompassed the publication of a "Green Paper" by the European Commission that served to canvas opinions. Based on these, the European Commission issued a "White Paper" containing a proposal. This proposal was the starting point for the discussions in the European Council, which concluded by consensus on the general outline of the targets – instructing the European Commission to translate them into detailed legislation. This legislation was then approved through the normal legislative procedure.

The resulting document would set out long-term, binding targets for the Member States. The process towards the publishing of a legally binding document in the EU ensures the involvement of a wide range of stakeholders during the drafting and the legislative process. A legally binding document would

[39] Due to be submitted as part of the Governance of the Energy Union Proposal, Art 14.

therefore have the highest possible level of ownership and provide the clearest and strongest communication signal. Such a signal is key to industry and investors, which need a framework that gives investment security, but also to civil society as a whole.

A successful, legally binding, LTCS would require a degree of political agreement from the Member States. It could more easily get transformed into the LDS, to be submitted at the UNFCCC in accordance with Article 14(9) of the Paris Agreement.

There is a substantial downside risk to making the LTCS binding. First, as the European Council operates largely by consensus there is a risk that opposition by a limited group of, or even individual, Member States could derail the entire project. Hence, without wide support from Member States and strong leadership from either the European Commission and/or key Member States governments, it is far from certain that consensus can be reached. Such an outcome could provide an even weaker signal to stakeholders than a non-legally binding Communication.

Moreover, the components of a long-term strategy do not lend themselves to act as a vehicle that is legally binding. Although a LTCS approved by the Council would without doubt provide a stronger signal, only the targets or milestones could in themselves be binding.

Furthermore, making a policy binding for more than 10 years into the future is unusual. It would not be perceived as very democratic.

3.2. Role of the LTCS in the overall climate and energy architecture

Issue

The LTCS will inevitably, and should, interact with other policy documents such as an EU energy strategy/roadmap, innovation strategy, industrial strategy, etc. The LTCS' role in the overall climate and energy framework will also determine to what degree climate change is a driver, or one among many, or part of an integrated approach.

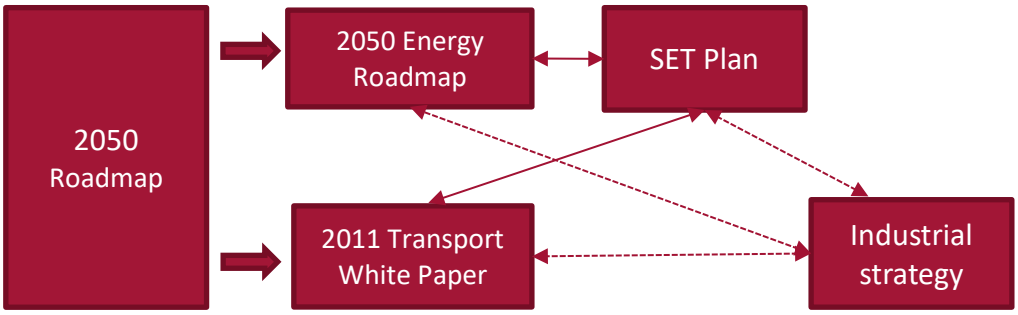
2050 Roadmap

The 2050 Roadmap redefined the EU's headline climate strategy, and from that emerged several sectoral action plans, including the 2050 Energy Roadmap[40] and the 2011 Transport White Paper[41]. While DG CLIMA led the development of the 2050 Roadmap, other European Commission services were involved in the development process.

[40] European Commission, 2011, "Energy Roadmap 2050".

[41] European Commission, 2011, "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system".

Option 1: A climate strategy that is followed by sectoral "action plans"



The LTCS could be the headline strategy, which would be followed by a series of other long-term strategies (for energy, innovation, transport, agriculture, etc.). In this option, the climate strategy guides the other subsequent strategies, and as such is given some level of preponderance over them. This priority for the climate change policy field is welcome if the EU wants to make the fight against climate change the first priority, and to send this signal to investors and to the international community.

In this option, the drafting of the first strategy (the LTCS) benefits from more flexibility than subsequent strategies, which would be constrained by the priorities set by the LTCS. Additionally, given the time constraints, it could be efficient to first produce an LTCS, which would then guide other policy strategies. Producing an all-integrated long-term strategy is time consuming, in the context of the urgency of climate change, the need to respond to international obligations and the need for clarity on the long-term policy perspective.

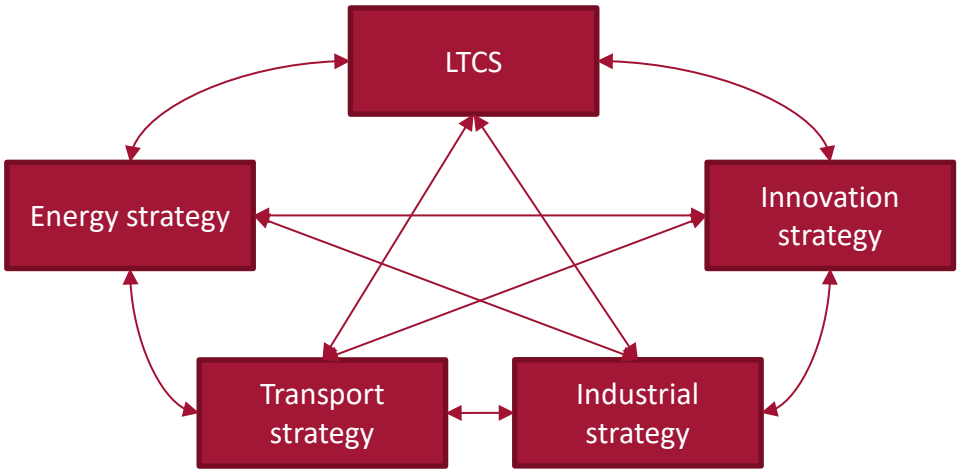
The climate strategy could distribute carbon budgets to various economic sectors, which could then be used as constraints in different sectoral plans. Close cooperation between the various EU institutions and European Commission services could ensure the feasibility of these sectoral carbon budgets.

There are however a number of drawbacks to this approach. First, it might not be realistic to expect climate change to drive all other policy domains in the current political reality. There are competing constraints, as well as benefits, and in defining climate change strategies society may want to stack all benefits and costs in determining the way forward.

Second, if the subsequent strategies all emerge from a single LTCS they might not benefit from cross-sectoral interaction and synergies. These interactions and synergies are not only highly desirable, but necessary.

This option is similar to the 2050 Roadmap but could be defined in a more stringent manner with carbon budgets rather than indicative ranges of effort considered realistic for various economic sectors.

Option 2: A series of equal and consistent strategies based on common modelling



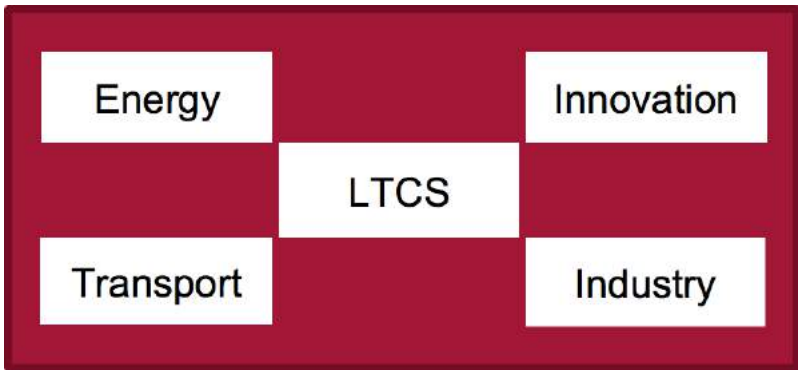
A second option would be for the LTCS to itself be part of a series of strategies, which would have coordinated but "equal standing". Consistency between the documents would be ensured through common modelling and close cooperation between the relevant actors during the drafting stages. Each of them would inform the others, but without any centralised coordination point: no *primus inter pares* strategy driving the others.

As the different policy strategies inform each other, some policy coordination and integration across the different economic sectors would be enabled. This can help prevent harmful policy overlaps, or anticipate their consequences (such as the overlap resulting in some of the oversupply in the EU ETS due to Renewable Energy and Energy Efficiency directives, in addition to international credits). It could also help guide public and private investment towards infrastructure/technologies where there are strong inter-sectoral synergies (e.g. the cross-sectoral gains of electrification).

This approach would also recognise the reality of multiple priorities for the EU, including areas such as green growth and energy security.

If climate change is considered the most pressing issue, this option will however not give it any level of prioritisation over other strategies. Additionally, it may be hard to achieve coordination without some degree of centralisation: otherwise, how do you achieve coordination between different objectives? If some objectives clash, how do you resolve this tension?

Option 3: One integrated long-term strategy, that includes a LTCS, an energy strategy, transport strategy, etc.



A third option would be to have one centralised, integrated long-term strategy, which would include long-term plans for climate change, energy, innovation etc. All these plans would have the same political weight, would be synchronised and integrated in one single document. This document would be far more comprehensive and far-reaching than the 2050 Roadmap.

Having one fully integrated strategy is the ideal option to achieve consistency of action in different economic sectors: it can help achieve full coordination and integration of policies across sectors, and guide public and private investment towards infrastructure and technologies that fully exploit cross-sectoral inter-connections and synergies.

An integrated strategy would allow for a holistic view and policy strategy for the low-carbon transition, addressing the effects of the transition on different sectors and on job creation and destruction.

Additionally, once an integrated strategy is defined, then priorities are set for the coming years: this means less flexibility for the policymakers, but also implies progress can be made faster, as the trade-offs have already been decided.

This would imply that it is feasible to design such an in-depth and overarching strategy, which might not be, politically or practically, a realistic expectation. An integrated document could come at the expense of the granularity of the strategy. This could potentially weaken the LTCS and reduce its potential impact.

Moreover, creating one single integrated strategy will create rigidity – the separate parts might not be updateable if they become outdated. This can be important, as long-term strategies have long-lasting impacts: the 2050 Roadmap figures were referred to and used to justify policies in subsequent years, despite some of the documents' clear mispredictions, such as the underestimation of renewables and the overestimation of CCS. One master-document might therefore live beyond its usefulness, especially if it is costly to renew or update – which might become necessary in light of the Paris Agreement five-year cycles.

3.3. Type of document

3.3.1. Update cycle

Issue

A LTCS can in principle take very different forms. We will discuss two crucial design questions here: (i) whether the LTCS is a one-off or a regularly repeated document and (ii) how comprehensive the update should be. The chosen format will affect the role of the LTCS in European climate discussions – it should therefore be decided based on the desired function of the LTCS (2.1).

2050 Roadmap

The 2050 Roadmap was a 15-page political document outlining *"milestones which would show whether the EU is on course for reaching its target, policy challenges, investment needs and opportunities in different sectors"* in very broad terms. It contained one key table (and a corresponding figure) that described possible sectoral contributions in 2030 and 2050 to achieve 80% domestic emission reduction. It was complemented by a 133-page Impact Assessment (that included 35 pages of annex). This Impact Assessment essentially served to underpin the 2050 Roadmap with European Commission and external analysis. Thereby, the main models underlying the analysis were used by the European Commission before and after the 2050 Roadmap for other official documents, ensuring a certain degree of consistency of analysis over time. The 2050 Roadmap itself was, however, not updated[42].

Option 1: One-off document

Producing a one-off LTCS would entail the least effort. This allows the LTCS and linked discussions to focus on the "questions of today" and not having to spend effort on making the exercise "timeless" and easy to update. One sub-option could be to have a one-off document focusing on today's questions, but basing it on a continuous modelling approach to ensure consistency and comparability of the analysis over time. Updates of the modelling analysis can be published online on a regular basis in order to enable anyone to check the progress *vis-à-vis* the LTCS. Such regular updates can increase transparency and be one way of involving citizens.

Option 2: Regularly reviewed and updated document

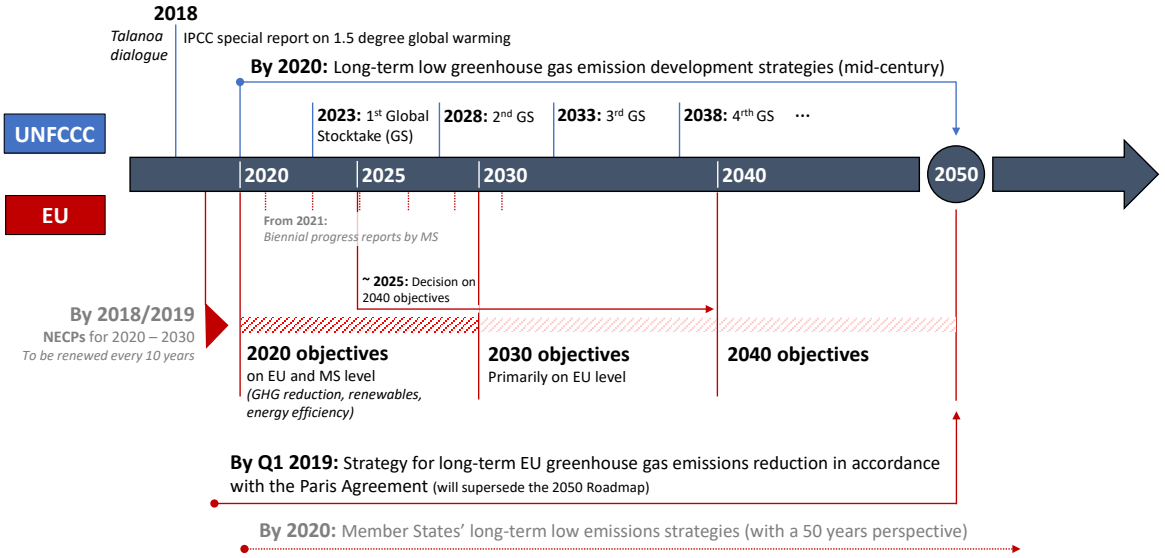
Redoing/updating the LTCS can be sensible as new information on crucial elements (e.g. macroeconomic developments, technology costs, international compliance) becomes available. We have seen that several assumptions underlying the 2050 Roadmap aged quite quickly. Nevertheless the 2050 Roadmap numbers continued to be used for political negotiations for a number of years, despite being outdated. Regularly updating the LTCS could allow for an assessment of whether model

[42] The Reference Scenario in both the 2050 Roadmap and in the 2050 Energy Roadmap were updated in 2013 and in 2016 though.

assumptions and parameters remain valid, and the incorporation of non-linear effects that can be difficult to anticipate in advance. This could provide policymakers with a useful compilation of relevant knowledge and its strategic implications. The updates could also add certainty for businesses and investors, and reduce the riskiness of various investment projects.

Redoing the LTCS, for example according to the five-year review cycle of the Paris Agreement, could establish a sensible analytical basis and process to comply with the reporting obligations – it could in fact be a role-model for other Parties to the Paris Agreement.

Figure 1: Climate Governance – UNFCCC and EU



Note: All information presented in grey is based on EU Commission's Proposal for a Regulation on the Governance of the Energy Union (2016) and is depended on the outcomes of the trialogue negotiations.

Table 3: Overview of UNFCCC and EU climate governance documents

Name	Content	Legal Nature	Legal Reference
	UNFCCC		
Nationally determined contributions (NDCs)	According to Article 4 of the Paris Agreement, "each Party shall prepare, communicate and maintain successive nationally determined contributions that it intends to achieve". The Parties are requested to submit NDCs every five years, with the next round in 2020. The NDCs stipulate the Party's contribution towards meeting the goal of the Paris Agreement, in terms of its intended	Mandatory by the Paris Agreement	Annex of the Paris Agreement, Article 4, Para. 2[44]

[44] https://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf

	mitigation and adaptation measures after 2020[43].		
Low GHG emission development strategies (LDSs)	The Parties are invited to submit low GHG emission development strategies (LDSs) to the UNFCCC Secretariat by 2020.	Optional	Decision 1/CP. 21, Para. 35[45]
EU			
National Energy and Climate Plans (NECPs)	Member States shall submit integrated NECPs that set out their objectives, policies and measures in all five areas of the Energy Union. The plans would cover the period 2021-2030 and would be renewed every ten years. Progress reports would be submitted every two years.	Mandatory	Proposal for a regulation on the Governance of the Energy Union (COM(2016) 759 final/2)
Long-term low emission strategies (LLESs)	Member States shall prepare LLESs, with the first set of such strategies to be reported to the European Commission by 1 January 2020.	Mandatory	Proposal for a regulation on the Governance of the Energy Union (COM(2016) 759 final/2)
2020 objectives	- Binding national and EU-wide non-ETS emissions reduction and renewables targets. - Binding EU-wide ETS emissions reduction targets. - Indicative national and EU energy efficiency targets.	Either binding or indicative	- Decision No 406/2009/EC - Directive 2009/28/EC - Directive 2003/87/EC - Directive 2012/27/EU
2030 objectives	- Binding* EU-wide and national non-ETS emissions reduction targets. - Binding EU-wide ETS emissions reduction targets. - Binding* EU-wide renewables target. - Binding* EU-wide energy efficiency target.	Binding	- The Effort Sharing Regulation Proposal (COM(2016) 482 final) - Directive (EU) 2018/410 of the European Parliament and of the Council - Proposal for a revised Renewable Energy Directive (COM(2016) 767 final/2) - Proposal for a revised Energy Efficiency Directive (COM(2016) 761 final)

Source: Proposal for a Regulation on the Governance of the Energy Union; http://fsr.eui.eu/mind-gap-proposed-governance-energy-union/; http://bigpicture.unfccc.int/#content-the-paris-agreemen; European Council (2018)

Note: * These objectives are 'binding' as far as they are stipulated as such in the proposals

Moreover, a repeated LTCS could be linked to the EU Energy Union governance process. The LTCS could serve to aggregate Member States' national climate strategies/plans and become a process to assess their inherent consistency as well as their consistency with one another (e.g. do electricity

[43] http://unfccc.int/focus/items/10240.php.
[45] https://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf.

export/import projections net out) and with the EU targets. In principle, this process could be targeted at either the Member States' long term low emission strategies[46] or the national energy and climate plans[47], or both. Using a repeated LTCS to aggregate Member States climate strategies/plans could be even developed into an ongoing process, in which Member State contributions shape the EU LTCS and vice versa.

But there might also be limits to such processes. A one-off LTCS might be more likely to catalyse substantial interest from a wide range of national and EU-level stakeholders, resulting in a productive debate. A repeated process might, however, essentially be run by national governments and the European Commission. As a result, a strongly formalised repeated process might fail to ensure the important buy-in of stakeholders.

Option 3: Constantly updated content in a fixed structure

An even more ambitious endeavour would be a "living structure" in which individual pieces of new information (e.g., from individual Member States or sectors) are added, when they become available. This would ensure that the scenarios at any point in time reflect the available information which would allow policymakers to monitor delivery gaps much faster. However, this would less be an LTCS than an information system.

3.3.2. Comprehensiveness

In terms of comprehensiveness, the LTCS can consist of a qualitative document outlining the EU's vision with respect to reducing emissions, a detailed analytical exercise that spells out – and analyses the feasibility of – elaborate decarbonisation pathways, or a combination of both.

Option 1: Visionary document

Many key drivers of long-term decarbonisation are highly uncertain (e.g., fossil fuel prices) or unknown (e.g., possible breakthrough technologies). Therefore, a mainly qualitative discussion of the implications of different ambition levels, the expected challenges involved in attaining them and the main principles to address the challenges might be the most credible guidance the European Commission can provide for the longer term. Examples of trade-offs for which principles might need to be defined include: primacy of national vs. EU measures; importance of market measures vs. non-market measures; sectoral vs. horizontal measures; the relative roles of demand-side and supply-side measures.

