# Technical annex

* 1. Detailed methodology for deriving cumulative emissions and EU ETS budgets associated with the European Commission’s Long-term Strategic Vision

While Article 15 of the EU Governance Regulation (EU 2018b) requires the Commission’s Long-term Strategy to address the strategy’s implications with regard to the remaining global and Union carbon budget, the budget considerations in the Commission’s Long-term Strategic Vision (in the following we refer to it as “EU LTS”) are rather limited. For the scenarios considered in the In-depth Analysis (EU 2018d), cumulative net carbon emissions (incl. Land Use, Land-Use Change and Forestry, LULUCF) are given in Table 9 of the document.

To assess the implications of a pathway consistent with a global warming of 1.5°C for the EU ETS, we derive cumulative emissions for the EU ETS. The EU LTS includes two scenarios that are stated to be consistent with a global pathway limiting warming to 1.5°C, 1.5TECH and 1.5LIFE (EU 2018c). For our assessment of the EU ETS budget, we consider the cumulative GHG emissions of the average of the scenarios 1.5TECH and 1.5LIFE as an emission budget target consistent with the Vision’s goal of achieving net-zero emissions by 2050. The total GHG emissions given there include GHG emissions from international transport, but exclude LULUCF. For a comparison with similar estimates, we consider total GHG emissions without LULUCF and remove GHG emissions from international transport based on data from the In-depth Analysis. Here, we assume that 10% of aviation is domestic and that the scenario 1.5LIFEMar for international transport is used in both 1.5TECH and 1.5LIFE.

The emission reduction in the scenarios 1.5TECH and 1.5LIFE is strongly non-linear between 2020 and 2050. We, hence, cannot estimate the cumulative emissions based on a linear pathway. However, the EU LTS does not provide information on the emission levels between 2030 and 2050 except for sectoral emissions of the scenarios 1.5TECH and 1.5LIFE in Figure 90 of the In-depth Analysis. The data underlying this figure are published on the EC website as supplementary information. We use these data to derive the total 2040 emission levels and estimate the EU ETS emissions in 2040 based on remaining emissions in the energy and the industry sector as well as negative emission from the use of CCS.

The In-depth Analysis (EU 2018d) provides information on the GHG emissions in the scenarios 1.5TECH and 1.5LIFE in 2030 and 2050 but for the EU ETS only in 2050 (in Table 9). However, all scenarios considered in the EU LTS differ only very little before 2030. They are based on the policies and regulations currently in place, in particular the RE target for 2030 of 32% and the energy efficiency 2030 target of 32.5%. The same assumptions are the basis for the scenario EUCO3232.5 considered in a recent technical note (EU 2019a). Moreover, all scenarios are based on the model PRIMES. Therefore, we assume that the data on the EU ETS emission in the scenario EUCO3232.5 for 2026 and 2030 applies to the scenarios 1.5TECH and 1.5LIFE as well. The EUCO3232.5 scenario specifies ETS emissions for the 2013 scope including aviation. Here, we work with the 2013 scope excluding aviation. Therefore, we apply the relative reductions in the scenario EUCO3232.5 (–32.8% by 2026 and -49.8% by 2030) instead of the absolute values. For 2015 and 2020, we assume that the current cap applies.

As no information for further intermediate years is available, we assume a linear decline in 2015-2020, 2020-2025, 2025-2030, 2030-2040 and 2040-2050 in the calculation of the cumulative emissions for the period 2016 to 2050. The final results can be shown to be equivalent to the cumulative emissions for 2016-2050 after a linear interpolation to all intermediate years. For the total cumulative GHG emissions in 2016-2050 (excl. LULUCF and international transport), we end up with 78 Gt CO2e[[1]](#footnote-1). For the GHG emissions in EU ETS sectors in 2016-2050, we find cumulative emissions of 33 Gt CO2e (see Table 5).

*--- Insert Table 5 about here ---*

* 1. Detailed methodological considerations for deriving emission budgets for the EU ETS from global emission pathways

In the main text, we present a globally cost-effective EU ETS share of the global 1.5°C emission pathways based on data from the IPCC SR1.5, the corresponding scenarios as well as data from the POLES-Enerdata model, namely the 2018 Enerfuture global energy scenarios and associated marginal abatement cost curves (MACC).[[2]](#footnote-2) Our calculations are based on the class of pathways called below-1.5°C pathways in the IPCC SR1.5. This most ambitious class of pathways is defined as achieving a probability of 50 – 66% of staying below 1.5°C of warming for the entire 21st century. These pathways are, hence, as close as possible to the requirement of limiting global warming to 1.5°C with 66% probability. However, the IPCC SR1.5 scenarios do not provide regional data for the EU and only aggregated sectoral data. That is why we use the POLES data for the regional and sectoral split. Here, we describe the technical details how we translate the global budget into an emission budget for the EU ETS step by step.

