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Global Energy and Climate Outlook 2025

Market Competitiveness of Clean Energy Technologies

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Contents

Abstract

Enhancing competitiveness became a key priority for policymakers in 2025.

Decarbonisation efforts hinge on the relative competitiveness of clean energy technologies compared to high-emitting counterparts. GECO 2025 assesses the competitiveness of a range of key clean energy technologies globally, within the context of meeting global temperature targets.

The report finds that a few technologies are already able to compete with their high-emitting counterparts, a few others are close to be able to do so, but many important clean energy technologies are far from maturity and require more support to reach the deployment levels required in the 1.5°C scenario.

In a world where tariffs and trade barriers are increasingly on the rise, GECO 2025 also investigates the impact of global trade patterns on economic growth and decarbonisation, finding minimal interaction between climate and trade policy at global GDP level.

International trade fragmentation may cause a limited reduction in GHG emissions but also hampers deep decarbonisation. Against this framework of structural change, climate mitigation reshapes international trade flows, where the scale of energy carrier transactions is set by the ambition of climate policies, and the volume of manufacturing commerce is driven by trade policy.

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Executive summary

Policy context

The Global Energy and Climate Outlook 2025 is released at a time of increasingly turbulent policy landscape. Many countries continue to pursue existing climate ambition and accelerate climate action, while some major regions remain laggards or are reversing climate action. In addition, recent years have witnessed increasing concerns over secure supply chains and the effects of high prices on industry and consumers. Within this context, GECO 2025 focusses on the competitiveness of clean energy technologies under current policies and the impacts of global trade on decarbonisation.

Key conclusions

Global climate mitigation efforts continue to fall short of what is needed. The rapidly improving competitiveness of clean energy technologies offers a crucial opportunity to raise ambition.

On the one hand, several low-carbon technologies such as solar, wind and electric vehicles are broadly competitive with the incumbent fossil fuel technologies in many world markets and are expected to achieve high levels of deployment in terms of total capacity installed, with little to no additional policy support. On the other hand, several other low-carbon technologies such as synthetic fuels and CO_2 capture are not expected to achieve the levels of deployment foreseen in a scenario aligned with the 1.5°C climate target without additional policy support.

Even if clean technologies can be scaled to rise to the decarbonisation challenge, there are concerns that the current climate of trade tensions could affect the global ability to reach the 1.5°C climate target. GECO 2025 looks at the possible effects of international trade fragmentation – as opposed to globalisation – on mitigation policy and finds that there is limited interaction between climate and trade policy at global GDP level. This limited interaction results from the impact of tariffs on GDP as well as on emission intensity: trade fragmentation puts downwards pressure on the global economy's total output, and therefore also on GHG emissions. However, fragmentation simultaneously increases the global economy's emission intensity, ultimately hampering deep decarbonisation.

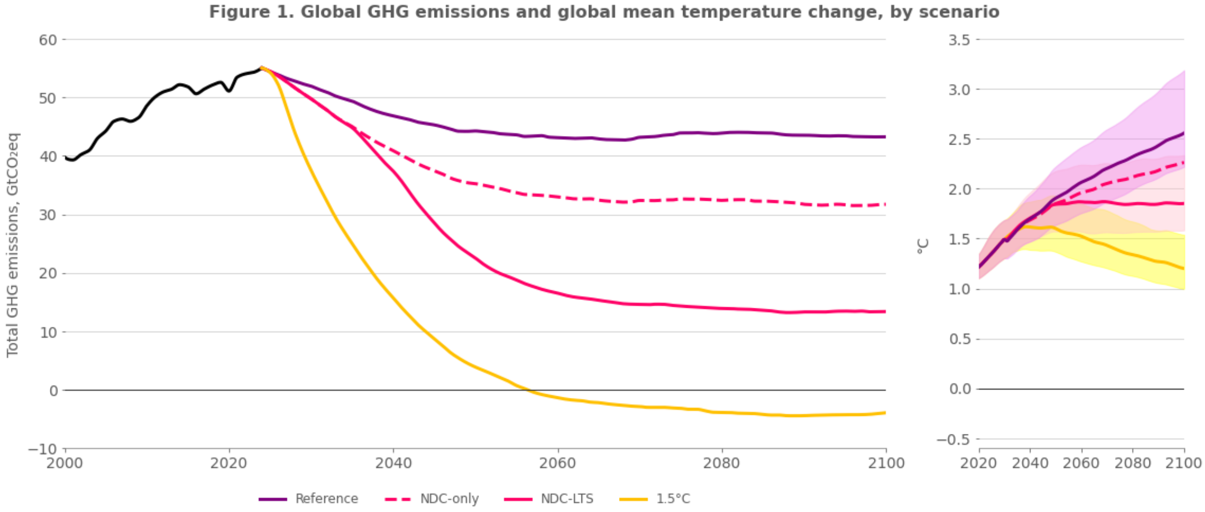
Main findings

Limiting global warming to 1.5°C by the end of the century requires an immediate reduction of emissions across all sectors and countries.

Under current legislated policies, global emissions peak immediately and decrease gradually to 2005 levels by 2050. The long-term emissions trajectory under currently enacted policies shows a similar evolution compared to last year, where emission reductions resulting from continuing rapid deployment of renewables and electric vehicles globally has been offset by a reversal of climate action in the US.

The recently announced emissions reduction pledges focussing on emission reductions by 2035 result in a global break from trend in the next decade, but still fall well short of the ambition needed to contain global climate change to well below 2°C.

Figure ES1. Global GHG emissions and global mean temperature change, by scenario

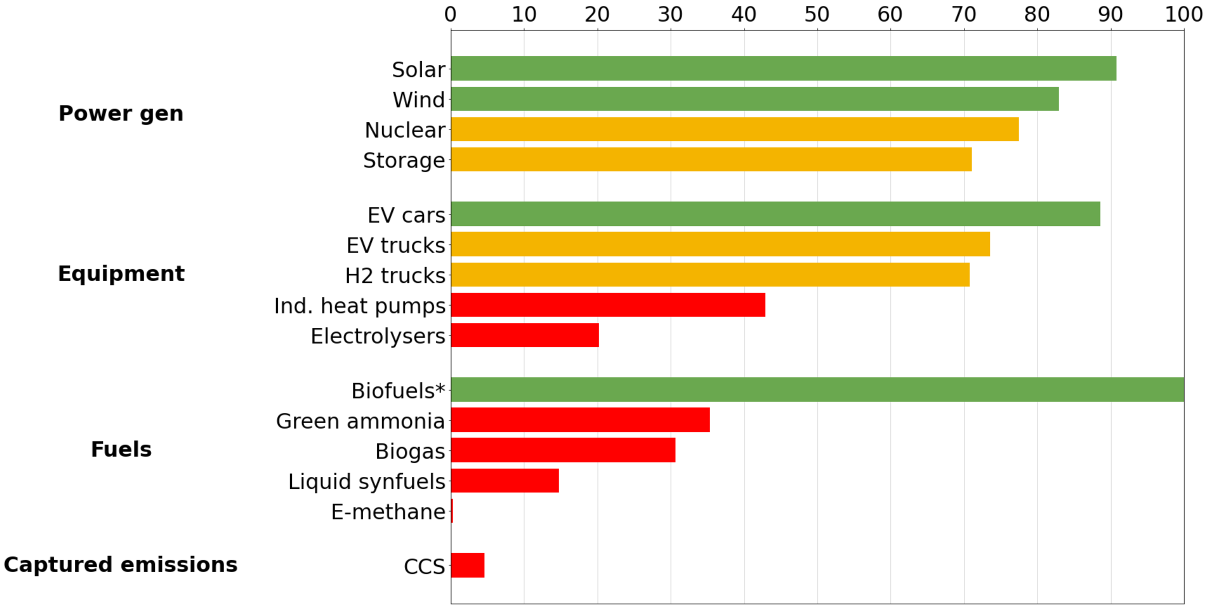


Source: POLES-JRC model, liveMAGICC (probabilistic setting).

GECO 2025 analyses the deployment, in terms of total capacity installed, of 15 key clean energy technologies required to keep the 1.5°C target of the Paris Agreement in reach and finds that 4 are rated as competitive under current global market conditions, 4 are almost competitive, and 7 are uncompetitive. The almost competitive technologies require additional policy support to scale-up in the coming decade. The uncompetitive technologies are mostly needed for the final stages of reaching net zero, are generally less mature technologically, and require earlier-stage policy interventions to support their progress towards widespread market deployment towards the middle of the century.

Over half of the analysed technologies being competitive or almost competitive could be considered an encouraging result, especially as those technologies represent a very large share of global emissions reductions. However, the gap between the current pathway and what's required for the remaining uncompetitive technologies highlights the significant amount of effort still required. While the uncompetitive technologies account for a smaller share of total emissions reductions, their role is critical: the full technology portfolio will be necessary to be mobilized to reach the 1.5°C scenario. The timely and sufficient deployment of all technological options is the complex task at hand to reach deep decarbonisation.

Figure ES2. Percentage of the 1.5°C scenario global level achieved in the Reference scenario, in 2050.



Source: POLES-JRC model.

Recent years have witnessed a shift in the rulebook for international trade policy, including changes in industrial policy and rising trade tensions. This context raises the question of whether there are potential interactions between climate and trade policy, and whether the fragmentation of international trade ties affects mitigation targets. GECO 2025 finds that there is overall minimal interaction between climate and trade policy when considering the effect on global GDP.

Fragmentation has a negative effect on global production volumes, which puts some limited downward pressure on GHG emissions. However, fragmentation also makes the global economy more emissions intensive, by fracturing global patterns of specialisation and encouraging domestic production where this might be less efficient. In a deep decarbonisation scenario, this increase in emission intensity dominates the output effect. As a result, fragmentation hampers the deep decarbonisation that is necessary in a 1.5°C scenario.

In terms of sectoral trade structures, the trade of energy carriers (such as coal or LNG) is affected more strongly by the direction of climate policy. Imports and exports of manufacturing on the other hand are more sensitive to changes in trade policy.

Related and future Joint Research Centre work

The Global Energy and Climate Outlook (GECO) is published annually since 2015. It contributes to the JRC work in the UNFCCC policy process, the IPCC Assessment Reports and the UNEP Emissions Gap Reports. Previous editions, accompanying energy and emission balances and multi-regional Input-Output tables serving as macro-economic baseline are available at the GECO repository.

Quick guide

GECO 2025 outlines the scenarios and assumptions used in Chapter 2, followed by Chapter 3 showing global results in the key sectors. Chapter 4 analyses the competitiveness of key clean energy technologies, and Chapter 5 explores the economic and decarbonisation impacts of global trade fragmentation. Finally, the Conclusion is followed by a series of Country Sheets for selected G20 countries and regions.

1

Introduction

1. Introduction

With 2025 being the third hottest year on record[1], the observed effects of increasing global emissions are increasingly more impactful, affecting private assets, public infrastructure equipment and severely damaging human welfare across the globe. These impacts highlight the urgency of a coordinated global response. In the lead up to COP 30 at the end of 2025 many countries submitted new emission reduction pledges looking a decade ahead with targets for 2035. While climate change mitigation policy support is ongoing, the gap between pledges and action persist, and is not reducing quickly enough to limit temperature increases to those aimed at in the Paris Agreement.

Alongside decarbonisation as a top global policy priority, the global economy has been in the process of reorganising in 2025 along new trade and tariff lines, that brought an increasing interest in competitiveness-enhancing policies[2]. Competitiveness can be defined in many ways, but when it comes to meeting decarbonisation targets the primary focus is on the cost-efficient substitution of incumbent fossil-fuel technologies with clean-energy technologies.

In the last decades, innovation in key technologies for the clean transition has led to sharp cost decreases, making them competitive compared to fossil alternatives. As of 2025, deploying a number of low-carbon technologies to cover new energy demand is not at odds with economic competitiveness, but is rather a way to enhance it. This report adopts a technology-specific view and assesses the extent of technology development that the world might achieve under currently legislated policies, as compared to the most ambitious global climate goals. GECO 2025 analyses the competitiveness of 15 key clean energy technologies, and highlights where and when policymakers can support these technologies, which are critical for limiting climate change.

The shift in the trade landscape also raises the question of whether there might be noteworthy interactions between climate and trade policy. GECO 2025 explores these interactions by comparing climate mitigation action in a setting of either globalisation or trade fragmentation.

GECO 2025 provides updated energy and emissions modelling and quantifies the gaps between the current global trajectory, what could be achieved under the latest targets and pledges, and what the global energy system looks like under the strongest temperature limit from the Paris Agreement of 1.5°C of warming. With this scenario comparison, GECO 2025 aims to support policymakers as they set and assess the strength of decarbonisation targets.

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[1] Global Climate Highlights 2025 (Guglielmo *et al.*, 2026)

[2] https://commission.europa.eu/strategy-and-policy/strategy-documents/commission-work-programme/commission-work-programme-2025_en

2

Scenarios and definitions

2. Scenarios and definitions

This chapter provides a detailed description of the scenarios and assumptions made for the projections presented in this report. GECO 2025 presents four main scenarios, a reference, an NDC-LTS, and a 1.5°C scenario. These scenarios are produced based on results from the partial equilibrium global energy model POLES-JRC and the general equilibrium model JRC-GEM-E3, covering the interactions between the global economy, the energy system and the environment[3].

Chapters 3 and 4 refer to modelling with POLES-JRC, in which all scenarios share common socio-economic assumptions. Chapter 5 refers to modelling with JRC-GEM-E3, where the macroeconomic costs of climate mitigation compared to the reference scenario are included in the 1.5°C scenario**.**

Reference **scenario: projections of energy and emissions are driven by market forces and existing policies.**

This scenario considers already legislated GHG policies, energy supply and demand policies, and concrete supporting energy-sector policies. Only policies that have been legislated up until early December 2025 are considered. This scenario does not aim to reach stated policies or targets, whether legislated or not, that have not been accompanied by concrete action plans. Correspondingly, policies that were superseded or legislated out were not included in the analysis. See Annex 4 for the list of policies considered in the *Reference* scenario.

In POLES-JRC, exogenous macroeconomic projections (GDP and population), with endogenously calculated energy prices and technological development specific to the model, together with the effect of enacted policies, result in projections of the energy system and GHG emissions. As a consequence, this scenario may differ from energy and emissions projections from official national sources and international organisations.

NDC-LTS **scenario: considers the emissions targets of NDCs (Nationally Determined Contributions) in the medium term and the LTSs (long-term strategies) in the longer term.**

This scenario assumes that the objectives in the NDCs (including conditional objectives) are reached in their relevant target year. This encompasses targets for 2030 and for 2035. NDCs submitted until December 2025 were considered for the analysis; not all NDC targets were included in the modelling[4]. See Annex 4 for a list of NDC and LTS objectives included in this scenario.

To meet the NDC emissions targets, carbon pricing mechanisms are put in place on top of the existing, legislated measures of the Reference scenario to reach sector-specific or economy-wide targets. Beyond the year of the NDC target, the objectives of the countries' net-zero emissions

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[3] A description of the POLES-JRC and JRC-GEM-E3 models can be found in Annex 1 and Annex 2. More detailed descriptions and specifications of the models and its settings can be found in ((Capros *et al.*, 2013; Després *et al.*, 2018; Schmitz *et al.*, 2025)). In addition, details on socio-economic assumptions and internationally traded fossil fuel prices can be found in Annex 3.

[4] Countries modelled individually cover 85% of non-LULUCF global 2024 emissions (2024 emissions estimates from PRIMAP-hist (Gütschow, *et al.*, 2025); including international transport), as per Annex 1; for these countries, NDCs for 2030 and, if available, for 2035, were included (see Annex 4 **Table 11**). For the remaining countries, modelled as country aggregates, the NDCs for 2030 of representative countries were used to derive regional emissions targets (see Annex 4 **Table 12**).

targets, where they exist, are pursued; if the country has not announced a net-zero target, it is assumed that no additional decarbonisation effort is made, and carbon prices, if they exist, are kept constant from those of the year of the NDC target.

This report's projections differ from national modelling exercises in the NDC documents. This can be due to different key macroeconomic assumptions and consequently energy demand growth, to operating patterns of the power sector or to other assumptions or modelling representations. This can lead to certain sectoral targets in an NDC document not being reached in our scenario; however, effort has been made to achieve the most important targets regarding renewables and emissions reductions. This scenario also considers decarbonisation proposals related to international aviation and maritime transportation sectors.

A variant case derived from the NDC-LTS scenarios was produced: an ***NDC-2035*** case, where in addition to the Reference policies; the NDC targets for both 2030 and 2035 are considered, but long-term net zero targets are excluded. This variant case allows to estimate the implementation and ambition gaps to the Paris Agreement objectives.

***2°C* and *1.5°C* scenarios: designed to limit global temperature increase at the end of the century to 2°C and 1.5°C.**

A single global carbon price for all regions is used in these scenarios, starting immediately (2026) and strongly increasing over time. These scenarios are constructed based on the policy settings of the Reference scenario, to which the global carbon price is added as the sole additional policy driver. These scenarios are therefore stylised representations of an economically efficient pathway to the temperature target, as the uniform global carbon price ensures that emissions are reduced where abatement costs are lowest. These scenarios do not consider financial transfers between countries to implement mitigation measures. In the 1.5°C scenario the use of negative emissions technologies and land use sinks, is considerable (18 $GtCO_2$/year in 2100 of CO_2 captured with negative emissions technologies, including CO_2 captured to produce synthetic fuels). CO_2 capture from combustion, industrial processes and CO_2 direct air capture technologies are made available progressively beyond 2030 (about 11 $GtCO_2$/year in 2050). The mobilisation of biomass as an energy resource is relatively limited (remaining below 180 EJ/year in all years), to reflect the use of only sustainably grown biomass[5]. Within the above economic and technological constraints, the overshoot of the temperature target is kept low (with a peak temperature at 1.6°C around mid-century, at median probability)[6].

In addition, Chapter 5 distinguishes between a ***Globalisation* and a *Fragmentation* scenario**: Chapter 5 looks at the interactions between global climate mitigation and trade policy. The chapter considers two alternative trade regimes for the future: a default – globalised - one where global value chains continue to be strongly integrated, and a fragmented one where there is more protectionism and a return to more domestic production. The Reference and 1.5°C scenarios are

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[5] There appears to be a moderate agreement in the literature for the potential of biomass for energy use of about 200 EJ/year, and a higher level of agreement for the more conservative figure of 90 EJ/year (Creutzig *et al.*, 2015).

[6] The 1.5°C scenario results in an approximately 74% probability of not exceeding the 1.5°C temperature limit. Global mean surface temperatures obtained with the online tool liveMAGICC, based on GHG and air pollutant emissions projections from POLES-JRC: http://live.magicc.org/.

implemented over these two alternative trade regimes. More information is provided in Chapter 5 (Box 3).

Box 1. Enhancements and updates of the POLES-JRC model, and differences compared to GECO 2024.

Several upgrades of the POLES-JRC model were conducted, both for input data and for modelling code.

A number of historical statistics been updated with the latest data for recent years: economic growth (IMF, 2025); international fuel prices (BP, 2025; EIA, 2026; World bank, 2026) and bioenergy prices (UNECE, 2026); power capacities (IRENA, 2025); road vehicles sales and stock by technology (battery, fuel cell, hybrid) and vehicle type (passenger cars, light and heavy trucks, buses) (ACEA, 2025; IEA, 2025). Historic GHG emissions for non-CO_2 GHG and process-related CO_2 emissions have been updated.

Certain technology costs assumptions were updated: electrolyser overnight investment costs were increased substantially reflecting recent cost revisions in (DOE, 2024; Eblé *et al.*, 2024) and (European Hydrogen Observatory, 2025); investment costs for renewable power generating technologies and utility battery costs (IRENA, 2025); hydrogen infrastructure costs related to passenger and freight transport on road; techno-economic factors for direct air capture of CO_2; electric technologies in industry. Wind energy potentials were revised downwards in South East Asian countries following assessments from (Davis *et al.*, 2023; Global Wind Atlas, 2026).

Further model enhancements were conducted. The most important ones were:

A cost optimisation for producing hydrogen by PV and wind powered electrolysers has been implemented. The optimisation considers an over-sizing of PV and wind capacities relative to the electrolyser's capacity. As a result, lower cost hydrogen production can be achieved as full load hours of the electrolyser operation increase. Moreover, the optimisation considers the potential to add batteries to balance intermittent PV and wind power generation.

Biofuel and synthetic liquids blending caps for road vehicles, airplanes and ships were revised.

Potentials for industrial heat pumps and CCS in chemical industry, non-metallic mineral sector and non-energy intensive industries (i.e. food, pulp & paper, manufacturing, etc.) were revised.

The car ownership ratio was revised following (Dargay *et al.*, 2007).

Buildings scrapping rate and renovation rate were made dependent to the carbon price.

The vehicle stock turn-over mechanism that drives vehicles sales was revised to obtain a closer fit to sales data.

As per GECO 2023 onwards, historical CO_2 emissions from agriculture, land use, land use change and forestry (AFOLU) are based on (Grassi *et al.*, 2023) and thus follow the conventions of national GHG inventories to UNFCCC for all countries. Land use fluxes projections report changes compared to the base year (based on data provided by the GLOBIOM-G4M models (Frank *et al.*, 2021). For the reporting at the global level, CO_2 AFOLU emissions were harmonised to global book-keeping models, as used in the Shared Socioeconomic Pathways (Riahi *et al.*, 2017) and IPCC AR6 WGIII (Intergovernmental Panel on Climate Change (IPCC), 2023), through a constant adjustment to match 2015 emissions of CMIP6.

3

Global energy and emission projections

3. Global energy and emissions projections

This chapter provides an update on global energy supply and demand and resulting emissions under the three main scenarios of the GECO 2025 report, based on recent energy data and updated energy and emissions policies and targets. It explores the gaps between scenarios, showing the fuels and technologies that increase and decrease over two key time periods (2023-2035 and 2035-2050), when moving from the Reference scenario to the 1.5°C scenario.

3.1. Global emission and temperature trajectories

In 2025, progress on narrowing the implementation and ambition gaps was mixed. While the continued deployment of clean energy technologies drove a reduction in Reference scenario emissions, this momentum was partially offset by the reversal of climate action in the US. As a result, Reference scenario emissions and global temperatures projections are similar to last year's GECO[7]. Despite this mixed situation, under the current legislated policies of the Reference, global emissions peak immediately and decrease gradually to 2005 levels by 2050.

The recently announced 2035 NDCs are broadly aligned with the trajectory of the NDC-LTS scenario between 2030 and 2050, rather than materially moving the NDC-LTS trajectory lower. This indicates the new pledges represent a continuation, rather than an increase, in existing ambition. The exception is the US, where the removal of NDC targets in this latest GECO edition consist in a marked reduction in ambition. The NDC pledges result in a global break from the Reference trend in the next decade, but still fall well short of the ambition needed to contain global climate change to well below 2°C.

In terms of the average warming level, the 1.5°C scenario sees the 1.5°C limit exceeded in 2031, the year of peak warming level reaches 1.6°C. The world reaches global net-zero CO_2 emissions in 2047 and net-zero GHG emissions a decade later, in 2056.

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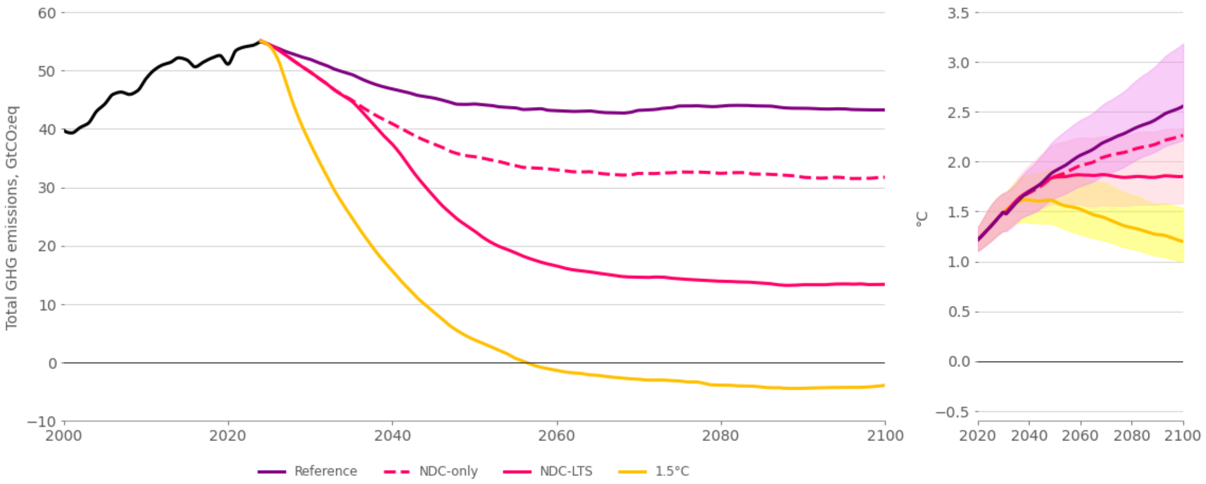
[7] Global GHG emissions in 2023 are 3 $GtCO_2e$ lower due to historical statistics updates (see Box 1). Reference emissions are 2 $GtCO_2e$ lower in 2050. In other words, 2023-2050 Reference emissions evolved in a similar way over the two GECO editions (-20% and -19%, respectively).

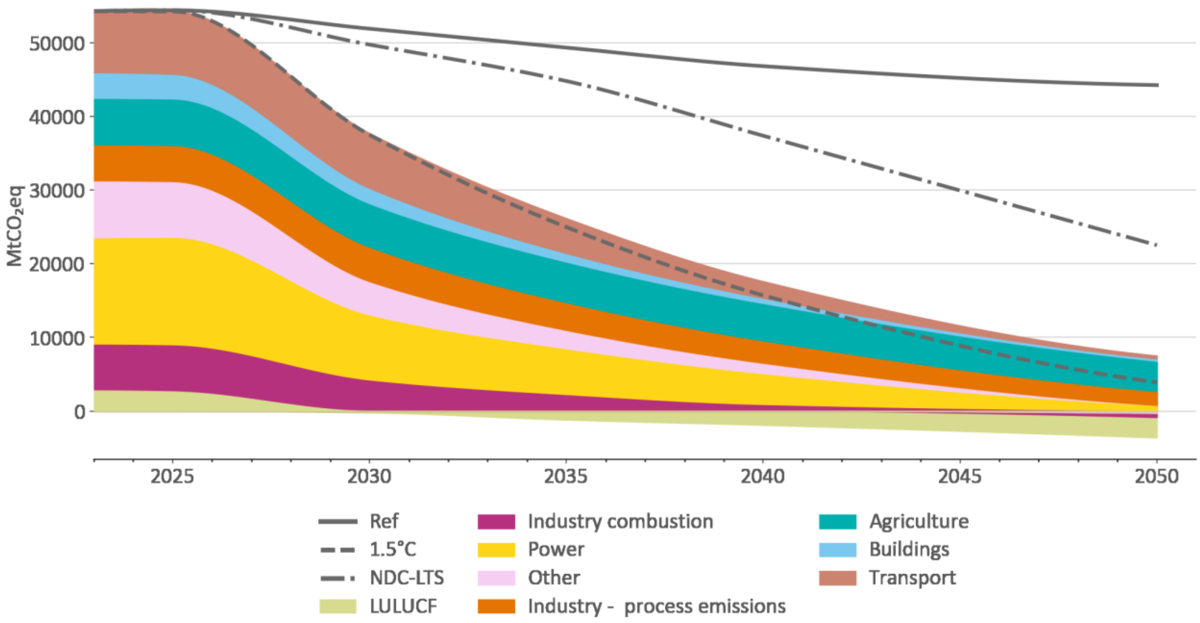
Figure 1. Global GHG emissions and global mean temperature change, by scenario



Source: POLES-JRC model, liveMAGICC (probabilistic setting).

The 1.5°C scenario sees sharp decreases in emissions over the coming decade, led by the power, transport and industry sectors. The need for negative emissions to offset continuing emissions from other sectors sees the LULUCF sector become a net sink around 2030 and deepen those reductions reaching -3 Gt by 2050 (**Figure 2**). Net-zero GHG emissions are achieved around 2056 in the 1.5°C scenario, and net emissions are -4 Gt in 2100.

Figure 2. Global emissions, by sector, 1.5°C scenario.



Source: POLES-JRC model. Other includes non-CO_2 emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production) as well as the sink from the direct air capture of CO_2.

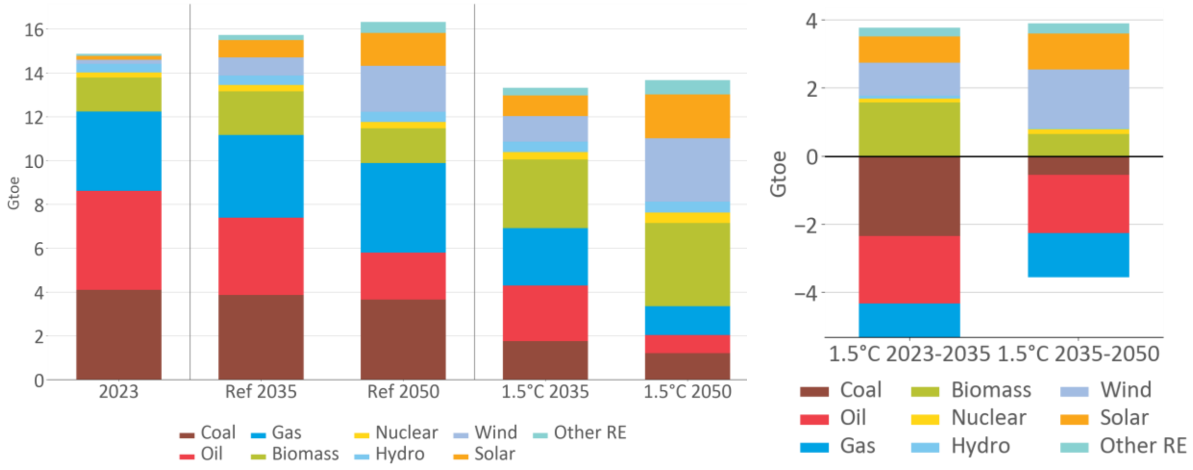
3.2. Global energy supply and demand gaps

The coming decades see a dramatic divergence between the current trajectory and what is required to be on a 1.5°C pathway. While total primary energy demand continues increasing in the Reference scenario over the next decades, it stabilizes in the 1.5°C scenario. As the economic growth and population assumptions are identical in both scenarios, the lower energy demand in the 1.5°C scenario is a result of the improved energy efficiency, largely brought about by the adoption of clean energy technologies.

Figure 3 shows a broad continuation of the existing fuel mix in the Reference scenario over the projection period. Oil demand is cut by half while coal and gas roughly maintain their volumes as additional electricity demand is met by increasing deployment of wind and solar.

In the 1.5°C scenario oil demand decreases even quicker, alongside reductions in coal and gas and a large expansion in wind, solar and biomass. Focussing on the 1.5°C scenario, the right-side graph shows that the decrease in coal demand occurs mostly in the coming decade; it is mirrored by the bulk of the biomass increase over the same timeframe.

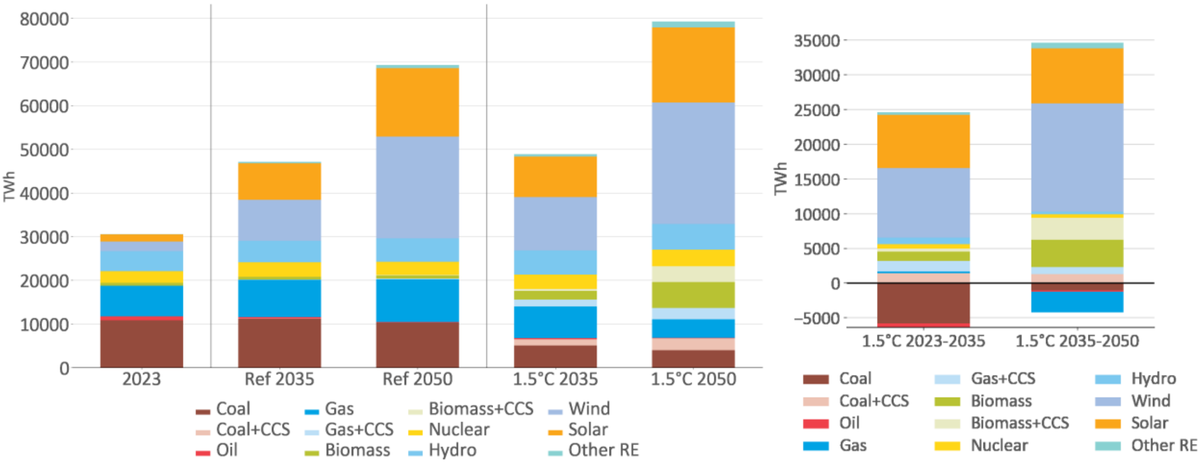
Figure 3. Global primary energy demand, by scenario (left) and change in global primary energy demand in the 1.5°C scenario, by timeframe (right).



Source: POLES-JRC model.

Global power generation grows dramatically in both the Reference and 1.5°C scenarios. Interestingly, wind and solar expansion is similar in both scenarios (see **Figure 4**), indicating that these significant expansions are “locked-in” and not dependent on potential changes in policy support, The main differences between the 1.5°C scenario and the Reference scenario is that the former sees a significant reduction in unabated fossil-fuel generation (mostly coal and oil), replaced by both renewables and fossil fuels fitted with carbon capture and storage (CCS). Approximately half of the residual coal consumption is projected to be combined with CCS by 2050. Biomass generation, both unabated and fitted with CCS, plays a role in balancing intermittent renewables and providing negative emissions in the 1.5°C scenario. Comparisons of the deployment rates of these technologies are further explored in chapter 4.

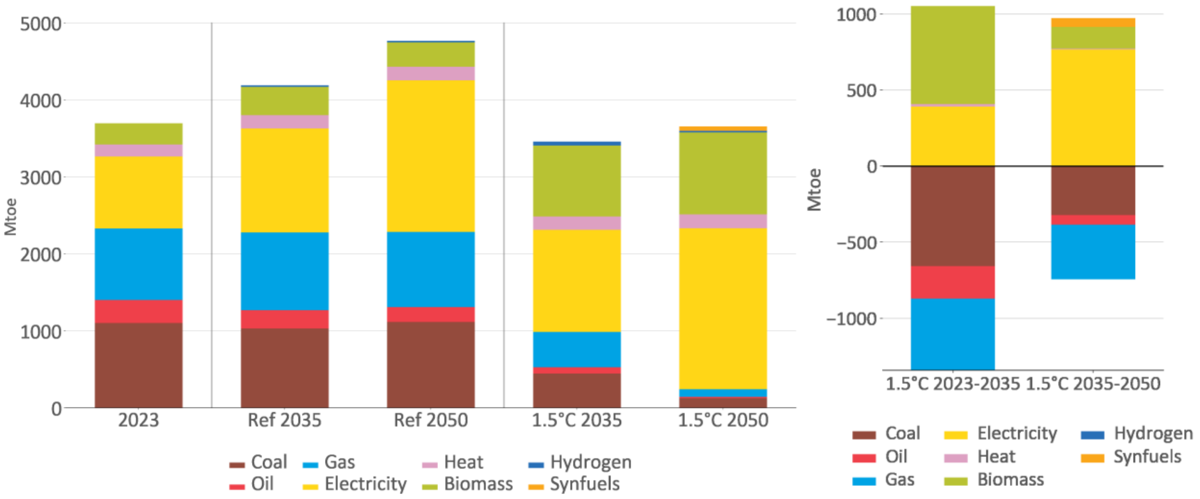
Figure 4. Global power generation, by scenario (left) and change in global power generation in the 1.5°C scenario, by timeframe (right).



Source: POLES-JRC model.

The industry sector sees an increase in electrification in both the Reference and the 1.5°C scenarios, of similar volumes, indicating the relatively little uncertainty to the degree of future industrial electrification (see **Figure 5**). The differences lie in the outlook for total industrial energy demand and for fossil fuels demand in industry, and, which both see a significant reduction in the 1.5°C scenario. This is the result of a combination of two factors: on the one hand increased energy efficiency reduces overall demand, and on the other hand electrified options out-compete less efficient fossil fuels.

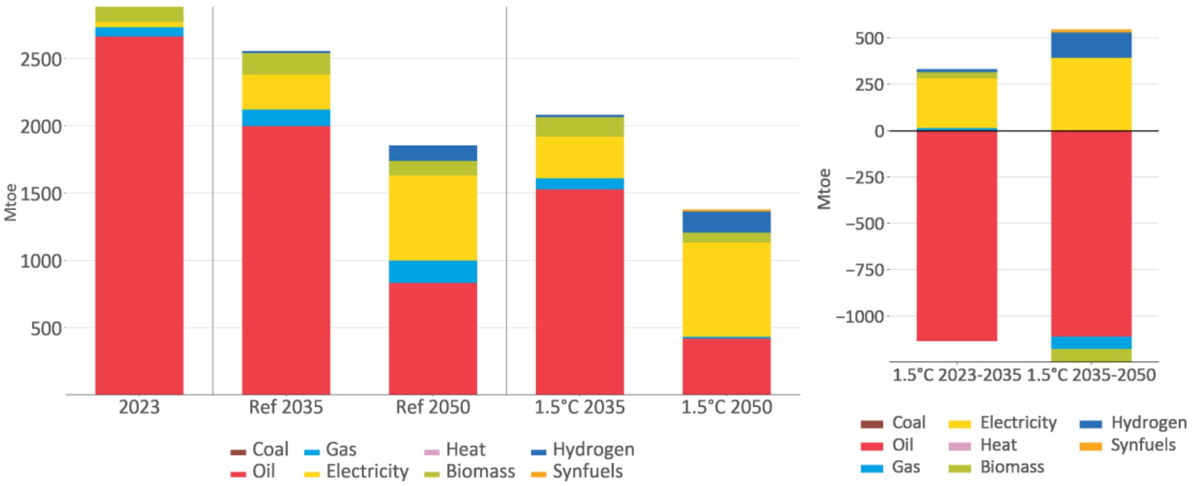
Figure 5. Global industry energy demand, by scenario (left) and change in global industry energy demand in the 1.5°C scenario, by timeframe (right).



Source: POLES-JRC model.

The transportation sector is rich in cost-effective electrification opportunities. Significant electrification occurs in both the Reference scenario and the 1.5°C scenario, leading to significant reductions in total transport energy demand in both scenarios, see **Figure 6**. The right-side graph shows how the fuel substitution of oil products by electricity takes place in both periods: first, electric vehicles take market share from internal combustion engines in passenger cars and light duty transport vehicles; second, both electric trucks and hydrogen fuel cell trucks penetrate in the heavy duty vehicles market segment after 2035 in the 1.5°C scenario.

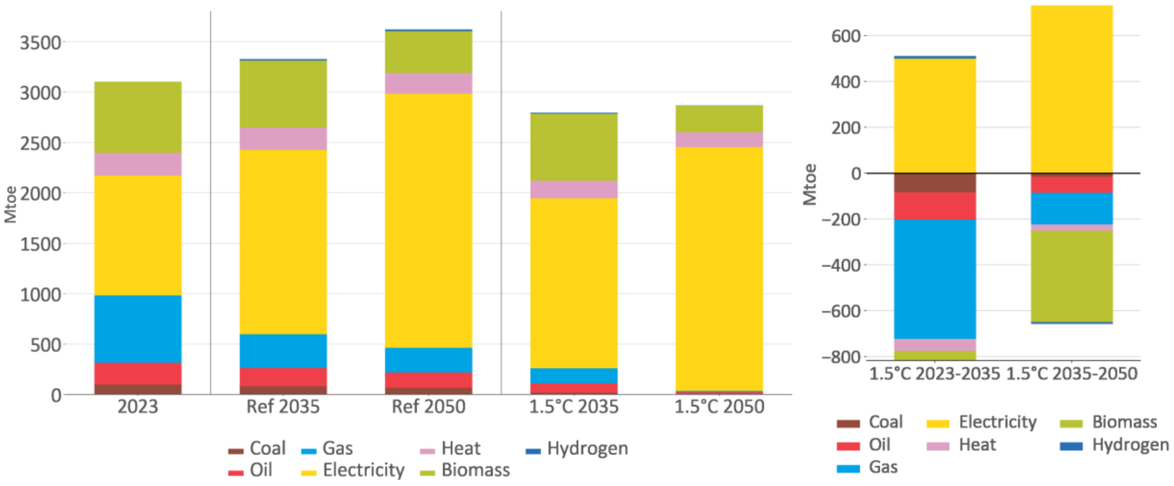
Figure 6. Global transport energy demand, by scenario (left) and change in global transport energy demand in the 1.5°C scenario, by timeframe (right).



Source: POLES-JRC model.

Energy demand in buildings is projected to undergo an important electrification process, a process which occurs even more intensely and quickly in the 1.5°C scenario compared to the Reference scenario. Electricity becomes the dominant fuel in both scenarios by the middle of the century, as shown in **Figure 7**. The electrification comes at the expense of fossil fuels, particularly gas in the coming decade, and with an accelerated phase-out of traditional biomass.

Figure 7. Global buildings energy demand, by scenario (left) and change in global buildings energy demand in the 1.5°C scenario, by timeframe (right).



Source: POLES-JRC model.

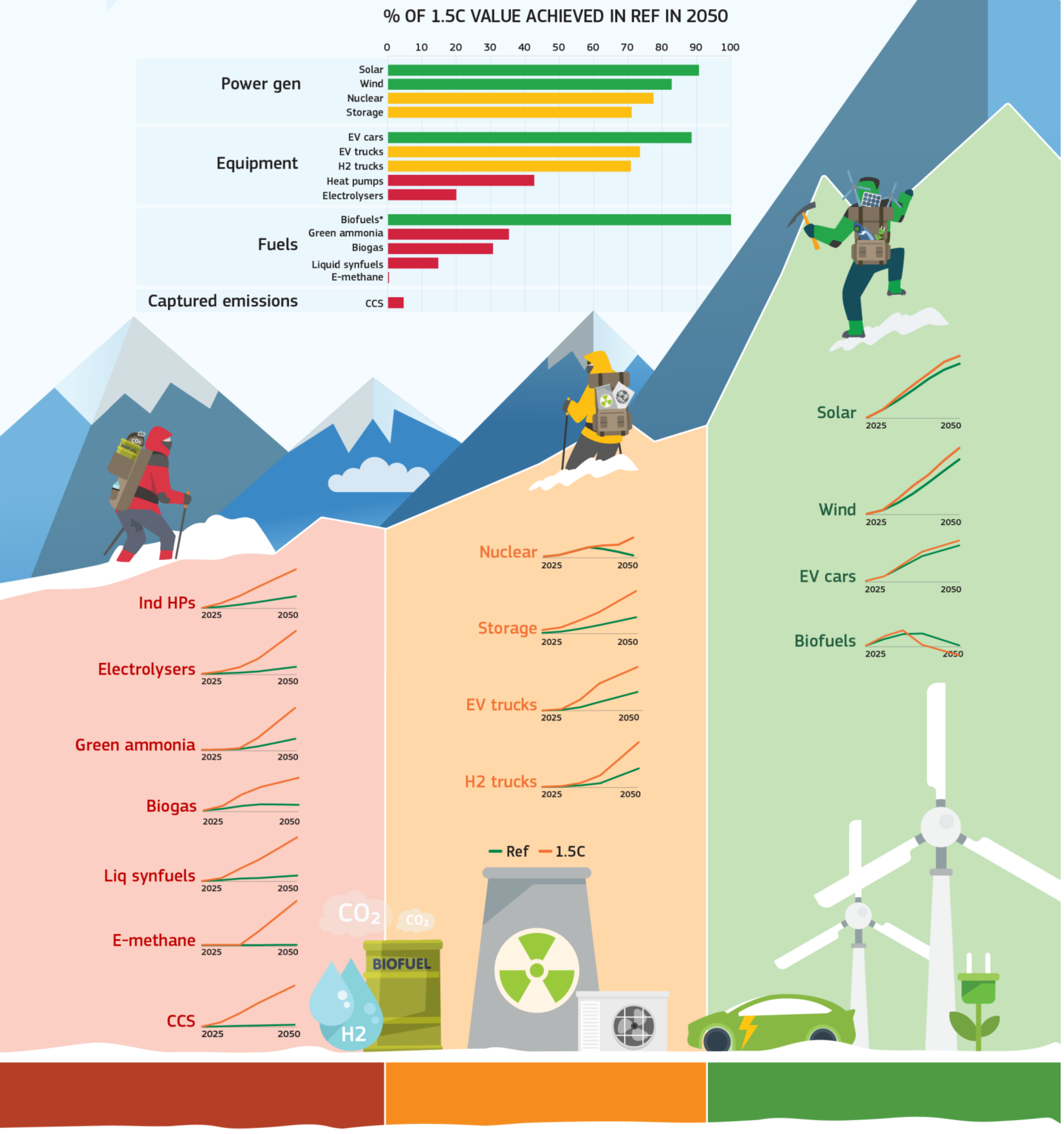
4

Global competitiveness of clean technologies

GECO 2025 analyses the deployment of 15 key clean energy technologies required to reach the 1.5°C target of the Paris agreement, by comparing the gap between their deployment in the Reference scenario compared to the 1.5° scenario in 2050.

Four technologies are rated as competitive under current global market conditions, four are almost competitive, and seven are uncompetitive.

The almost competitive technologies require policy support to accelerate their scale-up this decade, while the uncompetitive technologies generally require earlier-stage market interventions as their deployment is more important post-2035.



4. Global competitiveness of clean energy technologies

In 2025, the global economy reorganised along new trade and tariff lines that fostered a renewed focus on energy costs, innovation and global supply chains. Against this backdrop, competitiveness is the common thread connecting these developments. In the context of achieving the decarbonisation of the economy, the competitiveness of clean energy technologies compared to the incumbent fossil fuel technologies is the focus of this section.

Of the many factors that dictate competitiveness of a technology, upfront capital cost is only one of them. Other important factors include fuel costs of both electricity and fossil fuels, renewable energy resources, material inputs costs, labour costs and policy settings. All of these factors have an impact on the competitiveness of both clean energy technologies and incumbent technologies and dictate the speed at which fossil fuel technologies can be expected to be phased out.

A model-based scenario comparison approach to analysing competitiveness allows the inclusion a maximum number of the above factors and can provide insights on whether deployment rates match what is required to reach climate targets. Rather than assessing the competitiveness of a country or company compared to others in the global market, what we are interested in is the competitiveness of a technology as it pertains to its role in the global decarbonisation effort.

As such, the outcome of the technology comparisons is driven, to a large extent, by the policy settings of the various scenarios. The principal objective of climate policies is to address the economic externality of greenhouse gas emissions, hence modifying the competitiveness of low-emissions technologies; other objectives of climate policies can include energy security and resilience against international price shocks, fostering innovation and the growth of a domestic industry for new technologies, and employment reallocation towards low-emissions activities. In this section, we have identified which clean energy technologies are globally competitive and which ones need additional policy support.

Policy support can take many forms. It can be specific to the technology (cost and performance) but can also affect market conditions. In the scenarios of this report, the policy support that closes the gap between the Reference scenario and the 1.5C scenario addresses the environmental externality related to climate change and changes the market conditions for technologies. Hence, we focus on the *market competitiveness of clean energy technologies.*

There is no widely accepted single metric or type of analysis for judging whether a technology is competitive, and in order to provide orientation we have selected some broad bands of deployment levels, detailed below, which guide the reader's understanding of relative progress.

If, in the Reference scenario, a technology reaches 80% or above of its 1.5°C scenario deployment levels in 2050, in terms of total capacity installed, we classify it as ***competitive***. A technology being competitive means that the technology cost, over the projection period, is similar to those of the incumbent fossil fuel technology, and there exists enough policy support to see its deployment reach sufficient levels in major global markets. It is also possible that between today and 2050, countries and regions without policy support for this technology currently may introduce supporting measures, thus further increasing its deployment and reducing the gap between the Reference and 1.5°C levels.

If a technology's Reference deployment reaches 50-80% of the 1.5°C level it is classified as ***almost competitive***. These technologies have cost and market structures that prevent them from reaching competitiveness to the incumbent technologies under current policy settings and thus require increased policy support in most markets. However, as the gap is not too wide, the pathway to competitiveness is somewhat clear.

The technologies that remain below 50% of 1.5°C deployment in the Reference scenario are classified as ***uncompetitive***. For these technologies the current cost outlook and policy support are grossly insufficient to see their deployment reach the levels required for a 1.5°C trajectory. In many cases the costs remain far above those of the incumbent fossil fuel technologies and policy support remains in its infancy, indicating that the pathway towards competitiveness is more uncertain.

Section 4 explores the competitiveness of 15 key decarbonisation technologies.

4.1. Summary

Only 4 of the 15 investigated technologies are rated as competitive. *During the next decade policymakers ought to focus on closing the gap for the four almost competitive technologies, and on laying the groundwork for future policy support for the remaining seven uncompetitive technologies.*

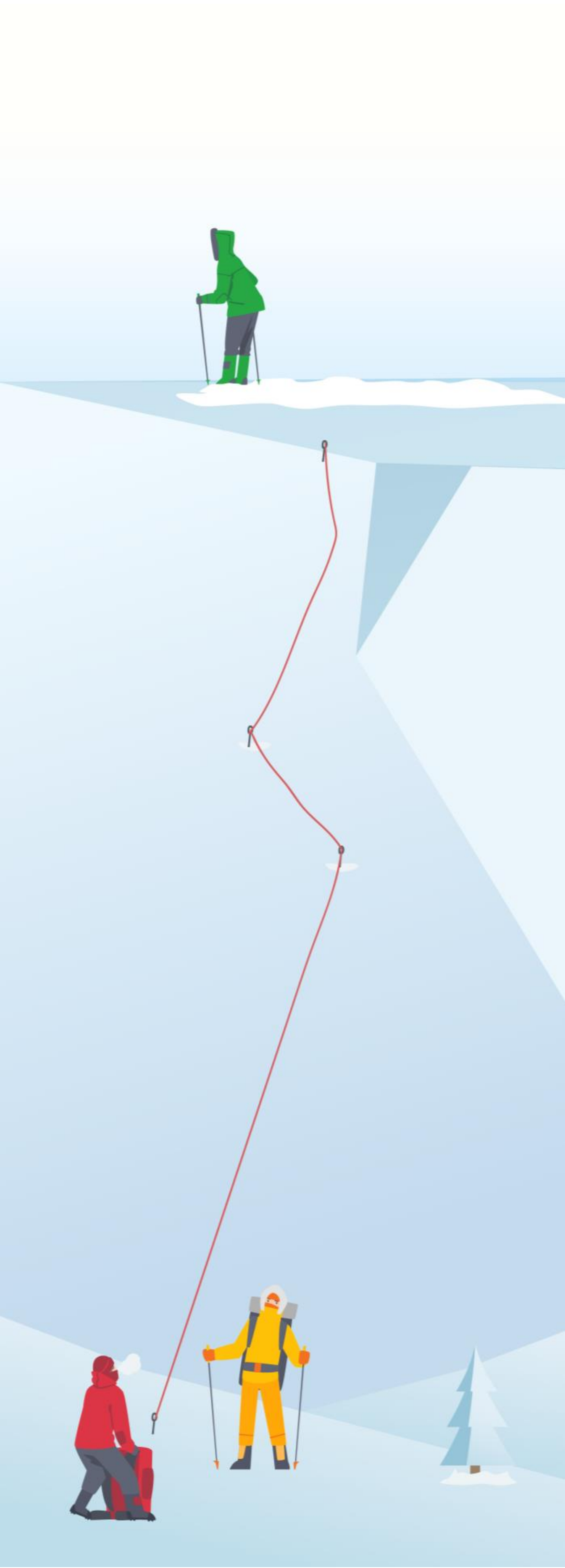


Figure 8 compares the 15 key clean energy technologies based on the share of deployment in 2050 in the 1.5°C scenario relative to the Reference scenario, applying a colour coding of green, yellow and red, depending on progress.

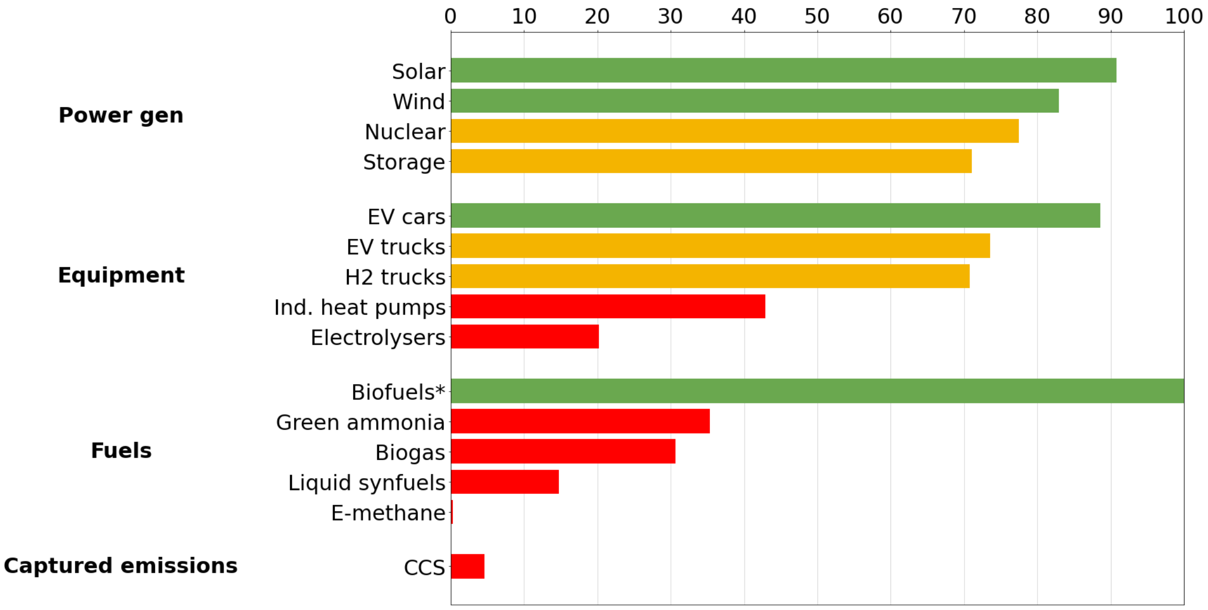
Four of the technologies are assessed as ***competitive***, four as almost competitive, and seven as uncompetitive. Two of the four competitive technologies are found in the power generation sector, where solar and wind are expected to be the main emission-free power generation technologies over the coming decades, and are already the lowest cost form of new generation in many markets. Likewise, rapidly accelerating global sales of electric cars and their total user cost advantage over their entire lifetime in some markets see electric cars being competitive with internal combustion engine cars over the next decades. Biofuels are also rated as competitive, but this is a particular case as their production in the Reference scenario exceeds that of the 1.5°C in 2050. As explained in more detail below, the higher climate ambition of the 1.5°C scenario sees a reduced role for biofuels overall as higher electrification occurs instead.

The group of ***almost competitive*** technologies includes nuclear as well as storage technologies which are required in the power generation sector to assist in integrating intermittent renewables. It also includes low-emission technologies used in end-use sectors of heavy transport and industrial heat. These technologies, while undergoing cost reductions, generally require additional policy support to enter the market at the deployment rates seen in the 1.5°C scenario.

Finally, the group of seven ***uncompetitive*** technologies cover the production of low-emission fuels, which see persistent cost premiums compared to fossil fuels over the projection period, and as such require significant additional policy support. Also in this group is the technology of CO_2 capture, required to provide CO_2 inputs to synfuel production and also produce negative emissions, which by definition in our scenario setup would be a policy-supported activity pursued in deep decarbonisation scenarios. While the uncompetitive technologies account for a smaller share of total emissions reductions, their role is critical: the full technology portfolio will be necessary to be deployed in a timely manner to reach the 1.5°C scenario.

An important additional **policy-relevant** lens is to consider the timing and nature of support required. The almost competitive technologies require additional policy support immediately, so as to begin to close the gap, increase the production capacity for these technologies and scale-up to a higher extent in the coming decade. Technologies in the uncompetitive group are at an earlier stage and require policymaker support in the form of pilots, R&D funding, early-stage market interventions and clear legal framework in support of their future uptake. Keeping in mind such timing differentiation allows the distribution and targeting of effort and the choice of policymaking tools.

Figure 8. Percentage of the 1.5°C scenario global level achieved in the Reference scenario, in 2050.



Source: POLES-JRC model.

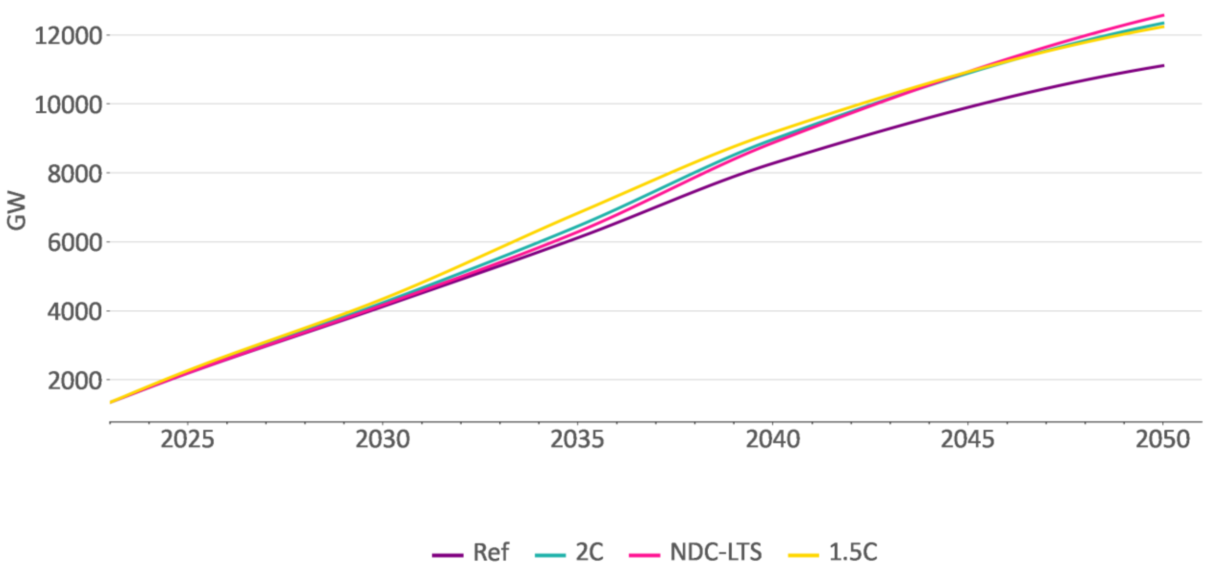
The rest of this section examines the competitiveness of each individual technology.

4.2. Power generation

4.2.1. Solar

Globally, solar power capacity increases from 1.3 TW in 2023 to reach 11.3 TW in 2050 in the Reference scenario and 12.9 TW in the 1.5C scenario (see **Figure 9**). All four scenarios show similar levels of installations through the projection period, indicating that, under future market conditions and related technology evolution, solar power is competitive with incumbent fossil fuel technologies. Only a minor additional policy support is required to achieve deployment aligned with 1.5°C levels.

Figure 9. Global installed capacity of solar power, by scenario.

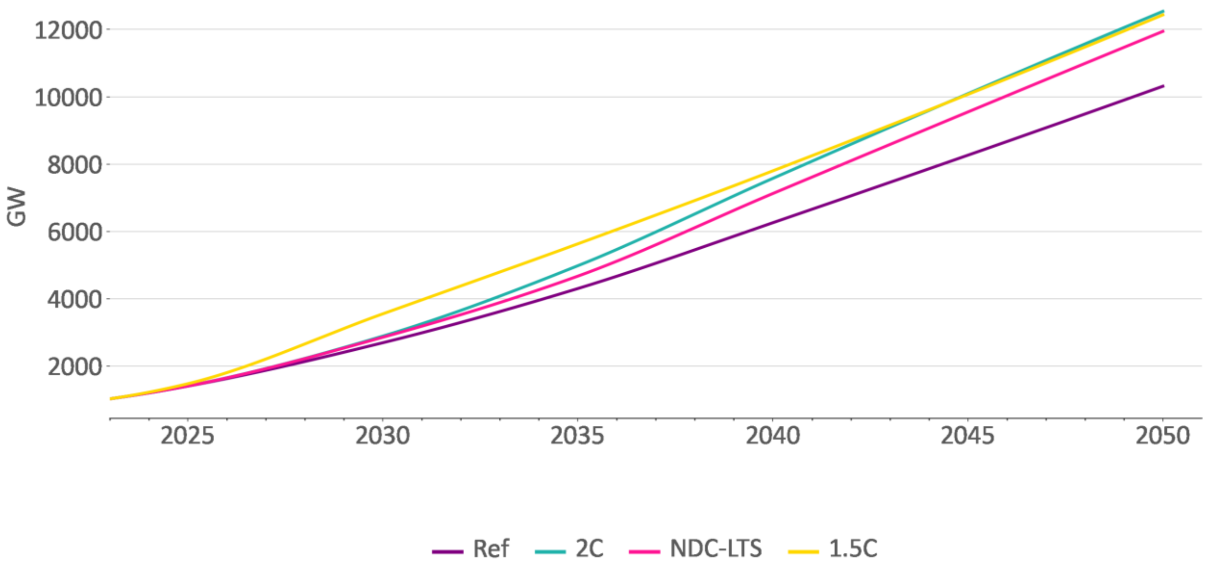


Source: POLES-JRC model.

4.2.2. Wind

Similar to solar, the other predominant renewable power generation technology, wind power, sees comparable deployment levels across all four scenarios, increasing from 1.0 TW in 2023 to reach 10.2 TW in 2050 in the Reference scenario and 12.2 TW in the 1.5°C scenario (**Figure 10**). Previous decades of supportive policy and technology development have led to the situation where future wind power deployment in the Reference scenario is only marginally short of what is required to be 1.5°C aligned.