This could still be informative for stakeholders if it spells out in broad terms how the EU intends to react to changes in global decarbonisation ambition or how the EU would plan to respond if it risks missing its targets. Furthermore, a more qualitative document might allow a wider array of stakeholders to get involved in the discussion – which would be more political and less technical.

[46] Article 14 in the proposed Governance of the Energy Union regulation.
[47] Article 4 in the proposed Governance of the Energy Union regulation.

However, such an approach would lack details on how this transition can best be implemented, such as concrete actions and the timings and costs related to those actions.

Option 2: Comprehensive document

A more detailed LTCS could provide more concrete information on the possible pathways to 2050. Such a LTCS could contain a broader long-term vision underpinned by a quantitative framework in which various possible scenarios are modelled. The analysis can focus on evaluating, in detail, a small number of possible transition scenarios. On the basis of the scenario analysis, a set of 'no regret options' to facilitate the transition process could be identified.

An advantage of combining a broad vision with detailed transition scenarios would be that it would provide more certainty for policymakers and businesses, and could help guide sectoral policies. An online tool can furthermore be used to show the variability of parameters and how they affect the various scenarios. A revision of these parameters on a regular basis can add credibility to the scenario analysis.

Option 3: Mixed document

A third option would entail a combination of the previous two options. Specifically, the LTCS could outline a comprehensive vision leading up to 2050, and a broader, more qualitative vision for the years after 2050. Including a pathway beyond 2050 could be relevant, since various projections (e.g. in the IPCC's Fifth Assessment report) suggest some transition scenarios might overshoot the atmospheric GHG concentrations required to achieve the goals of the Paris Agreement.

3.4. The role of the LTCS in the public debate on long-term climate action

Issue

The LTCS could fulfil several roles with respect to the public discussion on long-term climate policy. A broad societal debate could promote understanding, ownership and public support. Societal buy-in is necessary to ensure that long-term climate policies cannot easily be weakened or even turned around in the near future.

The role envisaged for the LTCS in the public debate has implications for its format and content. Different roles will require different levels of granularity and different presentation of information, for example as options for discussion, or a finished document, ready for discussion by stakeholders. In addition, this will also obviously have an impact on the way the consultation process associated with the LTCS is designed and carried out.

2050 Roadmap

The 2050 Roadmap (and its Impact Assessment) benefited from extensive stakeholder discussions before publication. The published work of experts and the results of an online questionnaire for individuals and organisations were used during the drafting of the Impact Assessment. The 2050 Roadmap, therefore, to some extent integrated contributions from stakeholders.

A more significant role for the 2050 Roadmap was to start discussion and contribute to policy-making (at various levels) on long-term decarbonisation. DG CLIMA describes the role of the 2050 Roadmap as: (1) providing guidance on how the low-carbon transition can be achieved; (2) inviting responses on its vision from EU institutions; and (3) a potential starting point for EU institutions, Member States and stakeholders when developing EU and national policies for achieving the goal of a low-carbon economy by 2050[48].

The 2050 Roadmap could therefore be considered mainly as a starting point for more focused discussions on long-term decarbonisation – discussions that in practice encompassed policymakers and other stakeholders.

Option 1: document as an initiator of debate

By providing insights into the European Commission's analysis on the possibilities for, and feasibility of, long-term climate action, the LTCS could start with wider societal discussions on how to decarbonise and how benefits and costs can be shared. Stakeholders (civil society, industry, policy-makers etc.) could use the European Commission's in-depth analysis and modelling to discuss their commitment to various decarbonisation pathways, and how to manage that transition in a sustainable way.

[48] DG CLIMA website, FAQ section on the 2050 low-carbon economy (https://ec.europa.eu/clima/policies/strategies/2050_en#tab-0-3).

The European Commission can use its unique experience in technical and data-driven analysis of a LTCS to inform stakeholders and subsequent debates, while leaving policy-making and decisions to democratically elected institutions such as Member State governments, the European Parliament and the Council.

If the LTCS is solely meant to initiate conversation, however, it will be the start of a longer and wider discussion that will take significant time and effort to conclude. Moreover, if this discussion is not held in a centralised and consistent manner, the outcome could be significantly different in various Member States and at various times.

Option 2: document sets out options to start discussions with stakeholders

The LTCS could also set out scenarios describing different decarbonisation pathways to allow a focused debate on the right approach to the low-carbon transition. Stakeholders would be presented with different pathways, allowing them to pick and choose between these outlooks and discuss merits and drawbacks of each.

Again, the European Commission can use its unique experience in technical and data-driven analysis of a LTCS to inform stakeholders and subsequent debates, while leaving policy-making and decisions to democratically elected institutions such as Member State governments, the European Parliament and the Council.

However, if this option might allow for a more constructive and focused debate, it could potentially lack openness and transparency with respect to the drafting and presentation of the options.

Option 3: document integrates contributions from stakeholders during drafting

Integrating contributions (opinions, analysis and expertise) from stakeholders in the LTCS during the drafting allows for a more comprehensive and less political document.

A thorough and broad stakeholder engagement process could be both more interactive and more transparent. This could be done through an iterative process, which allows participants to be, and feel, involved in the shaping of the document. This could be achieved for example by having a stakeholder engagement process on an early draft, and again on a more developed product (*ex-ante* and *ex-post* consultation). Different stakeholders could contribute at different stages tailored to their profile, allowing their experience to be used optimally.

By gathering views, informing a wide public and enhancing discussions on a topic that is critical for the future of the EU, the process could be as important as the final document.

Yet this process could be very time consuming for the European Commission, and significantly delay the publication of the LTCS – depending on how thoroughly stakeholders are consulted. In addition, the governance of the consultation should ensure that no individual stakeholders can capture the process.

4. Scope of the document

4.1. Scope of modelling

4.1.1. Should the LTCS entail modelling?

Issue

In contrast to other long-term strategies (such as on innovation or industry[49]), most national or sectoral climate strategies contain some form of modelling to underpin their strategic considerations (on decarbonisation pathways and/or policies). By including a contestable and complex quantitative analysis in a LTCS the European Commission would in fact not only change the format of the document, but also the nature of the debate.

2050 Roadmap

Modelling is a key element of the 2050 Roadmap. Extensive discussions on the modelling approach, assumptions and results as well as the use of the outcomes to justify a series of policy measures illustrate the important role modelling played in the 2050 Roadmap.

Option 1: Include modelling

Modelling can serve as a basis for discussion by ensuring consistency (modelling as an 'accounting framework' that prevents exceeding resource constraints or double-counting) and making a complex discussion on premises and assumptions transparent. This is particularly relevant when the strategy is developed in a participatory process to ensure stakeholder buy-in.

The complexity of the questions arises from the interconnectedness of modern economic systems which implies multidimensional ripple effects of climate actions (e.g. macroeconomic feedback loops, rebound effects, trade, etc.).

Furthermore the 'Better Regulation Initiative'[50] requires the European Commission to document and justify the results and possible proposals.

Option 2: No modelling

At least in theory there is also the option to completely refrain from modelling. Even the most sophisticated models will fail to adequately capture all the complexities and has an inherent status-quo

[49] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52017DC0479&from=EN.
[50] https://ec.europa.eu/commission/priorities/democratic-change/better-regulation_en.

bias (e.g. models that are typically calibrated with historic data cannot capture the possibility of disruptive change). Focusing too much on modelling may lead to relying too much on model results and thereby excluding possible pathways which are outside the scope of models. Furthermore, giving modelling such a high prominence in the debate may exclude experts that are not modelers from these crucial discussions.

4.1.2. What is the purpose of modelling in the LTCS?

Issue

Modelling can serve different purposes in the LTCS. The decision on what is modelled determines not only the modelling results, but also shapes the focus of the LTCS. Explicitly determining the purpose(s) of the modelling exercise upfront is crucial as different purposes imply different modelling approaches.

To simplify, we distinguish two different general modelling approaches (1) modelling techno-economic decarbonisation pathways and (2) modelling policies for decarbonisation. Most relevant questions typically addressed with modelling fall under one of the two approaches.

2050 Roadmap

The 2050 Roadmap was the first official EU-wide exercise that embarked on showing that decarbonisation is feasible[51]. This modelling of techno-economic decarbonisation pathways served to establish a decarbonisation ambition for 2050 and generate an understanding of the sectoral contributions. Both overall and sectoral decarbonisation pathways modelled in the 2050 Roadmap and subsequent scenarios and Roadmaps have been used to justify important policy choices (e.g., the 2012 Energy Efficiency Directive[52]).

Option 1: Modelling techno-economic decarbonisation pathways

Modelling techno-economic decarbonisation pathways seeks to assess the technological and economic possibilities to achieve certain ambition levels. There are very different modelling techniques in this category and they may serve many distinct purposes:

Assess feasibility of a certain ambition level: Modelling can provide evidence that a certain level of ambition is technically feasible at acceptable cost and under the model assumptions (i.e., it does not collide with constraints). Such an analysis would typically be conducted through back-casting, i.e., starting with a desired future and analysing backwards whether the steps to achieve the predetermined end-point are realistic. One prominent example is the ECF 2050 Roadmap[53].

[51] https://ec.europa.eu/clima/policies/strategies/2050_en#tab-0-3.
[52] Directive 2012/27/EU.
[53] http://www.roadmap2050.eu/project/roadmap-2050.

Forecast important variables: Modelling is sometimes used to forecast specific variables of interest (such as prices, GDP or emissions). Concrete fuel demand forecasts might, for example, be needed for infrastructure planning. By its very nature forecasting longer term developments in complex systems with many volatile exogenous variables is fraught with uncertainty and presenting the results to policy-makers might provide them with an unjustified expectation of foreseeability. Hence, most experts agree that forecasting should only be conducted for a reasonably foreseeable future and complemented with sensitivity analysis to account for different possible futures.

Identify the crucial levers: Models can help to identify the crucial levers (for example energy efficiency) and thereby help prioritise policy action.

Identify bottlenecks: Especially technology-rich models can help to identify crucial bottlenecks (such as energy storage) for achieving certain decarbonisation pathways.

Determine optimal ambition levels: In principle, modelling can be used to determine a cost-optimal or welfare-maximising pathway to keep emissions below a certain level. By taking the cost of climate change into account, Integrated Assessment Models are even able to determine endogenously the optimal emission pathway (e.g. by allowing for overshooting; or calling for even higher ambition if the cost of climate change exceeds the cost of mitigation). The corresponding pathways are, however, very sensitive to a large number of uncertain assumptions. For instance, the development of a breakthrough technology for carbon sequestration by 2030 might lead to drastically different outcomes of such a model. Consequently, assumptions need to be made very transparent and the sensitivity of results with respect to assumptions needs to be checked.

Measuring costs: Models can also be used to get an idea of the order of magnitude of the cost of different ambition levels.[54] The cost of different ambition levels might be contrasted to model estimates of the cost of inaction, or limited action. Models of the impact of climate change are, however, subject to particularly high levels of uncertainty which can make limit the usefulness of the results for policy-makers. In addition, the cost of climate change in Europe cannot be easily traced back to policy action in only the EU.

Assess outcomes (GDP, jobs, side-benefits, investment needs, etc.): Appropriate models allow to compare how politically relevant measures might develop under different decarbonisation scenarios. Depending on the model, information on economic development (GDP), labor market evolutions or other side benefits (such as air quality) might even be obtained at a national level.

Sharing the burden: Models allow to assess how much different sectors and countries have to contribute to decarbonisation under different scenarios[55]. This is crucial to inform corresponding policy decisions.

System choices: Technology-rich model can also assess, whether there might be some binary system choices (e.g., electricity vs. green gas for heating) and, if so, at what point to decide on which technology-branch to prioritise.

[54] Thereby the framing of the options might play a role for policy-maker. If they have to choose between doing nothing, 80% emission reduction and net-zero emissions, they might feel that choosing 80% is a sensible choice; if by contrast the options are 95%, net-zero and net-negative emissions they might find net-zero to be a good compromise.

[55] Obviously the corresponding result is conditional to the underlying target function and assumptions, see section 5.2.

Assess uncertainty: Modelling can also be used to assess the uncertainty of achieving the desired ambition level under a certain decarbonisation pathway, provided that a number of exogenous variables (e.g., technological developments) are uncertain. This can also help to identify no-regret options.

There are models available for each of the above-described purposes. But each model has a different strength. In an ideal world, the authors of the LTCS should select the purposes they deem most relevant and select the models (as well the subsequent modelling decisions) accordingly.

Option 2: Policy modelling

Other types of models analyse which policy mixes (and not which technology mixes) would allow to achieve certain ambition levels. They could provide important insights on the cost-optimal balance, targeting and timing of broad policy instruments such as carbon pricing, standards/bans, subsidies to investment and innovation.

Decarbonisation might require policy-makers to conduct (or not to conduct) certain system choices. For example, publicly driven infrastructure investments (e.g., the regulatory treatment of charging infrastructure or distributed generation) can catalyse the dominance of a certain technology pathway (for example electric vehicles instead of other low-carbon transport options). Modelling can determine which policy choices might imply difficult to reverse system choices, and indicate the implications of these choices.

Typically, less comprehensive modelling exercises can also be used for more detailed questions: Sometimes limited models can help to provide useful answers to relevant policy questions (e.g., which share of a fixed budget should be spent on deployment on R&D support for low carbon technologies).

4.2. Attribution of emissions: at source vs. embedded

Issue

Emissions are currently tracked at the source and the accounting is done downstream. The principal instrument for driving emissions reduction through carbon pricing is done through the EU ETS, which addresses emissions downstream or at source.

However, the ambitious goal of the Paris Agreement, to achieve net carbon neutrality by the second half of the century, will require an increasing look at the impact of trade flows. It is therefore important to ask not only what the appropriate way for the EU is to account for emissions now, but also how we may need to account as we get closer to the carbon neutrality timeline, when countries may want to be responsible for consumption and not production.

In other words, whether the LTCS should continue to use an emission source approach, or whether it should operate a shift towards an end-use approach.

2050 Roadmap

The 2050 Roadmap implicitly makes use of an emission source approach, first and foremost through its extensive reliance on the ETS: "The EU ETS will be critical in driving a wide range of low carbon technologies into the market". The ETS uses an emission source approach, and is de facto a downstream instrument. Moreover, no mention is made of embedded emissions. In its discussion of the transition towards carbon neutral electricity generation, for instance, the 2050 Roadmap does not discuss the emissions embedded in the technology itself. Finally, and very importantly, it does not look at imports of emissions.

Nevertheless, two instances suggest end-use approaches are not completely off-the-table. First, the EU ETS itself explicitly recognises the existence of indirect costs, which can be significant: in primary aluminium production, for instance, indirect EU ETS costs represented in 2015 3.6% of total production costs[56]. Any compensation scheme based on embedded carbon costs of electricity acknowledges the importance of carbon embedded in production inputs. Second, the 2050 Roadmap makes brief mention of biomass, for which an end-use approach is used.

Option 1: Emission source approach

For UNFCCC GHG accounting purposes, there needs to be a consistent accounting system throughout the world, which ensures there is no double counting and respects the sovereignty of national governments. The emission source approach is currently being used everywhere, and it is clearly a necessity for the EU to continue with that approach. It does not mean that it should not start looking at its consumption based emissions, but switching to this approach at this time may not be the most productive approach.

The use of end-use accounting in biomass, for instance, has created some accounting difficulties. By importing biomass for energy production, some Member States have been able to report lower emissions, since emissions from biomass are not reported at combustion. The reported reductions do not in fact reflect any actual mitigation at the point of combustion itself: the importing country is benefiting from the accounting rules, whilst the country exporting the biomass will be responsible for LULUCF reporting.[57]

An emission source approach may also be more pragmatic. If correctly identifying the carbon footprint of services and products can be important, models for end-use approaches are currently lacking, whereas the emission source models are well established. Therefore, even if an end-use approach could contribute to establish a fair effort sharing among countries, there is no generally accepted methodology for its implementation.

[56] CEPS, ECOFYS and Economisti Associati, 2016, "Composition and drivers of energy prices and costs: case studies in selected energy-intensive industries".

[57] European Academies Sciences Advisory Council (EASAC), 2017, "Multi-functionality and sustainability in the European Union's forests".

One issue that needs to be flagged is that under the emission-source approach, the competitive and decarbonisation dimensions may not be aligned. The emission source approach may generate competitive tensions, as asymmetric carbon policies create different implicit carbon prices.

Policy-makers must then deal with this misalignment through policies, and address the reality that the costs of embedded carbon are not factored in. Investors must make choices based on this misalignment, and on the policies available to redress it (free allocation, embedded cost compensation, etc.). If the misalignment is not appropriately corrected, this may become a disadvantage for Europe.[58] The analytical results might differ between a model in which an end-use approach is consistently used, and one in which an emission source approach is used and alignments for traded emissions are put in place in a second step.

A shift away from the emission source approach may also encourage the adoption of effective cross-sectoral synergetic policy options, such as policies promoting circular economy. These may provide GHG emissions reductions, that go beyond the mitigation opportunities targeting the source of emissions. In most current economic models of production, materials are extracted, used, and then disposed of.

By contrast, such an approach aims at the avoidance of the extraction of new material and its subsequent disposal.[59] Helping lower demand for material allows for significant emission reductions across the value chain. A shift away from an emission source framework may therefore enable alternative, and more ambitious, approaches to achieving carbon neutrality, and beyond that, negative emissions.

Option 2: End-use approach

The end-use approach, sometimes referred to as consumption-based accounting of emissions, allows to accurately determine the footprint and responsibilities of each country. An end-use approach to track the effect of mitigation measures can provide important insight into issues like carbon leakage and equity, which may not be well addressed under the current emission source-based approach.

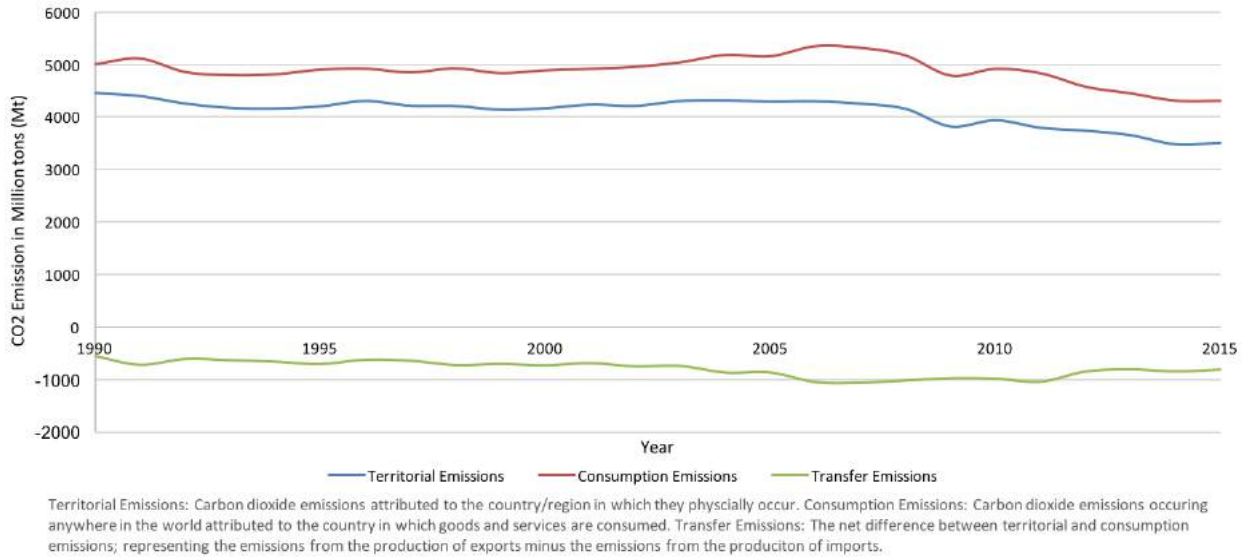
It may be thought that an end-use approach could have been more relevant under the Kyoto Protocol, of which a large number of countries were not Parties, than under the Paris Agreement, under which almost every world country has an NDC.

