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Global Energy and Climate Outlook 2020: A New Normal Beyond Covid-19

Estimating the effects of the pandemic on the energy system, with a focus on the transport sector

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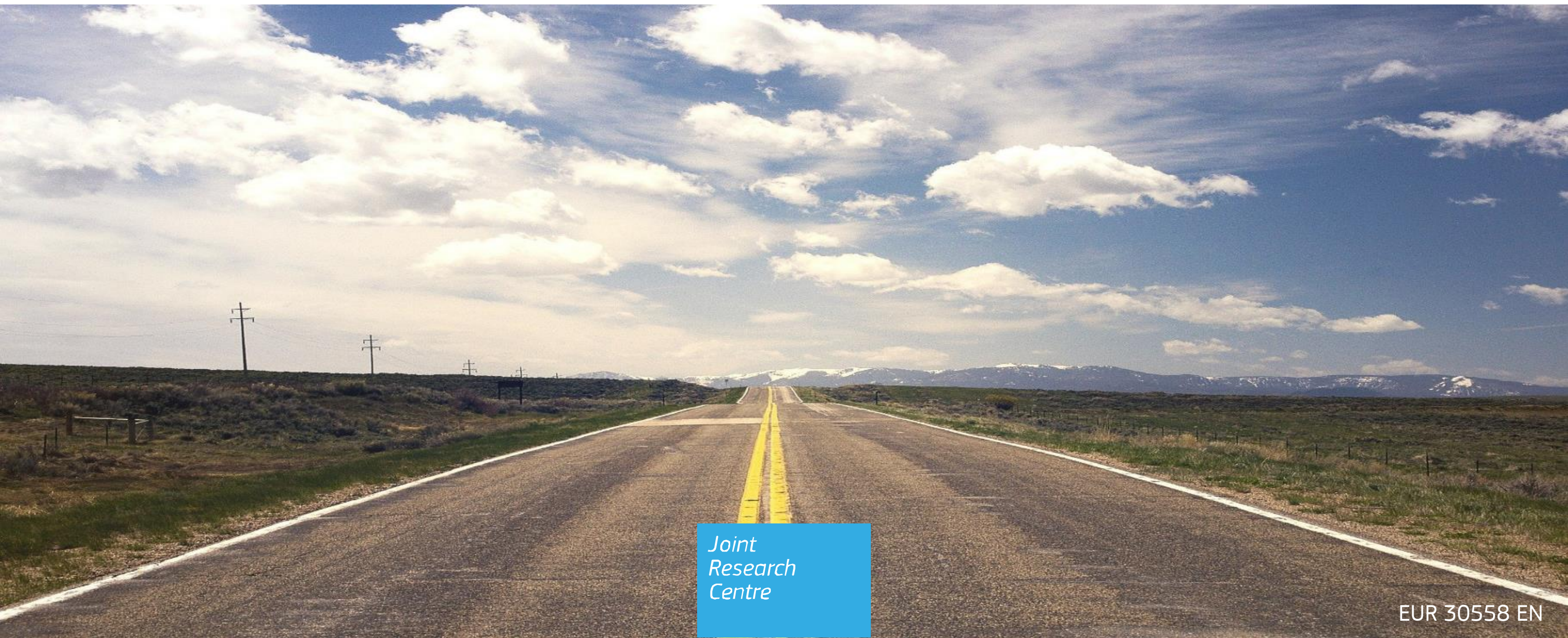

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Contents

Abstract

This edition of the Global Energy and Climate Outlook (GECO 2020) puts its focus on analysing the impact of the Covid-19 outbreak on the transport sector as a whole. The transport sector has suffered the greatest slump in mobility demand of the history during the lockdown period, while the oil price has plummeted. This report explores the impacts of transport activity trends that may persist in the future from the structural changes induced by the Covid-19 pandemic, as well as of policy initiatives that may be adopted as enabling measures for low-carbon transport. While greenhouse gas emissions in this "New Normal" differ significantly compared to previous projections, the emissions gap towards a 2°C pathway is closed only by some 29%, thereby stressing the need of more ambitious collective action to maintaining global temperature change to well below 2°C.

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Executive summary

This edition of the Global Energy and Climate Outlook (GECO) focuses on the effects of the Covid-19 pandemic on the global energy system and on the transport system in particular. We analyse several global pathways taking into account the immediate effects of the pandemic and projected changes brought about by a set of behaviour changes and policy measures focused on low-carbon recovery, and compare them to pathways compatible with the Paris Agreement targets of keeping global mean temperature change by the end of the century to well below 2°C. Focus is put on 2030 more particularly and projections by transport mode are examined, including international maritime and aviation bunkers. An important issue analysed is how some behavioural changes, reinforced by or induced by the Covid-19 global pandemic, could result in lasting structural changes in energy consumption patterns which could reinforce climate change mitigation policies and measures

Policy context

The 2015 UNFCCC Paris Agreement has set the goal to limit global warming to well below 2°C or 1.5°C above pre-industrial levels. The European Union submitted its long-term low greenhouse gas emission development strategy to the UNFCCC in March 2020, with the objective of achieving a climate-neutral EU by 2050, in line with the objectives of the Paris Agreement[1]. Nationally Determined Contributions (NDCs) and long-term strategies from other countries are expected to be submitted in 2020-2021 and be assessed in the 26th Conference of Parties in November 2021, which was initially planned in December 2020 but was postponed due to the Covid-19 pandemic.

The EU's current 2030 Climate & Energy framework targets a reduction in greenhouse gas emissions of at least 40% compared to 1990 levels. Political discussion to approve a new EU target is ongoing at this report's time of writing. As part of the European Green Deal[2] the commission proposed in September 2020 to raise the 2030 GHG emission reduction target (of at least 55% compare to 1990 levels). More recently, in December 2020, the European Union environment ministers agreed with the Commission proposal to the 55% target for 2030 as part of the Climate Target Plan, in order to set the EU on a responsible path to becoming climate neutral by 2050.

The international transport sectors, maritime and aviation, do not enter national jurisdiction and are represented in the UNFCCC conferences by two specialized agencies of the UN, the IMO and ICAO, which have announced a GHG emissions reduction strategy and aspirational goals of growth with carbon offsets, respectively.

Key conclusions

The Covid-19 pandemic accelerates certain underlying trends in investment patterns, behaviour change, technological adoption and policy action that push the global energy system into a "New Normal" compared to a Baseline situation without Covid-19. We project global GHG emissions to be significantly revised downwards compared to the Baseline (between 2 and 9% less emissions in 2030). These trends could be enough to break from the trend of growing global GHG emissions and be able to stabilise emission levels, but are still far from being sufficient to put the world on a trajectory compatible with 2°C or 1.5°C.

The "New Normal" scenario presented here is only one potential pathway of future development among several that are also possible. Greater (or smaller) divergence from the Baseline scenario could also occur. Despite the large uncertainty, the sense of the trends induced on energy demand and carbon emissions seems qualitatively robust.

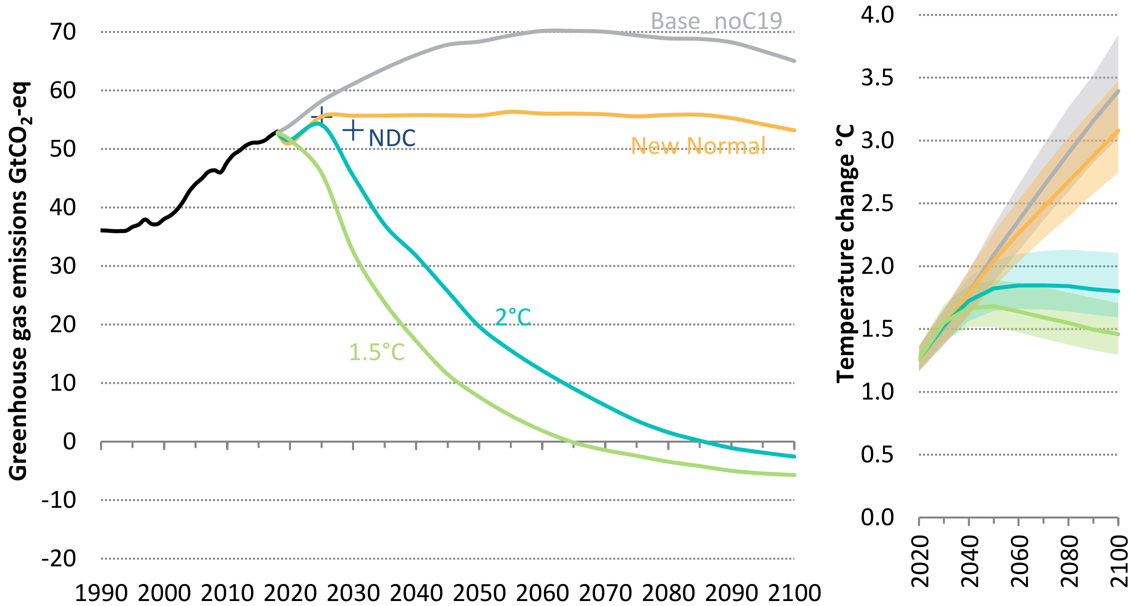
Main findings

The "New Normal" scenario differs from the Baseline scenario in three groups of modelled parameters: first of all, macroeconomic parameters (notably, global GDP is 6.3% below Baseline in 2030); then, transport and mobility changes (TC), mainly reflecting trends accelerated by the pandemic such as faster digitalization (teleworking, videoconferencing), and behaviour changes (shift to soft mobility, shared mobility) and shortening of supply chains; and new policies that could be reinforced post-pandemic (notably, supporting the adoption of electro-mobility and a moratorium on new inefficient coal power plant construction).

1 https://data.consilium.europa.eu/doc/document/ST-6612-2020-INIT/en/pdf
2 https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

The "New Normal" projects significant changes in transport activity for all modes: compared to Baseline, 2030 passenger activity in road transport and aviation are 11% and 21% lower, respectively; freight transport activity in maritime is 8% lower.

Figure 1: Global GHG emissions and global mean temperature increase



Note: Base_noC19 is a hypothetical projection without the inclusion of Covid-19 effects. New Normal is but one possible pathway of future post-Covid development, it differs from the Base_noC19 scenario in three groups of modelled parameters: macroeconomic parameters; transport changes; and new policies. The 2°C and 1.5°C scenarios were designed with a probability not to exceed their temperature change at the end of the century of 66% and 50%, respectively. NDC is the NDC scenario from GECO 2019.

The New Normal scenario narrows the emissions gap from Baseline to 2°C by about 35% in 2030, close to the global emissions reductions expected in an NDC scenario (50% of the gap). Despite the considerable shift in emissions compared to the Baseline, the New Normal scenario is still far from reaching the emissions mitigation required to limit temperature change to 2°C or 1.5°C.

In road transport, the market for electric vehicles is projected to experience a sustained strong growth over the next decade, of about 65% per year over 2020-2030. Electric vehicles (plug-in hybrids and full battery electric) are projected to reach 34% market share in the sales of light duty vehicles in 2030 and 16% in the fleet (some 3% and 1% for heavy duty vehicles, respectively).

In aviation and maritime, technological solutions such as electric aircraft, liquid synthetic fuels and hydrogen are expected to make an impact only beyond 2030; by 2030, revised activity projections and energy efficiency measures are the main drivers behind New Normal emissions projections.

Related and future JRC work

This report is the sixth edition of the Global Energy and Climate Outlook (GECO). It contributes to the JRC work in the context of the UNFCCC policy process and IPCC assessment reports. This release offers a global view of the energy system taking into account the Covid-19 pandemic.

Quick guide

The report uses quantitative energy-economy modelling to build several scenarios, a no-Covid (Base_noC19) and a post-Covid (New Normal) scenario and two scenarios aiming to limit global warming to 2°C and 1.5°C. Section 2 presents these scenarios and their assumptions in detail. Section 3 provides an overview of the global energy system and GHG emissions. Section 4 focuses on transport with an in-depth analysis of energy and GHG projections by transport mode – road, aviation and maritime. Section 5 informs about investments corresponding to the change observed in these scenarios. Finally, Section 6 provides details on the macroeconomic setup of the New Normal scenario.

1. Introduction

This year's Global Energy and Climate Outlook focuses on the question of how the Covid-19 pandemic could affect global energy demand and the related GHG emissions, and of how this might impact the efforts for the transition towards a low-carbon economy in the coming decades.

During the year 2020, the Covid-19 pandemic has unleashed unprecedented and unexpected social changes and has induced economic shocks leading, in some cases, to double-digit reductions in economic activity. Understandably, this has triggered massive disruptions in the energy sector, and while the forecast and timelines from the main international institutions vary, experts agree on two things: Covid-19 is here to stay (Scudellari, 2020), and the future is unknown. The duration and severity of the pandemic are among the major uncertainties, but so are the decisions that governments and individuals will make to avert the post-pandemic economic crisis while keeping in sight action to mitigate climate change. In this regard, 2020 represents a disruption of the world as we know it – and of the projections for the future.

The pandemic has caused a drop in total energy demand of about 5% (IEA, 2020), unique in recent energy statistics. Accordingly, energy-related CO_2 emissions are expected to drop between 4% and 9% during 2020 agreeing to different estimations[3]. But according to the WMO[4] there has been no reduction on CO_2 concentrations. On the contrary, CO_2 concentration in the atmosphere continue to rise despite the emission reduction during the pandemic. The significant (but temporary) drop in global emissions is projected to prevent only around 0.01°C of warming in 2100 (UNEP DTU Partnership, 2020) (Foster, Foster, & Evans, 2020). Practically, this decline is due to GDP contraction rather than structural changes.

Covid-19 has hit every economic sector in significant ways, with a drastic slowdown of global economic activity and a reduction of transport activity due to lockdown measures. During the pandemic, public health policies to slow down the spread of Covid-19 and individual behaviour change to limit people's exposure to the virus are the two main drivers that have reduced economic activity worldwide. According to near–real–time activity data, the largest and more persistent decrease in emissions in 2020 came from the transport sector (Liu, et al., 2020). Activity levels for passenger aviation in 2020 fell by about 40%, and oil products use for cars fell by 8% (IEA, 2020). Although some of the changes should be temporary, some might have long-lasting effects beyond the worst period of the pandemic, and have an impact on energy demand in the longer term. In certain countries, sectors such as transport might not exceed activity or energy demand levels seen pre-pandemic.

While the year-on-year change of GHG emissions has not been observed before in modern times, it is similar in scale to what is necessary to reach the 1.5°C target – but sustained over decades and voluntarily achieved. As it stands, a 5% relative reduction for global energy-related emissions seems to be small when compared to the magnitude and severity of the disturbance of human activity that Covid-19 has produced (Liu, et al., 2020). This has revealed the extent of the challenge countries are facing to deal with climate change: to achieve mitigation but without stalling the economic activities.

Consequently, the Covid-19 pandemic could be an opportunity. This on-going crisis can provide governments, the private sector and individuals the opportunity to tackle the challenges of climate changes by means of bolstering existing environmental plans, greening the economic recovery and accelerating investments in clean energy and energy efficiency. Indeed, according to the latest report on renewables from the IEA, despite the drawbacks, the fundamentals of renewable energy expansion have not changed. Solar PV and on-shore wind are the cheapest electricity generation plants in most countries today (IEA, 2020a).

Henceforth, this 2020 Outlook will analyse different scenarios where the transformation of the transport sector by behaviour change, technological adoption and policies focused on low-carbon recovery will play a central role.

[3] Estimates of CO_2-energy decrease in 2020 versus 2019: 7% (IEA, 2020); 8.8% (Liu, et al., 2020); between 4% and 7% (Le Quéré, et al., 2020); 8.6% (Enerdata, 2020).

[4] https://public.wmo.int/en/media/press-release/carbon-dioxide-levels-continue-record-levels-despite-covid-19-lockdown

Box 1: Differences with GECO 2019

Certain technology costs were updated (in particular, electrolysis costs for hydrogen production, costs of engine options in maritime and aviation), modelling in transport was updated (in particular, separation of intra- and extra-EU aviation, electric aircraft in aviation). The GECO 2019 Reference scenario has been re-run with this newer model configuration to provide a No-Covid comparison point (referred to as Base_noC19 in this report).

The scenarios in this report were developed to 2100; however, we bring a closer focus on 2020 and the immediate years following it.

2. Scenarios definition

The pandemic has opened different energy futures based on its economic impact, but also on the policy response and new behavioural changes. As mentioned, the transport sector has entailed the biggest contribution to 2020 emissions reductions (Liu, et al., 2020), which gives rise to the study of several possible post-Covid-19 scenarios. They can be associated to the consequences and responses to the crisis by the governments and individuals which are mainly based on (i) a global restructuration on mobility patterns, and (ii) the implementation of new policies on transport committed to green stimulus.

This outlook examines 3 main scenarios, (**Table 1**): (i) a "**Baseline**" scenario Base_noC19 where the Covid-19 pandemic never happened; (ii) a **New Normal** scenario where key macroeconomic parameters were updated to include the immediate effect of the Covid-19 pandemic, while also adopting certain structural changes in transport (TC) following the pandemic and implementing public policies in particular focused on accelerating the low-carbon transition in transport (iii) **2°C and 1.5°C** scenarios departing from the New Normal with added climate policies aiming to respect the Paris Agreement, at maintaining global mean temperature change below 2°C by 2100.

Adopted energy and climate policies in world countries until June 2019 are included in the Baseline and New Normal scenarios; these were removed in the 2°C and 1.5°C scenarios, subjecting all economies to a single carbon price. These differences in policy implementation help explain some deviations across results in the short-medium term (2021-2030 results). A full list of the policies considered can be found in Annex 4.

Table 1: Scenarios definition

Scenario	Adopted country policies as of June 2019	Projections without Covid-19	Adapted macro-economic parameter due to Covid-19	Transport structural changes adopted following Covid-19	Focused policies to accelerate low-carbon transition	Economy-wide carbon price
1. Base_noC19	x	X				
1a. **Base_C19** Covid-19 effect	x		x			
1b. **Base_C19+TC** Covid-19 effect +Transport changes	x		x	x		
2. **New Normal** Covid-19 effect + Transport changes + Low-carbon policies	x		x	x	x	
3. **2°C**			x	x	x	x
4. 1.5°C			x	x	x	x

The main scenarios were complemented by additional scenarios to identify the drivers of change between a world and the New Normal:

- The comparison of scenarios 1-1a shows the impact of reduced macroeconomic activity due to the Covid-19 pandemic on the evolution of the energy system and global GHG emissions.
- The comparison of scenarios 1a-1b shows the impact of transport behavioural changes (TC) induced by or accelerated by Covid-19 and may persist in the future
- The comparison of scenarios 1b-2 shows the impact of additional policies fostering low-carbon transport
- The comparison of scenarios 2-3 shows how the contribution of these additional policies in reaching climate targets, and the importance of putting the green transition at the heart of post-pandemic recovery plans.

Sources for the socio-economic assumptions and fossil fuel prices are presented in **Annex 7.**

2.1. Base_noC19

The Base_noC19 scenario is a hypothetical continuation of the 2019 world without a coronavirus impact. It is the continuation of a pre-pandemic scenario where countries pursue their currently existing (as of June 2019) policies for GHG emissions, renewables deployment and energy efficiency and do not strengthen their climate and energy policy ambitions over time (the objectives put forward in countries' NDCs are not considered, unless objectives are translated into law and accompanied by concrete action plans; see **Annex 4** for list of policies considered). Emissions are driven by income growth, endogenously calculated energy prices and technological development; market forces will favour greater efficiencies and greater learning for low-carbon technologies. This scenario, in particular, does not consider stated policies that have not been translated into law and accompanied by concrete action plans, nor does it consider the objectives put forward in countries' NDCs; it does not attempt the deep structural decarbonisation process needed for a 2°C emissions trajectory.

This scenario is very close to GECO 2019 Reference (see **Box 1** on differences with last year's GECO in the introduction).

2.2. New Normal

The current pandemic context increases uncertainty on several important drivers, such as the shape of the economic recovery; the relationship between economic activity and the demand for passenger and goods transport services. At the time of writing it is not known to what extent changes observed in 2020 will be conserved in the future, imposed or voluntarily adopted, as well as the extent to which public policy will channel investment toward more low-carbon solutions in the coming years. Therefore it is important to underline that projections are inherently uncertain and that it is even more so the case this year.

The "New Normal" scenario presented in this report is but one possible pathway of future development among several that are also possible. In this scenario the pandemic has permanently reduced passenger transport demand. Some changes occurring during the pandemic have become permanent (see section 2.2.2) and some policies have been implemented, promoting alternative transport modes (see section 2.2.3). Greater (or smaller) divergence from the *Base_noC19* scenario could also occur.

The "New Normal" scenario differs from the *Base_noC19* scenario in three groups of modelled parameters: macroeconomic parameters; transport changes; and new policies with a focus on accelerating the low-carbon transition. The pandemic permanently reduces passenger transport demand and the Covid-19 experience operates as a catalyst for switching to other transport modes.

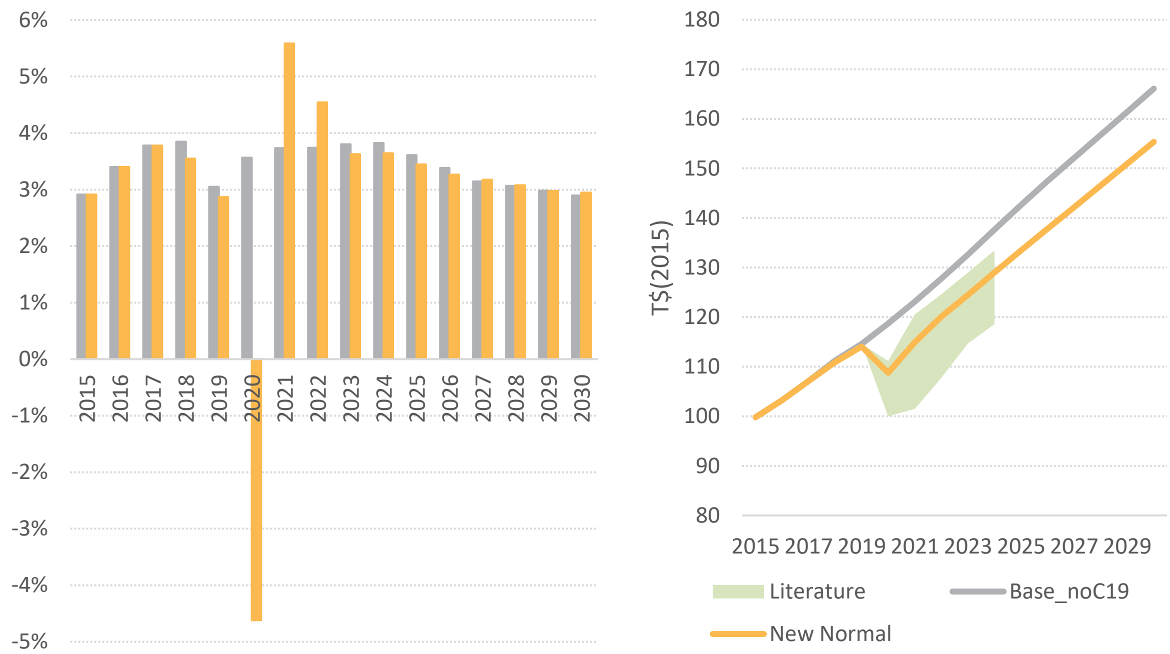
In effect, the *Base_C19* scenario describes a world with a return to pre-Covid consumption patterns and behaviours following a period of disturbance and under-investment, however with a permanent loss in GDP and a decelerated decrease in the emissions intensity of the global economy. The *Base_C19+TC* introduces certain structural and behavioural changes in transport, in addition. Finally, the *New Normal* scenario also includes certain theoretical policies to steer the recovery towards a greener path, resulting in a decrease of the emissions intensity of the global economy even faster than in the *Base_noC19* scenario.

2.2.1. Adapted macroeconomic parameters induced by Covid-19

No matter how, the "new normal" will be unavoidably tied with the size of the economy. There are already in literature some projections on whether the economy will recover and how fast this recovery will be, considering many future economic trajectories (OECD, IMF, Forbes, and Bloomberg). Those projections can imply substantially more economic uncertainty than most energy and emissions modelling efforts have typically assumed, with important implications for scenarios results. Of course, as long as emitting sources remain a high share of energy uses, the size of the economy will drive CO_2 emissions.

The "New Normal" scenario corresponds to projections with adapted macroeconomic parameters for 2020 and a phased recovery in the two years following, resulting from the Covid-19 pandemic see **Figure 2**.

Figure 2: Global GDP growth (left) and volume (right)



Source: Used for GECO 2020 WB, IMF (2020-2024), OECD (2027+) with an interpolation for the 2024-2027 period. The Shaded area, not used in the model, includes other projections from the IEA State Policy scenario and the Delay Recovery scenario (IEA, 2020), and also the OECD World double hit and single hit scenarios (OECD, June 2020).

GDP growth figures were taken from EU and IMF projections (see **Annex 7** for details). These assumptions lead to a global economy that permanently operates at a lower level compared to the pre-Covid situation, despite growth rates are returning to levels. Global GDP in 2030 is 6.3% lower than in Base_noC19 projections.