Figure 10. Global installed capacity of wind power, by scenario.



Source: POLES-JRC model.

Despite the technological progress, several challenges and limitations hinder the further expansion of solar and wind. Paradoxically, technology development is not the primary constraint.

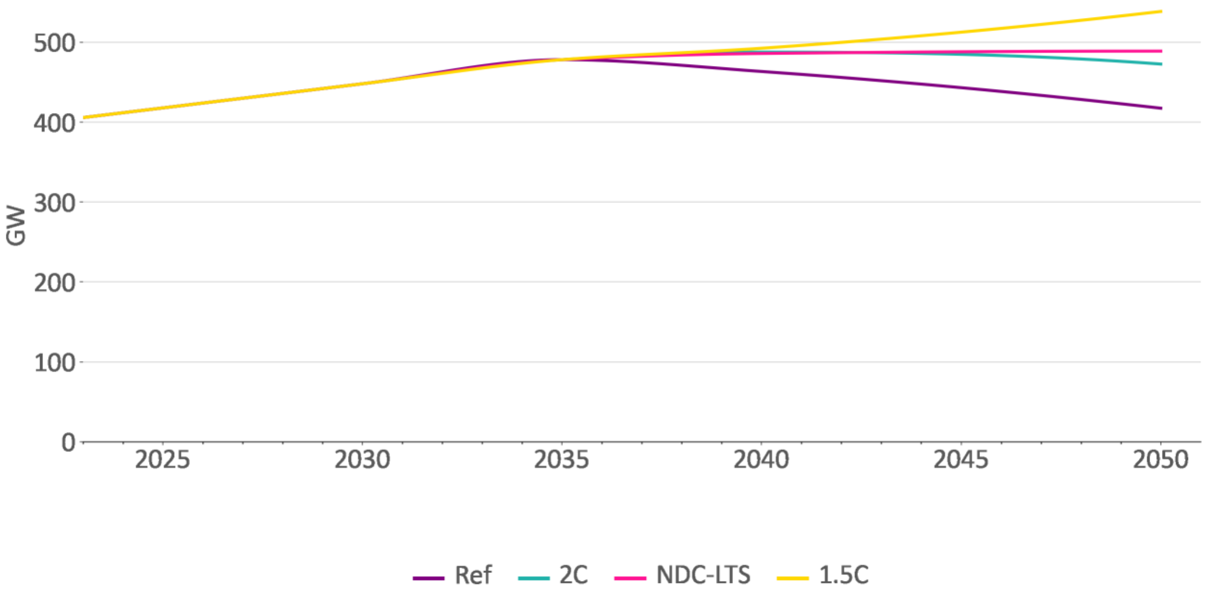
- One key challenge is the simultaneous scaling of PV, wind, and hydrogen production, which increases demand for materials and raises concerns about raw material scarcity. Supply chain limitations can lead to price spikes for critical materials (e.g., copper, and silver for PV).
- System integration limits also pose a significant challenge as the share of renewable energy sources in the energy mix increases. To balance supply and demand, electricity systems require more storage, demand response, dispatchable generation, and geographic balancing through large interconnections. A lack of these features can lead to grid congestion and curtailment.
- Furthermore, the expansion of renewable energy can be hindered by non-technical factors, including permitting delays for transmission lines, environmental litigation, and public opposition to high-voltage transmission lines and wind farms (NIMBYism). The competition for land use is another critical aspect, as renewable energy development must be balanced with agriculture, nature conservation, and other energy uses, such as biomass production.

4.2.3. Nuclear

Nuclear power generation currently accounts for approximately 10% of global electricity production. Within POLES-JRC, nuclear power is both a major source of electricity generation and is an option for hydrogen production via nuclear-powered electrolysers.

Nuclear power is experiencing renewed interest in recent years, however current policy support and recent technology cost developments[8] see nuclear power broadly maintaining its current level. In all four scenarios, capacities are between 420 and 550 GW over the projection period (**Figure 11**). Deployment of nuclear generation sees a slight decrease over the projection period in the Reference scenario, whereas an increase is required to reach the levels of the 1.5°C scenario, indicating the need for additional policy support above currently enacted policies.

Figure 11. Global installed capacity of nuclear power, by scenario.



Source: POLES-JRC model.

The nuclear sector is currently seeing a diversification of emerging nuclear technologies. Besides traditional Large Pressurized Water Reactors (LPWRs), new designs such as Small Modular Reactors (SMRs), Generation IV reactors, and Advanced Pressurized Water Reactors (APWRs) are being developed. These innovative designs aim to improve efficiency, safety, speed of deployment, scalability, flexibility, cost competitiveness and nuclear waste reduction.

Public perception and acceptance are essential for the development and deployment of nuclear power. Therefore, for a nuclear expansion to be successful, it is crucial to address safety, security,

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[8] Little technological learning is projected for nuclear. In the modelling for this report, nuclear investment costs are indexed on the high costs of Western economies. In addition, due to long permitting procedures and long construction times, the projections for nuclear capacities over the next decade are constrained by existing and mature projects, leaving only the period post-2035 for the expansion of capacities above those projects.

and environmental concerns through transparency and community engagement, fostering trust and public support.

4.2.4. Storage

The main electricity storage technologies explicitly considered are battery energy storage (BES), compressed air energy storage (CAE), and pumped hydro storage (PHS), while vehicle-to-grid (V2G) and demand-side management (DSM) are included only as supplementary flexibility options and remain comparatively limited in the scenarios. BES is represented as a single generic battery technology for stationary storage, whereas PHS and CAE are treated as established system-scale storage options.

The key technical and economic parameters of the storage options are mainly expressed through technology cost, learning dynamics and system constraints. For BES, the most important parameters are its overnight investment cost, which benefits from endogenous spillover from battery deployment in transport and declines from about 360 $/kWh in 2025 to 280 $/kWh by 2050 (with a learning rate of 12%). PHS is currently the dominant storage technology, but its further deployment is limited by site-specific constraints and low scalability. CAE has a similar storage-cost level to PHS but is constrained by the scarcity of suitable geological formations, which restricts large-scale expansion despite its favourable cost profile.

Deployment of storage technologies in the power sector[9] is set to increase dramatically in the coming years, in all four scenarios, as the increasing penetration of variable renewables presents increasing needs for balancing. Given the site constraints of PHS and CAE the bulk of electricity system balancing is provided by BES. **Figure 12** shows that storage installations increase from 400 GW in 2023 to reach 3200 GW in the Reference scenario and 4400 GW in the 1.5°C scenario by 2050. However, there is a large gap between the current pathway and what is required in the 1.5°C scenario, indicating that technology cost improvements and current market conditions are not enough to see storage achieve deployment rates aligned with the 1.5°C target. The Reference scenario sees an annual average growth rate of 8%, additional policy support is required to bridge the gap to the 10% growth rate of the 1.5°C scenario.

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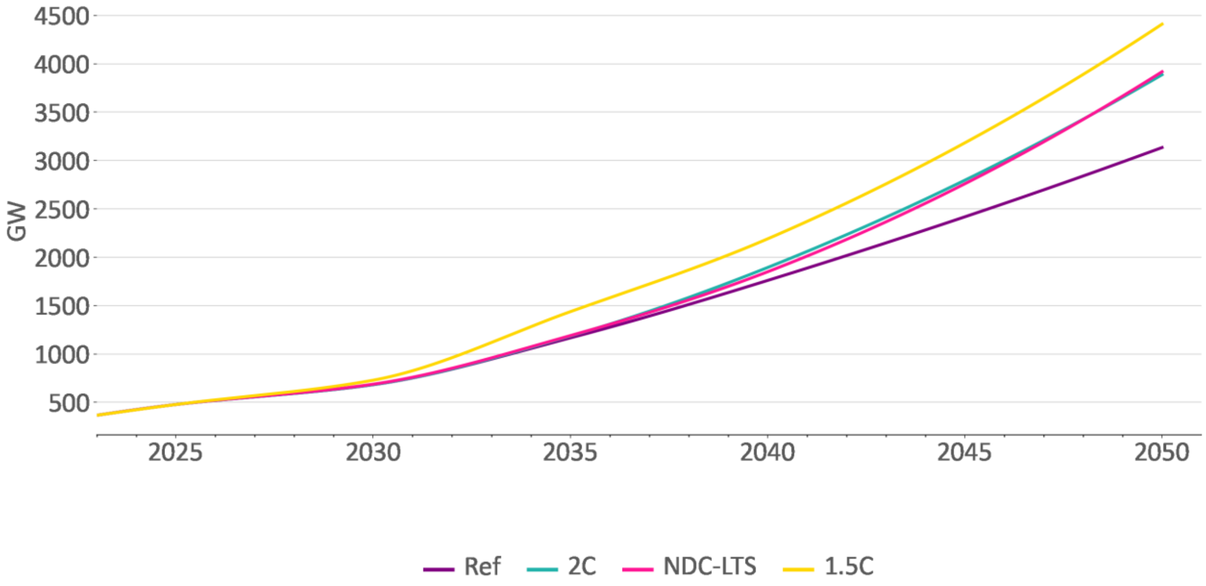
[9] In this definition, storage technologies encompass intra-day storage and flexibility options: hydro pumped storage, compressed adiabatic air storage, stationary batteries, electric vehicles-to-grid and demand-side management (i.e. load shifting).

Figure 12. Global installed capacity of storage in the power sector, by scenario.



Source: POLES-JRC model.

4.3. Equipment

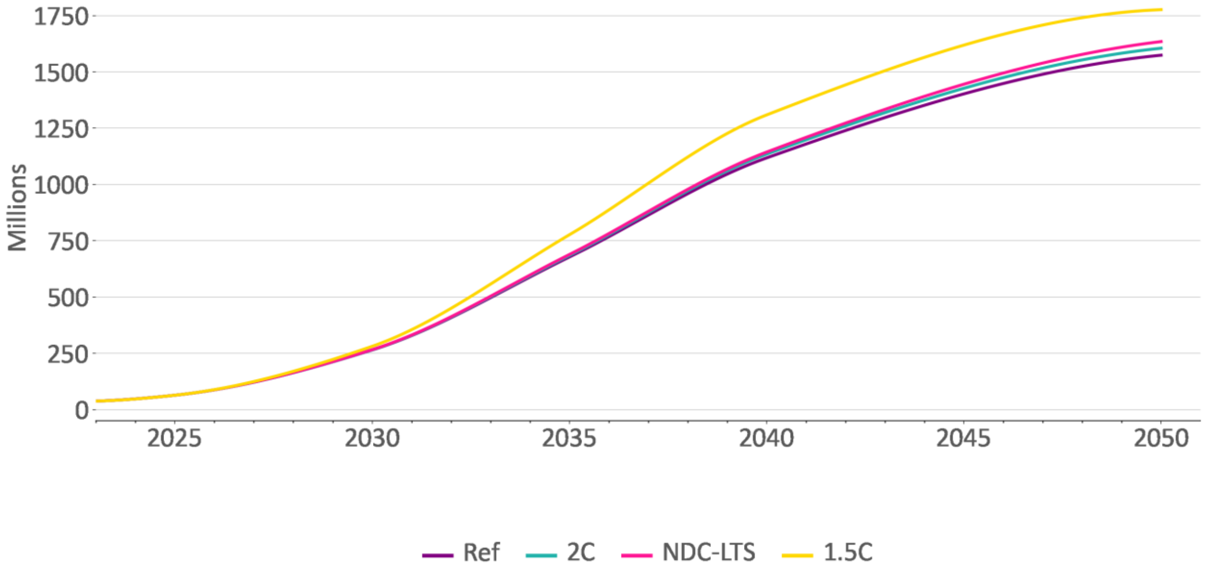
4.3.1. Electric cars

Electric cars and trucks (and hydrogen fuel cell vehicles) are described through a consistent set of techno-economic parameters, notably overnight investment costs, endogenous learning rates, and floor-cost constraints. Batteries are simplified into a generic battery technology per application, as the long-run “winning” chemistry remains uncertain, while costs are allowed to evolve in each application (cars, trucks, aircraft) depending on the sectors’ specific characteristics (energy capacity, cycles, weight).

Currently car batteries cost approximately 105 \$/kWh and have a high learning rate (13%), which drives rapid cost reductions as cumulative deployment increases over the projection period. A 42 \$/kWh floor cost is assumed for car batteries, reached around 2050.

The coming decades see a dramatic increase of the global electric passenger car fleet, increasing from around 38 million vehicles in 2023 to 1.6 billion in the Reference scenario and 1.8 billion in the 1.5°C scenario in 2050 (**Figure 13**), representing a 42-fold increase in the Reference scenario at an annual average growth rate of 15% over the projection period. The relatively small gap between the Reference scenario deployment levels and those of the 1.5°C scenario indicate that electric cars are competitive with internal combustion engines in most global markets over the projection period.

Figure 13. Global electric passenger car fleet, by scenario.



Source: POLES-JRC model.

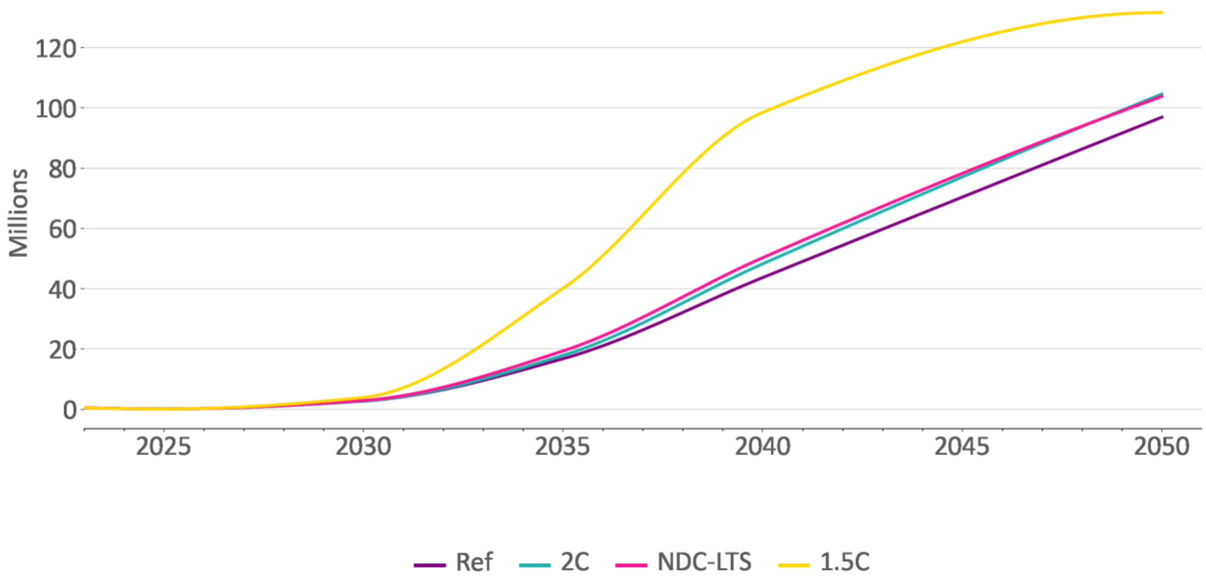
Barriers for large-scale electrification are linked to energy costs and infrastructure availability. On the electricity side, the competitiveness of electric vehicles depends not only on falling battery costs, but also on the cost of the increasingly low-carbon power generation, since higher retail electricity prices directly increase operating costs and can weaken the economic case for switching. Fleet expansion is also constrained by infrastructure rollout: electric vehicles need a sufficiently dense network of charging stations: without this enabling infrastructure, consumer acceptance (e.g., charging speed expectations) and EV sales can be dampened.

4.3.2. Electric trucks

Electric truck batteries remain more expensive per kWh than those of electric cars due to more complex battery-management needs, and costs only approach the floor costs after 2050.

Contrary to electric cars, electric trucks are not sufficiently competitive globally with internal combustion engine trucks over the projection period, showing a significant gap between the Reference scenario fleet of 95 million and the 1.5°C fleet of 130 million by 2050 (**Figure 14**). Purchase and operating costs are expected to decrease over the projection period, but additional policy support is required to reach levels seen in the 1.5°C scenario. Policy support is critical in the coming decade, as electric truck deployment in the Reference scenario lags significantly behind the accelerated expansion required by the 1.5°C scenario.

Figure 14. Global electric truck fleet, by scenario.



Source: POLES-JRC model.

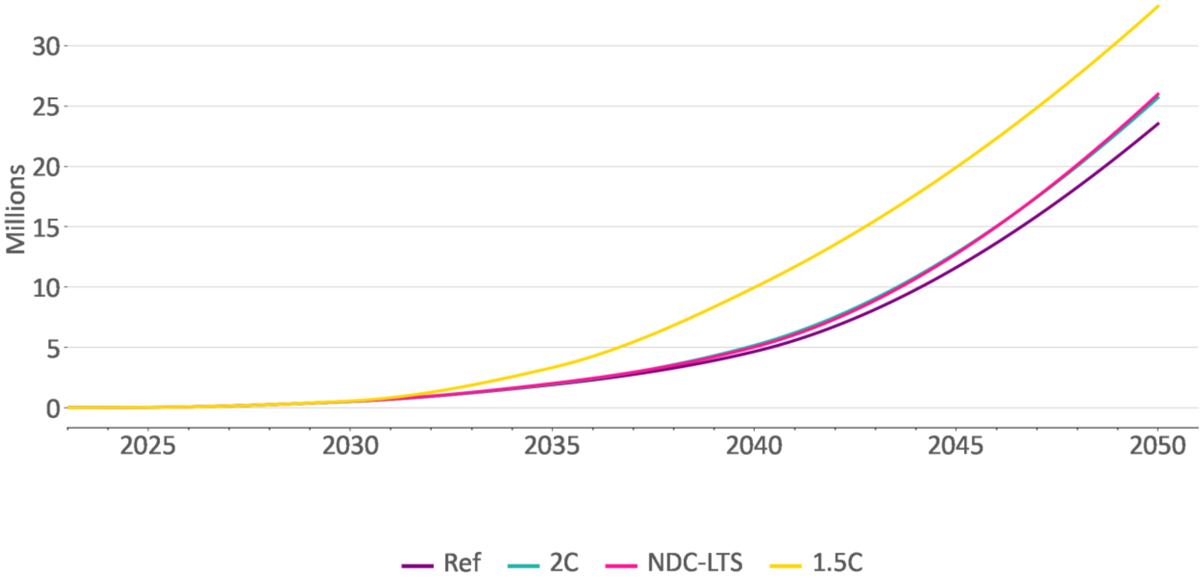
4.3.3. Hydrogen trucks

The barriers to adoption for hydrogen fuel cell vehicles is often higher than for electric vehicles[10]. Fuel cell systems (including the hydrogen tanks) cost about 310 $/kW today, decreasing to about 110 $/kW in 2050. The hydrogen fuel costs are also a major cost component in the total user cost. Low-carbon hydrogen costs reflect both electrolyser cost and electricity costs. In addition, transport and distribution costs are a significant cost in the hydrogen value chain, as fuel cell vehicles require the build-out of hydrogen logistics and refuelling networks, with delivery chains using pipelines or trucks and hydrogen refuelling stations.

The reduction in the costs of clean hydrogen production and hydrogen fuel cells are only sufficient to see hydrogen trucks become competitive with internal combustion trucks post 2035. By comparison, hydrogen cars have a lower market share in the cars market segment, due to the higher market share of battery-electric cars.

The global hydrogen truck fleet is in its infancy today and reaches 2 million vehicles in 2035, then 23 million in 2050 in the Reference scenario. In the 1.5°C scenario the global fleet increases, reaching 3 million in 2035 and 34 million in 2050 (**Figure 15**). Importantly, the take-off in the deployment of hydrogen trucks occurs later in the projection period, after 2035, and the scale of the hydrogen truck fleet reaches only around a quarter of the electric truck fleet. This indicates that for trucking, policymaker’s focus in the coming years should be on electric trucks.

Figure 15. Global H2 truck fleet, by scenario.



Source: POLES-JRC model.

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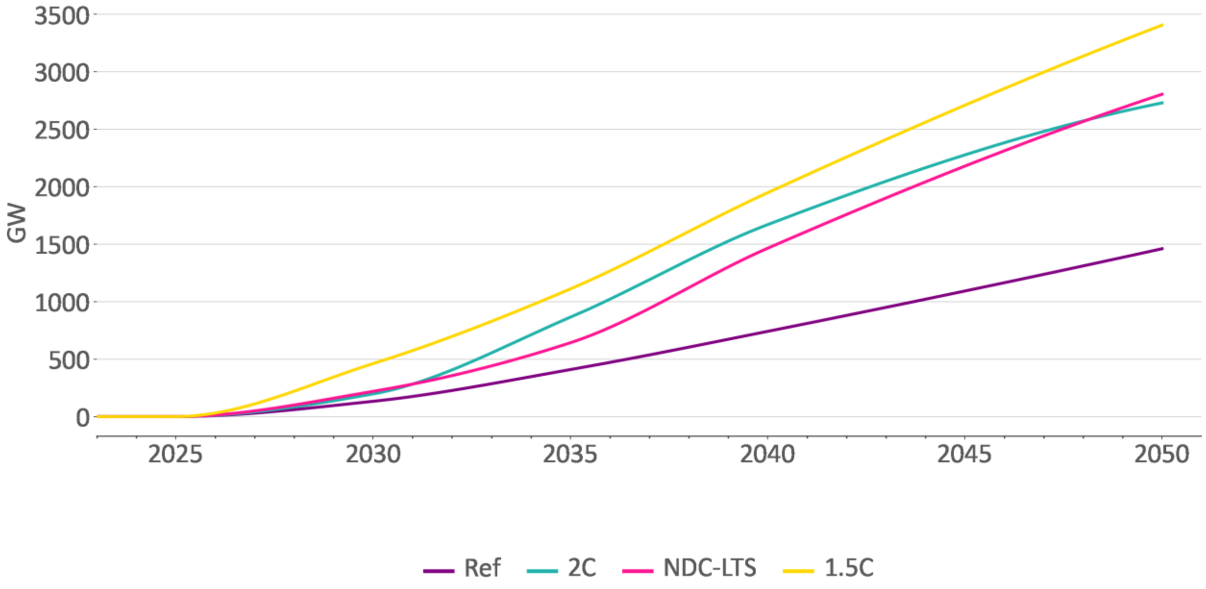
[10] When two clean energy technologies are competing in the same market, such as electric trucks and hydrogen fuel cell trucks, the resulting relative competitiveness across scenarios for each technology is impacted also by the other clean energy technology. As such, the acceleration of policy support for one technology can impact the competitiveness of the other technology.

4.3.4. Industrial heat pumps

Industrial heat pumps have significant potential for rapid electrification of industry, particularly in temperature ranges up to 200 °C. By using waste heat from other processes or ambient heat, industrial heat pumps can provide a reliable and efficient source of heat. Currently, heat pumps are well-established for applications requiring temperatures between 60–120 °C. Advanced systems for 150–200 °C are under development, defining the current technology frontier for industrial heat pumps.

Expected cost reductions and existing policy support sees industrial heat pumps starting to penetrate the market around 2030 in the Reference scenario. Under the three more ambitious scenarios, the rate of penetration of industrial heat pumps increases markedly, reaching more than twice the deployment of the Reference scenario by 2050. Industrial heat pumps are rated as uncompetitive. Further cost reduction and policy support for low-emission heat production is required to achieve deployment rates aligned with climate targets.

Figure 16. Global industrial heat pump installations, by scenario.



Source: POLES-JRC model.

The efficiency of heat pumps, as measured by the coefficient of performance (COP), is directly tied to the temperature differential between the heat required and the available heat source, which influences overall costs; the COP is expected to increase in the coming decades as the technology is deployed further. The other driver of competitiveness is the differential between electricity and fossil fuels costs; markets with low electricity costs and higher fossil fuel prices, such as in markets with carbon pricing schemes, see greater deployment of heat pumps.

However, several challenges impede the widespread adoption of heat pumps in industry. The high upfront costs and the sector's expectations for rapid returns on investment can discourage companies from investing in heat pumps, while the integration of these systems into existing processes can be complex. To overcome these hurdles and bridge the gap in capacity expansion between the Reference scenario and decarbonisation scenarios, targeted policy support and investment incentives are crucial.

4.3.5. Electrolysers

Electrolyser technologies are represented through two pathways for hydrogen supply: low-temperature (LT) electrolysis and high-temperature (HT) electrolysis. LT electrolysis is parametrised as a generic mix of alkaline and proton exchange membrane (PEM) electrolysers and is supplied by low-carbon electricity from dedicated solar and wind capacities, Generation III nuclear and, when available, grid electricity during wind or solar oversupply. HT electrolysis is introduced towards the middle of the century and is modelled as being powered by advanced Generation IV nuclear.

Both push and pull policies can influence the competitiveness of electrolysers. On the supply side, electrolyser uptake is constrained by cost: its overnight investment cost of electrolyser unit declines from about \$1500/kW$_{H2}$ today to as low as ~\$420/kW$_{H2}$ by 2050 (assuming a learning rate of 15%). In the POLES-JRC framework, the cost of producing hydrogen via electrolysis encompasses not only the investment costs of the actual electrolysers, but also the investment costs for the power plants (solar, wind, nuclear) which follow their own cost decrease dynamics. Consequently, the economics in the power sector affect the costs of hydrogen and thus the level of deployment of electrolysers.

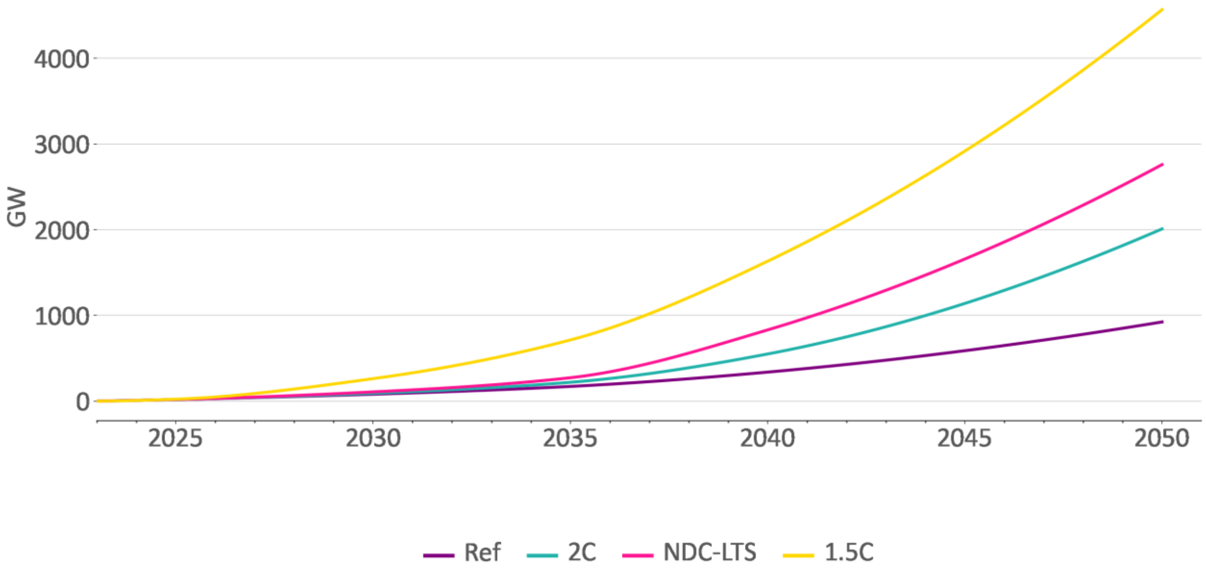
Electrolyser efficiency is also crucial as it sets electricity consumption per unit of hydrogen produced. Efficiency improves from roughly 65% today to about 75% by 2050, but even with these improvements the electricity supply remains a major cost component.

On the demand side, electrolyser uptake is constrained by the low demand of hydrogen and hydrogen derivatives.

In the Reference scenario, the global installed capacity of electrolysers remains insufficient, as technology costs and market conditions see only a modest increase in green hydrogen demand. Most of the green hydrogen demand emerges in maritime and aviation, where low-carbon fuel mandates are partially met through hydrogen-derivatives such as ammonia and synthetic fuels. Reference scenario deployments increase to 170 GW in 2035 and 890 GW in 2050 (**Figure 17**).

These levels fall far short of what is required in the 1.5°C scenario, which see electrolyser capacity reach over 600 GW in 2035, reaching levels in 2035 that the Reference scenario only sees a decade later. After 2035, global electrolyser capacity accelerates in the 1.5°C scenario, reaching 5200 GW of capacity by 2050. The large gap between scenarios, which widens post-2035, indicates a significant shortfall in market conditions, requiring enhanced policy support.

Figure 17. Global installed capacity of electrolysers, by scenario.



Source: POLES-JRC model.

The strong increases in electrolyser capacity in the NDC-LTS and 1.5°C scenarios are underpinned by major sectoral shifts in hydrogen demand. Compared to the Reference scenario, hydrogen demand declines in the chemicals sector and in refineries, while it rises sharply in transport and in energy-intensive industry, especially in iron and steel. This highlights the importance of sector-specific policy support: the scale-up of renewable hydrogen depends not only on supply-side support, but also on targeted demand creation in transport and industries that ultimately drive hydrogen and hydrogen derivatives use.

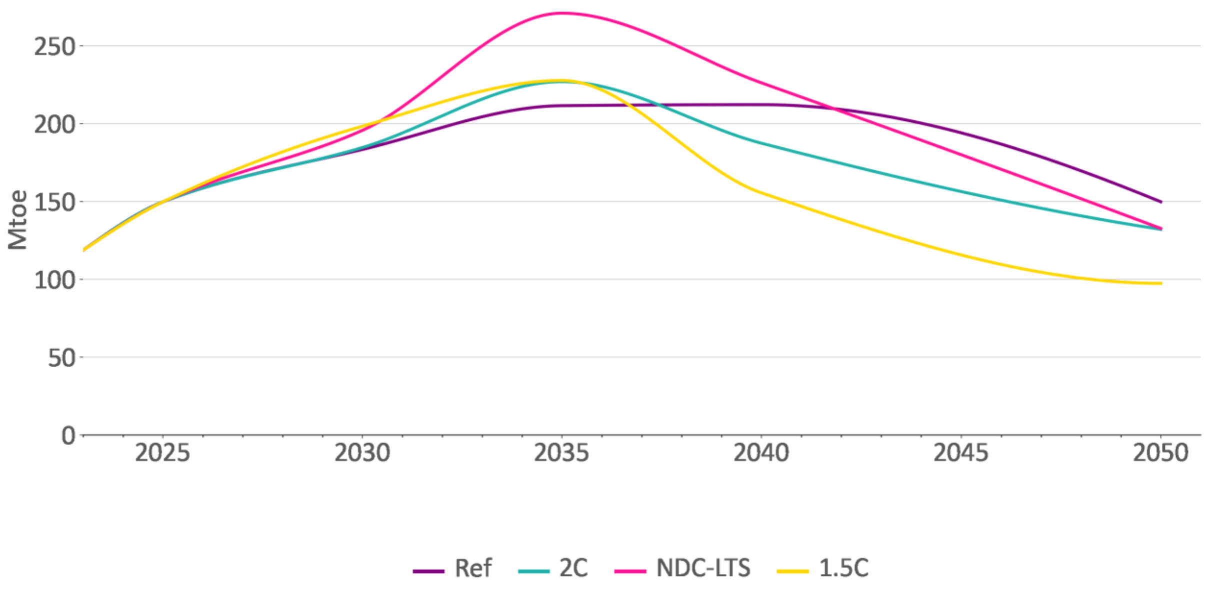
4.4. Fuels

4.4.1. Biofuels

In POLES-JRC, liquid biofuels are used exclusively in the transport sector and are produced through two main routes: first-generation (1st-gen) routes, which include corn dry-mill ethanol and biodiesel from oilseed crushing plus transesterification; and second-generation (2nd-gen) routes, which involve lignocellulosic ethanol production via enzymatic hydrolysis and lignocellulosic biodiesel production via gasification and Fischer-Tropsch synthesis.

The evolution of global biofuels production across the four scenarios highlights how strongly their role depends on the level of climate ambition (**Figure 18**). Under current policies, biofuels broadly maintain today's share in the transport fuel mix. As climate ambition increases, liquid biofuels tend to peak around 2030–2035 and then decline. Biofuels are progressively displaced in road transport by electric vehicle; in the maritime transport a growing share of demand is met by ammonia and hydrogen; and in aviation they are displaced by synthetic fuels (synfuels). In parallel, the phase-out of 1st-gen biofuels across all scenarios reduces the availability of lower-cost volumes, shifting the mix toward more expensive 2nd-gen pathways. As a result, in deep decarbonisation scenarios, liquid biofuels are increasingly reserved for the hard-to-electrify segments, even as overall production falls relative to the Reference scenario. In the 1.5°C case, the limited biomass resource is also reallocated toward options with higher decarbonisation potential, such as BECCS.

Figure 18. Global production of liquid biofuels, by scenario.



Source: POLES-JRC model.

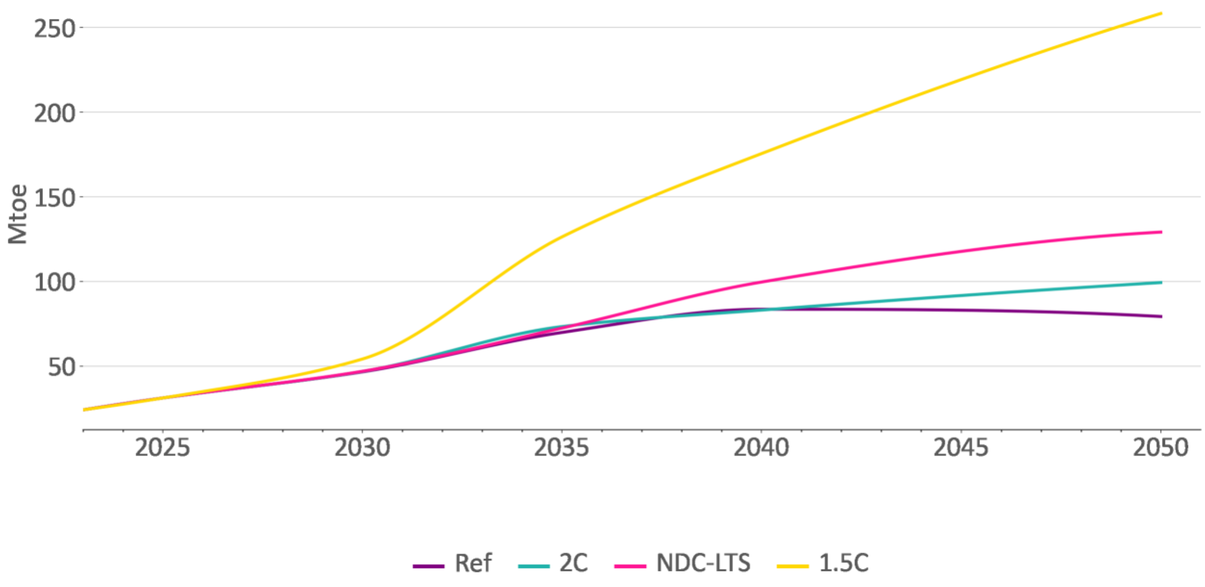
1st-gen biofuels (crop-based ethanol/biodiesel) face persistent obstacles linked to sustainability and market acceptance: concerns about land use for food vs. fuel, indirect land use changes induced by biofuel production, and broader environmental impacts can constrain political support. For 2nd-gen biofuels (advanced, residue/waste-based), the barriers are rather related to economics, scale-up risk, and logistics (Motola *et al.*, 2025). These projects are typically capital-intensive, often still carry higher production costs, and therefore depend heavily on stable policy support (e.g., mandates/premiums) to make a suitable investment case. On top of that, many advanced routes still involve technology maturity and integration challenges (e.g., lower technology readiness levels (TRLs) for some pathways).

4.4.2. Biogas

For gaseous bioenergy, the biogas pathway starts with anaerobic digestion (producing a CH_4/CO_2 mix) and then upgrading to grid-compliant biomethane that is a fossil gas substitute, and is blended into existing gas networks for heating, power generation and transport.

Biogas is expected to be an increasingly important low-emission gas substitute in all scenarios. Global biogas production increases from 24 Mtoe in 2023 to 70 Mtoe in 2035 and then 80 Mtoe in 2050 in the Reference scenario (**Figure 19**). The gap between the Reference and 1.5°C scenarios widens from 2030 onwards. In 2035 in the 1.5°C scenario global biogas production reaches 100 Mtoe and then 260 Mtoe by 2050, more than triple the Reference scenario.

Figure 19. Global production of biogas, by scenario.



Source: POLES-JRC model.

This stronger growth is driven by changing relative economics: while biogas production costs fall slightly over time due to learning, the effective cost of fossil gas increases as carbon prices rise, shifting the gas supply mix progressively in favour of biogas. The increasing global production of biogas in the next decade in the Reference scenario suggests that market conditions and policy support are already in place in some regions; however, these will need to be strengthened and extended to new markets to reach the levels required under the 1.5°C pathway.

4.4.3. Liquid synfuels

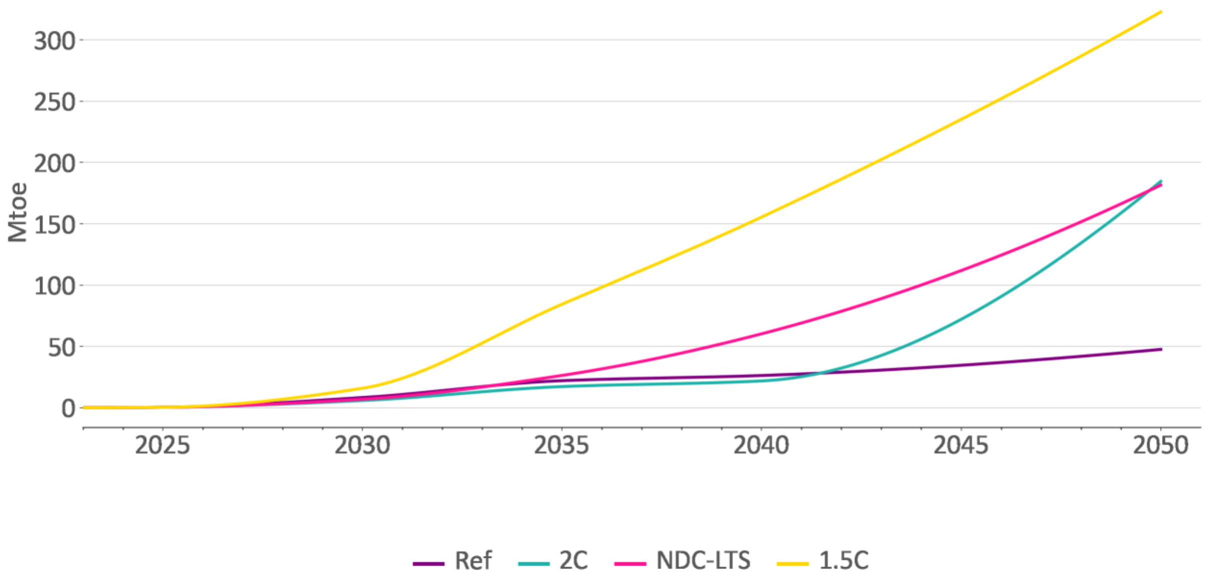
The production of synfuels involves a complex value chain, encompassing hydrogen production, CO_2 feedstock provision, and the actual synthesis of fuels. Synfuels are obtained from power-to-gas and power-to-liquid processes. In these processes hydrogen and CO_2 are converted to gaseous or liquid hydrocarbon fuels through methanation or Fischer-Tropsch synthesis. The required hydrogen is produced from electrolysis powered by renewables, and the CO_2 is sourced from direct air capture. Synfuels are referred to as renewable fuels of non-biological origin (RFNBOs).

The "drop-in" nature of synfuels allows for the continued use of existing engines and pipelines, mitigating the risk of stranded assets. Liquid synfuels are used only in transport—covering road, aviation, and maritime—as drop-in substitutes for oil products, and similar to oil products they can be traded across regions using pipelines and shipping.

Due to their high upfront cost, synfuels adoption is largely driven by policy.

Liquid synfuels offer an important decarbonisation option in the maritime and aviation sectors. The technology cost and market conditions in the Reference scenario see deployment of these fuels only in markets with specific targeted policies in their support and zero penetration outside of these markets, as they fail to be competitive with oil; liquid synfuels demand is below 50 Mtoe by 2050. In the 1.5°C scenario global production reaches 84 Mtoe in 2035 and 323 Mtoe in 2050. Importantly, global production takes-off post 2030 in the 1.5°C scenario and grows steadily at an average annual rate of 22%. The large gap between the current Reference scenario outlook at the 1.5°C projections needs to be addressed today to see a post-2030 market penetration at these higher growth rates.

Figure 20. Global production of liquid synfuels, by scenario.



Source: POLES-JRC model

Due to their high cost, policies have focused on creating a market pull for synfuels with sector-specific mandates, to drive cost reductions through learning effects in the long term. Early volumes of liquid synfuels for aviation are expected to enter mainly through Sustainable Aviation Fuel (SAF) mandates, with the EU's ReFuelEU Aviation regulation being the strongest near-term pull: it sets a binding SAF blending ramp-up (e.g., 6% SAF in 2030) and includes a dedicated sub-mandate for synthetic aviation fuels starting in 2030 (rising substantially towards 2050). Beyond such mandate-driven markets broad global uptake before mid-century is limited. Unless high enough carbon prices close the cost gap for DAC and green hydrogen pathways, synfuels remain niche.

To increase synfuel production from its current low level in the Reference scenario to the higher levels seen in stringent carbon policy scenarios, targeted Research and Innovation (R&I) to address technological bottlenecks:

- Direct Air Capture (DAC) of CO_2: still in the early stages of development, with a low Technology Readiness Level (TRL). DAC upfront costs include investment for the DAC unit and compressor, additional investment for dedicated wind/PV capacity and associated battery capacity to power the DAC process, and fossil gas input to provide process heat.
- Green hydrogen production: dependent on the cost of electrolyser and dedicated wind/PV capacities, which are all projected to experience cost reductions.
- Synfuel production: although the technology is mature, it suffers from low efficiencies and challenges when coupled with intermittent renewable hydrogen production.

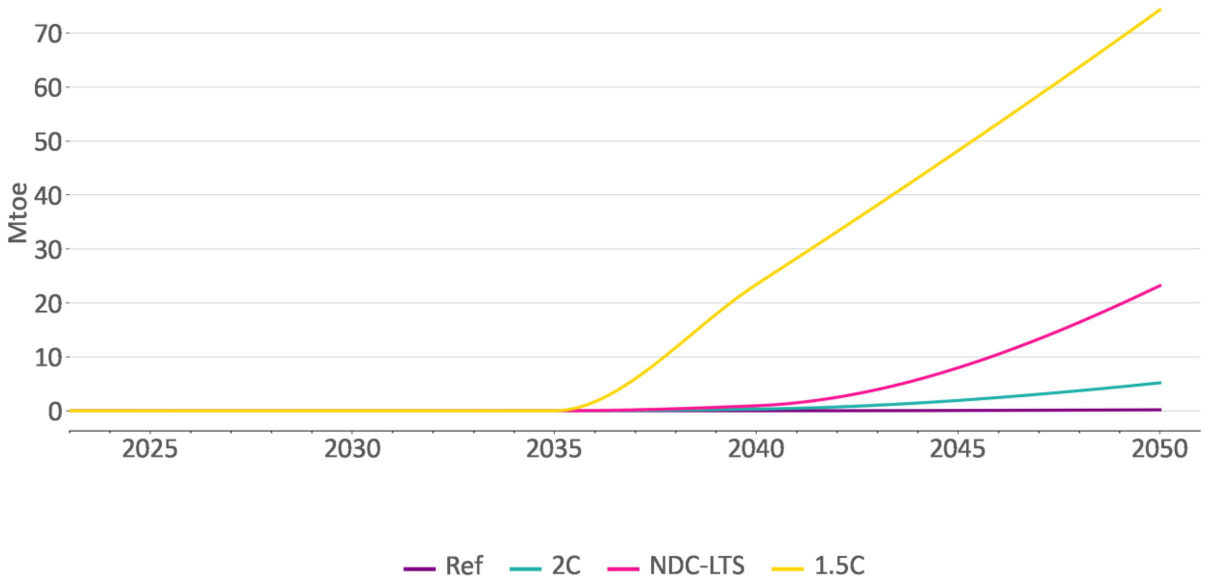
Additionally, developing the necessary infrastructure along the value chain, including system integration with variable renewables, CO_2 feedstock, transport and storage infrastructure, and ensuring compatibility with existing infrastructure. Reducing regulatory uncertainties along the value chain is also crucial.

To accelerate the expansion of synfuels, transitional technology combinations, such as using CO_2 feedstock from power or hydrogen production plants equipped with carbon capture, can play a vital role.

4.4.4. E-methane

E-methane[11], is a synthetic gas used as a replacement for fossil gas in industrial applications (notably steel, chemicals, and non-metallic minerals) that are located sufficiently close to low-cost production sites, or in road vehicles that use compressed natural gas (CNG) as a fuel. E-methane can provide a lower-emissions solution compared to coal-fuelled industrial processes; combined with carbon capture, it can result in a low-carbon option for high-temperature processes where electrification will be difficult to achieve. E-methane sees essentially zero production in the Reference scenario, due to its higher costs compared to fossil gas. The 1.5°C scenario sees a take-off in demand for e-methane around 2035, followed by steady growth to reach 80 Mtoe of global production in 2050 (**Figure 21**).

Figure 21. Global production of e-methane, by scenario.



Source: POLES-JRC model.

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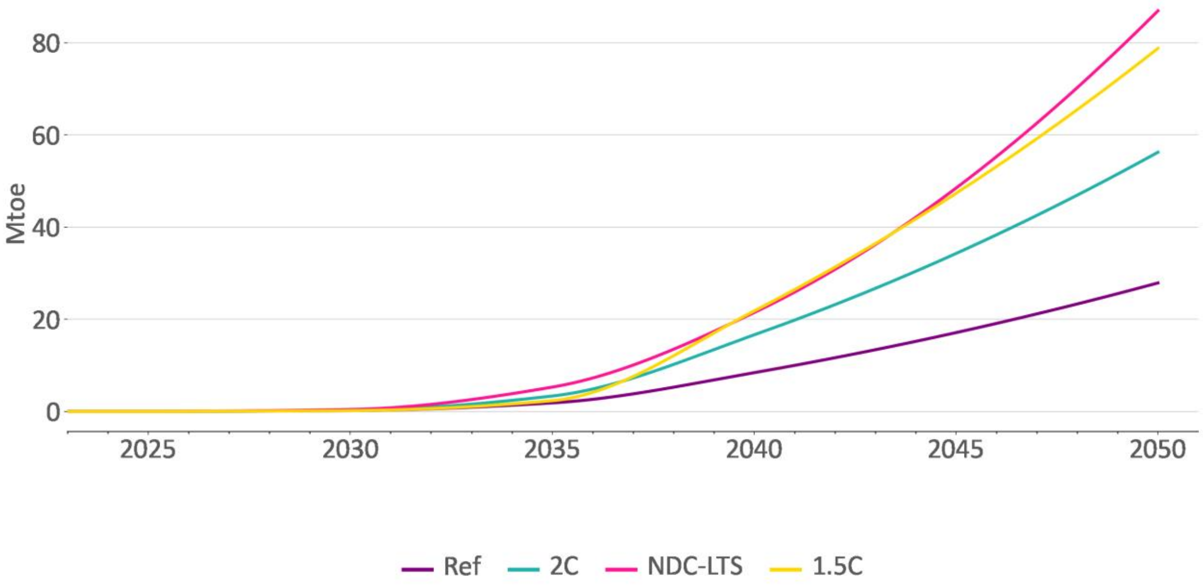
[11] E-methane is obtained from power-to-gas processes, in which hydrogen and CO_2 are converted to methane through methanation. The required hydrogen is produced from electrolysis powered by renewables and the CO_2 is sourced from direct air capture. E-methane is referred to as a fuel of non-biological origin (RFNBO).

4.4.5. Green ammonia

The production of green ammonia[12] is an important option for decarbonising the ammonia used in fertilisers, and as a fuel in shipping. Existing policy support, most notably in the EU, sees global production of ammonia-as-fuel take off post 2035, reaching 70 Mtoe in 2050. Production levels in the 1.5°C scenario also accelerate after 2035, reaching 130 Mtoe in 2050, representing a large gap to the Reference scenario levels. An extension of existing support until 2050 and a broadening of this support to more countries is needed to close the gap. Strong decarbonisation targets in the shipping sector see even larger production in the NDC-LTS scenario, reaching 170 Mtoe in 2050. The corresponding levels for green ammonia-as-fuel are displayed in **Figure 22**.

Figure 22. Global production of green ammonia for fuel, by scenario.



Source: POLES-JRC model.

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[12] Green ammonia uses green hydrogen, which is converted to ammonia by the Haber-Bosch process. It is primarily used as a means of trading hydrogen internationally via shipping. In the importing country the ammonia is re-converted into hydrogen. Additionally, green ammonia and ammonia produced using other types of hydrogen is utilised as a lower-carbon fuel alternative for maritime transportation.

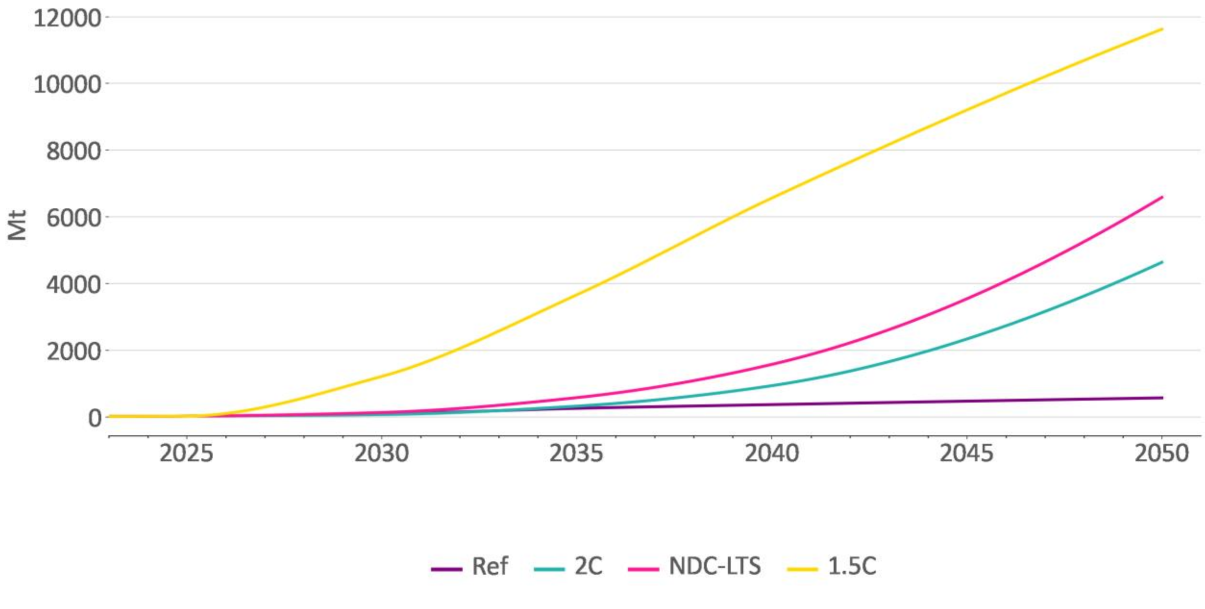
4.5. Captured emissions

4.5.1. CCS

Rather than competing with incumbent fossil-fuel technologies. the **capture of CO_2** has multiple roles in a decarbonised world: to provide CO_2 as inputs to produce various synfuels (see 4.4.3 and 4.4.4) and to reduce fossil fuel emissions or to create net-negative emissions with sequestration (CCS). The latter is achieved via capture and sequestration from biomass power generation (BECCS) and from direct air capture of CO_2 (DACCS).

CO_2 capture rates in the Reference scenario are relatively low over the projection period. Indeed, by scenario design, CCS is a policy-supported activity pursued in deep decarbonisation scenarios, as it does not provide any other service or product other than addressing the environmental externality of CO_2 emissions. In the Reference scenario, CO_2 capture remains uncompetitive in most regions as the market structures required to incentivise the capture of CO_2 remain largely non-existent; CO_2 capture is present only in markets with synfuel mandates and CCS emerges in markets with carbon prices (e.g., EU ETS). In the 1.5°C scenario, global CO_2 capture increases immediately and reaches 4 Gt in 2035 and 12 Gt in 2050 (**Figure 23**). The large gap between scenarios for such a key decarbonisation technology, starting already in the coming years, reveals a key area for increased policymaker attention.

Figure 23. Global capture of CO_2, by scenario.



Source: POLES-JRC model.

CCS technologies are relatively mature, with high TRLs. The more significant obstacle to the adoption of CCS technologies is the lack of economic incentives, as emitting CO_2 remains cheaper than capturing it in the absence of carbon pricing. Furthermore, in the presence of a carbon pricing, CCS faces competition from low-cost decarbonisation options, such as renewables combined with electrification and efficiency improvements. As a result, CCS only becomes a crucial component in deep decarbonisation scenarios.

Beyond the challenge of carbon pricing, the development of CCS technologies requires significant infrastructure build, to transport CO_2 via pipelines and shipping to storage sites. These sites must be capable of storing massive amounts of CO_2, over long time periods. To address this, policy support is required for the planning and provision of necessary infrastructure, accompanied by a clear and robust regulatory framework. In the absence of sufficient carbon prices, alternative measures such as mandatory capture rates and financial support for infrastructure development could help drive the adoption of CCS technologies.

5

Macroeconomic impacts of mitigation in a globalised vs fragmented world

5. Macroeconomic impacts of mitigation in a globalised vs fragmented world

The international trade system of the 2010s was a highly globalised one. Nonetheless, it is unclear whether this system will persist in the years to come. Increasing political uncertainties, rising trade tensions and changes in industrial policy raise the prospect of a shift towards a more fragmented global economy. As documented by the World Trade Organization (WTO), recent years saw the development of policies aimed at re-shoring production, the emergence of new challenges for the rules-based trade order as well as an increase in average tariff levels (WTO, 2024).

These changes in trade policy may affect traditional fossil fuel-related energy trade, but importantly also trade in the clean energy technologies discussed in Chapter 4. Chapter 5 delves further into relevant developments in the trade landscape, and investigates whether the degree of trade openness influences how countries reach their climate targets and their transition towards a 1.5°C-compatible pathway.

5.1. The tariff landscape in 2025

The WTO finds that nearly 20% of worldwide imports were affected by trade measures (predominantly tariffs) by late 2025, a marked increase from the 12.6% at the end of 2024. However, 2025 also saw the introduction of more trade-facilitating measures than the preceding year, reflecting certain countries' efforts to maintain smooth cross-border trade in times of increasing protectionism (WTO, 2025). In fact, five new regional trade agreements entered into force in 2025 (WTO, 2026), and at the time of writing progress is being made in trade talks by large economies such as the EU, India and the Mercosur region.

Before January 2025, imports into the US coming from the EU were subject to an average trade-weighted, ad-valorem tariff of only 1.1%. By January 2026, this had increased to 10.6%. Most other regions faced an average tariff of below 5% pre-January 2025, which increased to at least 10% or more in the span of one year (UN Trade and Development (UNCTAD), 2026).

The clean energy technologies discussed in Chapter 4 equally feel the impact of both trade-restricting and trade-facilitating measures. Electric cars are one of the technologies identified as competitive and market-ready in Chapter 4, and this extends into trade policy. Many regions are ramping up their EV production capacities and are aiming to establish a competitive position on the global market. Within this context, tariffs may be viewed as an industrial policy tool or as a way to safeguard domestic industries against unfair market practices abroad.

For example, many countries have a 0% Most-Favored Nation (MFN) tariff on electric cars,[13] but some emerging markets such as Indonesia, Thailand and Vietnam have import tariffs of over 25%. A similar logic applies to MFN tariffs on solar panels,[14] another competitive technology from

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[13] Based on HS 870380 - Motor cars and other motor vehicles principally designed for the transport of <10 persons, incl. station wagons and racing cars, with only electric motor for propulsion (excl. vehicles for travelling on snow and other specially designed vehicles of subheading 870310).

[14] Based on HS 854143 - Photovoltaic cells assembled in modules or made up into panels.

Chapter 4, where import tariffs are often 0%, but they can be considerably higher in some emerging markets (World Trade Organization Integrated Database, 2026).

At the same time, there are initiatives to actively reduce trade barriers for green technologies, such as the Agreement on Climate Change, Trade and Sustainability between New Zealand, Costa Rica, Iceland and Switzerland. This agreement liberalises, among other things, tariffs on solar panels, wind and hydraulic turbines and electric vehicles (i.e. reduces or eliminates tariffs for these products), to stimulate the development of these industries.

Imports related to fuels and mining are often not as protected by tariffs as other sectors (e.g., manufacturing), given that countries may not have domestic subsitutes for imports of natural resources. Still, the average tariffs on US imports of fuels and mining increased from 0.5% pre-January 2025 (trade-weighted), to 6.5% by early 2026.[15] While the US does have fossil fuel reserves, it is still heavily reliant on imports for certain critical minerals (U.S. Department of Energy (DOE), 2024).

Box 2. Evidence on the importance of trade for green technology supply chains

JRC-GEM-E3, as a general equilibrium model, has an aggregate sectoral structure that does not capture the role of individual technologies within the energy transition. Other studies focusing on these specific key technologies find that trade disruptions can negatively impact energy and climate policy.

For example, studies have found that US tariffs on solar panel imports were detrimental to climate objectives (Gerarden *et al.*, 2026). Not only did tariffs drive up solar panel costs for consumers, but they also reduced total US employment, as there were more job losses in solar installation and related sectors than there were job gains in other manufacturing.

Several World Bank reports warn emerging markets against using similar protective measures for imports of green technologies (Montfaucon *et al.*, 2023; Rosenow *et al.*, 2024). One report finds that imports along the solar value chain and the downstream segments of other green value chains are particularly sensitive to the imposition of tariffs. Thus, trade protectionism could hinder the short-term diffusion of green technologies (Rosenow *et al.*, 2024).

Similarly, related to green hydrogen, supply chain integration of energy-intensive industries can lead to cost savings (Seibold *et al.*, 2025). If the earlier stages of the supply chain (e.g., producing direct reduced iron) are located close to where green hydrogen is produced at a comparative advantage, this drives down production and transport costs. This implies the establishment of a few global production hubs where green hydrogen is produced cost-efficiently, and from where upstream products are shipped to different downstream production locations.

Also, instability and fragmentation in trade policy increase overall uncertainty in the global economy. This kind of economic uncertainty often leads to increased capital costs, which disproportionally affects green technologies (e.g., offshore wind), as they tend to be more capital-intensive compared to fossil fuel technologies.

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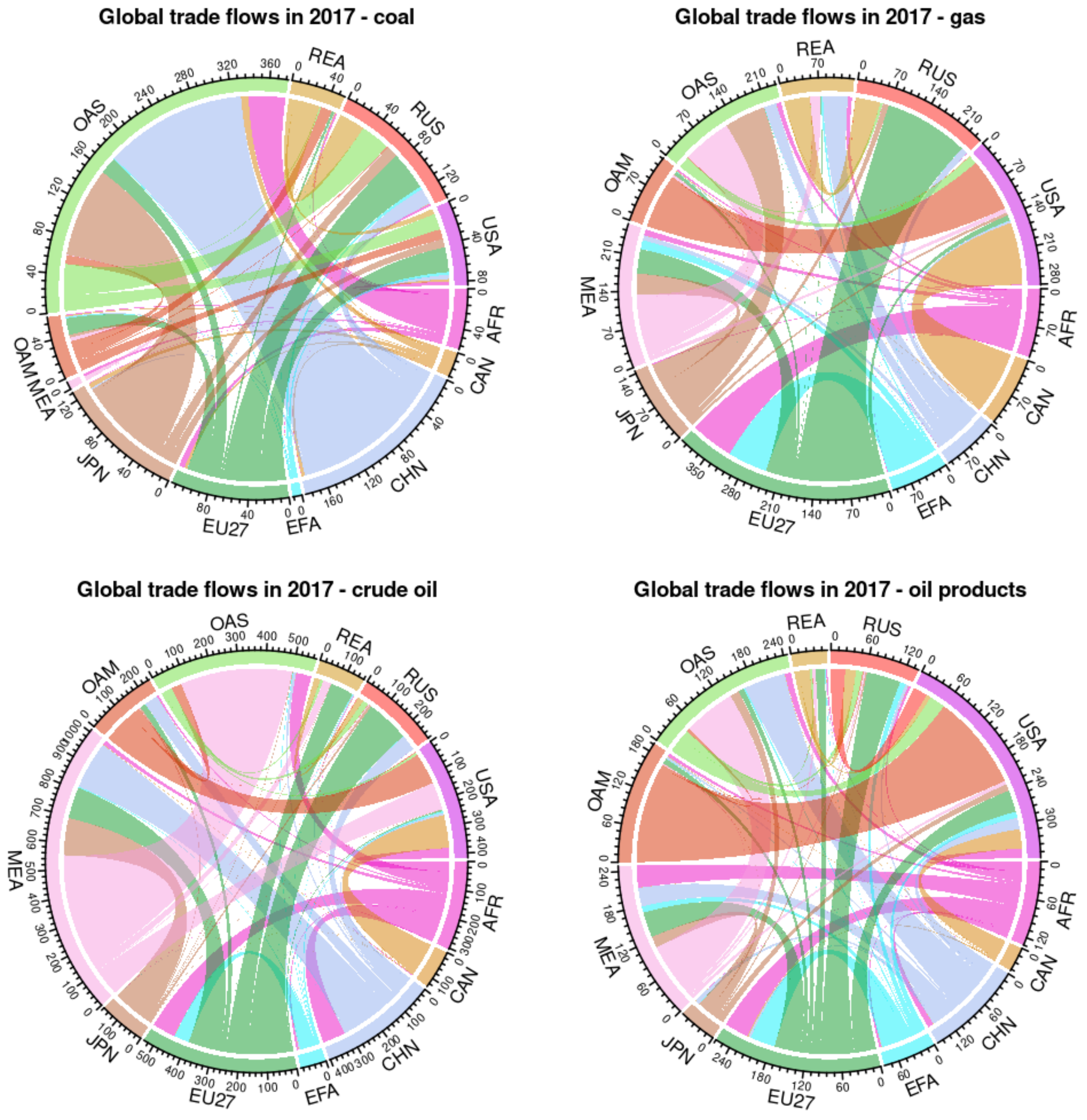
[15] Calculations based on (UN Trade and Development (UNCTAD), 2026).