However, over the Kyoto Protocol period, trade flows have vastly increased. Merchandise exports increased, in current USD, from 5.6 Trillion when the Kyoto Protocol was adopted in 1997, to 16.1 Trillion in 2016[60]. This significant increase of trade flows highlights the importance of calculating the emissions embedded in consumer goods and services.

[58] For a discussion of this issue, see Dieter Helm, 2015, "The Carbon Crunch – Revised and updated".
[59] Hoogzaad, Jelmer and Bardout, Matthieu (2018) "Looking beyond Borders: the circular economy pathway for pursuing 1.5 ° C".
[60] World Trade Organisation, 2018. https://data.worldbank.org/indicator/TX.VAL.MRCH.CD.WT?end=2016&start=1997.

The EU exports types of goods and services that are often less carbon intensive than those it imports, but also imports from countries with much higher carbon intensity. As shown by Figure 2, the EU has for several decades been a net importer of emissions[61].

Figure 2: Net transfer of EU emissions



Territorial Emissions: Carbon dioxide emissions attributed to the country/region in which they physcially occur. Consumption Emissions: Carbon dioxide emissions occuring anywhere in the world attributed to the country in which goods and services are consumed. Transfer Emissions: The net difference between territorial and consumption emissions; representing the emissions from the production of exports minus the emissions from the produciton of imports.

Source: Global Carbon Project 2017

In 2015, the EU's net import of C02 emissions was 813.5 Million Tons.[62] An end-use approach can contribute to track these imports and exports of emissions, whilst an emission source approach may miss a significant percentage of the EU's carbon footprint. Parties to the Paris Agreement having committed to achieve carbon neutrality during the second half of the century, an end-use approach could be useful to reflect the real footprint of each Party.

An end-use approach would also help address carbon leakage concerns. The emission-source approach and end-use approach offer in that respect different perspectives. The former is easier to implement, but requires to deal with cross-border issues in a second step, as it does not consider all emissions in the optimisation exercise. The latter is a better holistic optimisation, as it considers all emissions.

The end-use approach, however, is not widely used as an accounting system, and is not consistent with the international approach currently in use. The co-existence of the two systems could lead to double counting, if used to track progress towards targets. It is therefore only feasible if every country implements it.

[61] Consumption emissions are calculated as the territorial emissions minus the 'embodied' territorial emissions to produce exported products, plus the emissions in other countries to produce imported products. Therefore, Consumption = Territorial – Exports + Imports. As Transfer = Territorial – Consumption, Transfer = Exports – Imports. A negative Transfer therefore means a net import of emissions. For further explanations, see Le Quéré et al. (2017). https://doi.org/10.5194/essd-2017-123.

[62] Global Carbon Project, 2017. http://www.globalcarbonatlas.org/en/C02-emissions.

Investors also require clarity, and any transition from an emission source to an end-use approach must not only be done by every country, but also with long enough warning to avoid stranded assets.

Such a system also requires strong cooperation between countries. To investigate how much carbon is embedded in imported steel would be politically sensitive, and its implementation may require mechanisms and institutions which may go against the bottom-up ethos of the Paris Agreement.

If not, every country cooperates it may well contribute to create trade disputes. This also raises the general issue of data availability. The end-use approach is dependent on a thorough understanding of emissions in countries outside of the EU, which is currently lacking. Therefore, estimations of emissions would require assumptions that may require a significant level of uncertainty, as well as being politically sensitive.

Option 3: Hybrid option

A third, 'hybrid option' could look at both end-use and emission source approaches. For non-state actors – such as multinational companies, cities or regions – an emission source approach is typically not very sensible. Increasing the role of these non-state actors in climate action and negotiations will require a stable emission end-use accounting framework. The LTCS could facilitate the development of such an integrated end-use and emission-source accounting framework to ensure the consistency of the national (emission-source) and non-state (end-use) accounting.

4.3. Climate change as the driver for decarbonisation

Issue

Climate change policies can have a wide variety of potential co-benefits, ranging from air quality improvements to combatting soil erosion. The manner in which benefits of climate policies that are not directly linked to mitigate climate change are considered in the LTCS could shape which policy and technical options are prioritised.

2050 Roadmap

The 2050 Roadmap clearly highlights the co-benefits of climate action, three of which are explicitly referred to: energy security, green growth & employment, and improvements to air quality and health.

On energy security, the 2050 Roadmap mentions that "[In 2050 …] Imports of oil and gas would decline by half compared to today, reducing the negative impacts of potential oil and gas price shocks significantly"[63].

With respect to employment: "investing early in the low carbon economy would stimulate a gradual structural change in the economy and can create in net terms new jobs both in the short- and the

[63] A Roadmap for moving to a low competitive carbon economy in 2050, page 12.

medium-term"[64], adding that over 300.000 jobs were created in the renewable energy sector in the five years preceding the publishing of the 2050 roadmap.

In terms of clean air and related public health issues: "electrification of transport, and the expansion of public transport, could strikingly improve air quality inside Europe's cities"[65], with a linked reduction in health care costs. Climate change policy and air quality measures together would lower levels of air pollution by 65 per cent by 2030 (compared to 2005).

However, the main policy driver for the 2050 Roadmap are climate change mitigation targets, which are referenced to as the 'key benefit of the shift to the low carbon economy'[66] with the co-benefits added as 'other essential benefits' for climate action.

Option 1: Climate change as a stand-alone driver

Climate change is a transversal issue, and touches upon many – if not all – sectors of the economy and facets of society. Climate change is unique in its impacts on society, and the urgency for global and economy-wide action. Its potential impacts are an existential threat to many inhabitants of Earth's biosphere, including its human population. It therefore deserves special and focused attention.

If climate change is the sole driver of the new LTCS this would signal the urgency of addressing climate change and the importance that the EU attaches to addressing it to investors and civil society. It would also imply that policy-makers continue to mainstream climate change and address the impacts of other (non-climate related) policies on climate change policies and objectives.

Adding other drivers or policy objectives risks diluting attention from decarbonisation and it could potentially allow for future trade-offs between climate change and the identified co-benefits. Climate change as a stand-alone driver does not mean, however, that these co-benefits should be ignored or forgotten, rather the LTCS should acknowledge them and be transparent about the data on them. However, without diverting the spotlights from climate change objectives as legitimate and self-standing societal objectives of the highest priority.

Option 2: Climate change and co-benefits jointly presented as drivers

It is also an option to put all benefits of climate policy on the same level, abandoning the "climate change and co-benefits" discourse for a discussion of "multiple benefits". This could help garner broader support for policy action.

To make the case for policy interventions, all costs and benefits must be considered and factored in to accurately balance mitigation costs and benefits in the cost-benefit analysis. If co-benefits are not included, mitigation instruments may appear very expensive, thus providing a disincentive to act. In

[64] A Roadmap for moving to a low competitive carbon economy in 2050, page 12.
[65] A Roadmap for moving to a low competitive carbon economy in 2050, page 13.
[66] A Roadmap for moving to a low competitive carbon economy in 2050, page 11.

agriculture, for instance, mitigation instruments seem very costly, but the analysis may be lead to different results once co-benefits, such as water and air quality and biodiversity, are accounted for.

Ignoring synergies across sectors (and the economies of scale involved), cross-sectoral interactions, and systems-wide benefits could lead to sub-optimal action. Most NDCs, for instance, completely ignore electricity grids and related investments. Yet this is an area where major abatements and cost reductions can be triggered.

Modelling should take into account all possible changes occurring due to decarbonisation. Modelling results can only show and quantify co-benefits such as green jobs if the relevant variables are explicitly included. That implies recognising co-benefits from the start of the modelling exercise. This could be challenging for non-economic variables such as air quality, biodiversity and increased quality of life due to the provision of environmental services. However, substantial work has been done, for example, by the International Energy Agency with respect to including air quality in their Sustainable Development Scenarios. In addition, the avoided costs of inaction when modelling long-term low emission strategies are often overlooked. In an analytical framework of multiple benefits, the avoided climate-related costs of inaction might have to be explicitly quantified, to be able to identify the most desirable decarbonisation pathways.

Climate change is not the main policy driver in many countries, and is just one of the five objectives of the Europe 2020 Strategy (which also includes targets for employment, research and development, education, and poverty and social exclusion). We have seen in policy reversals in several countries, indicating that abstract temperature goals might be politically less resilient. Embedding climate change policy as a driver for policy with other policies provides stability and credibility.

The Sustainable Development agenda has seventeen goals, of which climate action is just one (although many of the other goals are directly impacted by climate change or have direct relevance for climate change action). In this context, climate change can be seen as just one part of sustainable development agenda, which includes climate change objectives, but also economic development, clean air etc.

Assessing the credibility of climate action could therefore also include an assessment of how climate policy is integrated with other policies. If climate change objectives are coordinated across ministries and sectoral policies it adds stability. If climate change policy comes from just one ministry or agency, without coordination and buy-in, the policy may be less credible, stable and predictable.

Option 3: Co-benefits as a stand-alone driver

Climate change mitigation is itself considered a co-benefit in some NDCs, especially in the case of developing countries, which have development priorities.[67] In the EU, local air pollution is seen in some

[67] In the Nigerian NDC, for instance, deployment of renewable energy is focused on bringing cheap off-grid electricity to people that are currently not connected, or using small scale diesel generators. Mitigation is more a co-benefit to the main goal that is development: "the policies and measures included in the Nigeria INDC will deliver immediate development benefits and do not compromise sustainable growth, on the contrary. Ambitious mitigation action is economically efficient and socially desirable for Nigeria, even when leaving aside its climate benefits. The policies and measures alleviate poverty, increase social welfare and inclusion, as well as improving individual well-being, which includes a healthy environment".
See http://www4.unfccc.int/ndcregistry/PublishedDocuments/Nigeria%20First/Approved%20Nigeria%27s%20INDC_271115.pdf.

communities as so great a health concern, that the climate aspects of decarbonising transportation are seen as a co-benefit. Policy-makers can use this to justify policies based on local concerns, and frame climate change as the co-benefit.

A global, societal and intergenerational issue is much harder to sell than solving visible and local issues, where climate change can be communicated as being a side effect.

It is, however, very hard to conceive a LTCS where climate change is not one of the main drivers. Doing so would reverse decades of communication about the urgency of climate change and climate action at the EU level, and send a very mixed signal to EU businesses and civil society and international partners in the fight against climate change. Co-benefits as stand-alone drivers is therefore an unlikely way forward.

4.4. General Focus of the LTCS

Issue

Climate action touches on a wide array of highly policy-relevant topics. Extensively dealing with all relevant topics is not practical – so the European Commission will have to decide on a focus. The relevant coverage given to individual topics in the LTCS will to some degree shape subsequent policy prioritisation.

2050 Roadmap

The 2050 Roadmap focused strongly on showing the feasibility of reducing emissions by 80% domestically and lining out the sectoral contributions to this overall aim. Macroeconomic effects were included in the modelling, while social and regional effects were less prominent. Innovation, the role of the ETS and other policy measures as well as international interactions where mentioned – without being thoroughly analysed. Adaptation, governance, climate finance and technology transfer where not discussed.

The Paris agreement goals and implications for the EU

There is an expectation that a new EU LTCS will look into what the Paris Agreement implies for the EU, in particular which mitigation effort the EU would need to contribute to meet the global targets set out in the Paris Agreement. This issue includes the following topics and questions:

(1) Scientific (what carbon budget is left);

(2) Political (what could a compromise with other countries look like);

(3) Economic (who can mitigate at the lowest cost); and

(4) Moral (what is the fair share of the EU)

The LTCS might then indicate how exactly, or based on which principles, the overall EU contribution is broken down to Member States and sectors.

Adaptation

There is robust evidence that rising atmospheric concentrations of GHG do not only result in rising average temperatures and sea levels, but also increase climate-related risks such as regional heatwaves, flooding or storms. Even when we achieve carbon neutrality climate change will continue. Hence adaptation needs to be an integral part of climate action, especially in vulnerable regions. Accordingly, the UNFCCC process – including the Paris Agreement – put strong emphasis on adaptation policies.

Adaptation – which will likely increase in importance in the coming decades - would fit into a new LTCS. An adaptation discussion can analytically be relatively well separated from the mitigation discussion (they deal with quite different sectors, technologies, policies and governance), and therefore an adaptation strategy could be outsourced to a different document. This would, however, risk reducing the importance of adaptation policies (which are crucial especially for specific southern and low-lying Member States).

Mitigation scope beyond the EU

In principle the Paris agreement allows countries to use mitigation outcomes achieved in other jurisdictions to meet its nationally determined contribution. In addition, climate finance and technology transfer can make a substantial contribution to GHG emission reduction beyond the borders of the EU. Consequently, the European strategies on these aspects might also be included in the framework of a LTCS.

Again, most of the strategic decisions on domestic decarbonisation pathways (that were at the core of the 2050 Roadmap) can be separated from the international aspects, and would therefore not be necessarily treated in an integrated manner.

Policy

As already discussed in the context of the overall purpose of the LTCS, a strategic document can serve to plan policies. In fact, we see two levels: governance and concrete measures. In terms of governance, a discussion can be held on which actions fall under the responsibility of which level of administration (EU, Member States, or sub-national). Clearly delimiting tasks in a strategic way can increase accountability. This is, however, a highly politicised matter that might be difficult to hardwire in a strategic document.

In terms of concrete measures, the LTCS could provide indication on the general policy mix it sees most useful for achieving our ambition. Those questions can be on a relatively abstract level (what do we expect the ETS to deliver?), or quite concrete (which carbon price would be "optimal" in different sectors?). In the existing crowded policy space characterised by complex overlaps and a multitude of

policy goals a guiding strategy could help simplify policy-making. Moreover, such a discussion could help investors to understand what type of policy actions to expect and explain to citizens the rationale for policy actions. However, there is currently no EU strategy document dealing with discussing the optimal climate policy mix.

However, the role of such a policy-planning document is constrained by the lack of foreseeability of the decision-making process. A nicely thought-through policy strategy might be easily derailed if key-components fail to attract the necessary majorities. If, for example, a strong ETS is paramount for a certain decarbonisation strategy, but cannot be agreed on by the legislator, the whole strategy might be worthless.

At present EU climate mitigation efforts are split between the ETS and non-ETS sectors. The model analysis is likely to indicate a gradual migration of emissions from the non-ETS sectors to the ETS, as transport and heating is being electrified. The LTCS could reflect on the appropriate policy consequences of this or other trends identified.

Innovation and cost reduction

Technological breakthroughs and evolutions can substantially reduce the cost of decarbonisation and/or allow much more ambitious climate targets. Innovation policy can try to support such technological developments and is hence a crucial component of climate policy (also because technologies developed in Europe can enable decarbonisation around the globe). Moreover, classic decarbonisation polices that increase the deployment of low carbon technologies, also affect innovation. Hence a LTCS might contain a dedicated discussion on where there is innovation potential and how it could be developed.

Such a discussion could look at how to best design policies to incentivise cost minimisation across sectors and mitigation options. Past and current successes *and* failures to reduce climate mitigation costs could be thoroughly analysed in order to discuss and potentially identify the most appropriate policies and tools to bring down costs significantly. In light of the lessons learned from this analysis the tool box available to the EU can be critically tested to see whether they can be expected to sustain ambitious cost-cutting.

However, the EU already has a Strategic Energy Technology Plan, that deals with low-carbon technologies. This plan had, however, a relatively limited impact. It might be worth exploring whether some stronger integration with the LTCS might raise the political profile of the SET Plan.

Social and regional impacts

Climate action will have different impacts on different regions and groups of people. In coal mining regions, jobs might be lost while some population segments might benefit disproportionately from additional investment opportunities. Such effects will also determine the political and societal acceptability of climate action. Hence, the LTCS might be a good place to evaluate the expected impacts.

This can in turn provide a basis for understanding how to possibly address unwanted social impacts of climate policies.

Macroeconomic impact

Climate policies can, to some degree, impact the fiscal position of countries, aggregate demand, trade flows, overall employment etc. These impacts need to be considered when comparing different decarbonisation pathways and policies. Hence, there is a case for modelling and discussing corresponding effects.

On the other hand, putting too much emphasis on macroeconomic impacts – that tend to be relatively small (they often do not differ much between scenarios) and uncertain – could dominate discussions on pathways and policies.

4.5. General focus of the LTCS: transition

Issue

There are a number of crucial strategic questions in the transition to a low-carbon economy by mid-century and in achieving a balance between emissions and removals of GHGs in line with the Paris Agreement goals. Whether, and at which level of detail those are addressed in the LTCS will have material implications on which regulatory/legislative action can be triggered and/or justified.

2050 Roadmap

The 2050 Roadmap raised several transitional issues (e.g. carbon leakage, increasing capital investment, job creation), but did not discuss the issues of (i) system choices, (ii) optimal timing of strategic decisions, (iii) resilience of the transition or stranded assets, (v) social implications of the transition.

4.5.1. Implications of system choices

Different pathways are conceivable to decarbonise the EU economy and to achieve a balance between emissions and removals. Some of those pathways might imply tipping points towards one techno-economic system or another. For example, the massive deployment of electric charging stations and battery electric vehicles might cause the cost of these technologies to recede and strong network effects to dominate, and hence make it rather unlikely that alternative transport modes (e.g., a hydrogen-based system) can develop a significant market share. Other potential system choices are (i) public vs. individual transport; (ii) managing renewables volatility on the upstream (networks, storage, peaking plants) or the consumption side; (iii) making low carbon energy cheap or reducing energy consumption drastically; (iv) heating with green electricity or green fuels; (v) the role of biomass in

energy, production, sinks and storage of CO2. Policy choices (e.g., on early deployment projects, research funding and industrialisation through policy-driven demand and competition) might play a role in triggering such tipping points and shaping the decarbonisation pathway. Consequently, it might be worthwhile discussing such system choices and whether, when and how they should be actively made. The LTCS can take different approaches to address such system choices.

Option 1: Explicit modelling

One option would be to explicitly analyse/model known system choices and provide indication under which conditions which option might be preferable, for each system choice (e.g., support the deployment of EV charging stations when the cost of electric vehicles fall below a certain level). This would fit into a LTCS as some choices are of very strategic nature. On the other hand, the corresponding questions are quite complex and contentious (interest groups will fight quite hard for their choices). Hence, this discussion might risk dominating the discussion on other elements.

Option 2: Identification of relevant system choices/Defining of principles for dealing with them

The development of one consistent general approach to all system choices could provide stakeholders with some clarity on where the European Commission might see some need for taking decisions, and based on the defined principles (e.g., "support no regret options", "invest in resilience" or "avoid all choices") gain some understanding under which conditions decisive policies to enable a certain system might be triggered.

Option 3: Separation into several (sectoral documents)

Another option would be to create separate (sectoral) documents such as the 2050 Energy Roadmap or the 2011 Transport White Paper can be a good place to discuss such system choices. This would allow the LTCS to mainly focus on determining ambition levels (supported by a high-level techno-economic analysis), while the sectoral roadmaps can provide more detail on the techno-economic issues. However, as sectoral boundaries are vanishing (e.g., with electrification, but also various sectors vying for limited carbon storage space), sectoral analyses of system choices might turn out to be inconsistent with each other.