*Step 1: Derive a global pathway for energy- and process-related CO2 emissions based on below-1.5°C pathways in the IPCC SR1.5 and the corresponding data in the IAMC 1.5°C scenario explorer*

As the marginal abatement cost curve data from the POLES-Enerdata model we use applies to the energy- and process related emissions only, we require these for the below-1.5°C pathways. Therefore, we derive the median level of global energy- and process-related CO2 emissions (called fossil fuel and industry emissions in the IPCC SR1.5 and the IAMC 1.5°C scenario explorer) for the years 2025, 2030, 2040 and 2050 from the IAMC 1.5°C scenario explorer (see Table 6). The figures for 2030 and 2050 are consistent with those provided for the below-1.5°C pathways in Table 2.4 of the IPCC SR1.5.

*--- Insert Table 6 about here ---*

*Step 2: Derive a global pathway for energy- and process-related GHG emissions by estimating non-CO2 energy- and process-related emissions*

Next, we need to take into account non-CO2 GHG emissions because both the data on the ETS in the Commission’s In-depth Analysis (EU 2018d) and the data from the POLES-Enerdata model we use include non-CO2 emissions. Note that while there are large uncertainties about the reduction of non-CO2 emissions from agriculture and waste, non-CO2 emissions in the EU ETS have been reduced to less than 1% of the total cap already. Hence, for the calculations regarding ETS sectors, non-CO2 emissions do not play a major role quantitatively. We translate the energy- and process-related CO2 emission levels into energy- and process-related GHG emission levels by adding a fixed increase of 15% to the energy- and process-related CO2 emissions[[3]](#footnote-3) throughout the period with positive emissions. In particular, this results in 18.9 Gt of CO2e energy- and process-related emissions globally in 2030 and 1.1 Gt CO2e in 2050. As the share of energy-related non-CO2 emissions in the EU is substantially smaller, this may lead to a slight overestimation of the EU emission budget.

*Step 3: Derive corresponding regional and sectoral emission pathways by applying a global carbon price pathway based on the POLES-Enerdata model (2018 version)*

At each time step, we translate the global energy- and process-related GHG emission pathways for the period 2016 – 2050 into national emission levels by applying a globally uniform shadow carbon price pathway that yields the globally required emission reductions according to the MACCs coming from the POLES-Enerdata model. We note that this minimizes the marginal abatement costs at each time step, but does not necessarily correspond to a cost-minimizing pathway in the POLES-Enerdata model, as the annual emission reduction requirements are based on the variety of models in the IPCC database (see Step 1). The resulting carbon price level is 220 USD/t in 2025, 800 USD/t CO2e in 2030. This steep increase reflects a sharp abatement cost increase beyond a certain level of mitigation.

For the years after 2030, the required emission reduction exceeds the reduction at the maximum carbon price of 1200 USD/t in POLES-Enerdata. Therefore, we assume the existence of a backstop-technology (e.g. a negative emissions technology) and scale the minimum sectoral emission levels in POLES to the required level uniformly across sectors. Then the globally uniform shadow carbon price is applied to derive a cost-effective share of the global emission pathway for the EU. The described scaling of the emissions after 2030 is applied here as well. This results in energy- and process-related GHG emission level in the EU of 1.7 Gt CO2e in 2030, 0.5 Gt CO2e in 2040 and 0.1 Gt CO2e in 2050 (see Table 7). The steep increase of the carbon price suggests that using the POLES data for an inter-temporal cost minimization would lead to a higher price level in 2025 and lower ones at later points in time. However, our intention here is to use the POLES data for the sectoral and regional split of emissions only, in order to derive a European emission pathway consistent with the global IPCC pathways.