The revised GDP has an effect on all sectoral drivers, this effect is introduced in *Base_C19*. However, beside transport, there was no finer calibration of drivers and energy consumption patterns in other sectors (residential, commercial, industry); changes such as the effect of teleworking on residential and commercial energy consumption patterns was not addressed. Transport and mobility changes are added to *Base_C19* in *Base_C19+TC*.

Short-term assumptions for **transport-related activities** were given particular care, given that during 2020 they were proportionally more impacted than economic activity in other sectors. Passenger and freight activities have been mainly assessed using estimations in 2020, as well as a hypothetic recovery to 2022. GDP assumptions for the 2020-2022 period are taken from IMF, and a calculated elasticity is used for each sector for 2020. Concerning passenger transportation, elasticities are determined for road (energy consumption provided by Enerdata) and air (traffic provided by ICAO); public transport activity is obtained by a transit-private ratio (Apple mobility data). An elasticity of 1 to GDP is employed to determine road, rail and air freight activity. Maritime transport is endogenously computed in the model.

Beyond 2022, these activities are projected with the default modelling configuration, typically linking per capita income growth to each activity (see POLES documentation, (Després, Keramidas, Schmitz, Kitous, & Schade, 2018)). More details on the methodology used are provided in **Annex 2**.

For **other energy demand sectors** (industry, residential, commercial and agriculture), projections of energy demand were obtained with the default modelling configuration, typically linking GDP growth to sector value added growth and per capita income growth to energy services demand.

To reflect the reduced propensity to invest in the purchase of new equipment due to the decelerated economic activity, the **rate of renewal of the stock** of energy-consuming equipment was decreased, across all sectors.

2.2.2. Transport changes induced and accelerated by Covid-19

Before Covid-19, passenger transport was responsible for around 40% of final oil products demand and 15% of global energy related carbon emissions (IEA, 2020c). Hence any crisis-induced changes to the way we travel will have significant global implications, if changes to transport behaviour persist after lockdowns are lifted.

The restrictions put in place during Covid-19 have had a wide impact on people's and goods' mobility patterns. The ground transportation sector accounted for the largest contribution to the global decrease in emissions during 2020 (Liu, et al., 2020). However, lockdown strategies are not meant to be permanent. Therefore, a key question is whether changes in transport behaviour during the crisis may result in a permanent change in behaviour, or if transport patterns will revert to 'business as usual' when the crisis ends. Research has shown that disruptions can be a catalyst for shifts towards more sustainable transport behaviours (Williams, Chatterton, & Parkhurst, 2012), but avoiding a return to pre-crisis behaviours requires governments to take decisive actions (IEA, 2020c).

The parameters included here (The pandemic has also impacted freight activities: trucking, rail, maritime and air cargo has experienced disruptions and slowdowns as a result of both border controls for sanitary measures and more limited demand around the world. The parameters for freight transport in the "New Normal" adopt some of the disruption suffered during the pandemic as a structural change for the future of freight instead of being a transitory event. In this context, an overall moderate reduction in demand due to a limited de-globalisation trend can be anticipated. The need for preparedness and flexibility in case of supply chain disruptions can contribute to shortening supply chains, to a more national or regional scope away from today's largest producing centres. This trend would reduce distances for the international trade, which would produce a shift towards more rail and truck as transport means and less maritime and aircraft. A more detailed look at transport changes observed during the pandemic and how they can be interpreted is provided in **Annex 1**

Table 2) propose a "what-if" scenario in which the pandemic permanently reduces passenger transport demand and the Covid-19 experience accelerates the switch to other transport modes. The global passenger transport demand does not return to its pre-crisis levels before several years, if at all, depending on the region considered.

New passenger mobility patterns could become the norm in the future, including teleworking and the wider use of video-conferencing, the shift to soft mobility[5] modes in cities, which could decrease the need for trips with other modes. Other new behavioural changes can result in higher private mobility compared to public modes, such as the fear of infection and interaction with large groups of people.

The pandemic has also impacted freight activities: trucking, rail, maritime and air cargo has experienced disruptions and slowdowns as a result of both border controls for sanitary measures and more limited demand around the world. The parameters for freight transport in the "New Normal" adopt some of the disruption suffered during the pandemic as a structural change for the future of freight instead of being a transitory event. In this context, an overall moderate reduction in demand due to a limited de-globalisation trend can be anticipated. The need for preparedness and flexibility in case of supply chain disruptions can contribute to shortening supply chains, to a more national or regional scope away from today's largest producing centres. This trend would reduce distances for the international trade, which would produce a shift towards more rail and truck as transport means and less maritime and aircraft. A more detailed look at transport changes observed during the pandemic and how they can be interpreted is provided in **Annex 1**

[5] Soft mobility includes any non-motorized transport (human powered mobility), as cycling, walking, roller-skating, etc.

Table 2: Parameters on transport changes

Sector	Type	Value versus no-Covid-19 Baseline	Motivation
Passengers: private cars	Trend for total mileage driven by car	Resulting in a drop versus Baseline of 15% to 22.5% spread over 20 to 30 years starting from 2023 (depending on country income group, with higher effect and fastest implementation for higher income countries; see example in the text following this table) Result of positive and negative trends	Fewer commuting trips (more home office / teleworking) Fewer business trips Shift to soft mobility for short trip distances More use of individuals cars vs public transport
	Trend for mileage driven by car, per vehicle	Resulting in an increase versus Baseline of 5% to 15% spread over 20 to 30 years starting from 2023 (depending on country income group)	Acceleration of shared mobility services
	Saturation level in car ownership ratio	Resulting in a drop versus Baseline of 5% to 15% spread over 20 to 30 years starting from 2023 (depending on country income group)	Values change Acceleration of shared mobility services
	Revenue elasticity of mileage driven by car	-25%	Fewer trips
Passengers: public transport	Trend for mileage driven by public transport	Resulting in a drop versus Baseline of 0% to 15% spread over 20 to 30 years starting from 2023 (depending on country income group)	Fewer trips (same as passenger cars) More use of individuals cars vs public transport
	Trend for mileage driven by rail	Resulting in a drop versus Baseline of 0% to 15% spread over 20 to 30 years starting from 2023 (depending on country income group)	Development of rail Rail covers short distance air trips
	Revenue elasticity of mileage driven by public transport	-15%	Fewer trips (same as passenger cars)
Passengers: aviation	Trend for mileage driven by air	Resulting in a drop versus Baseline of 5% to 15% spread over 20 to 30 years starting from 2023 (depending on country income group)	Less long distance travel (business and leisure) Competition with rail for short distances
	Revenue elasticity of mileage driven by air	-20%	Fewer trips
Freight	Trend for mileage driven by air	Resulting in a drop versus Baseline of 10% spread over 15 to 25 years starting from 2023 (depending on country income group)	More resilient supply chain Shortening of supply chains

	Economic activity elasticity of mileage by air	-35%	
	Economic activity elasticity of mileage by maritime	-30% for all products except energy	

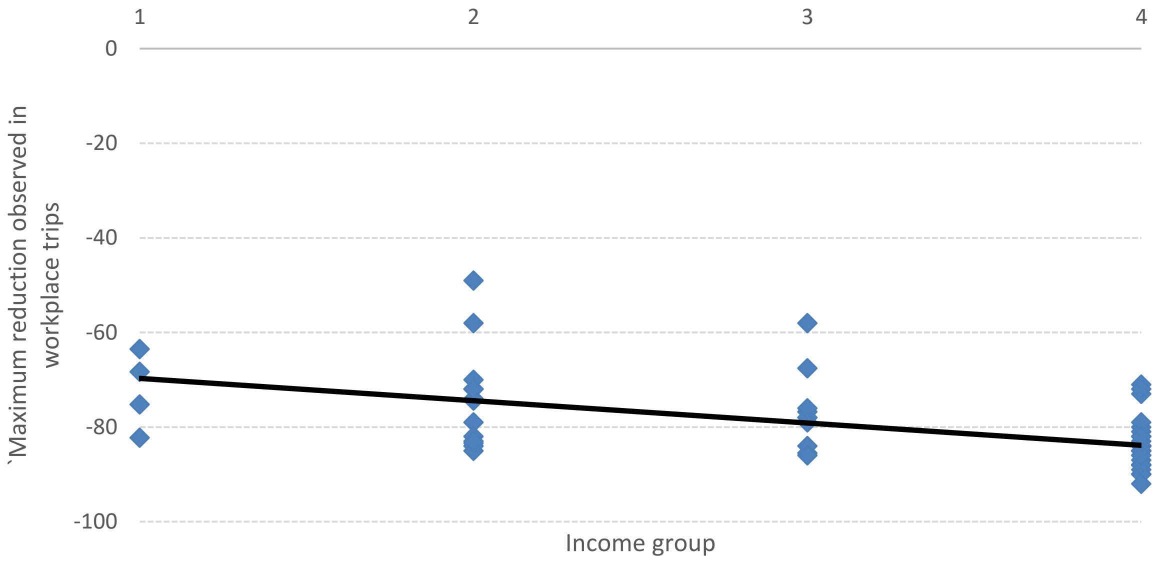
Due to the uncertainty on how the longer-term effects of COVID will play out, the quantification of activity levels in the New Normal scenario are more a result of the narrative itself than from hard scientific evidence. It is the purpose of “what-if” scenarios to explore potential futures in order to highlight the impact of foreseen/desirable changes, be they technological, economic, behavioural, or policy-related. As a general rule, the New Normal scenario presents a vision of the world in which, for many reasons, transport needs are progressively decoupled from economic activity. In quantitative terms, this is achieved using two main levers:

- Defining exogenous decoupling trends, so as to lower the growth of transport activity;
- Weakening the link between macroeconomic indicators (GDP, GDP per capita) and activity levels, through lower elasticities.

The underlying logic to quantify the decoupling dynamics relies on two pillars. First, we assume that changes will be implemented gradually over time in the coming decades, after the two-year crisis of 2020-2021 (defined in section 2.2.1). The Covid-19 crisis is seen as a catalyst to foster changes, a small fraction of which will remain permanent right after it (adopters economic agents), while the bulk will take longer to appear (followers). Second, it is reasonable to assume that countries will have very different potentials to transform their transport system: the structure of economic activity, the existence of transport infrastructure, ease of access to capital to build new infrastructure, structure of the economy and share of the workforce able to telework, etc. are likely to influence the speed and magnitude of the changes to come. Income per capita can be used as a proxy to capture the heterogeneity of responses across regions.

As an *example*, consider the long-term impact of remote working on commuting trips by car. No objective quantification of the phenomenon can be done a priori. However, data gathered during the lockdown period can provide an estimate of how much commuting trips have been reduced, at the country level (Google, 2020). Such estimates are upper bounds, because measures other than teleworking impacted commuting trips during the lockdown (e.g., partial unemployment). **Figure 3** shows these results plotted by income group, from 1 for low GDP per capita, to 4 for high GDP per capita (see **Annex 4** for definition of income groups). As could be expected by the stringency of the lockdown and share of the workforce in services in several higher income countries, the effect is larger for higher income groups.

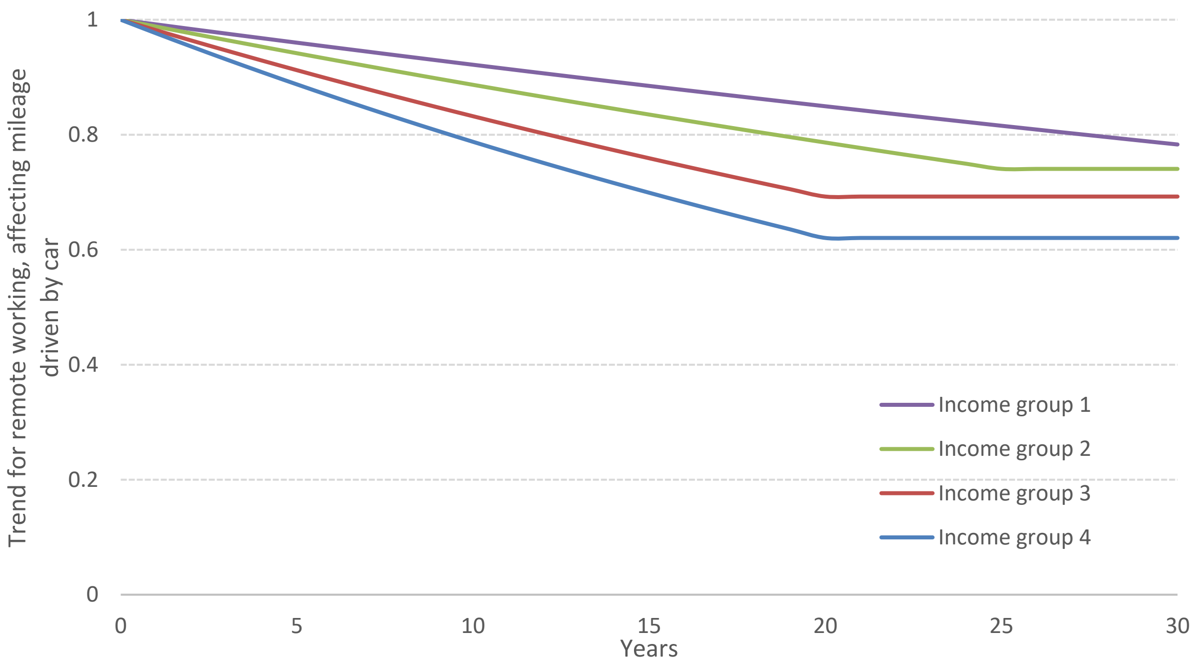
Figure 3: Maximum reductions in workplace trips vs income groups.



Source: based on (Google, 2020)

We assume that only a fraction of the reductions observed during the crisis will become permanent: from 30 to 45% of commuting trips in this case, out of average observed reductions spreading between 72% and 84%. Assuming different speeds of adjustment by income group, we obtain the decoupling trends of **Figure 4**.

Figure 4: Mileage driven by car decoupling trend, by income group



Note: The decoupling trend is applied on the top of immediate (2020) and short-term (2021-2023) pandemic changes (explained in 2.2.1 and Annex 2) Source: own calculations.

In the case of mileage driven by private cars, the above effect is partly counter-balanced by the car-sharing services effect: this effect results in a lower car ownership ratio and a trend that increases mileage driven by each car, which overlaps with the above trend.

To reflect a smooth transition from 2020 levels to a post-pandemic world, it was considered that part of the above effect is adopted from 2022, thereby adjusting the levels of 2022 activity initially calculated in 2.2.1. The rest of the effect is spread over the following years, with a complete diffusion of the effect in 2040-2050 depending on the income group.

2.2.3. Policies focused on a low-carbon recovery

Major economies around the world are facing important decisions affecting vast volumes of investment in order to accelerate their economies' recovery from the recession following the pandemic. Many governments have included into their programs green recovery measures for stimulating economic activity, designed to accelerate the renewal of capital stock while also reduce GHG emissions and fossil fuel energy demand. These decisions could shape the energy sector for decades to come; analysts have discussed that this could be the opportunity to ensure that 2019 was the "definitive peak" for global emissions (IEA, 2020b) if this is translated into actual policy. The recovery packages already announced have not delved in a great level of detail on the extent to which the money would be channelled towards or indexed to green investment.

For the "New Normal" scenario, we propose a number of policies – a mix of stimulus spending and taxation – that could realistically be adopted over the next years. Although these policies do not correspond to specific policies by countries, a number of real policies was used as background to construct this scenario – either by extending them in time or generalizing them to a wider group of countries. The policies evidence base for this scenario is described in **Annex 3**.

These parameters (**Table 3**) present a "what-if" scenario where policy measures are put in place after Covid-19 to reduce directly or indirectly the CO_2 emissions in transport – by lowering power generation emissions and making the transport sector more energy-efficient and lower-carbon. These measures include fiscal instruments like energy taxes for aviation and maritime, market-based instruments such as subsidies, and regulations such as the setting of a long-term objective for the phase-out of fossil fuel consuming equipment.

Table 3: Parameters on low-carbon recovery policies

Sector	Type	Value	Motivation
Power generation	Phase-out of inefficient coal capacities	No new commissioning from 2025 for technologies with more than 1000 gCO2/kWh (correspond to sub-critical coal)	Energy efficiency Provide greener electricity
Energy supply	Subsidies to hydrogen investment cost (electrolysis)	50% of cost for 2021-2025, then cost fully borne by purchaser	Jump-start the hydrogen economy Accelerate the adoption of fuel cells
Road transport	Phase-out of ICE	Zero sales by 2040/50/60, depending on the country. Applies to both LDVs and HDVs; does not apply to plug-in hybrids and CNG vehicles.	Emission reduction in the transport sector
	Subsidies to BEV purchase cost	25% of cost for 2021-2025, then cost fully borne by purchaser	EV sales increase
	Subsidies to BEV recharging points	100% of cost for 2021-2025, then cost fully borne by purchaser	EV sales increase Alleviate the chicken and egg problem for EVs and sufficient charging infrastructure
Aviation	Energy tax	300 $/toe 2030, 500 $/toe 2050	Energy efficiency Emission reduction in the transport sector
	R&D policy to improve energy density of batteries for electricity-powered aircraft	Learning accelerated by 10 years compared to Baseline (corresponds to 800 Wh/kg reached in 2040 instead of 2050); cost of policy not modelled	Emission reduction in the transport sector
Maritime	Energy tax	300 $/toe 2030, 500 $/toe 2050	Energy efficiency Emission reduction in the transport sector

2.3. Paris Agreement climate targets (2°C and 1.5°C scenarios)

The Paris Agreement scenarios assume a global GHG trajectory consistent with a likely chance of meeting the long-term goal of a temperature rise over pre-industrial times below 2°C (resp. well below 2°C, i.e. 1.5°C) by 2100. The 2°C and 1.5°C scenarios were designed with a probability not to exceed their temperature change at the end of the century of 67% and 50%, respectively, and correspond to a carbon budget over 2018-2100 of 870 and 330 Gt CO_2, respectively. The 1.5°C scenario aimed at little overshoot of the 1.5°C target in mid-century (1.8°C with 66% probability in 2050), resulting in ambitious emissions mitigation in the first half of the century and relatively conservative mobilization of negative emissions technologies in the second half of the century[6] .

This trajectory is achieved by the implementation of an economy-wide carbon price, starting from the year 2021. The carbon price increases over time at a decreasing annual rate. For land sectors (agriculture and

[6] Global net-zero GHG emissions are reached in about 2065 and 2055 in the 2°C and 1.5°C scenarios, respectively. Net GHG emissions in 2100 amount to-2 and -6 GtCO2-eq in the 2°C and 1.5°C scenarios, respectively. CO2 budgets over 2018-2100 are 920 Gt and 300 Gt for 2°C and 1.5°C, respectively. Temperature projections are provided in Figure 1

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 a specialized sectoral model[7]. All other sectors of the economy are subject to the same carbon price.

This carbon price is applied on top of the behavioural changes, policies and other parameters included in the New Normal scenario. This allows to evaluate the long term impact of the pandemic on the climate target, compared to similar Paris Agreement scenarios in previous editions of GECO.

In order to reflect different financing capabilities as well as to represent an equitable mitigation effort across nations, the ambition level of climate policies has been differentiated across countries according to their income level per capita. In the 2°C, the carbon price followed the differentiation presented in **Table 12**, with 100% representing a "leading" carbon price that increases over time (see **Annex 4**).

[7] The projections for agriculture and land use metrics in this report were done by soft-linking the specialized model GLOBIOM-G4M (IIASA, 2017) with the energy system model POLES-JRC.

3. Impact of the Covid-19 pandemic on global energy demand and emissions trends

The Covid-19 crisis is projected to have a prolonged aftermath, with activity and emission levels being impacted on the long term compared to projections done in 2019. 2020 represents a major break on many levels. The global downturn and the lockdowns periods are leading to a record-breaking drop in energy consumption, linked mainly to the drop in activity with a major impact on the transport sector.

Covid-19's short-term impacts on global GHG emission are already highly visible **Figure 5** (right). To date, however, it is difficult to forecast the duration of the pandemic and thus of the GHG emissions evolution on time. The consequences of the shock and the scale of the response will depend on how long the emergency will persist, how permanent the changes occurring during the crisis are, and how recovery policies at different sectoral and social levels will be implemented. The duration of the Covid-induced recession will only be obvious in hindsight, but what is fairly certain is that the pandemic will reset the expected growth of socio-economic indicators into a new "Normal", with several indicators projected at a lower level compared to Base_noC19.

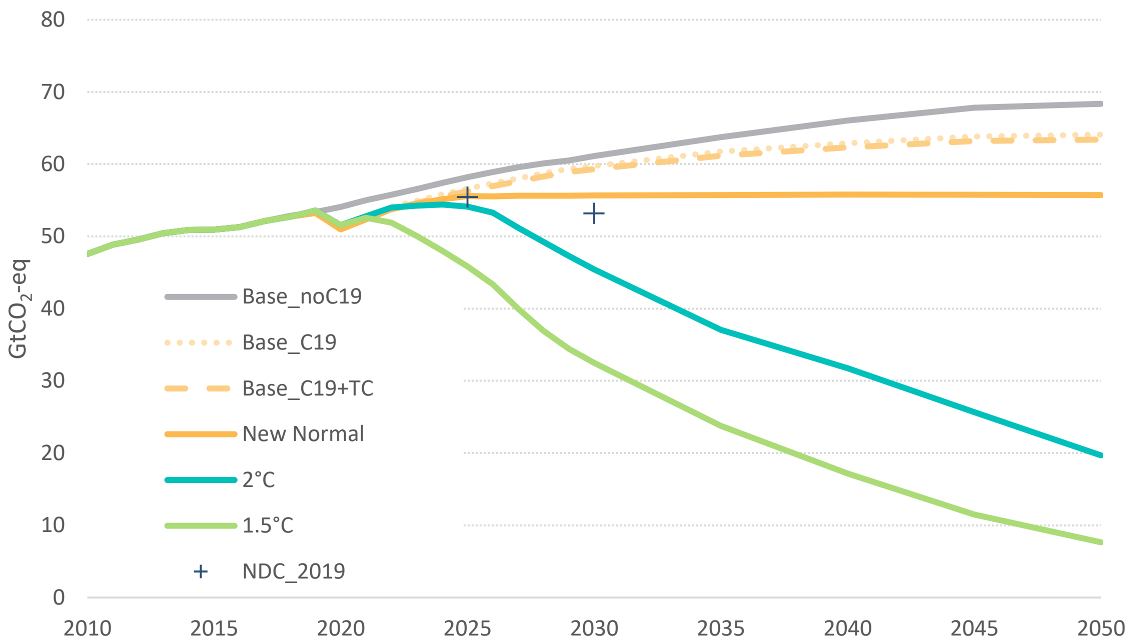
However, "New Normal" scenario will not bring us close to limit climate change to a 2°C scenario, therefore motivate the implementation of new climate policies became even more essential to reach the 2°C target. There is not a return to business as usual after the Covid-19 crisis, if the world is entailing with the Paris agreement commitment to reduce global warming to 2°C by 2100.

Prior to the Covid-19 pandemic, current policy projections of primary energy demand and GHG emissions led to a continued growth for both indicators, from 14.0 Gtoe and 52.8 $GtCO_2$-eq in 2018 reaching 16.7 Gtoe and 61.1 $GtCO_2$-eq in 2030, respectively (Base_noC19); these indicators are reduced to 15.4 Gtoe and 55.7 $GtCO_2$-eq, respectively, with the pandemic and accompanying changes in this report (New Normal).

The impact on global mean temperature change is limited to 0.05 °C in 2050 (New Normal compared to Base_noC19); the post-Covid New Normal scenario is still projected to lead to a temperature increase of approximately 2.1°C and 3.2°C above pre-industrial levels by 2050 and 2100, respectively (with 66% probability)[8] (see also **Figure 1**).

8 According to (Foster, Foster, & Evans, 2020), the direct effect of the pandemic on global mean temperature will be negligible, with a cooling of around 0.01°C by 2030. A strong green stimulus (investments amounting to ~1.2% of global gross domestic product) would be needed to bring the world on a trajectory compatible with the 1.5ºC limit, bringing about a decline of global CO_2 emissions towards net zero in 2050 and saving around 0.2ºC of future warming by 2050.

Figure 5: Global GHG emissions



Source: POLES-JRC

Compared to pre-Covid-19 estimates (Base_noC19), post-Covid scenarios (New Normal, Base_C19 and Base_C19+TC) emissions in 2030 are 2-9% lower depending on the effects taken into account. A more fossil-fuelled based recovery from Covid-19 results in 2030 emissions just 2% lower than Base_noC19 (Base_C19); behavioural and structural changes result in emissions 3% lower (Base_C19+TC); targeted low-carbon recovery measures result in emissions 9% lower (New Normal).

In 2030, the New Normal scenario covers about 35% of the emissions gap from Base_noC19 to 2°C, close to the global emissions reductions expected in an NDC scenario from GECO 2019 (Keramidas, et al., 2020) (which covers 50% of the gap, as defined by the Base_noC19 and 2°C scenarios from GECO 2020).

Despite the considerable shift in emissions compared to the Base_noC19, the New Normal scenario is still far from reaching the emissions mitigation required to maintain temperature change to 2°C or 1.5°C. Global GHG emissions in the New Normal increase only slightly compared to their 2015 level (+9% in 2050); whereas the 2°C and 1.5°C scenarios emissions would decrease by 61% and 85% compared to 2015, respectively.