5.2. The connectivity of international energy trade

Figure 24 visualises global energy trade flows in 2017,[16] highlighting the extent to which regional interdependencies shape the global energy system. Trade in fossil fuels is concentrated between resource-rich exporters and energy import-dependent economies.

Figure 24: Selected trade flows in 2017 – energy trade – billion USD 2017.



Global trade flows in 2017 - coal

Global trade flows in 2017 - gas

Global trade flows in 2017 - crude oil

Global trade flows in 2017 - oil products

Source: Calculations based on GTAP-Power database (Chepeliev, 2020; Aguiar et al.*, 2022)*
Notes: Each of the flows represents the total trade between two regions (imports and exports), without specifying the direction of the flow. 'AFR': Africa, 'EFA': European Free Trade Association, 'MEA': Middle East, 'OAM': Other Americas, 'OAS': Other Asia, 'REA': Rest of Eurasia.

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[16] 2017 serves as the base year in the JRC-GEM-E3 analysis.

Additionally, patterns of trade regionalisation are evident depending on the type of energy carrier. For example, there is considerable regional trade in coal between different Asian countries, including coal exports from ‘other Asia’ (OAS) to Japan. When it comes to gas trade, regionalisation patterns are visible between the US, Canada and ‘other Americas’ (OAM), and between the EU, Russia and part of Asia. Trade in crude oil and oil products, however, is less regionalised.

This structure of trade in energy products has been shaped by many different factors, including historical and political relations between regions, transport costs, and quality considerations. The patterns visible in **Figure 24** underscore the importance of secure energy supply chains, as most countries lack the natural resources to meet their demand domestically.

It is noteworthy that since 2017, energy trade between the EU and Russia has changed substantially because of the sanctions on Russia after its invasion of Ukraine. After 2022, EU imports of Russian mineral fuels dropped rapidly to below 2.5 billion USD (Bruegel, 2026).

5.3. Globalisation vs. fragmentation in international trade

GECO 2025 evaluates socio-economic climate policy impacts in two stylised trade policy settings: a globalised system with current levels of trade openness, and a fragmented system characterised by increased trade barriers and stronger push for domestic production. These are analysed in combination with the default GECO climate policy scenarios, namely the Reference and the 1.5°C scenarios (see **Table 1**). Unless otherwise noted, results are reported as changes relative to the Reference with the globalised trade regime. Some figures present absolute values, but the globalised Reference remains the benchmark for comparison.

Box 3. Modelling the fragmentation of international trade

The default GECO modelling with JRC-GEM-E3 is based on a representation of a globalised system of the world economy. JRC-GEM-E3 is based on GTAP-Power data with base year 2017 (Chepeliev, 2020; Aguiar *et al.*, 2022), a year in which trade openness was high. In standard modelling, as there are no explicit assumptions on changes in trade policy, the base year structure is implicitly maintained, meaning that the default GECO scenarios are based on a globalised version of the economy.

One exception is the changing trade relation for fossil gas between the EU and Russia after Russia’s 2022 invasion of Ukraine. Changes in the structure of fossil gas trade are incorporated in the baseline based on data from (Bruegel Dataset, 2026).

The fragmented version of the global economy, however, adapts this structure by introducing higher import tariffs; increasing average baseline tariff levels by 25 percentage points between all global regions (excluding intra-EU trade) from 2025 onward. This modelling approach follows similar methodologies used in the literature (Fujimori *et al.*, 2017; Arriola *et al.*, 2020), providing a stylised representation of a world with reduced trade integration. It is not intended to mirror current real-world policy developments, but it is rather a modelling approach to create an alternative version of the globalised economy where countries are more self-sufficient and less reliant on trade.

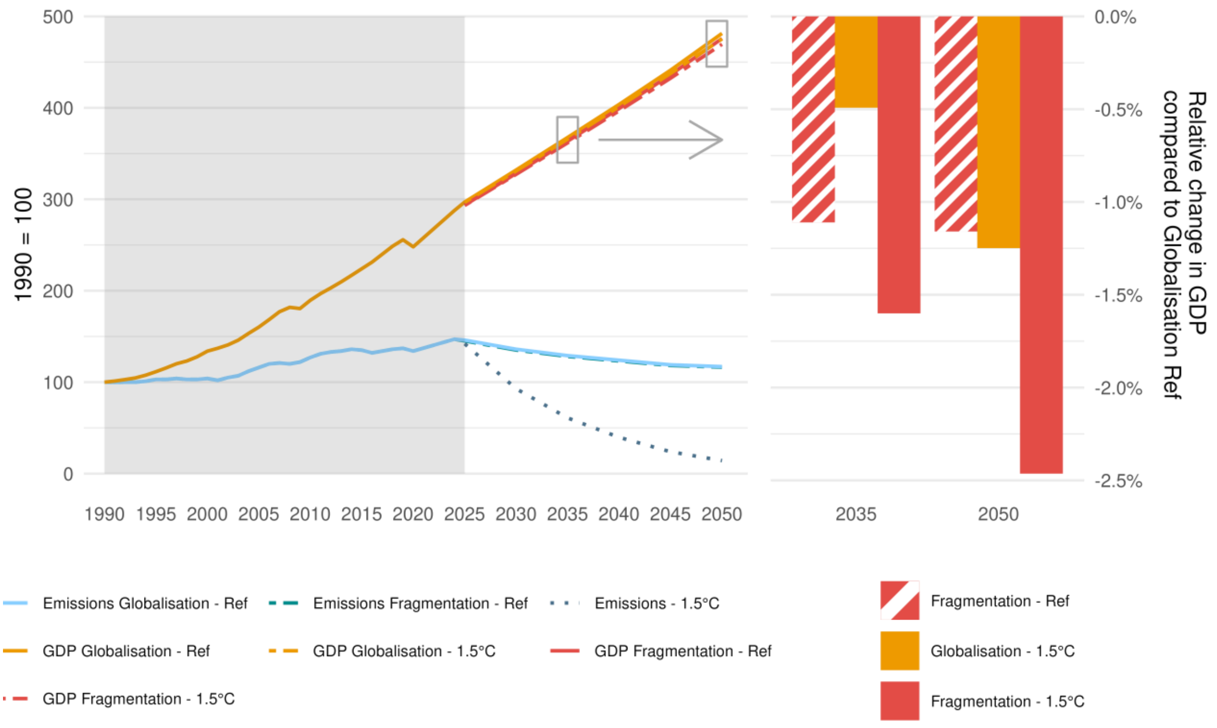
Table 1: Summary of the scenarios and references and their combinations.

International trade / Climate ambition	Globalisation	Fragmentation
Current policies (Ref)	Climate policies that have already been implemented into domestic legislation with current levels of global trade openness.	Climate policies that have already been implemented into domestic legislation in a world with more fragmented trade and more domestic production.
1.5°C	Temperature increase of 1.5°C by the end of the century with current levels of trade openness.	Temperature increase of 1.5°C by the end of the century in a world with more fragmented global trade.

Source: JRC-GEM-E3 scenarios.

5.4. Minimal interaction between climate and trade policy at global GDP level

Figure 25: Global GDP (excluding effects of climate change impacts) and global GHG emissions (including LULUCF), by scenario



Source: JRC-GEM-E3

Notes: The GHG emissions in the 'Globalisation' and '1.5°C' scenarios are based on results from POLES-JRC. By construction, GHG emission levels are identical in the globalised and fragmented 1.5°C scenarios. The GHG emissions in the 'Fragmentation' Reference are based on JRC-GEM-E3 modelling, using JRC-POLES as input, which captures the economic impact on GHG emissions of fragmentation.

Figure 25 compares global GDP and GHG emissions across the Reference and 1.5°C scenarios under both a globalised and a fragmented global economy. The left-hand side visualises the development of global GDP and GHG emissions across time. The right-hand side contrasts the relative changes in GDP in 2035 and 2050, by comparing the GDP level in different scenarios to the GDP of the globalised Reference.

Under the default – globalised – trade regime, GDP grows slightly more slowly in the 1.5°C scenario compared to the Reference, meaning that GDP is 0.5% and 1.25% lower in 2035 and 2050, respectively (right-hand side of **Figure 25**). While there are only small differences in GDP between the 1.5°C scenario and the Reference, the left-hand panel of **Figure 25** shows the sharp reduction in emissions required to meet the 1.5°C target. Emissions reduce by 88% compared to 1990 levels, reflecting structural changes such as fuel switching, efficiency improvements and investment in low-carbon energy systems.

This underscores that coordinated climate action can deliver deep mitigation at comparatively low direct macroeconomic costs. Moreover, this does not include the economic benefits from reduced climate damages and other co-benefits such as reduced air pollution. Similarly, the Reference does not reflect the costs of inaction or adaptation, which negatively impact GDP (Feyen *et al.*, 2020).

Next, **Figure 25** demonstrates how trade fragmentation negatively affects the global economy. GDP in the fragmented setting is 1.1% lower in both 2035 and 2050 compared to the globalised setting (**Figure 25**, right-hand panel), as trade restrictions put downward pressure on economic growth. However, the size of this effect differs across regions. Most regions experience relative GDP declines of 1-2%, while a smaller group sees reductions of up to 4%. These differences are related to countries' size and trade dependence, with larger and less trade-dependent economies being less affected by higher tariffs.[17]

Like GDP, GHG emissions decline when moving from globalisation to fragmentation in the Reference (-0.5% by 2050). However, this is the consequence of weakened economic activity, i.e. a negative output effect which lowers emissions. For example, some of the sectors that see the largest decline in output and GHG emissions are the transport sectors, particularly maritime transport. This is because of the reduction in trade, which leads to a strong reduction in international transport demand.

Importantly, slower economic growth because of fragmentation does not necessarily lead to structural decarbonization. On the contrary, fragmentation puts stronger downward pressure on GDP than on GHG emissions because fragmentation makes the global economy more emission intensive (around 0.5% more compared to globalisation). As trade barriers raise the cost of imports, some regions expand domestic production to partially substitute for foreign suppliers, even though these domestic industries may be less efficient and more emission intensive.

This is evident when comparing the 1.5°C scenario under a globalised vs a fragmented trade regime. By construction, GHG emission levels are identical in the globalised and fragmented 1.5°C scenarios, as the carbon price adjusts endogenously to achieve the target. Although the introduction of tariffs reduces overall output, the increase in emission intensity dominates this negative output effect in a deep decarbonization scenario. As a result, the global carbon price must be slightly

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[17] These results are in line with similar analyses of tariff hikes, such as (Nordgren *et al.*, 2024; Kiel Institute for the World Economy, 2025; McKibbin *et al.*, 2025).

higher (by USD 75/tCO2e[18]) in the fragmented 1.5°C scenario in 2050 to achieve the same emissions level as in the globalized 1.5°C scenario.

Overall, trade fragmentation results in very limited GHG emission reductions, in an economically inefficient way. This highlights the efficiency of energy policy in lowering GHG emissions, as the 1.5°C scenario achieves substantial emissions reductions with only a slight slowdown of GDP growth compared to the Reference.

Nonetheless, while trade fragmentation somewhat raises the global economy's emission intensity, the interaction between climate mitigation policy and trade fragmentation remains limited. This is visible from the right-hand side of **Figure 25**: In the fragmented 1.5°C scenario the effects of trade fragmentation and climate mitigation are almost perfectly additive (i.e. the combined effect of the bars representing the fragmented Reference and the globalised 1.5°C scenario).

Box 4. Exempting fossil fuels from trade restrictions

As a sensitivity test, an additional scenario explores the impact of exempting fossil fuels from the tariff hike in the fragmentation scenario. In this sensitivity scenario, tariffs between all regions (except intra-EU) are increased by 25 percentage points for all goods and services with the exception of trade in fossil fuels (see also **Figure 24**). This reflects the real possibility that governments are less likely to impose high tariffs on essential energy imports, especially in net-importing regions with few domestic fossil fuel resources. Because the energy transition will reduce the need for fossil fuel trade, there may be interactions between energy and trade policy in this area.

Exempting fossil fuels from the tariff hike does not have a strong impact on GDP if trade barriers are still applied to all other goods and services. In 2035 GDP is 0.05% higher with the fossil fuel exemption compared to when they are also covered by additional tariffs. This reflects how lower tariff coverage puts less downward pressure on GDP. However, in 2050, GDP is almost identical with and without the fossil fuel exemption. Especially in the 1.5°C scenario, the energy transition means that there is little fossil fuel trade, so whether this trade is subject to tariffs makes little difference. GHG emissions react similarly to GDP. As mentioned above, trade fragmentation means that a higher carbon price is necessary to reach a 1.5°C target. This effect is slightly exacerbated when fossil fuels are exempt from the tariff increase. This is because there are no tariffs providing a dampening effect on fossil fuel trade, while other industries are still relocating to potentially more emission-intensive domestic markets because of the remaining tariffs.

5.5. Climate and trade policy cause structural change

Fragmentation and mitigation both have the potential to reshape the structure of international trade. **Figure 26** illustrates changes in total global trade and its sectoral composition relative to 2017. In the globalised scenarios, manufactured goods – including both manufacturing and energy-intensive industry – remain the most traded products as the total volume of trade expands in 2035 and 2050. In the fragmented scenarios, however, trade volumes contract, reflecting the shift towards domestic production as well as the overall contraction of GDP.

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[18] USD 2017.

Figure 26: Total global trade by sector in different scenarios, relative to base year 2017 (index 2017 = 100).

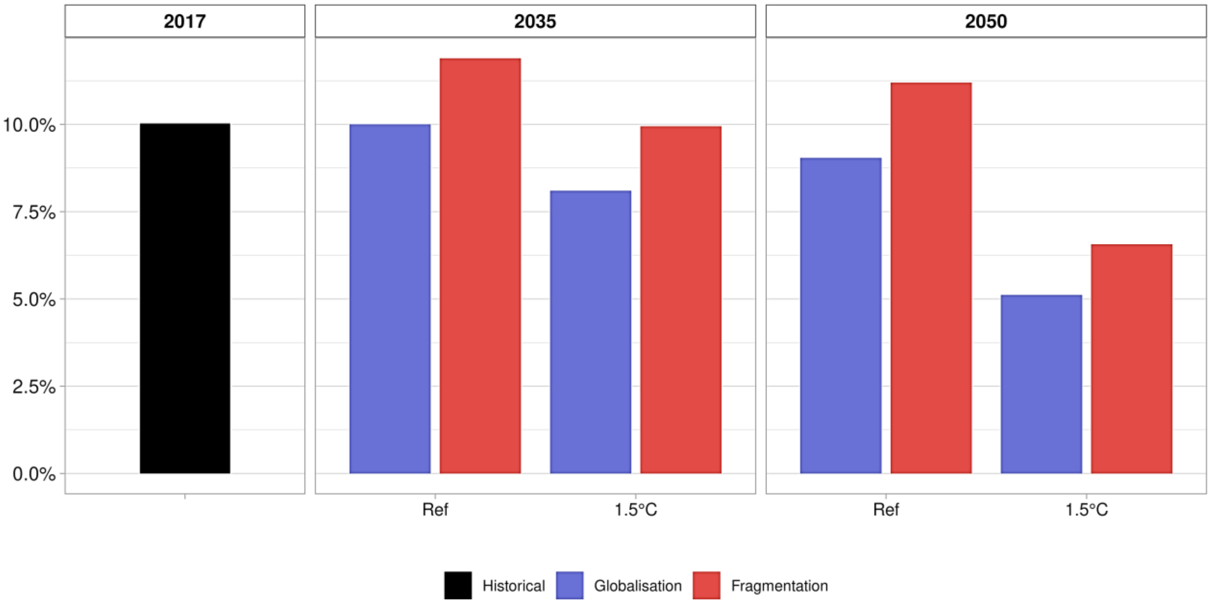
Source: JRC-GEM-E3

Figure 26 indicates that fossil fuel trade grows in absolute terms, albeit marginally, in both the globalisation and fragmentation Reference scenarios, while it decreases in the 1.5°C scenarios. In addition, **Figure 27** visualises the share of fossil fuels in global trade over time by singling out the global fossil fuel trade bars seen in **Figure 26**.

In the fragmented Reference scenario, the share of fossil fuels in global trade remains broadly stable, increasing only slightly from 10% in 2017 to 11% in 2050, reflecting the continued reliance on internationally traded energy resources. Notably, this does not mean that fossil fuel trade increases in absolute terms. Rather, fragmentation has a stronger negative effect on trade in other categories – particularly manufacturing – leading to a relative increase of fossil fuels in the global trade basket.

In the globalised 1.5°C scenario, the share of fossil fuels falls to around 5% by 2050 as the world decarbonises. In the fragmentated version of the global economy, the share declines more slowly, reaching around 7% in 2050. Overall, the results highlight how the levels of energy trade are more affected by climate policy, while levels of manufacturing trade respond more strongly to trade policy.

Figure 27: Share of fossil fuels in global trade across years and scenarios (based on trade in monetary terms).



Source: JRC-GEM-E3

6

Conclusions

6. Conclusions

The relative competitiveness of clean energy technologies is a vital factor in the achievement of global climate change mitigation targets. GECO 2025 assesses 15 clean energy technologies, and finds that 4 are competitive, 4 are almost competitive, and 7 remain uncompetitive over the next several decades under current market conditions. Policy support in the coming decade must be on scaling up the deployment of the group of technologies rated as almost competitive, and earlier-stage support such as pilots and market interventions for the technologies that are crucial to the final stages of reaching net zero towards the middle of the century.

In terms of the potential impact of trade fragmentation on mitigation efforts, GECO 2025 finds that there is overall minimal interaction between climate and trade policy when considering the effect on global GDP. Fragmentation causes a limited reduction in GHG emissions, because of the negative effect it has on global GDP. However, fragmentation also makes the global economy more emissions-intensive, by fracturing global patterns of specialisation and encouraging domestic production where this might be less efficient. As a result, fragmentation hampers the deep decarbonisation that is necessary in a 1.5°C scenario. In terms of sectoral trade structures, GECO 2025 shows that the trade of energy carriers (such as coal or LNG) is affected more strongly by the direction of climate policy. Imports and exports of manufacturing on the other hand are more sensitive to changes in trade policy.

Under currently enacted policies, Reference scenario emissions show a similar pattern compared to last year, as accelerating clean energy technology deployments – especially in solar, wind and electric cars – is offset by a reversal of climate mitigation policies in the US. In addition, recently announced NDCs fail to show an increase in climate change mitigation ambition. These two effects result in largely unchanged implementation and ambition gaps at the global level: the world is currently taking two steps forward and one step backwards in the fight against climate change.

7

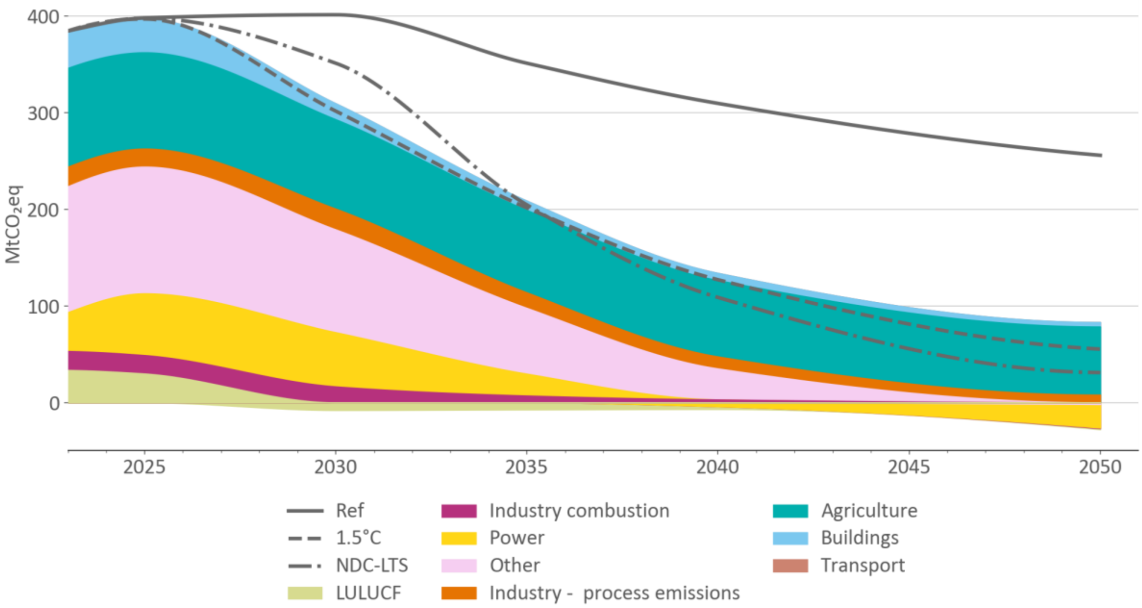
Annexes and Country Sheets

Country sheets

Argentina

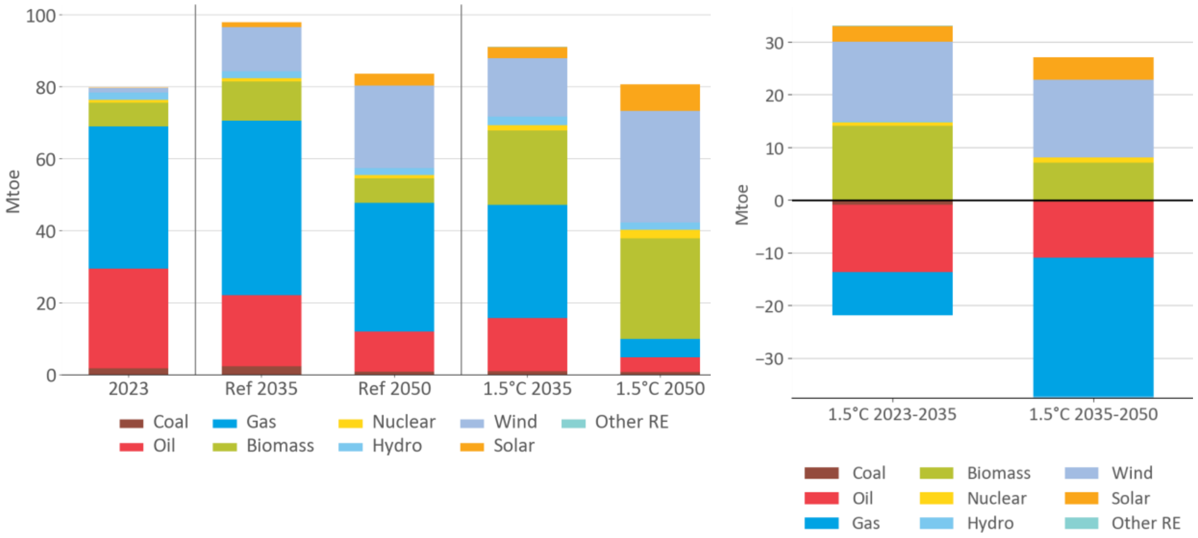
Argentina's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - Argentina

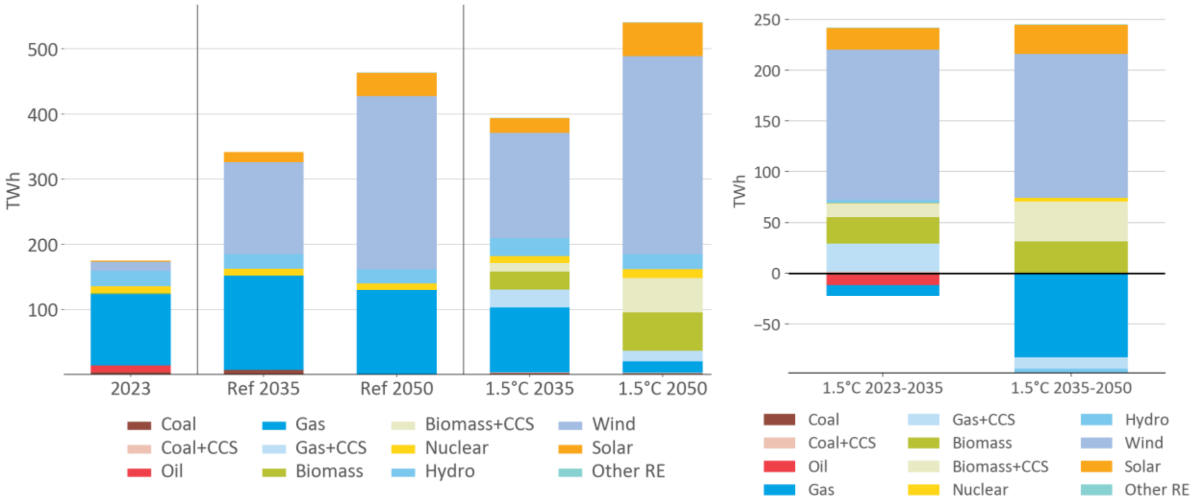


Note: the Other category includes non-CO_2 emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO_2.

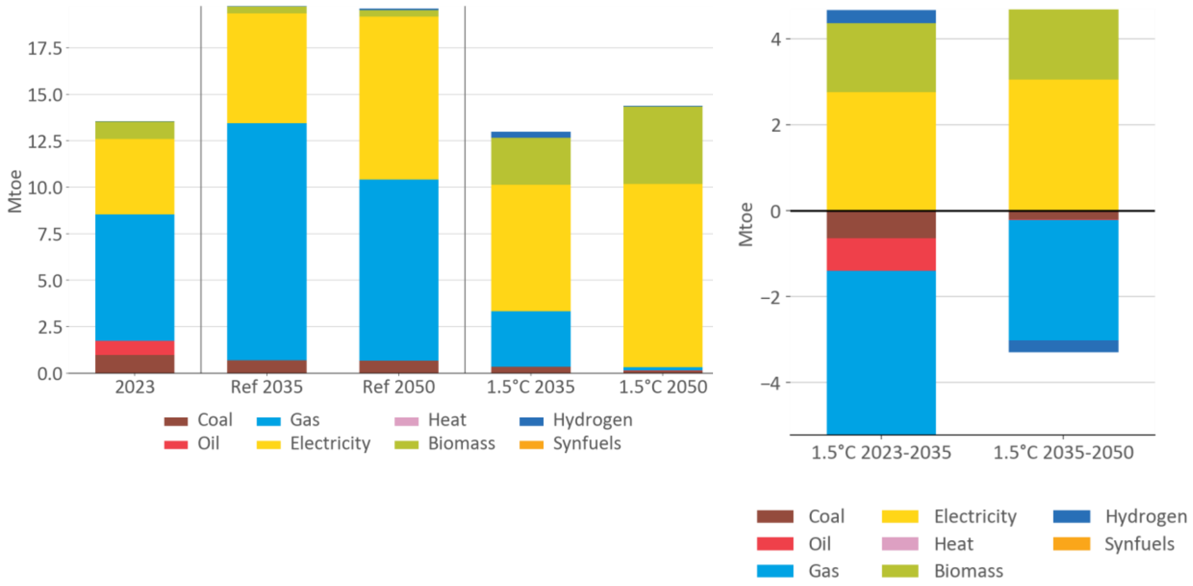
Primary energy demand, and change in primary energy demand - Argentina



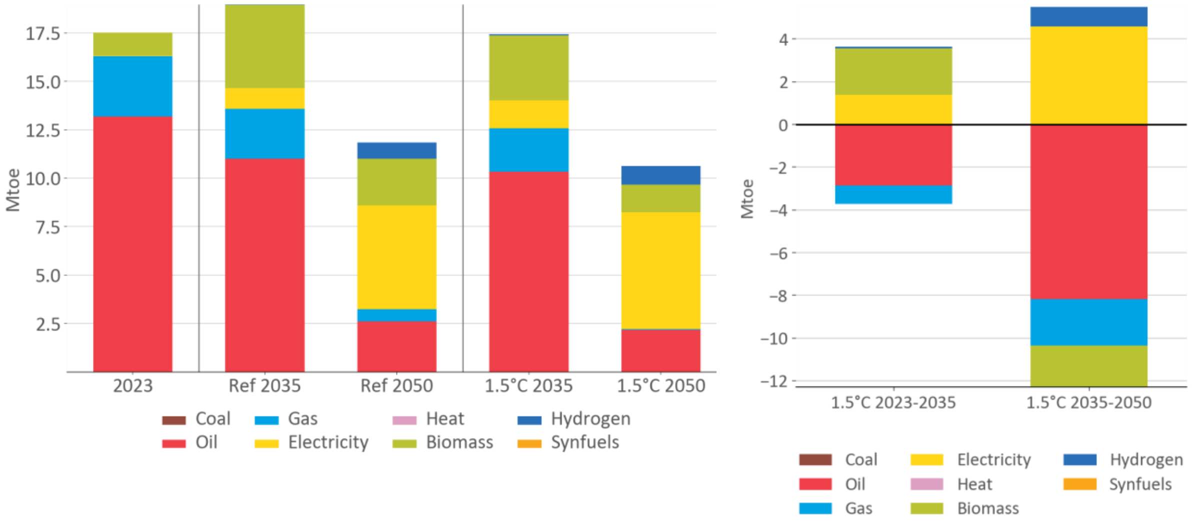
Power generation, and change in power generation - Argentina



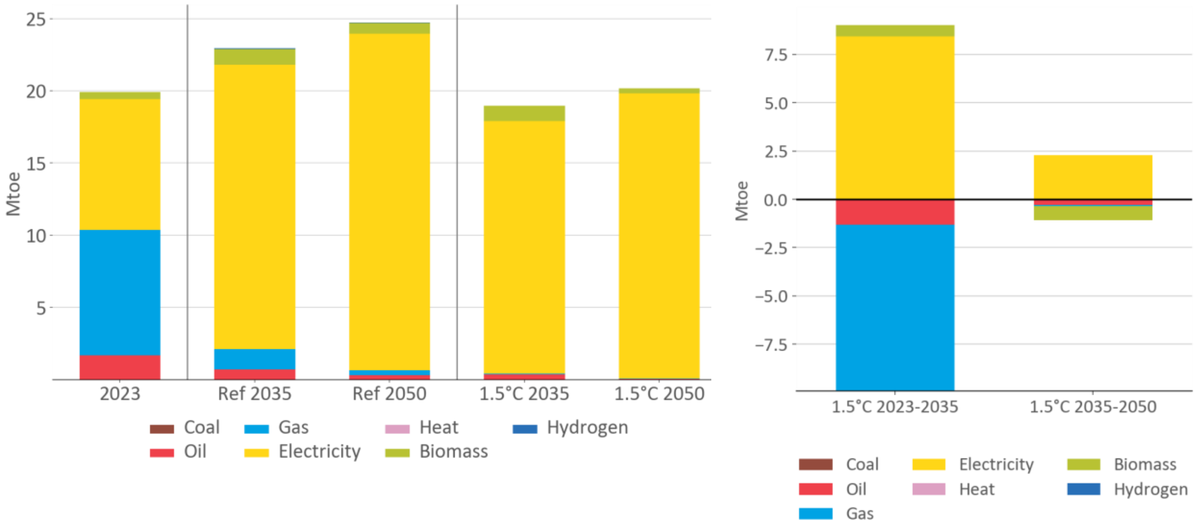
Industry sector demand, and change in industrial sector demand - Argentina



Transport sector demand, and change in transport sector demand - Argentina



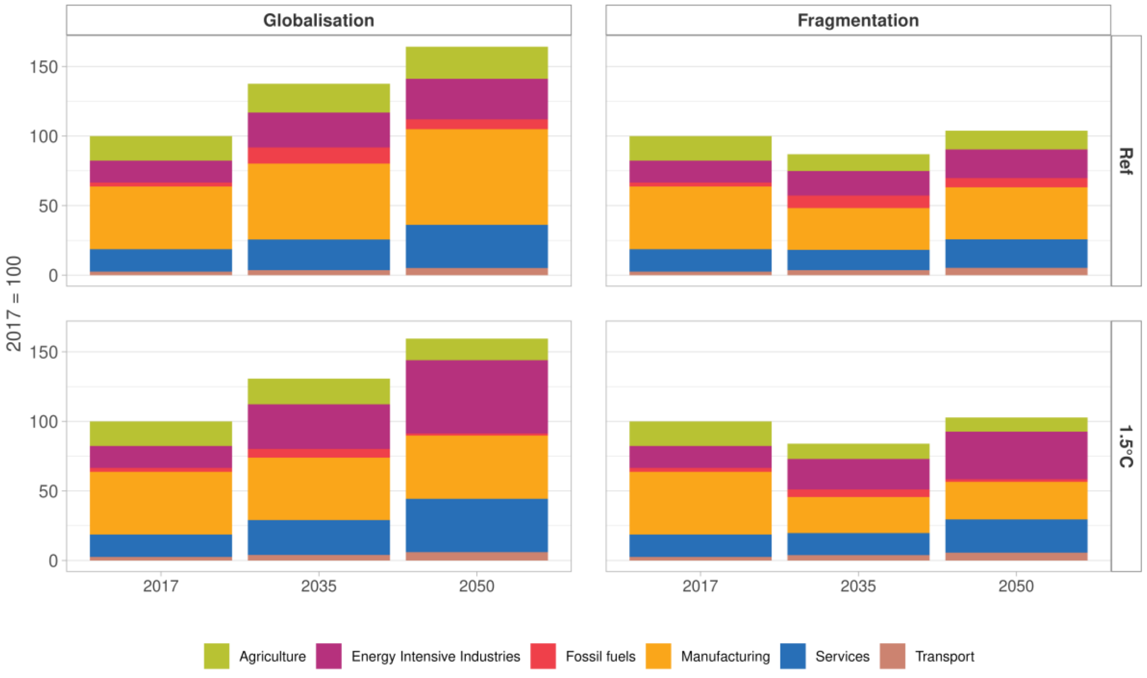
Buildings sector demand, and change in buildings sector demand - Argentina



Trade dynamics

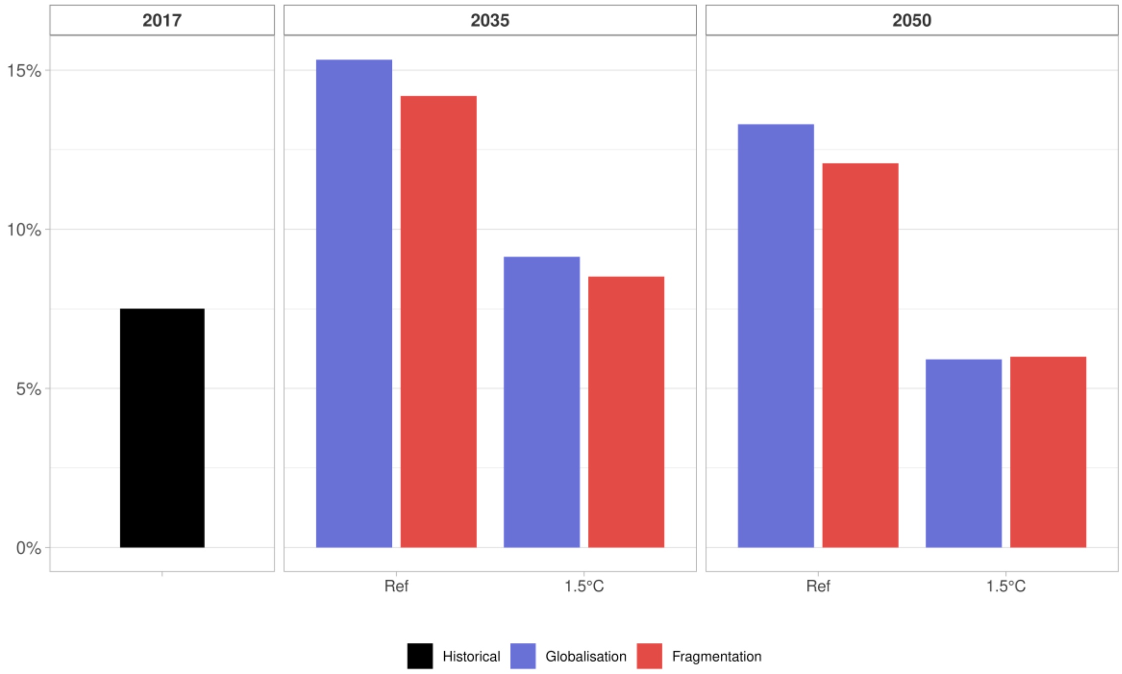
These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

Exports by sector for different scenarios - Argentina



Imports by sector for different scenarios - Argentina

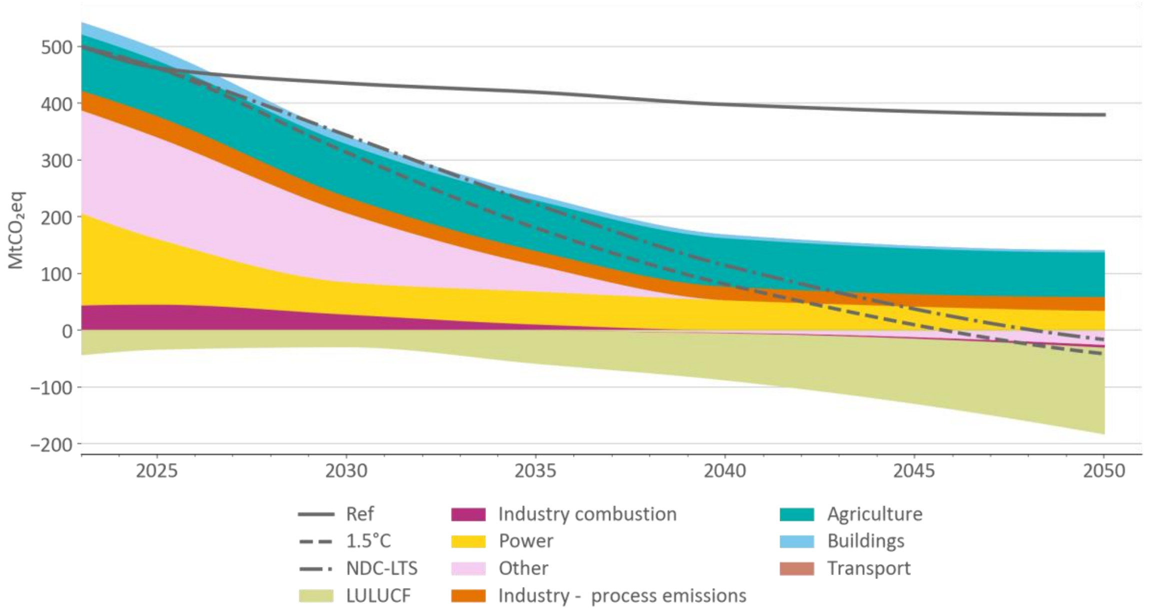
Share of fossil fuels in total imports for different scenarios – Argentina



Australia

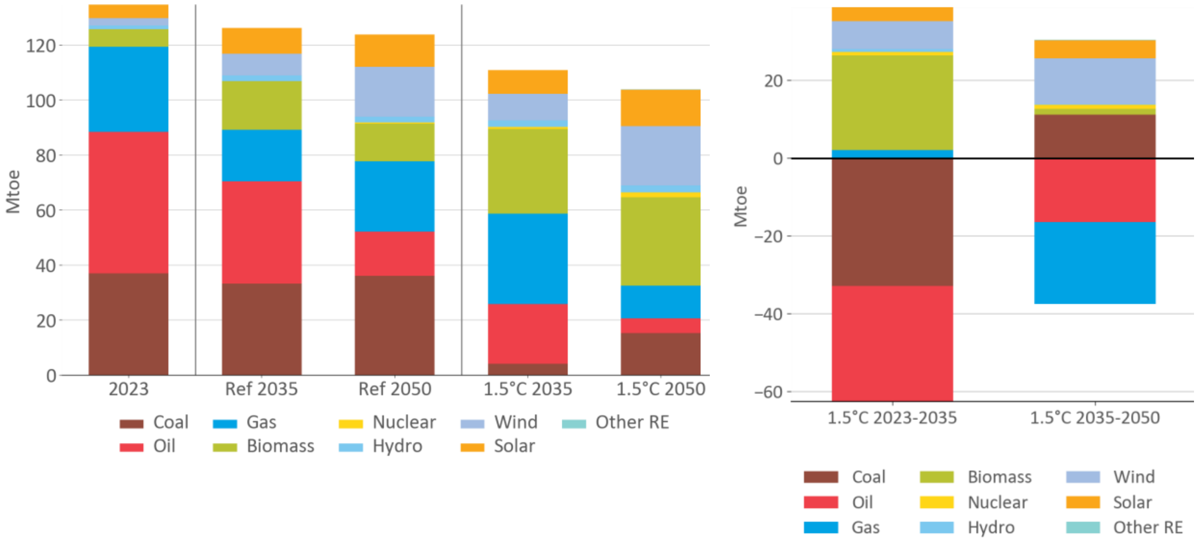
Australia's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - Australia

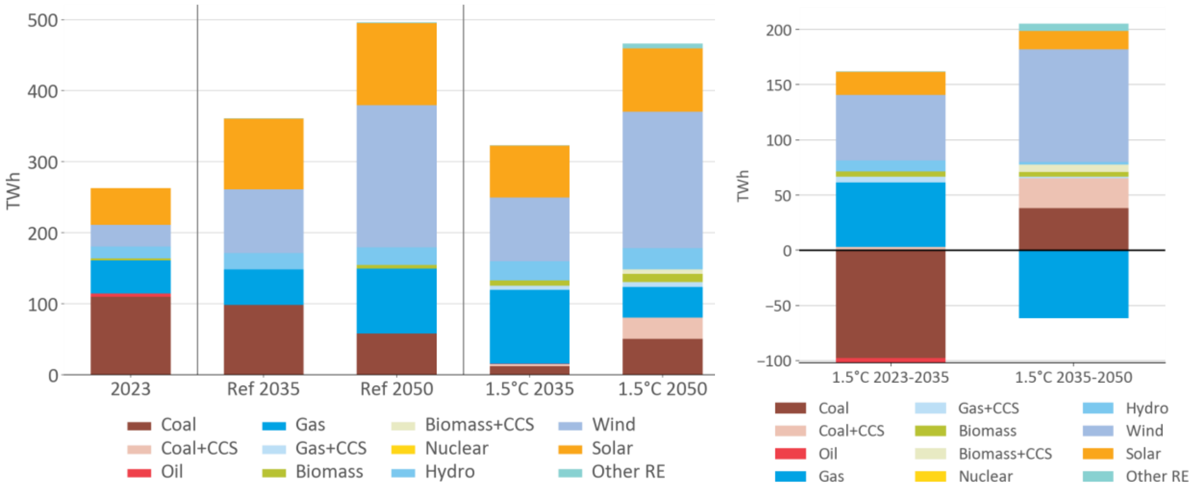


Note: the Other category includes non-CO_2 emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO_2.

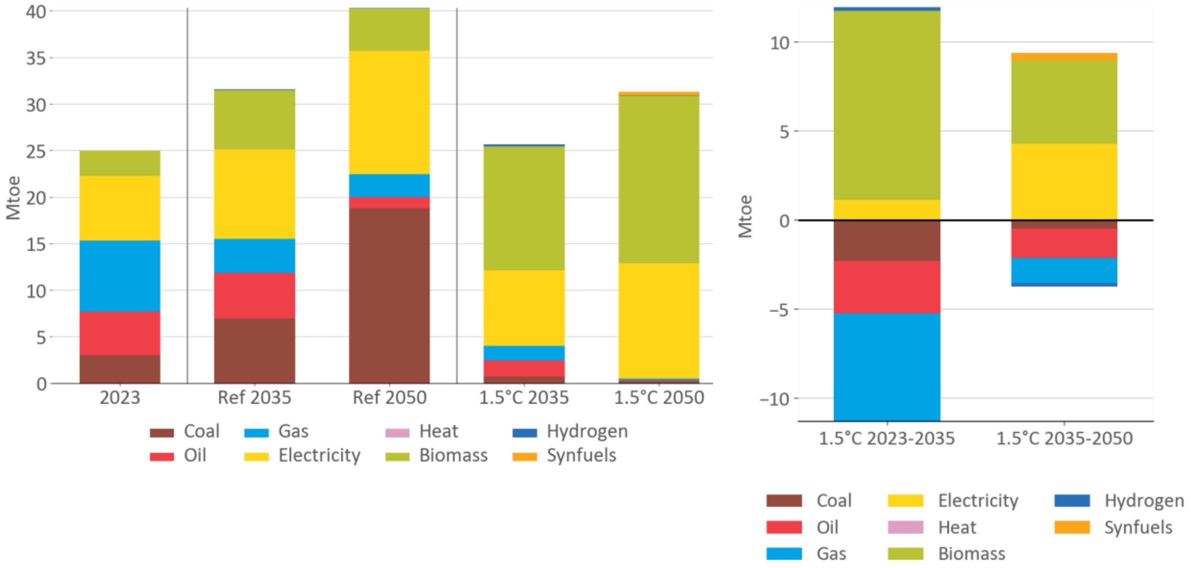
Primary energy demand, and change in primary energy demand - Australia



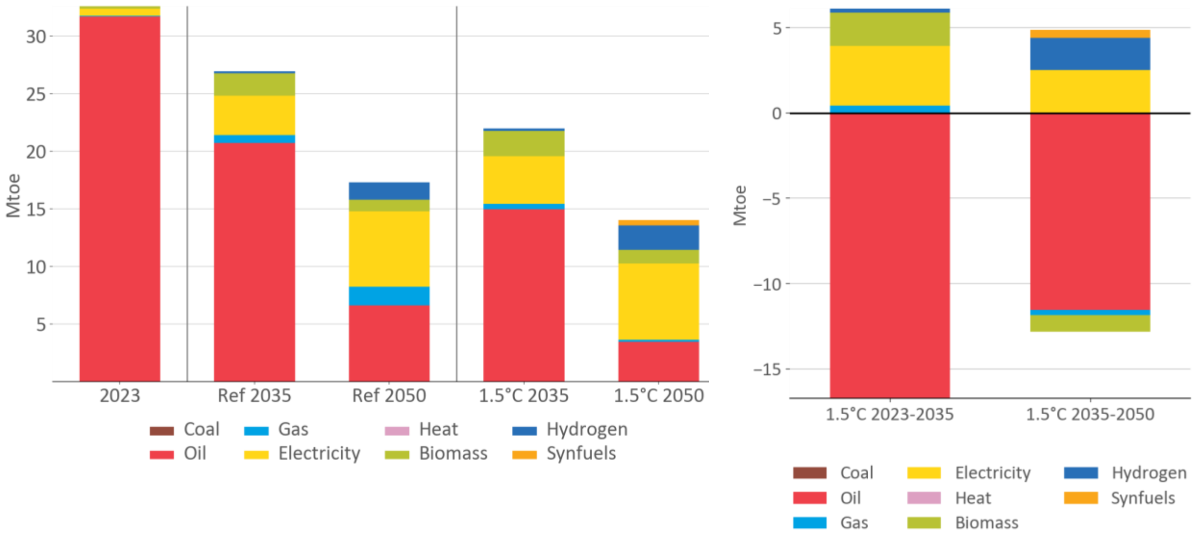
Power generation, and change in power generation – Australia



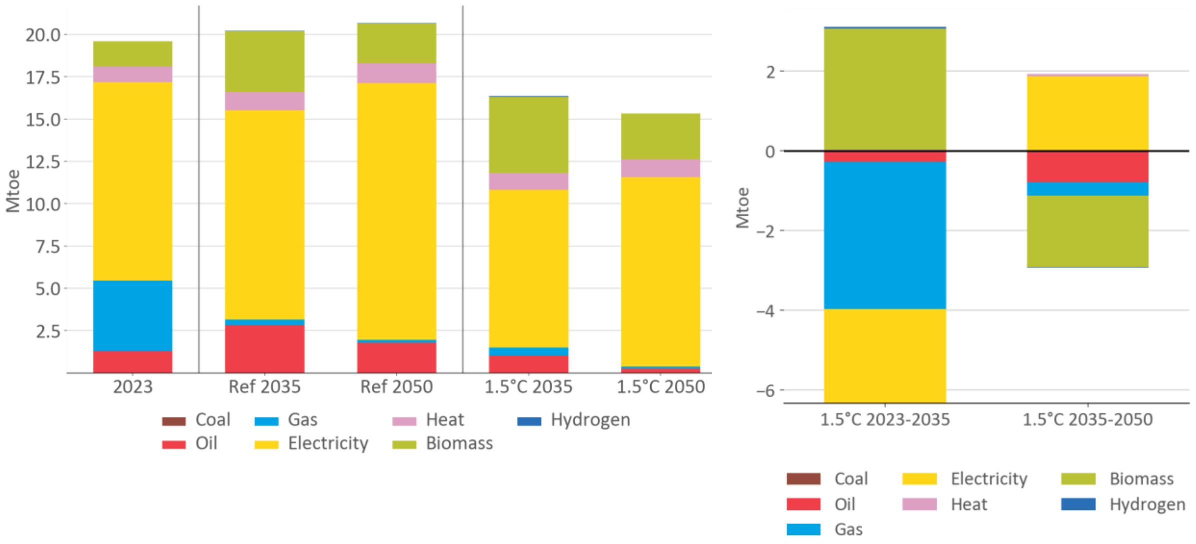
Industry sector demand, and change in industrial sector demand – Australia



Transport sector demand, and change in transport sector demand - Australia



Buildings sector demand, and change in buildings sector demand - Australia



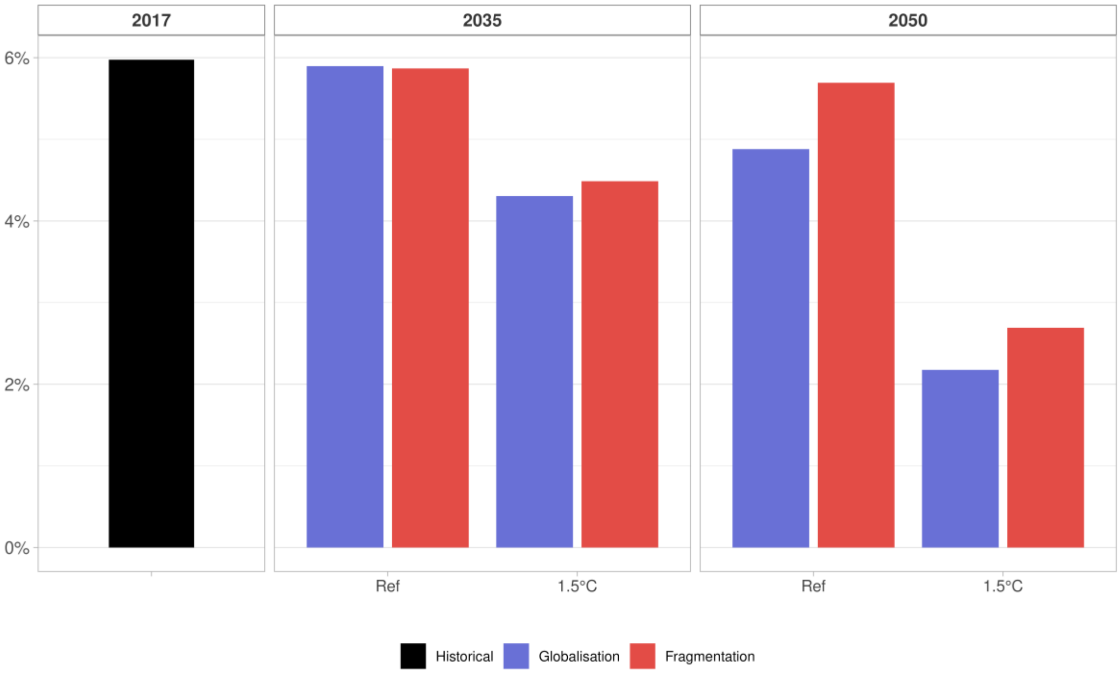
Trade dynamics

These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

Exports by sector for different scenarios - Australia

Imports by sector for different scenarios - Australia

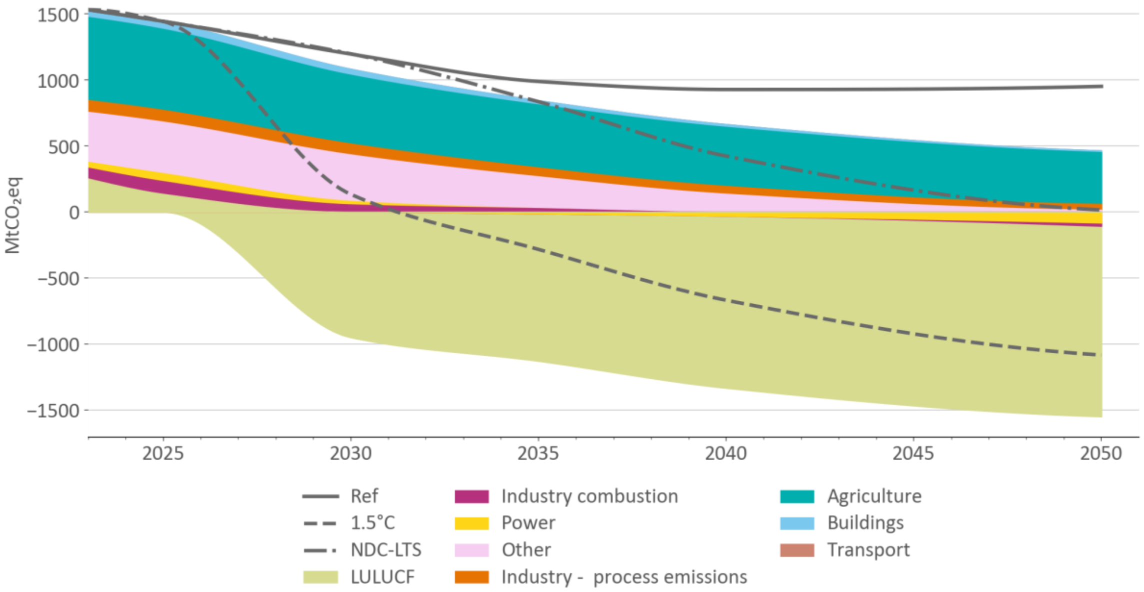
Share of fossil fuels in total imports for different scenarios – Australia



Brazil

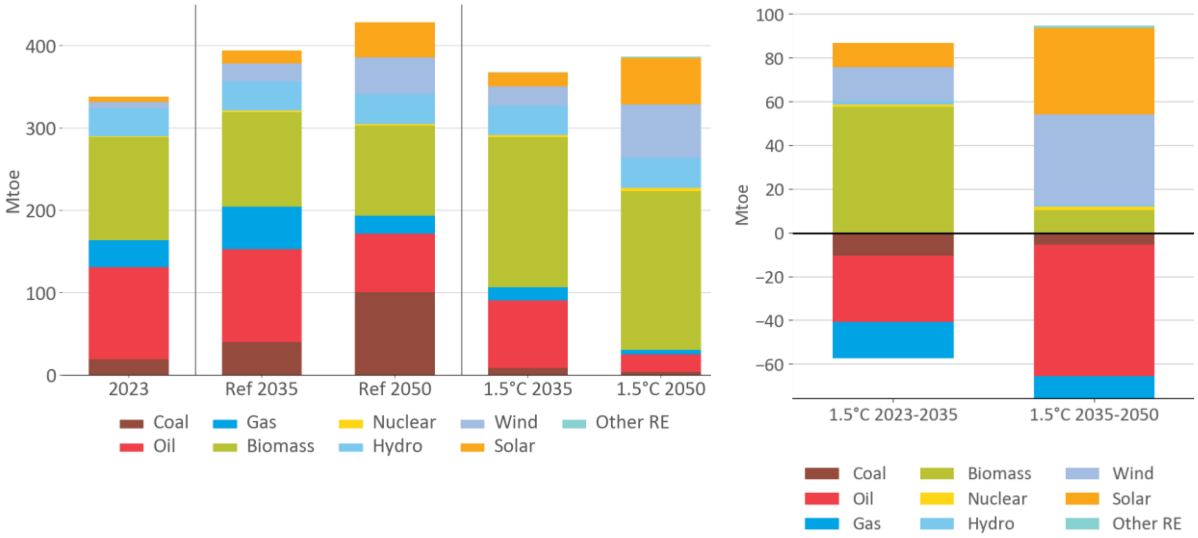
Brazil's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - Brazil

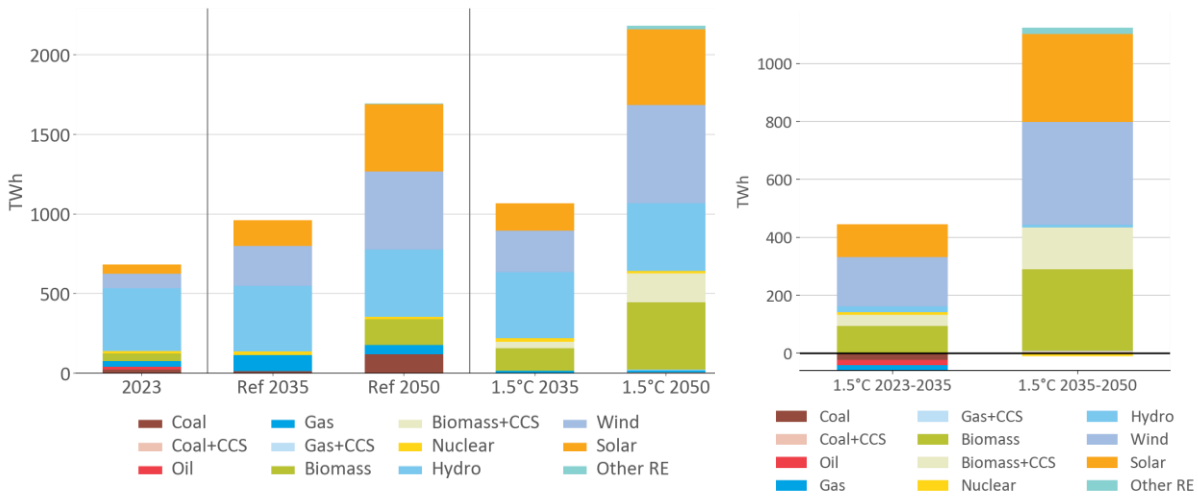


Note: the Other category includes non-CO₂ emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO₂.