Option 4: Ignoring system choices

If one is of the opinion that policymakers should stay away from system choices, it would not need to be put into a strategic document. A lot of uncertainty surrounds future pathways of technologies, which can make it difficult to ascertain which system choices to make in the present. Ignoring system choices can be one way of acknowledging the uncertainty and allowing technologies to develop in the absence of policy intervention.

4.5.2. Determining the timing of decisions

An issue related to system choices is the timing of policy decisions. We will learn more over time about the costs and capabilities of different technological options and how strong/fast other countries decarbonise. Consequently, it might be important for policy-makers and stakeholders to know at which point in time certain decisions need to be taken, in order to achieve the targets in the most efficient way (under uncertainty). Policy decisions should also take into account that the reduction targets might also change over time. The EU targets will, for instance, regularly undergo review as part of the ratchet-up mechanism of the Paris Agreement.

The timing of decisions is closely linked with the trade-off between supporting existing technologies at an early stage and taking late action with yet unavailable technologies. In effect, there are pathways conceivable where substantial decarbonisation is achieved with currently available technologies, possibly at significant cost (e.g., ban on internal combustion engines); while alternatively policy-makers can bet on technological development to offer cheaper decarbonisation options in the future. By relying on existing technologies, policy-makers can support long-term investments today. This can be advantageous if technologies take time to mature and require early support. On the other hand, it can be difficult to predict future technological developments, which complicates the task of deciding which technology to support at an early point in time.

The LTCS can deal with the timing of policy decisions in various ways. Below, four alternatives are discussed.

Option 1: Explicit modelling

It would be possible to explicitly analyse/model known key policy choices and provide indications on when they need to be taken so the EU still stands a chance to meet its targets. This can entail developing various scenarios to estimate the cost and potential of attaining the EU renewed climate objectives with existing technologies. However, modelling such scenarios can be a complex task, as it is difficult to predict how existing technologies will evolve in terms of their costs and benefits. Moreover, it can be difficult to assess whether supporting a technology today is preferable to postponing the decision, since new, unforeseen technologies may emerge in the future. This uncertainty can create a need for strong assumptions in a quantitative model, which may in turn reduce its credibility.

Option 2: Identification of relevant technologies and sectors

Identifying possible developments in key technologies and sectors using a qualitative framework can simplify the task of assessing at which point decisions should be made and reduce the need for making strong assumptions. Such a framework can identify a set of no-regret policies, to be implemented with little delay, that can be considered precautionary measures to advance the transition. In parallel, policies characterized by a greater degree of uncertainty with regard to the optimal timing of their implementation can also be evaluated.

Option 3: Separation into several (sectoral documents)

In order to reduce the size of the LTCS, the timing of policy decisions can be assessed in separate documents.

Option 4: Ignoring timing issues

Ignoring the issue implies that little attention in the LTCS is paid to the issue of when certain policy decisions should be made. On the one hand, this approach can reflect the uncertainty surrounding future technological developments and the associated difficulty of deciding whether a particular policy should be implemented in the present. On the other hand, by not assessing the impact of postponing decisions, policymakers can run the risk of not achieving the targets in time (due to, for instance, slow technological developments).

4.5.3. Resilient transition

Technology developments are hard to foresee, and both positive and negative surprises are possible. For example, a key decarbonisation technology might become unavailable due to other environmental concerns (e.g., CCS or nuclear) or a technology breakthrough (e.g., in batteries and PV) might make green energy unexpectedly cheap[68]. Negative surprises might make it impossible to reach the targets with a strategy that does not properly foresee such challenges. And having no strategic option left to respond to possible negative surprises might undermine the international credibility of the EU´s LTCS. In addition, the LTCS needs to be resilient in terms of possible changes to mitigation targets over time.

Option 1: Explicit modelling

A first option would be to explicitly analyse/model transition scenarios that are resilient to individual negative shocks and changes in the reduction targets would allow to address such risks in the most economical way. It would probably result in wider portfolios of technologies and some redundancy and overinvestment. This is valuable information for policy-makers, as pure market-mechanisms targeted to efficiently hit the target, might not be efficient any more when considering risks. However, corresponding modelling increases the number of assumptions and scenarios to be considered, while the complexity of the models might not allow for easy interpretations.

Option 2: Identification of possible risk factors

Another option could be to identify possible risk factors and describe possible mitigation options qualitatively that might resolve the credibility issue without complex modelling.

[68] For instance, Lazard (2017) estimates that the unsubsidised levelized cost of energy (LCOE) of wind and solar PV both decreased by more than 60 per cent between 2009 and 2017.
https://www.lazard.com/media/450337/lazard-levelized-cost-of-energy-version-110.pdf.

Option 3: Leave quantitative risk assessments to a different document

A third option would leave quantitative risk assessments to a different document in order to keep the LTCS slim. However, if the risk assessment is a follow-up, it might not deliver a co-optimisation of cost- and risk-minimisation.

4.5.4. Stranded assets in the transition

An efficient decarbonisation pathway might imply that certain assets (e.g., coal mines or coal fired power plants) might have to be scrapped before they reach the end of their initially planned economic lifetime. Those assets might be very unevenly geographically distributed across Member States. A strategy of how to deal with these assets might be required to ensure political acceptability of the LTCS. Furthermore, the LTCS might provide guidance on which types of high-carbon investments might be inconsistent with certain levels of ambition (and hence in the investors view become stranded).

Option 1: Explicit modelling

A first option could be to explicitly analyse/model which stranded assets might appear and propose scenarios for how to share the burden of retiring them between sectors and regions can be distributed. This would give stakeholders visibility on what might happen and policymaker's clarity on what actions might be required in order to deliver a just transition. However, clearly identifying "losers" will also make it more difficult to agree on an analysis. Hence, this discussion might risk dominating the discussion on other elements.

Option 2: Identification of possible stranded assets

Another option could be to identify possible stranded assets and describe possible strategies to address them qualitatively, without pointing out the individual regions and sectors might depoliticise the issue.

Option 3: Split into different documents

A third option would leave the discussion on stranded assets to another document.

Option 4: Ignore stranded assets

A fourth option could be to ignore the issue of stranded assets, e.g., by arguing that people that invested into such assets in the past decade were aware of this possible risk.

4.5.5. Competitive transition

Competitiveness concerns related to decarbonisation are partly addressed in the 2050 Roadmap. The issue remains on the agenda, as carbon-intensive companies fear that strong climate policies in the EU might put them at a disadvantage compared to foreign companies. On the other hand, it has also been argued that climate policy might enable early movers to develop a competitive edge.

Option 1: Explicit modelling of sectoral competitiveness impacts

This would give stakeholders visibility on the effect of different decarbonisation pathways on individual sectors and provide policy-makers with an analysis of how to address sectors that are adversely affected by the transition (and possibly how to support sectors to benefit from the transition). However, clearly identifying adversely affected sectors (e.g., that a certain industry will lose several thousand jobs) might make it more difficult politically to accept the LTCS.

Option 2: Identifying possible impacts in key sectors

A second option could entail to identify possible impacts in key sectors using a qualitative framework can simplify the analysis compared to a quantitative model and reduce the need for strong assumptions. The qualitative framework can concentrate on those sectors most at risk of being adversely affected by climate policies. However, assessing this risk can be challenging, which can complicate the selection of sectors. One way to side-step this issue is to choose sectors on the basis of their importance to, for instance, the economy (e.g. share of employment, output etc.). On the other hand, there is thereby a risk that sectors that would face a competitive disadvantage, but that do not carry a large weight in terms of overall economic importance, are neglected from the analysis.

Option 3: Assigning the discussion around competitiveness to separate documents

Another option could be to discuss the implication of climate policies on sectoral competitiveness in separate documents. This can reduce the size of the LTCS and potentially leave more room for an in-depth analysis of the competitiveness effects in the dedicated documents.

Option 4: Ignoring the issue of international competitiveness concerns,

A last option could be to ignore the issue of international competitiveness concerns since they are less relevant than under the Kyoto Protocol as a result of the EU's most important competitors also having signed the Paris Agreement.

4.6. Sectoral Focus of the LTCS

Issue

All sectors will have to contribute to decarbonisation in the coming decades. But sectoral differences will require very different pathways and imply different cost and policies. Accordingly, the LTCS might focus on certain sectors more than on others. It might, for example, look more on those that are either (i) having the highest abatement potential; or (ii) having the lowest/highest abatement cost.

Actually, some mitigation options have received increasing attention in the past years- and this might also have to be reflected in a new LTCS. For example, transport, land use, CCS and negative emissions are mentioned more often in the Fifth IPCC Assessment Report 2013 than they were in the Fourth IPCC Assessment Report 2007.

Table 4: Change in relative frequency of specific terms in the Mitigation Working Group Report of the 4th and 5th Assessment Report of the IPCC

	Fourth report 2007	Fifth report 2013	Change in relative frequency
transport	15%	23%	53%
power	12%	14%	17%
electricity	12%	13%	8%
land use	5%	11%	120%
industry	12%	11%	-8%
heat	11%	10%	-9%
CCS	4%	9%	125%
agriculture	7%	7%	0%
vehicle	8%	7%	-13%
nuclear	4,6%	5,1%	11%
heating	4,5%	3,7%	-18%
negative emission	0,1%	1,2%	1100%

Note: Comparison of the usage of the exact terms relative to the total usage of terms “mitigation”, “sector” and “reduction”.

However, additional action that drives transformation might be needed in all sectors. By focusing too much on specific sectors, there is a risk of misinterpretation that other sectors do not need much attention and action.

2050 Roadmap

The 2050 Roadmap focused strongly on the energy sector, which promised the largest abatement possibilities, while agriculture/LULUCF and negative emissions were much less discussed.

Electricity sector

The electricity sector is one of the biggest emitters of GHGs and one of the sector where technologies are available to drastically reduce emissions (renewables, coal to gas switch, nuclear)[69]. Hence, "electrification" of transport, heating and industry is one major conceivable pathway to decarbonisation. Given the remaining strong abatement potential and the relatively strong policy levers at the EU level (internal electricity market; environmental state aid; EU ETS), the LTCS might want to also put special emphasis on this crucial emitter. On the other hand, the techno-economic solutions as well as the necessary policies are clearer than in other sectors, thus meriting possibly less attention in the LTCS.

Transportation

In contrast to other sectors, transport sector emissions actually continue to increase. At the same time, the corresponding industry contributes significantly to the EU's economic success (car exports represent about a fifth of German exports). While electric vehicles made significant progress since 2011, it is still relatively uncertain what a decarbonised transport system will look like. Hence the LTCS might be a good opportunity to recalibrate targets and policy approaches. There are a number of strategic policy questions such as the speed of the phase-out of internal combustion engines or the future role of public transport that will need to be broadly discussed. On the other hand, the open questions are quite complex and far reaching, and might be more comprehensively dealt with in a separate transport strategy document[70].

Residential heating

Heating is a major source of GHGs that can be relatively easily abated. For residential heating there are at least three (complementary) decarbonisation pathways that are already technical feasible: (i) electrification; (ii) energy efficiency (up to the zero-energy or passive houses), or (iii) usage of clean fuels (such as green hydrogen). Given the slow asset-turnover a strategic vision and targets will be required relatively soon, in order to avoid stranded assets (e.g., new but badly isolated buildings). Hence the LTCS might spend some room on exploring these opportunities. However, like for electricity, heating decarbonisation is more a question of speed, cost and efficient policy approaches than of technical feasibility. Given that the heating and cooling strategy is from 2016, the LTCS might not need to put particular emphasis on this sector.

[69] Seasonal storage appears to be the main technical challenge at this stage.

[70] The 2011 Transport White Paper has been reviewed in 2016 and it was found that "there is still little progress achieved towards the goals set 2011". https://ec.europa.eu/transport/sites/transport/files/themes/strategies/doc/2011_white_paper/swd%282016%29226.pdf

Industry

The industrial sectors consist of different types of emitting activities, some of which are very difficult to decarbonise. To achieve ambitious decarbonisation targets, new solutions for the industrial sectors need to be found and brought to commercial viability. Policy tools for industry might need to be quite different from those in the other sectors, also because competitiveness concerns are strongly voiced by various industrial sectors. Currently there are no clear decarbonisation pathways for some parts of the industrial sectors and the EU LTCS might help provide some guidance on what scenarios are possible and which policy approaches can be expected. The existing industrial low-carbon roadmaps could be compared and consolidated in order to identify gaps and technology requirements. On the other hand, if industry stakeholders do not like the results of the detailed considerations, this discussion might risk dominating the discussion on other elements (this concern is, however, also relevant for other sectors with powerful stakeholder groups).

LULUCF/Agriculture

As the EU decarbonises energy and transport, the role of land use, land use change and forestry (LULUCF) as well as emissions related to agriculture will move to the forefront. Emissions and removals in these sectors are difficult to measure, often difficult to abate and might require very different policy approaches from the above-mentioned sectors[71]. The 2050 Roadmap did not touch upon agriculture and LULUCF in detail. A more focused approach will be required in the LTCS. It could look further into the mitigation and sequestration potential of agriculture, including the need for R&D in mitigation options and more cost-effective policies. The agriculture and LULUCF sectors have a key role to play in maintaining and enhancing sinks and reservoirs/storage of carbon and are therefore likely to play an important role in achieving a balance between emissions and removals.

The LTCS could look into the role of biomass. Forests and other biomass store a major part of emitted CO_2 and are an important buffer against global climate change. Afforestation could provide important contributions needed to balance remaining GHG-emissions. This can compete with using biomass for energy generation. The LTCS could analyse the climate implications of different biomass uses.

One of the big issues is accounting. The new LULUCF regulation provides a useful framework that can be used in the LTCS.

Carbon capture and Negative emissions

A somewhat cross-cutting area that can play a role in different of the aforementioned sectors is carbon capture and negative emissions. Industry, electricity sector and heating emissions can be partially decarbonised by carbon capture and storage (CCS) technology. Due to the limited carbon storage space, these sectors might be competing for corresponding assets. The LTCS might provide some insight into which sectors might have hope to abate some of their difficult to avoid emissions by putting them underground.

[71] One example is non-CO2 emissions in agriculture.

Like CCS, negative emission technologies (NET) (except for reforestation and afforestation) are not yet commercially feasible – and it is unclear at which mitigation cost they can operate. Discussed technologies are biofuel with CCS (BECCS), biochar, afforestation or direct air capture etc. NETs might not only be needed to compensate overshooting from too slowly declining emissions, but are also likely necessary for achieving the 2°C and 1.5°C targets[72]. Consequently, the LTCS might deliberate on how they fit in a strategy. On the other hand, giving them too much room, might overstate their likely role.

For example, a recent report[73] from the European Academies Science Advisory Council (EASAC) argues that NET *"…have limited realistic potential to halt increases in the concentration of greenhouse gases in the atmosphere at the scale envisioned in the Intergovernmental Panel on Climate Change (IPCC) scenarios. This new report finds that none of the NETs has the potential to deliver carbon removals at the gigaton (Gt) scale and at the rate of deployment envisaged by the IPCC,…."*.

[72] UNEP gap report 2017 chapter 7.
[73] https://easac.eu/publications/details/easac-net/.

Table 5: Selected international, national and sectoral strategies and scenarios

Author	Scope	Sector	Reduction Target
Austrian Government (2018)	Austria	All	36% by 2030 (compared to 2005)
WWF, Greenpeace and Global2000 (2017)	Austria	Energy	67% by 2030 98% by 2050
Belgium Government (2013)	Belgium	All	80/95%
German Government (2016)	Germany	All	80/95%
BCG/Stahl (2013)	Germany	Steel	-
BDI (2018)	Germany	All	80/95%
Greenpeace (2017)	Germany	Agriculture	50% (compared to 2010)
Swedish Government (2017)	Sweden	All	100% (by 2045)
The Swedish Shipowners' Association (2015)	Sweden	Maritime	100%
ECF (2010)	EU	All	80%
Öko (2018)	EU	All	100%
T&E (017)	EU	Buses and Freight	100%
Cembureau (2013)	EU	Cement	80%
Eurofer (2013)	EU	Steel	-
EAA (2012)	EU	Metals (Aluminium)	79%
Cefic (2013)	EU	Chemical	-
CEPI (2017)	EU	Paper	80%
Cerame-Unie (2012)	EU	Ceramics	65/78%
IEA (2017)	World	Energy	100% (by 2100)
Shell (2018)	World	All	100% (by 2100)
Shell (2018)	World	Energy	100% (by 2070)

Note: Unless specified otherwise, the targets in the table refer to 2050

5. Technical decisions

5.1. Is technology neutrality an appropriate assumption for the LTCS?

Issue

The LTCS could take two approaches to what drives decarbonisation. Decarbonisation could rest upon policy decisions, supporting specific technologies or sectors, or upon a "hands-off" market approach to determine the technology pathway.

While market approaches should in theory provide the most economical path to decarbonisation, there is also the reality of other constraints, including sectors where markets may not provide the appropriate response. As such, one question is if technology neutrality is an appropriate assumption.

This question can also be reformulated to include other dimensions, such as whether technology neutrality is an absolute, or whether there are various degrees of neutrality, as well as under what circumstances it is appropriate. All these questions can lead to different options in considering or not technology neutrality for the LTCS.

2050 Roadmap

The 2050 Roadmap rests upon an implicit, although probably generally accepted assumption of technology neutrality. This neutrality is most transparent in the 2050 Roadmap's reliance on the ETS, which is intended to drive decarbonisation in the most cost-effective way: "the EU ETS will be critical in driving a wide range of low carbon technologies into the market"[74].

Although specific technologies are mentioned, especially in the accompanying impact assessment, the 2050 Roadmap does not judge which technology pathways would be preferable. Nor does the 2050 Roadmap provide any clear indication for policies that would make some technologies viable.

Yet the 2050 Roadmap does clarify that "other tools, such as energy taxation and technological support may also be appropriate to ensure that the power sector plays its full part"[75].

Options

The options below make the case for situations in which markets, and technology neutrality may not be the best approach. It must be emphasized that throughout this paper, the guiding principle is that markets are the preferred tool, unless there are specific reasons why they need to be supplemented with policy interventions. Technology neutrality can be re-phrased as having only a total GHG-trajectory

[74] European Commission, 2011, "A Roadmap for moving to a competitive low carbon economy in 2050", p. 6.
[75] European Commission, 2011, "A Roadmap for moving to a competitive low carbon economy in 2050", p. 7.

and a carbon price trajectory, with sectoral trajectories presented only for informative analysis and to demonstrate feasibility – but not as part of the strategy.

Option 1: Technology neutrality as an appropriate assumption

While technology neutrality is in theory the most efficient way to decarbonise, there is also the reality of other EU goals and priorities. If the LTCS moves away from technology neutrality, these goals will need to be ranked, which could be politically sensitive.

At the same time, the rapid pace of change of technology could make technology-specific plans quickly obsolete. The 2050 Roadmap, for instance, forecast a net generation capacity from solar of 53 GW in 2020. Only five years later, in 2016, the reference scenario had increased this forecast to 136 GW (see Table 2), showing how rapidly a technology and its state of deployment can change.

The complex governance of making technological and sectoral choices is a strong reason for the LTCS to remain technologically neutral. The decision of which technologies to pursue, and in particular of who makes this decision, would become crucial. These questions would inevitably become very politicised, and make the governance very complex to navigate.

Finally, Member States have the right to decide on their energy mix, which is not for EU to prescribe. The Treaty on the Functioning of the European Union (TFEU) is clear in that respect: European Union measures on energy "shall not affect a Member State's right to determine the conditions for exploiting its energy resources, its choice between different energy sources and the general structure of its energy supply"[76].

