CLIMATE-CARBON INTERACTIONS IN THE CURRENT CENTURY

4C CARBON OUTLOOK 2021

NOVEMBER 2021

Fossil CO_2 emissions rebounded to just below pre-pandemic levels in 2021, reaching 36.4 $GtCO_2$ and further shrinking the remaining carbon budget to keep global warming below 1.5°C.

Despite recent progress in climate policy and technology, fossil CO_2 emissions are still not declining. Stronger climate policies are needed to trigger the necessary short-term action to reduce CO_2 emissions sufficiently in the coming decade to keep the option for 1.5°C alive.

2021 CO_2 EMISSIONS REBOUND TO PRE-PANDEMIC LEVELS

- Global fossil CO_2 emissions are expected to rebound 4.9% in 2021 (range, 4.1-5.7%), after a sharp reduction caused by the COVID pandemic in 2020 (5.4%).
- The emission increase in 2021 is projected to be 1.6 billion tonnes of CO_2 ($GtCO_2$), which is similar to that seen in 2010 after the global financial crisis of 2008-2009 (5.5%, 1.7 $GtCO_2$).
- Fossil CO_2 emissions in 2021 are estimated to reach 36.4 $GtCO_2$, remaining 0.8% below the pre-pandemic level of 2019, and slightly below the decade trend from 2010 to 2019.

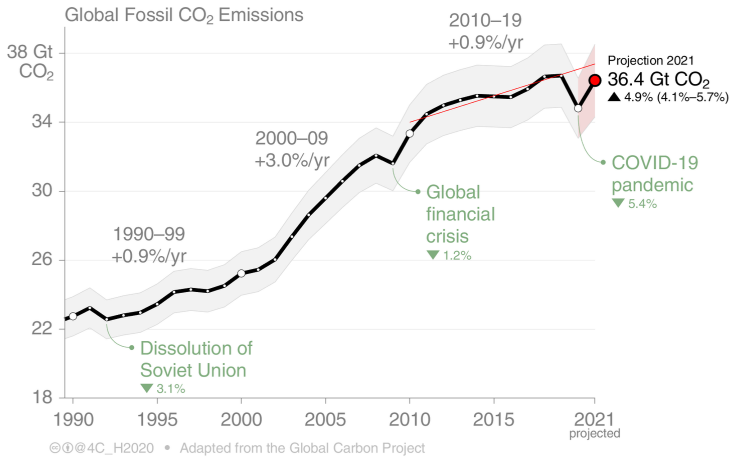

Figure 1. The 2021 projection is based on preliminary monthly data and modelling. The trend line is based on the data from 2010 to 2019 and extrapolated forward to 2021, showing that fossil CO2 emissions are almost back on trend.

DRIVERS OF FOSSIL CO_2 EMISSION[1]

- **Fossil fuel types**: Emissions from **coal** use in 2021 are projected to be 1.1% above their 2019 levels, but still below their peak in 2014. Emissions from **gas** use are also expected to rise 1.9% above their 2019 levels. CO_2 emissions from **oil** remain 5.7% below their 2019 levels in 2021 (Fig. 2A). Coal and gas remain on their decade trend estimated from 2010 to 2019, while oil remains well below the decade trend.
- **Economic sectors**: At the global level for 2021, emissions from the **power** and **industry** sectors are estimated to be above 2019 levels. Emissions in **road transport** and **aviation** still appear to be below 2019 levels, as this activity has not returned yet to pre-pandemic levels.[2]
- **Countries**: **China** was one of the only countries to have positive emissions growth in 2020 that has continued into 2021, with growth in all fossil fuels, with coal potentially exceeding its 2013 peak. The **USA** and the **European Union** (EU27) both had similar declines in 2020 (-11%) and similar increases in 2021 (-8%), putting them both -4% below 2019 levels, in line with pre-COVID trends. Emissions in **India** dropped 7% in 2020, but grew strongly in 2021, with coal up by 15% and total emissions now 4.4% above 2019 levels (Fig. 2B). The USA, EU27, and India have all returned to their decade trend from 2010 to 2019, while China is now slightly above its decade trend in 2021. The aggregate of all other countries, ~40% of global emissions, is well below its 2010 to 2019 trend.

Data for 2021 show that the countries responsible for most of the global fossil CO_2 emissions were China (30%), USA (14%), EU27 (7.5%) and India (7.5%), while the rest of the world accounts for 41% of emissions. These shares are based on territorial emissions and do not account for international trade.