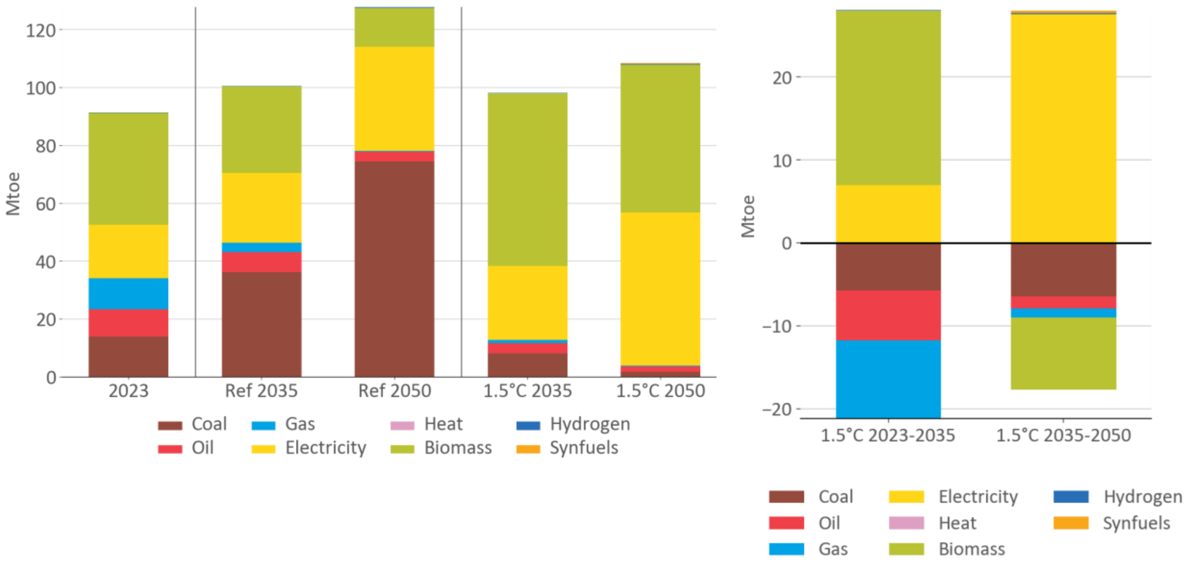
Primary energy demand, and change in primary energy demand - Brazil



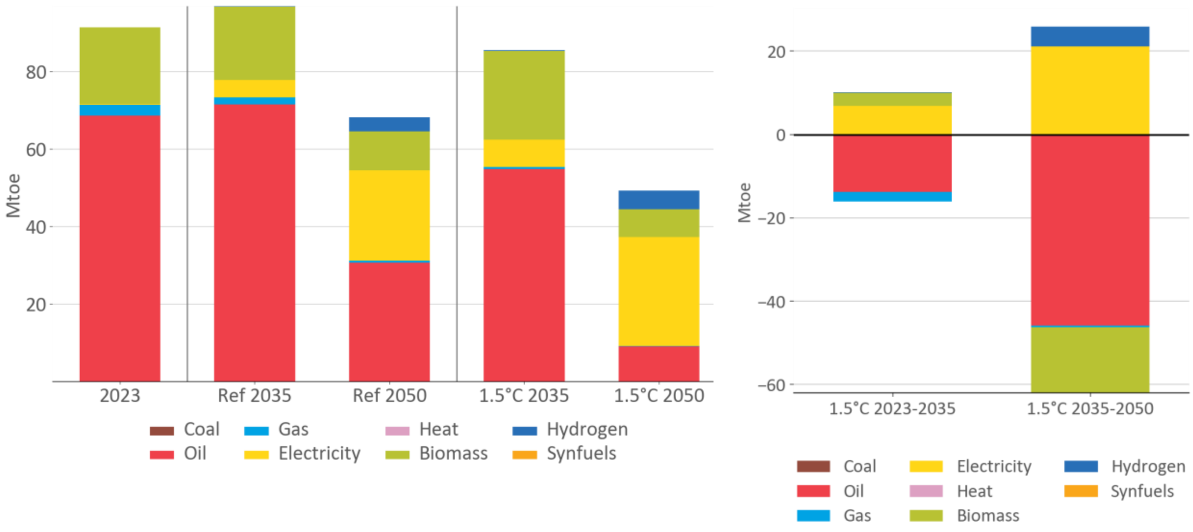
Power generation, and change in power generation – Brazil



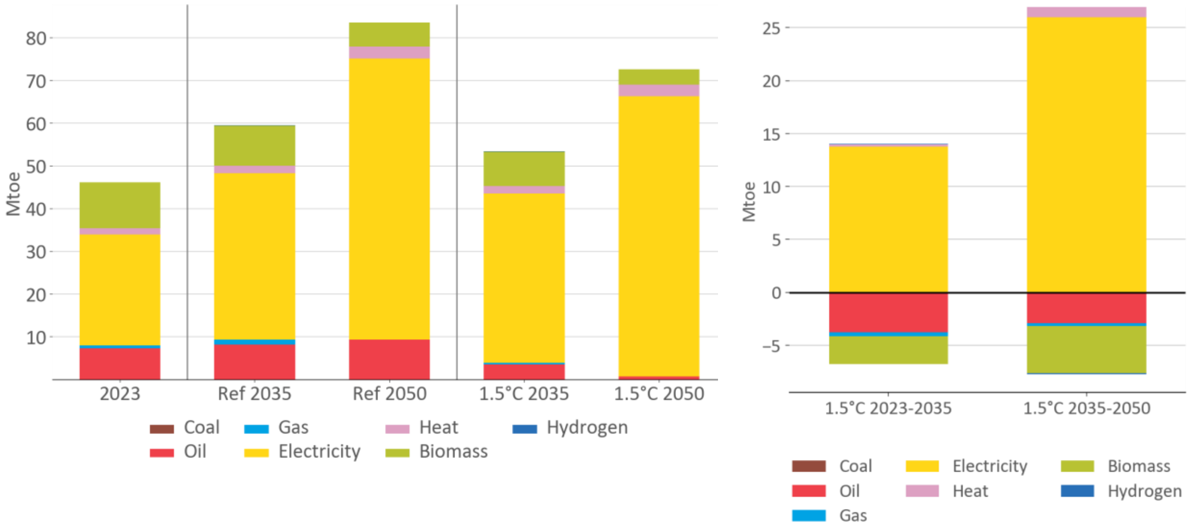
Industry sector demand, and change in industrial sector demand – Brazil



Transport sector demand, and change in transport sector demand - Brazil



Buildings sector demand, and change in buildings sector demand - Brazil



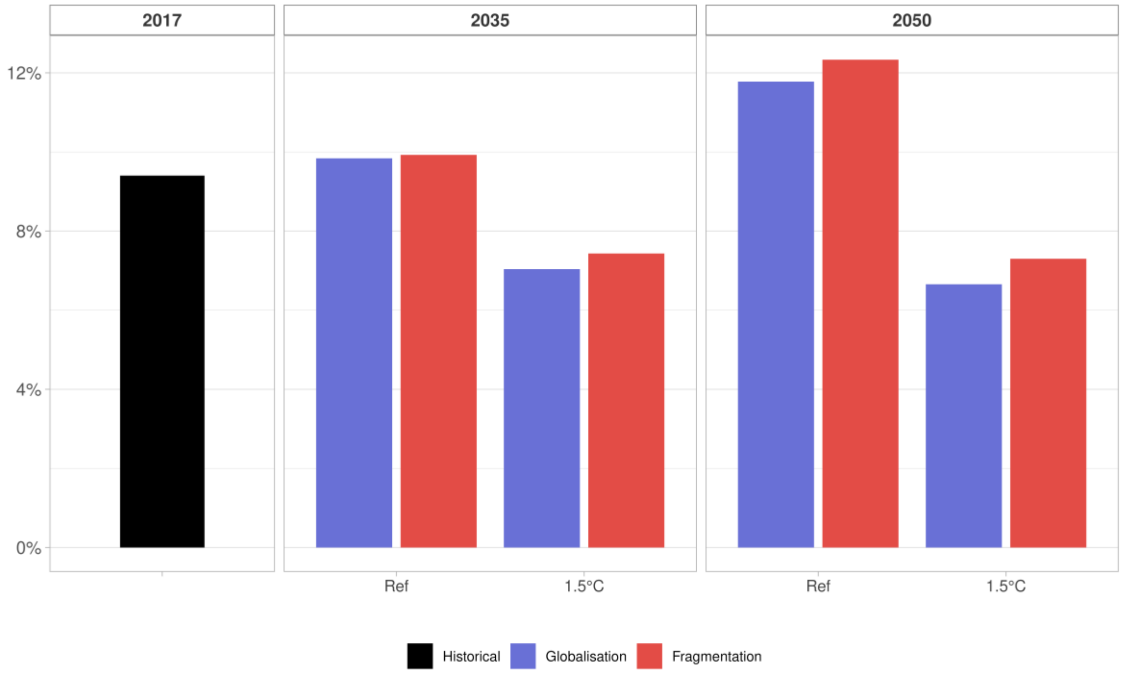
Trade dynamics

These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

Exports by sector for different scenarios - Brazil

Imports by sector for different scenarios - Brazil

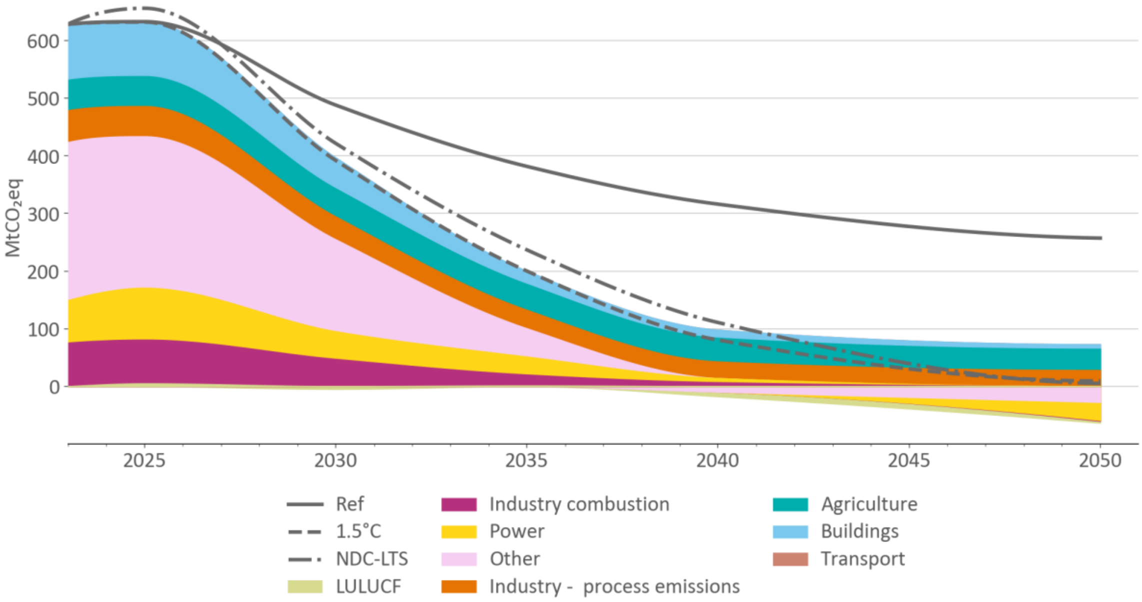
Share of fossil fuels in total imports for different scenarios – Brazil



Canada

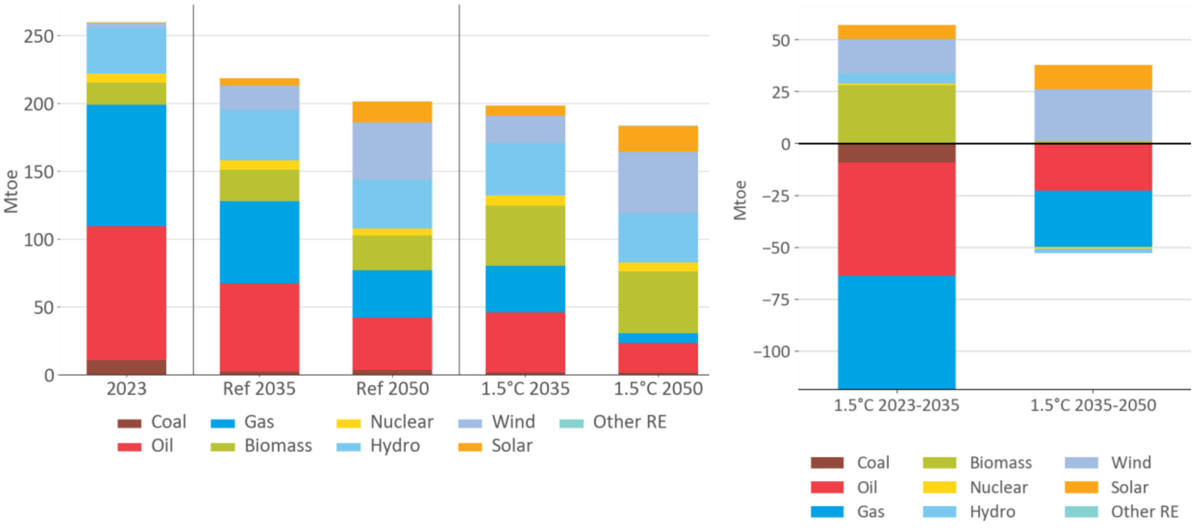
Canada's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - Canada

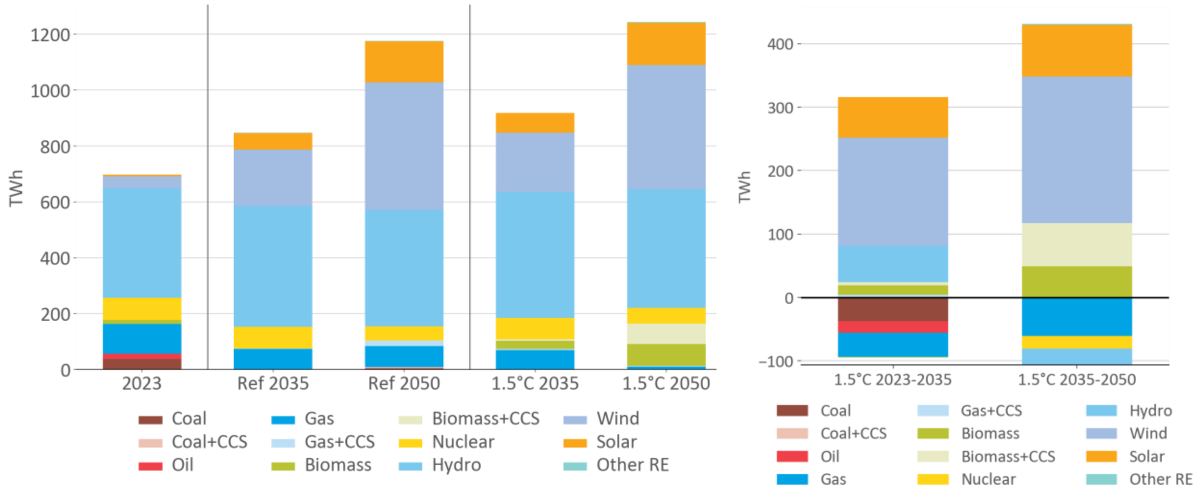


Note: the Other category includes non-CO_2 emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO_2.

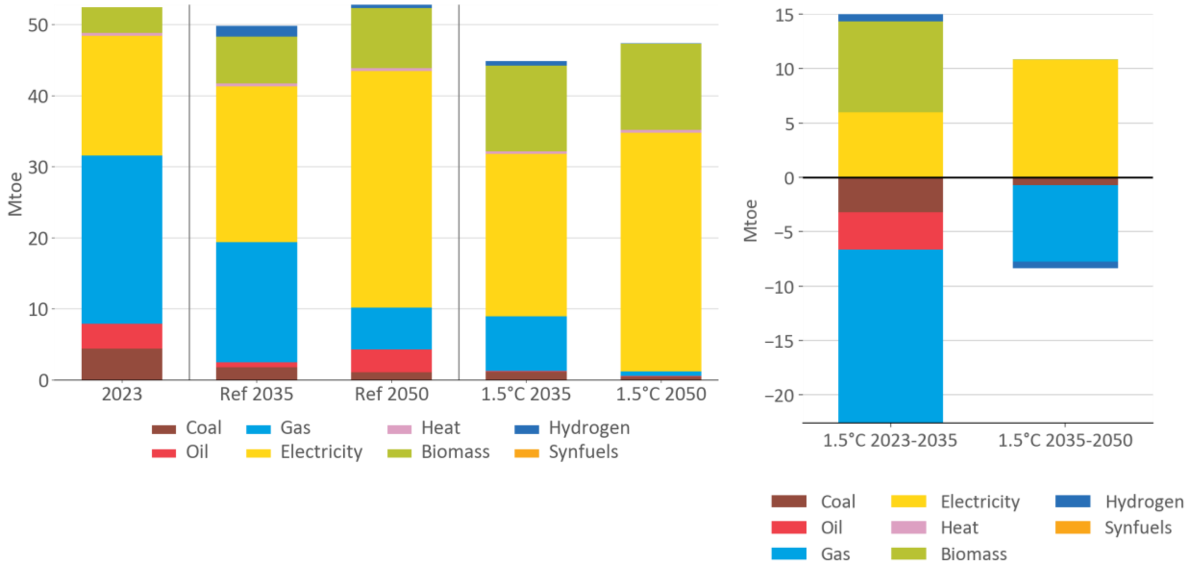
Primary energy demand, and change in primary energy demand - Canada



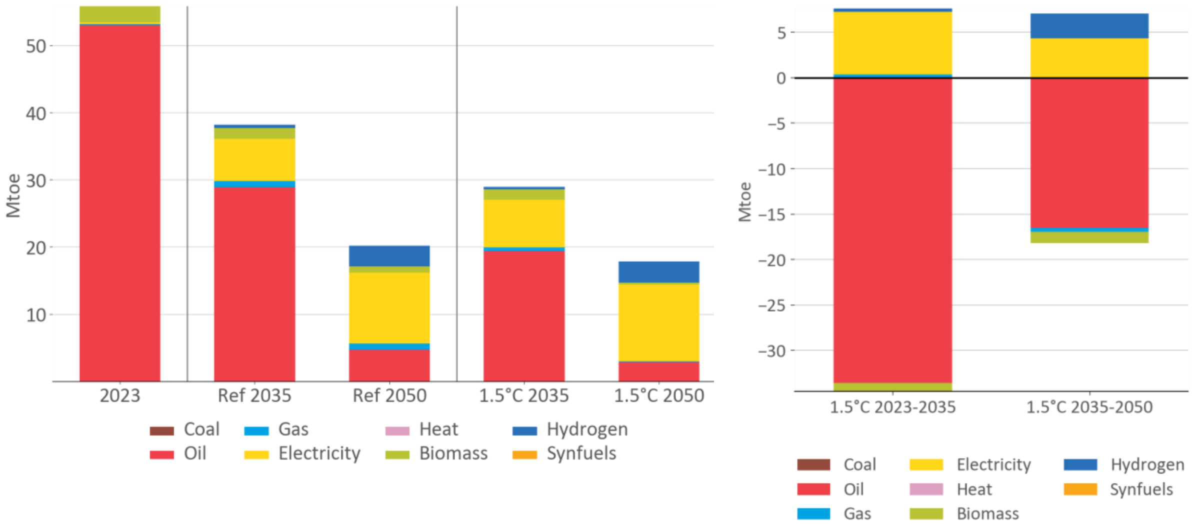
Power generation, and change in power generation - Canada



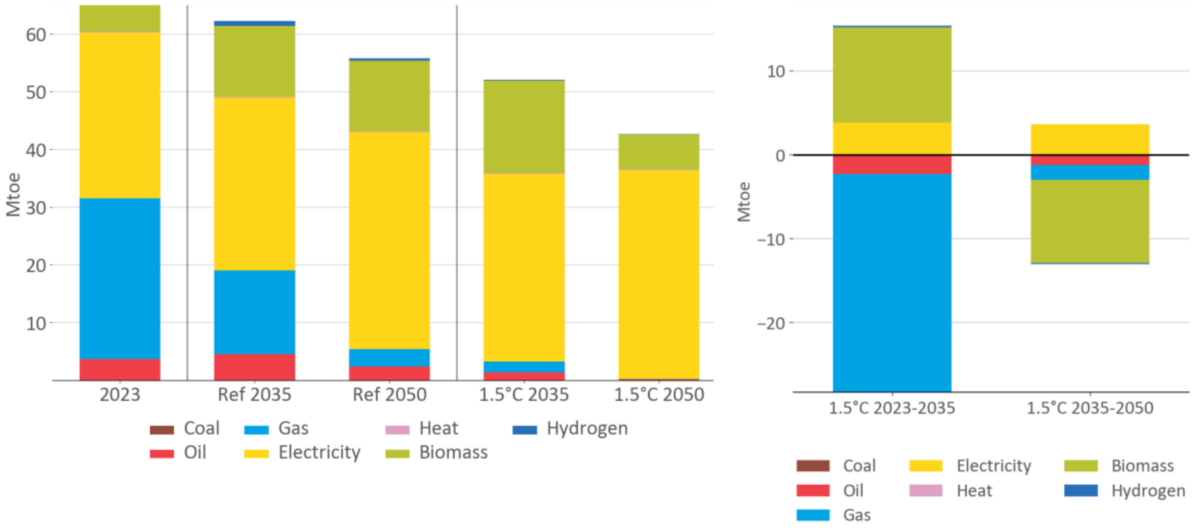
Industry sector demand, and change in industrial sector demand - Canada



Transport sector demand, and change in transport sector demand - Canada



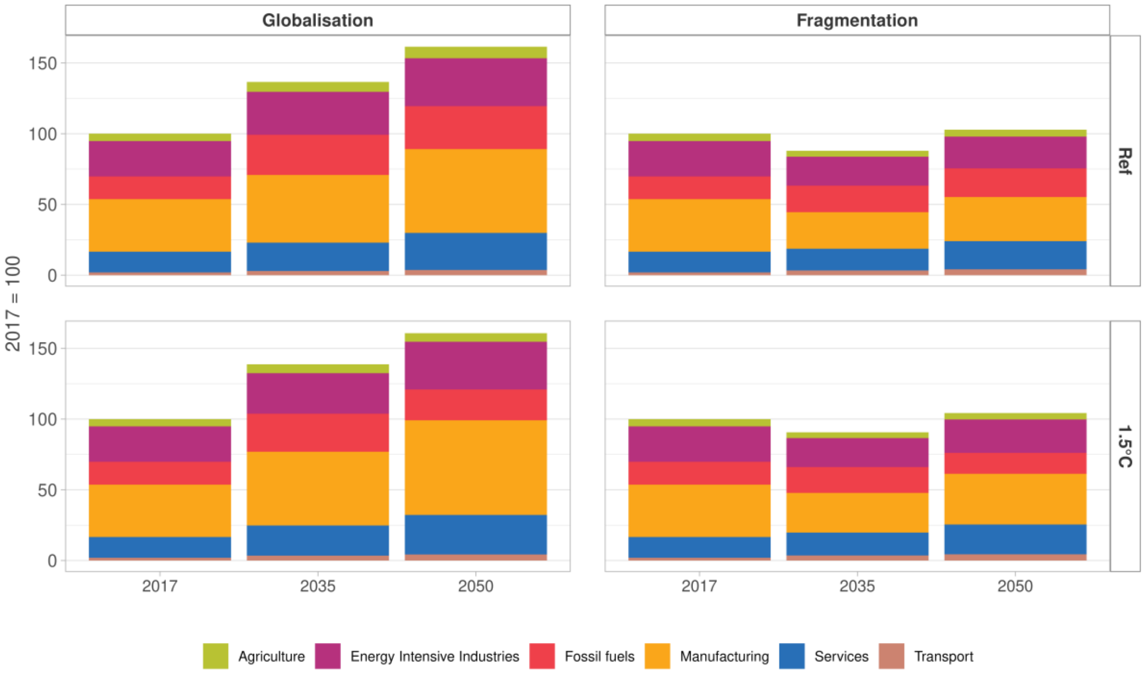
Buildings sector demand, and change in buildings sector demand - Canada



Trade dynamics

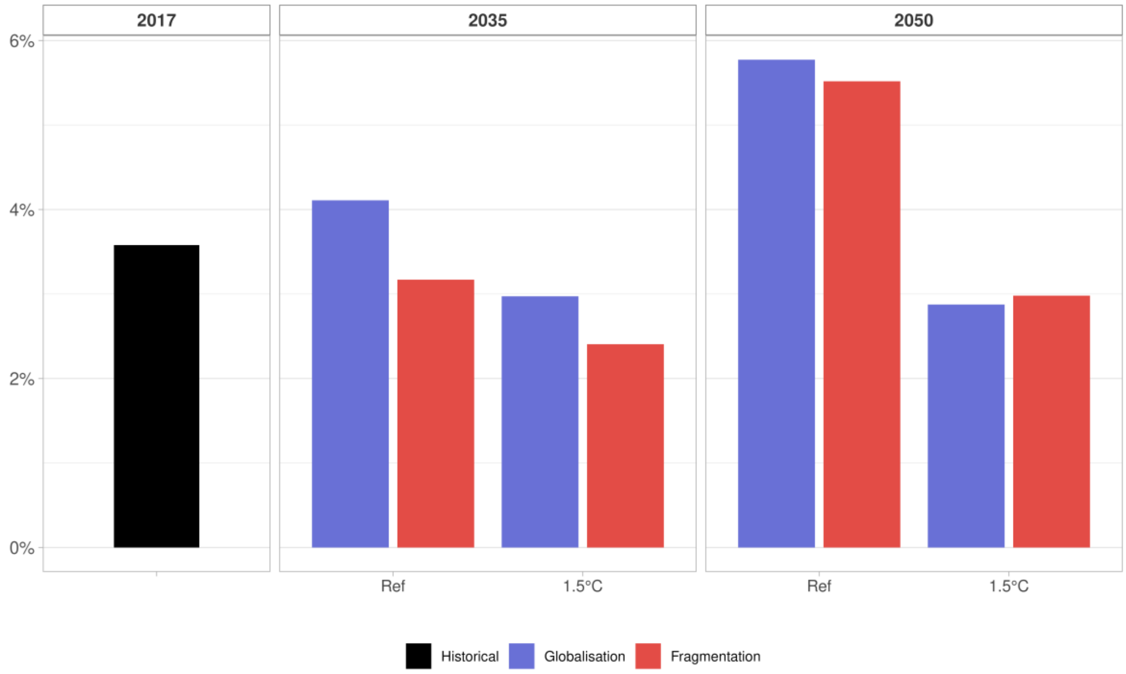
These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

Exports by sector for different scenarios - Canada



Imports by sector for different scenarios - Canada

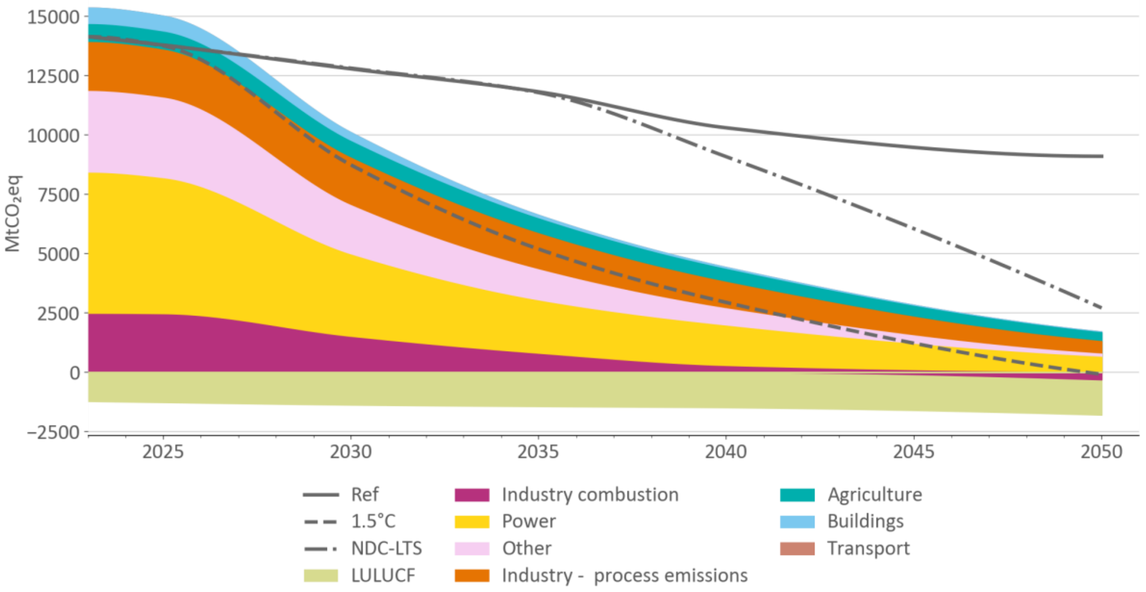
Share of fossil fuels in total imports for different scenarios – Canada



China

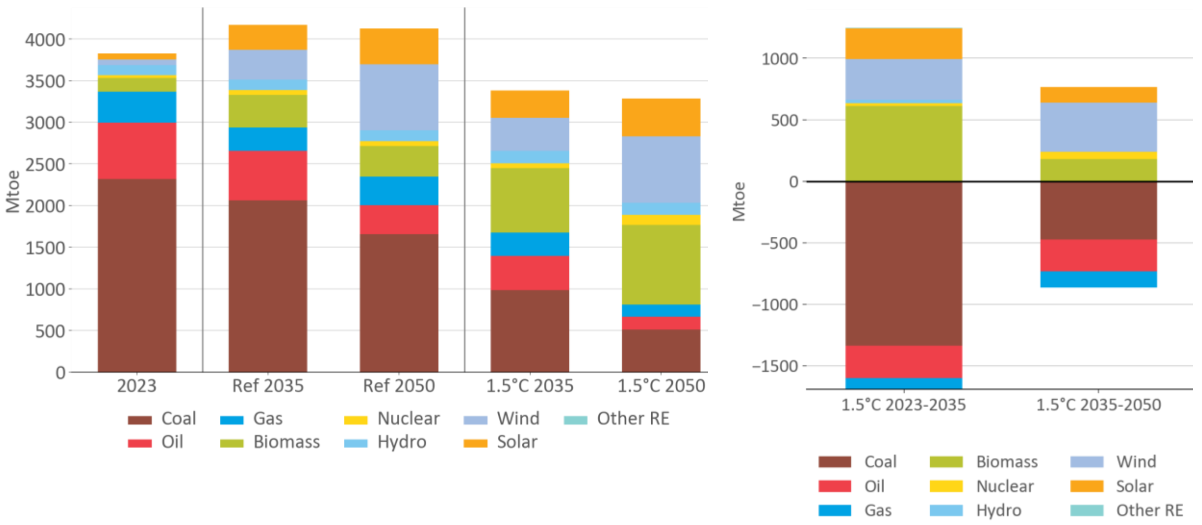
China's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - China

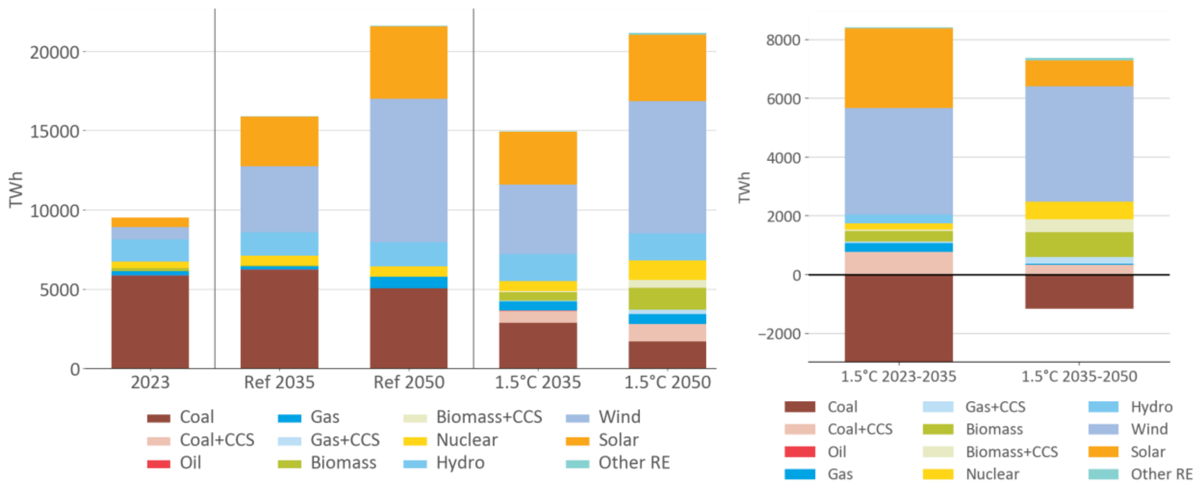


Note: the Other category includes non-CO_2 emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO_2.

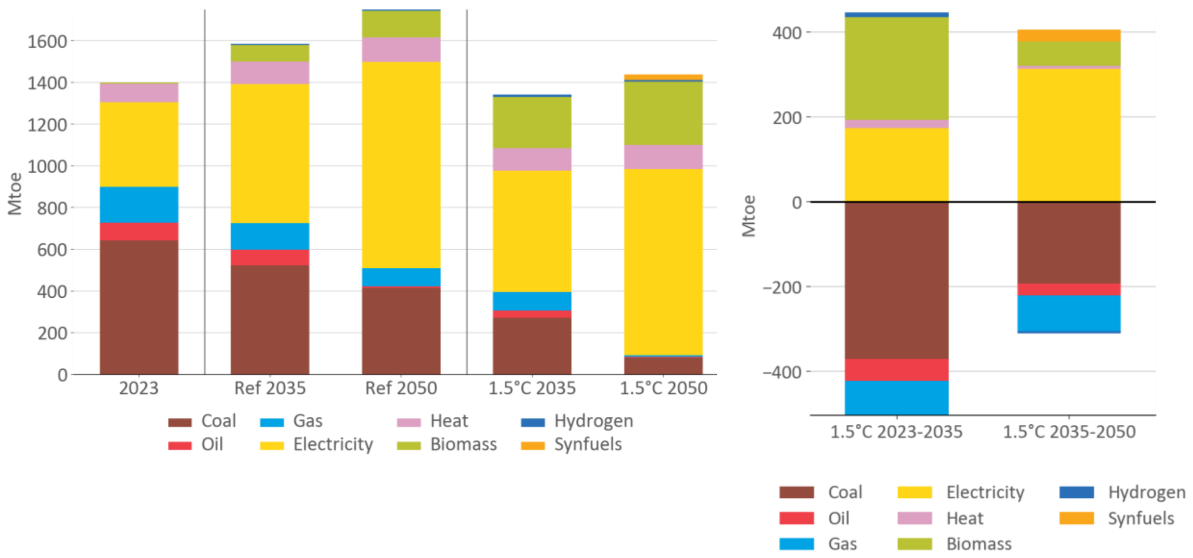
Primary energy demand, and change in primary energy demand - China



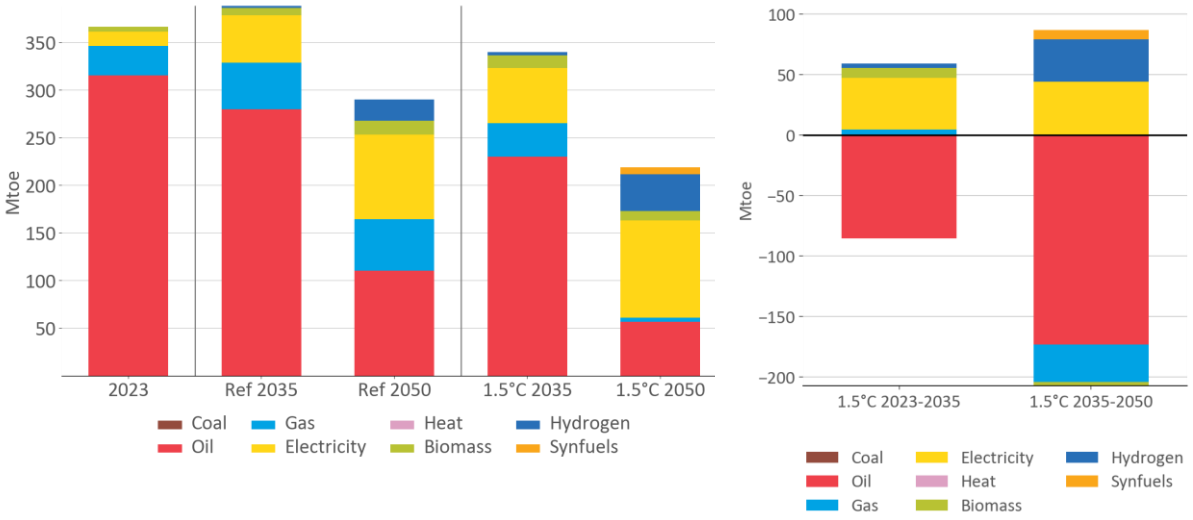
Power generation, and change in power generation - China



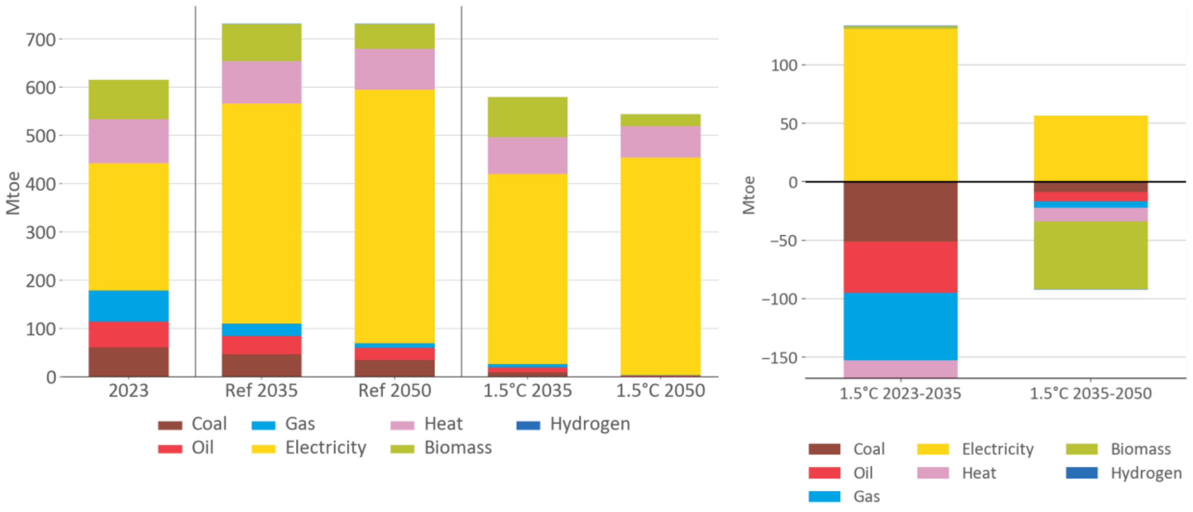
Industry sector demand, and change in industrial sector demand - China



Transport sector demand, and change in transport sector demand - China



Buildings sector demand, and change in buildings sector demand - China

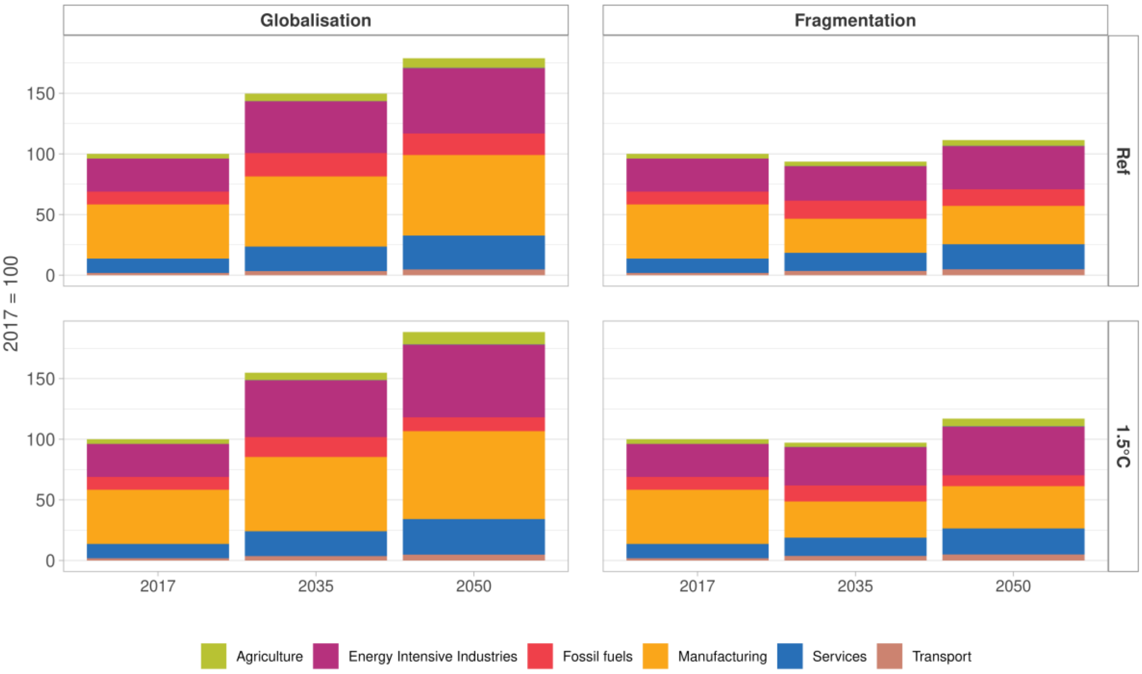


Trade dynamics

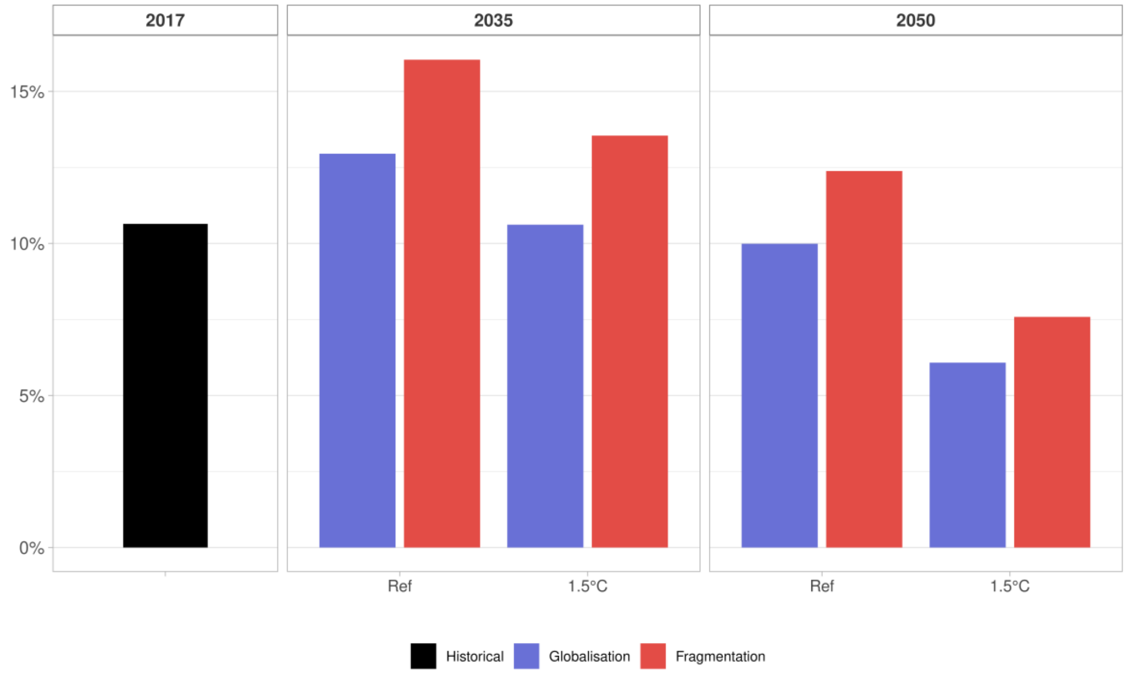
These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

Exports by sector for different scenarios - China

Imports by sector for different scenarios - China



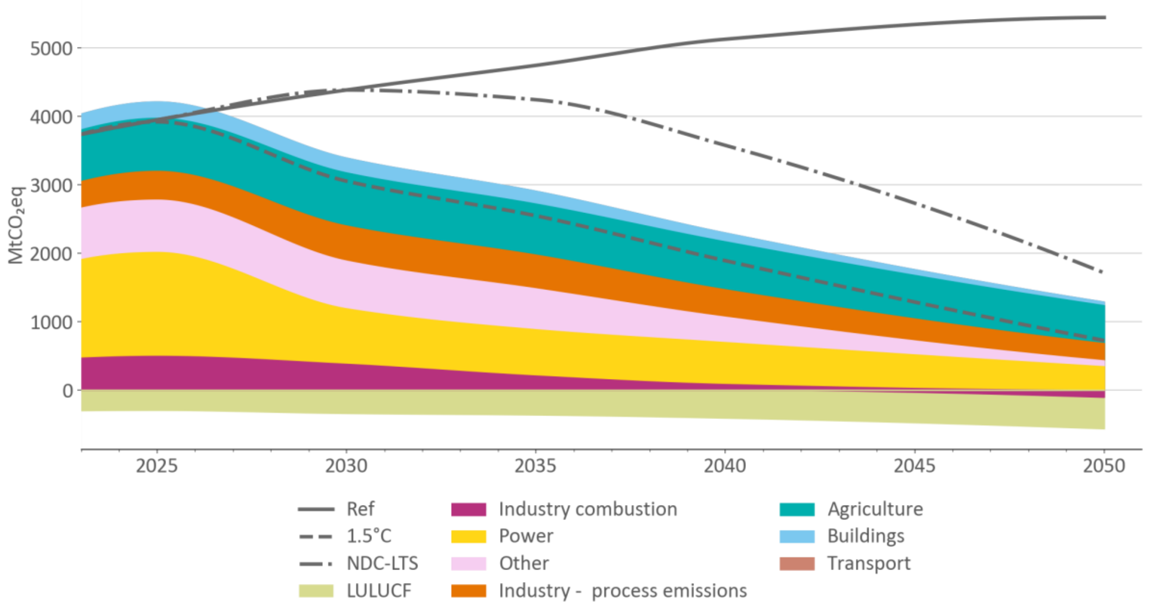
Share of fossil fuels in total imports for different scenarios – China



India

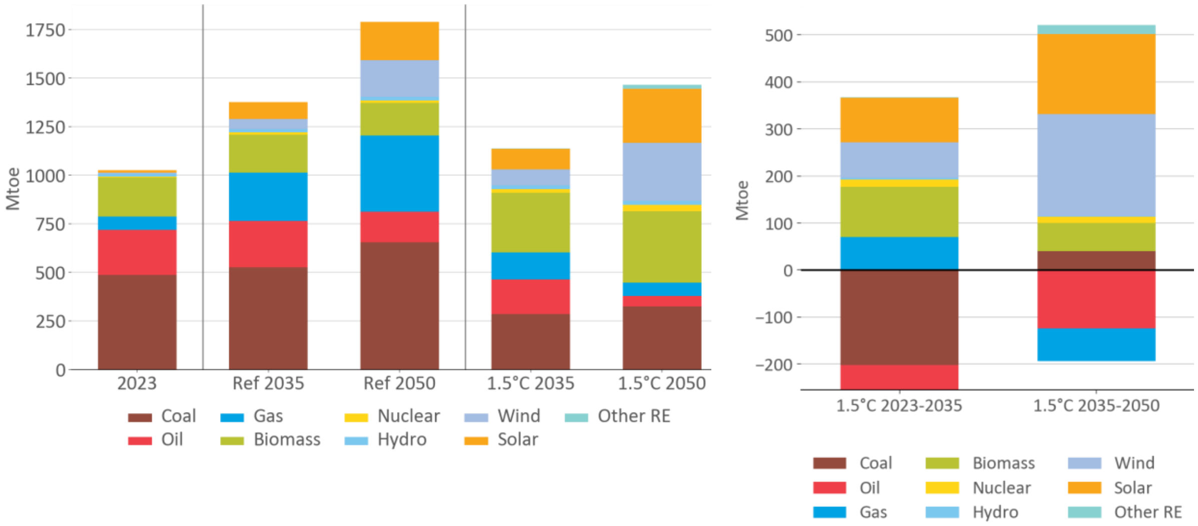
India's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - India

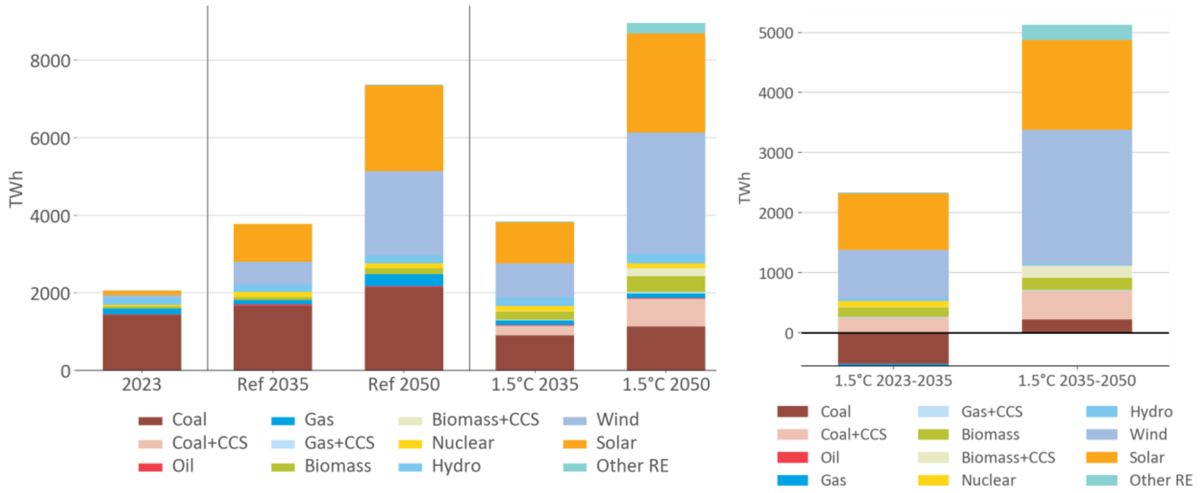


Note: the Other category includes non-CO_2 emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO_2.

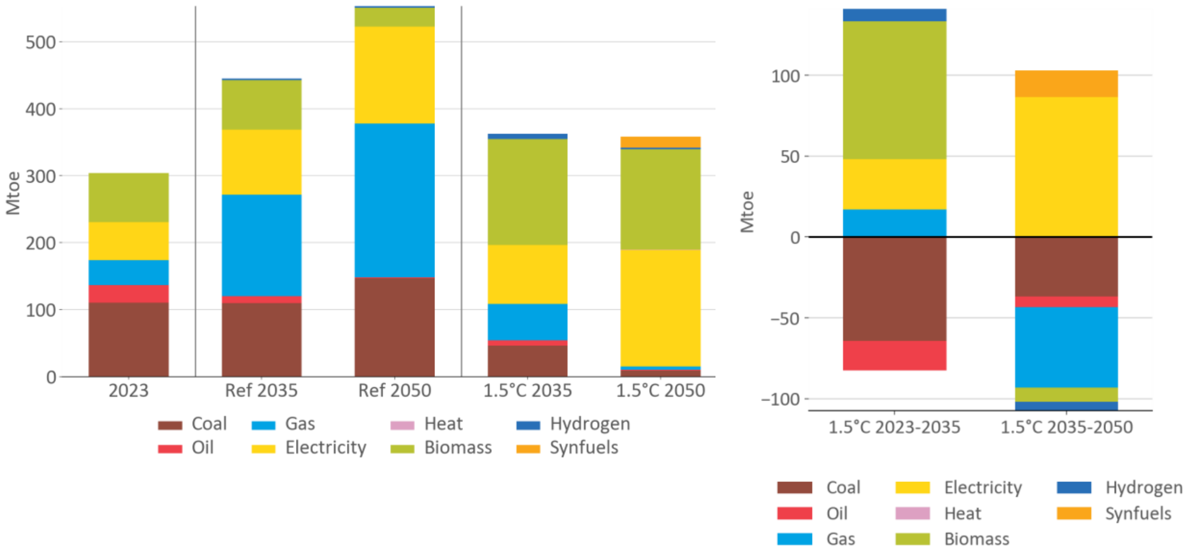
Primary energy demand, and change in primary energy demand - India



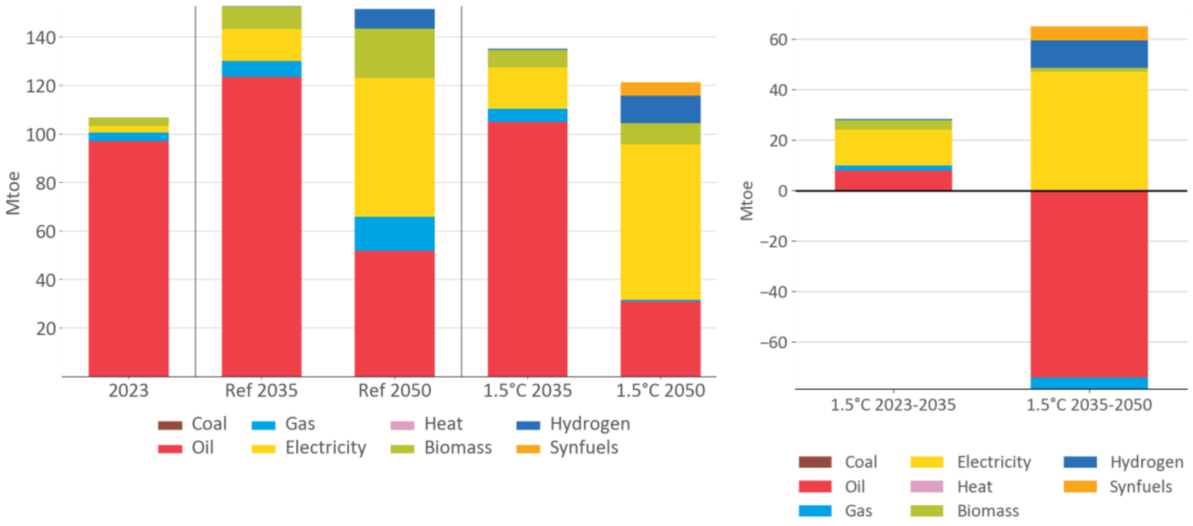
Power generation, and change in power generation - India



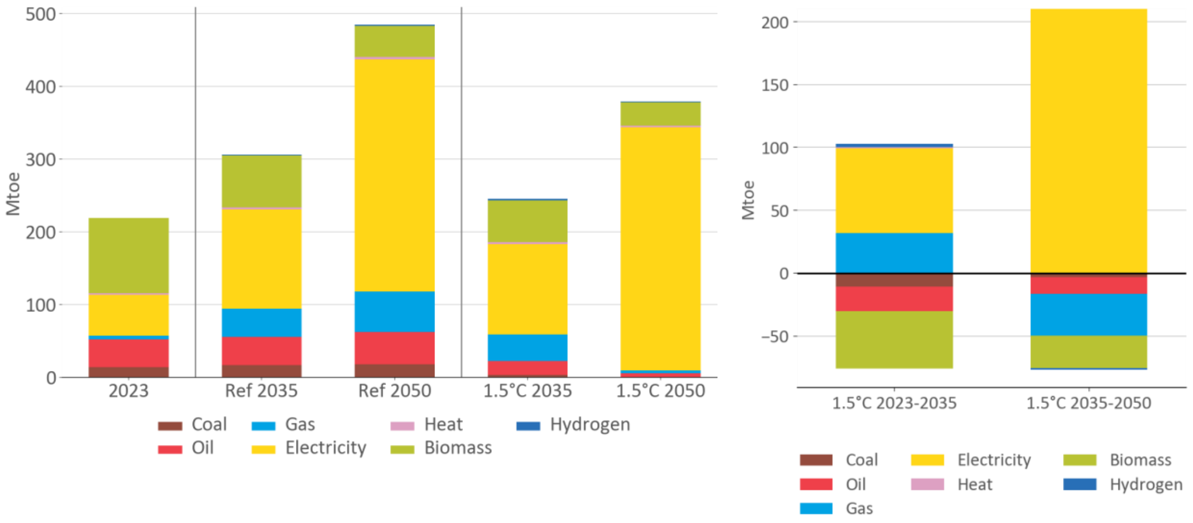
Industry sector demand, and change in industrial sector demand - India



Transport sector demand, and change in transport sector demand - India



Buildings sector demand, and change in buildings sector demand - India



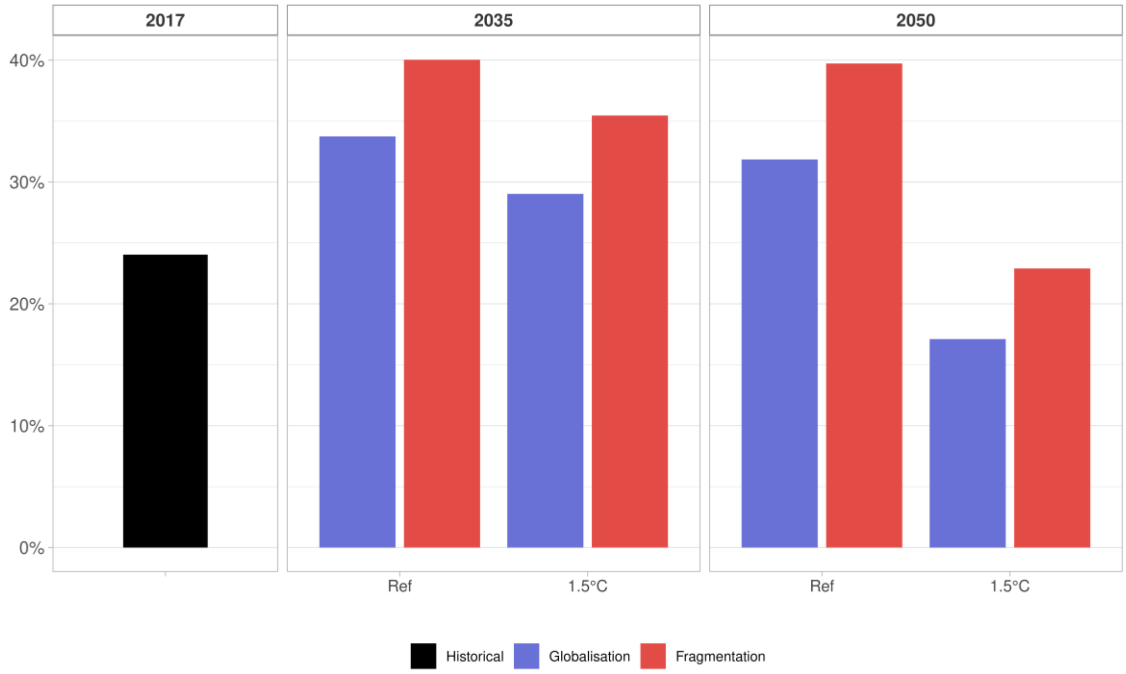
Trade dynamics

These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

Exports by sector for different scenarios - India

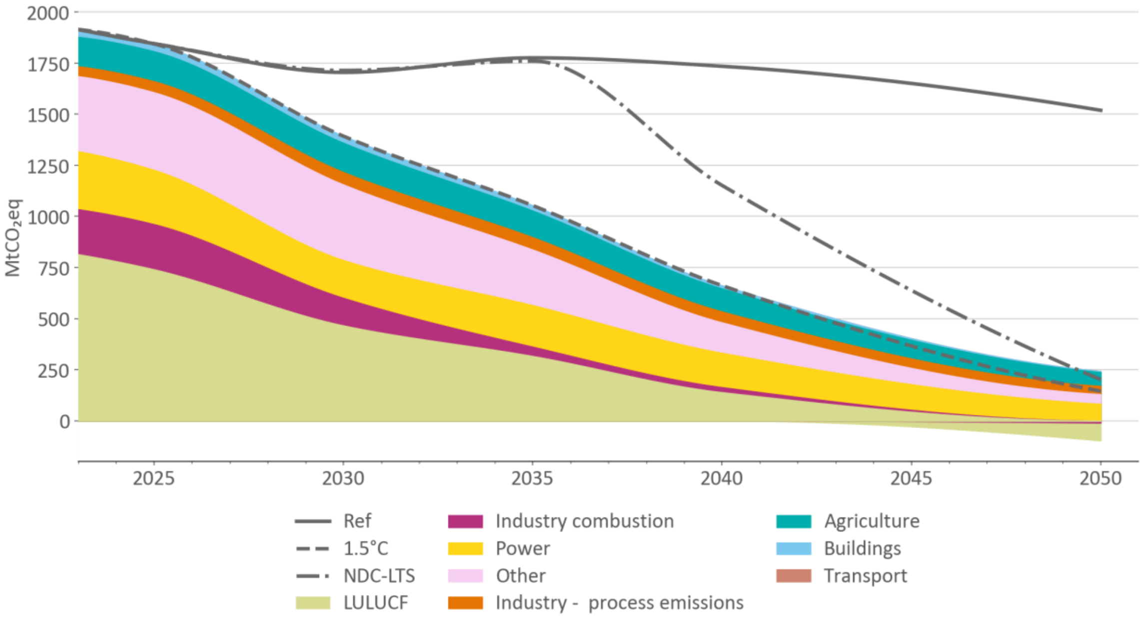
Imports by sector for different scenarios - India

Share of fossil fuels in total imports for different scenarios – India



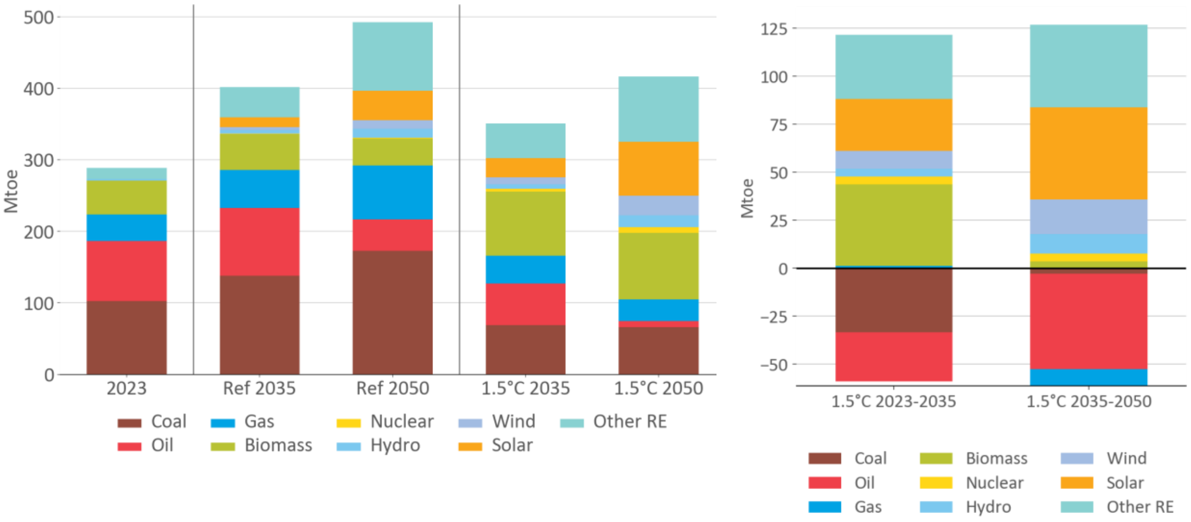
Indonesia

Indonesia's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).



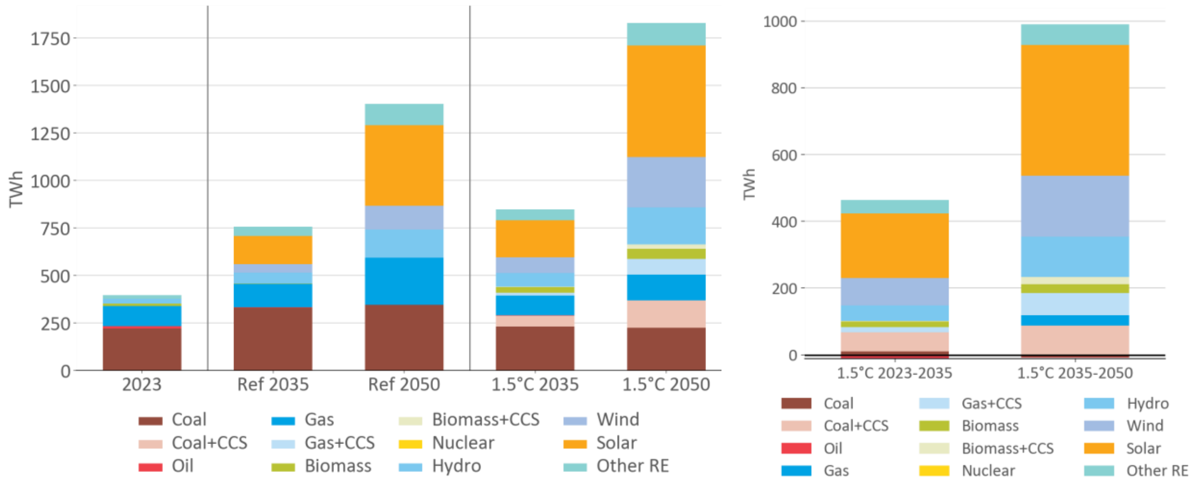
Emissions by scenario and sectoral breakdown of 1.5°C scenario - Indonesia

Note: the Other category includes non-CO_2 emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO_2.