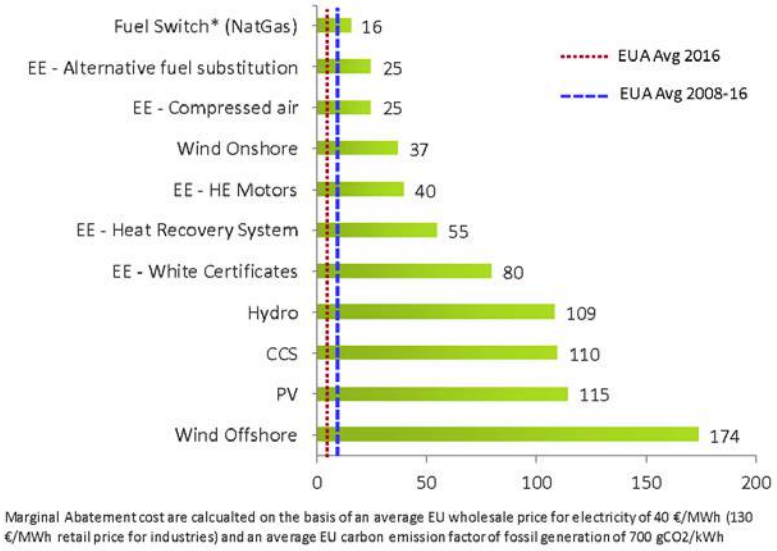
The LTCS could still provide policy-makers different pathways, putting emphasis on different technologies that would allow to reach the long-term goal of GHG neutrality, without however taking a prescriptive stance on the technologies themselves.

Option 2: Technology neutrality is not an appropriate assumption

If markets can in theory drive efficient decarbonisation, the EU ETS has struggled to fulfil that role. Figure 3 illustrates the degree to which the EU ETS has provided incentives for the deployment of cleaner energy sources, by comparing the cost of EUAs to the marginal abatement cost of different technologies.

[76] Treaty on the Functioning of the European Union, Art 194.

Figure 3: Estimates for Marginal Abatement Cost for different technologies (€/ton)



Source: 2017 State of EU ETS report [77].

This graph presents a cost of abating one tCO_2 ranging from 16 euros for switching electricity generation from coal to natural gas, to 174 euros for offshore wind power plants. These numbers are vastly over the EUA 2016 average price, or indeed the EUA average price between 2008 and 2016. Although important cost reductions have recently occurred and will likely continue to occur in renewable technologies like onshore and offshore wind. Figure 3 suggests that the EU ETS, in its current form, in spite of current upward movements on the price of EUAs, is not able to drive on its own the deployment of clean technologies.

Market failures are in fact widespread. One of these market failures for optimal decarbonisation is in innovation support. Markets may not invest enough in innovation, leaving the public sector to carry a significant part of the contribution. However, public funding being limited, choices need to be made on where to invest the available resources, thus taking a necessary step away from technology neutrality.

The recent experience in wind and photovoltaic (PV) technology has also shown that, when it comes to cost reduction, the industrialisation and economies of scale that public subsidies can help trigger can be just as important as innovation support.

Infrastructure, moreover, is not technology neutral, and does not exist in a vacuum: it can involve high fixed costs, and requires significant time to be built. The need to move fast to meet the goal of the Paris Agreement therefore requires some choices to be made for infrastructure.

The 2050 Roadmap recognised, for instance, that "investment in smart grids is a key enabler for a low carbon electricity system, notably facilitating demand-side efficiency, larger shares of renewables and distributed generation and enabling electrification of transport"[78].

[77] Marcu et al. (2017), "2017 State of the EU ETS Report".
[78] European Commission, 2011, "A Roadmap for moving to a competitive low carbon economy in 2050", p. 7.

Public funding effort in certain technologies is therefore widespread, as they may otherwise never be deployed. In renewables, for instance, the European Investment Bank (EIB) signed in 2017 a 180-million-euro agreement to support the largest European onshore wind farm in Northern Sweden[79]. Another 196 million euros loan to support to a solar PV project in Spain is currently under appraisal[80]. Fossil fuels also receive very important public funding. The EIB has recently approved a loan of 1.5 billion euros for the Trans-Adriatic natural gas Pipeline[81].

Pure technology neutrality, at any rate, is unlikely to exist. All technologies do not start on a level playing field. Although incumbents do also invest in innovative technologies, a bias may exist, making these incumbents offering strong support to existing technologies.

Option 3: Hybrid options

Option 3a: Technology neutrality on certain levels

Different levels of technology neutrality exist, with various levels of geographic and jurisdictional granularity. Some priorities could be set at a higher EU level, but be accompanied by technology neutrality at the lower level (Member State or sectoral level).

As it has been argued above, there may be a need for a public push in a certain direction, together with the building of the necessary infrastructure. CCS was for instance pushed at the EU level, being an important element of the 2050 Roadmap, the SET plans, and the innovation fund.

At a higher, European level of governance, there would therefore be no neutrality. The LTCS would however be built on the premise of technology neutrality at lower levels of governance (Member State and sectoral level). A European push for electrification could, for instance, leave for the market and the private sector the decision on how to implement this electrification.

Alternatively, technology neutrality could be respected at the higher, European governance level, while technology choices would be taken at lower levels of governance (i.e., Member States). Art 194 of the TFEU indeed protects the right of Member States to determine their own energy mix. If the EU does promote certain directions and finances infrastructure, it should overall remain technology neutral. Technology choices are then made at the Member State level. Renewable energy targets, for instance, can set an EU-wide direction, but technology choices (wind, solar PV, etc.) are left for the Member States.

Nuclear energy is perhaps the clearest example of a technology receiving strong support from some Member States – although other states like Germany take just as clear a stance against it. The United Kingdom's commitment to guarantee the operating company of Hinkley Point a price of £92.50 per MWh of electricity generated for the first 35 years implicitly guarantees long-term support for nuclear.

[79] http://www.eib.org/infocentre/press/releases/all/2017/2017-304-investment-plan-for-europe-eib-supports-largest-european-onshore-windfarm-in-northern-sweden.htm.
[80] http://www.eib.org/projects/pipelines/pipeline/20170180.
[81] http://www.eib.org/infocentre/press/releases/all/2018/2018-030-eib-backs-eur-6-5-billion-energy-sme-transport-and-urban-investment.htm.

Option 3b: Technology neutrality, but with a positive list or negative list of technologies

The LTCS could be based on technology neutrality, but nevertheless adopt positive or negative lists of technologies. A positive list could be envisaged, where the EU decides on which technology it wants to push. It could for instance support electric vehicles, whilst taking no position on the way electricity is produced. Positive lists could help support technologies that are identified as most likely to be important for the transition.

By contrast, the EU could produce a negative list of technologies that it does not want to see play a role, like CCS or clean coal. Negative lists could ban undesirable technologies, or currently attractive technologies that would not allow the EU to reach its long-term objectives.

The LTCS would then still rest upon a premise of technology neutrality, but would nevertheless include (appropriately justified) lists providing some technology prioritisation. This different form of hybrid option could also be compatible with Option 3a: neutrality at the EU level could be combined with lists at Member States level, and lists at the EU level could be combined with neutrality at the Member States level.

However, the complex governance of non-neutrality (see Option 1) would again be an obstacle to the drafting of these lists. Member States are unlikely to ever agree on clear positive or negative lists of technologies. The furthest such a strategy could go would likely be to offer no-regret options.

Option 3c: different levels of neutrality for different levels of technology maturity

Finally, a differentiated approach for different technologies on different levels of maturity could be adopted. Technology neutrality could be deemed suitable for mature technologies, while recognising that new technologies need to be supported to get off the ground.

The case of CCS is a prime example of a technology that is not mature, and whose large-scale deployment would require very important public support. SaskPower's Boundary Dam Integrated Carbon Capture and Storage facility, in Canada, cost a total of USD 1.5 billion, and had to receive USD 240 million support from the Federal Government. Bringing down these considerable costs through scale would require a significant amount of public funding, which would need to be made available early enough[82].

By contrast, renewable energy technologies have seen production costs drop significantly, to the point that some auctions for renewable projects are now won without any subsidies. Some renewables may therefore be reaching the level of maturity where public support is no longer needed, and where public authorities may wish to adopt a more neutral standpoint.

The likelihood of rapid cost reductions for the less mature technologies could be taken into account in the public support allocation decision. Technologies that can be mass produced in competitive markets, like wind turbines or batteries, may have a higher likelihood of rapid cost reductions than technologies which do not have such characteristics, like nuclear technologies. Historical learning curves for the technologies analysed, as well as learning curves that for similar technologies, could be used as guidance for public support.

[82] https://sequestration.mit.edu/tools/projects/boundary_dam.html.

5.2. Target function & Constraints used in Modelling

Modelling should ultimately help to (pre-)select or justify policy-options. But modelling results are not a neutral analysis that allow policy-makers to weight different factors to determine their preferred choice. Typically, modelling exercises imply inherent and implicit value judgements. This can be noticed in the choice of the target functions and constraints that are used in the modelling exercise. In optimisation models the target function describes which variable should be minimised (e.g., total cost) or maximised (e.g., welfare)[83], while the constraints are set limits to certain variables (e.g., the amount of nuclear power generation in Germany in a certain year). These choices can be major drivers of the results, and should therefore be selected carefully.

While the ambition level is technically a constraint – e.g., total GHG emissions shall not be larger than a certain value – they shall not be discussed here, but in section 5.7.

2050 Roadmap

Modelling did strive to identify lowest-cost pathways and was unconstrained by fairness or resilience considerations in the 2050 Roadmap. In spite of large variations in the models' assumptions regarding fossil fuel prices and technological innovation rates, all scenarios, interestingly, generated relatively similar results in terms of the magnitude and speed of the required emission reductions in the individual sectors over time.

Option 1: cost minimisation or welfare maximisation

Optimisation models feature explicit target functions that determine whether a model prefers one solution over another. But even in pure simulations (without optimisation) the results need to be aggregated to make them comparable among scenarios.

One target can be cost minimisation. This implies that a feasible solution with lower costs is always preferred to another solution with higher costs. The corresponding results might be quite different from a model that is set up to maximize welfare (e.g., including side-benefits/costs)[84]. Welfare maximization, even though potentially more in line with societal objectives, requires, however, an explicit weighting (or monetisation) of the side-benefits/costs, which could be politically difficult as it implies making up-front moral judgements.[85]

However, focusing on least-cost approaches might create policy recommendations that can become outdated in a few years' time, as costs are difficult to project. Furthermore, least-cost approaches can create discrepancies between short- and long-term trajectories (e.g., low-cost abatement potentials today in the electricity sector and high-cost abatement potentials in the agriculture sector risks drawing attention from urgency of adopting transformational measures in all sectors).

[83] The functions are often more complex as they, for example, might need to include a discount rate.
[84] The choice is not necessarily binary, as cost-minimising models can include side-benefits/costs in their cost function.
[85] For instance, measuring energy costs is easier than accounting for positive aspects of good air quality which might require monetizing the value of longer human life.

To identify the most desirable pathway, cost minimisation should not try to minimise costs for individual actors (as in the 2050 Roadmap), but minimise societal costs. This implies (1) using factor prices excluding taxes and subsidies[86], (2) using a social discount rate instead of the much higher private discount rates[87] and (3) include externalities like air pollution.

Option 2: ensure resilience

It is possible that emission reduction targets need to be adjusted over time[88] and there is ample uncertainty on key drivers of future emissions, many of which cannot be (fully) controlled by government action (e.g., current lack of cheap energy storage potential). However, governments can in principle hedge against corresponding risk (e.g., by encouraging overinvestments in all decarbonisation options and in the removal of CO2). And if desired, models can be constructed to ensure that decarbonisation pathways are resilient to specified negative shocks.

The resulting decarbonisation pathways might look quite differently (e.g., much broader technology portfolio and some "overinvestment") and help policy-makers to avoid getting trapped in cheaper pathways that turn out to not reach their mitigation targets. On the other hand, resilient models feature even more assumptions that need to be determined and they tend to show higher decarbonisation costs – which might be politically delicate.

Option 3: ensure "fairness"

Climate policy can have substantial distributive effects, within and between generations, and within and between countries. In any case, rising inequality is seen as undesirable. In modelling, the trade-off between the efficiency and fairness of climate polices can be addressed by putting restrictions on the distributive effects allowed by the model (e.g., by forcing the model to ensure that cost of decarbonisation is equally spread between Member States). While this might result in sub-optimal, but politically more easily feasible pathways, explicitly determining fairness criteria is a political challenge.

An alternative is to abstain from incorporating the fairness aspect in the model. Instead, disproportionate burdens for Member States from the implementation of an EU-wide least cost mitigation strategy could be solved by financial transfers. This would be a similar approach to the one used by the EU Emissions Trading System.

[86] Otherwise the optimisation will find that it is less useful to reduce energy consumption in countries with lower energy taxes.
[87] Otherwise the optimisation will find that it is less useful to invest in energy efficiency at the homes owned by poor households that feature high discount rates than in buildings owned by the state (that feature lower discount rates).
[88] For example, when it becomes apparent that certain temperature targets cannot be achieved with the planned decarbonisation pathway.

5.3. Should the LTCS provide an interpretation of the modelling results?

Issue

Once the modelling exercise is completed and identifies different decarbonisation pathways, narratives can help tie these results together in coherent stories that can help policy-makers better communicate the implications. However, if they can be helpful to justify policies, these stories can also be viewed as ideological by those who prefer to only be provided the raw data, which would then allow them their own interpretation.

2050 Roadmap

The 2050 Roadmap made use of several narratives. Energy security featured prominently in the analysis: if the EU succeeds in cutting by 2050 primary energy consumption by 30 per cent with respect to 2005 levels, "imports of oil and gas would decline by half compared to today, reducing the negative impacts of potential oil and gas price shocks significantly" (p. 12).

Green growth also featured as an important narrative: "Investing early in the low carbon economy would stimulate a gradual structural change in the economy and can create in net terms new jobs both in the short- and the medium-term" (p. 12).

Finally, air quality and health co-benefits were also highlighted: "electrification of transport, and the expansion of public transport, could strikingly improve air quality inside Europe's cities […] public health would be improved, with a reduction in health care costs" (p. 13).

Option 1: Do not include any narratives

The LTCS could hold back from developing and using any narratives for communication purposes. Climate change is sufficiently serious to justify action by itself, and there is as such no need to 'wrap' climate policy in other narratives. Given the complexity of the issue, no narratives should be imposed on the LTCS in a top-down manner. If any narratives should emerge, they should only emerge in a bottom-up fashion, from the facts and the modelling results.

Framing the LTCS with narratives may indeed have unwanted consequences. Narratives may dilute attention from decarbonisation and can create future trade-offs between climate change and other co-benefits.

A LTCS that includes narratives will also be facing the classical trilemma between energy security, energy equity and environmental sustainability. In this trilemma, it may be hard to take a position that is not perceived as ideological.

Option 2: Include narratives

Why including a narrative?

Narratives can be an effective communication tool for the LTCS, both to communicate reforms to citizens and increase public buy-in, as well as to push policy-makers to take ambitious action. In many countries, climate change is indeed not a sufficient policy driver, and framing the LTCS in different non-climate change narratives can contribute to pushing for mitigation policies.

Which narratives to consider?

If the LTCS makes use of narratives, it is unlikely that a single narrative can cover everything, given the complexity of the climate challenge. Several narratives could therefore be considered:

i. The *risk that inaction imposes on society* could be a powerful narrative. If effective action is not urgently taken to stop climate change, the damage to human and natural systems will be severe and irreversible.
ii. The need to realise the goal of the *Paris Agreement* could be a running narrative, as the Paris Agreement is a new, global framework with major significance for the EU's long-term policy, and which has captured the imagination of the public.
iii. *Green growth* is another potentially important narrative, which already featured prominently in the 2050 Roadmap. Considerations of competitiveness can provide important incentives to invest in the transition, as other countries and regions could eclipse Europe as an innovation hub and source of new green technology.
iv. *Energy security* considerations also featured in the 2050 Roadmap, and may be again present in the LTCS. The discussion on energy security, however, is shifting in focus. With the continuing deployment of renewable energies, the focus will increasingly shift from diversification of supply, towards security of the grid.
v. *Energy transition is cheaper* than maintaining business as usual. The LTCS could explore the narrative, that the benefits of the transition outweigh its cost.
vi. The LTCS could also highlight the *risks associated with carbon-intensive energy* sources and transportation. These risks include stranded assets, leaks from pipelines and oil spills (e.g. BP Gulf of Mexico leak), as well as political instability in the Middle East and other major oil producing countries.
vii. The *need for the European Union to be a global leader* could be another relevant narrative. Climate change is an arena where the EU wants to be a leader, and where it must lead by example, by being proactive and ambitious enough to convince other countries and regions to follow. The costs of climate mitigation are also a significant barrier to meeting the Paris Agreement goal. The EU can play a leading role by developing and maturing the technologies and policies that will lead to a more cost-effective green transition.

The LTCS could use as a narrative the *existing co-benefits of climate policy*, by highlighting the positive impacts on air quality, health, etc. Section 4.3 examines in greater detail the question of co-benefits, which could be seen as important enough to be framed as 'multiple benefits', on par with climate objectives.

5.4 Should political feasibility be considered in the LTCS?

Issue

This section examines the extent to which political reality and constraints should be factored in the analysis for the LTCS. The LTCS could aim to identify the purely least-cost/optimal decarbonisation pathways (a cost, or First Best, analysis). Alternatively, it could provide an analysis that is as embedded as possible in political reality (a policy, or Second Best, analysis).

Section 4.1 poses in greater detail the question of the purpose of the modelling exercise - whether the role of modelling is indeed to find lowest cost pathways, or whether it serves other purposes. This section instead focuses on whether the political constraints themselves should feature in the analysis.

2050 Roadmap

The roadmap issued in 2011 primarily offers a cost analysis, aiming to present cost-effective decarbonisation pathways[89]. It does, however, sometimes include political constraints, such as the public acceptance of technologies.

The 2050 Roadmap for instance makes use of a "delayed CCS scenario": "issues with public acceptance of transporting and storage of substantial amounts of CO2 would impede CCS deployment [...], delaying its effective deployment by 10 to 15 years. As a result of non-acceptance issues regarding storage, manufacturers anticipate smaller market for CCS. This causes lower technology learning due to slower development of mass production of the capture technologies, which in turn contributes to such delays."[90] The 2050 Roadmap was therefore somewhat inconsistent in its approach, by giving space to political constraints for some issues, but not for others.

Option 1: Cost analysis (First Best analysis)

A least cost analysis would present the optimal decarbonisation pathways. Indeed, in order for cost-efficiency concerns to drive policy, these cost-efficient pathways must first be identified. That, for many, is the main role of the LTCS.

A least cost analysis allows the comparison of different scenarios, based on different technologies, without "contamination" by political considerations. It can then provide policy-makers with a guide for investment in technologies: those technologies that are identified as pillars of the optimal decarbonisation pathways should receive most support. These optimal pathways could similarly guide private investment towards these crucial technologies. The costs of non-action (i.e. impacts of climate change) would also have to be part of the equation in order to give a complete picture of the costs involved.

[89] E.g. "The Commission's detailed analysis of cost-effective ways of reducing GHG emissions by 2050 has produced a number of important findings" (2050 Roadmap, European Commission, 2011, p.14).
[90] Impact Assessment, European Commission, 2011, p. 115.

Finally, focusing on a least-cost analysis to identify theoretical cost-efficient decarbonisation pathways can help show the feasibility of decarbonisation, which was one of the main achievements of the 2050 Roadmap. Including the political constraints (which can be subject to change) may weaken this statement of feasibility.

Option 2: Policy analysis (Second Best analysis)

It may be necessary (and more realistic) to include policy constraints in the analysis, as one might otherwise end up with politically unrealistic scenarios. German energy scenarios, for instance, would lose value were the political decision to move away from nuclear not factored in.