2°C and to a larger extent 1.5°C emissions diverge from the New Normal immediately with the imposition of the economy-wide carbon price in 2021. In the first years of the implementation of the carbon price, the difference with the emissions of the New Normal is largely due to mitigation taking place in the power sector (switch from coal to gas and renewables).

This would be in line with recent trends: total installed wind and solar PV capacity is on course to surpass natural gas in 2023 and coal in 2024 and renewables are set to overtake coal to become the largest source of electricity generation worldwide in 2025 (IEA, 2020a)

Table 4: Average annual evolution of the global CO_2-energy intensity of the economy

<table>
<tr><th></th><th>2015-2019</th><th>2020</th><th>2021-2025</th><th>2026-2030</th><th>2031-2050</th></tr>
<tr><td>Base_noC19</td><td rowspan="6">-2.3%</td><td>-2.3%</td><td>-2.0%</td><td>-1.9%</td><td>-2.1%</td></tr>
<tr><td>Base_C19</td><td rowspan="5">-2.0%</td><td>-1.5%</td><td>-1.7%</td><td>-2.2%</td></tr>
<tr><td>Base_C19+TC</td><td>-1.6%</td><td>-1.8%</td><td>-2.2%</td></tr>
<tr><td>New Normal</td><td>-2.0%</td><td>-3.2%</td><td>-2.7%</td></tr>
<tr><td>2°C</td><td>-2.3%</td><td>-6.6%</td><td>-6.4%</td></tr>
<tr><td>1.5°C</td><td>-7.5%</td><td>-11.1%</td><td>-10.7%</td></tr>
</table>

Due to the GDP contraction and new consumption patterns that form part of the new scenarios, none of the energy consumption and emissions of the new post-Covid-19 scenarios projected in this report exceed the pre-Covid-19 Base_noC19 scenario levels. In the New Normal scenario, emissions reach their 2019 level only in 2023 and never reach the 2019 peak level again in the 2°C and 1.5°C scenarios.

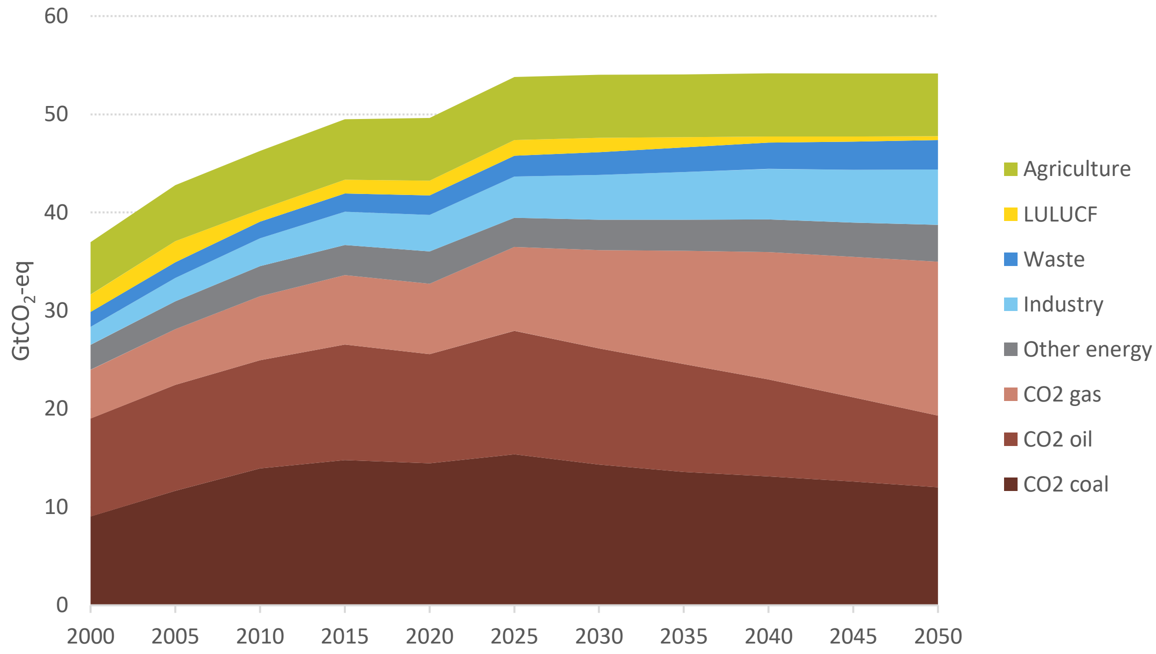
As a first approach, the pandemic appears as a catalyst to accelerate the pace of change to a more clean energy system. However, this is not a given. The pandemic results in a deceleration of the rate of decrease of the emissions intensity of the economy compared to the recent past: this is the case in 2020 in particular and in the subsequent years. This can be explained by a number of factors:

- In the context of low international fuel prices brought about by the pandemic, a certain rebound effect in fossil fuel consumption can be expected. However, this effect is not sufficient for total emissions to exceed pre-Covid-19 projections.
- The decreased economic activity reduces public and private investment in the purchase of newer, more efficient and low-carbon energy-consuming equipment or power production capacities; the renewal of stock is decelerated and the reductions in sectoral emissions intensity that were projected pre-Covid-19 are delayed.

In this new macroeconomic context, it is only with the implementation of focused policies that the emission intensity reduction recovers to its previous high level (New Normal beyond 2022); however, this is still a slower pace than that needed for a higher climate ambition (2°C and 1.5°C), see **Table 4**.

Emissions in the New Normal remain roughly stable beyond 2025 (**Figure 6**), despite a growing economy. This is the aggregate result of many underlying drivers in several sectors of the economy, such as a turn away from coal in the power sector, an increasing penetration of alternatives to oil products in transport.

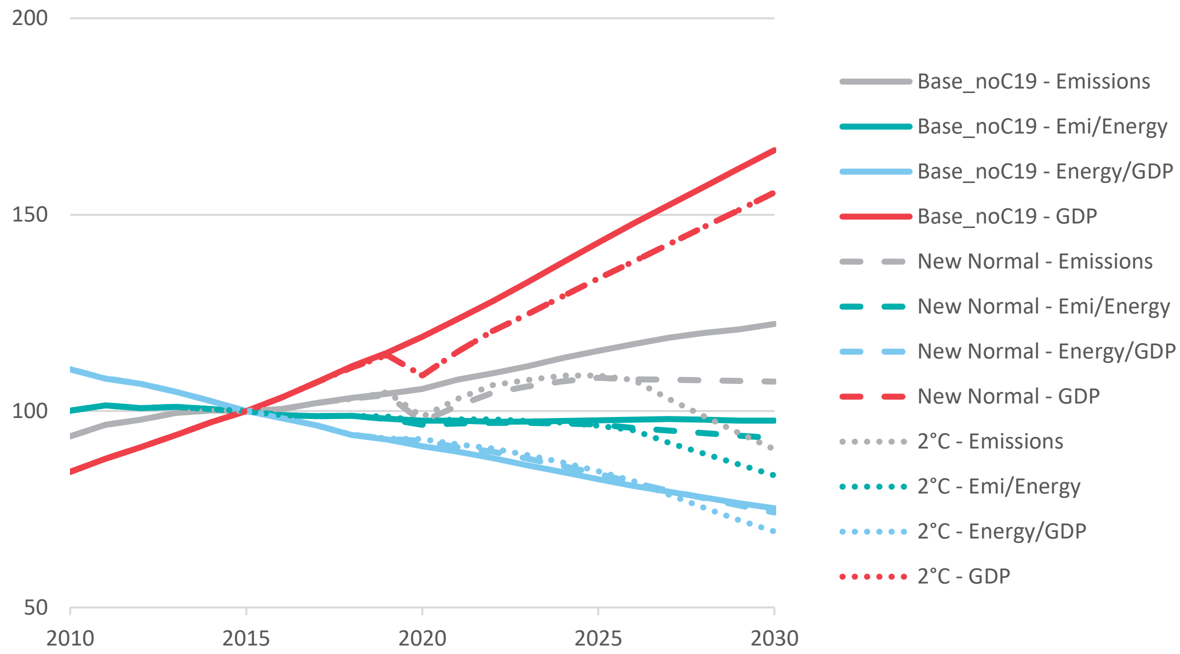
Figure 6: Decomposition of GHG emissions in the New Normal scenario



Source: POLES-JRC

As shown in **Figure 7**, the decrease in emissions to 2030 in New Normal is mainly due to the decrease in economic activity; whereas more intense efforts are pursued in the CO_2 content of energy and in energy efficiency in the 2°C scenario.

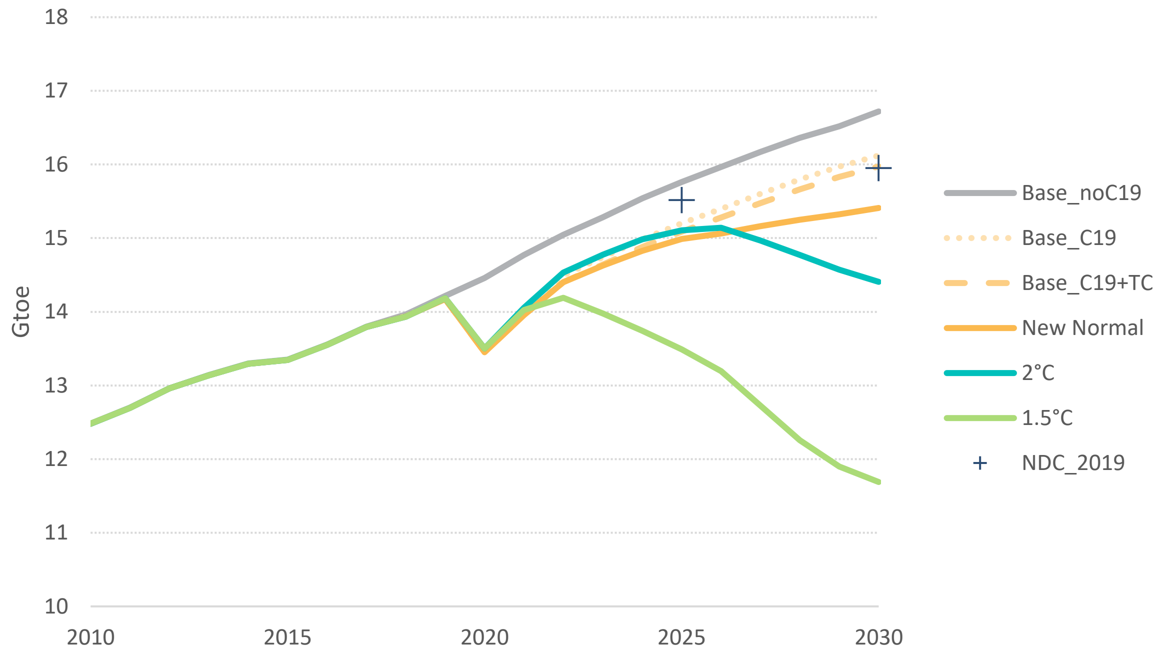
Figure 7: Kaya decomposition of global CO_2-energy emissions, Base_noC19 (solid lines), New Normal (dashes), 2°C (dots), indexed to 2015



Source: POLES-JRC

The effects on the energy system can be seen in **Figure 8**. While the emissions trajectory of the New Normal bring global emissions close to the NDC level, this is achieved with a different path in terms of energy.

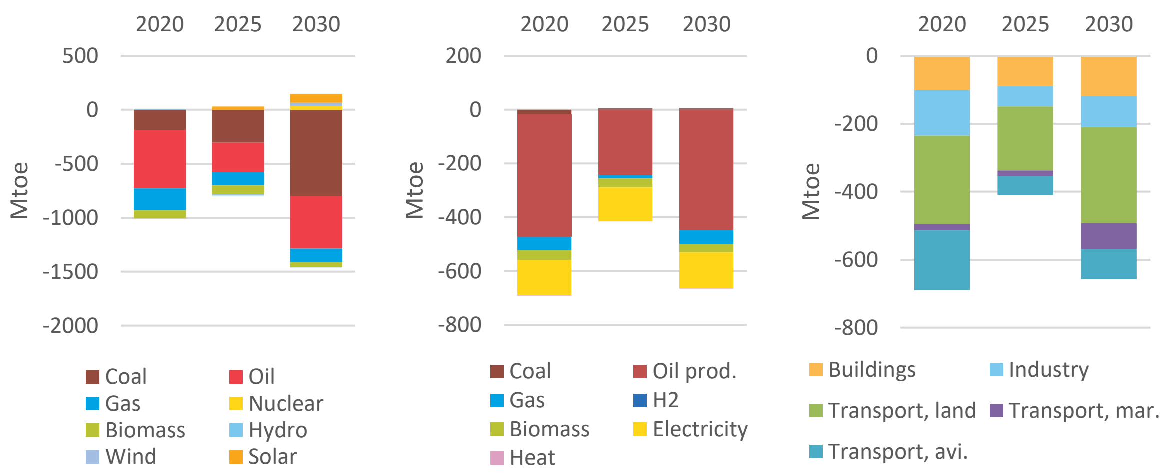
Figure 8: Global total primary energy supply



Source: POLES-JRC

The pandemic inserts changes in the energy system that are felt throughout the 2020s decade (see **Figure 9**). The differences to the pre-Covid-19 Base_noC19 in 2020 are mainly found in oil consumption, in the road transport and aviation sectors and, to a lesser degree, electricity, gas and coal in buildings and industry. These differences are largely maintained throughout the 2020s decade, either decreasing due to economic recovery or increasing due to the effects of new behaviour and consumption patterns and policies aimed at fostering low-carbon growth.

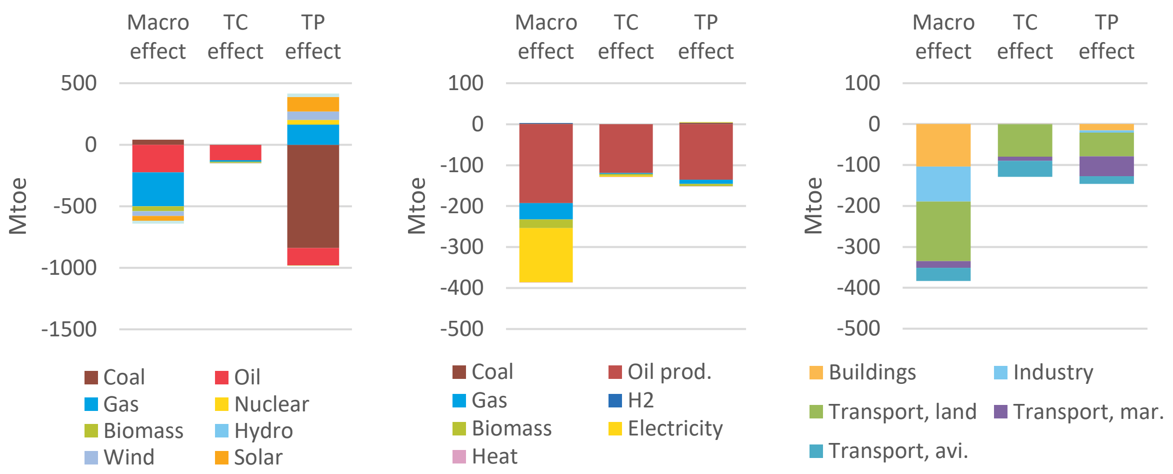
Figure 9: Differences between the Base_noC19 and New Normal scenarios, in TPES by fuel (left), TFEC by fuel (middle) and TFEC by sector (right)



Source: POLES-JRC

Figure 10 shows the differences in energy consumption decomposed by effect in the New Normal scenario. "Macro effect" designate the difference between Base_noC19 and Base_C19 scenarios; "TC effect" designate the difference between Base_C19 and Base_C19+TC; "TP effect" designate the difference between Base_C19+TC and New Normal; the sum of these differences correspond to the comparison of Base_noC19 and New Normal.

Figure 10: Differences between Base_noC19 and New Normal scenarios in 2030 decomposed by type of effect, in TPES by fuel (left), TFEC by fuel (middle) and TFEC by sector (right)



Source: POLES-JRC. Note: The drivers behind each of the effects are explained in section 2.2. The three effects sum into the difference between Base_noC19 and New Normal scenarios.

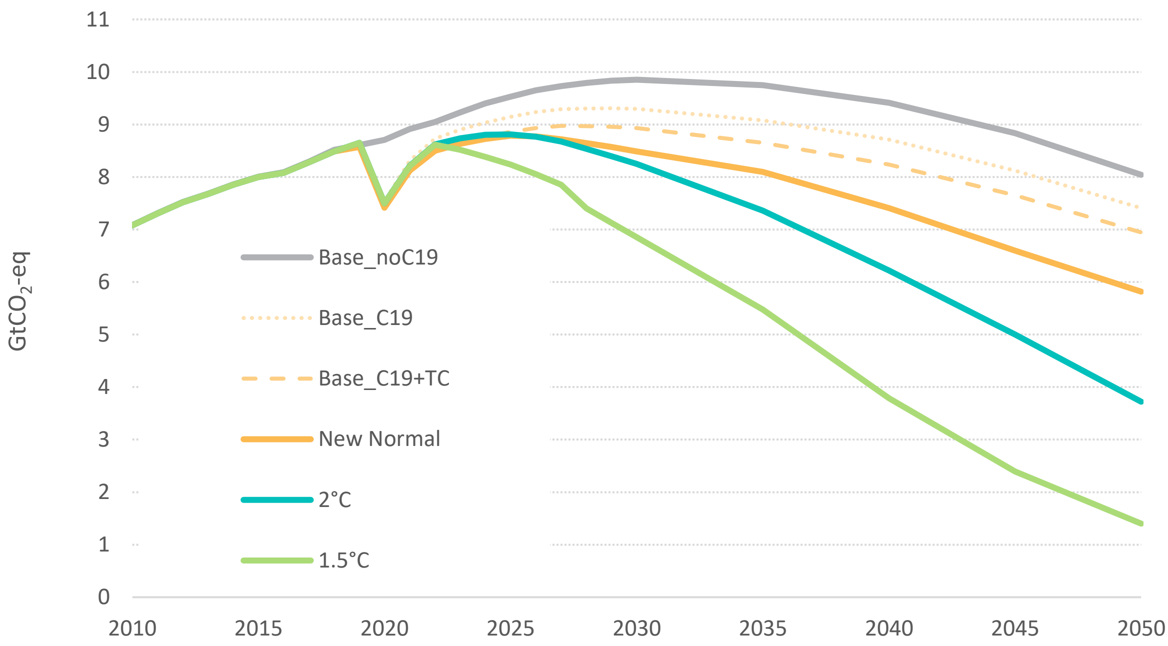
The revised macroeconomic parameters mainly impact oil products consumption in the road transport sector, but also electricity consumption in buildings and industry. The transport changes mainly affect oil products consumption; the effect is equally shared between road transport and aviation. The additional policies have several effects, most notably the decrease in coal consumption in the power sector (and the associated increase in demand for other power sector inputs); the increase in electricity consumption mainly in road transport (however, these amounts are about 1% of the total electricity demand); and the decrease in oil consumption in road transport (electrification) and maritime transport (less coal traded).

4. Focus on transport

As a consequence of the coronavirus outbreak, the measures applied in order to limit the propagation of the disease resulted in an extensive mobility restrictions with pronounced impact on most transport modes (JRC European Commission, 2020). The pandemic have also produces supply chains disruptions across international borders (IFC, 2020). Consequently, this crisis has affected all forms of transport, from passengers to logistics and transportation industry, at national and international level. Global road transport activity was almost 50% below the 2019 average by the end of March 2020 and commercial flight activity almost 75% below 2019 by mid-April 2020 (IEA, 2020c).

The transport sector has been heavily dependent on oil products according to historical data (>85%), the highest dependence on a single fuel across all final demand sectors. The next decades promise to bring significant changes in mobility. Technology changes are at the core of this transition, with electrification or the introduction to new low-carbon fuels. Other factors are also playing an important role as well, mainly related to new regulations and behavioural change – such as gasoline or diesel cars ban regulations, shared mobility, autonomous vehicles. Some of these effects were already taking place before the pandemic – indeed, the no-Covid-19 Baseline is already projecting a peak in total CO_2 emissions of transport in 2030 **Figure 11** – but these effects are projected to accelerate by the large scale impact of the Covid-19 pandemic.

Figure 11: Global CO_2 emissions of transport (including international aviation and maritime)



Source: POLES-JRC

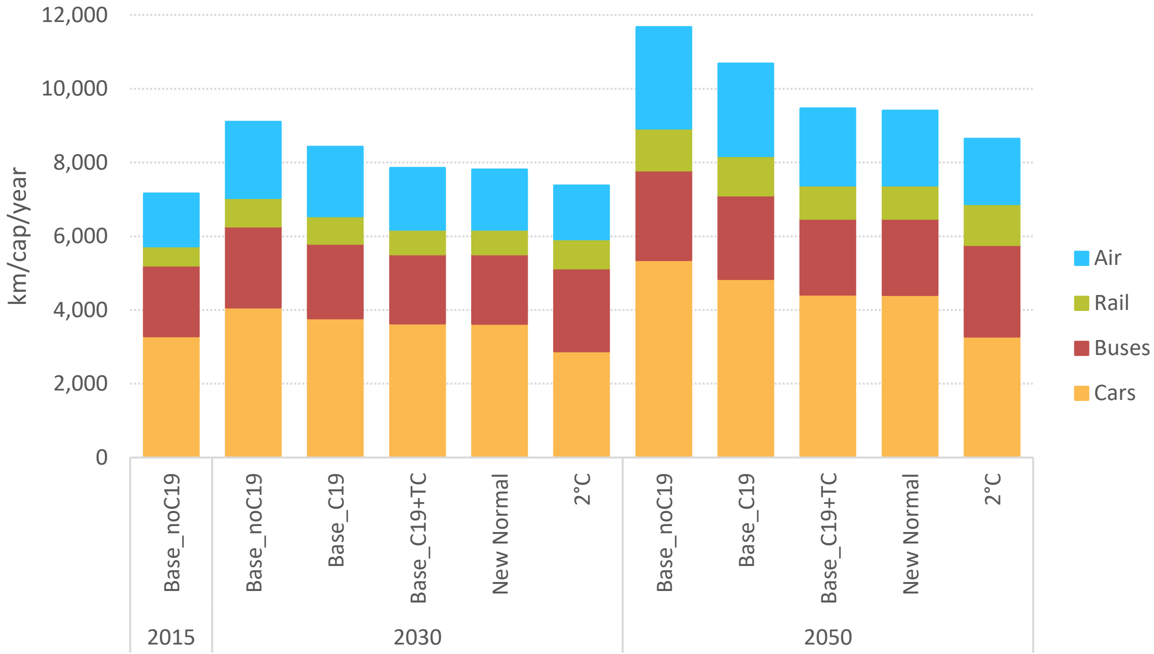
The effects of the Covid-19 pandemic on transport emissions are more pronounced than on total emissions. Emissions in the New Normal scenario are closer to the 2°C level than the Base_noC19 level in 2030. Indeed, thanks to the pandemic, deployment of energy efficient and low-carbon technologies and changes in behaviour, emissions are projected to never exceed their historical high of 2019. In 2030, New Normal emissions for total transport are 14% below those in the no-Covid-19 Baseline, thus covering 80% of the gap from no-Covid-19 Baseline to 2°C.

In the rest of this section, we examine the drivers behind these changes, in transport activity and by mode.

4.1. Activities

Global average passenger mobility per capita by mode of transport is presented in **Figure 12**. In the Base_noC19 scenario, average global mobility is projected to have strong and sustained growth, with private cars and aviation making up the largest contributions to the growth for 2015-2030. In the New Normal scenario, the growth is much less pronounced, with only aviation and, to a lesser degree, rail marking some increase. The stronger climate policies in the 2°C scenario also impact mobility, notably limiting the growth in aviation and modal shift from private to public land-based transport modes.