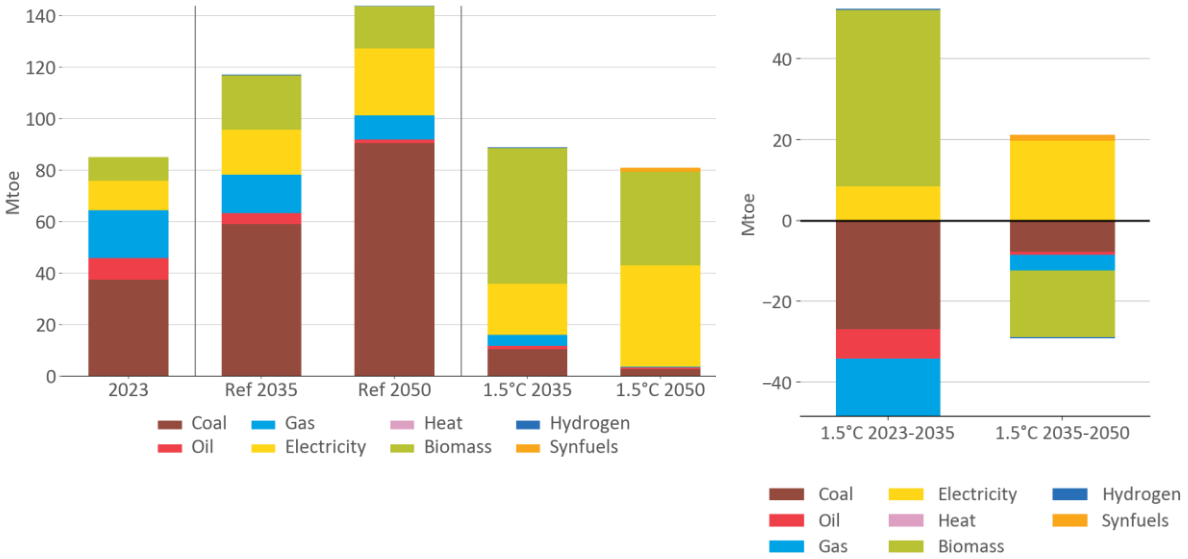


Primary energy demand, and change in primary energy demand - Indonesia

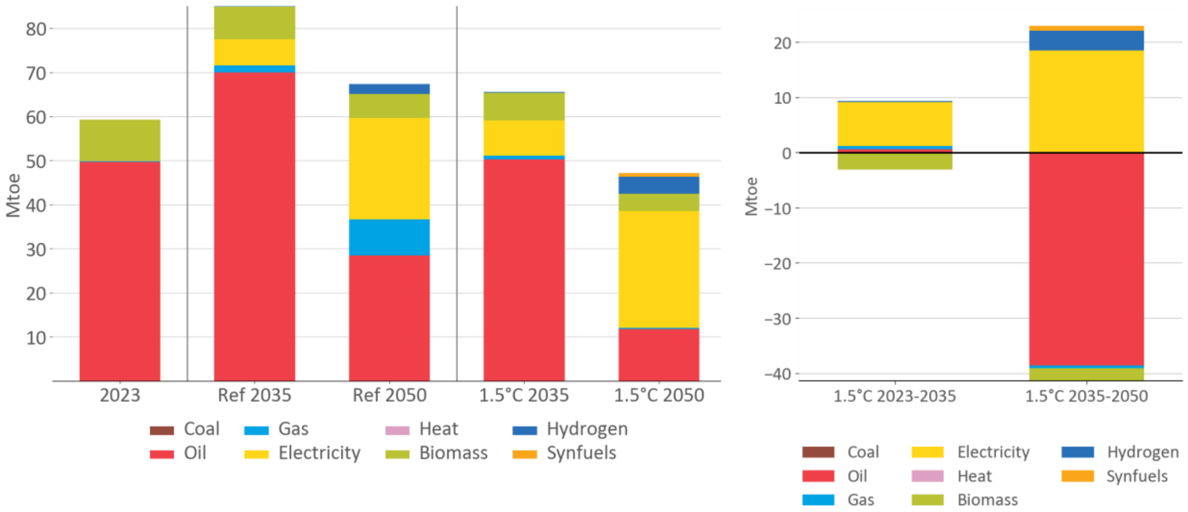
Power generation, and change in power generation - Indonesia



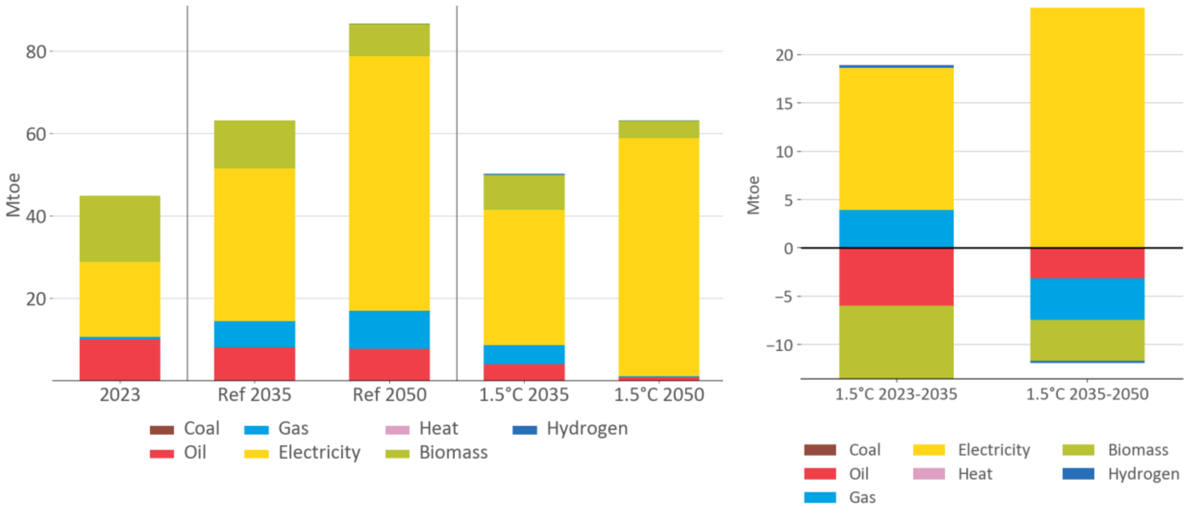
Industry sector demand, and change in industrial sector demand - Indonesia



Transport sector demand, and change in transport sector demand - Indonesia



Buildings sector demand, and change in buildings sector demand - Indonesia



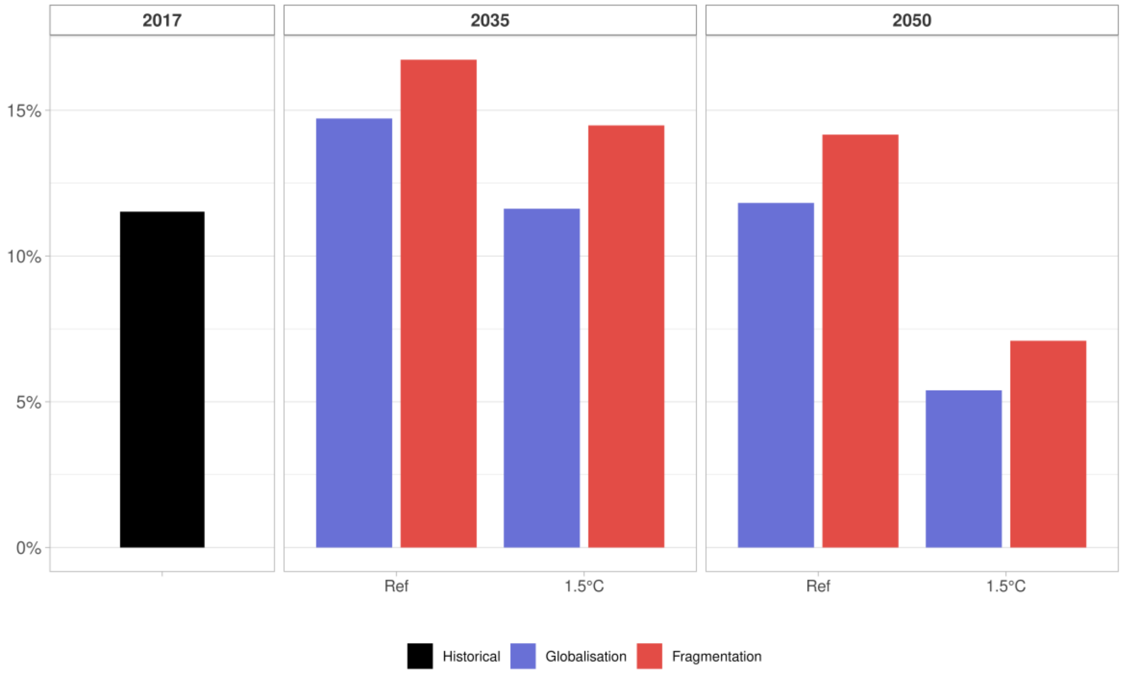
Trade dynamics

These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

Exports by sector for different scenarios - Indonesia

Imports by sector for different scenarios - Indonesia

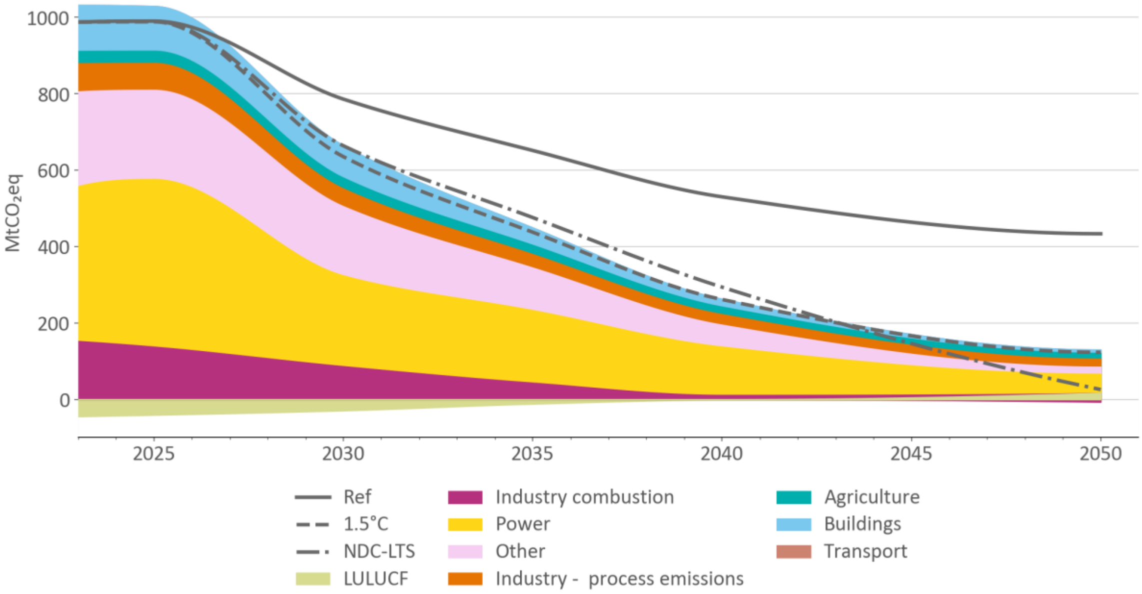
Share of fossil fuels in total imports for different scenarios – Indonesia



Japan

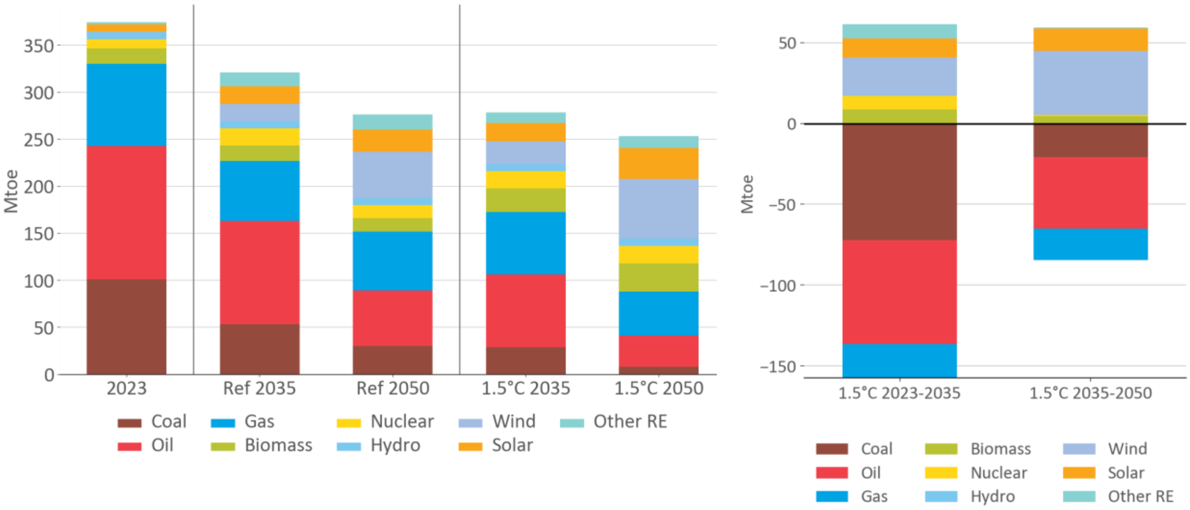
Japan’s decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - Japan

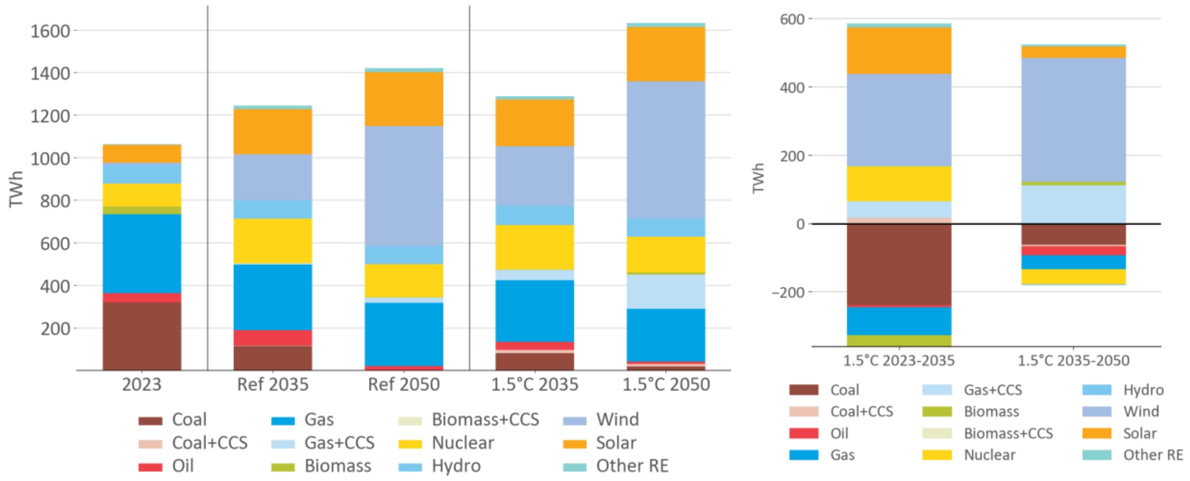


Note: the Other category includes non-CO_2 emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO_2.

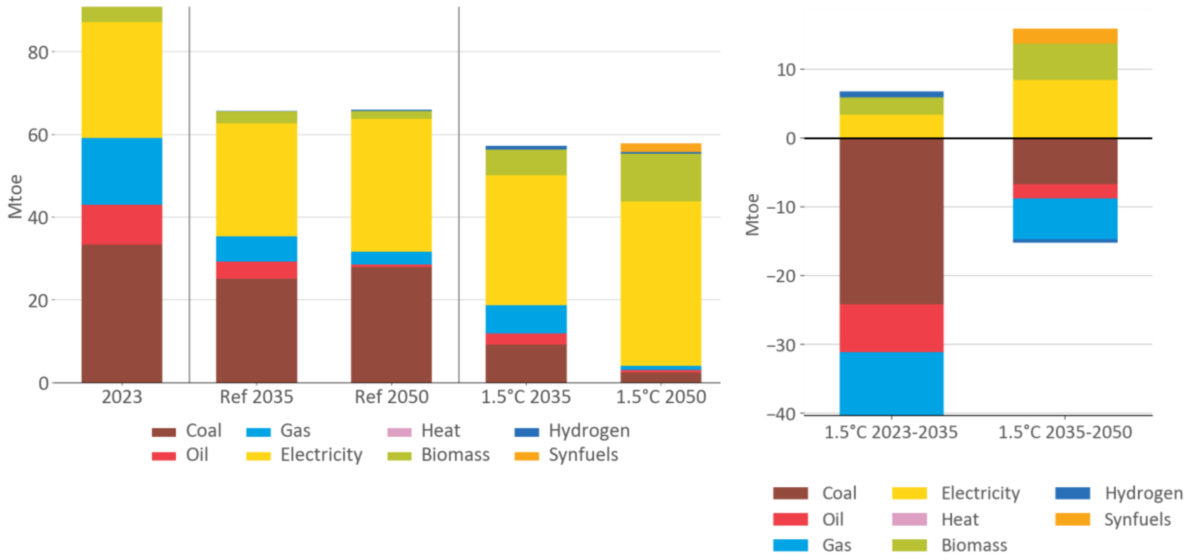
Primary energy demand, and change in primary energy demand - Japan



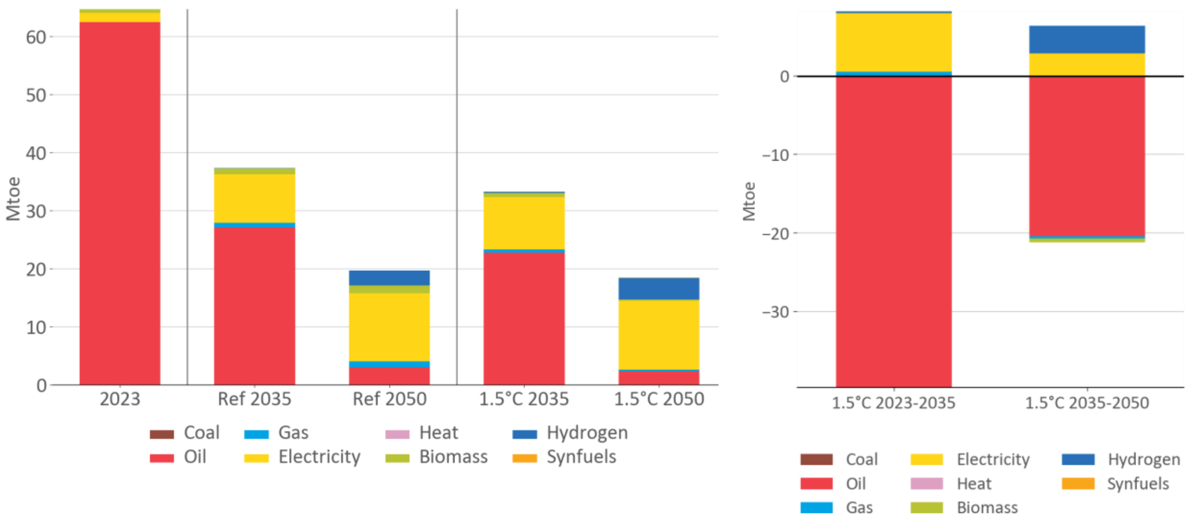
Power generation, and change in power generation - Japan



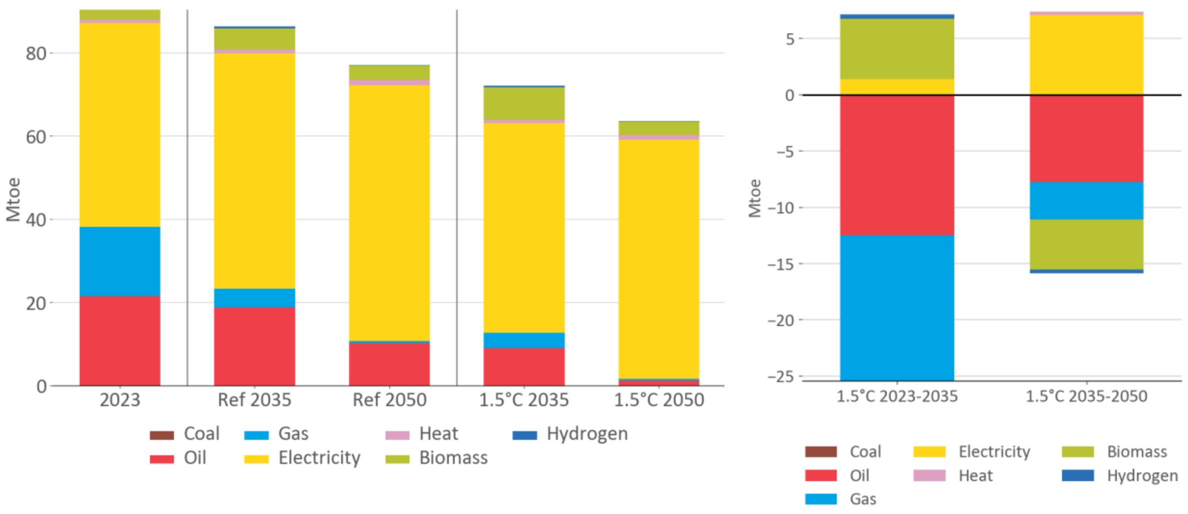
Industry sector demand, and change in industrial sector demand - Japan



Transport sector demand, and change in transport sector demand - Japan



Buildings sector demand, and change in buildings sector demand - Japan



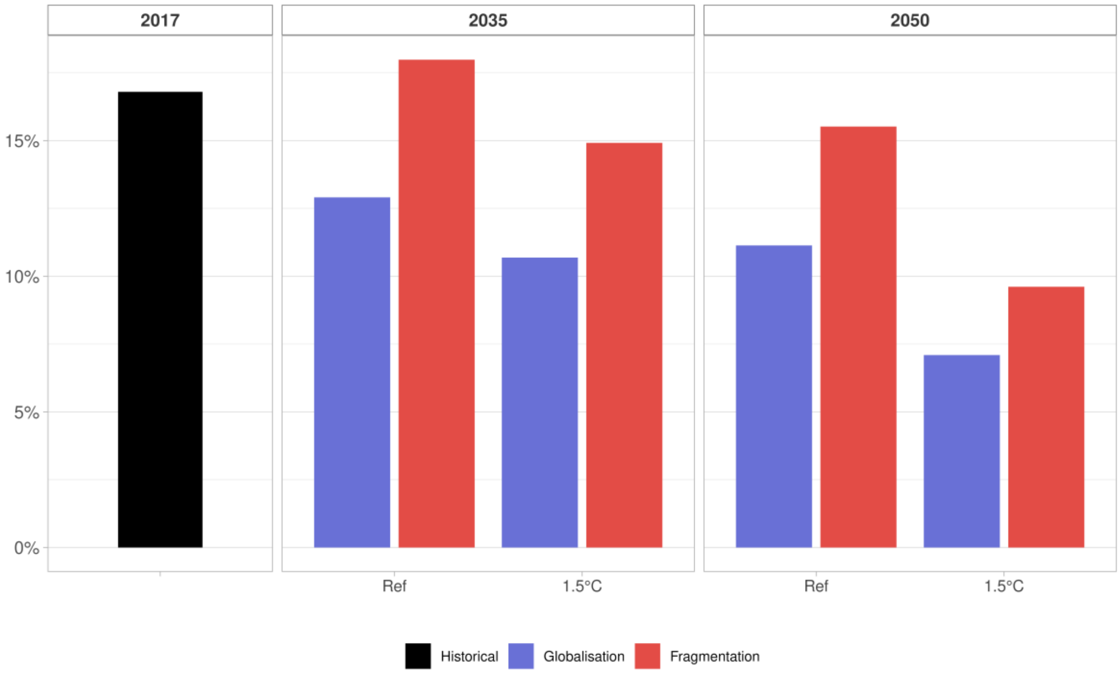
Trade dynamics

These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

Exports by sector for different scenarios - Japan

Imports by sector for different scenarios - Japan

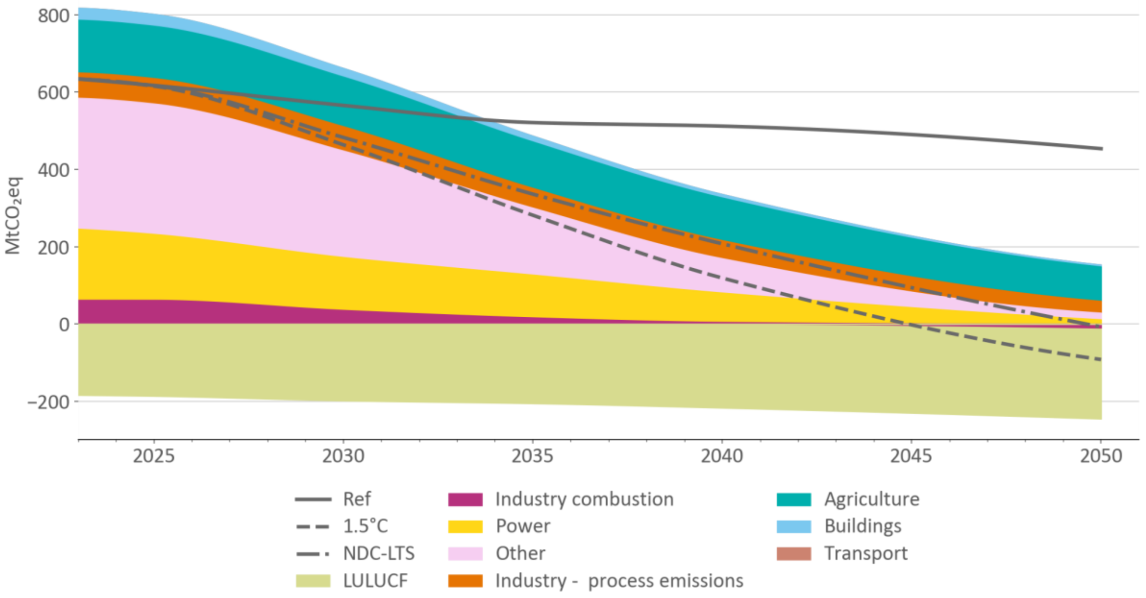
Share of fossil fuels in total imports for different scenarios – Japan



Mexico

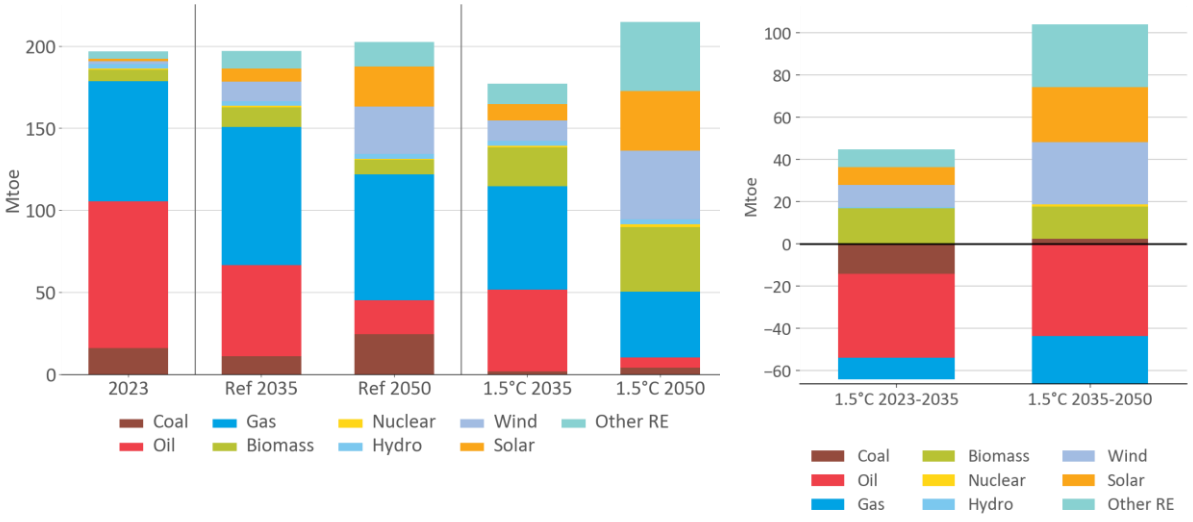
Mexico's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - Mexico

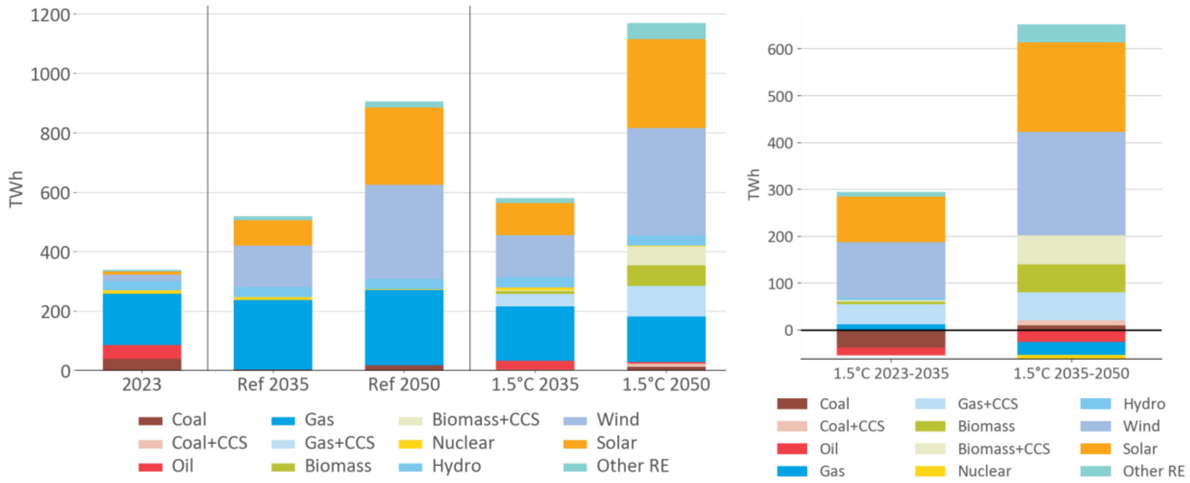


Note: the Other category includes non-CO_2 emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO_2.

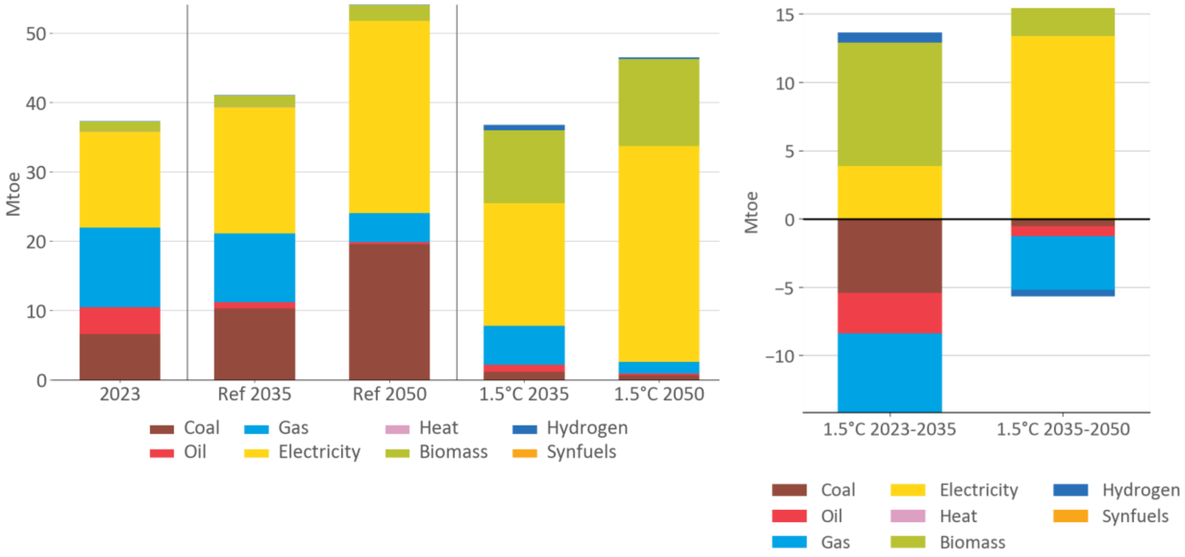
Primary energy demand, and change in primary energy demand - Mexico



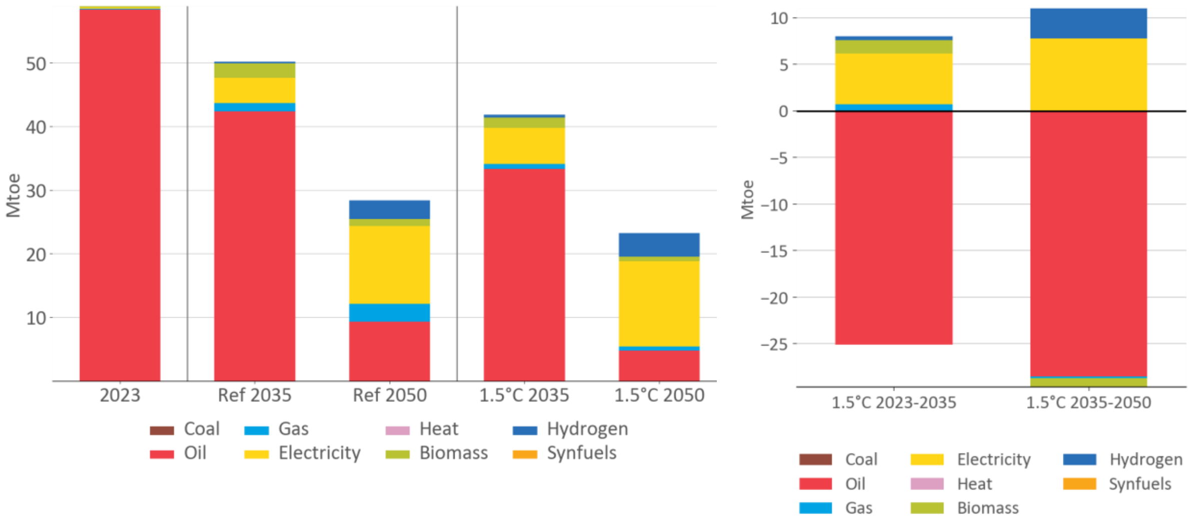
Power generation, and change in power generation - Mexico



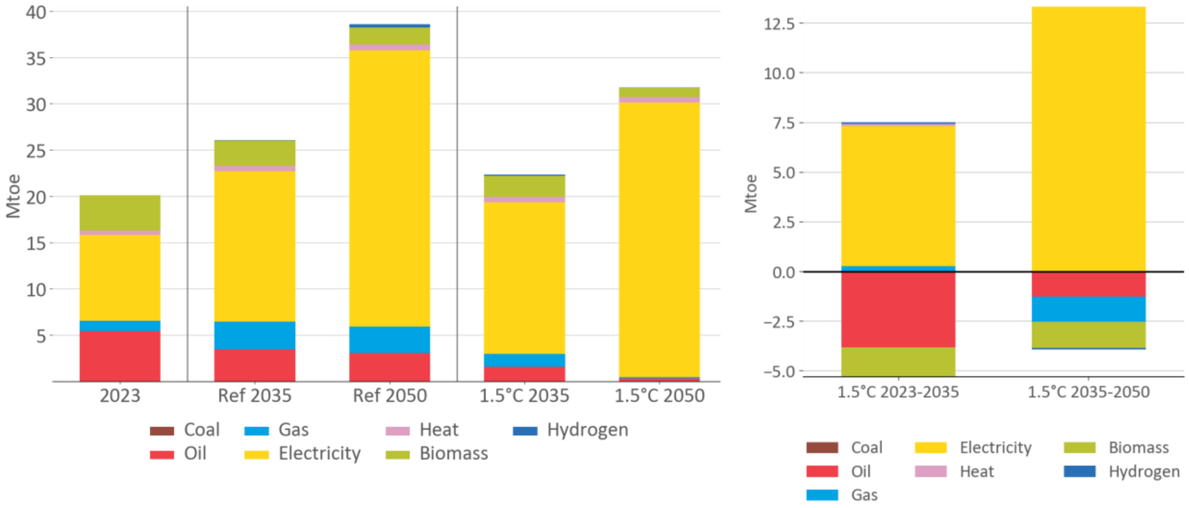
Industry sector demand, and change in industrial sector demand - Mexico



Transport sector demand, and change in transport sector demand - Mexico



Buildings sector demand, and change in buildings sector demand - Mexico



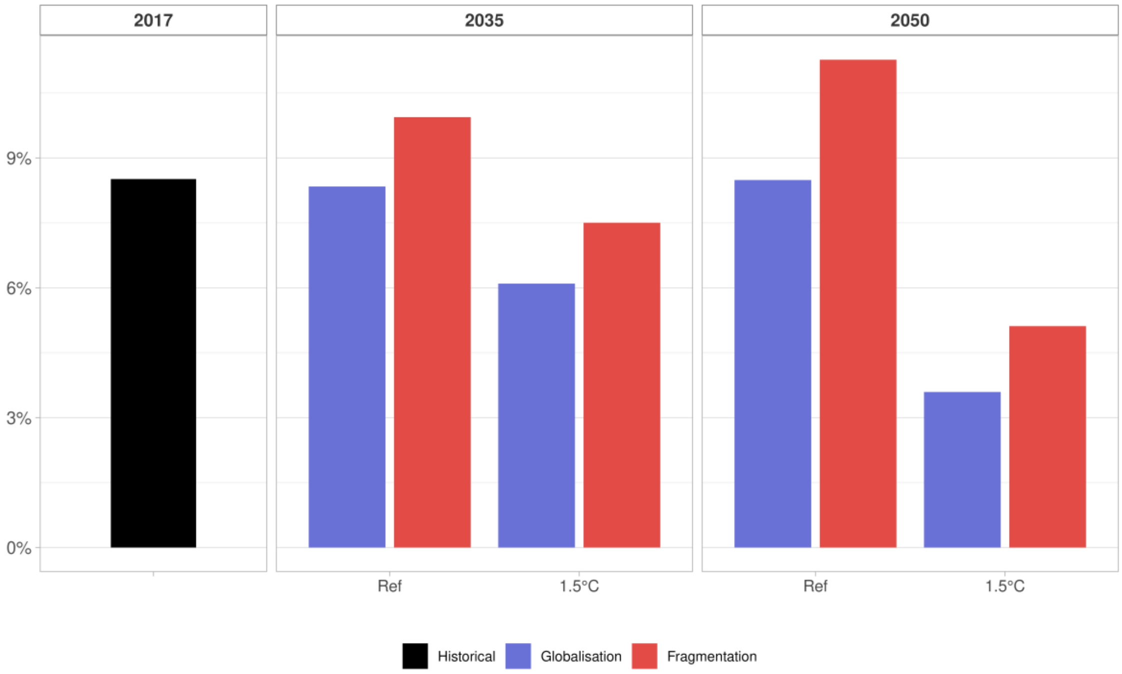
Trade dynamics

These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

Exports by sector for different scenarios - Mexico

Imports by sector for different scenarios - Mexico

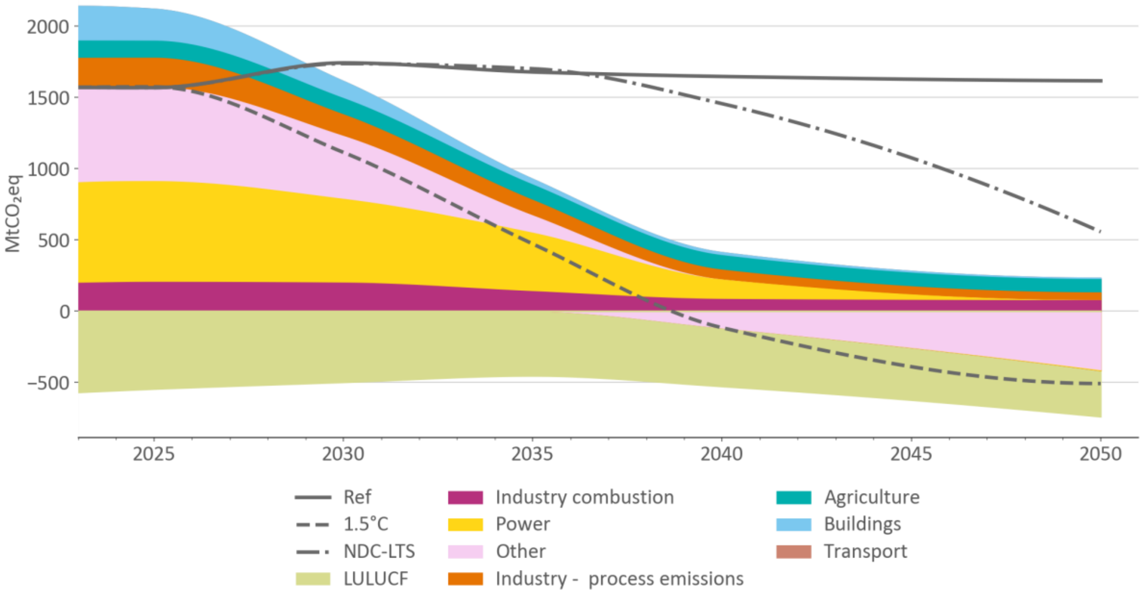
Share of fossil fuels in total imports for different scenarios – Mexico



Russia

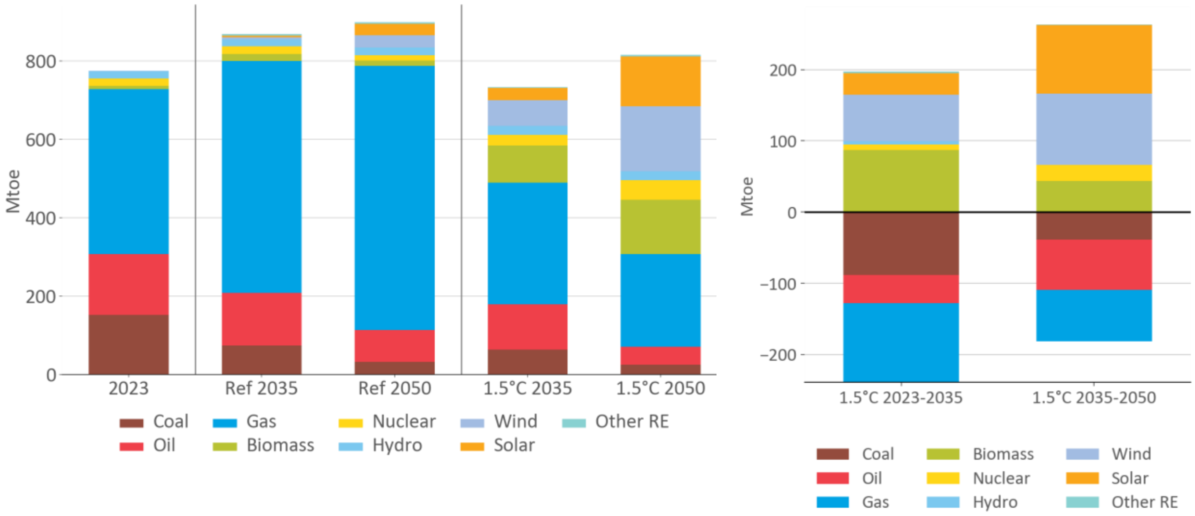
Russia's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - Russia

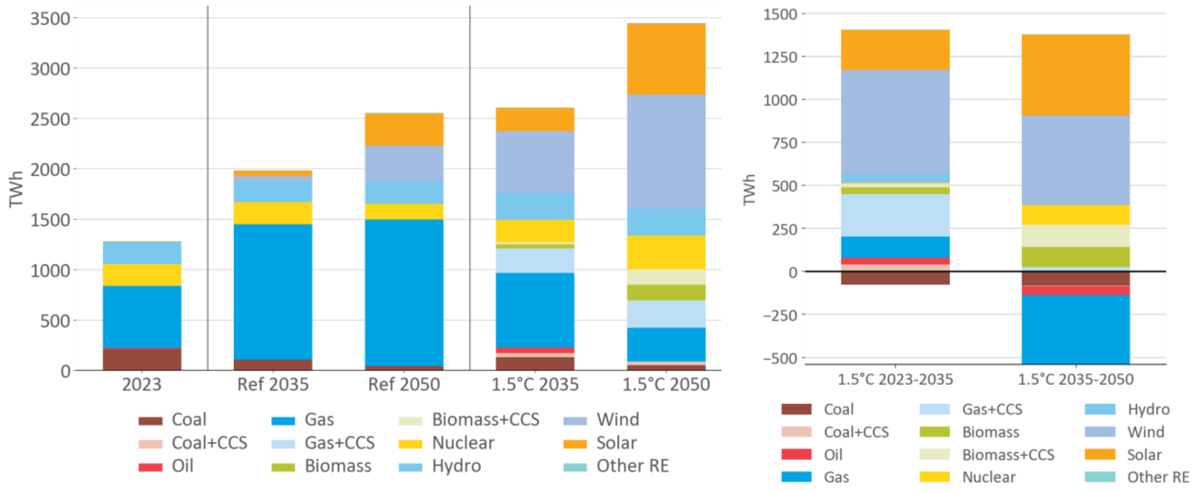


Note: the Other category includes non-CO_2 emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO_2.

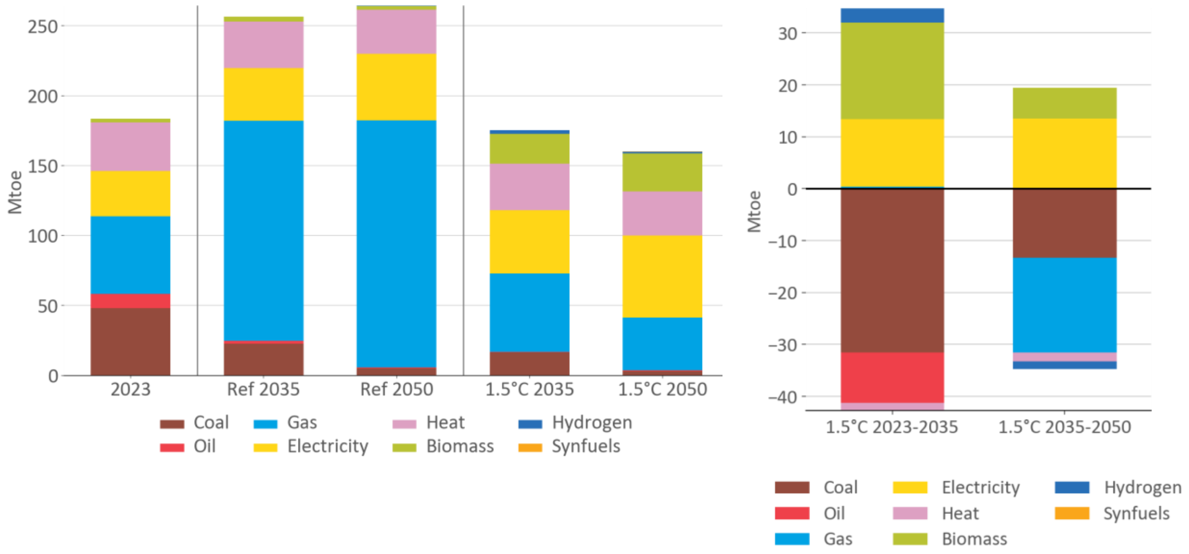
Primary energy demand, and change in primary energy demand - Russia



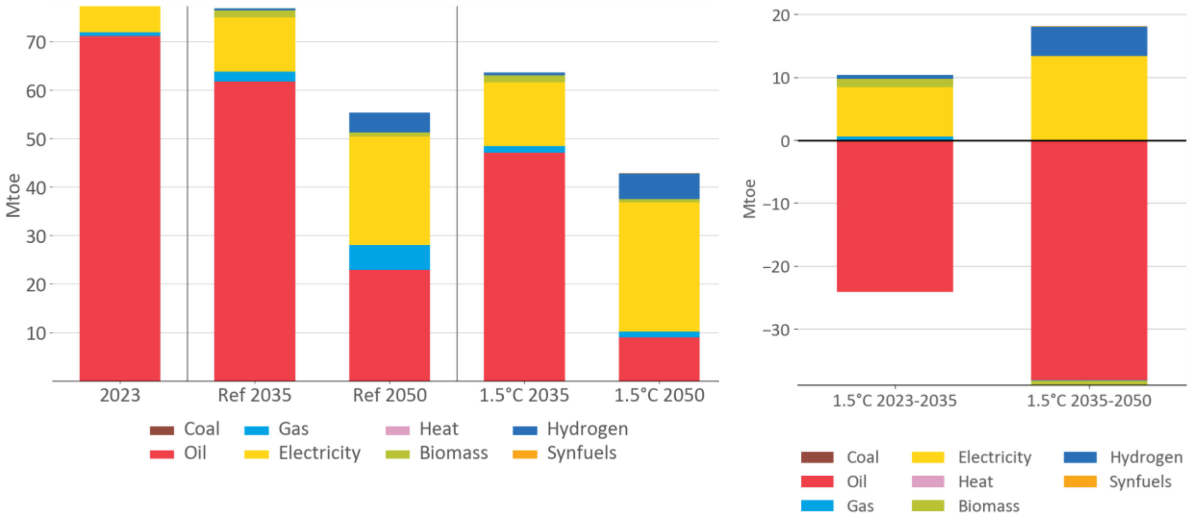
Power generation, and change in power generation - Russia



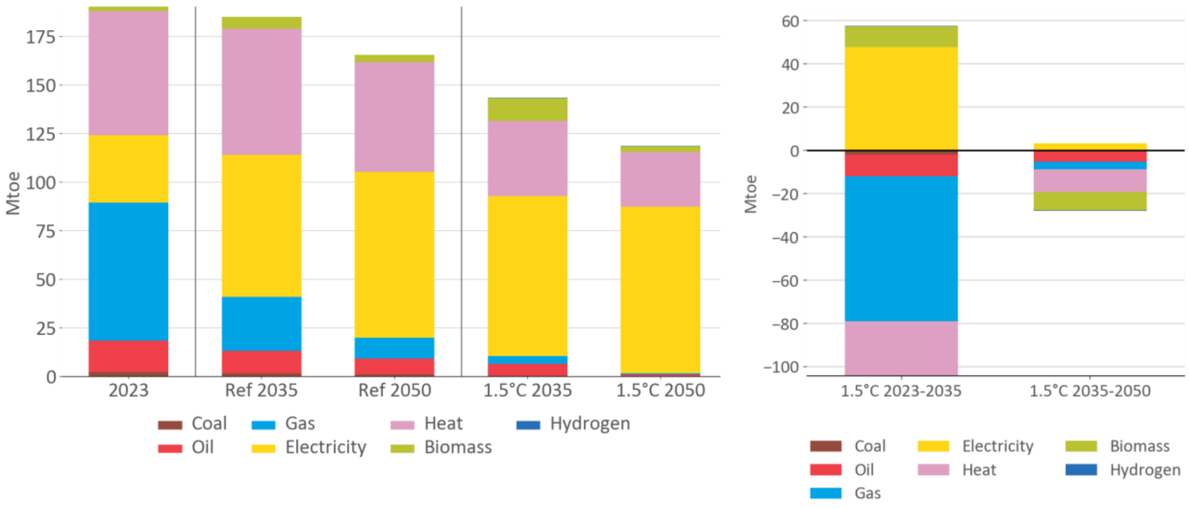
Industry sector demand, and change in industrial sector demand - Russia



Transport sector demand, and change in transport sector demand - Russia



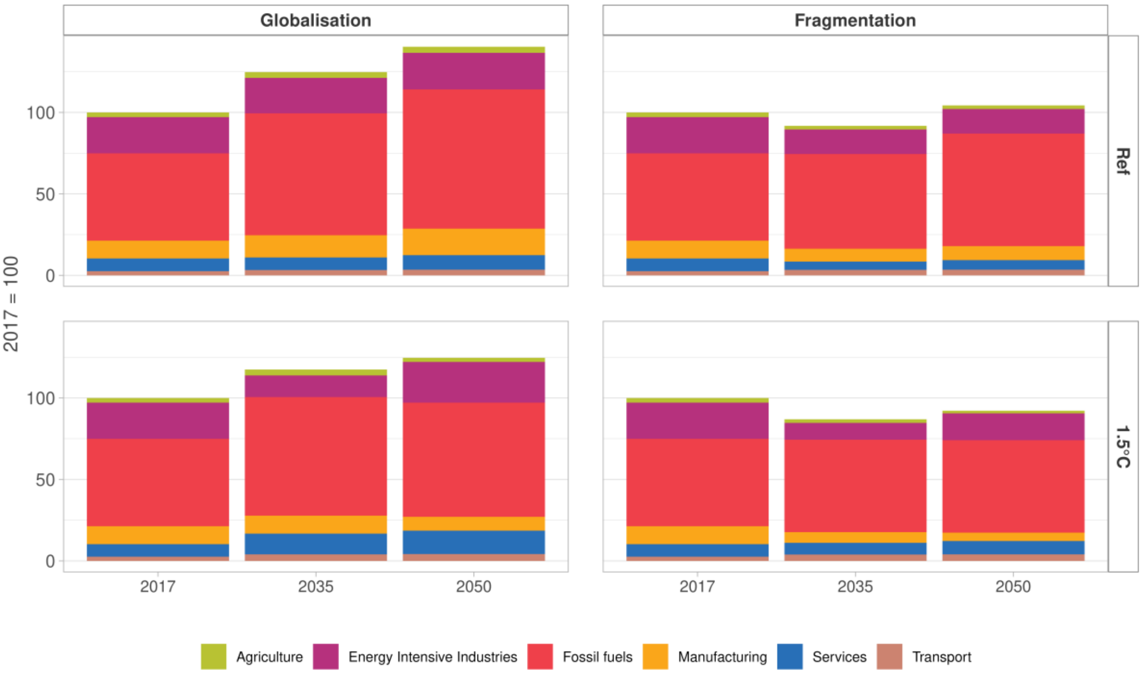
Buildings sector demand, and change in buildings sector demand - Russia



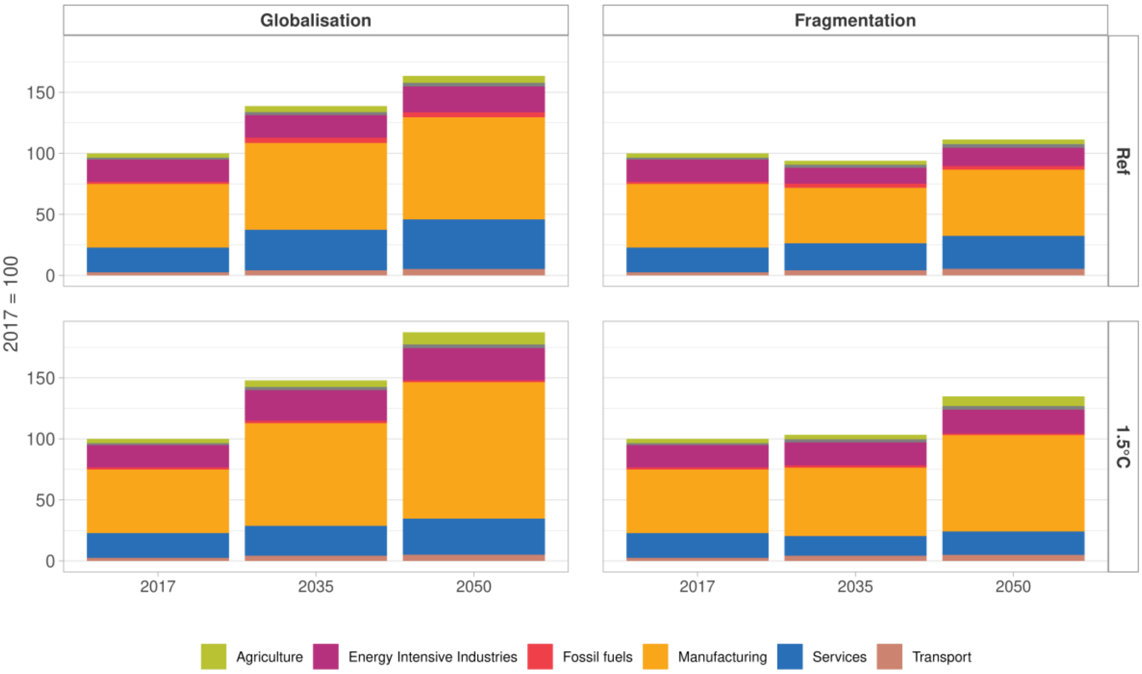
Trade dynamics

These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

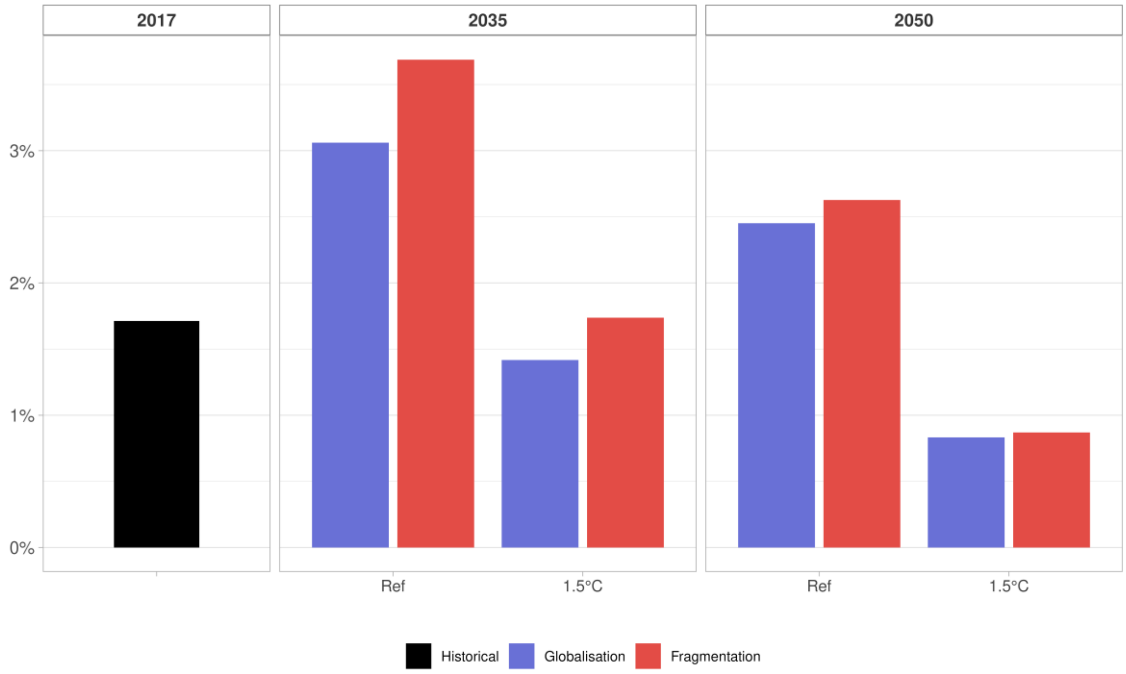
Exports by sector for different scenarios - Russia



Imports by sector for different scenarios - Russia



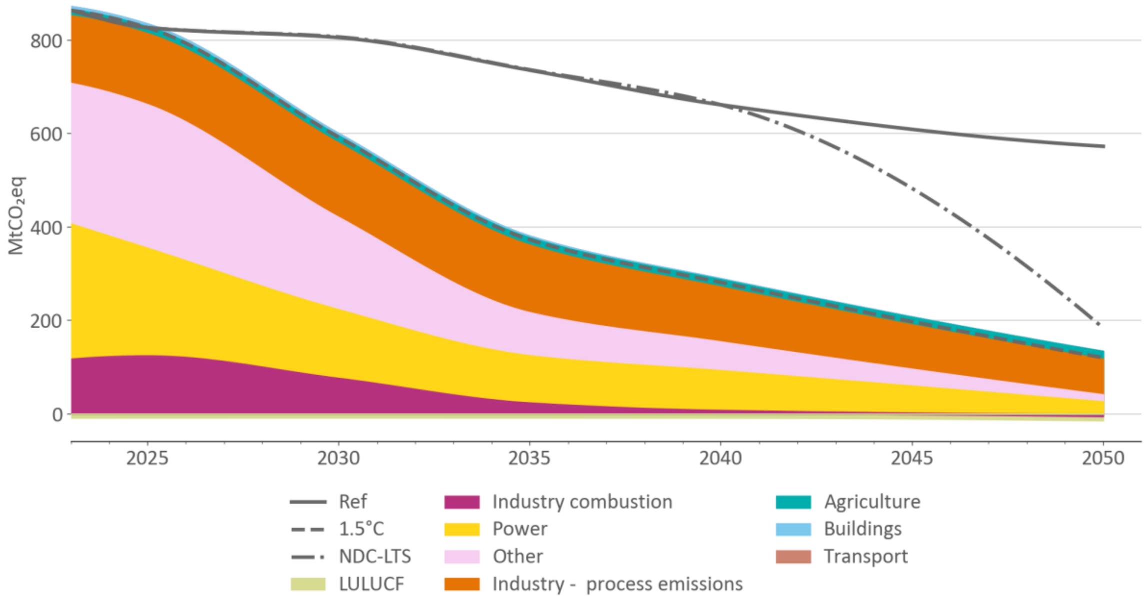
Share of fossil fuels in total imports for different scenarios – Russia



Saudi Arabia

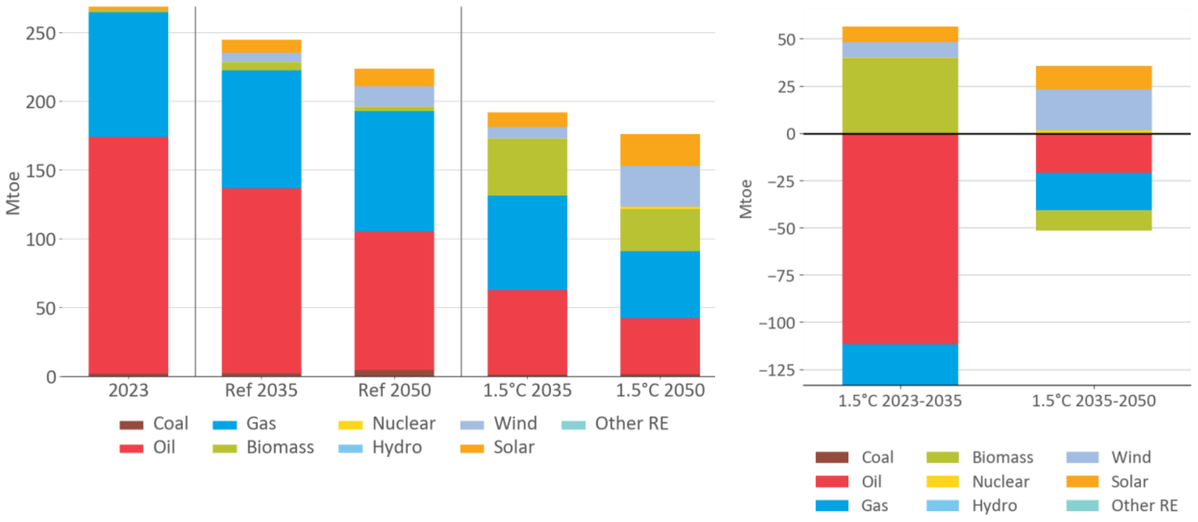
Saudi Arabia's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - Saudi Arabia

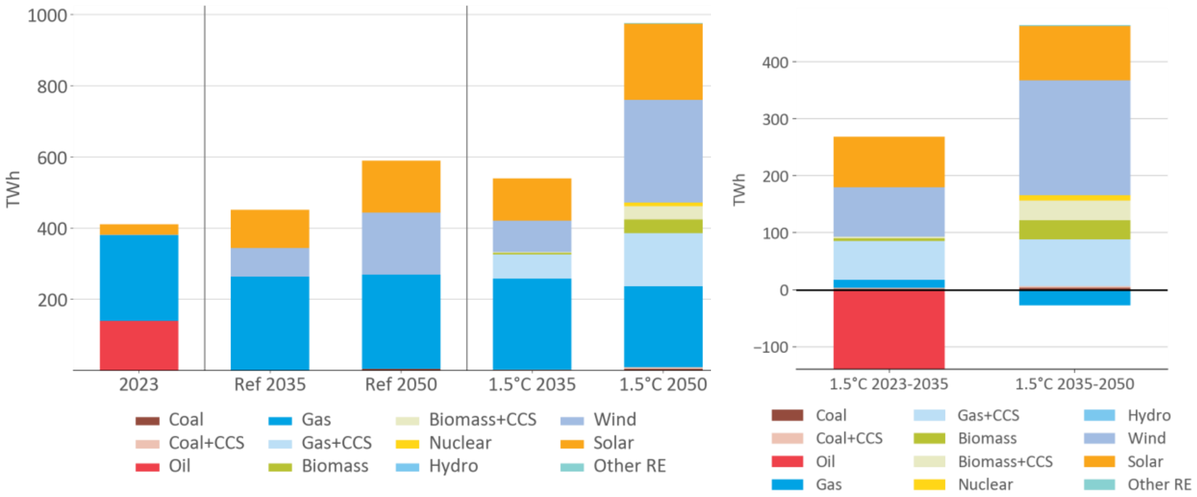


Note: the Other category includes non-CO_2 emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO_2.