The modelling exercise should not only find the lowest cost decarbonisation pathways, but also see if these are *feasible*. This requires examining political constraints, which are key to any feasibility analysis, as well as technological constraints.

The modelling results themselves can be very sensitive to these political decisions and constraints. A political decision to shut down coal plants would have major effects on carbon prices, and so would be decisive for the rest of the analysis in the LTCS. These decisions should therefore feature in the LTCS.

While an LTCS is not really a fully "investable document", whatever value will be attributed to it by investors will be significantly diminished, as they cannot rely on decarbonisation pathways identified by a purely least-cost analysis, with no (political) constraints factored in. Including policy constraints in the analysis may increase the realism of the LTCS' conclusions, and therefore potentially make it a better guide for investment.

Taking into account policy constraints can finally help introduce a potentially welcome more granular analysis – different Member States are at different stages of decarbonisation, and have different priorities, which should also be reflected in the LTCS.

Such a Second-Best analysis, however, does have its drawbacks. It may open the door to possible political pressures on the analysis. If the LTCS does take account of different national and sectoral political realities, different stakeholders may try to influence the elaboration process of the LTCS. If policy constraints are to be included, it must be decided which ones will feature in the analysis – a decision in which important room is left for discretion.

Option 3: Both a cost and a policy analysis

Cost and Policy analyses are not mutually exclusive. A least-cost analysis could first be presented, identifying optimal decarbonisation pathways. Then, an analysis featuring political constraints could show how policy can hinder or further the achievement of these pathways. This sequencing also allows to identify the costs associated with different policy constraints.

5.5 LTCS under different Paris Agreement outcomes

Issue

The signing in 2015 of the Paris Agreement is one of the most important reasons for reviewing the 2050 Roadmap. Yet the Paris Agreement can be seen as a promise, it is mainly a framework for building trust and gradually increasing the level of ambition to collectively deliver the goal of the Agreement.

The LTCS will indeed not operate in a vacuum, and its implementation will be done in the context of the Paris Agreement, and in interaction with international developments. Climate policy responds to political change, as demonstrated by the US withdrawal from the Paris Agreement.

While the expectation is that action will be taken by all Parties to the Paris Agreement, what needs to be seen is to what degree they all move on the same slope, or if there may be divergence on the level of ambition, with any possible gap emerging in time between different Parties. In the latter case, it is a natural issue for debate on whether the LTCS should in some way provide insight on what should be the EU reaction in such circumstances, if any.

The EU's policy may or may not be affected by what may be short-term gaps that emerge, possibly due to political variations. The determination may well be made that moving at the pace that it sets itself would provide the EU a first mover advantage, in such a way that what others may do should not have any bearing on EU behaviour.

However, the uncertainty needs to be addressed and recognized.

The new EU LTCS could therefore be built on two different assumptions:

i. The LTCS could assume that the Paris Agreement will function as expected and desired, with the ratchet-up mechanism delivering and all Parties gradually increasing ambition to the level needed to deliver the goal of the Agreement.
ii. The LTCS could consider the uncertainty of the level of delivery of the Paris Agreement, with Parties potentially taking diverging pathways, some of them not increasing ambition to the level required, and not keeping up with the other Parties.

2050 Roadmap

The 2050 Roadmap did make use of different pathways or scenarios of global action. The Impact Assessment (p.28-29) thus compares a global baseline, where "globally no additional climate action is undertaken up to 2050," to a global action scenario, where "global action that leads to a reduction of global emissions of 50 per cent by 2050 compared to 1990," but also to a fragmented action scenario, where "EU pursues an ambitious reduction strategy […] but other countries do not follow the Global action scenario[91]." Table 6 compares primary Energy Demand forecasts under these three scenarios.

[91] European Commission, 2011, "Impact Assessment. Accompanying document to A Roadmap for moving to a competitive low carbon economy in 2050".

Table 6: Primary energy demand in the Baseline, Global action and Fragmented action

Region	Scenario	1990	2000	2005	2010	2020	2030	2040	2050
		%							
World	Global baseline	100	115	130	139	164	190	218	249
	Global action	100	115	130	139	155	153	145	138
	Fragmented action	100	115	130	139	158	177	199	224
Developed	Global baseline	100	102	105	100	105	107	111	113
	Global action	100	102	105	100	96	86	75	65
	Fragmented action	100	102	105	100	98	95	93	91
Developing	Global baseline	100	139	178	211	273	340	411	495
	Global action	100	139	178	211	265	275	271	271
	Fragmented action	100	139	178	211	268	327	393	470
EU27	Global baseline	100	104	110	105	107	107	107	108
	Global action	100	104	110	105	100	90	78	67
	Fragmented action	100	104	110	104	99	89	76	65

Source: 2050 Roadmap Impact Assessment, p. 39

Option 1: The LTCS will only consider the assumption that the Paris Agreement will function as expected and desired

The Paris Agreement states in Art 4.1 that the goal is to "undertake rapid reductions […] so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of GHG in the second half of the century." The LTCS putting in play different scenarios, depending on how other Parties will behave, may have the effect of shifting attention from the domestic action required to reach carbon neutrality, towards a debate of whether everyone is doing their part, and what is expected from different Parties.

Moreover, signalling that the EU doubts the effectiveness of the Paris Agreement might be counterproductive, from both a diplomacy and a public perspective.

From a diplomacy perspective, it signals to other Parties that the EU does consider the possibility of not increasing ambition to the level required, albeit under some circumstances which by definition may be difficult to define clearly and precisely. The Paris Agreement (Art 4.19) invites all Parties to develop their own LDSs: the LTCS should not create uncertainty for the strategies of other Parties, which expect that the EU will be one of the engines of the Paris Agreement. The EU hedging against the risk that others are not sufficiently ambitious might become a self-fulfilling prophecy.

From a public perspective, it also signals to the European public the EU's doubt, wait-and-see attitude, in other Parties' delivery, which may make the public less supportive of the EU as a first mover. A LTCS that assumes the Paris Agreement ratchet-up mechanism will deliver, and that the EU does not see any other way forward, may also encourage private investment in green technologies, and thus help create a self-fulfilling prophecy.

Finally, since the EU represents less than 10 per cent of global emissions, EU action will be insufficient if the other major Parties do not deliver. In such a case, the EU would necessarily need a new strategy. It is therefore best to create a document that assumes the Paris Agreement delivers, and, if it does not, nothing prevents the EU to react to this new reality. There is no need to consider, in the LCTS, what happens if the Paris Agreement does not deliver.

Option 2: The LTCS should consider the uncertainty of the level of delivery of the Paris Agreement

It is important for the modelling exercise to consider the uncertainty of diverging paths of action, and compare scenarios under different sets of actions (e.g. EU-only, fragmented action - there could also be diverging policies *within* the EU, and the LTCS may want to consider the uncertainty related to some Member States lagging behind).

The 2011 document did include a scenario of 'fragmented action', and this did not create any difficulties. Importantly, this is not an either/or question. The LTCS need not assume that the ratchet-up mechanism will automatically work perfectly, nor that it will not work at all. A plausible scenario is that climate action is taken, but not enough by some to reach the goal of the Paris Agreement, thus creating a positive 'action gap'. Recent developments in non-European carbon pricing mechanisms (e.g. the significant weakening of the China ETS, the US promise to withdraw from the Paris Agreement) suggest that this is an important uncertainty that needs to be considered and possibly hedged against.

Taking this uncertainty into account does not mean the EU itself may not deliver, or does not intend to deliver. Accounting for this uncertainty will allow for different patterns of ratchet-up, but can assume that the EU does take sufficient action, and remain a frontrunner.

If anything, considering this uncertainty may mean that the EU can, if required, decide to step up its ambition even more, and do more than its "fair share". It would also mean that the LTCS signals that the EU will monitor the situation, and will consider situations as they emerge. Not doing so may simply not be a credible way forward for any entity facing uncertainty in a strategic era.

Another clear implication of this option is that it encourages policy-makers to better understand how to deal with carbon leakage under different scenarios. A LTCS that only considers a perfectly functioning Paris Agreement will be less able to deal with carbon leakage concerns under different scenarios. By contrast, a LTCS that considers the uncertainty of the level of delivery of the Paris Agreement will consider the impact of the EU leading climate action, in scenarios of diverging paths.

Moreover, if the LTCS describes how it would react to the mitigation pathways in the rest of the world, this could help to increase ambition of other parties. Such reaction might be in terms of adjusting the EU's own ambition level[92], or in terms of other policy measures (e.g. trade[93]). Hence, the LTCS could be a signal to other parties.

[92] But there is also a risk that, as after the Copenhagen COP in 2009, the EU would force itself to do less than it could. As other countries did not agree to a strict regime, the EU reduced its 2020 ambition from 30 to 20 per cent, only to maintain international credibility.
[93] See the announcement of President Macon not to enter into trade deals with countries outside the Paris Agreement.

5.6 What economic and technological developments should the LTCS take into account, and how?

Issue

A number of economic and technological developments have the potential to enable completely different decarbonisation pathways. It will therefore have to be decided which of these technological developments should the LTCS take into account, and in what way.

Technological development could be incorporated into the LTCS in different manners:

i. A development could not feature at all in the LTCS.
ii. Some developments, deemed as potentially important, may be only mentioned in the LTCS.
iii. Potentially important developments may be treated extensively in other European Commission documents, to which the LTCS could refer.
iv. Some technological developments, deemed very important, may have an extensive qualitative discussion in the LTCS. They may not, however, be included in the modelling exercise, due to quantitative or modelling limitations.
v. The respective technological development is deemed very important, and should be included in the modelling exercise of the LTCS.
vi. A development may be so crucial that it deserves to be the core focus of the LTCS.

For the sake of transparency, and to reduce arbitrariness, the drafting of the LTCS could apply a systematic approach in deciding on how to address a particular technological development in the LTCS. The next section puts forward such an approach in Table 7.

Table 7: Classification of technical and economic developments

Category	Importance of the phenomenon for the low-carbon transition	Description
1. Not at all		Although the development may in itself have importance, the literature does not establish any significant bearing on the low-carbon transition.
2. Mention the issue		The literature establishes the phenomenon's potentially important bearing on the low carbon transition.
3. Refer to other EC documents		The literature establishes the phenomenon's potentially important bearing on the low carbon transition, and some other European texts that already treats the subject can be referred to.
4. Discuss qualitatively		The literature establishes: - Relative certainty that the phenomenon will continue/accelerate in coming years - strong evidence of the phenomenon's very important bearing on the low carbon transition
5. Include in Modelling		The literature establishes: - relative certainty that the phenomenon will continue/accelerate in coming years - strong evidence of the phenomenon's very important bearing on the low carbon transition. Additionally, the phenomenon is quantifiable, and can be introduced in models. (e.g. behavioural change: if it was easier to model, behavioural change could be included in 4. Given it is hard to model, it should be discussed qualitatively)
6. Core focus of the LTCS		The literature establishes: - high level of certainty that the phenomenon will continue/accelerate in coming years - the phenomenon is both quantifiable and can be introduced in models. - Long-Term decarbonisation cannot be envisaged without this development

Legend	
	No importance
	Some importance
	Very important
	Crucial

Which developments should the LTCS take into account?

The case of electricity storage

A high-profile example of on-going developments that may deserve to be taken into account in the LTCS is the rapidly falling costs of electricity storage technologies. Electricity storage will be crucial for non-dispatchable renewable energy sources (such as solar or wind). It also has a role to play in the decarbonisation of other sectors such as transport.

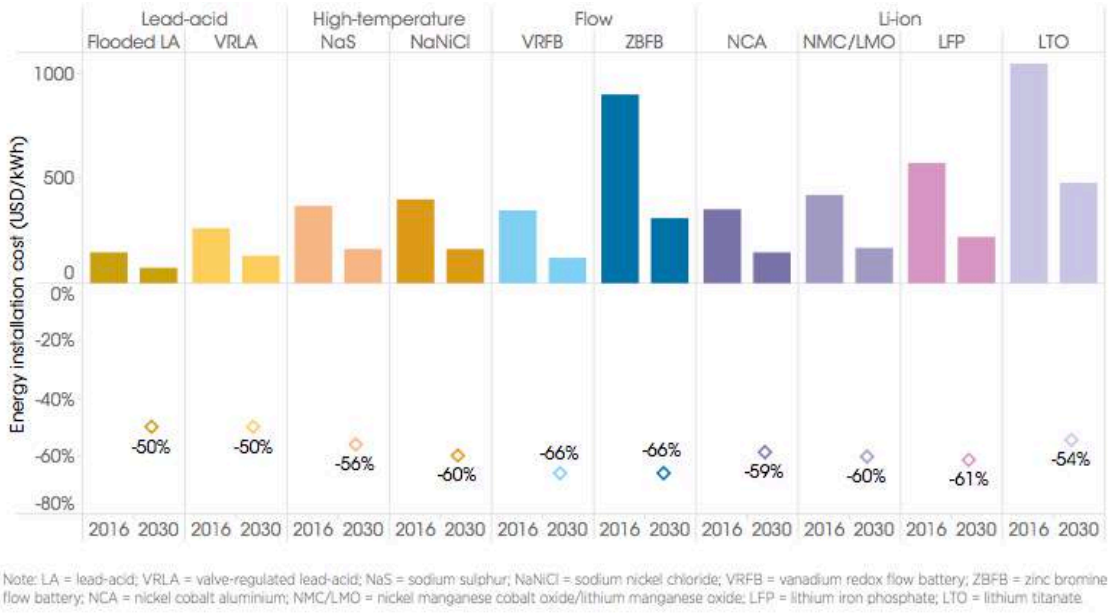
IRENA[94] estimates that, to double the share of renewables by 2030, the total stock of electricity storage capacity will need to grow from an estimated 5 TWh in 2017 to 12-16 TWh. Such an increase in capacity can only be made possible by plummeting storage costs.

Pumped Hydro Storage, a mature technology which has little potential to reduce total installed costs and where most favourable sites have been already exploited, currently accounts for 96 per cent of total storage capacity. Its share is projected to decrease to 45-51 per cent in the doubling of renewables scenario[95].

In contrast, other storage technologies have seen dramatic cost reductions, through economies of scale and technology improvements. The cost of Lithium-ion batteries for transport has fallen by as much as 73 per cent between 2010 and 2016[96] (BNEF, 2017). In stationary applications, it is estimated that the cost could, between 2016 and 2030, decrease by 54-61 per cent for Lithium-Ion batteries, with similar numbers for other technologies (see 5).

[94] Irena, 2017 "Electricity storage and renewables: costs and markets to 2030", p. 14.
[95] Irena, 2017 "Electricity storage and renewables: costs and markets to 2030", p. 14.
[96] Bloomberg New Energy Finance, 2017. https://about.bnef.com/blog/lithium-ion-battery-costs-squeezed-margins-new-business-models/

Figure 4: Battery electricity storage system installed energy cost reduction potential (2016-2030)



Source: Irena, 2017[97]

Therefore, using the methodology proposed above:

i. There is significant probability that the decrease in costs will continue in coming years: projections show a continued strong decrease in costs.
ii. There is strong evidence of its impact on the low carbon transition, as electricity storage is crucial for non-base load renewable energy sources.
iii. The phenomenon is quantifiable, and can enter a modelling exercise.

The increasing availability of electricity storage could therefore be considered in the fourth category of our proposed system: it would need to be included in the modelling of the LTCS.

<u>Other developments</u>

Other developments that could be included in the LTCS are:

- Blurring of sectoral boundaries
- Risk of stranded assets in fossil fuel exploitation and energy-intensive infrastructure
- Dematerialisation of demand (reduction in quantity of materials required)
- Behavioural change and changing consumption patterns

[97] Irena, 2017 "Electricity storage and renewables: costs and markets to 2030", p. 18.

- Digitalisation
- Uncertainty on trade openness (increasing trade flows, yet potential rise of protectionism)
- Decentralisation
- Increasing social inequality
- Automatisation
- Circular economy, material and product circularity
- Bioeconomy
- Carbon neutrality
- Higher utilisation of existing assets
- Artificial Intelligence
- Sharing economy
- Social impact of climate policy, just transition
- Macroeconomic developments, including the challenging of idea of eternal growth
- Climate justice
- Climate litigation
- Negative emissions technologies

5.7. Ambition

5.7.1. How is (mitigation) ambition defined?

Issue

Different approaches to measure the level of ambition of a long-term mitigation[98] strategy exist. In the political process, the metric of ambition can be used to define targets (e.g., the 20% emission reduction compared to 1990 level for 2020). The chosen metric is not just a technical question, different metrics can imply quite different optimal mitigation pathways.

2050 Roadmap

The 2050 Roadmap stipulates the EU's ambition of reducing *overall* emissions by a range of 80-95% by 2050 compared to 1990 levels. However, it only analyses the pathway to reducing *domestic* emissions by 80%[99].

[98] We refer here only to domestic mitigation, which will be a core component of the LTCS. Other ambition, such as with respect to climate finance or adaptation are not discussed here.
[99] 'Domestic' implies real internal reductions of EU emissions without offsetting through international carbon markets or offsetting mechanisms.

Option 1: Temperature

The ultimate aim of emission reductions is to mitigate climate change. The conventional measure of climate change is the increase in global temperatures compared to pre-industrial levels. Correspondingly, the Paris Agreement ambition is defined as "Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels".[100]

A LTCS will have to indicate whether it envisages 1.5 °C or well-below 2°C, as this choice will have a substantial impact on the EU's decarbonisation pathway.

However, only using a global temperature measure to define the LTCS's ambition might not be advisable, as most of the necessary action will lie outside of the control of the EU.

Option 2: Carbon Budget

What matters for climate change are not the emissions in an individual year, but the cumulative net GHG emissions that contribute to the concentration of GHGs in the atmosphere. In simplified terms, the global carbon budget is the total amount of GHGs that can be emitted minus the GHGs that are removed from the atmosphere. Different estimates for this global carbon budget exist.

Carbon Brief estimates the carbon budget as of beginning of 2017 to 162 Gt of CO2eq for the 1.5-degree target with high probability, and 762 Gt of CO2eq for the 2-degree target with high probability.[101]

This global carbon budget can then be divided over countries or sectors. This analytically clear approach has inter alia the advantage of encouraging countries to act early on relatively cheap mitigation options (as this saves them carbon budget for the more difficult to decarbonise sectors). However, politically, carbon budgets imply a zero-sum game of distributing a fixed carbon budget between different countries/sectors. This makes carbon budgets an impractical measure to be used in international negotiations.

Option 3: Emission in target year

Both at the European and international level ambition is mostly defined in terms of the amount of GHG-emissions in a target year. This is typically formulated as emission reduction in the target year compared to a [convenient] benchmark year (e.g., the EU Kyoto target was relative to 1990). Emissions in a target year are relatively easy to measure and it allows countries quite some flexibility with respect to the pathway. The flip-side is, that it allows countries to push problems to the future while reaching the emissions target in the target year is not a guarantee for not exceeding it again in subsequent years.

[100] Article 2(2).

[101] https://docs.google.com/spreadsheets/d/1GJSvGUtvgQifLYMOCUVJywaaTdSUJQjFq3qr5eC_Dzg/edit#gid=372766592; https://www.carbonbrief.org/analysis-four-years-left-one-point-five-carbon-budget.

Option 4: Year in which net emissions reach zero

Another definition of ambition could be the time by when net emissions reach zero. This would also be in line with Article 4 of the Paris Agreement that affirms that parties aim "to achieve a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the second half of this century". Such a definition of ambition would reinforce the notion that the ultimate aim is to achieve "net-zero" emissions and it would highlight the role of carbon removals in the discussion. So, in contrast to an incomplete reduction target (say 95% by 2050) no country or sector could hope to use the remaining carbon budget. However, by targeting a specific net-zero year, countries/sectors could still emit an unnecessarily high amount of GHG, in the time before this date.