Figure 12: Global passenger mobility by mode

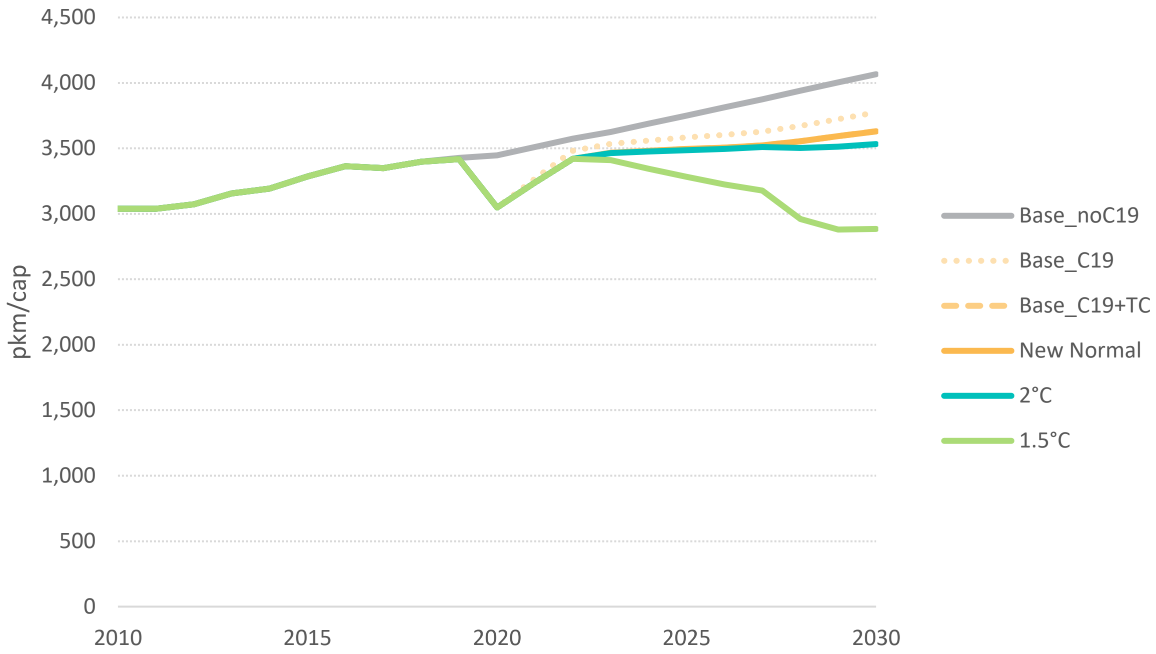


Source: POLES-JRC

Although significantly impacted in the New Normal compared to the Base_noC19, mobility by cars and aviation actually maintain and increase their market share, respectively. Behind global averages, there is great disparity in country-level figures for total mobility – for instance, an estimate of 19,000 km/cap/year for OECD versus 5,000 km/cap/year for non-OECD in 2015 – as well as modal distribution – about two thirds by private car in OECD versus about a third in non-OECD, with a bigger prevalence of public transport modes.

Passenger mobility by mode is detailed in the following figures.

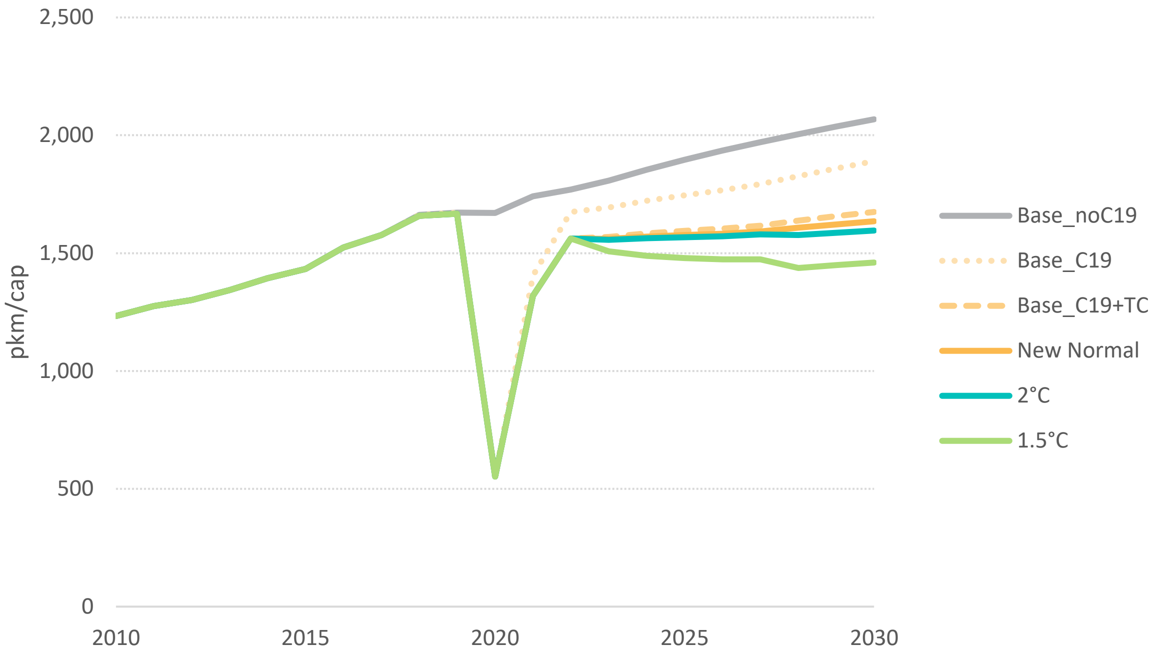
Figure 13: Global passenger mobility in road transport, private cars



Source: POLES-JRC

The pandemic is projected to result in a durable loss of private car mobility beyond the year 2020. We estimate the drop in mobility compared to Base_noC19 to be 11.5% in 2020, with the difference first narrowing as economic activity recovers and then widen with time as behaviour and technological changes set in. This is the result of many trends, notably the digitalization trend that results in less commuting and business trips. New Normal passenger mobility in road transport is projected to be 11% below that of the Base_noC19 in 2030 – very close to that of the 2°C scenario.

Figure 14: Global passenger mobility in aviation



Source: POLES-JRC

Aviation is the transport mode most impacted during the on-going Covid-19 pandemic, with a loss in activity estimated at 67% in 2020. New Normal passenger mobility in aviation would recover to 21% below that of the Base_noC19 in 2030, very close to the levels in the 2°C scenario (23% below Base_noC19).

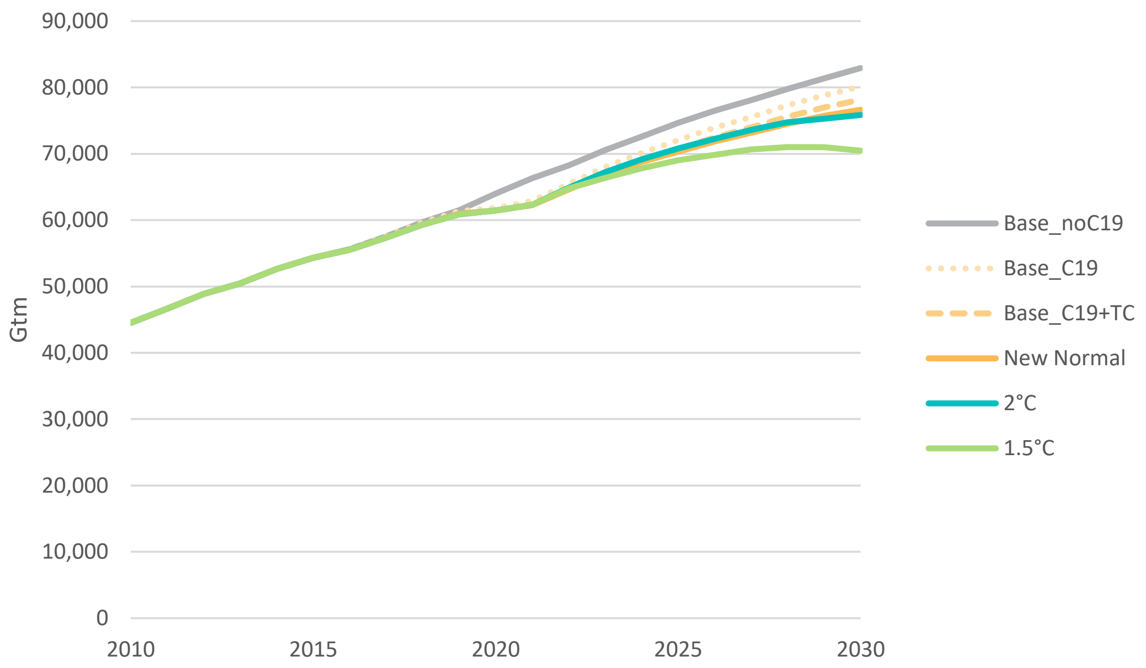
About three quarters of aviation transport activity is covered by passenger mobility, a share that is kept in our projections across all scenarios. Activity is detailed into domestic and international traffic per region; while both are projected to decelerate their annual growth over time even in the Base_noC19 scenario, international traffic is projected to sustain a higher growth than domestic (**Table 5**).

Table 5: Average annual growth of passenger mobility in aviation

	2000-2015	2015-2035	2035-2050
Domestic			
1.5°C	5.9%	1.0%	0.5%
New Normal		1.7%	0.5%
Baseline		2.7%	0.6%
International			
1.5°C	5.3%	1.2%	1.2%
New Normal		1.9%	1.2%
Baseline		3.4%	1.4%

Goods traffic across all modes is impacted by the decelerated economic activity following the pandemic. Traffic in maritime in particular is further impacted by less need for international fossil fuels trade.

Figure 15: Global goods traffic in maritime



Source: POLES-JRC

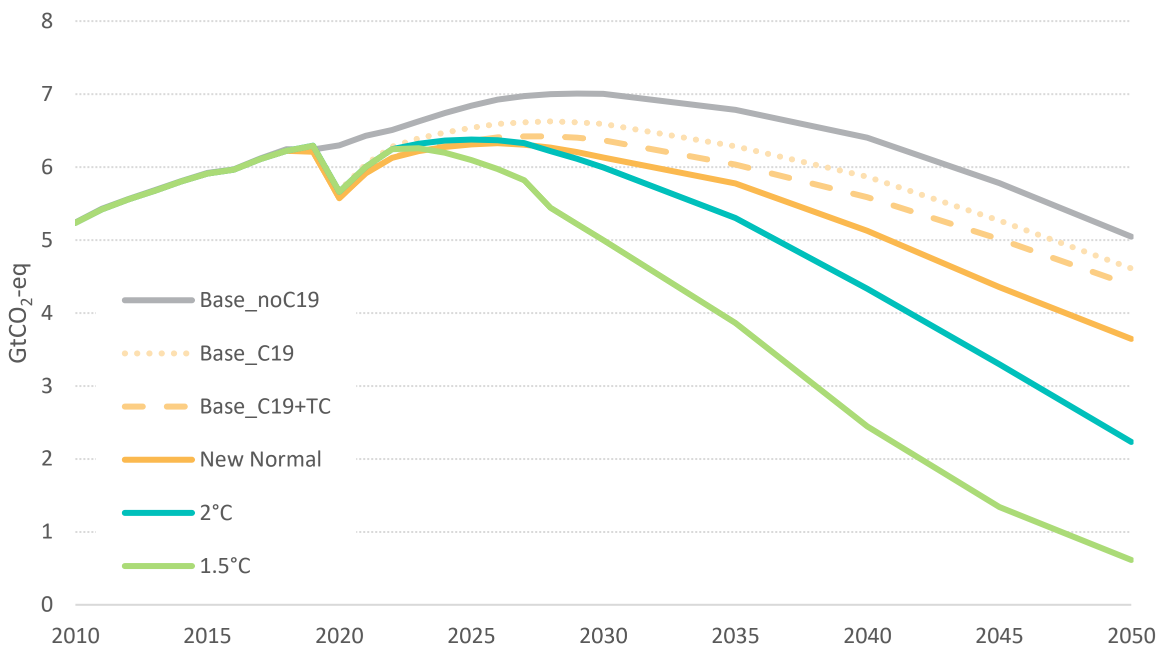
Maritime activity loss in 2020 is close to that of the evolution of world GDP, at 7%. New Normal goods traffic in maritime is 6% below that of the Base_noC19 in 2030. Differences between Base_noC19 and New Normal scenarios come from the decrease in fossil fuels trade (mainly less coal trade from the coal power policies in 2.2.3 and less oil trade from the decelerated economic activity in 2.2.1 and transport changes in 2.2.2). Further decreases can be expected in the 2°C and 1.5°C scenarios due to the further decrease in fossil fuels trade (not counter-balanced by the increase in solid biomass trade); further details are provided in **Figure 27**.

4.2. Road transport emissions and energy trends

In the New Normal, road transport emissions never quite recover to the level reached in 2019 (**Figure 16**). This is the result of a combination of factors, among which some technologies that are reaching maturity and can directly compete with dominant technologies with little policy support in key transport segments, notably electricity-powered vehicles (battery-electric and fuel cell vehicles). Indeed, Base_noC19 emissions already reach a peak and decline in around 2030, largely due to the deployment of battery-electric vehicles; reduced economic activity, behavioural changes in transport patterns and shared mobility anticipate this peak by a few years (Base_C19, Bace_C19+TC); it is only with the additional policies aimed at faster battery-electric and fuel cell vehicles deployment where emissions effectively peak in 2019.

Emissions are temporarily lower than 2°C and 1.5°C in the 2020s, due to the inclusion in the New Normal of certain country-level energy policies such as energy taxes and renewable support policies.

Figure 16: CO_2 emissions of road transport

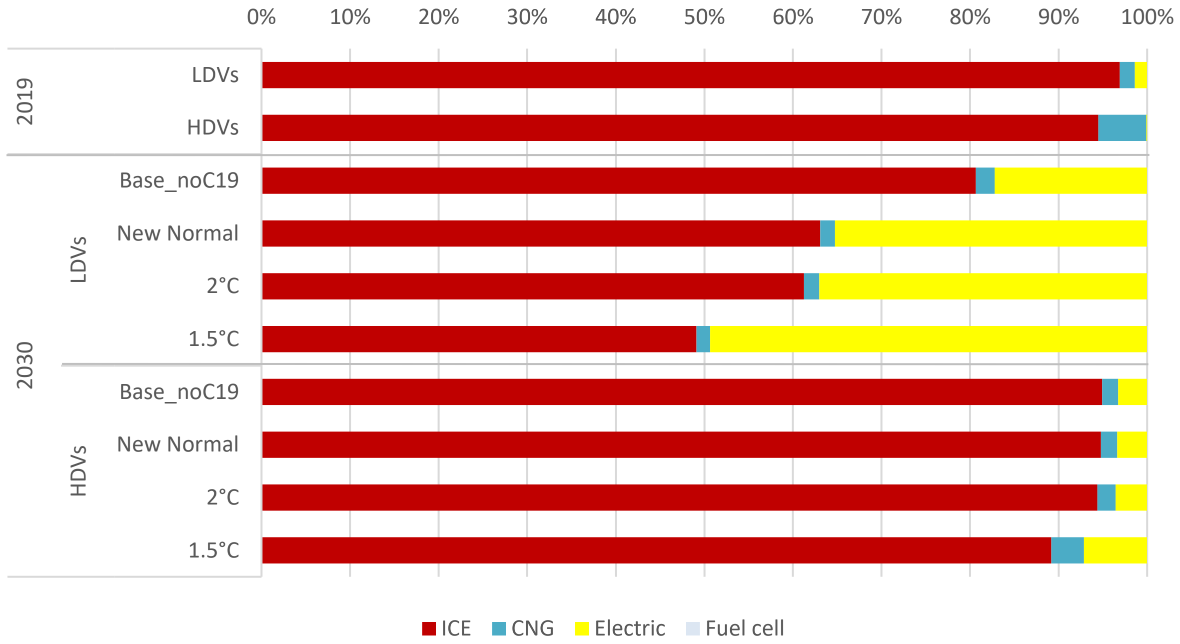


Source: POLES-JRC

Technology factors can play an important role in the future reduction of CO_2 emissions in road transport. These measures will include improving combustion engine technologies (turbocharged downsized engines, direct injection), reducing the need for power (reducing vehicle weight, changing vehicle design to limit drag and enhancing performance) and transitioning to low-carbon energy sources either still using combustion technologies (natural gas, biofuels, e-fuels) or using different engines altogether (full hybridisation, electrification, fuel cells).

The investment increase in EVs recharging stations and the direct subsidies provided to EVs purchase as part of the New Normal scenario result in an acceleration of the adoption of EVs, especially in LDVs (**Figure 17**). Electric vehicles (plug-in hybrids and full battery electric) are projected to reach 35% market share in the sales of light duty vehicles in 2030 (some 3% in heavy duty vehicles sales).

Figure 17: Global market share in new sales of road transport vehicles by technology, 2030

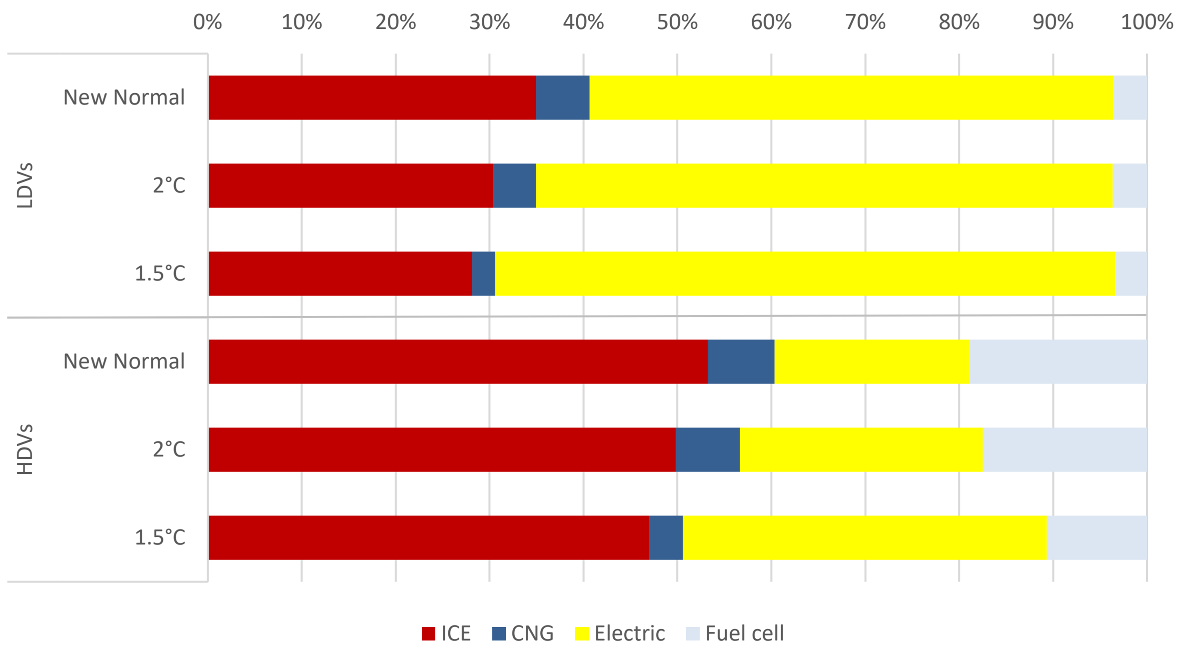


Note: Electric cover plug-in hybrids and full battery electric vehicles. Fuel cell cover hydrogen-fuelled and methane-fuelled fuel cell vehicles. ICE and CNG vehicles can be fuelled by hydrogen-derived e-fuels. Source: POLES-JRC

Figure 18 shows the resulting global stock by technology in 2050. EVs (plug-in hybrids and full battery electric) emerge as the technology "winners" in the segment of LDVs, while the segment of HDVs presents a more diverse picture. In HDVs, while the penetration of alternative electricity-powered technologies (battery-electric and fuel cells) increases with a stronger carbon price compared to fossil-fuelled technologies, the relative competitiveness of options changes: overall, the carbon price impacts the production cost of electricity less than it impacts the production cost of hydrogen, resulting in a lower competitiveness for hydrogen fuel cells.

In addition, for the strong climate policy scenarios and starting from 2030, the deployment of e-fuels as low-carbon – but energy-intensive in their production – alternatives to fossil fuels allows ICE and CNG vehicles to retain a certain market share that would have been even lower otherwise; in 2050, some 31% (resp. 54%) of liquids (resp. methane) in road transport are e-fuels in the 1.5°C scenario. The contribution of e-fuels in the New Normal scenario remains marginal throughout 2050.

Figure 18: Global stock of road transport vehicles by technology, 2050

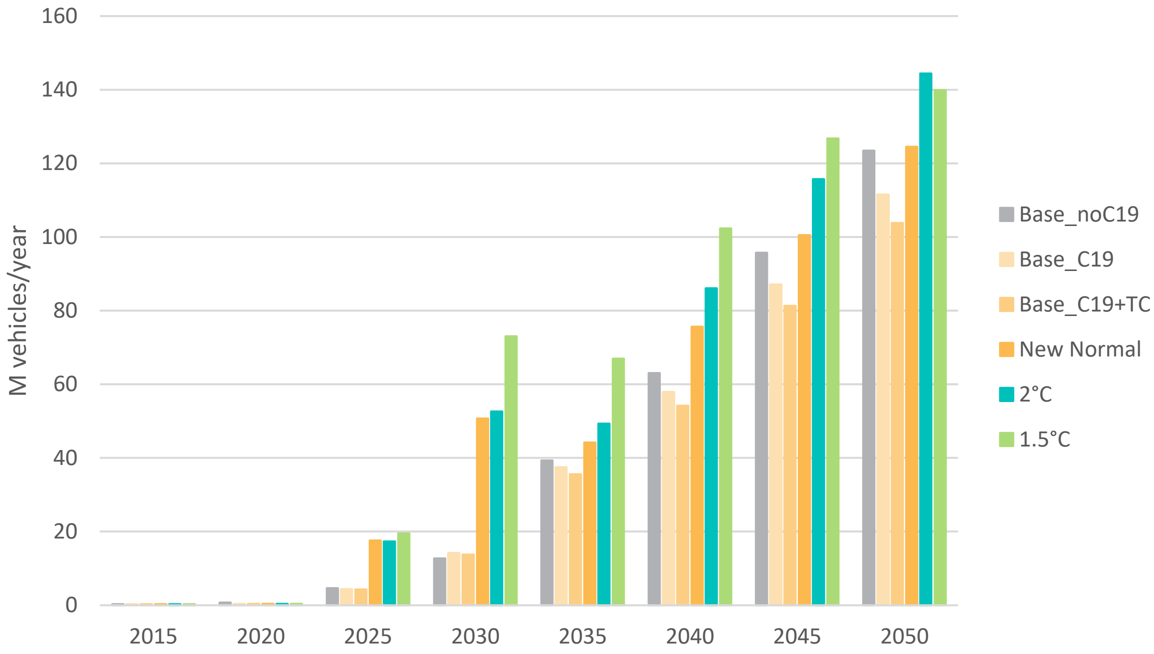


Note: Electric cover plug-in hybrids and full battery electric vehicles. Fuel cell cover hydrogen-fuelled and methane-fuelled fuel cell vehicles. ICE and CNG vehicles can be fuelled by hydrogen-derived e-fuels. Source: POLES-JRC

For countries where the ICE phase-out happens sooner, in OECD for instance (phase-out acted in 2040), stocks for 2050 are significantly different from the global average displayed in **Figure 18**. Concerning light vehicles, the ICE share in the stock decreases to 17% in the New Normal (down to 12% in the 1.5°C scenario) while electric vehicles fill most of the gap (up to 70% share in the New Normal, more than 80% in the 1.5°C). CNG and fuel cell vehicles shares are slightly higher than the global average (less than 2 percentage points more for CNG, less than 3 for fuel cell for the New Normal).

The impact of a sooner ICE phase-out is also substantial for heavy vehicles. In OECD countries, stocks evolve quickly leading to a notable spread compared to the global average. The share of ICE in the stock is around 28 pp lower than the global average in all scenarios in 2050. A combination of the other technologies takes their place in the stock, with variations depending on the country. For instance, electric trucks would play a major role in the 1.5°C scenario for Canada (more than 60% share in the stock); options are more balanced in Australia, where electric and fuel cell vehicles respectively account for 43% and 34% of the stock.

Figure 19: Annual global sales of battery-electric LDVs



Source: POLES-JRC

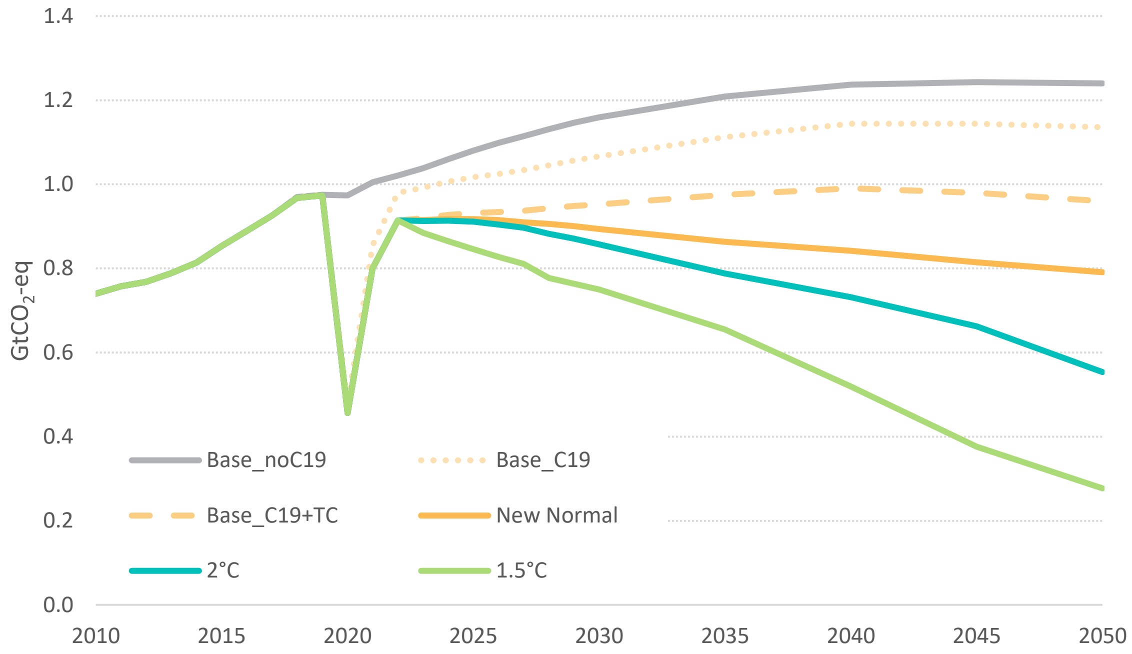
2019 sales of battery-electric vehicles were 1.5 million. 2015-2019 annual market growth was 47%. The market for electric vehicles is projected to experience a sustained strong growth over the next decade. 2020-2030 annual market growth is projected to range from 64% (New Normal) to 68% (1.5°C), considerably stronger than the market growth in the Base_noC19 (33%).