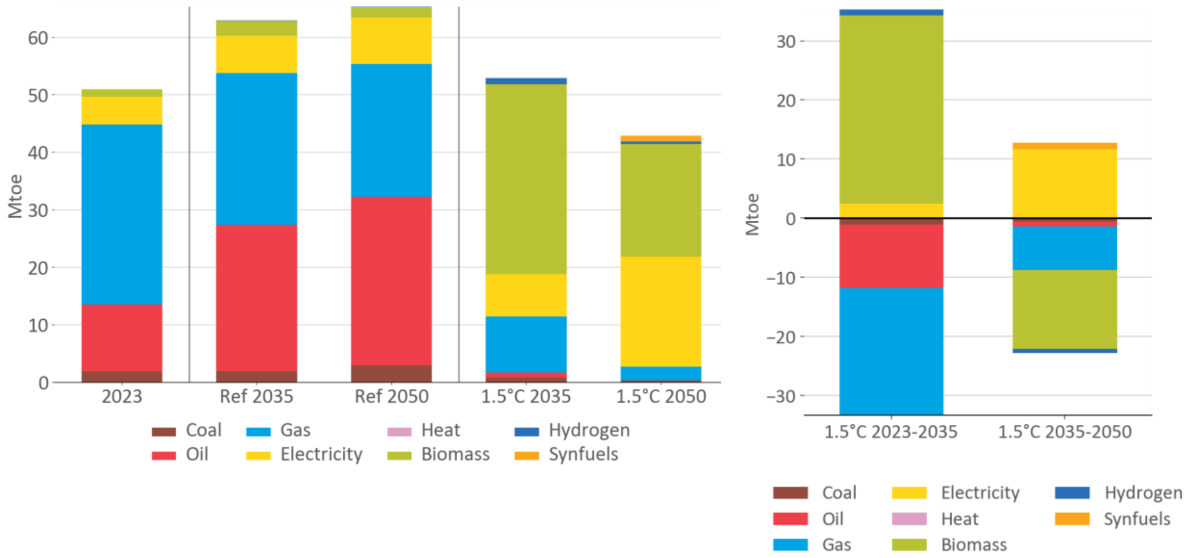
Primary energy demand, and change in primary energy demand - Saudi Arabia



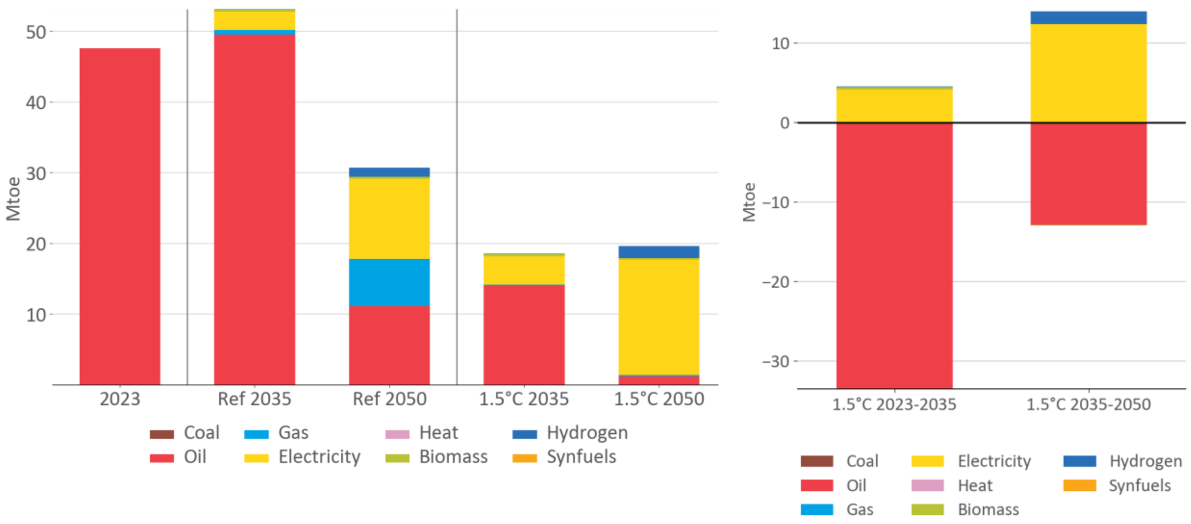
Power generation, and change in power generation - Saudi Arabia



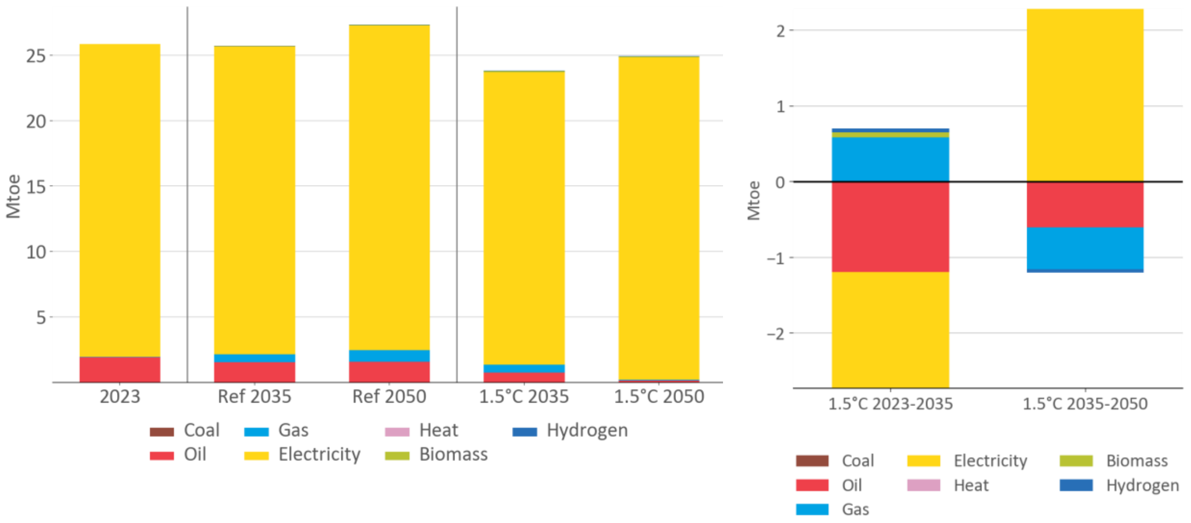
Industry sector demand, and change in industrial sector demand - Saudi Arabia



Transport sector demand, and change in transport sector demand - Saudi Arabia



Buildings sector demand, and change in buildings sector demand - Saudi Arabia



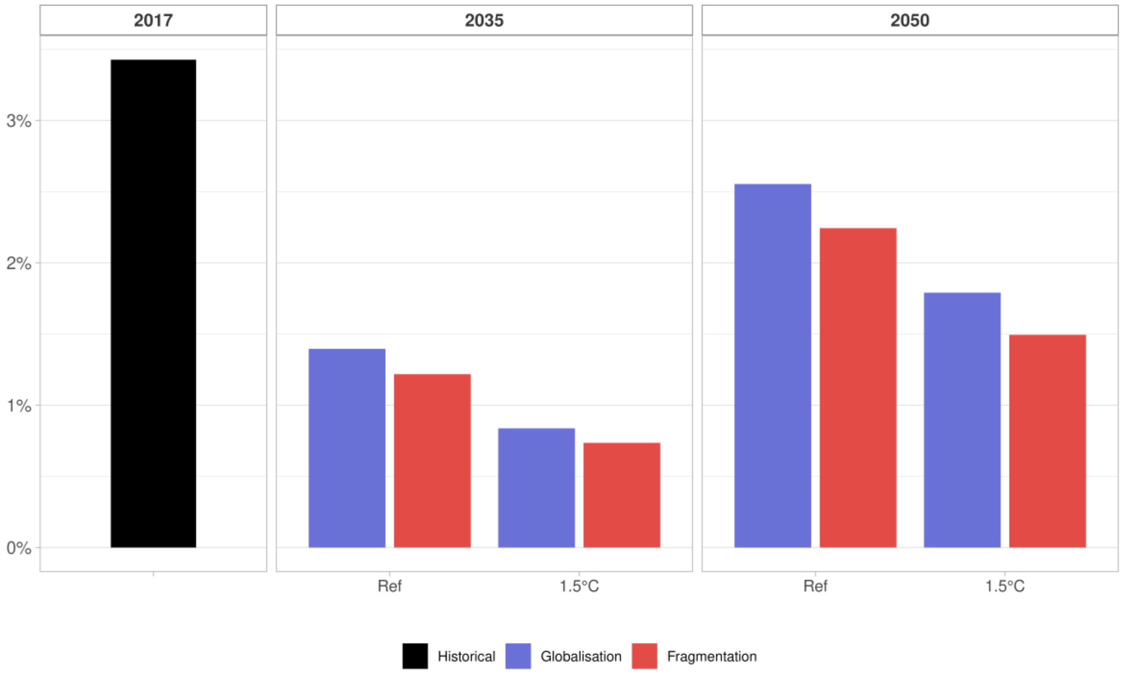
Trade dynamics

These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

Exports by sector for different scenarios - Saudi Arabia

Imports by sector for different scenarios - Saudi Arabia

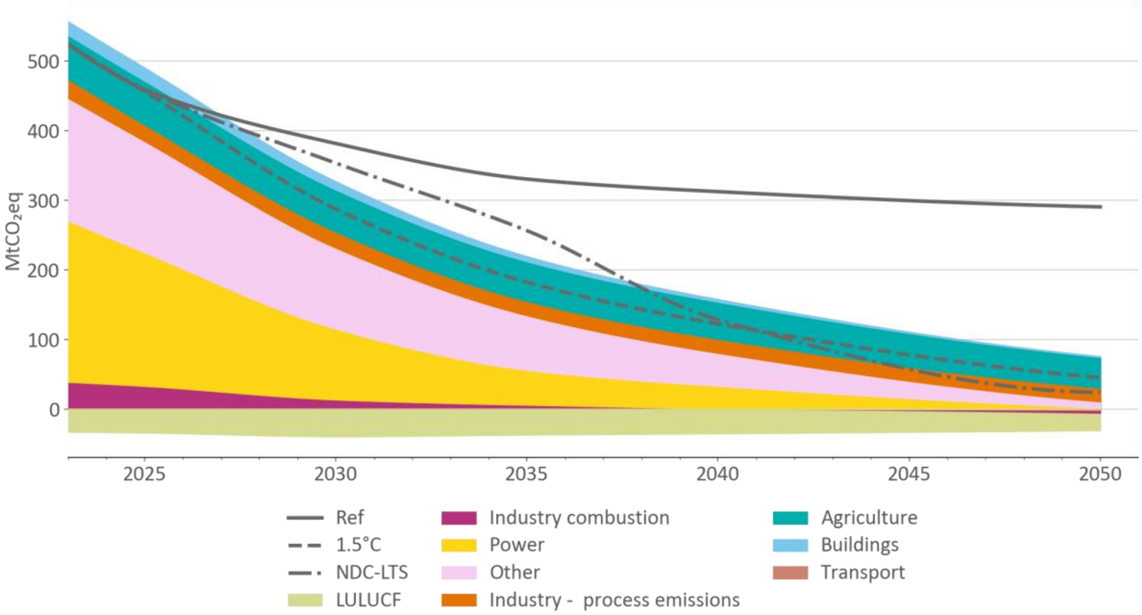
Share of fossil fuels in total imports for different scenarios – Saudi Arabia



South Africa

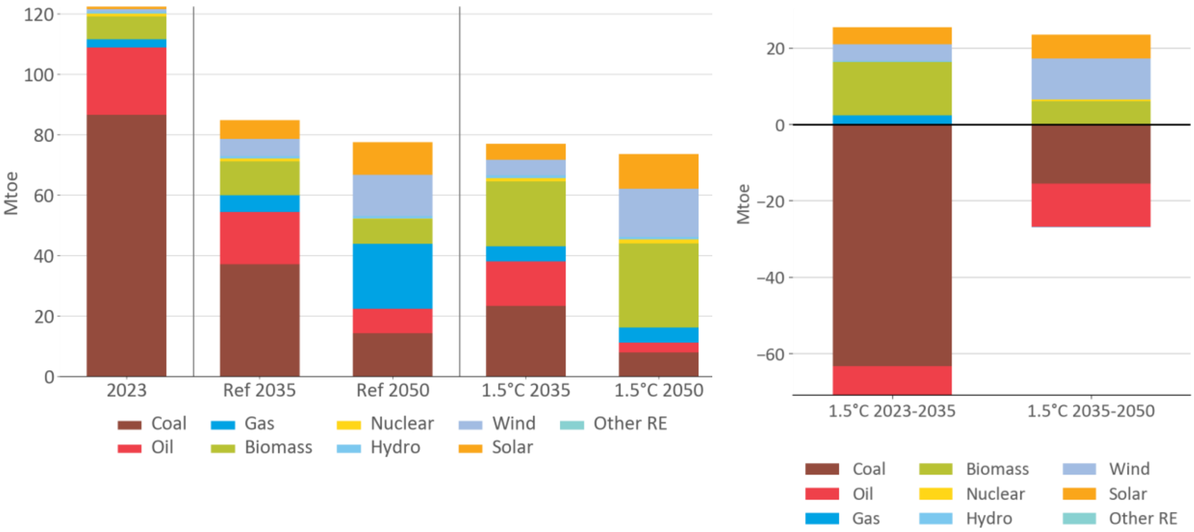
South Africa's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - South Africa

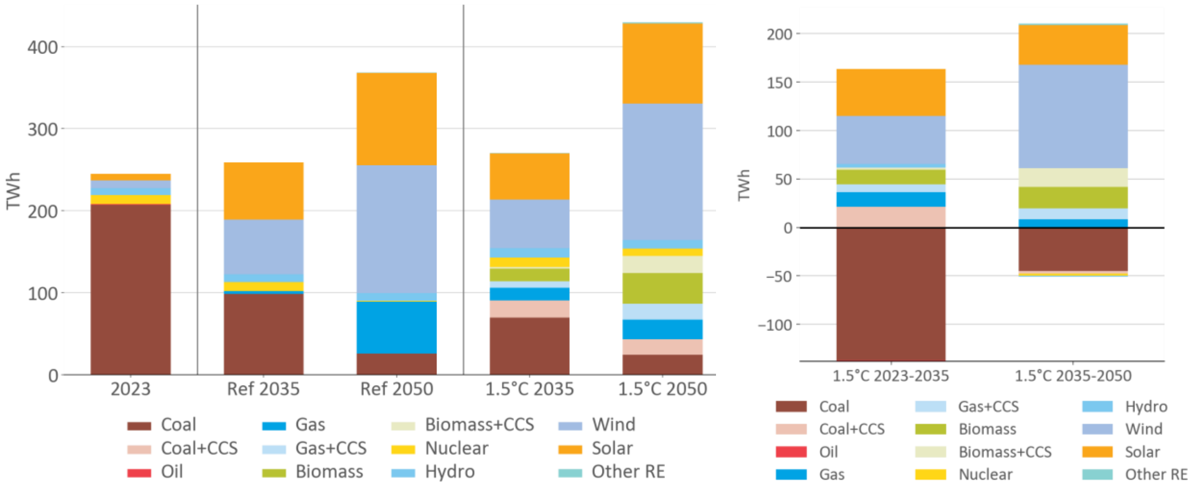


Note: the Other category includes non-CO$_2$ emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO$_2$.

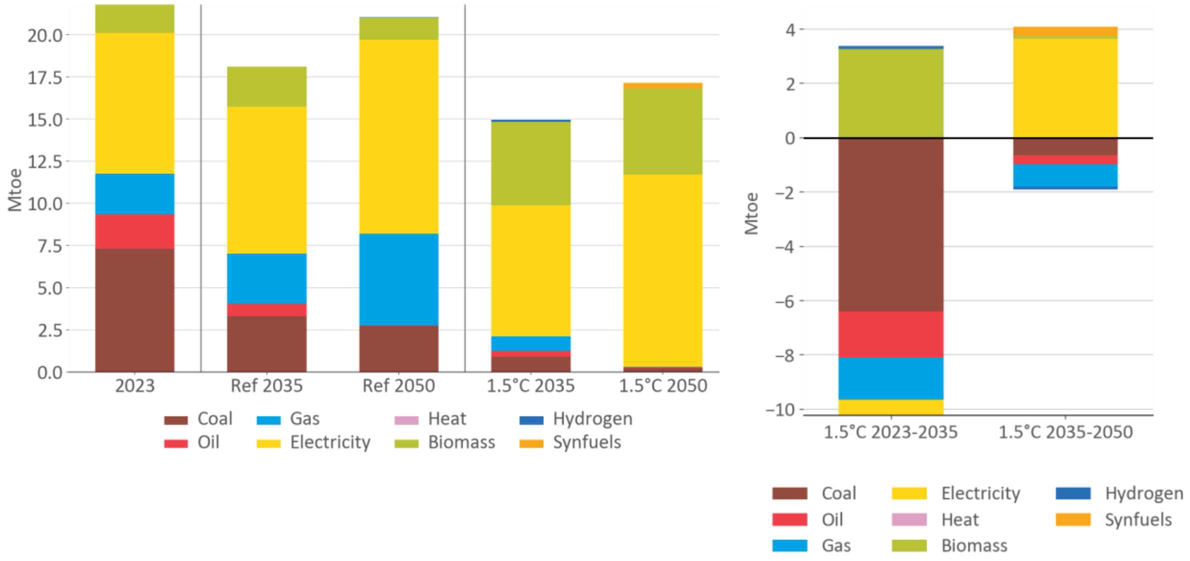
Primary energy demand, and change in primary energy demand - South Africa



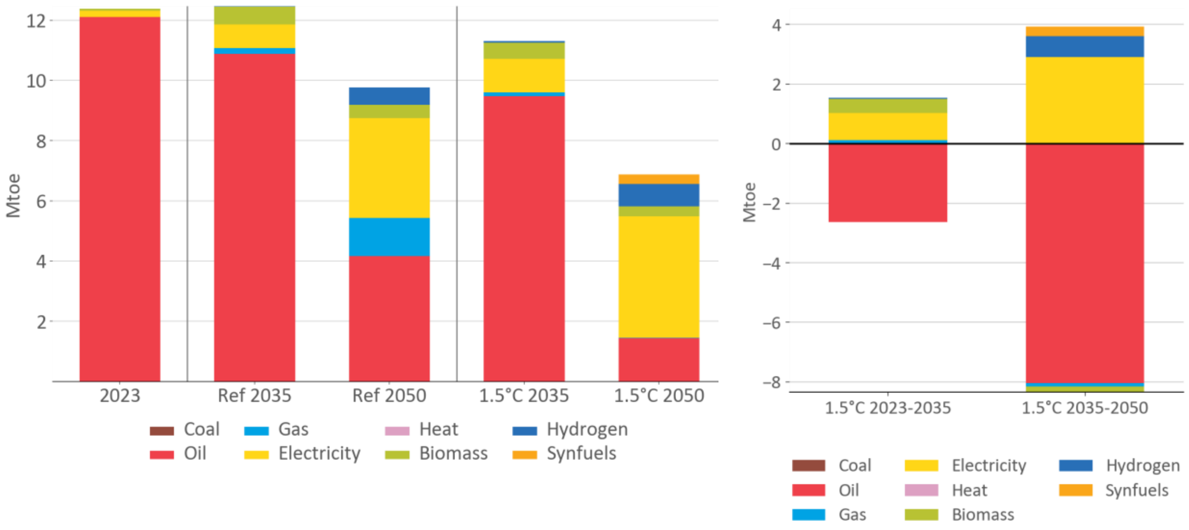
Power generation, and change in power generation - South Africa



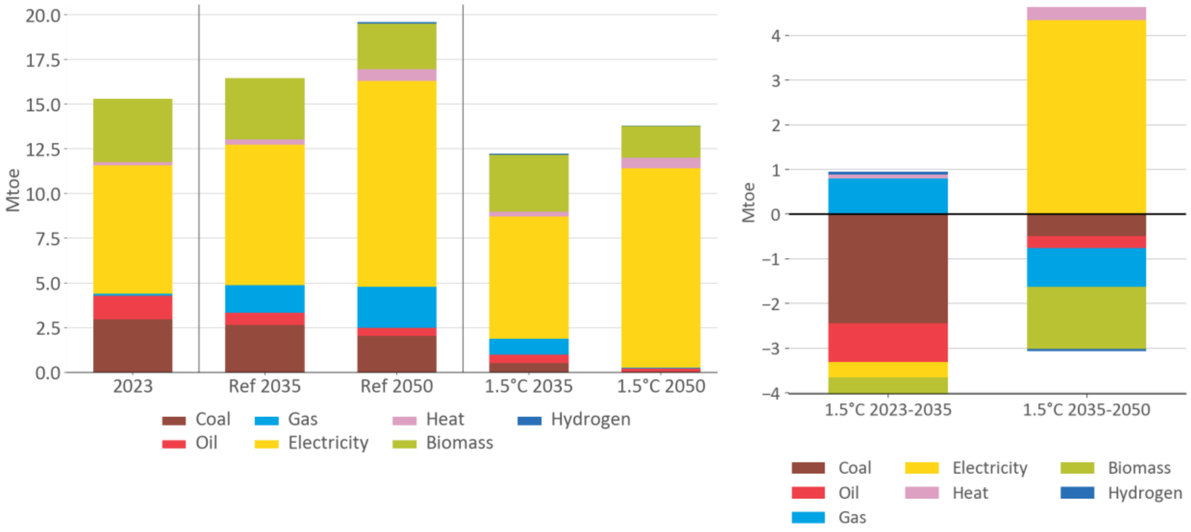
Industry sector demand, and change in industrial sector demand - South Africa



Transport sector demand, and change in transport sector demand - South Africa



Buildings sector demand, and change in buildings sector demand - South Africa



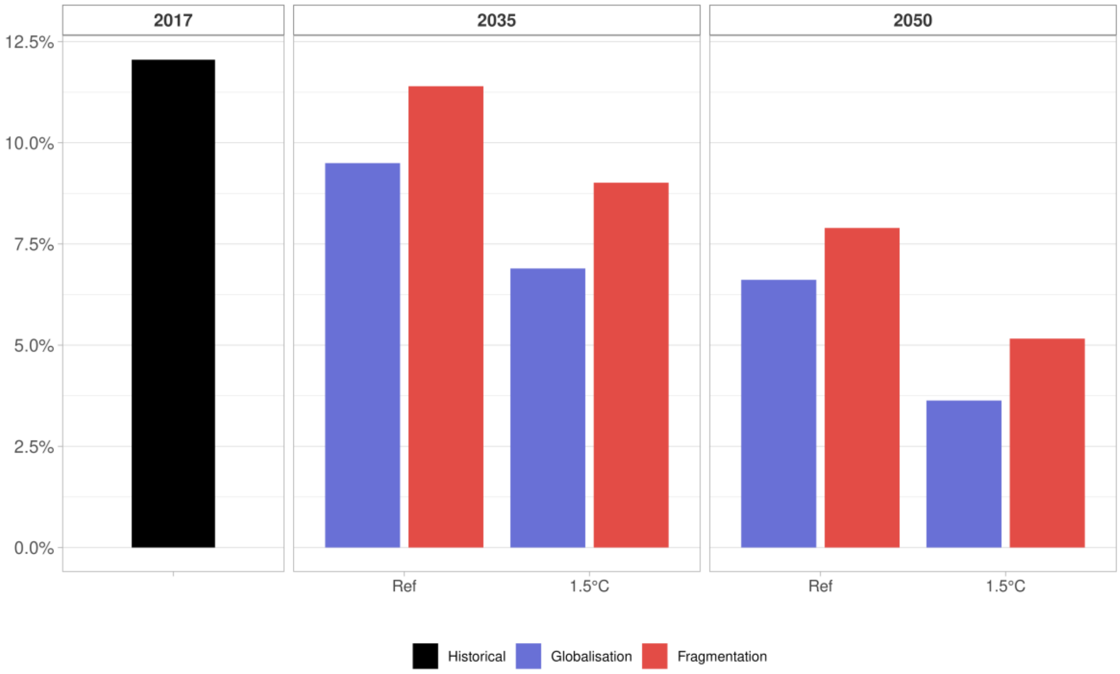
Trade dynamics

These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

Exports by sector for different scenarios - South Africa

Imports by sector for different scenarios - South Africa

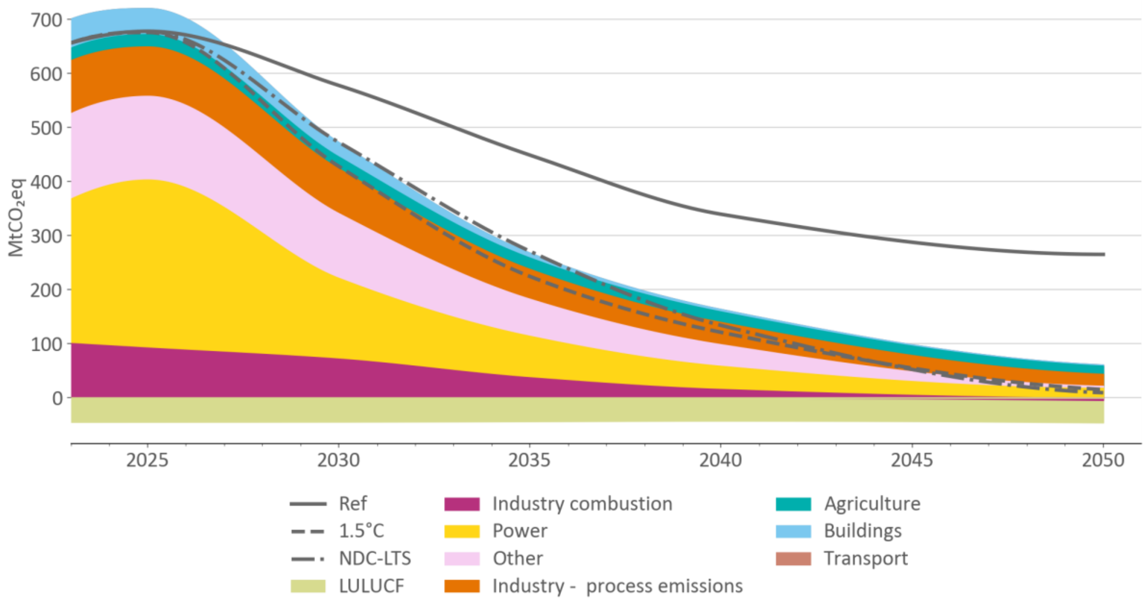
Share of fossil fuels in total imports for different scenarios – South Africa



South Korea

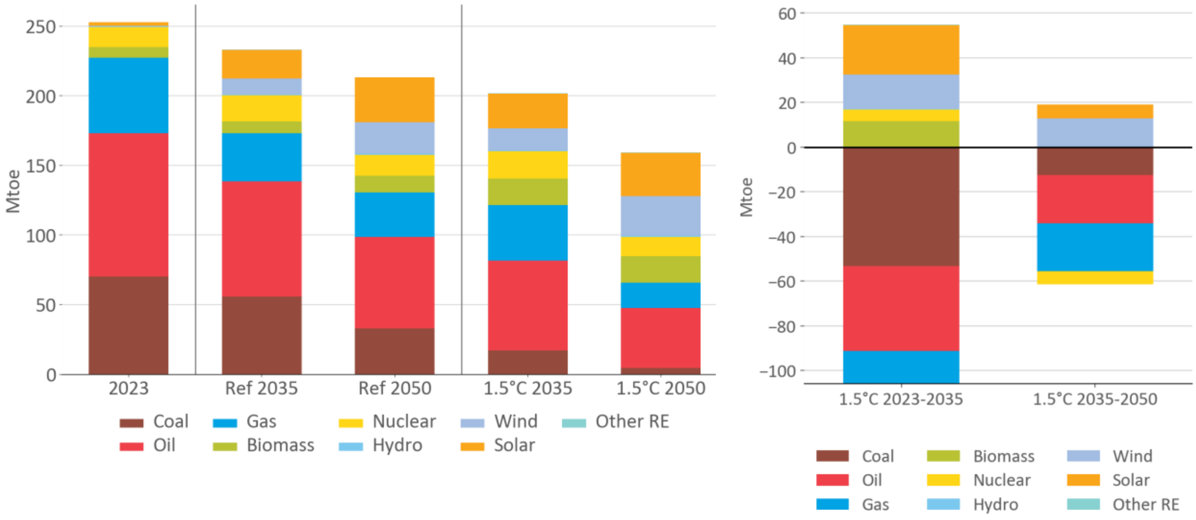
South Korea's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - South Korea

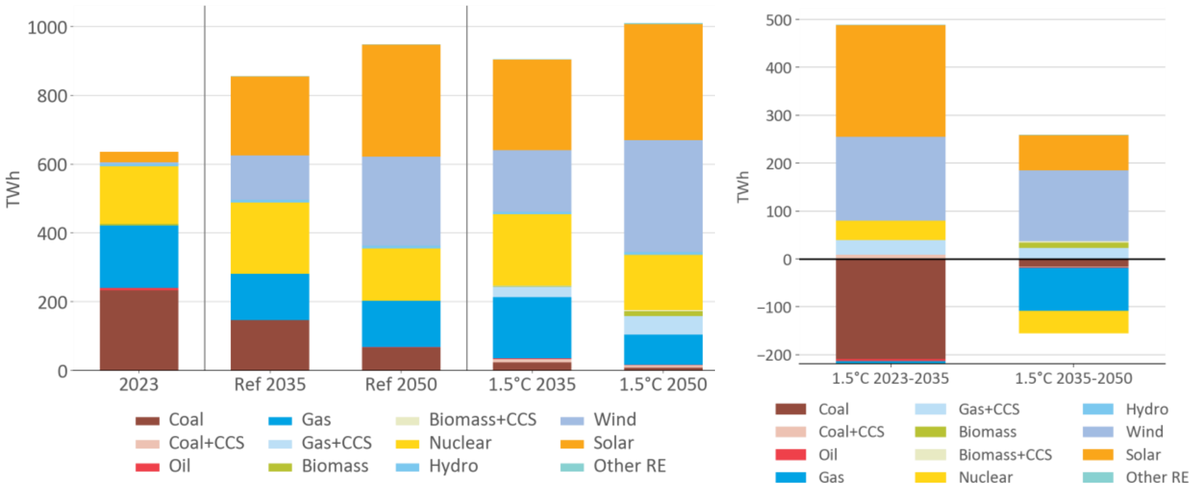


Note: the Other category includes non-CO_2 emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO_2.

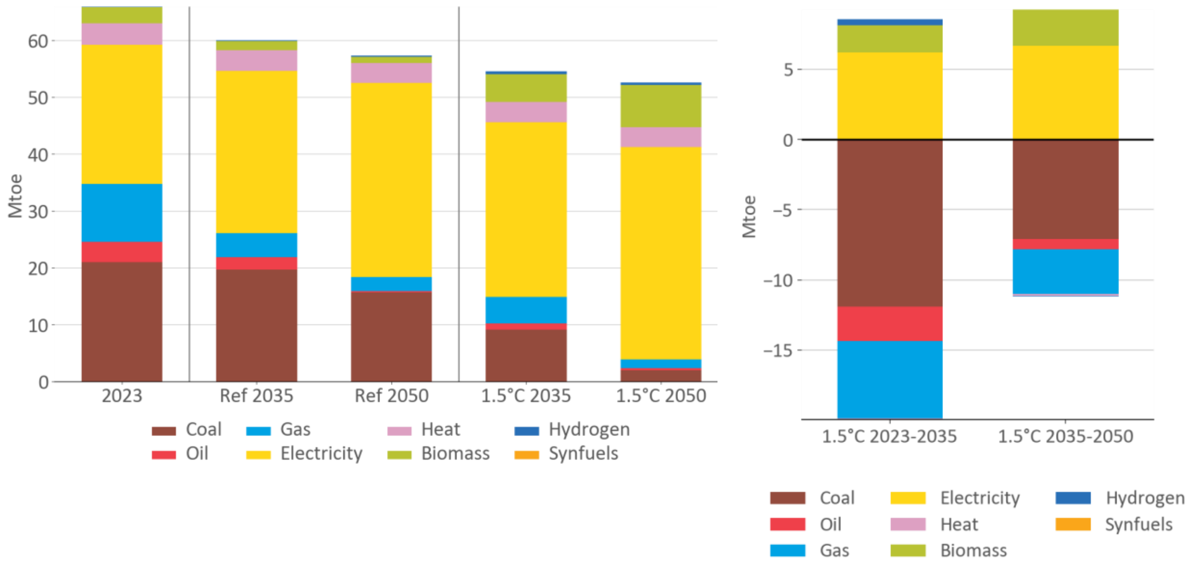
Primary energy demand, and change in primary energy demand - South Korea



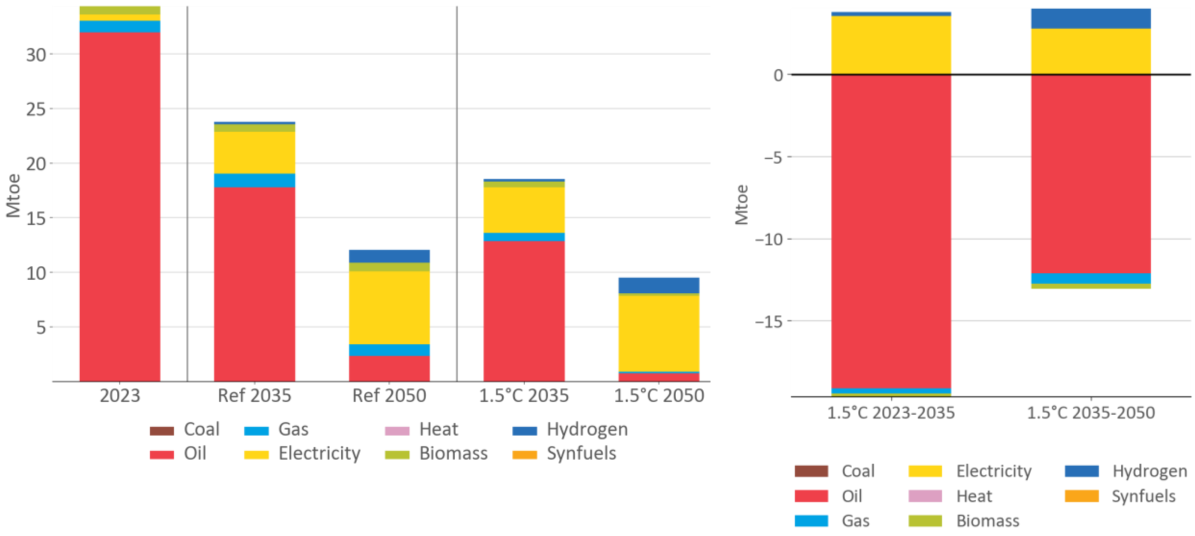
Power generation, and change in power generation - South Korea



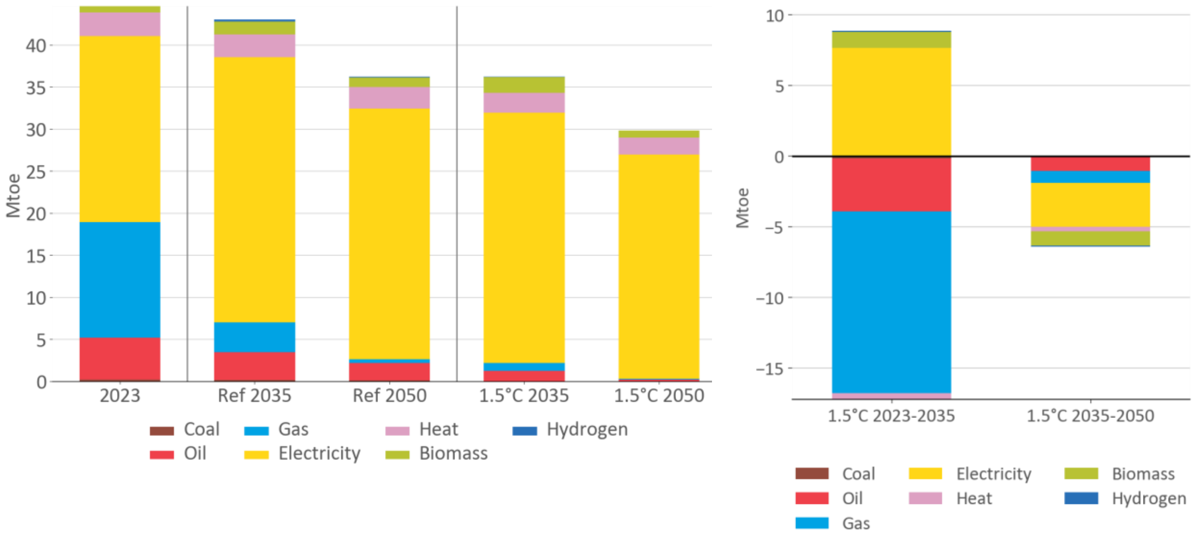
Industry sector demand, and change in industrial sector demand - South Korea



Transport sector demand, and change in transport sector demand - South Korea



Buildings sector demand, and change in buildings sector demand - South Korea

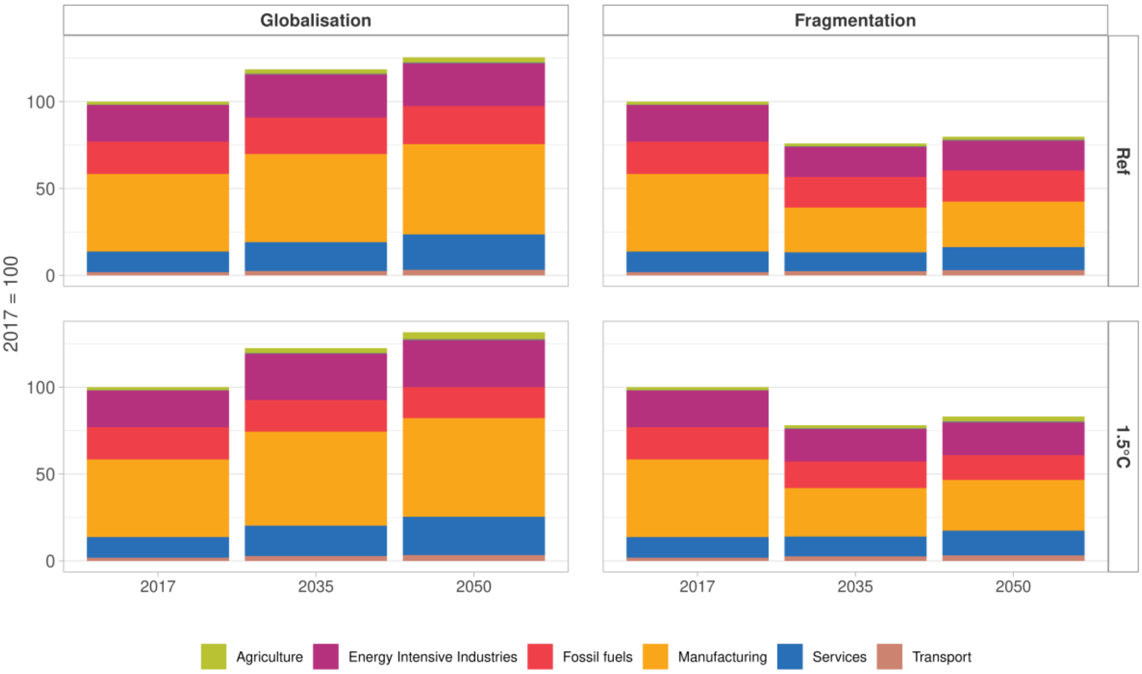


Trade dynamics

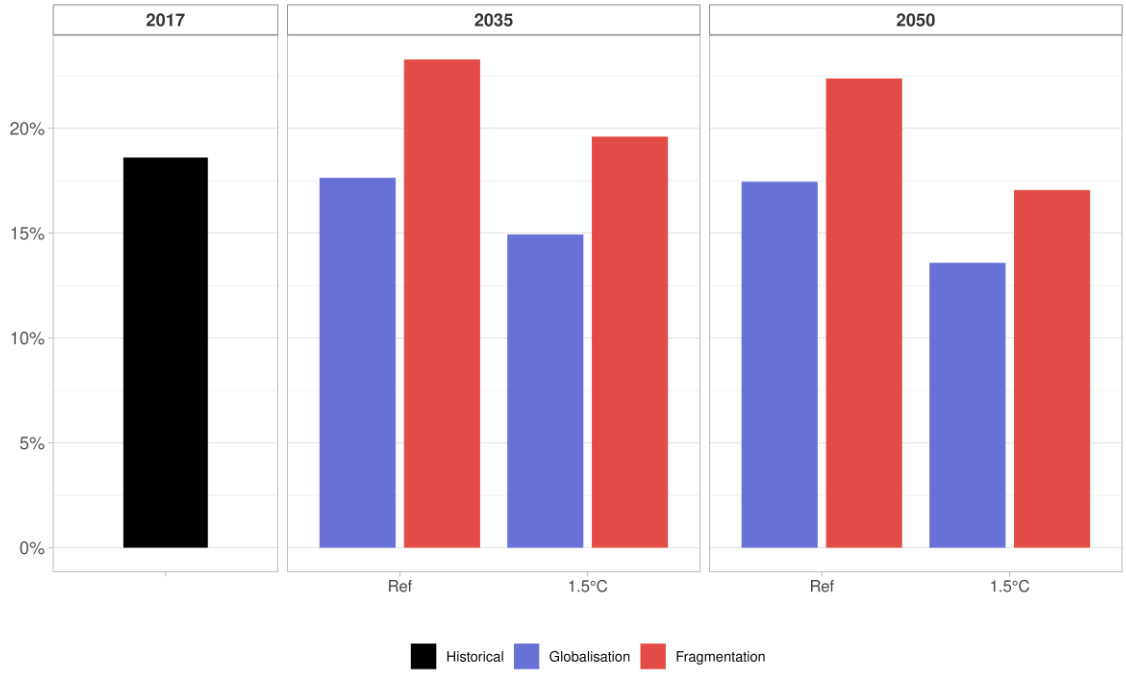
These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

Exports by sector for different scenarios - South Korea

Imports by sector for different scenarios - South Korea



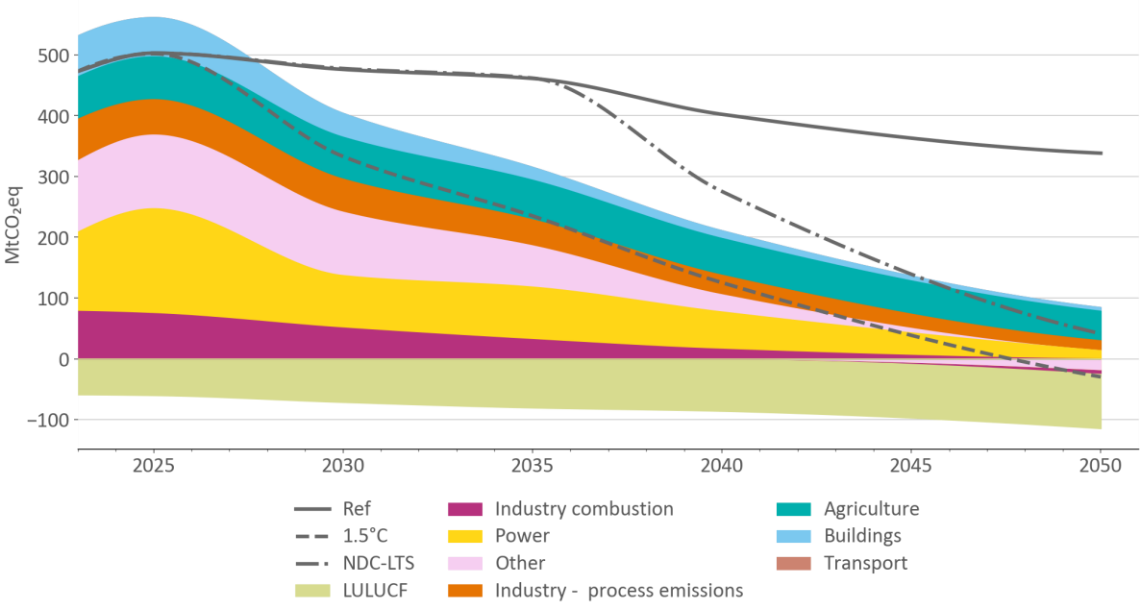
Share of fossil fuels in total imports for different scenarios – South Korea



Türkiye

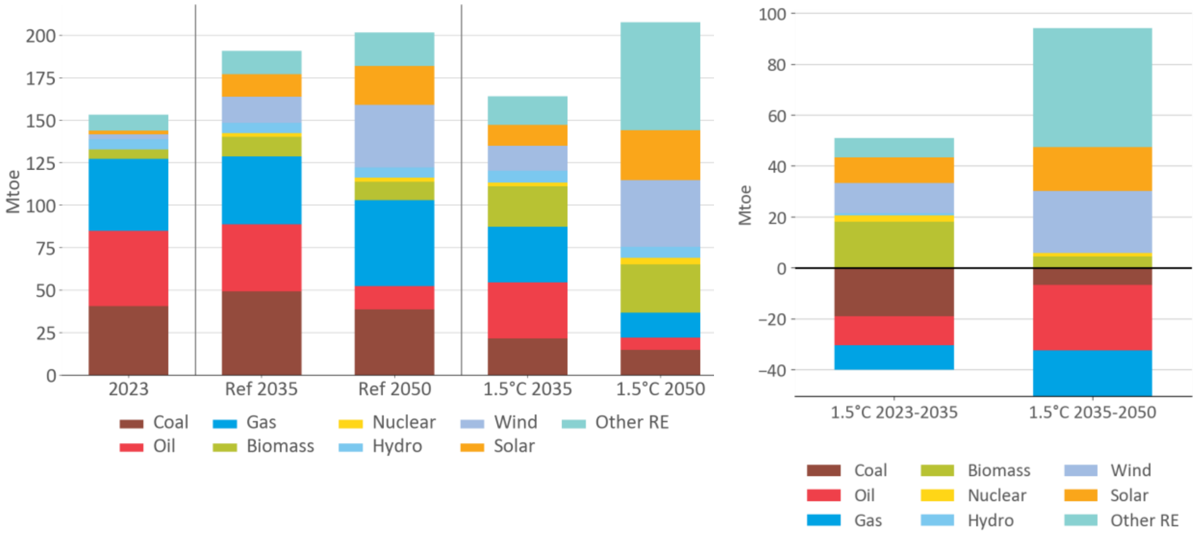
Türkiye's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - Türkiye

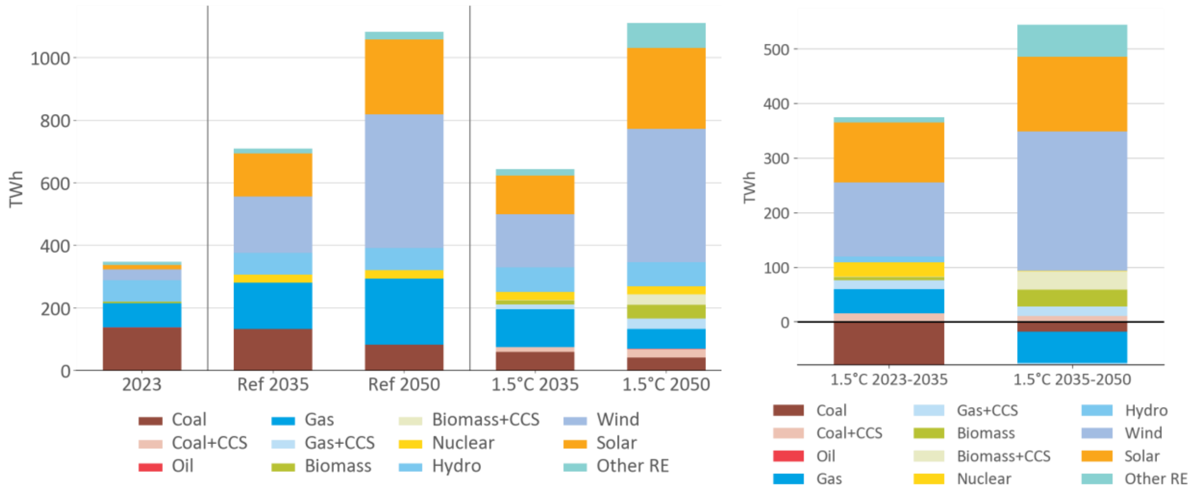


Note: the Other category includes non-CO$_2$ emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO$_2$.

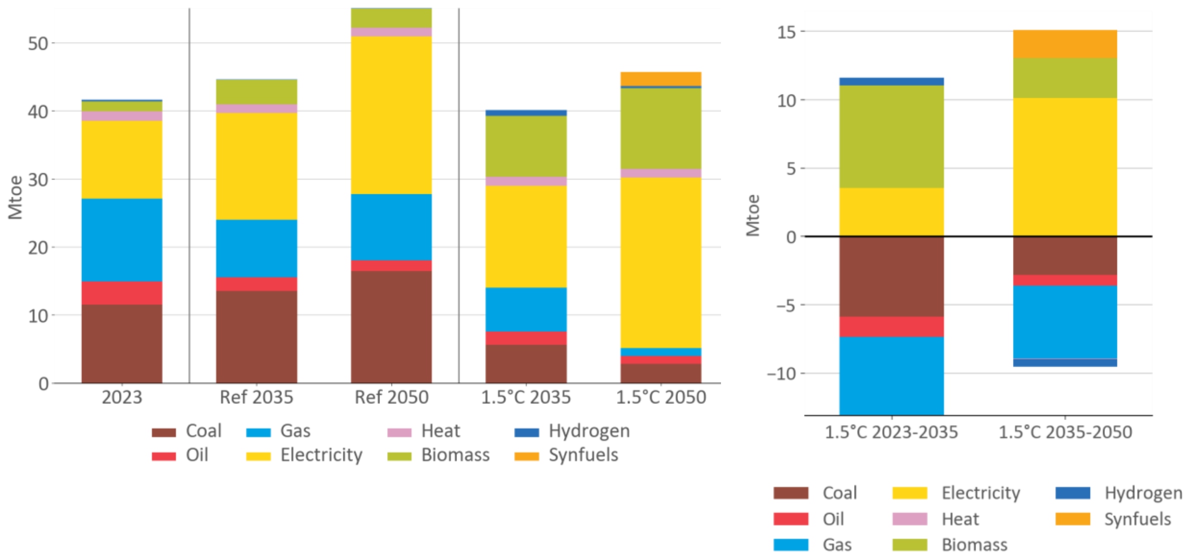
Primary energy demand, and change in primary energy demand - Türkiye



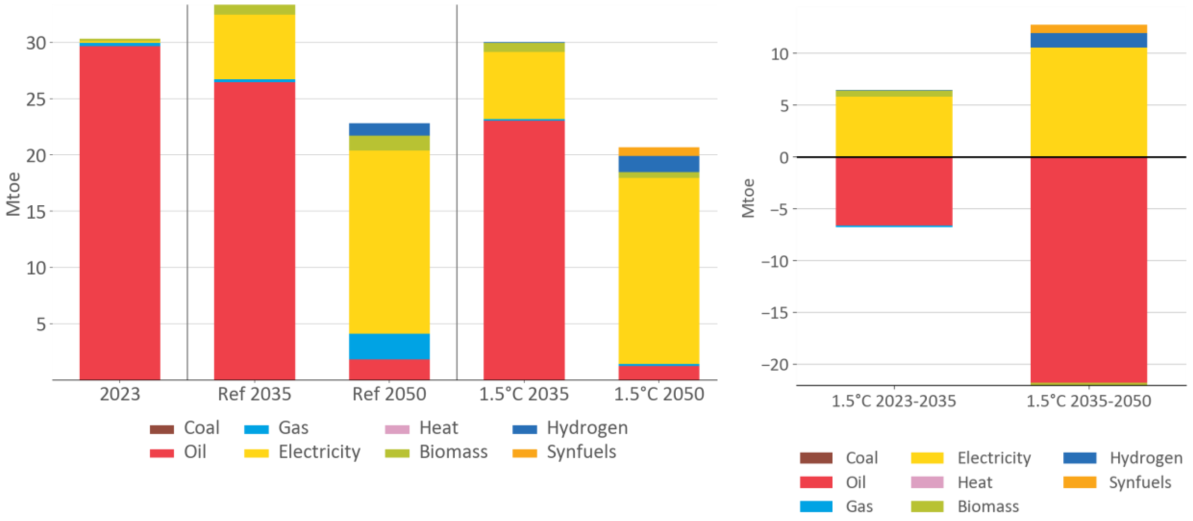
Power generation, and change in power generation - Türkiye



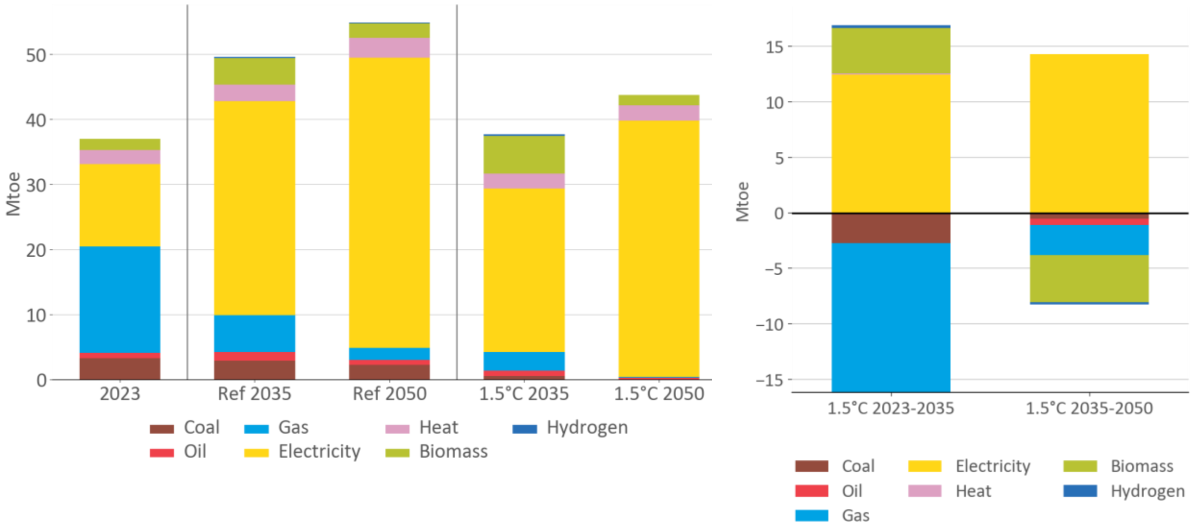
Industry sector demand, and change in industrial sector demand - Türkiye



Transport sector demand, and change in transport sector demand - Türkiye



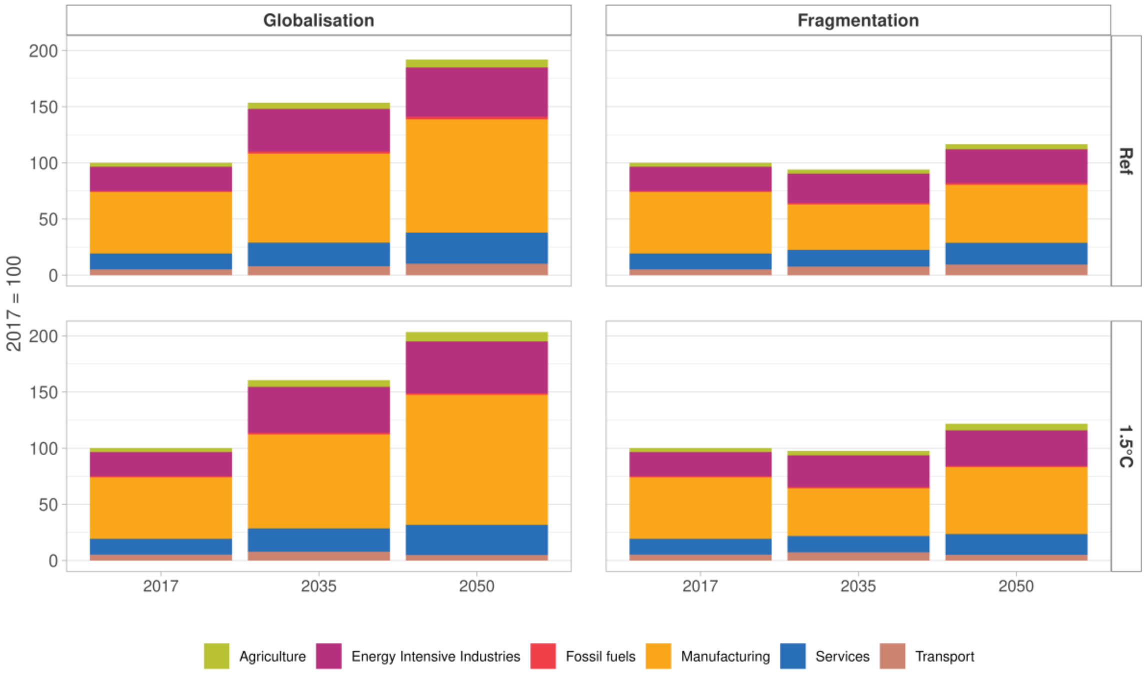
Buildings sector demand, and change in buildings sector demand - Türkiye



Trade dynamics

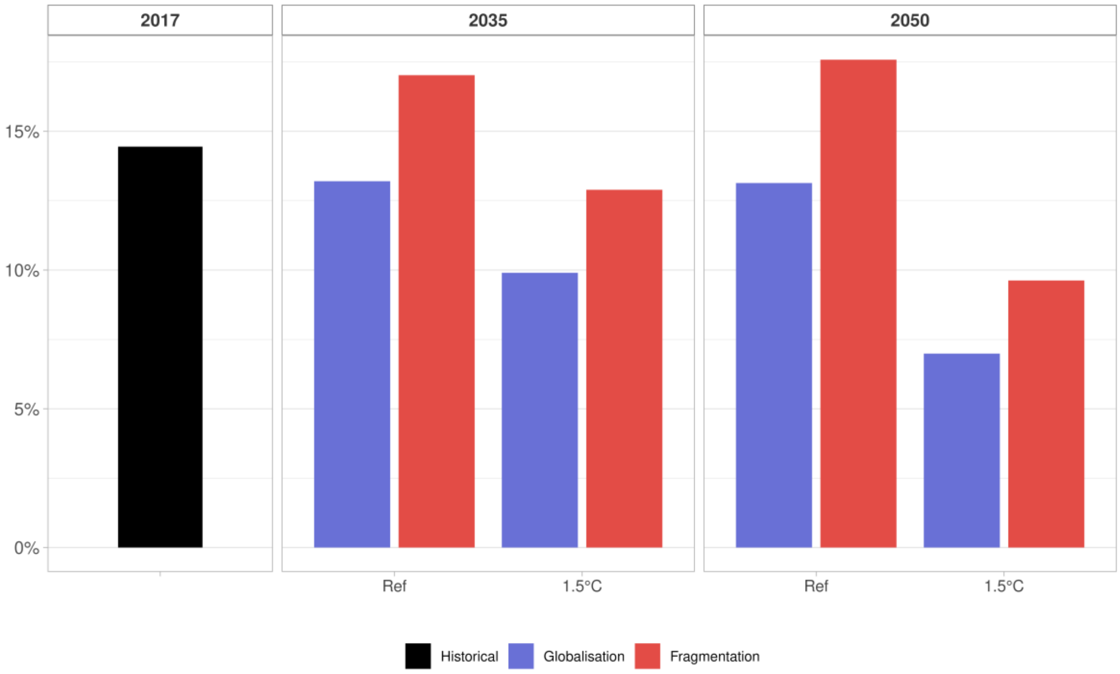
These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

Exports by sector for different scenarios - Türkiye



Imports by sector for different scenarios - Türkiye

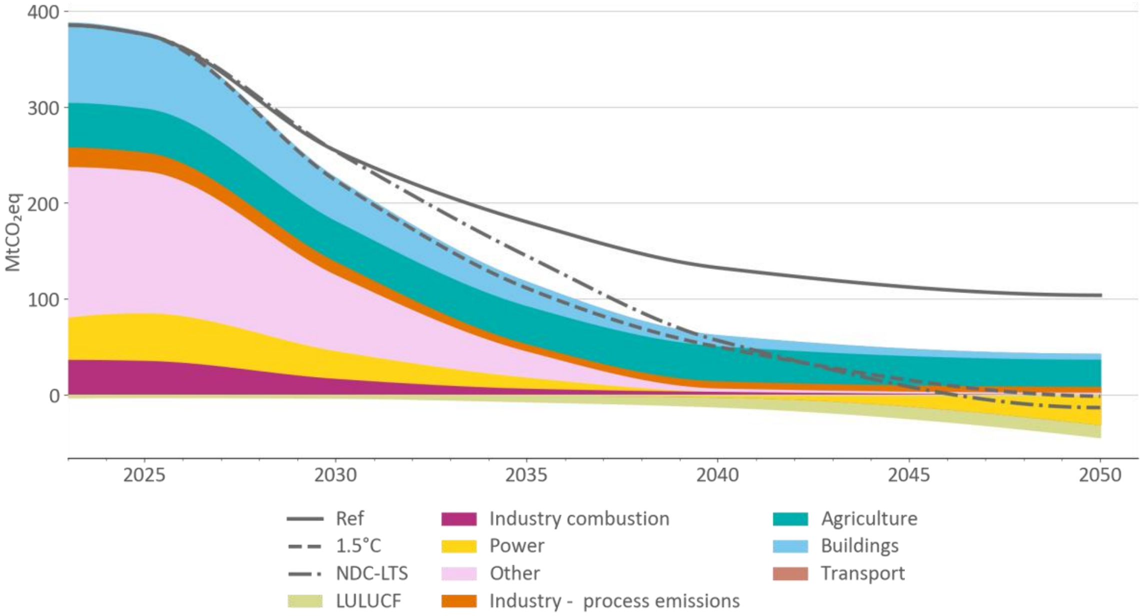
Share of fossil fuels in total imports for different scenarios – Türkiye



United Kingdom

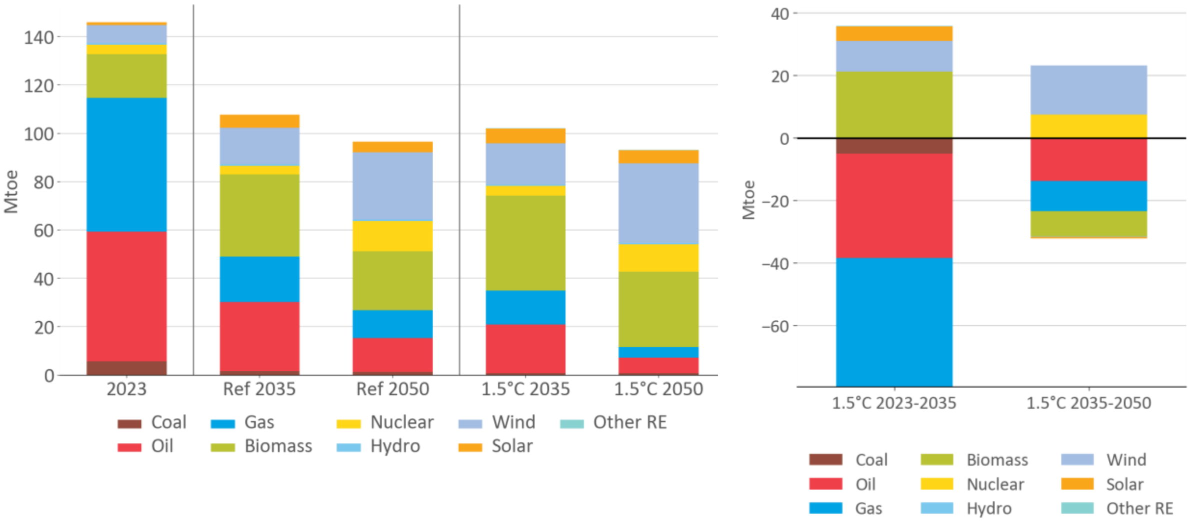
United Kingdom's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - United Kingdom

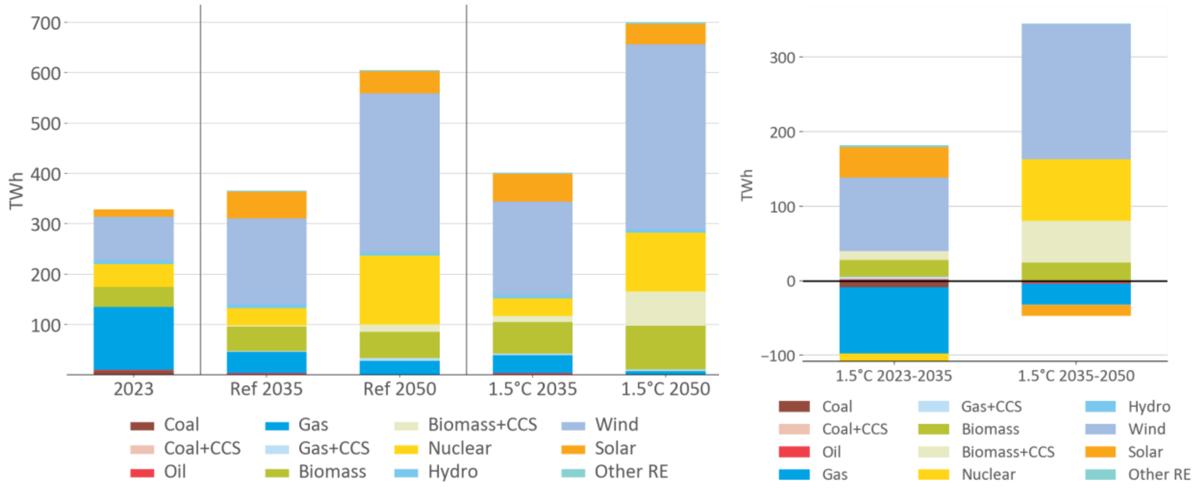


Note: the Other category includes non-CO$_2$ emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO$_2$.