*--- Insert Table 7 about here ---*

*Step 4: Derive consistent evolution of the emission cap for the EU ETS sectors*

The ENERDATA-Poles model provides data at the sub-sectoral level for the electricity sector as well as for the steel, the cement and the chemical industry. We use the sum of these four sectors as a basis for the estimate of the emissions of stationary ETS installations. To this end, we calibrate their sum for 2015 to the EU ETS emissions, where they made up roughly three quarters of the EU ETS emissions. Other options here would be to use the total industry emissions or the total energy-sector emissions from ENERDATA-Poles for the calibration. This changes the estimate by less than 2%. Our choice is based on the fact that the selected sectors include almost no non-CO2 emissions, thereby leading to less uncertainty in this regard. Then, the globally uniform shadow carbon price is applied to derive a cost-effective share for all the sectors in the EU. The emissions of the electricity, the steel, the cement and the chemical industry are used to estimate the EU ETS emission levels based on the calibration for 2015. This results in EU ETS emissions of 0.9 Gt CO2e in 2030, 0.3 Gt CO2e in 2040 and net-zero emissions in 2050 (see Table 8).

*Step 5: Derive a cost-effective EU ETS budget by calculating the cumulative emissions of EU ETS sectors in a cost-effective pathway*

Analogously to the calculation for the EU LTS, we assume a linear decline in 2015-2020, 2020-2025, 2025-2030, 2030-2040 and 2040-2050 in the calculation of the cumulative emissions for the period 2016 to 2050. For the calculation, we again multiply the mean of the end and start year of the various periods with the corresponding number of years, and add up the results for all periods. Afterwards, we add half of the value in 2050 and reduce the result by half of the value in 2015 to obtain the result for the period 2016 to 2050. In this way, the cost-effective GHG emission budget for the EU ETS is calculated to be about 30 Gt (see Table 8).

*--- Insert Table 8 about here ---*

Table 5: Annual and cumulated GHG emissions of the EU Long-term Strategic Vision (mean of the scenarios 1.5LIFE and 1.5TECH)

| [Gt CO2e] | 2015 | 2020 | 2030 | 2040 | 2050 | 2016-2050 |
| --- | --- | --- | --- | --- | --- | --- |
| Total GHG (excl. LULUCF incl. international transport) | 4.6 | 4.1 | 3.1 | 1.2 | 0.4 | 85 |
| Total GHG (excl. LULUCF and international transport) | 4.3 | 3.8 | 2.8 | 1.0 | 0.3 | 76 |
| EU ETS GHG emissions | 2.0 | 1.8 | 1.2 | 0.3 | 0.0 | 33 |

Source: Own calculations (Fraunhofer ISI) based on EU (2018d), Figures 60, 61, 90 and Table 9. Emission levels are calculated using the mean of the scenarios 1.5LIFE and 1.5TECH

Table 6: Global energy- and process related CO2 emissions in the median below-1.5°C pathways in the IAMC 1.5°C scenario explorer

| [Gt CO2] | 2025 | 2030 | 2035 | 2040 | 2050 |
| --- | --- | --- | --- | --- | --- |
| Median of the below-1.5°C pathways | 25.6 | 16.4 | 9.8 | 6.0 | 1.0 |

Source: Own calculations (Fraunhofer ISI) based on the IAMC 1.5°C scenario explorer

Table 7: Annual energy- and process-related GHG emissions of the EU in a cost-effective pathway compatible with a global below-1.5°C pathway

| [Gt CO2e] | 2025 | 2030 | 2035 | 2040 | 2050 |
| --- | --- | --- | --- | --- | --- |
| EU energy- and process-related GHG emissions | 2.7  | 1.7 | 1.0 | 0.5 | 0.1 |

Source: Own calculations (Fraunhofer ISI) based on data from the ENERDATA-Poles model

Table 8: Annual and cumulated GHG emissions of the EU ETS in a cost-effective pathway compatible with a global below-1.5°C pathway

| [Gt CO2e] | 2015 | 2020 | 2030 | 2040 | 2050 | 2016-2050 |
| --- | --- | --- | --- | --- | --- | --- |
| EU ETS GHG emissions | 2.0 | 1.8 | 0.9 | 0.3 | 0.0 | 30 |

Source: Own calculations (Fraunhofer ISI) based on data from the ENERDATA-Poles model

1. The In-depth Analysis lists cumulative CO2 emissions of 48 – 49 Gt CO2 for 2018-2050. Note that these include LULUCF and exclude non-CO2 GHG emissions. Moreover, the period considered differs from ours by two years characterized by high emissions. [↑](#footnote-ref-1)
2. See <https://www.enerdata.net/solutions/poles-model.html> for a description of the POLES model and <https://www.enerdata.net/research/forecast-enerfuture.html> for a description of the Enerfuture global energy scenarios [↑](#footnote-ref-2)
3. This reflects the global 2015 share of energy- and process-related CO2 emissions in total energy- and process-related GHG emissions of 87%. [↑](#footnote-ref-3)