The New Normal scenario results in sales that reach the levels of the 2°C scenario throughout 2040.

4.3. Aviation emissions and energy trends

Aviation has been one of the fastest-growing sectors in terms of emissions in recent years (+3.4%/year over 2010-2018). This growth is projected to be severely influenced by the Covid crisis and its aftermath.

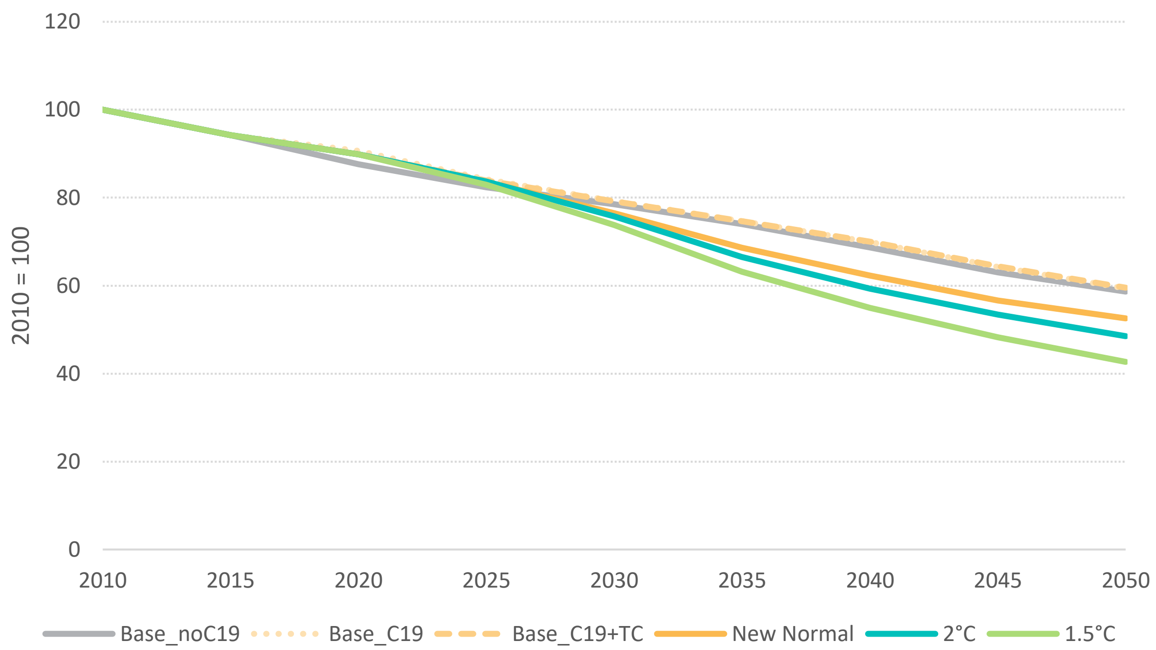
Figure 20: CO_2 emissions of aviation (domestic and international)



Source: POLES-JRC

The transport activity changes and the aviation fuel tax projected in the New Normal scenario result in aviation emissions that do not recover their historical levels (**Figure 20**).

Figure 21: Energy intensity of the global aviation sector

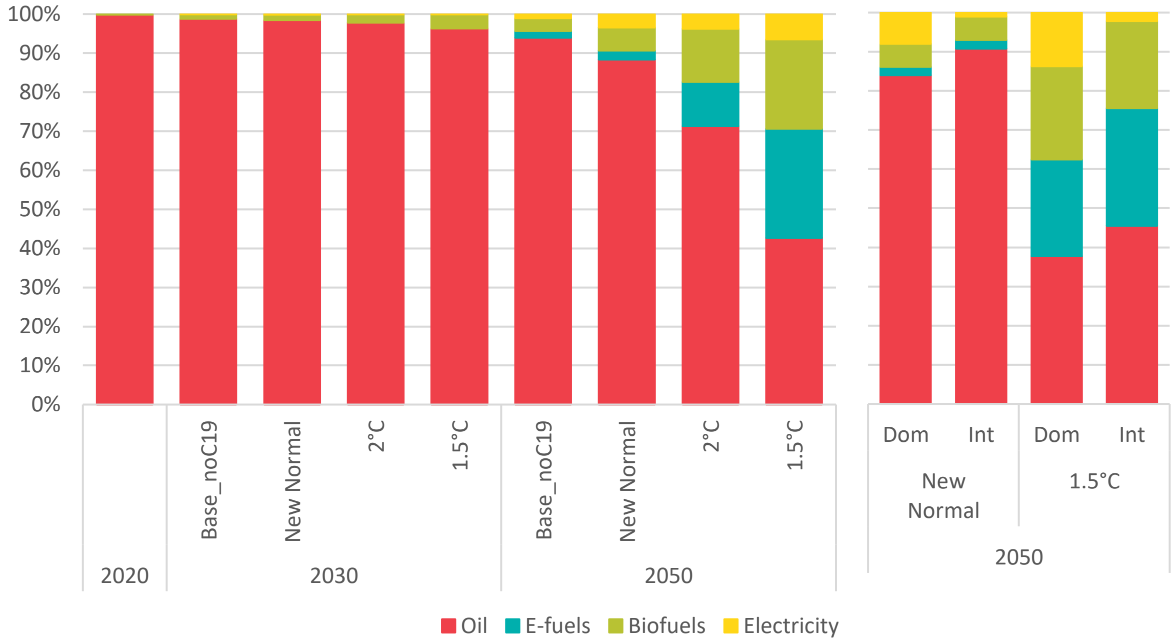


Source: POLES-JRC

Much of the energy efficiency is expected to take place over time due to technology progress and market forces (**Figure 21**). The 2030 fleet is 20% more efficient compared to 2015 in the Base_noC19; the New Normal would push that figure to 25%, a similar level to the 2°C and 1.5°C scenarios (26% and 29%), thanks to the energy efficiency effects of the energy tax applied to aviation fuels. This is achieved with both fuel use efficiency (more efficient engines, re-engining) and non-engine-related efficiency measures (better air traffic management, flight pattern) (Dahlmann, et al., 2016)[9].

The deployment of electric aircraft would make a sensible effect on energy consumption only after 2030. Electric aircraft contribute in the increasing difference in energy efficiency between the Base_noC19 and the New Normal scenarios after 2030. By 2050, electricity would cover 4% of aviation's energy consumption in the New Normal scenario. However, electric-powered aircraft are more suited to short-distance flights due to battery size and weight issues as well as potential altitudes that can be reached. Despite increasing technology learning, electric aircraft are still mostly limited to domestic flights by 2050: in the New Normal, electricity would cover just 1% of international flights' energy demand, but 9% of domestic flights' energy demand.

Figure 22: Global fuel mix in aviation, total (left); and split for domestic and international for 2050 (right)



Source: POLES-JRC

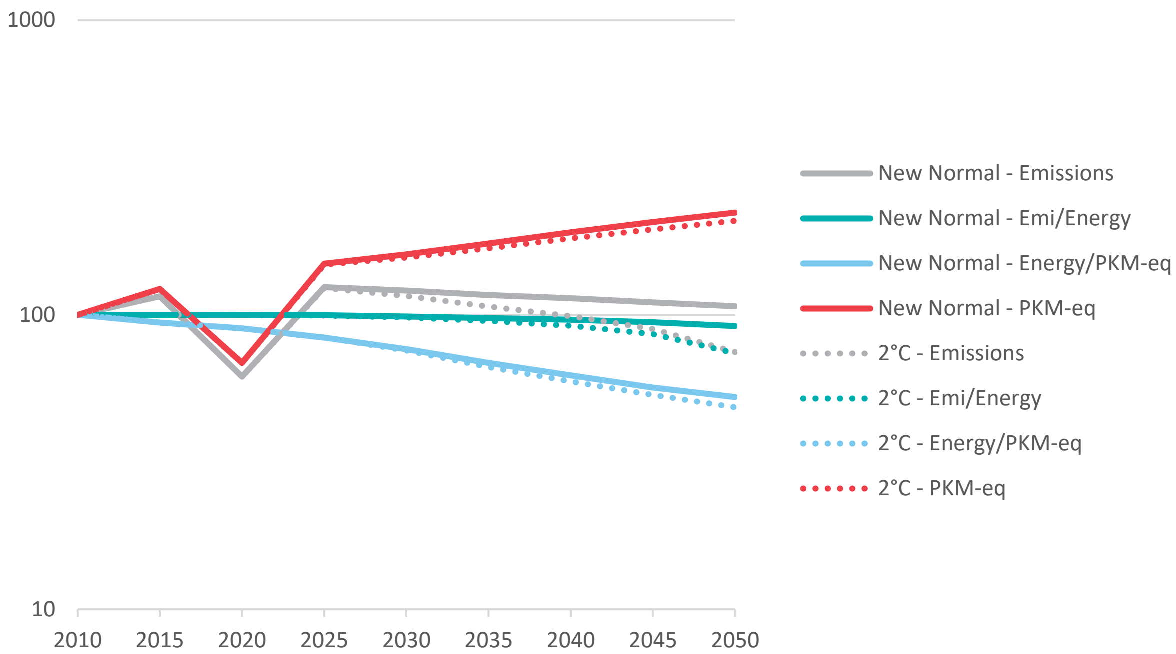
In the medium term, no fuel option appears to be readily available to massively decarbonize the aviation fuel mix (**Figure 22**). Other fuel alternatives appear more adapted to reduce the carbon content of aviation than electricity, namely biofuels and e-fuels. Starting from 2030, these alternative fuels start gaining market share. While they still remain marginal in the New Normal scenario by 2050, they are mobilized much more in the strong climate scenarios: they come to represent half of the liquids consumed in 2050 in the 1.5°C scenario.

E-fuels here signify liquid fuels produced from hydrogen[10]; while more costly to produce than hydrogen, such fuels can directly substitute oil products without significant costs to adapt aircraft engines. Hydrogen-powered aircraft, where hydrogen gas is burnt in engines, are not explicitly modelled in this exercise; however, they present additional costs to adapt engines and pressurized or liquid storage costs. Due to this trade-off, the market share would not be expected to change much if hydrogen aircraft were included with e-fuels.

[9] The principal efficiency measures in the modelling are a change of flight patterns (lower altitudes), air and ground traffic management, engine retrofit and cabin weight reductions (for the fleet); and aircrafts designed and more efficient engines (for new aircraft).

[10] Production of hydrogen progressively switches from mainly methane reforming to electrolysis and reforming and bioenergy coupled with CCS.

Figure 23: Kaya decomposition of global aviation CO_2 emissions, New Normal (solid lines) and 2°C (dots), indexed to 2010 (logarithmic scale)



Source: POLES-JRC

As seen in **Figure 23**, additional emissions reductions to 2°C are mainly achieved through the increased use of low-carbon energy vectors (electricity, biofuels, e-fuels) and a limitation of traffic[11].

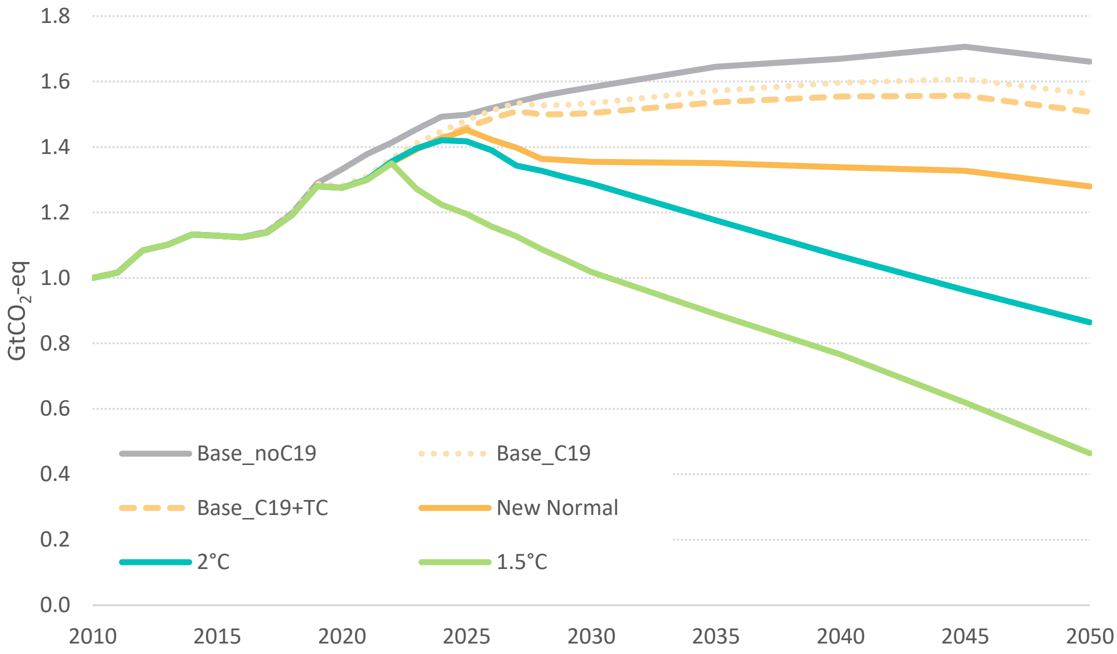
The Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) aims at making all flights after 2020 "carbon-neutral". The baseline for international aviation is defined as the average of total CO_2 emissions for the years 2019 and 2020 on the routes covered by CORSIA offsetting in a given year from 2021 onwards (ICAO, 2019). The Covid-19 pandemic results in a decrease of CO_2 emissions from international aviation in the scenarios including Covid-19 effects versus the no-Covid-19 Baseline by about one quarter to a third, for the average of 2019 and 2020. All the effects included in the New Normal related to aviation – the effects of Covid-19, its induced transport changes, the aviation fuel tax, the accelerated learning of batteries – result in CO_2 emissions that are about 23% above this new 2019-2020 average baseline in 2050.

4.4. Maritime emissions and energy trends

The maritime transport sector is also one of the fastest-growing sectors in terms of emissions in recent years (+3.0%/year over 2010-2018), fuelled by global trade. This growth is projected to be influenced by the Covid crisis and its aftermath but to a much lesser extent than the aviation sector.

[11] A Kaya decomposition is also made by (Sharmina, et al., 2020), leading to a 36% decrease in 2050 from 2010 in the 2°C scenario compared to a 27% increase in their Reference (without Covid), a 63 pp gap. The spread between the New Normal and the 2°C scenarios for the 2010-2050 evolution is of 32 pp; this difference in gaps can be explained by the lower levels of emissions in New Normal versus the publication's Reference. Moreover, while the spreads in energy intensity (-4 pp in GECO 2020 versus -14 pp in the publication) and CO_2 intensity of energy (-18 pp versus -9 pp) are similar, significant differences are observed for service demand (-14 pp versus -78 pp). Considering that a further 80 pp spread in service demand evolution between Base_noC19 and New Normal is observed, the decompositions are found to be close.

Figure 24: CO_2 emissions of maritime (domestic and international)

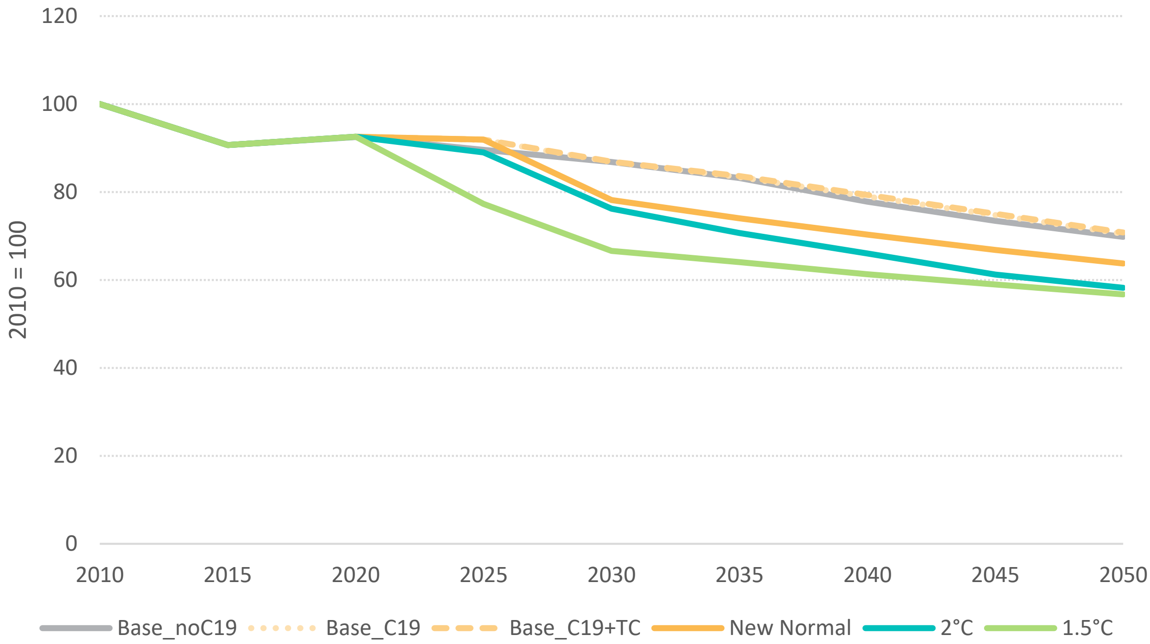


Source: POLES-JRC

Much of the energy efficiency presented in **Figure 25** is expected to take place over time due to technology progress and market forces. The 2030 fleet is 15% more efficient compared to 2010 in the Base_noC19; the energy tax on maritime fuels in the New Normal would push that figure to 28%, a level approaching that of the 2°C scenario (37%)[12].

[12] The principal efficiency measures in the modelling are speed reduction, hull retrofit, propeller maintenance and operational measures (for the fleet); and propeller and propulsion measures, hull coating and air lubrication (for new ships).

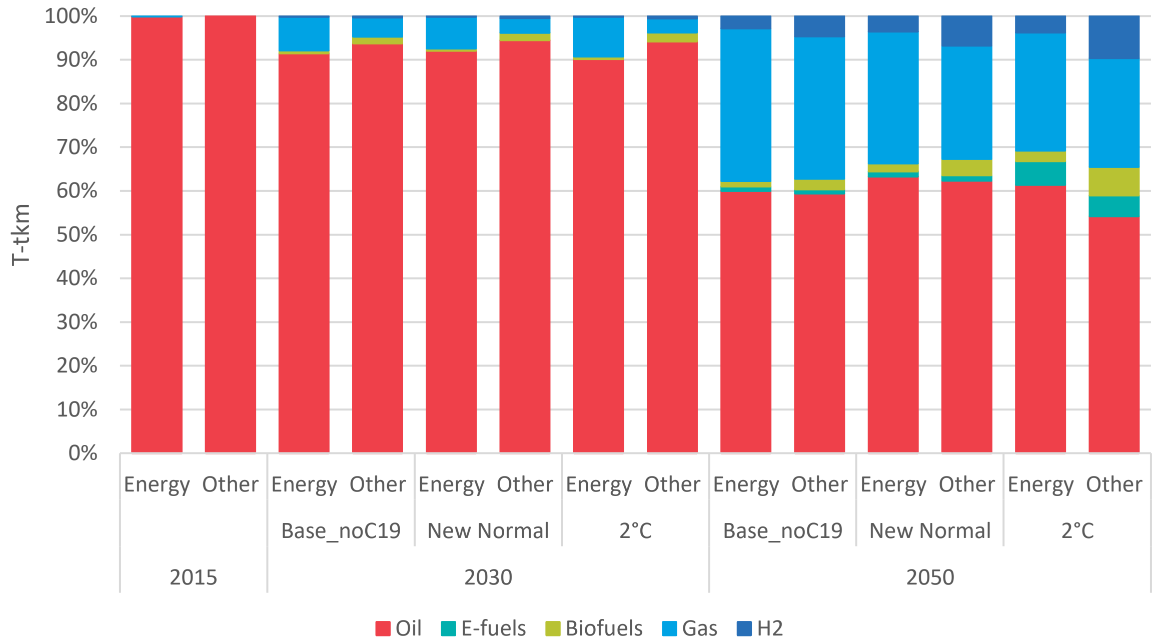
Figure 25: Energy intensity of the global maritime sector



Source: POLES-JRC

The fuel mix is presented in **Figure 26**. In the absence of a strong carbon price, natural gas plays an important role in the maritime sector progressively beyond 2030. The 2°C and 1.5°C scenarios favour even less carbon-intensive fuels such as biofuels and hydrogen-derived e-fuels; this is the result of price-based competition (taking into account the price of carbon) but also the result of the decrease in international LNG trade over time due to the decrease in natural gas demand. Indeed, LNG ships are more suited to switching to using gas as propellant than cargo ships; correspondingly, oil tankers are more eager to continue using fossil oil instead of switching to other fuels.

Figure 26: Global fuel mix of maritime



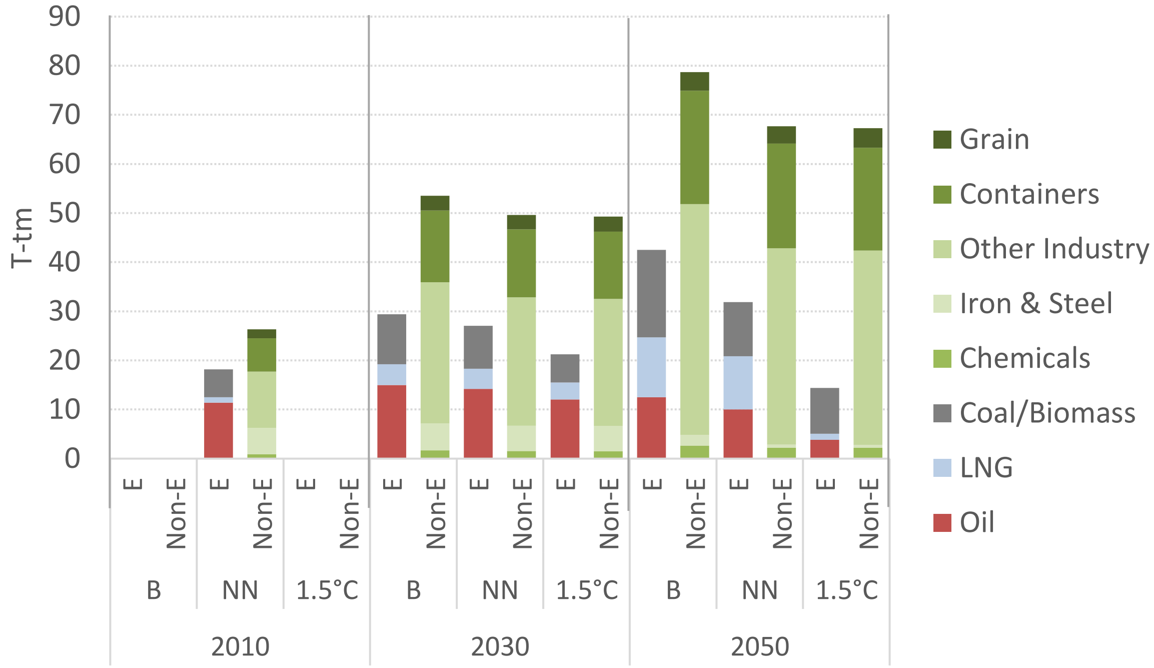
Source: POLES-JRC

Compared to **Figure 15**, in **Figure 27** maritime activity is further split into energy trade (oil tankers, LNG tankers, coal and solid biomass transport ships) and trade of other goods (grains, chemicals, iron and steel, other industrial products and consumer goods). The drop in energy trade volumes compare to the Base_noC19 can be seen. The share of low-carbon fuels (biofuels, hydrogen, e-fuels) for each category shows the higher propensity of non-energy goods transport for the adoption of alternative fuels.

In the New Normal scenario the impact of efficiency measures in the maritime sector increases compared to the Baseline, but remains limited to a certain extent. Together with a minor switch towards low-carbon fuels CO_2 emissions are still higher in 2050 than in 2010, while the International Maritime Organisation (IMO) is aiming at a 50% GHG reduction in 2050 compared to 2008 (IMO, 2018). As shown in **Figure 28**, additional emissions reductions to 2°C are mainly achieved through higher carbon values pushing further efficiency measures and leading to an increased use of low-carbon energy vectors (biofuels, e-fuels, hydrogen), while also limiting traffic mainly due to the decreased use of fossil fuels associated with the transition to a low-carbon economy[13].