Additional consideration: Include uncertainty

An aspect of all aforementioned options of defining ambition is how they deal with uncertainty. There is uncertainty on many levels: (1) The impacts of climate change on our societies is uncertain, (2) The sensitivity of the climate to GHG levels and emission fluctuations is uncertain, (3) emissions depend on unforeseeable factors (e.g. weather, business cycle, …) and (4) the availability and cost of different decarbonisation options in the future is highly uncertain, hence, pathways that appear feasible and economic today might not materialise (or more ambitious pathways might become feasible).

Ambition defined in deterministic terms (e.g., 80% by 2050) cannot be exactly hit. This might allow countries/sectors to claim that, while their action was aimed at hitting the exact target, "unforeseen" circumstances led them to underachieve the target.

Alternatively, ambition might be defined as a minimum target with a strict condition that underachieving is not permissible under any external circumstances (e.g., in no case less than 80% by 2050). This would require a very resilient pathway that hedges against a wide array of uncertainties, potentially leading to a quite costly approach.

Finally, ambition can be defined in probabilistic terms. This is what the IPCC is doing by trying to identify GHG-concentration levels that imply a "likely" (i.e., 66%) chance to keep temperature increases below 2°C. Modelling can allow to identify pathways that achieve certain ambition levels with a certain degree of probability. This gives some flexibility to policy-makers: asking for very high confidence to achieve the ambition level will probably imply more expensive pathways; while less costly pathways will tend to be riskier.

This flexibility, however, requires policy-makers to be transparent about the fact, that with a certain probability the ambition level will not be achievable.

5.7.2. Where is the ambition level determined?

Issue

The LTCS will have to make choices which ambition level(s) to analyse and discuss. This selection will already frame the discussion. Consequently, the way in which the ambition level(s) to be analysed in the LTCS are selected is crucial.

2050 Roadmap

In the 2050 Roadmap the ambition level was predetermined at 80% by 2050. This ambition was underpinned by Council conclusions and position endorsed by world leaders in the Copenhagen and the Cancun Agreements. It was justified by the IPCC Report that estimated that a 80-95% reduction until 2050 for developed countries was necessary to keep temperature increases below 2°C.

Option 1: Describe how to achieve a predefined ambition level

Like the 2050 Roadmap the new LTCS can analyse the different pathways to achieve one predefined ambition level. This ambition level would mostly likely be politically set based on the EUs interpretation of its commitments under the Paris Agreement.

Having one ambition level allows a clearer discussion on the different possible pathways and reaffirms the EUs commitment. On the other hand, the Paris Agreement framework is built around ratchet-up ambition. Hence, just analysing pathways to achieve one predefined ambition level might fall short of this spirit.

Option 2: Compare implications of different predefined ambition level

Alternatively, different ambition levels can be assessed in the LTCS. This would allow to analyse what the impacts of more aggressive ambition levels could be. It might, for example, appear that they are not that much costlier; or that they require a completely different decarbonisation pathway already in the near future. Hence, the LTCS would be an input into the debate over the desired ambition level.

However, the initial selection of options can frame this debate. If, for example, no net-zero ambition is modelled at all, this option might not be on the table in the political discussions.

Option 3: Determine “optimal” ambition level(s) based on the analysis

A third possibility is to use the analysis to come up with the optimal ambition level for the EU. That is, the model based on an integrated assessment of climate and decarbonisation related costs would indicate, which ambition level the EU should pursue. It might sound attractive to circumvent complicated political discussions by relying on modelling results. However, the result will be shaped by a large number of

controversial assumptions. Consequently, such an approach might disguise a genuinely political discussion and make it less transparent.

5.8. Granularity of the analysis

Issue

The LTCS will have to make choices how granular the analysis should be, into how many time-steps and levels it should be broken down, as for example whether it should analyse only the EU as a whole or also break the decarbonisation pathways down to individual Member States.

5.8.1. Number of time-steps

2050 Roadmap

In the 2050 roadmap a reduction pathway with three time-steps – 2020, 2030 and 2050 - was provided[102]. The modelling results at the time indicated that implementation of the then existent policies would lead to a 25% reduction in GHGs by 2020. This would exceed the EU 2020 target (-20%) but still fall short of the optimal pathway, which would have implied steeper reductions in the first period. Although the scenarios had similar results, a reference scenario, that showed the pathway given current trends and policies, was developed. The reference scenario was, in other words, a benchmark against which new policy measures could be evaluated. The intermediate targets added granularity to the comparison with the reference scenario since the extent of the pathway divergence could be observed at several points in time.[103]

[102] The modelling results had actually five-year time-steps, the impact assessment reported ten-year timesteps, while the main table in the 2050 Roadmap only reported results for 2030 and 2050. The three time-steps referred to, are those discussed in the text of the 2050 Roadmap.

[103] "The aim of the reference scenario is to project trends up to 2050 based on already implemented EU and national policies". The reference scenario "provides a long term baseline or benchmark with which the results of the decarbonisation scenarios can be compared. It is a projection of developments in the absence of new policies which will be decided at the EU and national level. It is not a forecast but a benchmark for evaluating new policy measures against developments under current trends and policies." Impact Assessment 2011

Table 8: Sectoral reductions

GHG reductions compared to 1990	2005	2030	2050
Total	-7%	-40 to -44%	-79 to -82%
Sectors			
Power (CO_2)	-7%	-54 to -68%	-93 to -99%
Industry (CO_2)	-20%	-34 to -40%	-83 to -87%
Transport (incl. CO2 aviation, excl. maritime)	+30%	+20 to -9%	-54 to -67%
Residential and services (CO_2)	-12%	-37 to -53%	-88 to-91%
Agriculture (non-CO_2)	-20%	-36 to -37%	-42 to -49%
Other non-CO_2 emissions	-30%	-72 to -73%	-70 to -78%

Source: A Roadmap for moving to a competitive low carbon economy in 2050, p. 6

Option 1: Intermediate time-steps

For the analysis underlying the LTCS it would be natural to model decarbonisation pathways over time. This implies using a relatively granular time-grid (current models typically apply one-year [Potencia] or five-year [PRIMES] time-steps[104]). Another question is whether the interpretation of the analytical results in the LTCS focuses on specific milestones (eg., 2030 and 2050). If a lot of emphasis is put on these milestones in the LTCS they acquire some normative characteristic as policy-makers will have to justify if they decide to deviate from them. As such, milestones allow to monitor whether the EU is on the track described in the long-term strategy. They can be easily communicated and catalyse political momentum when certain milestones risk being missed.

It has been suggested that at least having a milestone for 2030 is important, as the policy cycle could still deliver additional efforts by this date – when needed. More frequent milestones could allow an even more granular monitoring. Having milestones for every five years would also allow these to be used for interaction with the UNFCCC (with the five-year ratchet-up mechanism) and in the proposed EU policy process (ten-year cycle of NECPs).

Option 2: Carbon budgets

An alternative – essentially equivalent to continuous monitoring – is having carbon budgets. In climate terms this makes more sense as it is the cumulative amount of emissions that counts, and not the emissions in a particular year (which are also subject to some randomness such as weather and economic cycle) that determine the speed of climate change. Using carbon budgets can also be one way of highlighting the urgency of action. In addition, in the event of overshooting before 2050, the carbon budgets can compensate for this with negative emissions after 2050.

Option 3: No intermediate time-steps

[104] For specific questions such as electricity adequacy assessments it might make sense to even use hourly data, in the corresponding sub-model.

Milestones are very political. This implies that discussions on individual milestones can dominate the policy discussion and this might derail the entire project.

Milestones are often associated with imperfect indicators whose achievement might only offer limited information about the progress. Furthermore, changes in underlying assumptions might render initial milestones inappropriate. For example, cost breakthroughs for solar would allow significantly larger shares than initially expected; or weak economic development allows stronger carbon reductions.

Having multiple very different scenarios might somewhat reduce the political suspicion that granular time-steps hardwire targets before policymakers can discuss them.

5.8.2. Granularity of emissions attribution

In the LTCS, GHG emissions can be attributed to different gases, different emitting sectors, different types of emitting activity or different final consumption of certain services. The way in which emissions are attributed and the level of granularity of breaking down emissions into different categories can lead to substantial differences in the interpretation of the results.

2050 Roadmap

In the 2050 Roadmap emissions were mainly broken down into six sectors (Power, Industry, Transport (incl. CO2 aviation, excl. maritime), Residential and services, Agriculture (non-CO2), Other non-CO2 emissions).

Option 1: Only total GHG emissions and removals

The most simplistic approach would be to only report on total emissions and removals. This is what needs to be reported to the UNFCCC and what the EU long term targets will likely consist of.

This would overcome the problem that - especially in the long-term – it is very difficult to break down emissions into individual sectors and sources, as sector boundaries shift and sectoral dynamics can be quite volatile.

Option 2: Breaking down emissions into individual GHGs

The UNFCCC reporting requirements foresee breaking down emissions into nine GHGs and areas (net CO2 emissions/removals; CO2 emissions (without LULUCF); CH4; N2O; HFCs; PFCs; Unspecified mix of HFCs and PFCs; SF6; NF3). Especially after decarbonisation of most of fossil fuel combustion, the relative share of non-CO2 emissions (currently below 20% in the EU) might merit separate reporting.

Option 3: Breaking down emissions into individual production sectors

The UNFCCC reporting requirements foresee breaking down emissions into six main categories (1. Energy, 2. Industrial Processes and Product Use, 3. Agriculture,4. LULUCF,5. Waste, 6. Other) and 32 sub-

categories.[105] This is a different categorisation than the one used in the 2050 Roadmap, and more distant from the EU policy instrument approach to distinguish traded (Emissions Trading System) and non-traded (effort sharing) sectors.

A sectoral breakdown of emissions could be helpful for a prioritisation and sequencing of policies. If this is the purpose, the categorisation of emissions should be less focused on gases or underlying processes; but on clustering emissions in different fields governed by somewhat separate policy frameworks (like the EU did in the 2050 Roadmap – maybe with the exception of heating/cooling).

The level of detail of the sectors is again a trade-off between the desire to produce politically useful results and the risk of too clearly identifying losers that might derail the whole exercise (e.g., if transport sector pathways would clearly show that aviation will have to substantially decrease emissions by 2030 that might cause a fiercer opposition by that industry, than if the analysis only shows a substantial reduction in overall transport emissions)[106].

5.8.3. Geographic resolution

The geographic resolution of the LTCS has two components: its granularity (i.e., whether it deals only with the EU as a whole or also provides pathways for its Member States) and the extent to which neighbouring and associated countries are covered.

Option 1: Only one aggregate pathway

Providing only one pathway for the entire region and not breaking it down into countries might, first of all, avoid obvious inconsistencies between the modelling results and national realities/plans/constraints. Just think of a European model that would imply one country having much higher costs than another country or a currently unwanted technology being used (e.g., nuclear in Germany). It is unclear whether a model that delivers the mid-century targets and meets all "national constraints" can be constructed in a sound way. Furthermore, any "national numbers" might clearly indicate winners and losers – possibly fermenting fierce opposition to accepting the LTCS.

Option 2: National pathways

After the 2050 Roadmap there was a strong demand by many stakeholders (including many Member States) to provide results at the national level. We expect that centrally calculated national pathways could gain normative power (e.g., in the energy union governance process). While this might make them quite powerful, it might also politicise (or even obstruct) the process of determining them.

A related option is to not publish national pathways for all Member States, but instead deliver a national pathway on demand for a Member State. This could be helpful for those Member States with limited capacities for commissioning their own projections.

[105] Fuel combustion – which is responsible for 82% of the emissions in the EU - is further broken down into five sub-sub categories.
[106] The capability of models to provide robust results at lower levels of granularity might be less of a problem.

Option 3: Subnational or supranational regional pathways

Subnational pathways can help to properly address the significant within-country heterogeneity and supranational regional pathways can address cross-country spill-overs. While both types of regions play a strong role in combatting climate change, they might, however, not have sufficiently strong political instruments to achieve climate targets.

Beyond the EU

EU climate policy forms the basis for climate policy in a number of associated countries such as the EFTA countries and the Energy Community countries that largely follow the EU acquis communautaire. Consequently, (somewhat) integrating their climate strategies with the EU climate strategy might seem sensible – but would possibly complicate the process.

Furthermore, countries that are strongly integrated with the EU – especially in terms of energy – such as the post-Brexit UK, Algeria, Norway, Switzerland or Russia will have an impact on relative energy prices in the EU. There might hence be a reason to include energy sector and low-carbon developments in closely linked countries into the analysis of the LTCS[107].

On the other hand, the EU cannot directly guide climate-relevant legislation in these countries and might refrain from including them in a strategic concept as the EU has no jurisdiction over which climate action neighbouring countries are expected to undertake.

5.9. Timeframe

Issue

In choosing the timeframe, a distinction can be made between the targets and the modelling. Setting targets beyond 2050 (e.g. also for 2060 or 2100) can induce countries to plan their mitigation efforts over a longer horizon. Longer time frames can also increase the likelihood of countries targeting negative emissions, which will likely be necessary to be in line with the Paris Agreement goals[108]. On the other hand, the large degree of uncertainty risks making any analysis on how to reach the targets beyond 2050 less realistic. However, modelling beyond 2050 can provide useful insights into whether the path towards the 2050 targets remains effective and sustainable beyond this date. Further, longer-term models can be used to roughly estimate when carbon neutrality can be achieved.

Another alternative is to use a rolling timeframe, whereby the start and end date are updated fluidly (e.g. 40 years into the future). This method can allow information in the previous period to be incorporated in targets and models relating to the next period.

[107] One illustrative example are renewables projects in the southern Mediterranean – that, if they were realistic and used for energy exports to the EU – might have an impact on the European carbon footprint.
[108] https://www.nature.com/articles/s41560-018-0124-1.

2050 Roadmap

The 2050 roadmap focused on how 80%-95% decarbonisation, compared to 1990 levels, can be achieved by 2050.

Option 1: 2050

Looking into 2050 would be consistent with the 2050 Roadmap and fit the "mid-century" aspiration of the Paris Agreement. As it will be only 30 years in the future, many policy decisions today (e.g., infrastructure and generation investments) will lock-in decarbonisation pathways until 2050 – so corresponding scenarios can serve to inform those decisions.

Option 2: 2060/2070

For a decarbonisation strategy it could be useful to look beyond 2050. Most existing decarbonisation scenarios assume that carbon budgets will be overshot and that there will be a need for compensating this with negative emissions in the future. The LTCS can provide some clarity on the feasibility of such approaches and indicate trade-offs between stronger early abatement and higher volumes of negative emissions after 2050. And there are also other intertemporal considerations that might merit to look beyond 2050, when designing decarbonisation strategies for mid-century. For example, if most easily usable carbon storage space were to be used up by energy sector emissions by 2050, it might become more difficult to use CCS for industry beyond that date. And restoring degraded forests and peatlands, afforestation or increasing carbon sequestration in agricultural soils, needs long lead-times.

Consequently, a strategy that investigates into 2060 or 2070 might help policy-makers to understand what the implications of strategies that essentially borrow carbon-budget (or abatement options) from the future are. Furthermore, delivering negative emissions in the land use sector, such as restoring degraded forests and peatlands, afforestation or increasing carbon sequestration in agricultural soils, needs long-term planning due to the time lag between the introduction of measures and an increase in carbon sinks.

At the same time, the perception that a strategy beyond 2050 would imply postponing meaningful climate action to a later date must be avoided.

Option 3: 2100

Climate change will not stop after the mid-century and temperatures can only be stabilised in the long term by stabilising the GHG concentration in the atmosphere. Consequently, a view on a sufficiently long-time horizon such as 2100, might avoid the problem of optimising a strategy towards an end-date target by 2050 without considering this is not the end of the journey. In effect, some technologies that can deliver the 2050 target may not be able to deliver the emission cuts needed beyond.

6. Process

6.1. How should the consultation process be organised – Breadth of consultation

Issue

Consultation processes are important, not only to improve the quality of the product, but also to promote understanding, ownership and public support.

In the climate change debate the pendulum is moving towards more prescriptive approaches to climate action, where policy, instead of more market-oriented approaches, drives decarbonisation. To get societal buy-in for the LCTS, the way the consultation process is organized, and the feeling of ownership that it must create, is increasingly important and necessary. Participation by, and transparency towards stakeholders bring ownership – depending strongly on the depth and breadth of the consultation process. An LTCS that has gone through rigorous consultations could be perceived as more stable, sustainable and credible.

Moreover, the EU consultation process may be seen as especially important, as it could be an example for other countries submitting their strategies for the UNFCCC process, especially in terms of transparency. The European Commission has extensive experience with stakeholder consultations, as have many state and non-state actors in the EU.

Stakeholder consultations can take many forms, with formal and informal elements. As an example, activities that are part of this project could be considered an informal part of the consultation process. The consultation process can also vary with respect to the degree of transparency, and how feedback loops are considered. It should also be linked to the purpose of the LTCS: is it meant to start a (wide) debate, or to provide technical data for discussions at the political level?

2050 Roadmap

The 2050 Roadmap and its Impact Assessment used both formal, and more informal elements. On the informal side, there were publications and reports by various stakeholders, including by business associations, research institutes and NGOs. On the formal side, an online questionnaire was set up to gather the input of both individuals and organisations. The questionnaire received a total of 288 responses; mostly from citizens (132), from companies and professional associations (96) and the NGO community (35). Relatively few public authorities think-tanks, trade unions and academics responded (less than 10 from each).

For the LTCS a number of options may be considered:

Option 1: Standard European Commission consultation

The European Commission has a lot of experience conducting this type of consultation, as it routinely consults with stakeholders on Impact Assessments for proposals on upcoming legislation, and during the review of existing legislation. With respect to climate, DG CLIMA hosts online questionnaires, usually open to all citizens and organisations. In addition, meetings and workshops may be organized to receive feedback from selected groups of stakeholders.

Stakeholders have experience with this method of consultation, and understand the process. This consultation can be done with relatively low administrative burden, and takes less time than other more iterative processes.

The written responses from stakeholders are publicly available, and the European Commission usually publishes a report summarizing the feedback received. By using multiple-choice questionnaires, stakeholders are asked to choose directly between available options, which increases the clarity of the responses.

To alleviate any concerns regarding transparency, the governance of the process could also be subject to an initial consultation, for instance, on the modelling methodologies used. Existing external documents, such as external sectoral strategies, could also be used, thus reducing the need to gather new input.

European Commission consultations follow a process whereby comments are sought on a (draft) document, to which stakeholders are open to contribute. However, the process is limited in terms of outreach, and the European Commission can choose how to incorporate the input received. Moreover, the governance of the process can lack transparency. Stakeholders do not know how the questions are selected, how decisions are made on the timing of the consultation, and on how replies are incorporated into the proposal, and reasons for adoption or rejection.

Option 2: Limited and focused stakeholder engagement

A relatively limited and focused stakeholder engagement process could be more interactive, through the use of (repeated) workshops and requests for in-depth replies sent to a limited number of selected stakeholders, who are deeply engaged in and knowledgeable of the subject matter. Stakeholders with more experience, knowledge and capacity to contribute are in this way given the stage to participate, which may allow for deeper and more focused discussions.

Stakeholders that could be invited include EU institutions, Member States, academics, business associations, labour unions, think tanks and local governments. An open call for stakeholders could potentially be launched in order to identify interested parties.

By limiting the consultation process, administrative burdens and the necessary time to conduct the consultation are also limited.