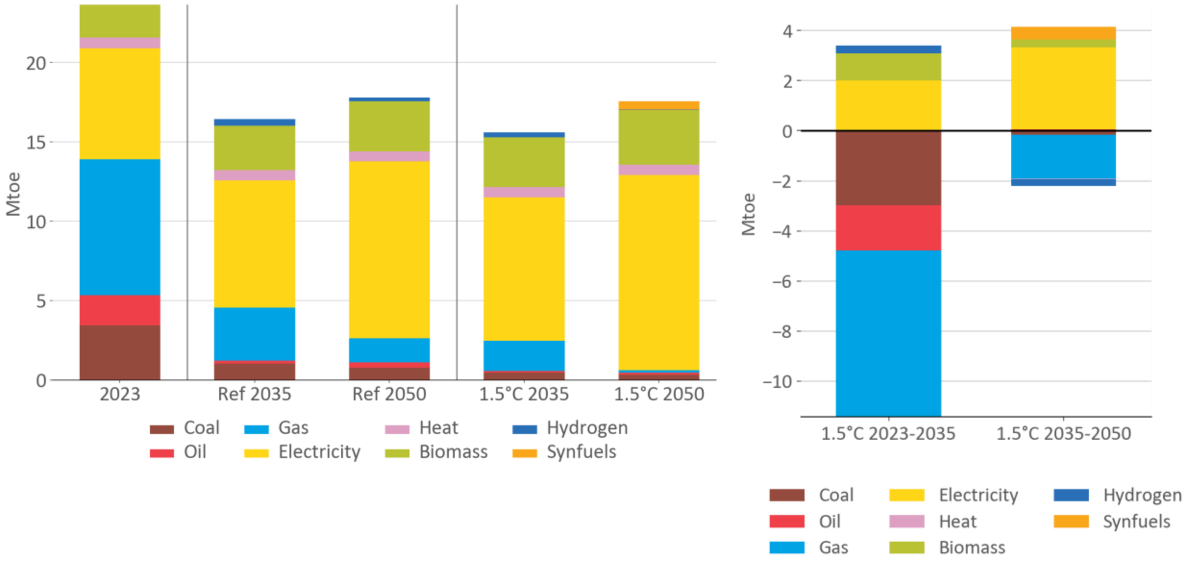
Primary energy demand, and change in primary energy demand - United Kingdom



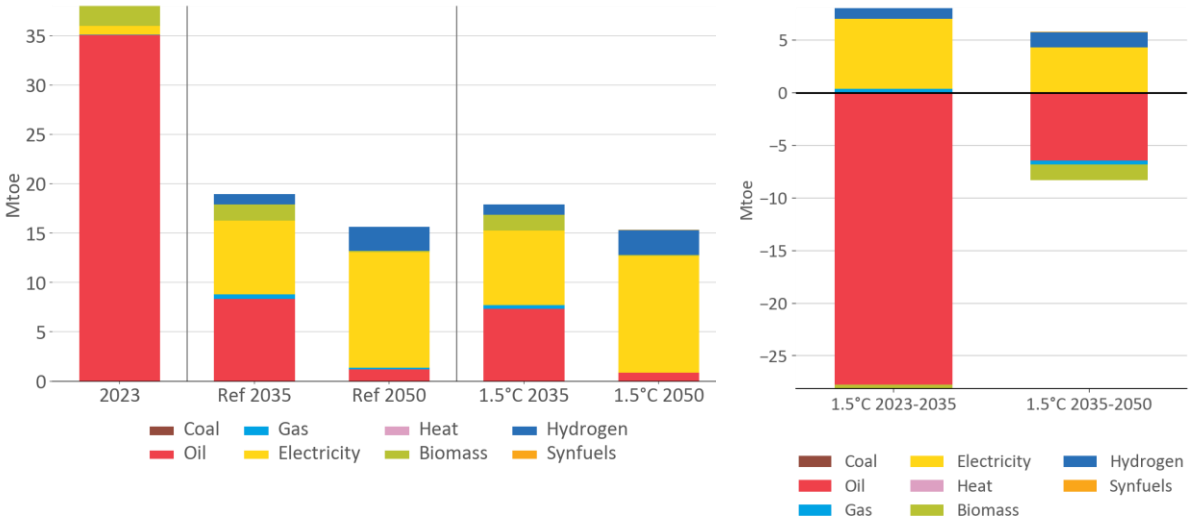
Power generation, and change in power generation – United Kingdom



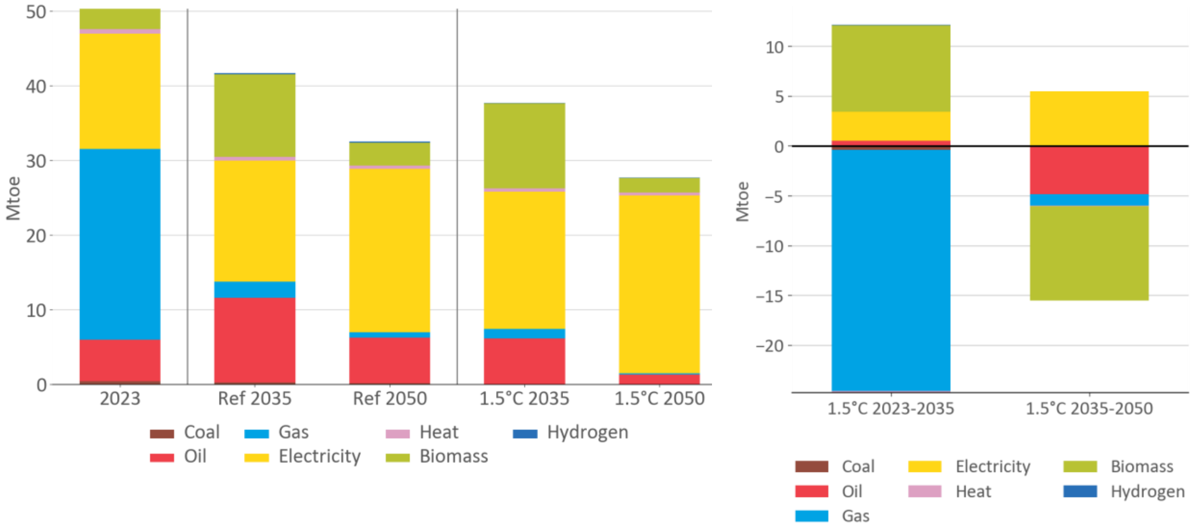
Industry sector demand, and change in industrial sector demand – United Kingdom



Transport sector demand, and change in transport sector demand - United Kingdom



Buildings sector demand, and change in buildings sector demand - United Kingdom

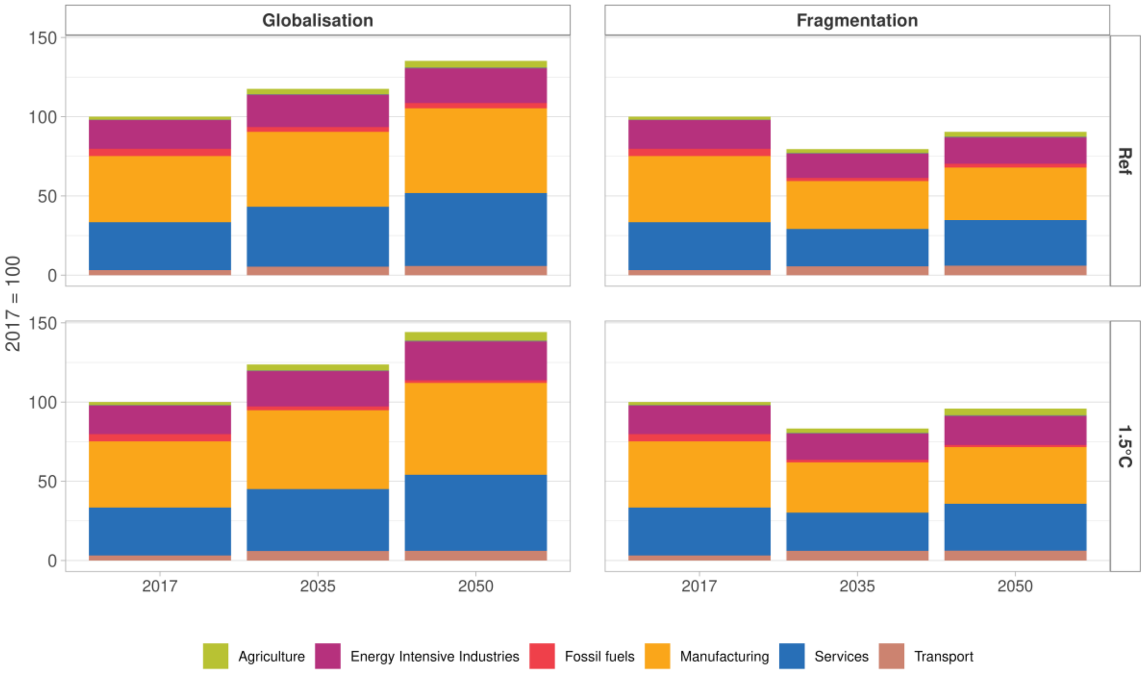


Trade dynamics

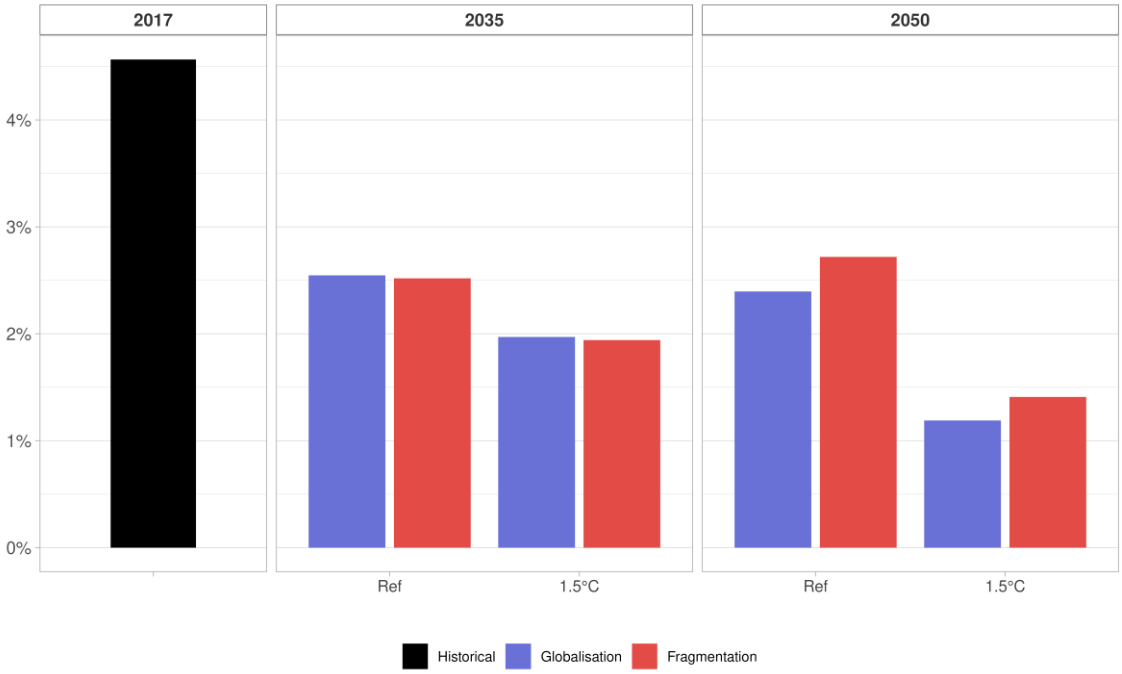
These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

Exports by sector for different scenarios - United Kingdom

Imports by sector for different scenarios - United Kingdom



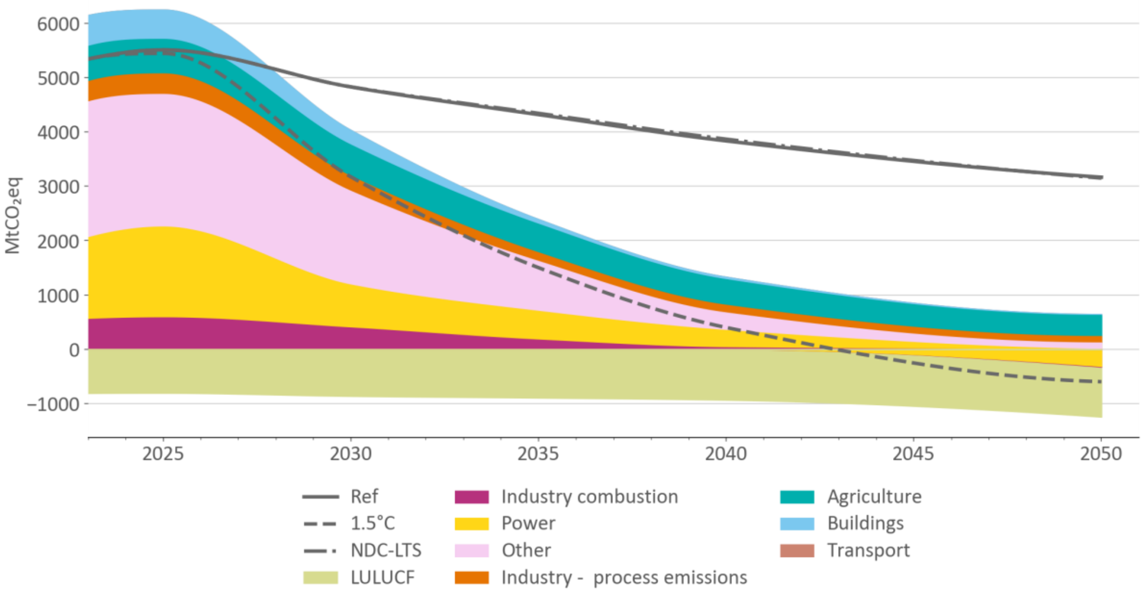
Share of fossil fuels in total imports for different scenarios – United Kingdom



United States

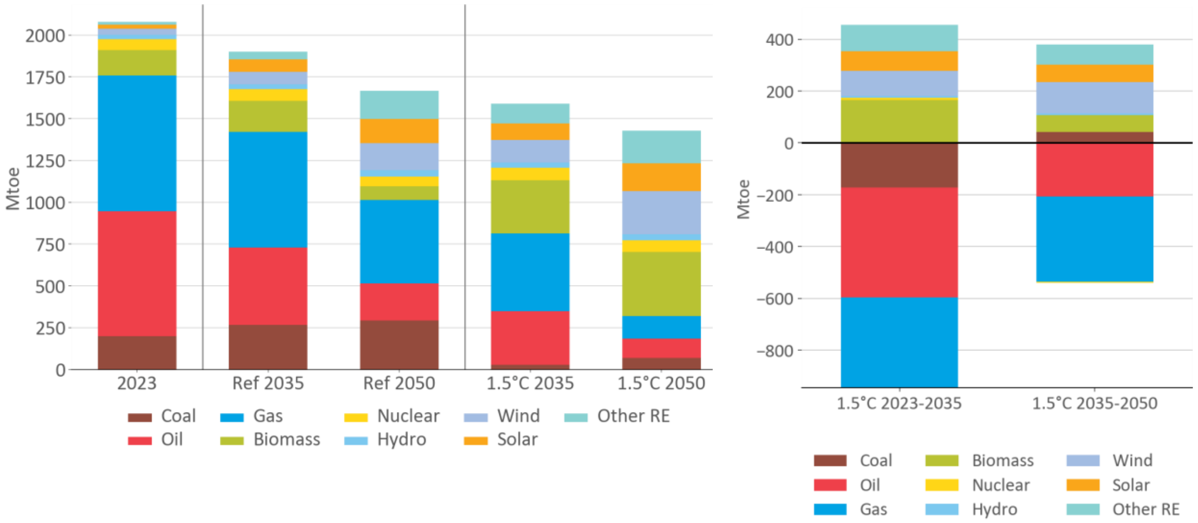
United States's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - United States

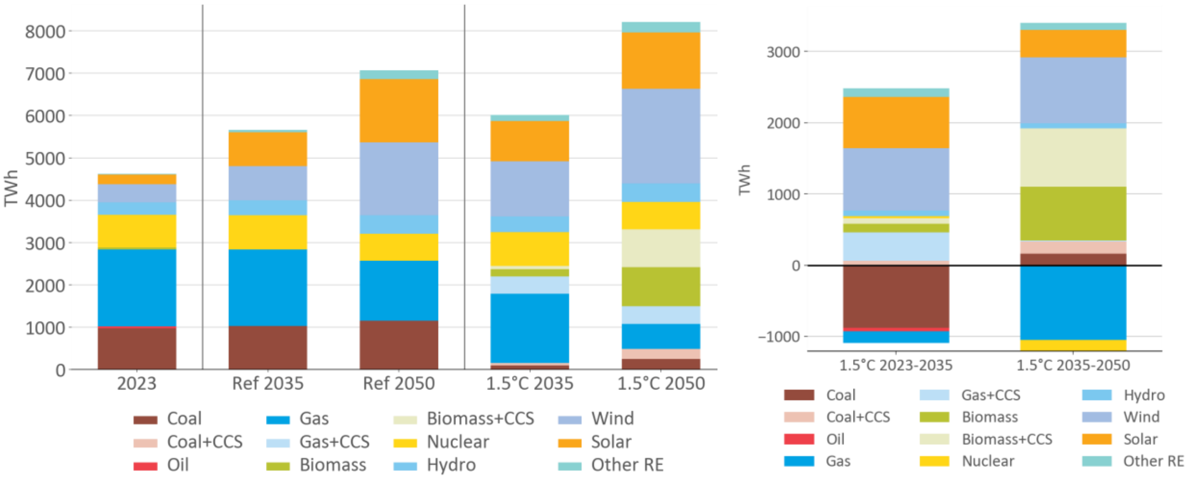


Note: the Other category includes non-CO₂ emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO₂.

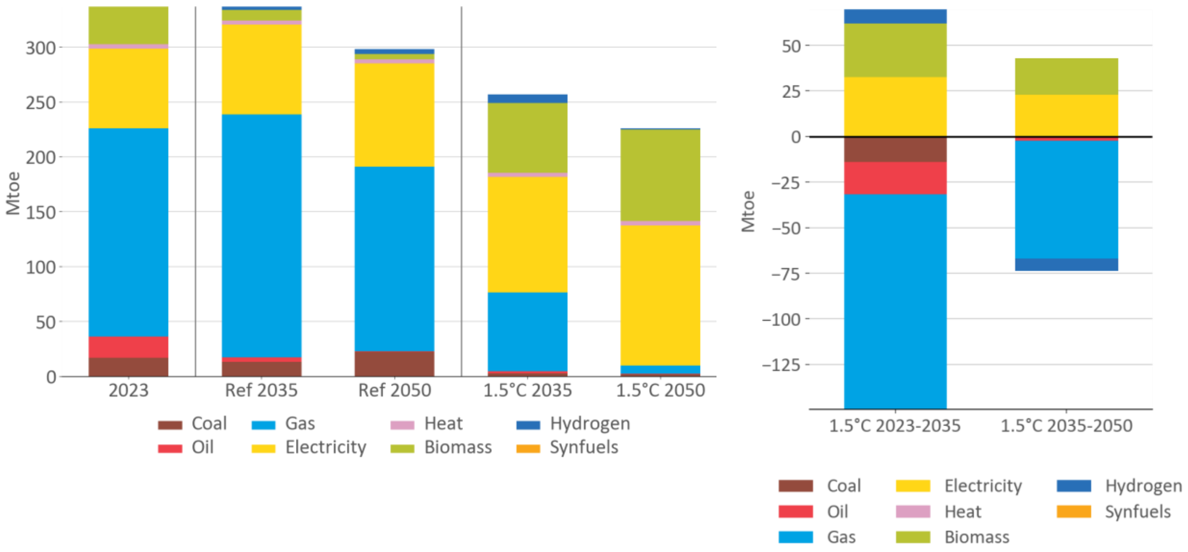
Primary energy demand, and change in primary energy demand - United States



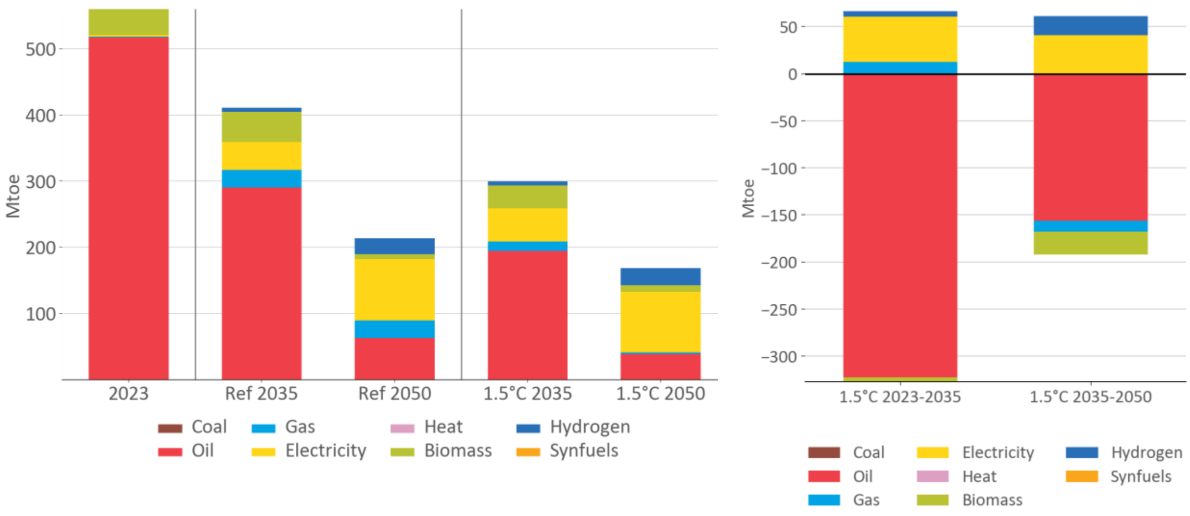
Power generation, and change in power generation - United States



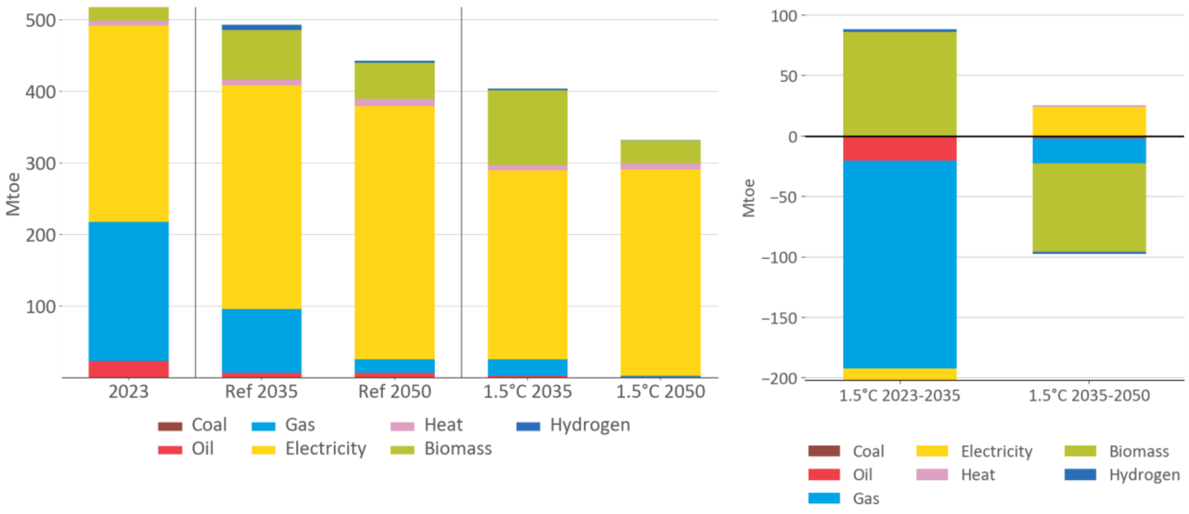
Industry sector demand, and change in industrial sector demand - United States



Transport sector demand, and change in transport sector demand - United States



Buildings sector demand, and change in buildings sector demand - United States



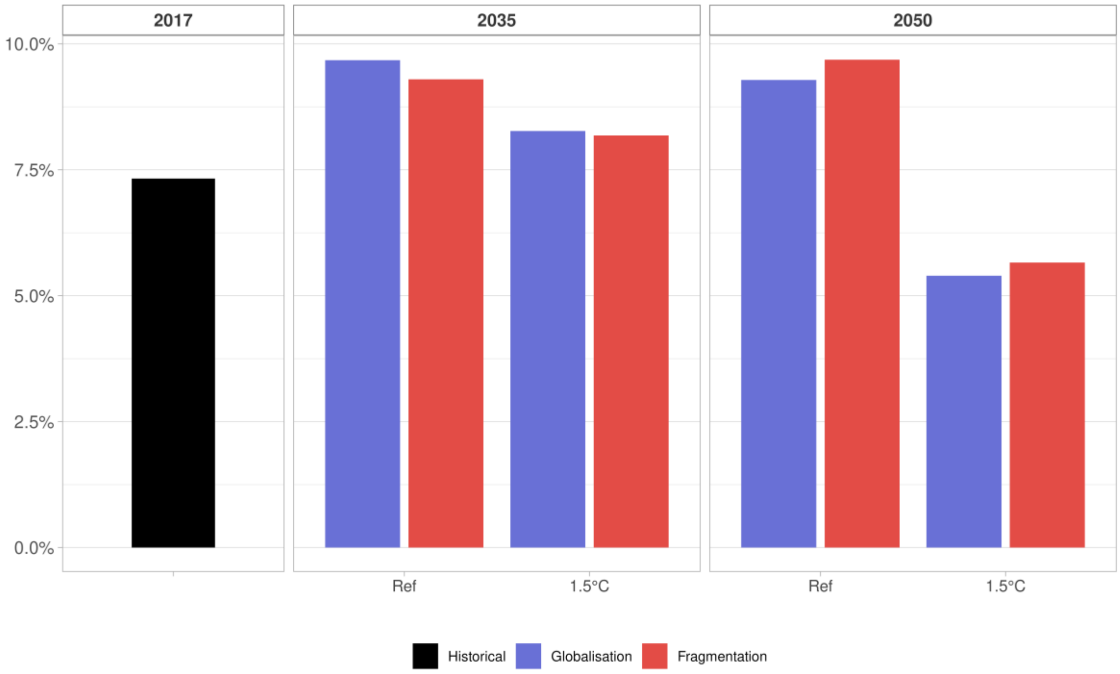
Trade dynamics

These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

Exports by sector for different scenarios - United States

Imports by sector for different scenarios - United States

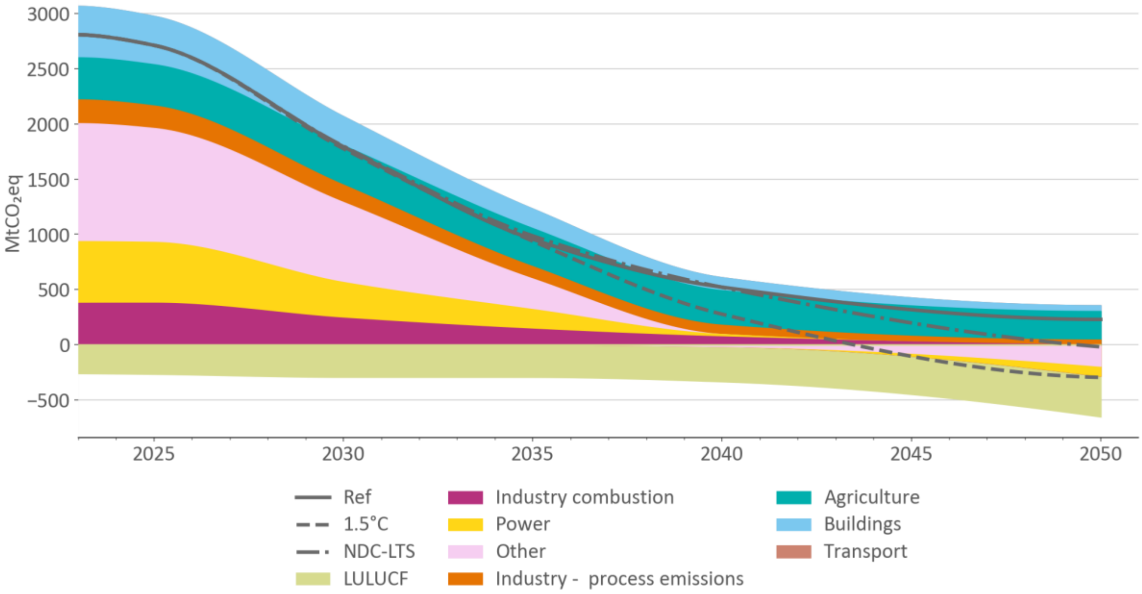
Share of fossil fuels in total imports for different scenarios – United States



European Union

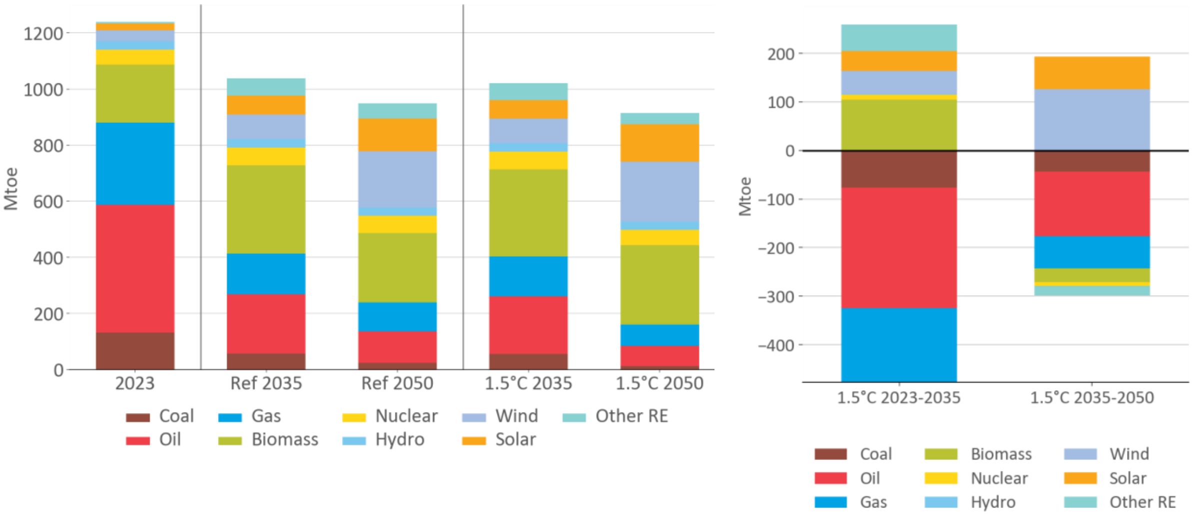
European Union's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - European Union

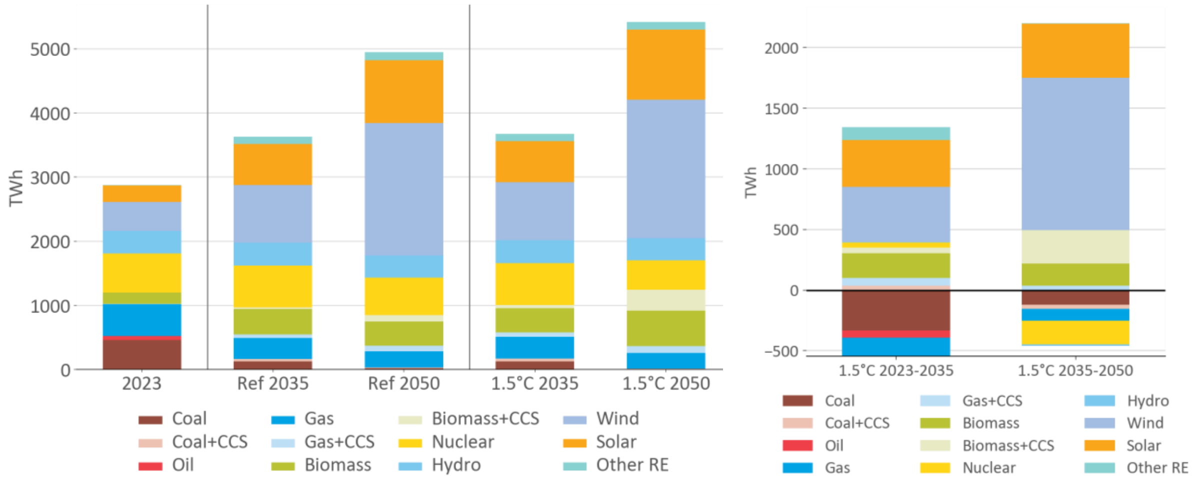


Note: the Other category includes non-CO_2 emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO_2.

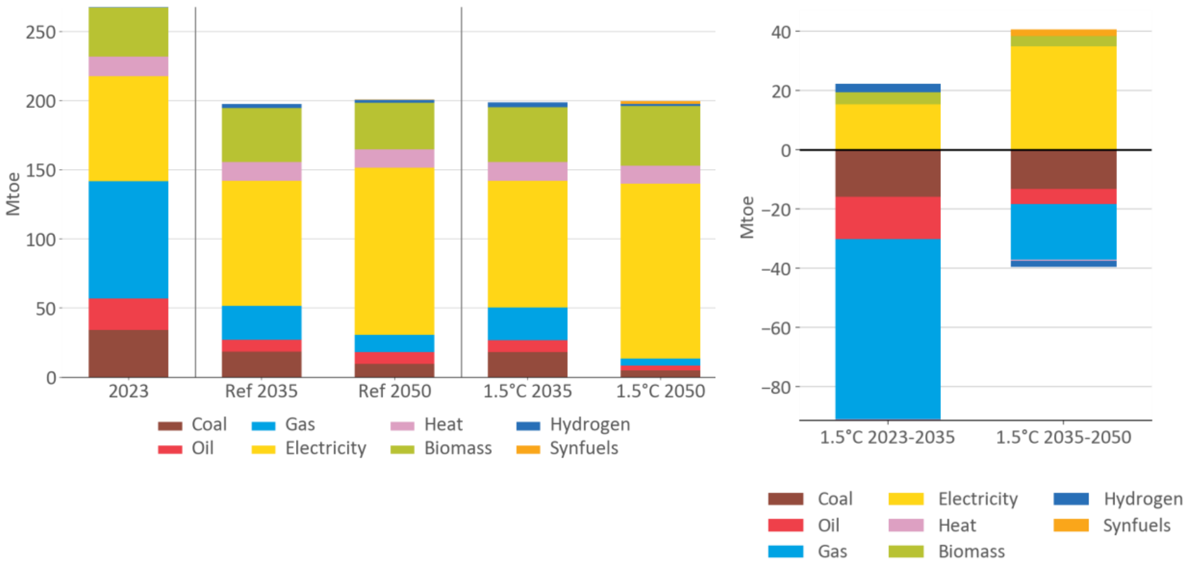
Primary energy demand, and change in primary energy demand - European Union



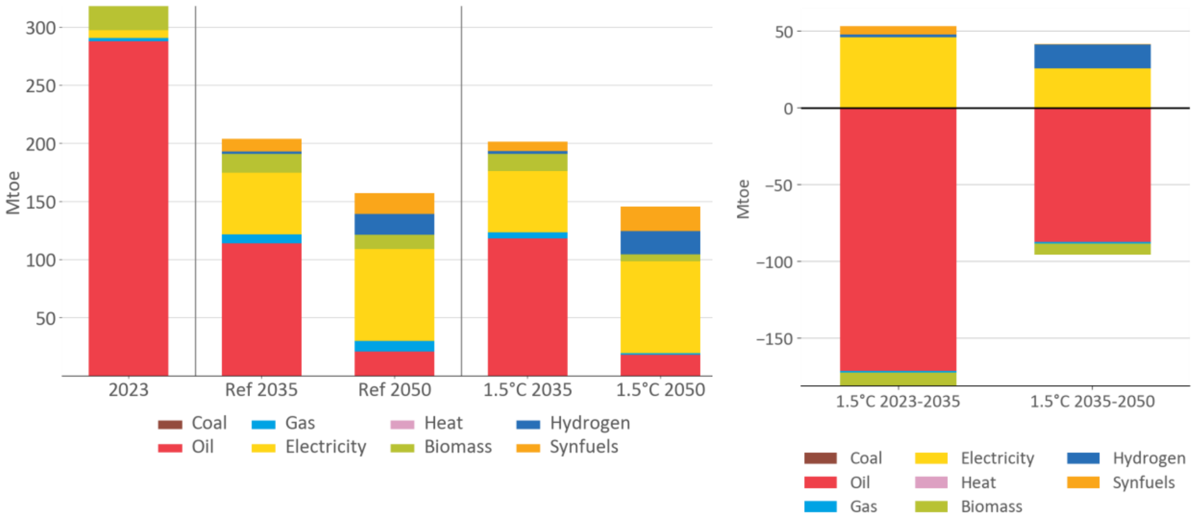
Power generation, and change in power generation – European Union



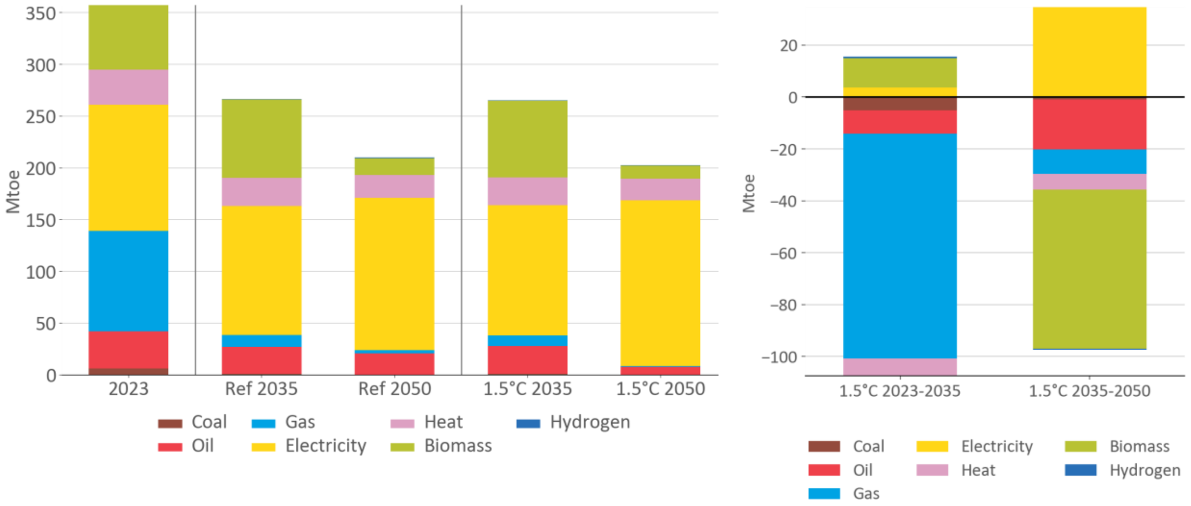
Industry sector demand, and change in industrial sector demand – European Union



Transport sector demand, and change in transport sector demand - European Union



Buildings sector demand, and change in buildings sector demand - European Union



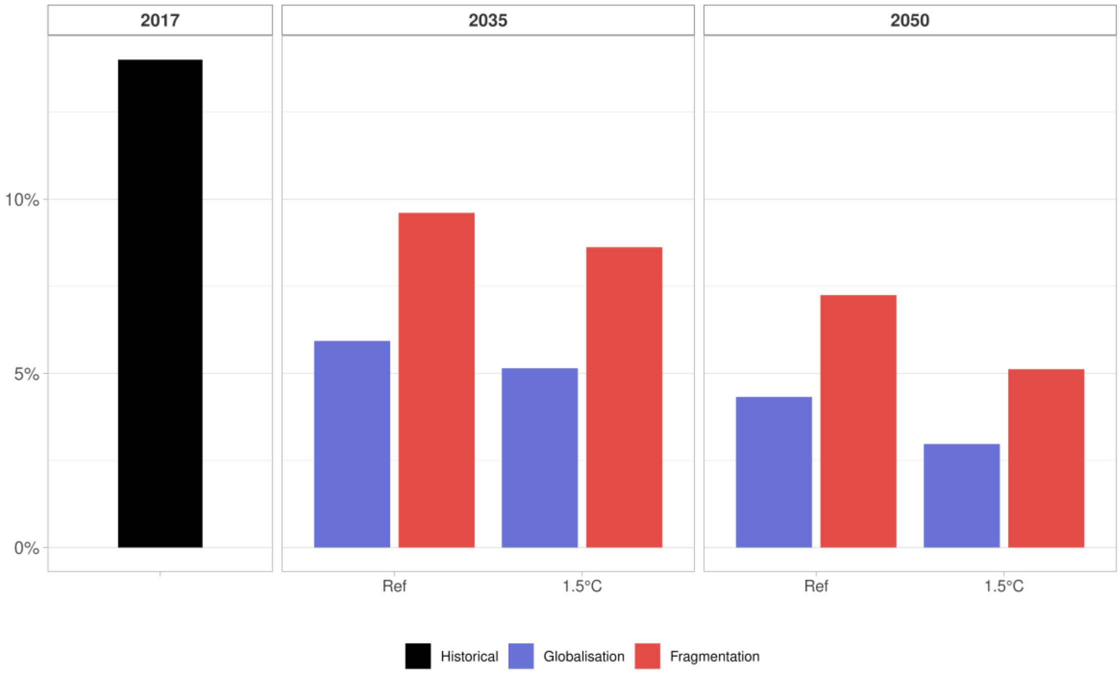
Trade dynamics

These figures show the sectoral composition of exports and imports in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The third figure calculates the share of fossil fuel imports over total imports, to give insight into energy-related trade dependencies in each of the scenarios.

Exports by sector for different scenarios - European Union

Imports by sector for different scenarios - European Union

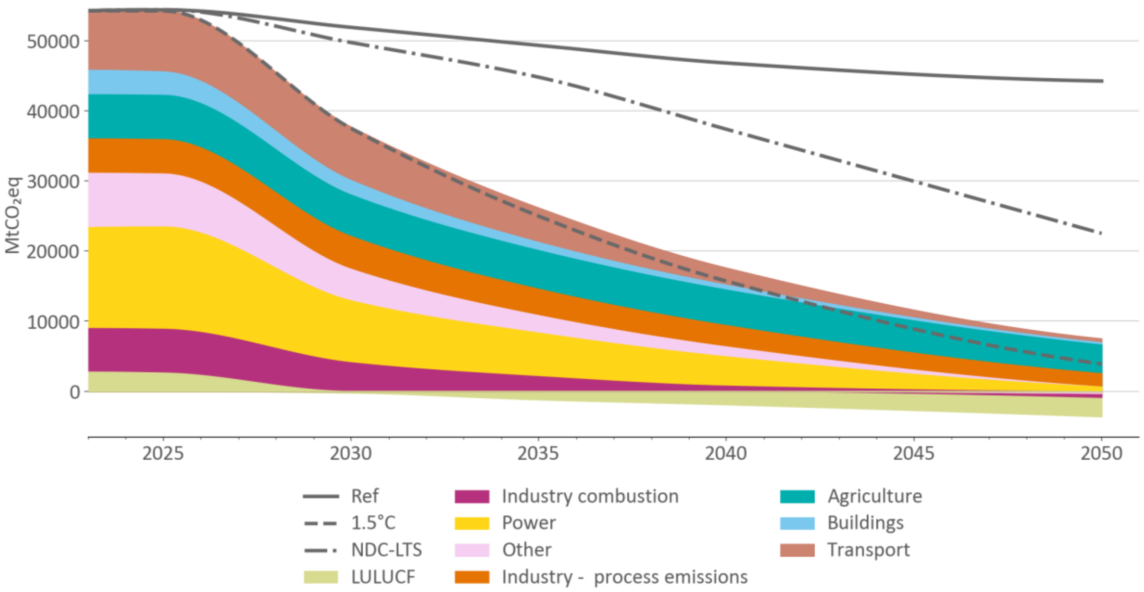
Share of fossil fuels in total imports for different scenarios – European Union



World

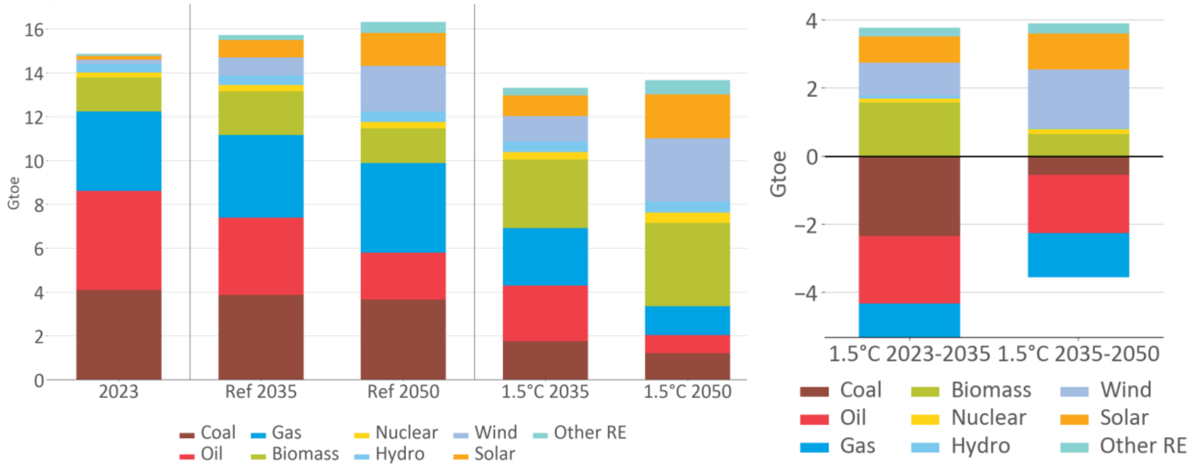
World's decarbonisation pathways are presented in the figure below, showing economy-wide GHG emissions over time in the 1.5°C scenario (stacked area), as well as in the NDC-LTS and Reference scenarios (dashed lines).

Emissions by scenario and sectoral breakdown of 1.5°C scenario - World

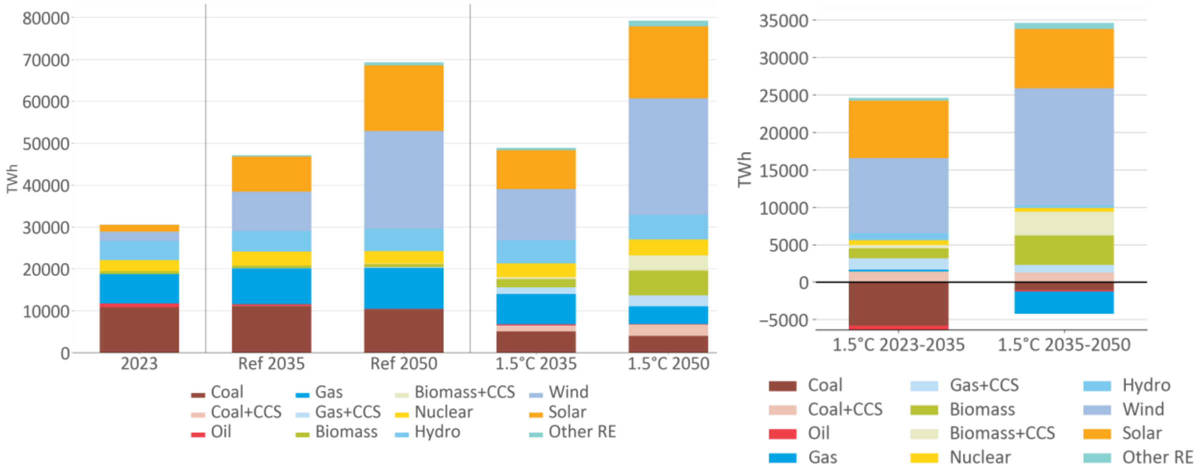


Note: the Other category includes non-CO₂ emissions in energy, emissions from other energy transformation (biofuels production, hydrogen and derived fuels production), and the sink from the direct air capture of CO₂.

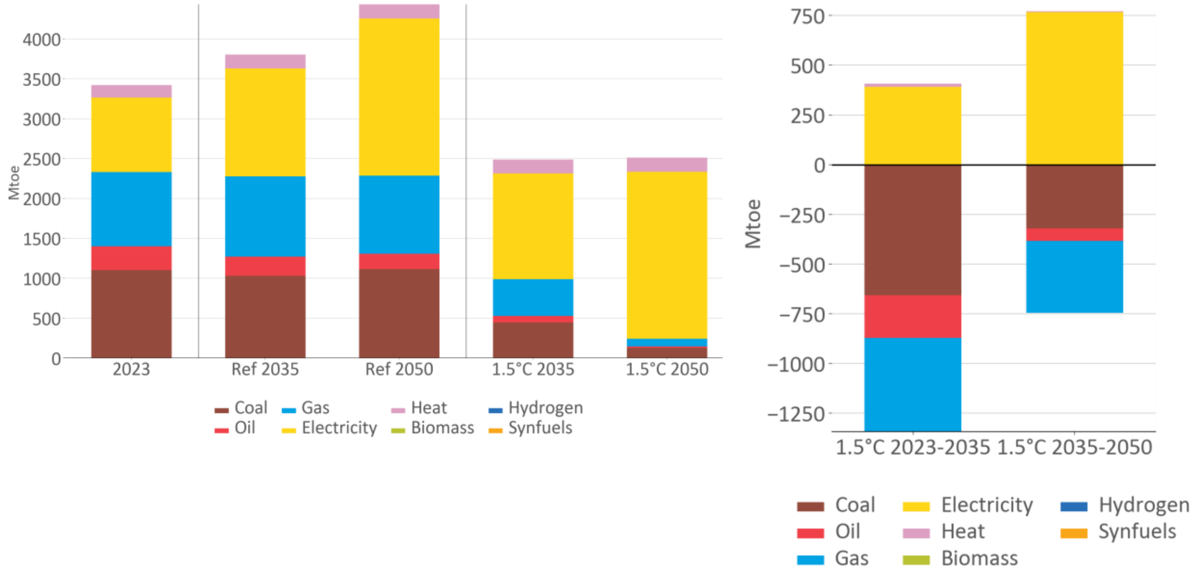
Primary energy demand, and change in primary energy demand - World



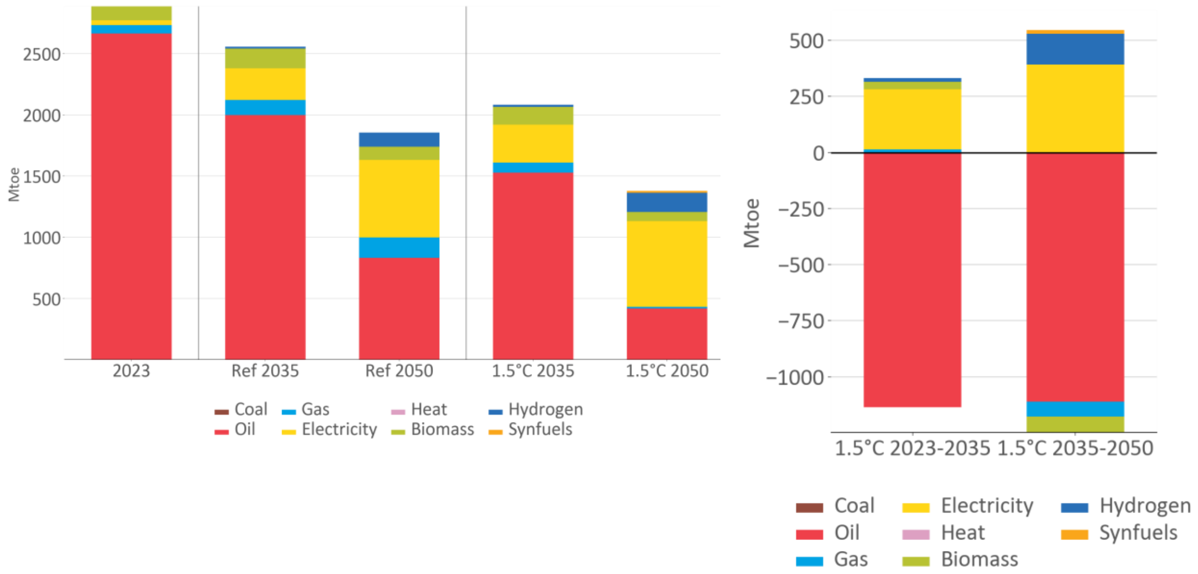
Power generation, and change in power generation - World



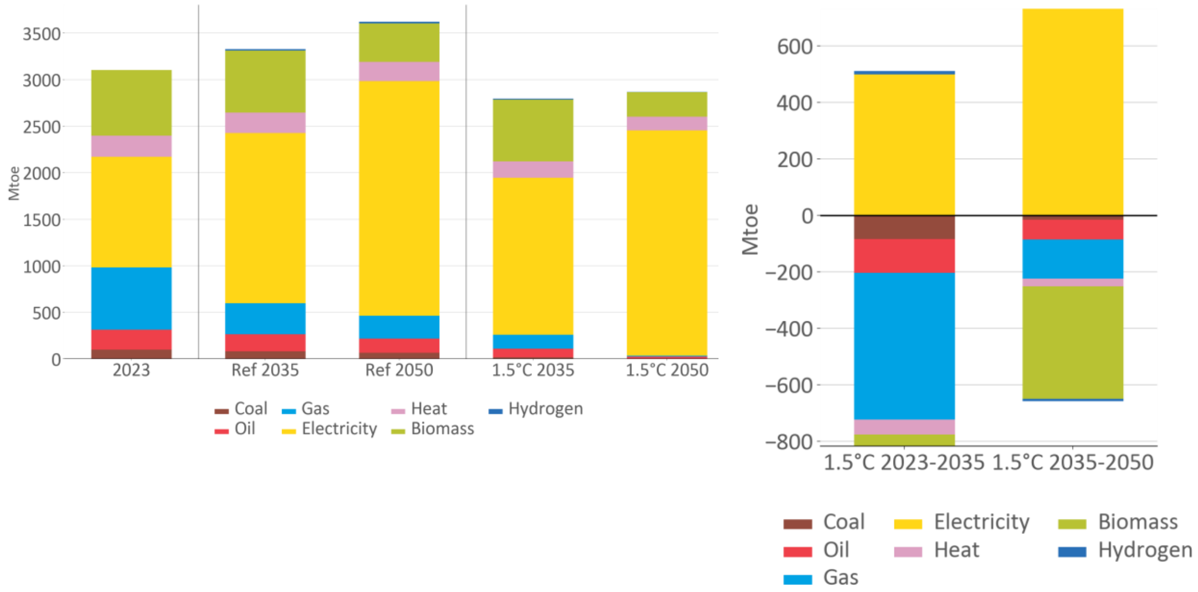
Industry sector demand, and change in industrial sector demand - World



Transport sector demand, and change in transport sector demand - World



Buildings sector demand, and change in buildings sector demand - World

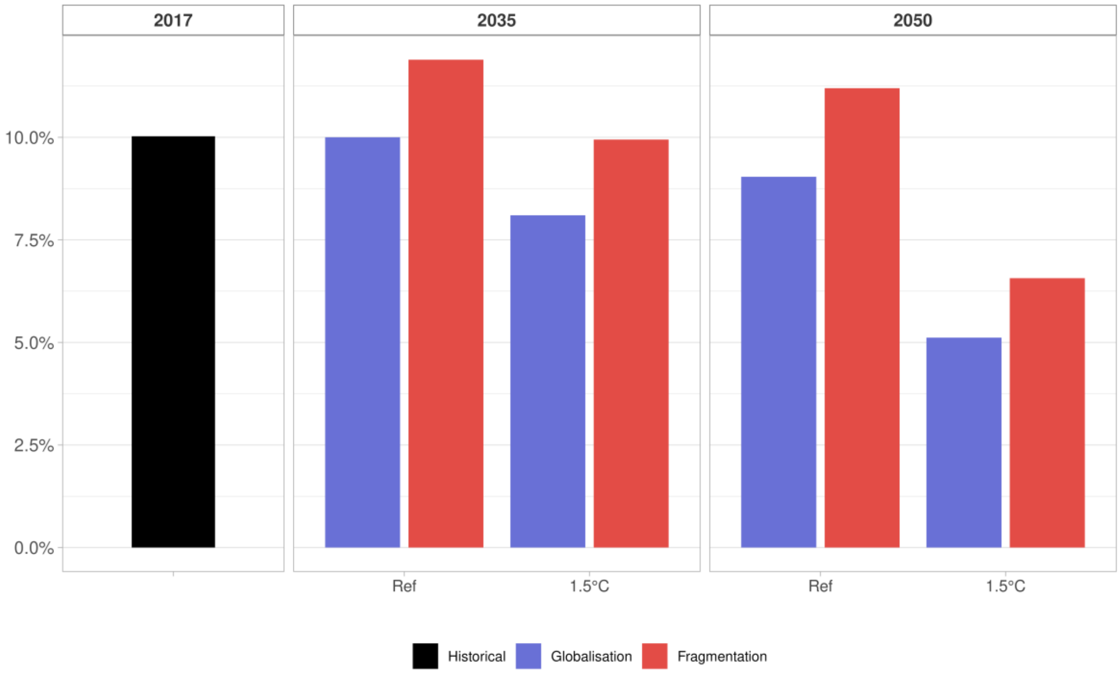


Trade dynamics

The first figure shows the sectoral composition of global trade in the Reference and the 1.5°C scenarios. These scenarios are set in two different versions of the global economy: 1) A globalisation case where trade openness levels remain at similar levels as today and, 2) a fragmentation case where trade openness levels decrease significantly. The second figure calculates the share of fossil fuel trade over total world trade, to give insight into energy-related trade dependencies in each of the scenarios.