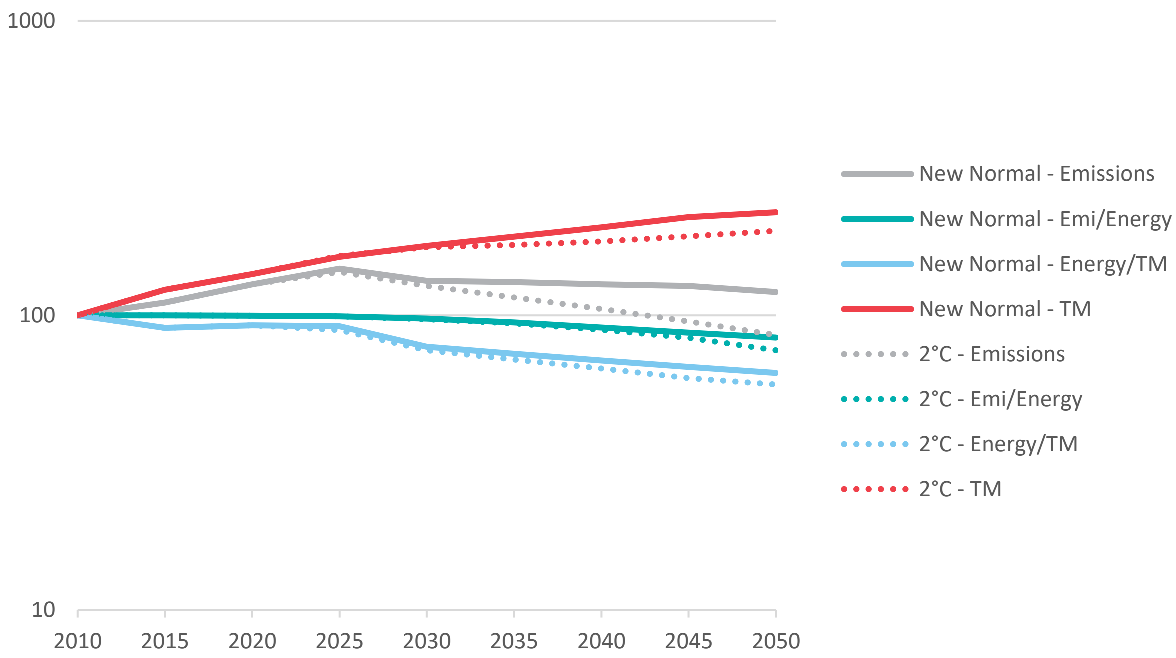
[13] A Kaya decomposition is also made by (Sharmina, et al., 2020), leading to a -31% decrease in 2050 from 2010 in the 2°C scenario compared to +43% in their Reference (without Covid), a 74 pp gap. Differences exist with GECO 2020, as the spread in 2010-2050 evolution between the New Normal and the 2°C scenarios is of 34 pp this difference in gaps can partly be explained by the lower levels of emissions in New Normal versus the publication's Reference. Moreover, the contribution of the components of emissions is different: while the reduction in energy intensity is similar (-6 pp in GECO 2020 versus 0 pp in the publication), notable differences are observed for CO_2 intensity of energy (-8 pp versus -30 pp) and service demand (-30 pp versus -18 pp). Considering that a further 48 pp spread in service demand evolution between Base_noC19 and New Normal is observed, the decompositions are found to differ significantly only in CO_2 intensity of energy.

Figure 27: International maritime activity decomposed by type of goods transported



Source: POLES-JRC

Figure 28: Kaya decomposition of global maritime CO_2 emissions, New Normal (left) and 2°C (right), indexed to 2010 (logarithmic scale)



Source: POLES-JRC

5. Investments

Investments are needed to accelerate in order to realize the global energy transformation required by the Paris Agreement. Due to the global economic slowdown following the Covid-19 pandemic, outstanding questions remain as to whether investments will also decelerate or will be successfully maintained, thanks to underlying economic recovery packages.

So far only the EU and South Korean pledges have reflected low-carbon measures in a concrete way in their stimulus plans. However, despite the pandemic during 2020 several major economies have made significant long-term climate commitments, which should help channel investments towards more low-carbon and energy-efficient options, see **Box 2.**

Box 2: Major economies economic stimulus plans and long-term climate commitments during 2020

In July, the **European Union** governments approved an economic stimulus plan called Next Generation EU (NGEU) of EUR 750 billion starting in 2021, in support of the revamped Multiannual financial framework (MFF) budget for 2021-2027 of EUR 1,074 billion. In November the European council and the European parliament agreed on the recovery instrument of more than EUR 1.8 trillion[14] that it will help to rebuild a post-Covid Europe. The MFF, reinforced by NGEU, are the main instruments for implementing the recovery package in response to the socio-economic consequences of the Covid-19 pandemic in the EU. NGEU earmarks 30% of the entire package for climate protection, contributing to achieving the Union's new 2030 climate targets, and comply with the objective of EU climate neutrality by 2050. This translates to more than EUR 500 billion over the next seven years[15], around 0.55% of the EU GDP, the EU most ambitious climate change plan to date[16]. The EU spending is designed to be consistent with the Paris Agreement objectives.

In September, at the State of the Union the European Commission presented its plan to reduce GHG emissions by at least 55% by 2030 compared to 1990 levels, putting the EU on a pathway to reaching net-zero emissions by 2050. In October, EU environmental ministers made the bloc's pledge to be climate neutral by 2050 legally binding.

In July, **South Korea** presented its Green New Deal, a $37 billion plan aiming at boosting green infrastructure, clean energy and electric vehicles by 2025. South Korea has also announced a further $7 billion spending on carbon-cutting measures. South Korea also presented its Green New Deal, that seeks to bring carbon dioxide emissions to net zero, but no concrete timelines are given.

In September, at the UN General Assembly **China** announced its plan to become carbon-neutral by 2060. China is expected to provide mid-term objectives for emissions reductions with its 13th Five-Year Plan in the spring of 2021.

In October, **Japan** announced its pledge to reduce GHG emissions to net-zero by 2050. Japan announced a target to massively increase renewable electricity capacity to 50% by 2030.

More countries are expected to announce net-zero targets ahead of 2021 UNFCCC climate conference. The 2020 **United States** president–elect Joe Biden has presented a plan to ensure the U.S. achieves a 100% clean energy economy and reaches net-zero emissions no later than 2050[17]. These announcements are not taken into account in the modelling behind this report.

Up to the time of writing (end of 2020), governments have approved altogether over $12 trillion of support in response to the Covid-19 pandemic (Andrijevic, Schleussner, Gidden, McCollum, & Rogelj, 2020) (Bloomberg NEF, 2020a). Although several governments have announced their intentions to allocate portions of their packages for a "green recovery," the exact details remain largely unclear for most of the countries. As of September 2020, only a very small share of this recovery packages (1%) is intended to reduce greenhouse-gas emissions or aid climate adaptation. A further 7% has been unveiled for carbon-intensive companies and sectors such as transport, oil and gas supply, and construction. The vast majority of the $12 trillion is classified as 'neutral', meaning that it is not yet known how much of this funding will be green or CO_2-intensive (Bloomberg NEF, 2020a).

The opportunity for a post–Covid-19 economic recovery efforts to be used to catalyse the necessary longer-term transformation toward a pathway compatible with the Paris Agreement, required the fully decarbonisation by mid-century of the energy supply (McCollum, et al., 2018), (Rogelj, et al., 2018) (Clarke, et

[14] https://www.consilium.europa.eu/en/press/press-releases/2020/11/10/next-multiannual-financial-framework-and-recovery-package-council-presidency-reaches-political-agreement-with-the-european-parliament/

[15] Conclusion adopted by the European Council at the Special meeting of the European Council (17,18,19,20 and 21 July 2020)

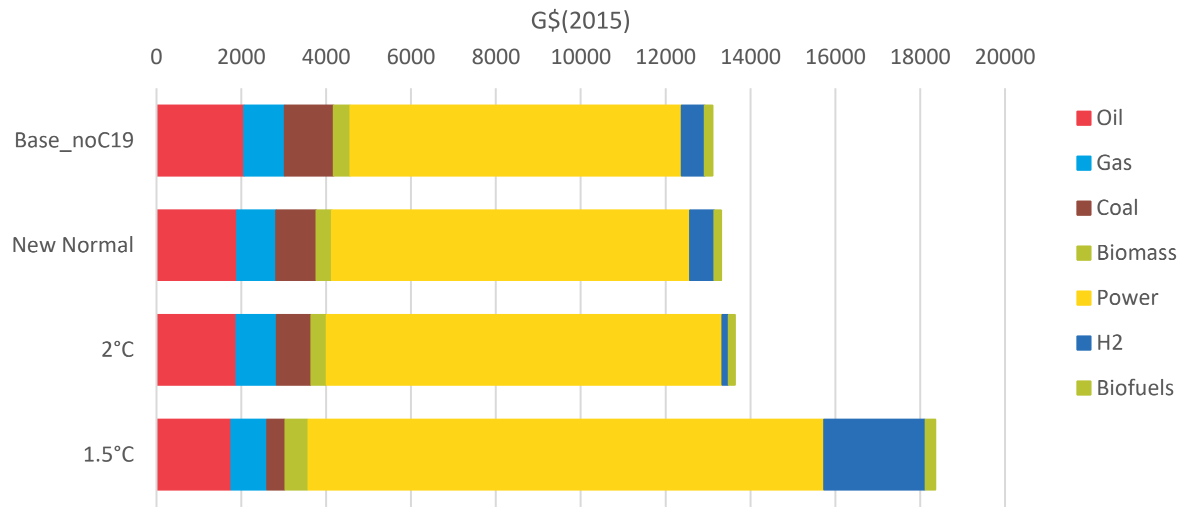
[16] https://www.bloombergquint.com/technology/eu-approves-biggest-green-stimulus-in-history-with-572-billion-plan

[17] The Biden plan for a clean energy a revolution and environmental justice. https://joebiden.com/climate-plan/

al., 2014). Average annual low-carbon energy investment for a Paris compatible pathway have been estimated at about $1.4 trillion per year globally between 2020-2024 (Andrijevic, Schleussner, Gidden, McCollum, & Rogelj, 2020) (McCollum, et al., 2018). This is about 12% yearly of the total ovid-19 stimulus to data. Therefore according to (Andrijevic, Schleussner, Gidden, McCollum, & Rogelj, 2020) only a minor fraction of announced Covid-19 economic recovery packages is needed to provide the necessary financial basis for a decided shift toward a Paris Agreement–compatible future.

Projections of global gross investments in energy supply for the 2020s decade are given in **Figure 29**. Investments in power generation and storage make up most of the investments of the period. As we move towards more low-carbon scenarios, power sector investments make up a growing share of total supply investments and investment in power capacities of renewables technologies make up a growing share of power sector investments. Total figures and figures for electricity are comparable with literature[18].

Figure 29: Global investments in energy supply, cumulated 2021-2030



Source: POLES-JRC

Methodologies, perimeters and granularity of representation for energy demand investments vary across studies, with up to an order of magnitude in differences of resulting investments estimates (McCollum, et al., 2018); though not entirely comparable to supply-side investments, figures provided here for the demand side are given as an indication and can be used to assess differences in investment needs between scenarios.

Select investments in the demand-side of the energy system are shown in **Figure 30**. In this figure, investments in energy efficiency and low-carbon technologies are displayed as differences compared to a reference point, reflecting additional cost to increase energy efficiency (e.g. renovating towards a more insulated buildings shell) or extra cost relative to a reference technology (e.g. ICE vehicles).

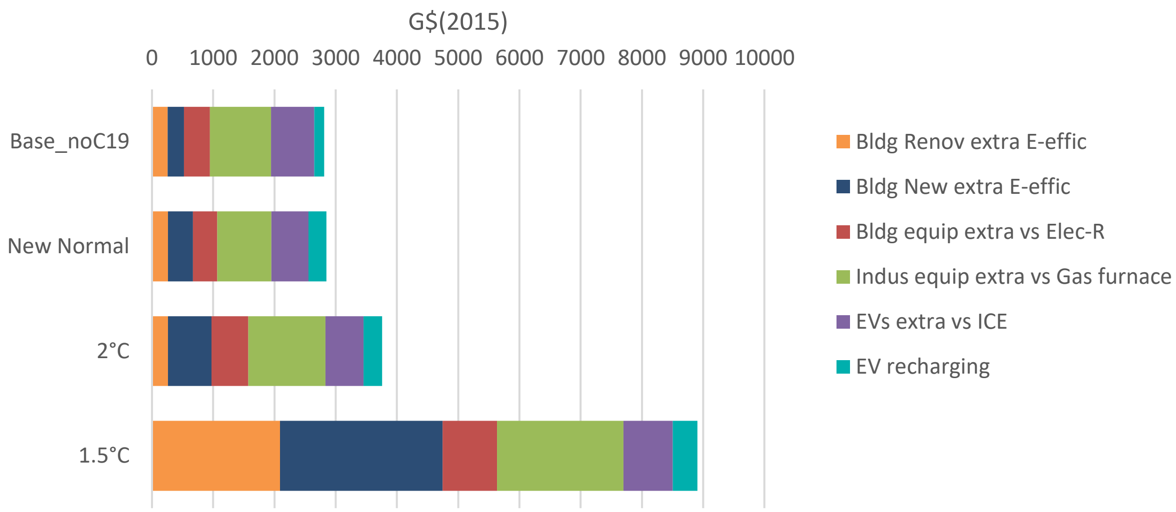
Investments for building efficiency (including new built and renovation) are comparable with the investments for end-use energy efficiency of the Sustainable development scenario (SDS) from the last World Energy Outlook (IEA, 2020)[19].

Investments accelerate with the 2°C and 1.5°C global targets, notably due to energy efficiency in buildings ushered by the carbon price: the renovation rate is accelerated (from about 0.3%/year historically to as much as 2%/year), the building codes become stricter and move towards low-energy-consumption buildings for both renovated and new surfaces.

[18] Total supply for 2°C: 1800 G$/year for 2016-2030 in (McCollum, et al., 2018) compared to 1400 G$/year for 2021-2030 for GECO2020. Total power for 2°C: 900 G$/year for both.

[19] The definition of SDS is in-between our 2°C and 1.5°C scenarios: SDS is defined with a 50% probability of limiting the temperature rise to less than 1.65°C (in line with the Paris Agreement objective of "holding the increase in the global average temperature to well below 2 °C"). Efficiency in SDS: 550 bn $/year for 2021-2030, compared to 120 and 390 bn $/year for buildings in GECO2020 2°C and 1.5°C, respectively.

Figure 30: Estimation of select global investments in energy demand related to energy efficiency and low-carbon technologies, cumulated 2021-2030



Note: *Bldg Renov* and *Bldg New* refer to investment cost in buildings' shells for increasing energy efficiency of renovated and new buildings; *Bldg equip* and *Indus equip* refer to extra cost in purchasing energy-consuming equipment in buildings for space heating and in industry process heat compared to purchasing a reference technology (electric resistive heating in buildings and gas-fuelled furnaces in industry); *EVs* refers to extra cost in purchasing battery electric and plug-in hybrid LDVs and HDVs compared to purchasing ICE vehicles; *EV recharging* refers to the full investment cost of recharging stations for vehicles. Source: POLES-JRC

In **Table 6**, energy supply-side investments (gross) and demand-side investments (extra to achieve higher energy efficiency or lower carbon content) versus GDP are displayed. These investment levels can be put in perspective by comparing them with overall investment in the economy, which ranged between 23 and 25% of global GDP over 1980-2018[20]. By comparison, the EU budget under negotiation for climate protection (MFF and NGEU) is at 0.55% of EU GDP (see **Box 2**).

Table 6: Global energy investments versus GDP, average annual for 2021-2030

	Total supply-side	***Of which low-carbon***	**Total demand-side**	**Total supply & demand**
Base_noC19	0.91%	*0.41%*	0.21%	1.11%
New Normal	0.98%	*0.52%*	0.22%	1.20%
2°C	1.04%	*0.64%*	0.29%	1.33%
1.5°C	1.17%	*0.86%*	0.57%	1.75%

Note: See **Figure 30** for definition of demand-side investments.

Definition issues make the comparison of these figures with literature difficult; however, they are not entirely dissimilar[21].

[20] https://data.worldbank.org/indicator/NE.GDI.FTOT.ZS?year_high_desc=true

[21] According to (Andrijevic, Schleussner, Gidden, McCollum, & Rogelj, 2020), average global annual energy investments compatible with the 1.5°C global mean temperature would be equivalent to 2.5% of GDP.

6. A macro-economic baseline with the effects of Covid-19

The measures to limit the spread of Covid-19 had strong economic implications, likely resulting in the largest economic downturn since the Second World War. Economic forecasts indicate that economic growth rates may bounce back relatively quickly, such that the year 2020 may become somewhat of an outlier in economic time series data. For this reason, modelling efforts should strive to incorporate the disruption from Covid-19 when the focus is on the short run, while baselines developed to study long-run policy questions cannot freeze the image of the economy in the year 2020. In this section, we describe how we integrate the POLES-JRC work into a broader macro-economic dataset of input-output tables underlying the JRC-GEM-E3 model. These macro-economic tables, building on the Base_C19+TC scenario, can be downloaded as a complement to this GECO report. The tables provide an update to the macro-economic tables published in 2018 (Rey Los Santos, et al., 2018), see **Box 3** for key differences. The internally consistent tables provide a useful starting point for economic analysis of international climate policies taking into account key aspects of Covid-19.

The baselines are built using the PIRAMID framework (Wojtowicz K. , et al., 2019) combining various data sources in a build stream that produces a time series of input-output tables up to the year 2050 in five-year steps. At its core, input-output tables are projected forward, taking macroeconomic projections and results from energy models such as POLES-JRC as constraints in a balancing algorithm (Temursho, et al., 2020). Exogenous GDP projections are disaggregated into the main components: public consumption, private consumption, international trade and investment. Income-driven final demand changes are translated into sector-specific evolution of output.

Box 3: Key differences from previous Baseline tables (GECO 2018)

A first set of macroeconomic tables were published as a complement to the GECO 2018 report 2018 (Rey Los Santos, et al., 2018). Since 2018, the PIRAMID methodology has been updated and improved in a number of ways, hence interpreting a direct comparison with previous tables is not straightforward as differences stem both from updates in key economic and energy trends, notably in the context of Covid-19, and from changes in the modelling framework.

The underlying data has been updated in several aspects. The GTAP dataset, describing economic flows between agents in the base year has been updated to the latest version, GTAP 10 (Aguiar, Chepeliev, Corong, MacDougall, & Van der Mensbrugghe, 2019). The regional aggregation has also been modified (**Annex 6**). For the projections of the IO tables, the macroeconomic, population and energy assumptions have been updated; the sources behind the macroeconomic assumptions are presented in **Annex 7**. EU energy trends are calibrated to the PRIMES model's Covid Baseline from the impact assessment of the 2030 climate target plan, underlying the proposal for an increased EU climate target in 2030. Finally, non-EU energy trends are incorporated from POLES-JRC and are consistent with the Covid Base_C19+TC scenario as described in section 2.2. This scenario takes into account macroeconomic effects and potential behavioural changes in the transport sector, but unlike the New Normal scenario, it does not include any new policies. Note that this scenario does not specifically take into account the nationally determined contributions (NDC) under the Paris agreement – these were included in the 2018 Baseline. As such, this Baseline incorporates only currently implemented energy and climate policies, and could serve as a meaningful counterfactual to assess additional climate policies. Using a consistent macro-economic outlook across various research endeavours and policy initiatives may facilitate the comparison of results. We make the tables publicly available to help reducing redundant work in various departments and institutes, and to enhance the transparency of our numerical framework. As the Covid-19 crisis also brings in additional uncertainty, we expect further updates of the Baseline, which can be accessed at:

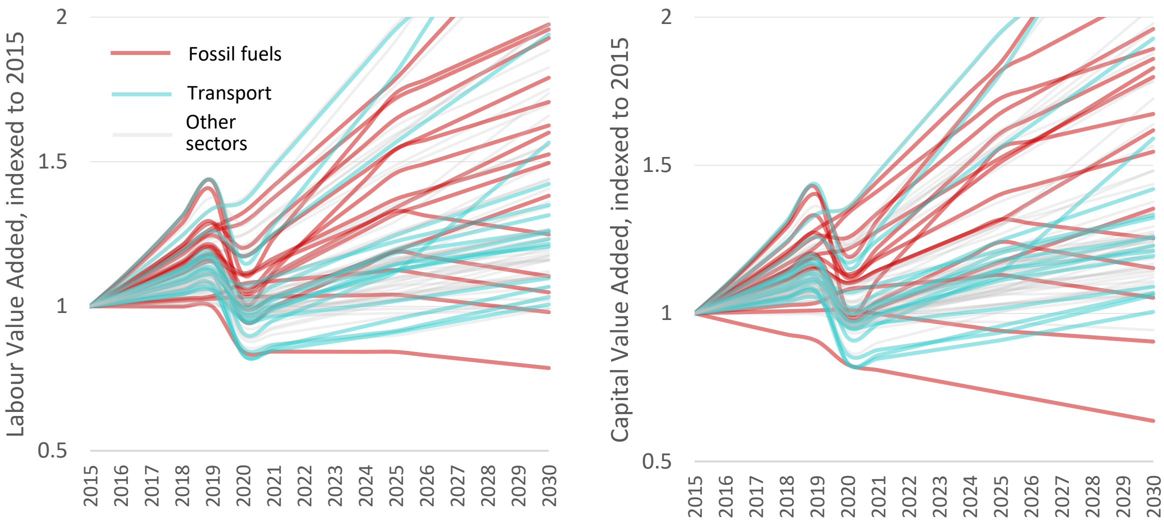
https://ec.europa.eu/jrc/en/macroeconomic.baselines.for.policy.assessments.

To account for the impacts of Covid-19, we make several adjustments. Most importantly, we use GDP projections that are taking into account the economic dip in 2020 and a potential level effect in the future compared to previous projections. In line with the rest of the report, we use IMF projections (complemented with EU projections taken from the 2021 Ageing report (European Comission, 2020b). In addition, we also take into account unemployment projects from the same sources. As the IMF projections are only available for the short term, we complement this by long term projections from the ILO. This allows to attribute change in aggregate income of labour to changes in unemployment and wages.

The effects on the economic activity is taken into account for a number of sectors, especially the energy intensive ones, by aligning economic output and energy use with energy system models. Therefore, emission and energy balances are in line with the POLES Base_C19+TC scenario. For the EU, sectoral projections, energy and emissions are in line with the modelling used for the 2030 Climate Target Plan (European Comission, 2020a), in particular the PRIMES baseline scenario that is considering the effects of COVID-19. Most importantly, transport activities and energy use and emissions were adjusted in a consistent manner.

The resulting input-output tables are published as a complement to this report. **Figure 31** illustrates the evolution of value added of labour (left) and capital (right) for all regions and three aggregate sectors through 2030. In line with the focus of this report, we highlight the evolution of value added in Base_C19+TC in fossil energy (coal, oil and gas) and transport (land, aviation and maritime). The impact of the Covid-19 crisis is clearly visible in the projections of value added, especially in the transport sector. The value added projections feature as one component in the encompassing and internally consistent input-output tables. In addition to the input-output tables, the published database also includes 'consumption matrices' that map production sectors (aggregated from GTAP) to categories of consumption by purpose (COICOP). These matrices are based on (Cai & Vandyck, 2020), but at a more aggregated level and including refinements for the energy-related goods.

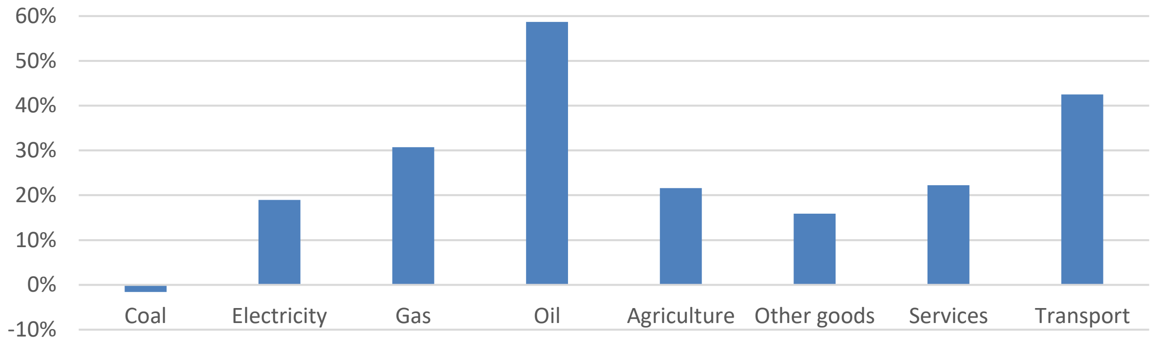
Figure 31: Value added by region and three aggregate sectors of the economy, labour and capital.



Note: This figure is an illustrative representation based on the macro-economic tables, as yearly time steps between 2015 and 2020 are based on growth rates after 2020. The tables are available for download in five-year steps. Sources: own calculations

The time series of input-output tables can also be compared for different years. Comparing the tables for 2020 and 2025 also indicates how much sectors were hit by the immediate impacts of Covid-19. **Figure 32** shows global private consumption expenditures for some sectors. Overall, consumption expenditures in 2025 are about 22% higher in 2025 relative to 2020. Depending in how hard consumption was hit in 2020 and how general trends shape private consumption changes, the sectors grow quite differently. Coal is the only sector projected with lower household expenditure in 2025 relative to 2020. This is less the effect of Covid-19, but rather a general trend to move away from coal as heating and cooking fuel in households. Expenditure for oil and gas increases, due to an increase in demand, especially in petroleum products (oil), but also due to a recovery of prices from their low in 2020. Transportation services purchased by households go up as well, especially for air transport – global private household expenditures for aviation might more than double from 2020 to 2025. Other goods and services experience a growth around the global average of 22%.