By definition, however, not all stakeholders would be engaged in this type of process. The governance of the choice of stakeholders, the number of meetings and their location would have strong

repercussions on the type and quality of received feedback. Due to its non-inclusive nature, there would also be a perceived lack of transparency related to such a process.

Option 3: Enhanced stakeholder engagement (Example: French Low-carbon transition process)

The bottom-up ethos of the PA has brought in a new perspective on climate change policy-making, which gives momentum for broader stakeholder consultations from an earlier phase. A thorough and broad stakeholder engagement process could be both more interactive and more transparent. Tailored outreach workshops and brainstorming sessions with citizens and organisations could allow for broad participation and in-depth informed discussions with all relevant stakeholders that wish to contribute. This does imply organizing different sessions, and types thereof, throughout Europe.

Stakeholders that could be invited again include: citizens, EU institutions, Member States, academics, business associations, labour unions, think tanks and local governments.

The iterative nature of the consultation allows participants to be, and feel, involved in the shaping of the document. This could be achieved, for example, by having stakeholder engagement in the process in an iterative manner, at different stages of the LCTS elaboration, such as on an early draft, and then again on a more developed product (ex-ante and ex-post consultation).

Different stakeholders could contribute at different phases tailored to their profile, allowing their experience to be used optimally. Stakeholders with more specific knowledge could be consulted before the draft, to set out the guidelines. Broader stakeholder and civil society consultations could take place after the first draft is published.

Alternatively, a multi-layered process could allow for wide inclusivity, combined with focused results. Initial meetings could be organized by Member States, local governments or other actors, with conclusions then passed on to a consultation with more experienced and engaged stakeholders on that particular topic.

If the LTCS is conceived as a dynamic document, with a regular review process, stakeholder consultation could be organised in such a way that it continuously interacts with the dynamic review process.

Such a process would allow for maximizing participation and ownership across Europe and by different types of stakeholders. By gathering views, informing a wide public and enhancing discussions on a topic that is critical for the future of the EU, the process would be as important as the final document. A thorough stakeholder consultation early on would then facilitate later discussions, and may increase support for political compromises when that time comes.

The administrative burdens and the necessary time to conduct the consultation are however extensive. The timeline by which the document is needed (for example to submit at the UNFCCC level) is therefore critical for determining the breadth and depth of such a consultative process.

The European Commission will also need to develop methodologies and procedures to not only conduct the stakeholder engagement, but also to process the feedback received. New digital information tools could alleviate or exacerbate this issue.

6.2. How should the outreach be organized?

Issue

For the LTCS to provide a clear signal to policy-makers at various levels, industry and civil society, its vision and findings need to be communicated. Outreach needs to be done in the public space as much as possible. This must be contrasted with an outreach focused on specific and well-identified expert stakeholders, be they policy-makers, researchers, or the industry. This will ensure broad ownership and societal buy-in. It must be clear that outreach can be ex-ante and ex-post, with different objectives, and each possibly involving different approaches and tools.

2050 Roadmap

The outreach related to the roadmap issued in 2011 was organised at several levels. First, there were dedicated press releases to the publication of the document. Second, the European Commission presented its 2050 Roadmap in a number of capitals. Third, a short summary of the 2050 Roadmap was issued specifically for citizens. While clearly extensive, the success of this outreach effort, however, is difficult to quantify in hindsight.

Option 1: Ex ante outreach

As soon as the outreach process is started, in-depth communication on the process (including vision, objectives and timeline) needs to be sent out as widely as possible. This can involve sending press releases to national and international press, conducting interviews with journalists for news broadcasts and television programs, advertisements in major newspapers and on social media. This implies a broad and inclusive communication strategy and effort.

Ex-ante outreach informs stakeholders before a final document is available, and can help involve stakeholders in consultation efforts during the process. It increases transparency and allows for informed discussions, not only in line of the consultation process but in wider societal debate.

Early outreach could also force policy-makers to formulate their position earlier rather than later, increasing the potential for meaningful discussion at an early stage.

However, providing information widely on what is still work-in-progress may hinder the development of the document, as it risks communicating positions that may change significantly during the process. A difficult balance needs to be found between communicating on the process and on the content. In addition, it may trigger early lobbying, interfering with the process, which may evolve into an early negotiation.

Moreover, once outreach is started, it needs to be maintained until the finalisation of the document to keep momentum going and allow for continued stakeholder participation. This could make ex-ante outreach a very costly exercise.

Option 2: Ex post outreach

Ex-post outreach enables clear and coherent communication on the outcome of the process. There is less potential for stakeholders, especially those not closely involved, to be confused over the messages and the stage of the process. It is an easier and less costly type of outreach, as the documents being sent out are not under review – there is no need to re-do the communication. The same types of outreach activities could be envisaged as under ex-ante outreach.

As communication focuses on the outcome and results of the process, however, stakeholder ownership is somewhat limited. For instance, important feedback could be received during the outreach activities, that can no longer be included in the substance of the LTCS.

Option 3: Ex ante and ex post outreach

A combination of ex-ante and ex-post outreach can have significant benefits, and is probably currently expected by stakeholders. Stakeholders could be informed of the objectives and process behind the LTCS in the initial phase – helping garner interest for the LTCS and related stakeholder consultations – while communicating results and the outlook upon completion helps inform and mobilize stakeholders.

Such communication however requires a constant effort that could be costly and increase the burdens on the staff working on the LTCS. There is moreover a trade-off in terms of what is communicated, and when. Sharing all possible information each time the process proceeds to a next phase could overload stakeholders and decrease public interest, investment and cooperation.

Therefore, while there is an expectation for both types of engagement, there is a balance that needs to be observed, as well as an understanding of the level of attention and engagement that the public may have on a specific topic, that may seem distant from everyday life.

6.3. Model choice process

6.3.1. How to select the model, assumption and scenarios?

Over the past decade a number of modelling exercises for (some of) the aforementioned purposes discussed in section 2.1 have been developed – and nothing prevents a well-funded modelling team from developing yet another approach. At the same time there is an infinite number of possible scenarios and assumptions but only very limited resources to run and interpret different scenarios in different models. Therefore, someone has to decide which models to use, which scenarios will actually be run, and which set of assumptions to base the exercise on. This choice of models, scenarios and assumptions will drive the modelling results. There is hence a substantial political component in these choices. We cannot discuss the implication of all these choices, here, but rather focus on the governance of model-related decision-making.

Figure 5: A taxonomy of climate models

Source: Tomaschek J (2013) Long-term optimization of the transport sector to address greenhouse gas reduction targets under rapid growth: application of an energy system model for Gauteng province, South Africa. Dissertation, Universität Stuttgart, Stuttgart. doi:10.18419/opus-2313 [seen in Cao et al. Energy, Sustainability and Society (2016) 6:28 DOI 10.1186/s13705-016-0090-z]

2050 Roadmap

In the 2050 Roadmap, the European Commission and the modelling team decided on the scenarios and the assumptions mostly on their own. For some critical decisions they consulted with the Member States. There has been and there is still some discontent with the lack of transparency with respect to how the European Commission decided on assumptions and scenarios.[109]

Option 1a: Inside the European Commission – one modelling partner

Maintaining the relatively limited outside access to setting the assumptions and scenarios can somewhat depoliticize this stage and hence speed up the process. In fact, it is not clear whether a consensus on several scenarios (that should all be inherently consistent) can be found. Modellers and academic partners contracted by the European Commission, might have a less biased view on the modelling exercise and their assumptions.

As decisions on assumptions are made in a smaller circle within the European Commission and the modelling team, transparency might be a problem. The possibility to influence these decisions is also

[109] In contrast to the 2050 Roadmap, the "Reference Scenarios" 2013 and 2016 were "external studies" made for three DGs in the European Commission. In both publications, it was stated that "views [in the scenario] should not be considered as a statement of the Commission's or the Directorate-General's views".

reduced. Successful influencing of the decisions might however be more impactful as the number of deciding agents is relatively small as well.

Option 1b: Inside the European Commission – several modelling partners

Another option could comprise a similar model than Option 1a, but in which the European Commission sub-contracts the modelling exercise to several partners. If different tasks are given to different partners, a good coordination (via the European Commission) has to be ensured so that the modelling approaches are compatible.

It would also be possible to assign the same task to several partners and giving them more freedom. Although this approach would be more expensive, and it requires more coordination efforts than Option 1a, the advantages of Option 1b would lie in the possibilities of allowing for different methodological approaches and thus for different results as well.

Option 2: Co-creation with Member States

Another option is a process in which Member States and the European Commission choose the assumptions and define the scenarios jointly. Hence, Member States governments would lend their democratic legitimization to the process which could facilitate a smoother implementation later on in the process. Given the manageable number of actors and their repeated interactions, it might be easier for them to find compromises than for larger groups of stakeholders that do not necessarily trust each other.

In such a process, it would be crucial to define in which models/sector an additional value is rendered by the cooperation of the EU level and Member States and in which cases a single modelling exercise on the EU level is sufficient. Unless a harmonized way of decision making is implemented at the Member State level, this option could lead to an opaquer process as stakeholders could try to influence the policy-makers not only at the EU level but also at the national level.

Option 3: Co-creation with experts/expert stakeholders

Another option is to devise a process that involves a selected group of external experts in the choice of scenarios and assumptions. Given the complexity of the analysis, expert knowledge can be quite helpful to map the uncertainty around specific assumptions and draw up sensible scenarios. On the other hand, experts in a specific area often have some bias (ranging from an unconscious bias to a clear conflict of interest). Hence, the processes of selecting (and paying) experts and of finding an agreement are crucial to ensure obtaining least contestable results.

Option 3a: Institutional experts/expert stakeholders

Within this governance option, one could design a structure in which modelling is primarily done by the European Commission together with an external modelling team (as currently done) but that external

institutional expert and stakeholders are involved more strongly than in the last roadmap. One could think of an institutional expert team ("Energy and Climate observatory") consisting of experts from Eurostat, the Joint Research Center (JRC), and the European Environment Agency (EEA).

Option 3b: External experts/expert stakeholders

Another option could comprise the inclusion of a wider range of experts and expert stakeholders that stem primarily from academia, business and civil society. One could think of even including experts from more "exotic" fields such as foreign policy experts that could significantly enhance the quality of the discussion. A main challenge, as already briefly outlined above, is to choose the right and knowledgeable experts as well as to keep the panel balanced.

Option 4: Co-creation with all stakeholders

A fourth option would be to open up the process to all stakeholders, including non-experts. Such broad participation could strengthen legitimacy and modelling could even serve as a communication tool to a broader audience. However, the complexity of the exercise increases the risk that particularly active interest groups might get over-represented in the discussions or even steer the discussion intentionally in a certain direction. If it proves manageable, designing and conducting a co-creation process for such a complex exercise would set an impressive precedent and could set even a new benchmark of inclusive politics. In addition, it could ensure the quality of the modelling (i.e. the data and the code itself) as it would be checked by many actors. Other projects, namely software development using the open source approach, have proven that an integration of a large audience in a single project is feasible.

6.3.2. How many models should be run?

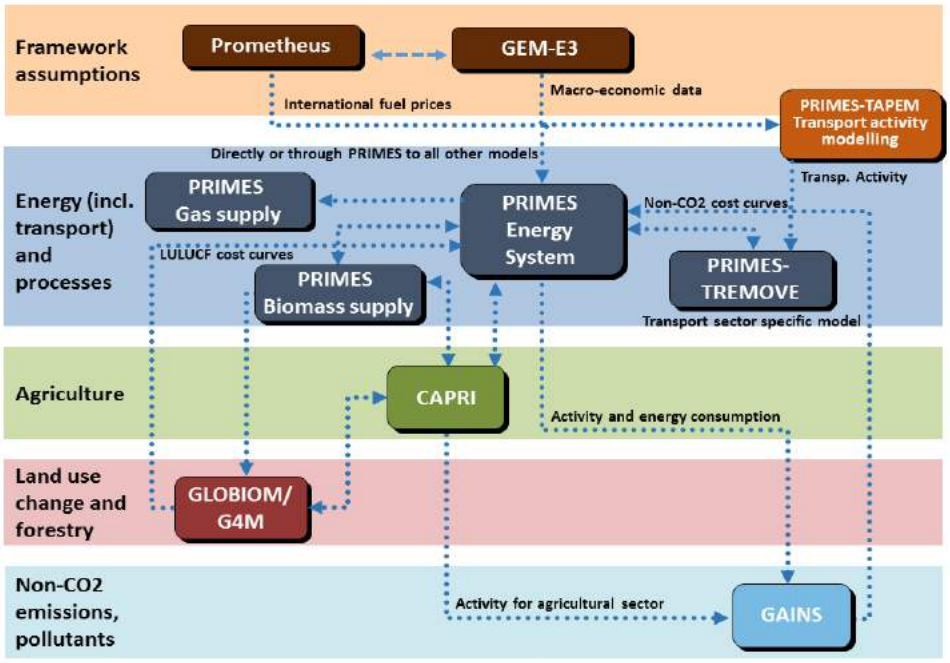
Issue

Due to the substantial amount of work that is needed to build models and fill them with data, there is only a limited number of models available that can capture decarbonisation pathways for the EU. The existing models use different approaches (backcasting, optimization, …) and offer different levels of detail for the covered sectors. The selection of one (or multiple models) will have an implication on the results but also on the process – as only transparent (i.e., not fully proprietary) modelling exercises allow for an in-depth stakeholder involvement at the modelling stage.

2050 Roadmap

In the 2050 Roadmap, a range of modelling tools was employed.[110] As the European Commission did use the selected modelling tools already before 2011 it ensured a good understanding of the model and a trustful relation with the modellers.

Figure 6: Models currently used by the European Commission for climate and energy modelling



Source: DG CLIMA[111]

[110] "The models used are POLES for the global energy system modelling and PRIMES for the EU energy system modelling. … Non-CO2 emissions from agriculture and industry are assessed with the GAINS model, with input from the CAPRI agricultural model … The LULUCF emissions and removals are assessed with the G4M and GLOBIOM." Economic impacts were assessed using the GEM E3 model. [IA (2011, p26f)]

[111] https://ec.europa.eu/clima/policies/strategies/analysis/models_en.

Option 1: One consistent modelling suite for all purposes

Having one central modelling suite would naturally focus the debate on the modelling choices in this one model. This would reduce complexity and could help to catalyse a very productive discussion, even on relatively technical assumptions, that might be critical.

Option 2: Several models run in parallel

Being able to compare the results of different models is helpful to ensure robustness. And choosing only one modelling approach might open up this exercise to massive political pressure on modelling choices and open the door to claims that the exercise is not impartial. Hence, either running similar scenarios in different models for the LTCS, or at least encouraging and enabling the modelling community to be able to replicate the "official" scenarios could strengthen credibility.

There are technical solutions to make different models and scenarios comparable. This could somewhat resolve the issue of getting overwhelmed by the hundreds of outputs, several scenarios run on dozens of models. The globalcalculator.org/ is one noteworthy open-source approach.

One option would be to use also sectoral or national models to add depth to the analysis. This could be helpful to complement the analysis or provide robustness checks for larger EU-exercises. Furthermore, discussing divergences might allow to enter a constructive dialog.

6.4. Transparency

Issue

Even a purely academic modeller would find it difficult to come up with unbiased scenarios and assumptions, given that the public discourse is driven by interest groups. Hence, the first option would be to make the assumptions and scenarios transparent and possibly provide some justifications for the choices (e.g., by referring to corresponding sources/literature). This will increase the credibility of the exercise and allow for a fact-based discussion of the results. It would, however, be likely that some interest groups will still disagree with the choice ex post.

The degree to which the analyses underlying the LTCS are made public has strong implications on its credibility. But full transparency also comes at certain costs. Therefore, the new LTCS needs to find a good balance between credibility and manageability.

2050 Roadmap

Regarding the 2050 Roadmap, discussions about its transparency of the analysis almost dominated over the actual results. The 2050 Roadmap featured a 100-page impact assessment that underpinned the statements of the Roadmap. This impact assessment mainly contained the results of the actual modelling, and had little to say about the complex modelling choices that drove the results. As the underlying main model was proprietary (incl. the detailed set of assumptions) the only way to broadly

check the assumptions and replicate the results for outsiders was by purchasing the model. Over time, the documentation of the model was improved, and a couple of key assumptions were made public – and sometimes fiercely debated. But many stakeholders argue that an initially more open approach could have been the basis for a more fruitful discussion.

Option 1: Case for proprietary data and model

Proprietary data and models might be of better quality, more up-to-date and easier to use than those in public domain.[112] Some are run by experienced modelling teams. Replicating this in public domain is very costly and time intensive. The EU has been commissioning the same model for two decades, which not only helped to build expertise on both sides (provider/user) but also ensured continuity of the approach – which makes results comparable over time. Furthermore, a less open approach can allow to avoid endless discussions on hundreds of sensitive assumptions, that might arise when individual stakeholders worry that numbers in the reference scenario might become "official" (e.g., over the import-price elasticity of cement in different EU countries).

Another argument is that there are still legal issues around public licensing of models and especially data – as well as privacy concerns for certain data-sets.

Option 2: Case for full transparency of model inputs

The European Commission will most likely disclose key assumptions (such as discount rates or technology cost) of the different scenarios. However, other input into the models – such as assumed learning curves - can have substantial impacts on the results. Moreover, disclosing this information early would allow external modelling teams to replicate the European Commission's model runs. This would help to identify discrepancies, allow other stakeholders to play around with alternative scenarios and strengthen the credibility of the European Commission's exercise[113].

In fact, the European Commission plans to go into this direction by building an open database (JRC–IDEES[114]) to underpin its new POTEnCIA[115] model.

Option 3: Opening the model to other stakeholders

Putting the models underpinning the LTCS into public domain would allow all interested and capable stakeholders (i) to form a view on whether the model(s) is/are a suitable representation of the main drivers of decarbonisation, (ii) allow stakeholders to provide feedback to improve the model (iii) run the

[112] Quote: "The list of reasons why energy models and data are not openly available is long: business confidentiality; concerns over the security of critical infrastructure; a desire to avoid exposure and scrutiny; worries about data being misrepresented or taken out of context; and a lack of time and resources." [Pfenninger (2017), Nature 542, 393]
[113] Actually, the results of the 2050 Roadmap were largely confirmed by other models some years later (John Weyant et al, Clim. Change Econ. 04, 1302001 (2013)), after they got access to the relevant inputs.
[114] https://ec.europa.eu/jrc/en/publication/jrc-idees-integrated-database-european-energy-sector-methodological-note.
[115] https://ec.europa.eu/jrc/en/publication/potencia-model-description-version-09.

model to test alternative scenarios and (iv) and even improve the model. Such an open approach can provide some degree of trust in the modelling exercise[116].

Again, legal issues (e.g., appropriate licensing regime) are a concern. Furthermore, it is feared that it might be easier to show the limitations of open models and hence for interested parties to discredit the entire exercise.

A more nuanced approach than full open-source would be to provide different groups of users with different user rights (e.g. Member States representatives can run scenarios; or an independent expert panel can get full access to the server).

Additional consideration: Documentation

An issue closely linked to model-transparency is documentation. Thereby the needs of different audiences need to be considered. For modellers, releasing code with a clean and documented interface might be the main priority. For policymakers, attention to clearly documenting input data and assumptions (and where they come from) and allowing reproducibility may well take precedence over code itself.

Additional consideration: Ensure transparency for external models

Transparency issues are not only relevant for the European Commission's own modelling, but also in case results of external models are used in the argumentation. Some standardised score-card for external models – that informs about the transparency and the funding of external models – could set a standard for the "modelling industry".

[116] Open-source is widely used in many domains where security and reliability are an issue – and it actually improves the software when everybody can check everything.