Global trade by sector for different scenarios - World

Share of fossil fuels in total trade for different scenarios – World



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List of abbreviations and definitions

Abbreviations	Definitions
AFOLU	Agriculture, forestry and land-use
BAU	Business as usual
BECCS	Bio-Energy combined with Carbon Capture and Sequestration
BEV	Battery electric vehicle
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe
BP	BP p.l.c., British multinational oil and gas company
CCS	Carbon Capture and Sequestration
CDD	Cooling Degree-Days
CETO	Clean Energy Technology Observatory
CGE	Computable General Equilibrium model
CH_4	Methane
CO_2	Carbon dioxide
CNG	Compressed Natural Gas
COM	Communication from the European Commission
COP	Conference of the Parties
DAC	Direct Air CO_2 Capture
DACCS	Direct Air CO_2 Capture and Sequestration
DG ECFIN	Directorate-General for Economic and Financial Affairs
EC	European Commission
Enerdata	Enerdata, energy data and research company, Grenoble (France)
ETS	Emission Trading Scheme
EU	European Union as of date of publication (27 Member States)

Abbreviations	**Definitions**
EV	Electric Vehicle
GDP	Gross Domestic Product
GECO	Global Energy & Climate Outlook
GHG	Greenhouse Gases
GLOBIOM-G4M	Global Biosphere Management Model – Global Forest Model
GTAP	Global Trade Analysis Project
GWP	Global Warming Potential
H2	Hydrogen
HFCs	Hydrofluorocarbons
IATA	International air transport association
ICAO	International Civil Aviation Organization
ICE	Internal Combustion Engine
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
IFC	International Finance Corporation, World Bank Group
ILO	International Labour Organisation
IMF	International Monetary Fund
IMO	International Maritime Organisation
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre of the European Commission
LNG	Liquefied Natural Gas
LTS	Long Term Strategy

Abbreviations	**Definitions**
LULUCF	Land Use, Land Use Change and Forestry
MER	Market Exchange Rate
MRIO	Multi-regional input-output (table)
N_2O	Nitrous oxide
NDC	Nationally Determined Contribution
NIMBY	Not In My Backyard
NCSC	National Centre for Climate Change Strategy and International Cooperation
NREL	US National Renewables Energy Laboratory
OECD	Organisation of Economic Co-operation and Development
O&G	Oil and Gas
PFCs	Perfluorocarbons
PIRAMID	Platform to Integrate, Reconcile and Align Model-based Input-output Data
POP	Population
PPP	Purchasing Power Parity
POLES-JRC	Prospective Outlook on Long-term Energy Systems, model version used in the JRC
ppm	parts per million
R/P	Ratio Reserves by Production
RES	Renewable Energy
RFNBO	Renewable Fuels of Non-Biological Origin
SAF	Sustainable Aviation Fuel
SDS	Sustainable development scenario from IEA

Abbreviations	**Definitions**
SF_6	Sulphur hexafluoride
TC	Transport changes
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USGS	US Geological Survey
WEC	World Energy Council
WMO	World Meteorological Organisation

List of boxes

List of figures

List of tables

Annexes

Annex 1. Description of POLES-JRC

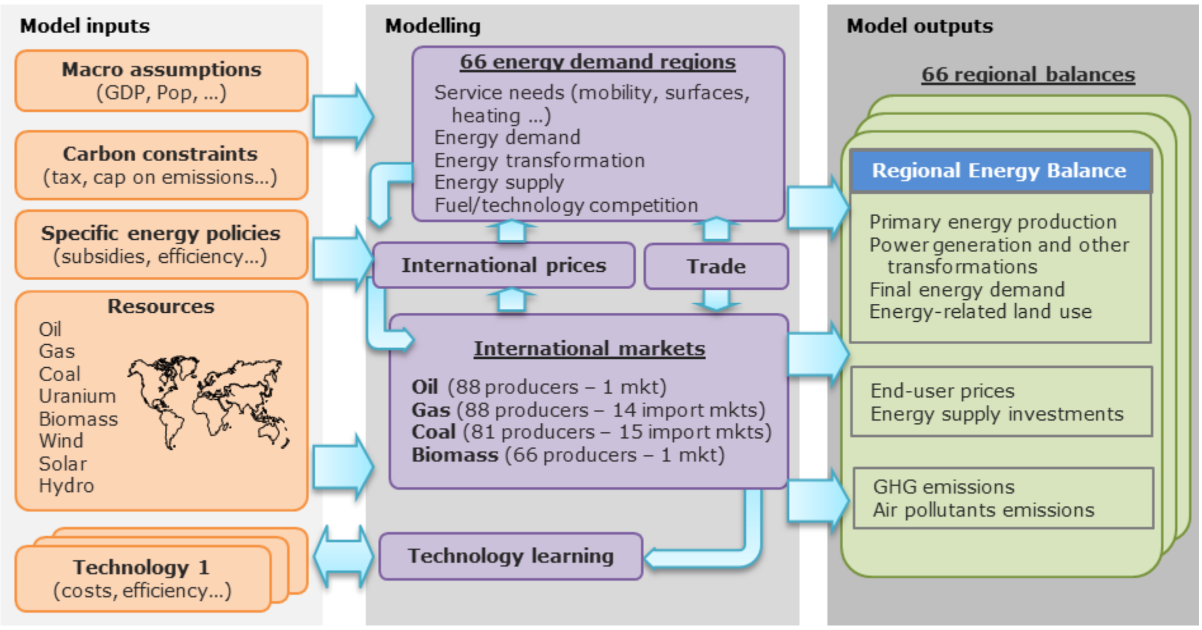
For a more comprehensive description of the model, see (Després *et al.*, 2018).

POLES-JRC is a world energy-economy partial equilibrium simulation model of the energy sector, with complete modelling from upstream production through to final user demand. It follows a year-by-year recursive modelling, with endogenous international energy prices and lagged adjustments of supply and demand by world region, which allows for describing full development pathways to 2050 (see general scheme in Figure 28).

The model provides full energy and emission balances for the EU plus 39 countries or regions worldwide (including an explicit representation of OECD and G20 countries), 14 fuel supply branches and 15 final demand sectors.

This exercise used the most recent POLES-JRC 2024 version as a starting point. This version differs from POLES model versions used in previous GECO reports and POLES model version used by other entities than JRC.

Figure 28. POLES-JRC model general scheme.



Source: POLES-JRC model. "mkt": market. The list of items in each box is not exhaustive.

Final demand

The final demand evolves with activity drivers, energy prices and technological progress. The following sectors are represented:

- industry: chemicals (energy uses and non-energy uses are differentiated), non-metallic minerals, steel, other industry;
- buildings: residential, services (detailed per end-uses: space heating, space cooling, water heating, cooking, lighting, appliances);

- transport (goods and passengers are differentiated): road (motorcycles, cars, light and heavy trucks; different engine types are considered), rail, inland water, international maritime, air (domestic and international);
- agriculture.

Power system

The power system describes the capacity planning of new plants and the operation of existing plants.

The electricity demand curve is built from the sectoral distribution.

The load, wind supply and solar supply are clustered into a number of representative days.

The planning considers the existing structure of the power mix (age structure per technology type), the expected evolution of the load demand, the production cost of new technologies and the resource potential for renewables.

The operation matches electricity demand considering the installed capacities, the variable production costs per technology type, the resource availability for renewables and the contribution of flexible means (stationary storage, vehicle-to-grid, demand-side management).

The electricity price by sector depends on the evolution of the power mix, of the load curve and of energy taxes.

Other transformation

The model also describes other energy transformations sectors: liquid biofuels, coal-to-liquids, gas-to-liquids, hydrogen, centralised heat production.

Oil supply

Oil discoveries, reserves and production are simulated for producing countries and different resource types.

Investments in new capacities are influenced by production costs, which include direct energy inputs in the production process.

The international oil price depends on the evolution of the oil stocks in the short term, and on the marginal production cost and ratio of the Reserves by Production (R/P) ratio in the longer run.

Gas supply

Gas discoveries, reserves and production are simulated for individual producers and different resource types. Investments in new capacities are influenced by production costs, which include direct energy inputs in the production process.

They supply regional markets through inland pipeline, offshore pipelines or LNG.

The gas prices depend on the transport cost, the regional R/P ratio, the evolution of oil price and the development of LNG (integration of the different regional markets).

Coal supply

Coal production is simulated for individual producers. Production cost is influenced by short-term utilisation of existing capacities and a longer-term evolution for the development of new resources.

They supply regional markets through inland transport (rail) or by maritime freight. Coal delivery price for each route depends on the production cost and the transport cost.

Biomass supply

The model differentiates various types of primary biomass: energy crops, short rotation crop (lignocellulosic) and wood (lignocellulosic). They are described through a potential and a production cost curve – information on lignocellulosic biomass (short rotation coppices, wood) is derived from look-up tables provided by the specialised model GLOBIOM-G4M (Global Biosphere Management Model – Global Forest Model) (Frank *et al.*, 2021). Biomass can be traded, either in solid form or as liquid biofuel.

Wind, solar and other renewables

They are associated with potentials and supply curves per country.

GHG emissions

CO_2 emissions from fossil fuel combustion are derived directly from the projected energy balance. Other GHGs from energy and industry are simulated using activity drivers identified in the model (e.g., sectoral value added, mobility per type of vehicles, fuel production, fuel consumption) and abatement cost curves. GHG from agriculture and LULUCF are derived from GLOBIOM-G4M lookup tables.

Definitions

In this report, hydrogen demand refers to hydrogen used as a fuel for energy use and non-energy applications, such as hydrogen used as feedstock for ammonia production.

E-fuels refers to fuels obtained from power-to-gas and power-to-liquid processes, in which hydrogen and CO_2 are converted to gaseous or liquid hydrocarbon fuels through methanation or the Fischer-Tropsch process. In both cases the CO_2 is sourced from direct air capture powered by renewables. E-fuels are renewable fuels of non-biological origin (RFNBO).

Hydrogen demand as feedstock (pure hydrogen for the production of ammonia and other industrial applications) appears in “Non-energy uses” in the balances, except for hydrogen demand in steelmaking which appears in industry energy demand. Hydrogen uses mixed with other gases (such as methanol) are not considered. Energy inputs for the production of hydrogen, for both energy and non-energy uses, appear in “Other energy transformation and losses” in the balances.

Hydrogen demand as industrial feedstock is included in total hydrogen demand. Ammonia demand as an energy fuel is only included in international maritime bunkers grouped together with e-fuels.

Domestic e-fuel production can be both gaseous and liquid fuels; however the international trade of e-fuels is exclusively liquid fuels.

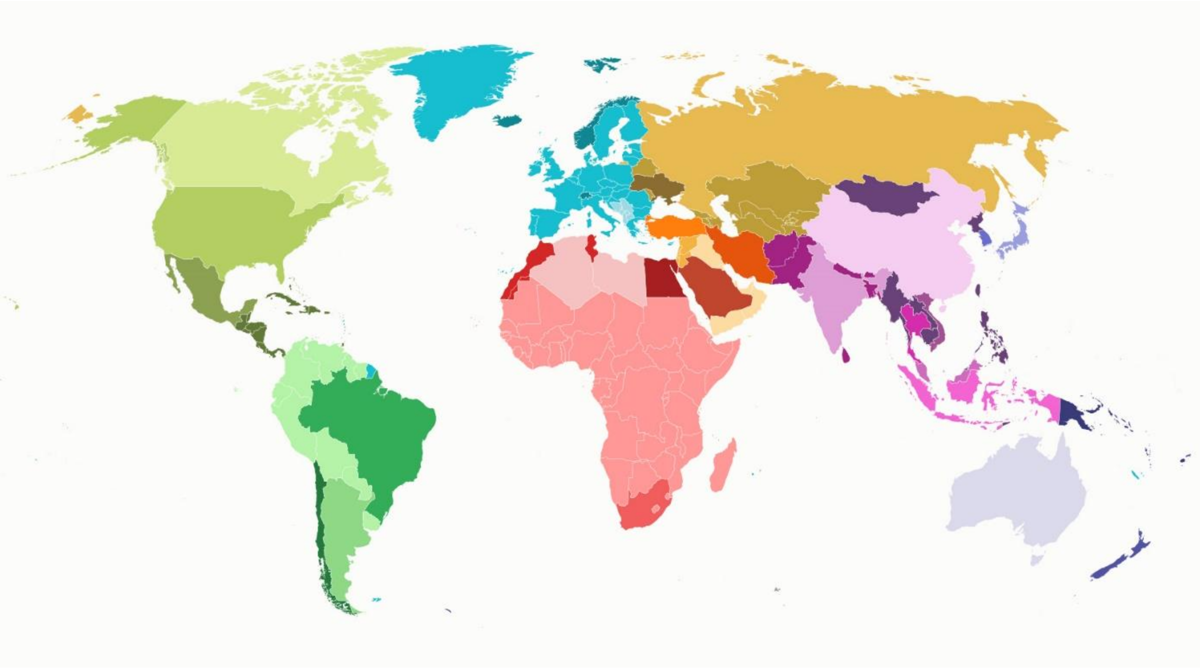
Internationally traded e-fuels can only be produced from renewables (“green hydrogen”).

Biomethane is produced from biomass and agricultural wastes, and the inputs of which are accounted for in primary energy as biomass. Biomethane is then mixed together with fossil gas for final users and appears as gas in final energy demand.

Countries and regions

The model decomposes the world energy system into the EU, 27 non-EU individual countries and 12 residual regions see **Figure 29**, to which international bunkers (air and maritime) are added.

Figure 29. POLES-JRC model regions (for energy balances).



Source: POLES-JRC model.

Table 2. List of non-EU individual countries represented in POLES-JRC (for energy balances).

Argentina	Indonesia	South Africa
Australia	Iran	South Korea
Brazil	Japan	Switzerland
Canada	Malaysia	Thailand
Chile	Mexico	Türkiye
China	New Zealand	Ukraine
Egypt	Norway	United Kingdom
Iceland	Russia	United States
India	Saudi Arabia	Vietnam

Source: POLES-JRC model. Note: Hong-Kong and Macau are included in China.

Table 3. Country mapping for the 12 regions in POLES-JRC (for energy balances).

Algeria & Libya	Algeria, Libya
Mediterranean Middle East	Israel, Jordan, Lebanon, Syria
Morocco & Tunisia	Morocco, Tunisia
Rest Balkans	Albania, Bosnia-Herzegovina, Kosovo, Macedonia, Moldova, Montenegro, Serbia
Rest Central America	Bahamas, Barbados, Belize, Bermuda, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Grenada, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, NL Antilles and Aruba, Panama, Sao Tome and Principe, St Lucia, St Vincent & Grenadines, Trinidad and Tobago
Rest of Commonwealth of Independent States	Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, Uzbekistan
Rest of Persian Gulf	Bahrain, Iraq, Kuwait, Oman, Qatar, United Arab Emirates, Yemen
Rest Pacific	Fiji Islands, Kiribati, Papua New Guinea, Samoa (Western), Solomon Islands, Tonga, Vanuatu
Rest South America	Bolivia, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay, Venezuela
Rest South Asia	Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, Pakistan, Seychelles, Sri Lanka
Rest South East Asia	Brunei, Cambodia, Lao PDR, Mongolia, Myanmar, North Korea, Philippines, Singapore, Taiwan
Rest Sub-Saharan Africa	Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Congo DR, Cote d'Ivoire, Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia

Source: POLES-JRC model.

Table 4. POLES-JRC model historical data and projections

Series		Historical data	GECO Projections
Population		(Lutz *et al.*, 2018; European Commission DG ECFIN, 2024b)	
GDP, GDP growth		(World Bank, 2024; IMF, 2025)	(Riahi *et al.*, 2017; OECD, 2021; IMF, 2025)
Other activity drivers	Value added	World Bank	POLES-JRC model
	Mobility, vehicles, households, tons of steel, …	Sectoral databases	
Energy resources	Oil, gas, coal	USGS, WEC, Upstream Solution Database (Rystad Energy, 2019), BGR (BGR, 2016)	
	Uranium	(OECD-NEA, 2015)	
	Biomass	GLOBIOM-G4M models[19]	
	Hydro	Enerdata	
	Wind, solar	NREL, DLR, Global Wind Atlas (Global Wind Atlas, 2026)	
Energy balances	Reserves, production	BP, Enerdata	
	Demand by sector and fuel, transformation (including. power), losses	Enerdata, IEA (multiple years)	
	Power plants	(IRENA, 2025), S&P Global Commodity Insights (S&P, 2022), Enderdata	
Energy prices	International prices, prices to consumer	Enerdata, IEA (multiple years)	POLES-JRC model

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[19] (Frank *et al.*, 2021)

GHG emissions	Energy CO_2	Derived from POLES-JRC energy balances	POLES-JRC model
	Other GHG Annex I (excl. LULUCF)	UNFCCC (UNFCCC, 2025)	POLES-JRC model, GLOBIOM-G4M[19] models
	Other GHG Non-Annex I (excl. LULUCF)	UNFCCC (UNFCCC CRT NIR, 2025), EDGAR (Crippa *et al.*, 2025)	POLES-JRC model, GLOBIOM-G4M[19] models
	LULUCF	(Grassi *et al.*, 2023)	POLES-JRC model, GLOBIOM-G4M[19] models
Air pollutants emissions		GAINS ECLIPSE v5a[20], EDGAR, IPCC, national sources	GAINS model, national sources
Technology costs		Techno-economic parameters (costs, learning rates, etc.) used in POLES-JRC documented in (Schmitz *et al.*, 2025) including its references.	

Source: JRC analysis.

Energy emissions data is calculated by POLES using emission factors and historical energy consumption data (mostly sourced from Enerdata). Most historical data series are available until 2022, while the remaining mainly go until 2021. Non-energy emissions data comes from three sources: (i) UNFCCC (UNFCCC, 2025; UNFCCC CRT NIR, 2025), (ii) EDGAR (Crippa *et al.*, 2025), and (iii) LULUCF emissions data until 2020 comes from (Grassi *et al.*, 2023).

UNFCCC inventories were used for Annex I countries (UNFCCC, 2025), and for Argentina, Brazil, Chile, Mexico, South Korea, Egypt, South Africa and Indonesia (UNFCCC CRT NIR, 2025) with most recent historic years 2022 to 2024. EDGAR was used for the remainder of the non-Annex countries with 2024 as most recent historic year.

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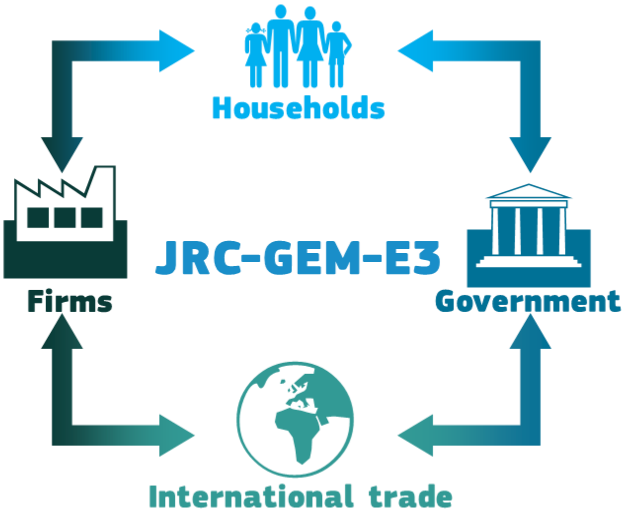
[20] (Amann *et al.*, 2011; Stohl *et al.*, 2015)

Annex 2. Description of JRC-GEM-E3

Brief description of main features

The JRC-GEM-E3 model is a global, multi-region, multi-sector, recursive-dynamic computable general equilibrium (CGE) model designed to analyse energy, climate and environmental policies (Capros *et al.*, 2013) and has been used extensively for analysis at the EU and global level to inform policy making (Garaffa *et al.*, 2023; Weitzel *et al.*, 2023)[21]. The agents in the model are households, firms and governments (**Figure 30**). Households are endowed with production factors and spend their income on consumption and savings. Firms produce goods and services using production factors and intermediate inputs. Different regions in the model are connected by international trade. Governments collect taxes, pay subsidies and undertake government consumption.

Figure 30. Schematic overview of the JRC-GEM-E3 model.



Source: JRC analysis.

The model version used in GECO 2025 is aggregated into 31 sectors (see **Table 5**), including crude oil, refined oil, gas, coal, and electricity generation, with the latter further disaggregated into 8 generation technologies. The generation technologies are modelled using a Leontief production function, while production in other sectors is described by nested constant elasticity of substitution (CES) production functions. The model version for GECO 2025 represents the 27 EU Member States as well as 22 other regions (see **Table 6**) Bilateral international trade flows between these regions are modelled following the Armington formulation (Armington, 1969) and linkages between sectors are included based on GTAP 11-power data (Aguiar *et al.*, 2022).

Labour and capital are assumed to be mobile between sectors, but not across regions. Baseline labour supply and unemployment rates are calibrated to the 2024 Ageing Report (European Commission DG ECFIN, 2024b) for the EU, and to projections by the International Labour Organisation (ILO, 2017) for non-EU regions. The analyses done for this report build on the assumption of flexible wages, abstracting from short-term rigidities. Investment is determined by

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[21] See also https://joint-research-centre.ec.europa.eu/scientific-tools-and-databases/jrc-gem-e3-model_en

the rental price of capital and the cost of the investment good. Holding the real interest rate fixed allows for variation of the balance of payments.

A consumption matrix (Cai *et al.*, 2020) translates output from the production sectors into household consumption by purpose. Purchases of durables (vehicles and appliances) are determined by the price of the durable goods and the price of the cost of operation, while purchases linked to the operation of these durables (operation of vehicles and household energy, respectively) are determined by the stock of durables and the cost of operation (Capros *et al.*, 2013). Household purchases of the different consumption categories are governed by a Stone-Geary utility function.

Table 5. Sectors in the JRC-GEM-E3 model.

Sector name	#	Sector name	#	Sector name	#
Crops	01	Non-metallic Minerals	11	Non-market Services	21
Coal	02	Electric Goods	12	Coal-fired Electricity	22
Crude Oil	03	Transport Equipment	13	Oil-fired Electricity	23
Oil	04	Other Equipment Goods	14	Gas-fired Electricity	24
Gas	05	Consumer Goods Industries	15	Nuclear Electricity	25
Electricity Supply	06	Construction	16	Biomass Electricity	26
Ferrous Metals	07	Transport (Air)	17	Hydro Electricity	27
Non-ferrous Metals	08	Transport (Land)	18	Wind Electricity	28
Chemical Products	09	Transport (Water)	19	Solar Electricity	29
Paper Products	10	Market Services	20	Livestock	30
				Forestry	31

Source: JRC analysis.

Table 6. Regional aggregation of the JRC-GEM-E3 model

Regions in the JRC-GEM-E3 model	Abbreviation	Regions in the JRC-GEM-E3 model	Abbreviation
European Union	EU27	Türkiye	TUR
United Kingdom	GBR	South Africa	SAF
United States	USA	Mexico	MEX
Japan	JPN	Argentina	ARG
Canada	CAN	Indonesia	IDN
Australia	AUS	EFTA	EFA
Russian Federation	RUS	Middle East	MEA
Brazil	BRA	Africa	AFR
China	CHN	Other Americas	OAM
India	IND	Other Asia	OAS
South Korea	KOR	Rest of Eurasia	REA
Saudi Arabia	SAU		

Source: JRC analysis.

Regarding GHG emissions, all gases other than CO_2 from land use (and land use change) and forestry are covered in the model. Besides CO_2 emitted from fossil fuel combustion and industrial processes, all non-CO_2 Kyoto GHGs are modelled explicitly in JRC-GEM-E3: methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), and sulphur hexafluoride (SF_6). Abatement of non-CO_2 emissions, industrial process emissions and abatement through CCS are implemented by preserving various bottom-up technologies in JRC-GEM-E3 (Weitzel *et al.*, 2019).

The reference year is constructed by generating input-output tables based on GTAP's initial base year (2017). Projections for economic activities, energy use and emissions are harmonized with POLES-JRC, so that the economic starting point for the analysis closely resembles that of the Reference scenario of the energy model, as described in more detail in the next section. In addition, different inputs from the energy models feed into the construction of the scenarios (see following section).

Reference scenario construction

The macroeconomic balances for the Reference scenario are constructed on the basis of a variety of data sources, achieving an integration of macroeconomic forecasts with energy balances from the POLES-JRC model, see (Rey Los Santos *et al.*, 2018; Wojtowicz *et al.*, 2019). The integration approach uses the Platform to Integrate, Reconcile and Align Model-based Input-output Data (PIRAMID) to construct input-output tables for future years in 5-year-steps, using a balancing procedure that ensures consistency of the various data sources within a National Accounting framework. The RAS procedure is extended to include data from various sources in a multi-regional context (hence, multi-regional generalised RAS, or MRGRAS) (Temursho *et al.*, 2021).

The main data sources for the version used in GECO 2025 include:

- The input-output tables and the data on bilateral trade flows, which are derived from the 'Global Trade Analysis Project (GTAP) 11-power database' (Aguiar *et al.*, 2022). The GTAP 11-power database is aggregated to the 31 commodities in **Table 5** and the regions listed in **Table 6**.
- GDP growth rates as described in Annex 4.
- The International Labour Organisation (ILO) database is used to project population and labour statistics such as labour force, unemployment rates and the share of skilled and unskilled workers. Short term unemployment projections were taken from IMF as the ILO projections do not include the effects of Covid-19, implying the implicit assumption that Covid-19 will not have an effect on long-term unemployment. For the EU27, data from the 2024 Ageing report (European Commission DG ECFIN, 2024b) was used.
- Energy and emission data using energy balances from POLES-JRC. The alignment with energy balances implies that the emission levels of greenhouse gases (totals and by sector) and the shares of electricity generation technologies are harmonised with the Reference scenario between the POLES-JRC and JRC-GEM-E3 models.

Scenario implementation

In the policy scenarios, decarbonisation options for some sectors are implemented by adjusting model parameters in JRC-GEM-E3 based on changes in POLES-JRC. This "soft-link" can help to align both models and better capture mitigation responses in complex sectors that are represented in more detail in energy models (Weitzel *et al.*, 2023). Specifically, information is used when adjusting input shares in production functions of JRC-GEM-E3 via a one-way soft-link (Delzeit *et al.*, 2020), i.e., without feeding information (e.g., on activity levels) back to POLES-JRC. In order to fully capture the changes in the energy mix of specific sectors, information on costs is also added. There are three main sectors making use of this approach: electricity generation, commercial transport sectors, and household energy use (in private transport and other use, including cooling and heating).

For electricity generation, the JRC-GEM-E3 production function that aggregates electricity from the different generation technologies is replaced into a single supply sector through a Leontief function and the share parameters based on electricity generation are adjusted as projected by POLES-JRC.

In commercial transport sectors (aviation, land transport, water transport), fuel use of different energy carriers is imposed exogenously by collapsing the energy nest of the CES production function into a Leontief aggregation and adjusting the share parameters to reflect changes in the fuel mix and efficiency improvements. The scenarios account for a more expensive vehicle fleet by adjusting the non-fuel part of the production function of the transport sectors.

Regarding energy use by private households, a similar approach applies for energy use for private transportation and for other energy use, including heating. For private transportation, the shares of different fuels are adjusted in the consumption matrix based on energy modelling results, reflecting a shift towards cleaner transport. Any additional cost related to the introduction of a higher share of more efficient or electric vehicles is introduced by adjusting the efficiency of vehicle consumption in the consumption matrix. For household heating and electricity use, the share and the efficiency of fuel use is translated into changes of parameters in the consumption matrix to replicate energy use. Additional costs are modelled as increases in the required (or subsistence) consumption in the Stone Geary consumption function and through an efficiency parameter for purchasing "housing"-related consumption categories, resulting in additional housing expenditure.

In addition, the scenarios implement a carbon tax to harmonize the emissions between models. Carbon prices (e.g., in the 1.5°C scenario) may differ between regions that would have the same carbon prices in POLES-JRC. In reaction to the emission prices, the model endogenously adjusts the inputs to the production process, switching between different fuels of varying emission intensity, decreasing the input of energy at the expense of additional capital and labour inputs, reducing the use of emission intensive products and applying end of pipe abatement (CCS and non-CO_2 emissions).

Investment Matrix

JRC-GEM-E3 contains an investment matrix to more accurately represent the investment flows across sectors, providing insight into investment trends both in the Reference and in the scenarios. The sectoral demand of investment in the JRC-GEM-E3 model is determined by changes in the output of this sector and the cost of capital goods over time. On the investment supply side, the "delivering sectors" are the sectors that deliver goods and services to build additional capital stock. JRC-GEM-E3's updated investment matrix is based on (Norman *et al.*, 2023), which describes the data collection and the steps used to build the investment matrix. A RAS-balancing procedure brings (aggregate) sectoral investment supply of the investment matrix in line with the investment supply reported in the GTAP database.

Previous versions of the JRC-GEM-E3 model used only a single vector of sectoral investment deliveries, regardless of the investing sector. However, the investment structure differs by investing sector. For example, the solar PV sector requires more electric goods for the formation of capital stock, while the air transport sector relies more on the transport equipment sector as a share of total investment. The GECO 2025 edition makes use of the updated investment matrix to capture the heterogeneity of capital formation across sectors, recently extended to include OECD data for non-EU27 countries (Alsamawi *et al.*, 2020).

Jobs

The JRC-GEM-E3 model accounts for economy-wide job impacts across sectors, including both direct and indirect jobs created by investment activities. The Reference scenario relies on long term projections for the labour force, unemployment rate, and shares of skilled and unskilled workers from the International Labour Organization (ILO) database. JRC-GEM-E3 projects the number of workers in the energy sectors (including power generation technologies) based on the employment factors (number of direct jobs/energy unit produced) from (Czako, 2020; Pai *et al.*, 2021). The employment factors are multiplied by the total output of the energy sectors to calculate and project the total number of direct jobs in those sectors.

The indirect jobs are those jobs that are created in the sectors that deliver goods and services for the investment needs of other sectors, also called the 'delivering sectors'. Based on the JRC-GEM-E3 investment matrix, the model results include the investment needs of each sector, as well the sectors that deliver on these investment needs. The sectoral investment deliveries are combined with the delivering sector’s wages and the sector’s overall share of value added to obtain the number of indirect jobs. Importantly, these calculations capture only the first-round effects of this investment when creating indirect jobs. Purchases of intermediate inputs by the delivering sectors would also create economic activity and require additional workforce to produce but are not accounted for.

Tariffs

In the default GECO scenarios, trade tariffs in JRC-GEM-E3 are derived from the GTAP 11-Power database with base year 2017. The default scenarios assume that the 2017 tariff levels remain unchanged across time, implicitly maintaining the same levels of trade openness throughout the projection from 2017 up to 2050.

GECO 2025 additionally includes a non-default scenario where international trade becomes highly fragmented from 2025 onwards. This fragmentation is achieved by increasing the GTAP import tariffs (i.e. reflecting tariff levels in 2017) between all regions (excluding intra-EU trade) by 25 percentage points in 2025. These increased tariffs are then maintained throughout the remainder of the projection period.

Annex 3. Socio-economic assumptions and fossil fuel prices

Historical GDP levels are taken from the World Bank (World Bank, 2024).

The population assumptions follow Europop (European Commission DG ECFIN, 2024b) for EU and JRC-IIASA projections (Lutz *et al.*, 2018) for the rest of the world. The GDP projections for the EU The GDP projections follow numbers of the 2024 Ageing Report for the EU (European Commission DG ECFIN, 2024b).

For the EU, the population and GDP assumptions follow the numbers of the 2024 Ageing Report (European Commission DG ECFIN, 2024b). For the short term (up to including 2026), GDP projections are based on the 2024 autumn forecast from ECFIN (European Commission DG ECFIN, 2024a).

For the rest of the world, the population assumptions follow JRC-IIASA projections (Lutz et al., 2018). GDP assumptions follow the IMF World Economic Outlook of April 2025 (IMF, 2025) for the short term (up to including 2030) and the OECD long-tern baseline projections (OECD, 2021) and Shared Socio-economic Pathway (SSP) 2 (Riahi *et al.*, 2017) for the long term.

Table 7. World population and GDP

	2000	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100
Population (billion)	6.1	6.9	7.8	8.5	9.1	9.6	9.9	10.1	10.1	10.1	9.9
GDP (purchasing power parity)	82.8	117.8	154.6	216.1	281.2	351.6	430.4	517.0	607.4	701.8	801.9

Source: JRC. GDP values are in trillion USD of 2022.

Table 8. GDP assumptions

Group	Historical (to 2023)	2023-2027	2028-2030	2031-2060	2061-2100
EU	WB Apr-2024[22]	ECFIN Autumn-2024[23]	EU Ageing Report 2024[24]	EU Ageing Report 2024[24]	GDP/cap as SSP[26], Pop EU Ageing Report 2024[24]
Large non-EU	WB Apr-2024[22]	IMF Apr-2025[25]	interpolation	GDP OECD 2021[26]	GDP/cap as SSP[26], Pop IIASA-JRC[27]
Rest of World	WB Apr-2024[22]	IMF Apr-2025[25]	interpolation	GDP/cap as SSP[26], Pop IIASA-JRC[27]	GDP/cap as SSP[26], Pop IIASA-JRC[27]

Source: JRC. Large non-EU: OECD (Australia, Canada, Chile, Iceland, Japan, Republic of Korea, Mexico, New Zealand, Norway, Switzerland, Türkiye, United Kingdom, United States); non-OECD (Argentina, Brazil, China, India, Indonesia, Russia, Saudi Arabia, South Africa).

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[22] (World Bank, 2024)

[23] (European Commission DG ECFIN, 2024a)

[24] (European Commission DG ECFIN, 2024b)

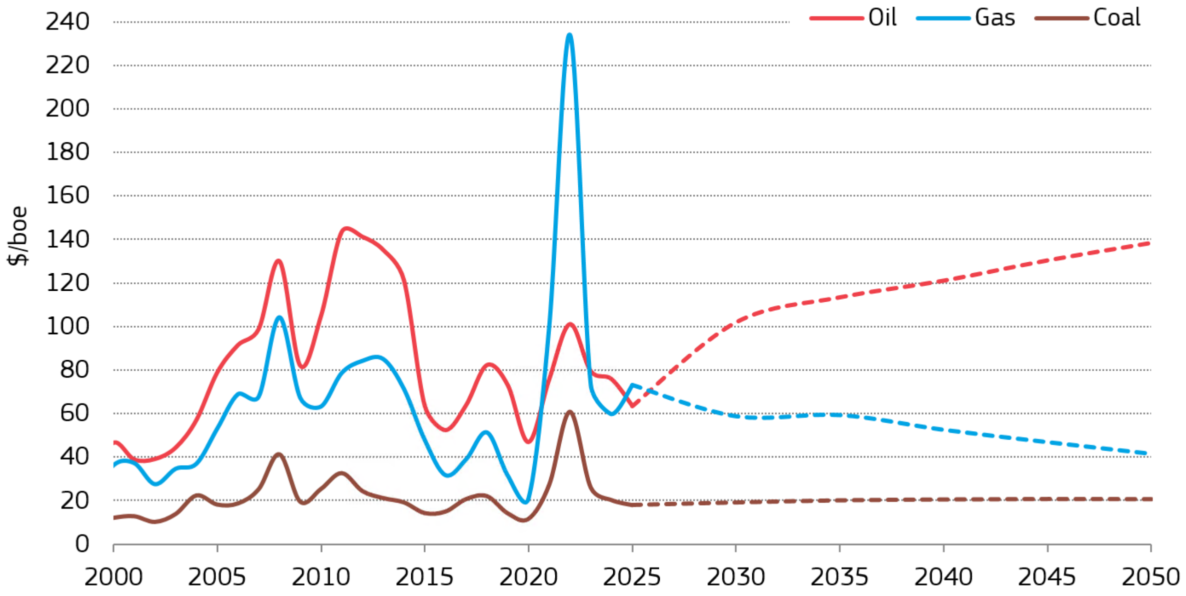
[25] (IMF, 2025)

[26] (Riahi *et al.*, 2017; OECD, 2021)

[27] (Lutz *et al.*, 2018)

The international fossil fuel prices in the Reference scenario are shown in **Figure 31**.

Figure 31. International fossil fuel prices in the Reference scenario.



Source: POLES-JRC model. Note: Oil prices refer to Brent; gas and coal prices refer to the average imports to the European market. Values are in USD of 2022 per barrel of oil equivalent.

Annex 4. Policies considered

The Reference scenario considers multiple policies on the energy mix and emissions.

The NDC-LTS scenario includes the policies of the Reference scenario as well as additional policies for 2030 and beyond. The conditional (maximum mitigation) targets of NDCs were considered.

The 1.5°C scenario has the Reference scenario as a starting point; the country-level GHG policies of the NDC-LTS were removed from the 1.5°C scenario, in order to subject all countries to a homogeneous policy driver. This allows to compare country-level pathways that include national policies with the "economically-efficient" pathways of the single carbon price scenario. The 1.5°C scenario subjects all regions and all sectors of the economy to the same carbon price starting from 2026; this price follows a sigmoid curve with an inflection point in 2035.

For land sectors (agriculture and emissions related to land use, land use change and forestry): the carbon price is capped (where necessary) to the maximum carbon price point provided by the soft-linking with specialized sectoral models.[28]

The following tables summarize all the policies considered to build the emissions pathways in the Reference scenario (**Table 9**, **Table 10**) and the NDC-LTS scenario (**Table 11**, **Table 12**).

For POLES-JRC regions that are country aggregates, the Reference pathway is derived purely from the modelling without additional policies. The NDC-LTS pathway necessitated aggregation work. First, the component countries' NDCs were accounted as quantities of emissions; then, the sum of emissions was converted into a target in terms of growth (or decrease) compared to a historical base year, using the PRIMAP-hist national historical emissions time series (Gütschow, *et al.*, 2025) to translate countries' base years into a single base year; this growth target was used to calibrate POLES-JRC model results for that region (**Table 12**).

EU refers to the European Union as of the date of publication (27 Member States).

Table 9: Reference policies

Country	Target Indicator	Value Min	Value Max	Unit	Base Year	Target Year
Argentina	Minimum blend of ethanol in gasoline	15	15	%	2016	2030
Australia	Share of renewables in electricity production	82	82	%		2030
Australia	Share of EVs in car sales	43	43	%		2030
Australia	Energy productivity increase	0.4	0.4	M$/PJ	2015	2030

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[28] The projections for agriculture and land use metrics in this report were done by soft-linking the specialised models GLOBIOM-G4M (Frank *et al.*, 2021) with the energy system model POLES-JRC.

Brazil	Biodiesel share in diesel in road transport	20	20	%	2005	2030
Brazil	SAF share in aviation fuel mix (biofuels and efuels)	3	3	%	2030	2030
Brazil	SAF share in aviation fuel mix (biofuels and efuels)	8	8	%	2035	2035
Brazil	Share of renewables in primary energy	48	48	%		2031
Brazil	Share of renewables in electricity production	85	85	%		2031
Brazil	Nuclear power capacity	4.395	4.395	GW		2031
Brazil	Wind power capacity	30.336	30.336	GW		2031
Brazil	Solar power capacity	10.383	10.383	GW		2031
Canada	SAF share in aviation fuel mix (biofuels and efuels)	10	10	%		2028
Canada	Coal power capacity	0	0	GW		2030
Canada	Subnational carbon tax	65	170	CAD/tCO2e	2023	2030
Canada	Methane emissions	-75	-75	%	2012	2030
Canada	Share of renewables in electricity production	90	90	%		2030
Canada	Share of zero-emission vehicles in cars sales	100	100	%		2035
Canada	SAF share in aviation fuel mix (biofuels and efuels)					2030
Chile	SAF share in aviation fuel mix (biofuels and efuels)	50	50	%		2050
Chile	Renewables share in power production	60	60	%		2035
Chile	Renewables share in power production	70	70	%		2050
Chile	Final energy consumption reduction	-10	-10	%	2019	2030
Chile	Final energy consumption reduction	-35	-35	%	2019	2050
Chile	Coal power capacity	0	0	GW		2040
Chile	Share of EVs in cars and vans sales	100	100	%		2035
China	Share of low-emissions vehicles in cars sales	25	25	%		2027

Egypt	Share of renewables in electricity production	42	42	%		2030
EU	Domestic GHG emissions reduction	-55	-55	%	1990	2030
EU	GHG emissions from ETS sectors	-62	-62	%	2005	2030
EU	GHG emissions from ETS2 sectors	-42	-42	%	2005	2030
EU	Share of renewables in gross final energy consumption	42.5	45	%	2023	2030
EU	Final energy consumption	750	750	Mtoe	2023	2030
EU	Renewables power capacity	300	300	GW		2050
EU	Share of EVs in cars sales	100	100	%		2035
EU	Share of renewables in transport	29	29	%		2030
EU	GHG intensity reduction	-14.5	-14.5	%	2022	2030
EU	Share of renewables	49	49	%		2030
EU	Share of renewables	15	15	%	2021	2030
EU	Renewables power capacity	60	60	GW		2030
EU	Renewables power capacity	1	1	GW		2030
EU	Biomethane production	35	35	bcm		2030
EU	Hydrogen demand	16.2	16.2	Mt		2030
EU	SAF share in aviation fuel mix	6	6	%		2030
EU	SAF share in aviation fuel mix	20	20	%		2035
EU	SAF share in aviation fuel mix	34	34	%		2040
EU	SAF share in aviation fuel mix	42	42	%		2045
EU	SAF share in aviation fuel mix	70	70	%		2050
EU	Maritime emissions intensity	-6	-6	%	2020	2030
EU	Maritime emissions intensity	-15	-15	%	2020	2035
EU	Maritime emissions intensity	-31	-31	%	2020	2040
EU	Maritime emissions intensity	-62	-62	%	2020	2045
EU	Maritime emissions intensity	-80	-80	%	2020	2050
United Kingdom	Wind power capacity (offshore)	43	50	GW		2030
United Kingdom	Wind power capacity (onshore)	27	29	GW		2030

United Kingdom	Share of ICE vehicles in cars sales	0	0	%		2035
United Kingdom	Share of plug-in hybrids in cars sales	0	0	%		2035
United Kingdom	Share of zero-emissions vehicles in cars sales	100	100	%		2035
United Kingdom	Share of zero-emissions vehicles in vans sales	100	100	%		2035
United Kingdom	Share of ICE vehicles in heavy trucks sales	0	0	%		2040
United Kingdom	Share of ICE vehicles in vans sales	0	0	%		2035
United Kingdom	Nuclear power capacity	24	24	GW		2050
United Kingdom	Solar power capacity	70	70	GW		2035
United Kingdom	SAF share in aviation fuel mix	22	22	%		2040
United Kingdom	SAF share in aviation fuel mix	10	10	%		2030
Indonesia	SAF share in aviation fuel mix (biofuels and efuels)	1	1	%		2027
Indonesia	Share of renewables in primary energy	31	31	%		2050
Indonesia	Share of gas in primary energy	24	24	%	2014	2050
Indonesia	Wind power capacity	37	37	GW	2017	2060
Indonesia	Solar power capacity	264	264	GW	2017	2050
Indonesia	Carbon tax	2	2	$/tCO2	2025	2050
Indonesia	Biodiesel share in transport energy mix	50	50	%	2023	2029
Indonesia	Bio-ethanol share in transport energy mix	10	10	%		2030
Indonesia	Coal power capacity additions	6.3	6.3	GW	2025	2034
Indonesia	Solar power capacity (PV)	5	5	GW		2030
Indonesia	Share of renewables in primary energy	34	34	%		2030
India	SAF share in aviation fuel mix (biofuels and efuels)	1	1	%		2030
India	Share of renewables in electricity production	45.1	45.1	%	2022	2032

India	Share of EVs in new cars sales	30	30	%		2030
India	Bioethanol share in petrol in road transport	20	20	% bioethanol in gas	2018	2030
India	Nuclear power capacity	19.7	19.7	GW		2032
India	Wind power capacity	121.9	121.9	GW		2032
India	Solar power capacity (PV)	364.6	364.6	GW		2032
Japan	SAF share in aviation fuel mix (biofuels and efuels)	10	10	%		2030
Japan	Share of EVs in cars sales	100	100	%		2035
Japan	Wind power capacity	10	10	GW	2020	2030
Japan	Wind power capacity (onshore)	18	26	GW		2030
Japan	Share of nuclear in power production	20	20	%		2040
Japan	Share of renewables in power production	40	50	%		2040
South Korea	SAF share in aviation fuel mix (biofuels and efuels)	1	1	%		2027
South Korea	Final energy consumption	-18.6	-18.6	%	BAU	2040
South Korea	Share of renewables in power production	32.89	32.89	%		2038
South Korea	Share of nuclear in power production	35.24	35.24	%		2038
South Korea	Stock of plug-in hybrid and EV cars	6.2	6.2	million vehicles	2019	2040
South Korea	Stock of hydrogen fuel cell cars	2.9	2.9	million vehicles		2040
South Korea	Share of renewables in power production	21.72	21.72	%		2030
Mexico	Share of renewables in power production	40	40	%		2030
Mexico	Solar power capacity additions (utility-scale)	6.2	6.2	GW	2023	2027
Mexico	Solar power capacity additions (decentralized)	1.9	1.9	GW	2023	2027
Mexico	Wind power capacity additions	1.9	1.9	GW	2023	2027
Mexico	Solar power capacity additions (utility-scale)	7.5	7.5	GW	2028	2038
Mexico	Solar power capacity additions (decentralized)	5.9	5.9	GW	2028	2038

Mexico	Wind power capacity additions	19.4	19.4	GW	2028	2038
Mexico	Nuclear power capacity additions	2.0	2.0	GW	2028	2038
Malaysia	SAF share in aviation fuel mix (biofuels and efuels)	1	1	%		2026
Norway	Share of zero-emissions vehicles in truck sales	50	50	%		2030
New-Zealand	Share of renewables in final energy consumption	50	50	%		2035
New-Zealand	Share of renewables in power production	100	100	%		2030
New-Zealand	Biogenic methane emissions reduction	-10	-10	%	2017	2030
New-Zealand	Biogenic methane emissions reduction	-25	-47	%	2017	2050
Russia	Wind power capacity	3	3	GW		2035
Russia	Solar power capacity	2.2	2.2	GW		2035
Russia	Share of EVs in cars sales	5	30	%		2030
Saudi Arabia	Share of renewables in electricity production	50	50	%	2023	2030
Saudi Arabia	Share of gas in electricity production	50	50	%	2023	2030
Thailand	Share of renewables in final energy consumption	34	34	%	2010	2037
Thailand	Energy intensity reduction	-30	-30	%	2010	2036
Thailand	Share of renewables in electricity production	21	21	%		2037
Thailand	Solar power capacity	15.6	15.6	GW		2037
Thailand	Wind power capacity	3	3	GW		2037
Thailand	Share of renewables in transport	25	25	%		2037
Thailand	Share of coal in power production	12	12	%		2036
Thailand	Share of gas in power production	53	53	%		2036
Türkiye	Solar power capacity	52.9	52.9	GW		2035
Türkiye	Wind power capacity	29.6	29.6	GW		2035
Türkiye	Nuclear power capacity	7.2	7.2	GW		2035

Türkiye	Share of renewables in electricity production	54.7	54.7	%		2035
Türkiye	Share of renewables in primary energy consumption	20.4	20.4	%		2030
Türkiye	Share of renewables in primary energy consumption	23.7	23.7	%		2035
Türkiye	Share of EVs in cars sales	100	100	%		2040
Ukraine	Share of renewables in power production	25	25	%		2030
Ukraine	Share of coal in power production	0	0	%		2035
Ukraine	Methane emissions reduction	-30	-30	%	2020	2030
Ukraine	Share of renewables in final energy consumption	27	27	%		2030
Ukraine	Share of renewables and electricity in transport	50	50	%		2035
Viet Nam	Share of renewables in primary energy consumption	15	20	%	2020	2030
Viet Nam	Share of renewables in primary energy consumption	25	30	%	2020	2045
Viet Nam	Wind power capacity	27.88	27.88	GW	2025	2030
Viet Nam	Wind power capacity	130	169	GW	2025	2050
Viet Nam	Solar power capacity	12.8	12.8	GW	2025	2030
Viet Nam	Solar power capacity	168.6	189.3	GW	2025	2050
Viet Nam	Biofuels share in transport	13	13	%		2030
Viet Nam	Biofuels share in transport	25	25	%		2050
Viet Nam	Methane from waste emissions reduction	-30	-30	%	2020	2030
Viet Nam	Share of EVs in cars sales	50	50	%		2030
Viet Nam	Nuclear power capacity	10.5	14	GW	2025	2050
South Africa	Share of renewables in power production	33.8	39.7	%		2030
South Africa	Nuclear power capacity	1.86	1.86	GW	2010	2030
South Africa	Renewables power capacity	17	45	GW		2030
South Africa	Coal power capacity	33.3	33.3	GW		2030
South Africa	Coal power capacity	27.27	27.27	GW		2035
South Africa	Coal power capacity	2.77	2.77	GW		2050

Bunkers	Maritime operational efficiency (tCO2/tkm)	-2.625	-2.625	%	2029	2030
Bunkers	Maritime CO2 emission per energy	-30	-43	%	2008	2035

Source: JRC analysis.

Table 10: Coal and nuclear phase-out policies (additional Reference policies)

Country	Tech	Year
Austria	Coal	2025
Belgium	Coal	2017
Canada	Coal	2033
Chile	Coal	2045
Denmark	Coal	2030
Finland	Coal	2029
France	Coal	2022
Germany	Nuclear	2025
Germany	Coal	2038
Greece	Coal	2028
Ireland	Coal	2025
Italy	Coal	2025
Netherlands	Coal	2029
Portugal	Coal	2030
Sweden	Coal	2022
Ukraine	Coal	2035
United Kingdom	Coal	2025

Source: JRC analysis.

Table 11: NDC and LTS policies, large emitters

Country	Target Indicator	Value Min	Value Max	Unit	Base Year	Target Year
Argentina	GHG emissions (excl LULUCF)	-21	-21	%	2007	2030
Argentina	GHG emissions (incl LULUCF)	-100	-100	%	2022	2050

Australia	GHG emissions (incl LULUCF)	-43	-43	%	2005	2030
Australia	GHG emissions (incl LULUCF)	-62	-70	%	2005	2035
Australia	GHG emissions (incl LULUCF)	-100	-100	%	2005	2050
Brazil	GHG emissions (incl LULUCF)	-50	-50	%	2005	2030
Brazil	GHG emissions (incl LULUCF)	-59	-65	%	2005	2035
Brazil	GHG emissions (incl LULUCF)	-100	-100	%	2005	2050
Canada	GHG emissions (incl LULUCF)	-40	-45	%	2005	2030
Canada	GHG emissions (incl LULUCF)	-45	-50	%	2005	2035
Canada	GHG emissions (incl LULUCF)	-100	-100	%	2005	2050
Switzerland	GHG emissions (incl LULUCF)	-50	-50	%	1990	2030
Switzerland	GHG emissions (incl LULUCF)	-65	-65	%	1990	2035
Switzerland	GHG emissions (incl LULUCF)	-100	-100	%	1990	2050
Chile	GHG emissions (excl LULUCF)	88	95	MtCO$_2$e		2030
Chile	GHG emissions (excl LULUCF)	90	90	MtCO$_2$e		2035
Chile	GHG emissions (incl LULUCF)	-100	-100	%	2005	2050
China	GHG emissions intensity (tCO2/GDP)	-65	-65	%	2005	2030
China	CO2 emissions peak					<2030
China	GHG emissions below peak	-7	-10	%	Peak year	2035
China	CO2 emissions	-100	-100	%	2021	2060
Egypt	GHG emissions (excl LULUCF)	69	75	%	2010	2030
EU	GHG emissions (incl LULUCF)	-66.25	-72.5	%	1990	2035

EU	GHG emissions (incl LULUCF)	-90	-90	%	1990	2040
EU	GHG emissions (incl LULUCF)	-100	-100	%	1990	2050
United Kingdom	GHG emissions (incl LULUCF)	-68	-68	%	1990	2030
United Kingdom	GHG emissions (incl LULUCF)	-78	-78	%	2005	2035
United Kingdom	GHG emissions (incl LULUCF)	-100	-100	%	1990	2050
Indonesia	GHG emissions (incl LULUCF)	-32	-43	%	BAU	2030
Indonesia	GHG emissions (excl LULUCF)	56	74	%	2019	2030
Indonesia	GHG emissions (incl LULUCF)	10	30	%	2019	2035
Indonesia	GHG emissions (excl LULUCF)	54	84	%	2019	2035
Indonesia	GHG emissions (incl LULUCF)	-100	-100	%	2005	2060
India	GHG emissions intensity (CO2e/GDP)	-45	-45	%	2005	2030
India	GHG emissions	-100	-100	%	2022	2070
Iran	GHG emissions (incl LULUCF)	4	4	%	BAU	2030
Iceland	GHG emissions (incl LULUCF)	-55	-55	%	1990	2030
Iceland	GHG emissions (incl LULUCF)	-100	-100	%	1990	2040
Japan	GHG emissions (incl LULUCF)	-46	-46	%	2013	2030
Japan	GHG emissions (incl LULUCF)	-60	-60	%	2013	2035
Japan	GHG emissions (incl LULUCF)	-73	-73	%	2013	2040
Japan	GHG emissions (incl LULUCF)	-100	-100	%	2013	2050
South Korea	GHG emissions (incl LULUCF)	-40	-40	%	2018	2030
South Korea	GHG emissions (incl LULUCF)	-53	-61	%	2018	2035

South Korea	GHG emissions (incl LULUCF)	-100	-100	%	2018	2050
Mexico	GHG emissions (incl LULUCF)	-18	-18	%	2013	2030
Mexico	GHG emissions (incl LULUCF)	-25	-39	%	2013	2035
Mexico	GHG emissions (incl LULUCF)	-100	-100	%	2013	2050
Malaysia	GHG emissions intensity	-15	-30	MtCO$_2$e	Peak year	2035
Malaysia	GHG emissions (incl LULUCF)	-100	-100	%	2023	2050
Norway	GHG emissions (incl LULUCF)	-55	-55	%	1990	2030
Norway	GHG emissions (incl LULUCF)	-60	-67	%	2005	2035
Norway	GHG emissions (incl LULUCF)	-95	-95	%	1990	2050
New Zealand	GHG emissions (incl LULUCF)	-50	-50	%	2005	2030
New Zealand	GHG emissions (incl LULUCF)	-51	-55	%	2005	2035
New Zealand	GHG emissions (incl LULUCF)	-100	-100	%	2005	2050
Russia	GHG emissions (incl LULUCF)	-30	-30	%	1990	2030
Russia	GHG emissions (incl LULUCF)	-80	-80	%	1990	2050
Russia	GHG emissions (incl LULUCF)	-100	-100	%	1990	2060
Saudi Arabia	GHG emissions (incl LULUCF)	-278	-278	MtCO$_2$e	BAU	2030
Saudi Arabia	GHG emissions (incl LULUCF)	-7	-7	%	2015	2030
Saudi Arabia	GHG emissions (incl LULUCF)	-335	-335	MtCO$_2$e	BAU	2040
Saudi Arabia	GHG emissions (incl LULUCF)	2	2	%	2015	2040
Saudi Arabia	GHG emissions (incl LULUCF)	-100	-100	%	2015	2060
Thailand	GHG emissions (incl LULUCF)	-47	-47	%	2019	2030

Thailand	GHG emissions (incl LULUCF)	-100	-100	%	2005	2065
Türkiye	GHG emissions (incl LULUCF)	693	693	MtCO$_2$e		2030
Türkiye	GHG emissions (incl LULUCF)	643	643	MtCO$_2$e		2035
Türkiye	GHG emissions (incl LULUCF)	0	0	MtCO$_2$e	2005	2053
Ukraine	GHG emissions (incl LULUCF)	-65	-65	%	1990	2030
Ukraine	GHG emissions (incl LULUCF)	-65	-65	%	1990	2035
Ukraine	GHG emissions (incl LULUCF)	-100	-100	%	1990	2050
Viet Nam	GHG emissions (incl LULUCF)	-15.8	-43.5	%	BAU	2030
Viet Nam	GHG emissions (incl LULUCF)	-100	-100	%	2010	2050
South Africa	GHG emissions (incl LULUCF)	350	420	MtCO$_2$e		2030
South Africa	CO2 emissions (incl. LULUCF)	320	380	MtCO$_2$e		2035
South Africa	CO2 emissions (incl. LULUCF)	0	0	MtCO$_2$e		2050
International Maritime	GHG emissions	-20	-30	%	2008	2030
International Maritime	GHG emissions	-70	-80	%	2008	2040
International Maritime	GHG emissions	-95	-100	%	2008	2040

Source: JRC analysis.

Table 12: NDC policies, rest of the world

Region	Based on most recent NDC of	Value	Base Year	Target Year
Mediterranean Middle East	Israel, Jordan, Lebanon	-2%	2010	2030
Morocco & Tunisia	Morocco	6%	2010	2030
Algeria & Libya	Algeria	-30%	2010	2030
Rest Central America	Cuba, Dominican Republic, Honduras, Nicaragua, Panama	61%	2010	2030
Rest Balkans	Serbia	-13%	2010	2030
Rest of Commonwealth of Independent States	Kazakhstan, Turkmenistan	-3%	2010	2030
Rest of Persian Gulf	Iraq, United Arab Emirates	4%	2010	2030
Rest Pacific	Papua-New Guinea, Solomon Islands	93%	2010	2030
Rest Sub-Saharan Africa	Angola, Chad, Mozambique, Nigeria, Sudan, Tanzania	7%	2010	2030
Rest South America	Colombia, Ecuador, Venezuela	9%	2010	2030
Rest South Asia	Pakistan	119%	2010	2030
Rest South East Asia	Myanmar, Philippines	87%	2010	2030

Source: JRC analysis.

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