Figure 32: Growth in global private consumption expenditures between 2020 and 2025.



Sources: own calculations

7. Conclusion

Analysing the impact of the Covid-19 outbreak on the total energy system and GHG emissions can provide significant information that can help determine how policy makers could tackle climate change in the future and how to spend the recovery packages budget.

This edition has focused on the impact of the Covid-19 pandemic on the transport sector, during the pandemic and what changes could be expected beyond it. We analysed a “New Normal” scenario where we assumed that the pandemic has permanently reduced passenger transport demand, with some behavioural changes occurring during the pandemic becoming permanent or being gradually adopted over time (as seen in section 2.2.2), and with certain policies promoting low-carbon and more efficient transport being implemented (as seen in section 2.2.3).

The “New Normal” scenario presented here is only one potential pathway of future development among several that are also possible. Despite the large uncertainty, the sense of the trends induced on energy demand and carbon emissions seems qualitatively robust.

As seen, the New Normal scenario has narrowed the emissions gap from Baseline to 2°C by about 35% in 2030, close to the global emissions reductions expected in an NDC scenario (50% of the gap). Despite that, the “New Normal” will not bring the world close to limiting climate change to 2°C or 1.5°C; the implementation of new and more ambitious climate policies than those described in the New Normal are essential to reach the 2°C or 1.5°C targets. If the world is to follow through with the Paris Agreement commitment to limit global warming to well below 2°C by 2100, there is no return to business as usual after the Covid-19 crisis.

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List of abbreviations and definitions

BECCS: Bio-Energy combined with Carbon Capture and Sequestration

BEV: Battery electric vehicle

CCS: Carbon Capture and Sequestration

CDD: Cooling Degree-Days

CGE: Computable General Equilibrium model

COM: Communication from the European Commission

COP: Conference of the Parties

DACCS: Direct Air CO_2 Capture and Sequestration

EC: European Commission

ETS: Emission Trading Scheme

EU: European Union as of November 2019 (27 Member States)

EV: Electric Vehicle

GDP: Gross Domestic Product

GECO: Global Energy & Climate Outlook

GHG: Greenhouse Gases

GLOBIOM: The Global Biosphere Management Model

GTAP: Global Trade Analysis Project

GWP: Global Warming Potential

IATA: International air transport association

ICAO: International Civil Aviation Organization

ICE: Internal Combustion Engine

IEA: International Energy Agency

IIASA: International Institute for Applied Statistical 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

LULUCF: Land Use, Land Use Change and Forestry

MRIO: Multi-regional input-output (table)

NDC: Nationally Determined Contribution

NCSC: National Centre for Climate Change Strategy and International Cooperation

NREL: US National Renewables Energy Laboratory

OECD: Organisation of Economic Co-operation and Development

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: part per millions

R/P: Ratio Reserves by Production

RES: Renewable Energy

SDS: Sustainable development scenario from IEA

TC: Transport changes

UN: United Nations

UNFCCC: United Nations Framework Convention on Climate Change

USGS: US Geological Survey

WEC: World Energy Council

WMO: World Meteorological Organisation

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Annexes

Annex 1: Mobility-changes effects on transport during Covid-19

The transport sector finds itself in a totally unprecedented situation that could cause a shift to a new order. On top of this demand shock, the energy sector experiences a supply shock. As Covid-19 hit global oil demand and OECD+ countries refused to curtail production, oil prices collapsed close to 20 $/bbl for the Brent and (momentarily) below 0 for the WTI in April 2020. Since then there has been a gradual recovery of oil demand, but demand and price have remained below 2019 levels (IEA, 2020d). This oil price crash could be different than previous ones as consumers, governments and the private sector globally are becoming more climate-aware and more mindful of security of supply.

Passenger transport

Under the lockdown measures, for several months private and public passenger transport has decreased significantly or even come to a near-standstill. Year-to-date global road transport activity was almost 50% below the 2019 average by the end of March 2020 and commercial flight activity almost 75% below 2019 by mid-April 2020 (IEA, 2020c). Global passenger car sales in 2020 are expected to drop by 15% compared to 2019 (IEA, 2020b), although a very large part of this drop is linked only to the level of activity (Enerdata, 2020). In the new normal scenario a reduction in car sales takes place during and after the pandemic.

The crisis might heavily influence the passenger transport sector for years to come. But still many uncertainties lie ahead as for example, the long-term effects of Covid-19 on tourism and long-distance travel. However, international journeys are expected not to recover soon and long national journeys will also suffer severe setbacks. The air transport sector will therefore likely be the heaviest affected transport mode.

Road transport has experienced an unprecedented plunge, mainly steered by the restricted mobility measures during the lockdown, the economic slowdown and the emergence of new mobility patters. These new modes include teleworking, which decreases the need for commuting, requiring less vehicles, rail and business trips. The shift to the healthiest modes of transport, e.g. increasing walking and cycling in cities can also contribute to reduce the need for private cars and public transportation. But other new behavioural modes can be also relevant, such as the fear of infection and interaction that can boost private mobility back up.

The Covid-19 pandemic can reshape the world in a very different way. A recent survey with 26000 respondents carried out by the YouGov-Cambridge Globalism Project and the Guardian found the widespread intention to drive more after the pandemic than before – a most alarming trend in climate terms. This trend was found in all 25 countries included in the survey (Watts, 2020).

Covid-19 has had a major impact on **air transport**. With nearly all passenger fleet grounded for many airlines around the world, the sector has been hit very hard by the pandemic as governments closed borders and passengers shunned avoidable travels. Airlines have come under serious financial peril. Some national governments have responded by supporting the industry with emergency bailouts, in some cases seeking to attach environmental conditions to rescues plans, which will bolster the low-carbon energy transition.

By the end of the strong confinement measures, domestic passenger flights were slowly recovering. In contrast, international passenger flight were not showing any sign of recovery yet (Bloomberg NEF, 2020). If this trend continues after the crisis, international flights would globally be more affected in a long run than domestic flights. The associated change in behaviour would be that a smaller portion of the population would be willing to fly, because of new working conditions (generalized use of teleworking, reduction in business trips) but also as a lifestyle choice associated to increased concern about climate change.

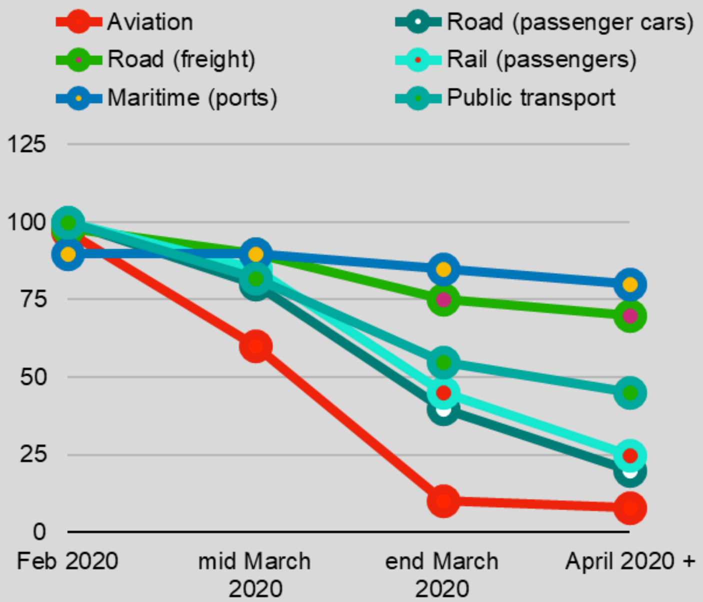
Rail transport, as a part of public transport, has suffered the consequences of the pandemic. For the short term, the Covid-19 pandemic has had a severe impact on railways, due to temporary transport restrictions and lower demand. Most international trains journeys/trips were cancelled and domestic traffic has decreased by up to 90% compared to 2019 (European Parliament and the Council, 2020).

On the other hand, the long-term can bring new opportunities that could benefit rail. Rail travel is the most energy-efficient transport mode for journeys under 800 km (IEA, 2019a), requiring on average 12 times less energy per passenger-kilometre than airplanes and road vehicles (IEA, 2020b). Out of 4000 people asked in France, Germany, Italy, Spain, and China, the majority of business travellers surveyed were willing to accept travel times of two to three hours on trains; this time was much higher for leisure travellers, with the majority prepared to go on rail journeys five to six hours or even longer (USB Investment Bank, 2020). This trend can encourage the growth of high-speed trains with a reduction of airplane trips for these distances in the long run. Amid concern for climate change, the use of trains instead of flying or driving can gain momentum, as it contributes to reduce emissions of the transport sector.

Box 4: Effect of Covid-19 on mobility in the EU

As shown in **Figure 33**, during the stronger lockdown measures in EU, the sharpest drops have been observed for passenger transport demand, in aviation, road and rail, followed by public transport (busses). The latter is especially vulnerable to the changing trends after the pandemic. In a post Covid-19 situation, it is expected that public transport could be actively avoided by part of the population, because of concerns of disease transmission. This would produce a shift of demand back to private cars, but also to biking and even walking (Future of transport: Update on the eonomic impacts of COVID-19).

Figure 33: Changes in EU transport activity (baseline=100)

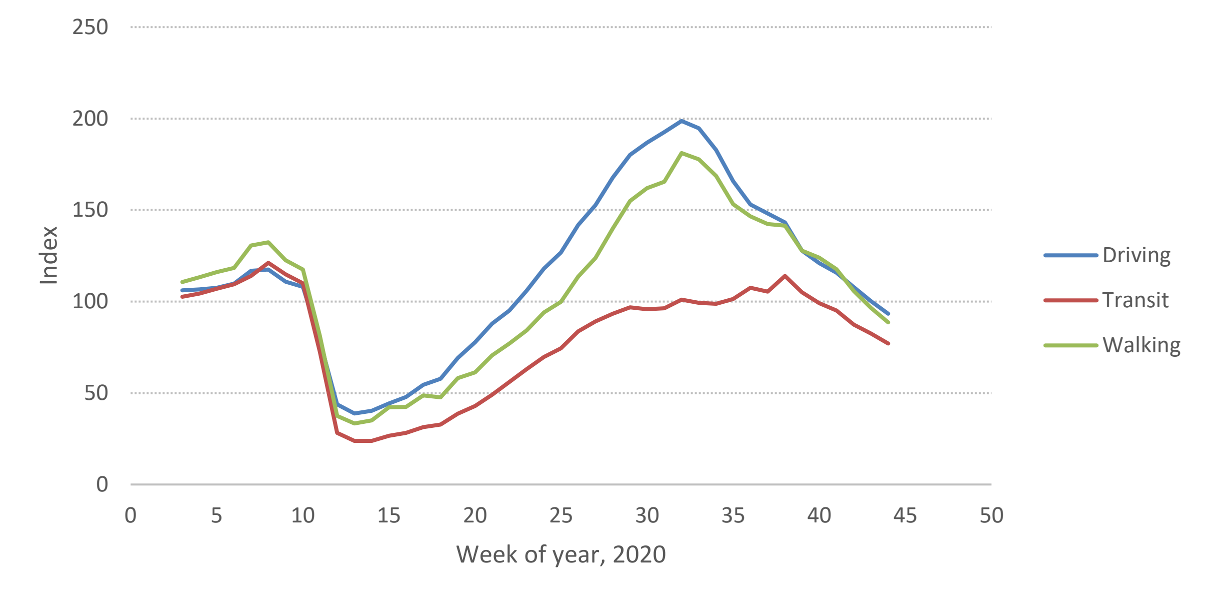


Source: JRC estimates based on data from EUROCONTROL, Google, Apple. (JRC European Commission, 2020)

For the same period of time, Apple has released a mobility data trends tool[22] to show the impact of Covid-19 in mobility. The mobility data in **Figure 34** show the change in volume of people driving, walking or taking public transit in the EU during the pandemic. Public transport (transit) seems to be the most affected mode, compared to driving and walking, which have experienced a rebound after the first wave of the pandemic. This could be explained by the higher perception of risk of contagion in the enclosed environment of public transport.

[22] apple.com/covid19/mobility.

Figure 34: Mobility trends data in EU (baseline=100)



Sources: Apple mobility trend data

The two figures shown above present contrasting pictures on how transport modes are impacted (public transit more or less impacted than private transport) and how uncertain observed statistics for the year 2020 are at the time of writing. Accordingly, the uncertainties in estimating the short- and long-term impacts of the pandemic are still large.

Table 7 shows the short- and long-term factors affecting passenger transport, due to the Covid-19 pandemic and due to other emerging trends. These factors and their expected effects informed the implementation of measures in the New Normal scenario (see section 2.2.2).

Table 7: Factors affecting the use of passenger transport after Covid-19

Short-term trend	Factors	Consequences	Overall effect
Pandemic lockdown measures	Massive reduction of mobility	Drastically reduces all types of trips modes	Lower mileage per capita, all modes

Long-term trend	Factors	Consequences	Overall effect
Emergence of new working conditions	Increase of teleworking and use of videoconferencing services as a "new normal" thanks to digitalization Reduced pressure on real estate and relocation process: increased attractiveness of smaller-size cities	Fewer commuting trips Reduced amount of business trips	Lower mileage per capita, all modes
Quest for new lifestyles	Increased weight of health and environmental factors in transport choices Experience and adoption of soft mobility	Increased use of “soft” transport modes in cities: walking, biking…, and low-carbon technologies Reduced amount of long-distance recreational trips, shifts towards shorter distances Users’ preference for rail versus air Wider adoption of shared mobility	Lower ownership ratio for private cars Reduced market share for private cars and aviation Increased market share for trains, public transport and non-motorized modes Higher mileage for cars used in shared mobility services Boost in low-carbon mobility
Build more resilient & sustainable cities	Reorganize cities from pendular to polycentric	Increased offer of essential services within short range	Lower mileage per capita, for public transport and cars

Freight transport

According to the international air transport association (IATA) statistical data (IATA, 2020), during the pandemic freight transport by **air** decreased by 15% as of March 2020 compared to March 2019 (by comparison, the 2008 crisis resulted in a temporary decrease of 23%). Still, this is much less than the decrease for passenger air traffic. Indeed, airborne freight is relatively price inelastic and cargo planes are at low risk of acting as vectors for spreading diseases. Due to fewer flights combining passenger and cargo transport, global capacity fell as the largest share of air freight was sustained by (scarce) cargo-only flights. As a consequence, air freight rates increased. Whether the capacity will reach pre-Covid-19 levels is still uncertain.

Rail freight also declined in volumes during the pandemic. However, due to increasing air freight rates and long transit times with ocean freight, long-distance rail could expect to increase their competitiveness and benefit somewhat from the crisis.

Maritime transport demand decreased sharply; ports around the world are way below their capacities. A recovery is still foreseen (OECD International transport Forum, 2020).

Road freight traffic for goods has been hit during the pandemic, but at lower levels than air or maritime, thanks to the increase of e-commerce during lockdowns and the inflexible need for staple foods (OECD International transport Forum, 2020). Road freight has played a vital role in transporting essential products such as pharmaceuticals and medical equipment during the pandemic. The increase in home delivery and e-commerce should result in a larger fleet of vehicles delivering goods to consumers.

Table 8 shows the short- and long-term factors affecting freight transport, due to the Covid-19 pandemic and due to other emerging trends. These factors and their expected effects informed the implementation of measures in the New Normal scenario (see section 2.2.2).

Table 8: Factors affecting freight transport beyond Covid-19

Short-term trend	Factors	Consequences	Overall effect
Pandemic lockdown measures	Large to moderate reduction of traffic	Reduces all types of freight modes	Lower mileage, all modes

Long-term trend	Factors	Consequences	Overall effect
Build for more resilient supply chain	Diversification of supply chain	Re-localisation of (part of) the supply chain, at country or regional levels Increase of short-distance supply Reduced average transport distance for goods and materials	Shift towards shorter distance trips Increase in the share of "local" trade Increase for road and rail freight transport Decrease for ocean and air transport
Increased digitalisation	Growth of e-commerce	Increased last-mile activity	Increased trend for light duty vehicles freight transport and non-motorized modes Development of drones delivery
Low-carbon transition, reduction of fossil fuel consumption	Decelerated economic activity, shift towards lower-carbon sources and renewables in the overall energy system, shift towards alternative fuels in transport	Decrease of fossil fuel trade (different trends per fuel depending on energy system effects)	Lower traffic volumes in maritime transport

Annex 2: Short-term assumptions for transport

Short-term assumptions for passenger and freight activities have been mainly made using GDP variations in 2020, as well as a hypothetic recovery to 2022. GDP assumptions for the 2020-2022 period are taken from IMF (see Annex 7), and a calculated elasticity detailed below is used for each sector for 2020:

Passenger transportation for 2020

Road:

Private vehicle activity is determined using an elasticity between energy consumption in road transport and GDP. Indeed, Enerdata provides 2020 energy consumption variation for a few countries, the European Union and the G20. These data are thus used as they are for given countries in the model, as well as for areas included in the two groups. The average of the available data is considered for the remaining countries. As an elasticity of 1 is assumed between energy consumption in road transport and road activity, the equation is defined by:

$$RoadAct_{2020} = RoadAct_{2019} * (1 + EnerGrw_0 + \frac{GDPgrw - GDPgrw_0}{Elasticity_{Energy-GDP}})$$

Where:

- RoadAct = Road activity for private vehicles
- $EnerGrw_0$ = Energy consumption growth between 2019 and 2020 forecasted before Covid-19
- GDPgrw = GDP growth estimated between 2019 and 2020
- $GDPgrw_0$ = GDP growth between 2019 and 2020 estimated before Covid-19
- $Elasticity_{Energy-GDP}$ = Calculated elasticity between GDP and Energy consumption in road transport

Public transport (rail and bus):

Activity in public transportation is determined using ratios between public and private uses. Apple mobility provides day-by-day changes in driving, transit and walking in some countries, on a 100 base on January 13, 2020. Taking an average on the entire year until mid-October for the available countries, a ratio is calculated between transit and private averages. For other countries, assumptions are made using given data. These ratios are applied to the private vehicles variation to get the public transportation one.

Air:

Air activity is split between domestic and international. The same method as for private vehicles is used, but with air traffic instead of road energy consumption. The International Civil Aviation Organization (ICAO) provides regional data concerning decreases in passengers' number compared to a baseline scenario. Considering the "scenario 1" of the ICAO, which is a V-Shaped optimistic scenario, it is possible to calculate the elasticity between air traffic and GDP. Then, the equation is:

$$AirTraf_{2020} = AirTraf_{2019} * \left(1 + AirGrw_0 + \frac{GDPgrw - GDPgrw_0}{Elasticity_{Air-GDP}}\right)$$

Where:

- AirTraf = Air passengers traffic
- $AirGrw_0$ = Air traffic growth between 2019 and 2020 forecasted before Covid-19
- GDPgrw = GDP growth estimated between 2019 and 2020
- $GDPgrw_0$ = GDP growth between 2019 and 2020 estimated before Covid-19
- $Elasticity_{Air-GDP}$ = Calculated elasticity between GDP and air passenger traffic

Freight transportation for 2020

Road, rail and air:

An elasticity of 1 to the GDP is assumed.

Maritime:

The POLES model endogenously calculates the Covid-19 impact, for each of the different categories of maritime freight (oil tankers, LNG ships, coal transport ships, iron ore ships, bulk chemicals transport, other industrial products transport, grains transport, and container ships for other goods transport).

Activity for 2021-2022

For Base_C19, 2022 sectoral activity is assumed to be as much impacted as GDP compared to no-Covid-19 Baseline. For scenarios with the added transport changes, 2022 sectoral activity is further adjusted with part of the underlying trends described in 2.1.2: with the pandemic acting as a catalyst, part of the effects of drivers (teleworking, digitalization, shortened trips) are considered to be included already in 2022, with the rest of the effect introduced progressively over time as explained in **The pandemic** has also impacted freight activities: trucking, rail, maritime and air cargo has experienced disruptions and slowdowns as a result of both border controls for sanitary measures and more limited demand around the world. The parameters for freight transport in the "New Normal" adopt some of the disruption suffered during the pandemic as a structural change for the future of freight instead of being a transitory event. In this context, an overall moderate reduction in demand due to a limited de-globalisation trend can be anticipated. The need for preparedness and flexibility in case of supply chain disruptions can contribute to shortening supply chains, to a more national or regional scope away from today's largest producing centres. This trend would reduce distances for the international trade, which would produce a shift towards more rail and truck as transport means and less maritime and aircraft. A more detailed look at transport changes observed during the pandemic and how they can be interpreted is provided in **Annex 1**

Table 2.

Year 2021 is calculated by interpolation, assuming a recovery of 75% between 2020 and 2022.

Annex 3: Background policies used as a reference for the New Normal scenario

Up till now[23,] governments have approved over $12.7 trillion of economic stimulus packages in response to the Covid-19 pandemic (Vivid Economics, 2020). However, most countries have failed to prioritize green stimulus, to date, green recovery investment equivalent to 1% over the total response to the Covid-19 pandemic (Bloomberg NEF, 2020a). Governments continue to support polluters, maintaining damaging measures for airlines and other heavy polluters, without environmental strings attached, and rollbacks in environmental regulations (Vivid Economics, 2020). Thus, bigger efforts must be required to ensure an economic recovery that address climate change mitigation and adaptation measures. According to the greener of stimulus index, (Vivid Economics, 2020) announced stimulus to data will have a net negative environmental impact in 16 of the G20 countries and economies

For the New Normal scenario, regulators and legislators have considered actions to help the recovery of the transport sector. The crisis has opened a favourable window for governments to implement regulatory measures directed towards green transport as stimulus plans or as fiscal incentives. Additionally, some governments have conditioned financial support with climate conditions. For example, in France Air France will have to cut its carbon emissions in domestic flights as conditions for government financial support (Reuters, 2020). In this way, the pandemic provides an opportunity to cut CO_2 emissions in the transport sector.

Possible green stimulus plans to make mobility more sustainable can be implemented through accelerating the transition to EV and fuel cell vehicles and supporting the expansion of the necessary infrastructure. Efforts to accelerate the renewal of capital stock and phase out inefficient fossil fuel power plants and engines can be also part of the recovery packages.

Below is an overview of policies and announcements that were used as background references to build the policies in the New Normal scenario (section 2.2):

Actions by country to phase-out Coal power plants

Coal is the most carbon intensive fossil fuel and phasing it out is a key step to achieve the emissions reductions needed to limit global warming. Most emissions from coal are in the electricity sector, and thus directly impact the indirect emissions related to the use of electric vehicles.

[23] by October 2020

Table 9: Main countries legislating actions for phasing-out inefficient coal power plants

Country	Status of ICE Phase-out	Date of action
United Kingdom	plans a coal phase out by 2024 (GOV.UK)	2015
Finland	The Finnish parliament approved a government proposal to ban the use of coal to produce energy from May 1, 2029.	2019[24]
Canada	plans a coal phase out by 2030 (Government of Canada)	2016
Germany	plans a coal phase-out by 2038 (German Commission on Growth, Structural Change and Employment)	2019
Denmark	plans a coal phase out by 2030 (Climate Policy plan Denmark)	2017
Belgium	became coal power free in 2016[25]	
Portugal	The remaining two coal plants in Portugal are expected to close by latest in the 2021[26]	
Austria	closed its last coal-fired power plant on April 2020, becoming the second EU country to exit coal after Belgium in 2016	
Spain	plans a coal phase out by 2030 (PLAN NACIONAL INTEGRADO DE ENERGÍA Y CLIMA 2021-203)27	2018

Source: For the EU: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52020DC0564&from=EN

Actions by country to Phase-out ICE and promote EV and Subsidies to BEV purchase cost

Following the Paris Agreement, several countries have announced to stop the sale of vehicles using fossil fuels as a way to decarbonize the transport sector. Currently, more than 20 countries have taken varying types of actions to phase out ICE vehicles and increase the number of EVs.

Table 10: Main countries legislating actions for phasing-out ICE vehicles and incentivising EV vehicles

Country	Status of ICE Phase-out	Date of action
Belgium	No new ICE vehicles sold after 2026 (De Tijd, 2020)	2020
Canada	No new ICE vehicles sold after 2040 (Canada Climate Plan)	2017

[24] https://uk.reuters.com/article/finland-energy-coal/finland-approves-ban-on-coal-for-energy-use-from-2029-idUKL5N20N6QV
[25] http://www.caneurope.org/publications/press-releases/987-belgium-says-goodbye-to-coal-power-use
[26] https://www.euractiv.com/section/electricity/news/portugals-coal-phase-out-jumps-forward-by-two-years/
[27] https://ec.europa.eu/energy/sites/ener/files/documents/es_final_necp_main_es.pdf

UK	No new ICE vehicles sold after 2030 (Department for Transport, *UK)*	October 2020
China	End production and Sales of ICE vehicles by 2040 (Bloomberg, 2017)	September 2017
Denmark	End sales of ICE 2030 (Morgan, 2018) 5000 EVs on the road by 2019 tax incentive in place	October 2018 Since 2008 (reduced in 2015)
Egypt	No new ICE vehicles sold after 2040 (Burch & Gilchrist, 2020)	2018
France	No new ICE vehicles sold after 2040[28]	July 2017
India	No new ICE vehicles sold after 2030 (Government target)	April 2017
Ireland	No new ICE vehicles sold after 2030 (Government bill)	July 2017
Israel	No new ICE vehicles import after 2030[29]	February 2018
Japan	Incentives program in place for EV sales	Since 1996[30]
Netherlands	No new ICE vehicles sold after 2030 (coalition agreement)	October 2017
Norway	Incentives program in place for EV sales (tax and usage incentives) No new ICE vehicles sold after 2025[31]	Since 1990 2017
Singapore	No new ICE vehicles sold after 2040 Incentives EVs	2020[32][33]
Portugal	Official target and incentive in place for EV sales (Burch & Gilchrist, 2020)	Since 2010
South Korea	EV's account for 30% of auto sales by 2020 (Burch & Gilchrist, 2020) Green new deal incentives for EVs	June 2016 July 2020
Spain	Official target: and incentives in place for EV sales[34] No new ICE vehicles sold after 2040[35]	June 2017

28 https://www.reuters.com/article/us-france-autos-idUSKCN1TC1CU
29 https://www.timesofisrael.com/israel-aims-to-eliminate-use-of-coal-gasoline-and-diesel-by-2030
30 http://www.evaap.org/pdf/incentive.pdf
31 https://elbil.no/english/norwegian-ev-policy/
32 https://www.reuters.com/article/us-singapore-economy-budget-autos-idUSKBN20C15D
33 https://www.straitstimes.com/singapore/transport/singapore-budget-2020-push-to-promote-evs-in-move-to-phase-out-petrol-and-diesel
34 https://wallbox.com/en_us/spain-ev-incentives
35 https://phys.org/news/2018-11-spain-sale-gas-diesel-cars.html

		2018
Taiwan	Official target: Phase-out fuel powered motorcycles by 2035 and fuel powered vehicles by 2040 (Burch & Gilchrist, 2020)	December 2017
Sweden	Official target Phase out ICE vehicles after 2030 (Government offices Sweden, coalition agreement)	2019

Subsidies for green hydrogen production (electrolysis)

Hydrogen can play a fundamental role in achieving a greener economy. To recover from the economic recession caused by Covid-19, investments in hydrogen can help to scale up the nascent hydrogen industry.

Table 11: Main incentives for promoting H_2 renewable production capacity by electrolysers

Country	Status	Date of action
EU	Hydrogen strategy for a climate neutral Europe. The European clean hydrogen alliance[36] First phase: install at least 6 GW of electrolysers in the EU to produce 1Mtn of renewable hydrogen. Second phase: install at least 40 GW electrolysers to produce up to 10Mtn of renewable hydrogen in the EU	(2020-24) (2024-30)
Norway	hydrogen produced through electrolysis is exempt from electricity consumption taxes (not from grid tariffs though (Dolci, et al., 2019))	
Netherlands	Specific subsidies: Ministry of Economic Affairs established a subsidy programme for energy projects, including a specific subsidy for hydrogen-related projects (not limited to production). The maximum allowable funding is 750,000 € per project (Dolci, et al., 2019)	

Energy taxation for international aviation and maritime transport

Currently, emissions from international aviation and maritime transport are not taxed at all (OECD, 2019). Fuels used in domestic aviation and domestic navigation are sometimes taxed. Most of these emissions are not subject to emissions trading systems either. An exception is the intra-EU aviation sector, which is part of the EU Emissions Trading System.

In November 2019, EU finance ministers discussed taking action to end the fuel tax exemptions enjoyed by the aviation and shipping sectors[37]. Nine EU States (Belgium, Bulgaria, Denmark, France, Germany, Italy,

[36] Communication COM/2020/301: A hydrogen strategy for a climate-neutral Europe

[37] https://www.transportenvironment.org/news/eu-finance-ministers-move-tax-aviation-fuel-after-un-agency-dithers

Luxembourg, the Netherlands and Sweden) called on introducing an EU-wide tax on aviation[38], in the form of both uniform air passenger taxes as well as kerosene taxes.

Furthermore, as a part of the European Green Deal, the inclusion of international maritime shipping in the EU ETS is under discussion.

R&D investment for Energy density of batteries for electricity-powered aircraft

Currently, the UK has positioned itself at the forefront of electric and hybrid aircraft research and development. The Business and Energy Secretary announced in 2018 that from the total (£343 million) government industry investment for research and development, £255 million should go towards 18 new research and technology projects, including the development of cleaner and greener hybrid aircraft (GOV.UK).

[38] https://www.euractiv.com/section/aviation/news/nine-eu-countries-urge-new-commission-to-tax-aviation-more/

Annex 4: Policies considered

The scenario presented in this report builds on past work: GECO 2018 (Keramidas, et al., 2018) and GECO 2019 (Keramidas, et al., 2020). The Base_noC19, Base_C19, Base_C19+TC and New Normal scenarios all build from the GECO 2019 Reference scenario, which included adopted energy and climate policies in world countries until June 2019. A full list of the policies considered in the GECO 2019 Reference scenario can be found in the GECO 2019 report. The New Normal includes additional policies described in section 2.2.3.

The 2°C and 1.5°C scenarios include the policies of the New Normal scenario of section 2.2.3 and an economy-wide carbon price. The country-level policies of the New Normal inherited from GECO 2019 Reference were removed from the 2°C and 1.5°C scenarios, 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 carbon price scenarios.

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 a specialized sectoral model[39].

For the 2°C scenario, the carbon price is differentiated by country according to per capita income until 2050, with the same price afterwards. The corresponding carbon price followed the differentiation presented in **Table 12**, with 100% representing a "leading" carbon price that increases over time.

Table 12: Carbon price differentiation in the 2°C scenario

Income in 2030 (USD(2015)/cap)	Countries	2021	2030	2050 and beyond
> 30,000	EU, Australia, Canada, Iceland, Japan, Korea (Republic), New Zealand, Norway, Switzerland, United States	100%	100%	100%
20,000-30,000	Chile, China, Malaysia, Russian Federation, Saudi Arabia, Turkey	60%	100%	100%
10,000-20,000	Algeria and Libya, Argentina, Brazil, Iran, Mediterranean Middle-East, Mexico, Rest of Balkans, Rest of CIS, Rest of Persian Gulf, Rest of South America, South Africa, Thailand, Tunisia, Morocco and Western Sahara, Ukraine	40%	100%	100%
<10,000	Egypt, India, Indonesia, Rest of Medium America and Caribbean, Rest of Pacific, Rest of South Asia, Rest of South-East Asia, Rest of Sub- Saharan Africa, Vietnam	20%	67%	100%

[39] The projections for agriculture and land use metrics in this report were done by soft-linking the specialized model GLOBIOM-G4M (IIASA, 2017) with the energy system model POLES-JRC.

Annex 5: Description of POLES-JRC

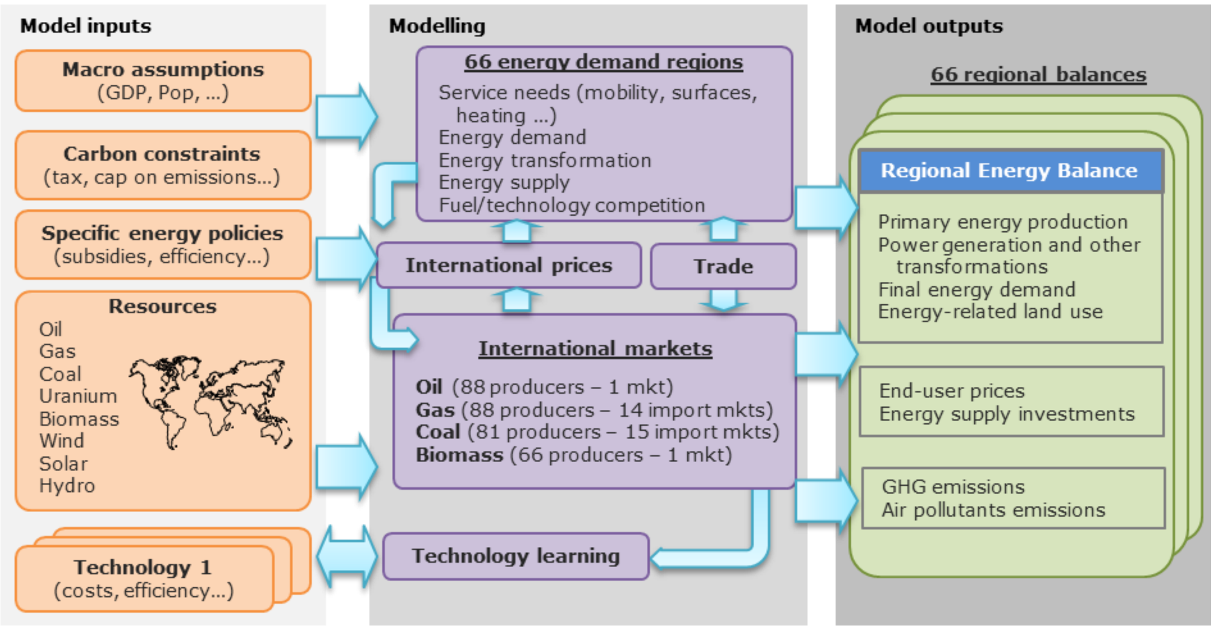
For a more comprehensive description of the model, see (Després, Keramidas, Schmitz, Kitous, & Schade, 2018).

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 35**).

The model provides full energy and emission balances for 66 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 POLES-JRC 2019 version as a starting point. Differences with other exercises done with the POLES-JRC model, or with exercises by other entities using the POLES model, can come from different model version, historical data sets, parameterisation, and/or policies considered.

Figure 35. POLES-JRC model general scheme



Source: POLES-JRC model.

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 (vintage 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). 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.

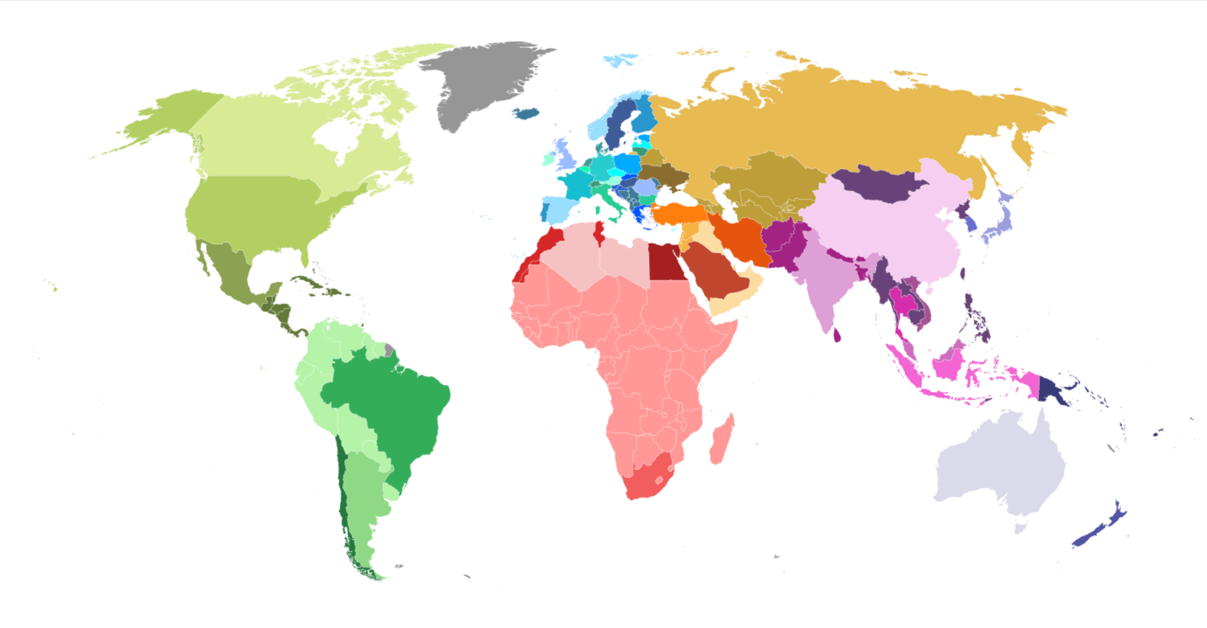
GHG emissions

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.

Countries and regions

The model decomposes the world energy system into 66 regional entities: 54 individual countries and 12 residual regions see **Figure 36**, to which international bunkers (air and maritime) are added.

Figure 36. POLES-JRC model regional detail map (for energy balances)



Source: POLES-JRC model

Table 13. List of 54 individual countries represented in POLES-JRC (for energy balances)

Non-EU individual countries	EU Member States
Argentina	Austria
Australia	Belgium
Brazil	Bulgaria
Canada	Croatia
Chile	Cyprus
China	Czech Republic
Egypt	Denmark
Iceland	Estonia
India	Finland
Indonesia	France
Iran	Germany
Japan	Greece
Malaysia	Hungary

Mexico	Ireland
New Zealand	Italy
Norway	Latvia
Russia	Lithuania
Saudi Arabia	Luxembourg
South Africa	Malta
South Korea	Netherlands
Switzerland	Poland
Thailand	Portugal
Turkey	Romania
Ukraine	Slovak Republic
United Kingdom	Slovenia
United States	Spain
Vietnam	Sweden

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

Table 14. Country mapping for the 12 regions in POLES-JRC (for energy balances)

Rest Central America	Rest Balkans	Rest Sub-Saharan Africa (continued)	Rest South Asia
Bahamas	Albania	Burkina Faso	Afghanistan
Barbados	Bosnia-Herzegovina	Burundi	Bangladesh
Belize	Kosovo	Cameroon	Bhutan
Bermuda	Macedonia	Cape Verde	Maldives
Costa Rica	Moldova	Central African Republic	Nepal
Cuba	Montenegro	Chad	Pakistan
Dominica	Serbia	Comoros	Seychelles
Dominican Republic	**Rest CIS**	Congo	Sri Lanka
El Salvador	Armenia	Congo DR	**Rest South East Asia**
Grenada	Azerbaijan	Cote d'Ivoire	Brunei
Guatemala	Belarus	Djibouti	Cambodia
Haiti	Georgia	Equatorial Guinea	Lao PDR
Honduras	Kazakhstan	Eritrea	Mongolia

Jamaica	Kyrgyz Rep.	Ethiopia	Myanmar
Nicaragua	Tajikistan	Gabon	North Korea
NL Antilles and Aruba	Turkmenistan	Gambia	Philippines
Panama	Uzbekistan	Ghana	Singapore
Sao Tome and Principe	Mediterranean Middle East	Guinea	Taiwan
St Lucia	Israel	Guinea-Bissau	Rest Pacific
St Vincent & Grenadines	Jordan	Kenya	Fiji Islands
Trinidad and Tobago	Lebanon	Lesotho	Kiribati
Rest South America	Syria	Liberia	Papua New Guinea
Bolivia	Rest of Persian Gulf	Madagascar	Samoa (Western)
Colombia	Bahrain	Malawi	Solomon Islands
Ecuador	Iraq	Mali	Tonga
Guyana	Kuwait	Mauritania	Vanuatu
Paraguay	Oman	Mauritius	
Peru	Qatar	Mozambique	
Suriname	United Arab Emirates	Namibia	
Uruguay	Yemen	Niger	
Venezuela	Morocco & Tunisia	Nigeria	
	Morocco	Rwanda	
	Tunisia	Senegal	
	Algeria & Libya	Sierra Leone	
	Algeria	Somalia	
	Libya	Sudan	
	Rest Sub-Saharan Africa	Swaziland	
	Angola	Tanzania	
	Benin	Togo	
	Botswana	Uganda	
		Zambia	

Source: POLES-JRC model.

Data sources

Table 15. POLES-JRC model historical data and projections

Series		Historical data	GECO Projections
Population		(European Comission, 2020b), (Eurostat, 2020)	
GDP, growth		(World Bank, 2019); (IMF, June 2020) (IMF, April 2020)	(OECD, Long-term baseline projections, No. 95 (Edition 2014), 2014) and (OECD, Long-term baseline projections, No. 103, 2018)
Other activity drivers	Value added	World Bank	POLES-JRC model
	Mobility, vehicles, households, tons of steel, …	Sectoral databases	
Energy resources	Oil, gas, coal	BGR, USGS, WEC, Rystad, sectoral information	
	Uranium	NEA	
	Biomass	GLOBIOM model	
	Hydro	Enerdata	
	Wind, solar	NREL, DLR	
Energy balances	Reserves, production	BP, Enerdata	
	Demand by sector and fuel, transformation (including. power), losses	Enerdata, IEA	
	Power plants	Platts	
Energy prices	International prices, prices to consumer	Enerdata, IEA	POLES-JRC model
GHG emissions	Energy CO_2	Derived from POLES-JRC energy balances	POLES-JRC model
	Other GHG Annex 1	UNFCCC	POLES-JRC model, GLOBIOM-G4M model
	Other GHG Non-Annex 1 (excl. LULUCF)	EDGAR	POLES-JRC model, GLOBIOM-G4M model
	LULUCF Non-Annex 1	National inventories, FAO	POLES-JRC model, GLOBIOM-G4M model
Air pollutants emissions		GAINS model, EDGAR, IPCC, national sources	GAINS model, national sources
Technology costs		POLES-JRC learning curves based on literature, including but not limited to: EC JRC, WEC, IEA, TECHPOL database	

Annex 6: Description of PIRAMID

The macroeconomic balances for a scenario with COVID-19 are constructed on the basis of a variety of data sources, in particular achieving an integration of macroeconomic forecasts with energy balances from PRIMES for the EU27 and POLES-JRC for non-EU regions (see (Rey Los Santos, et al., Global macroeconomic balances for mid-century climate analyses, 2018) and (Wojtowicz K. , et al., 2019). The main data sources for the version used in GECO 2020 include

- The input-output tables and the data on bilateral trade flows are derived from the Global Trade Analysis Project (GTAP) 10 database (Aguiar, Chepeliev, Corong, MacDougall, & Van der Mensbrugghe, 2019). We aggregate the GTAP data to 31 commodities and the regions listed in **Table 16**.
- GDP growth rates are assumed to be the same as in the PRIMES and POLES-JRC models for the EU and non-EU regions, respectively. The GDP assumptions are described in **Annex 7**. Projections include the effects of Covid-19.
- The International Labour Organisation (ILO) database was used to project population and labour statistics such as labour force, unemployment rate 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 2021 Ageing report (European Comission, 2020b) was used.
- Energy and emission data using energy balances from PRIMES (for EU27) and POLES-JRC (Base_C19+TC scenario, for non-EU regions). The alignment with energy balances and emission factors implies that the emission levels of greenhouse gases (totals and by sector) and the shares of electricity generation technologies are harmonised with the reference in the POLES-JRC and PRIMES models.

In simple terms, our integration approach uses the Platform to Integrate, Reconcile and Align Model-based Input-output Data (PIRAMID) to construct input-output tables for future years up to 2050 in 5-year-steps, using a balancing procedure that ensures consistency of the various data sources within a National Accounting framework. We extend the procedure, commonly known as RAS procedure, to include data from various sources in a multi-regional context (hence, multi-regional generalised RAS, or MRGRAS).

Before applying the balancing MRGRAS framework, the data has to be pre-processed. This includes the translation of the GTAP data into a multi-regional input-output (MRIO) table, taking into account the intra-region trade for aggregate regions (e.g. trade within the Other Asia region, which consists of an aggregation of GTAP regions). In a first step, all MRIO components are projected into the future, excluding the value added by sector. For this, GDP is first decomposed into its components (private consumption, government consumption and investment) which are then translated into final demand for the 31 commodities (Rey Los Santos, et al., 2018). Certain demand categories can be directly specified, such as demand for energy goods as these are harmonized with data from the energy models. Likewise, certain elements of the input-output tables (e.g. energy demand for key sectors) is taken from the energy models and is not adjusted in the re-balancing procedure, using quantity and price information to calculate monetary flows needed for the input output table. Value added over all sectors sums to GDP per definition, and we align sectoral value added projections for key sectors to be consistent with the overall macroeconomic projections and in particular the energy use projections by sector. In the context of GECO 2020, this is especially important for the transport sectors where a strong decline in value added and energy use is observed for 2020. In the next step, the tables are re-balanced using the MRGRAS routine and then the value added block is decomposed into its components (capital, labour, taxes and subsidies). Taxes and subsidy rates are constant in the forward projection except for carbon taxes which are taken from the energy models.

Table 16. Regional aggregation of the macroeconomic baseline tables

Regions in the JRC-GEM-E3 model	Abbreviation
European Union	EU27
United Kingdom	GBR
Brazil	BRA
Canada	CAN
China	CHN
India	IND
Japan	JPN
South Korea	KOR
Russia	RUS
United States	USA
Oceania	ANZ
Middle East	MEA
Africa	AFR
Other Americas	OAM
Other Asia	OAS
Rest of Europe (EFTA, Western Balkans, Ukraine, Belarus, Moldau)	REU

Annex 7: Socio economic assumptions and fossil fuel prices

The population assumptions follow Europop (Eurostat, 2020) for EU and JRC-IIASA projections (JRC-IIASA, 2018) for the rest of the world.

The GDP projections follow numbers of the 2021 Ageing Report for the EU (European Comission, 2020b); for the rest of the world, the sources are IMF (World Economic Outlook) and the OECD (CIRCLE project). The projections for the EU are based on the 2020 spring forecast (European Commission, 2020) which assumed a relatively fast recovery. The IMF June projections only cover large non-EU countries, gaps for other regions were filled using the more detailed IMF April forecast. See references at **Table 17**.

Table 17: GDP assumptions

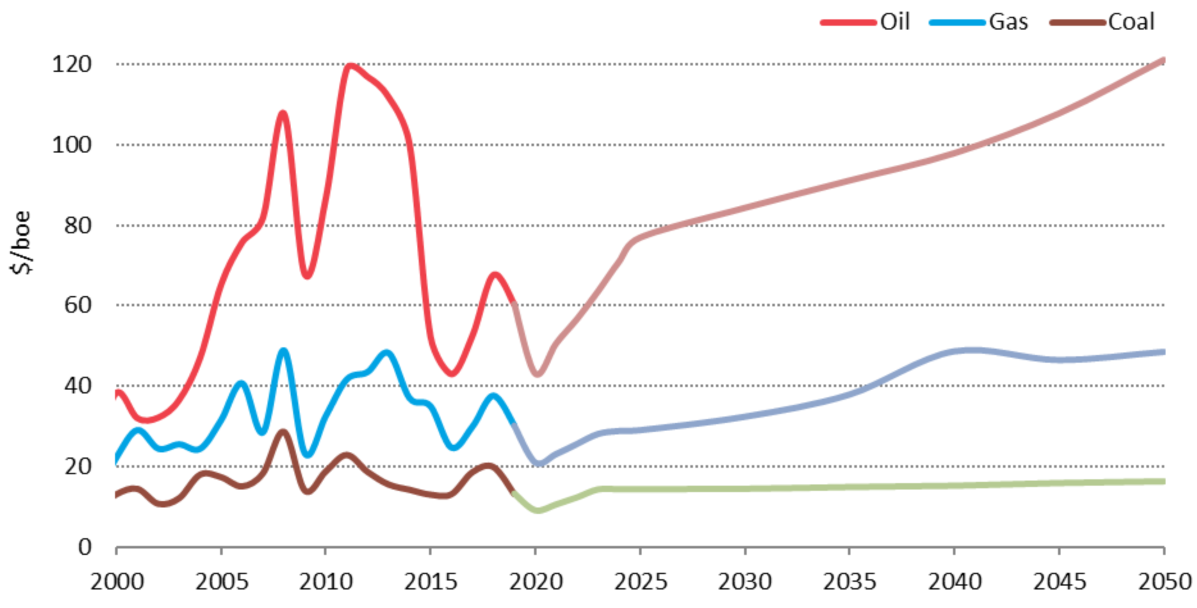
Group	Historical (to 2019)	2019-2024	2025-2030	2031-2050	2051-2060	2061-2070	2071-2100
EU27	WB Oct-2019	2021 Ageing Report			intrapolation	GDP/cap as SSP x Europop	
Large non-EU	WB Oct-2019	IMF June-2020	intrapolation	GDP OECD Jul-2018 (2) / Pop IIASA-JRC		intrapolation	GDP/cap as SSP x Pop IIASA-JRC
Rest of World	WB Oct-2019	IMF Apr-2020	intrapolation	GDP/cap as SSP x Pop IIASA-JRC			

Sources: (Eurostat, 2020), (IMF, June 2020) (World Bank, 2019), (European Comission, 2020b) (IMF, April 2020) (OECD, Long-term baseline projections, No. 103, 2018), (OECD, Long-term baseline projections, No. 95 (Edition 2014), 2014)

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

The international fossil fuel prices in the New Normal scenario are shown in **Figure 37**. They were endogenously calculated by the POLES-JRC model.

Figure 37: International fossil fuel prices in the New Normal scenario



Note: Oil prices refer to Brent; gas and coal prices refer to the average imports to the European market. Source: POLES-JRC model.

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