[1] Other human activities and other greenhouse gases produced are also contributing to climate change. This analysis focuses solely on CO_2, which is the major driver of climate change.

[2] Data from Carbon Monitor, https://carbonmonitor.org/

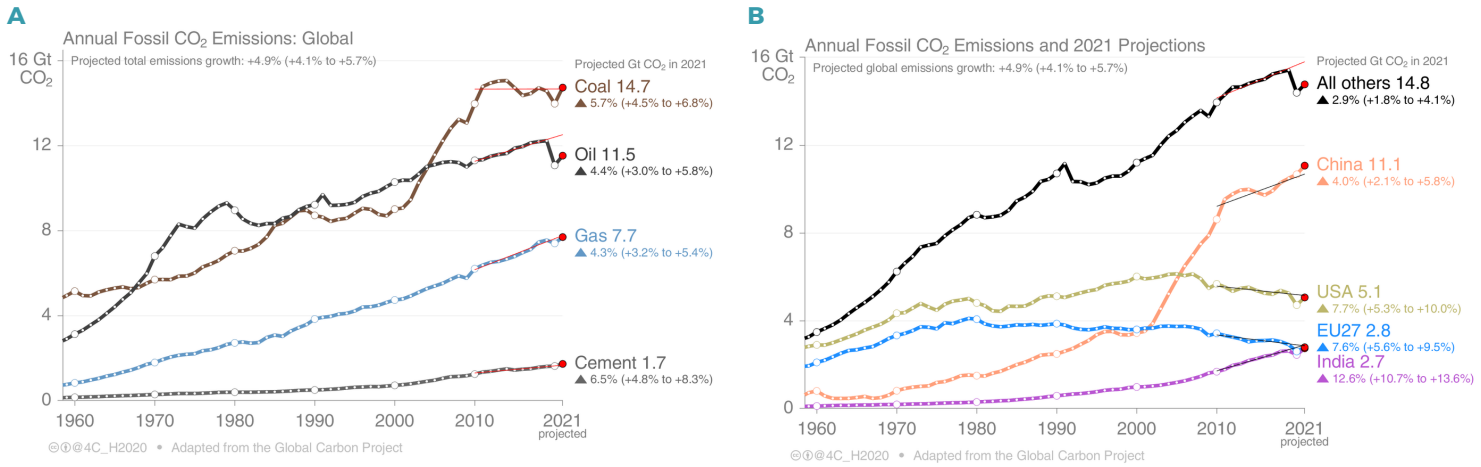

Figure 2. Annual fossil CO_2 emissions by type (A) and country (B). The 2021 projection is based on preliminary monthly data and modelling. The trend line is based on the data from 2010 to 2019 and extrapolated forward to 2021.

ATMOSPHERIC CO_2 ACCUMULATION

- The level of CO_2 in the atmosphere is expected to exceed 415 parts per million (ppm) at the end of 2021, showing an annual increase of 2.0 ppm compared to 2020 levels.
- Global-average atmospheric CO_2 concentrations in 2021 are 50% above pre-industrial levels.
- The CO_2 concentration has a distinct seasonal cycle driven by photosynthesis and respiration of the terrestrial biosphere (Fig. 3). A drop in concentration is seen as the Northern Hemisphere spring starts and photosynthesis strengthens, and the opposite happens during the Northern Hemisphere autumn leading to a peak in the cycle.

CARBON SINKS

- Over the last five years the atmospheric CO_2 concentration has increased by ~2.5 ppm per year, which is about half of the total amount of CO_2 added to the atmosphere by human activities. The remaining CO_2 is taken up by the land and ocean sinks, which exhibit interannual variability of ~0.5 ppm.
- Despite the significant reduction in emissions in 2020, atmospheric CO_2 concentrations increased in line with the decade trend, but this is well within the expected variability.
- Even though a significant increase in emissions is predicted in 2021, the atmospheric CO_2 concentration is expected to rise only 2.0 ppm due to La Niña conditions in 2021, enhancing the natural land carbon sink (Fig. 4).
- However, **the sinks are growing slower as a result of climate change**, so they are expected to take up less carbon from the atmosphere in the future. In the past decade (2011-2020), climate change reduced the land sink by about 15% and the ocean sink by about 5%.

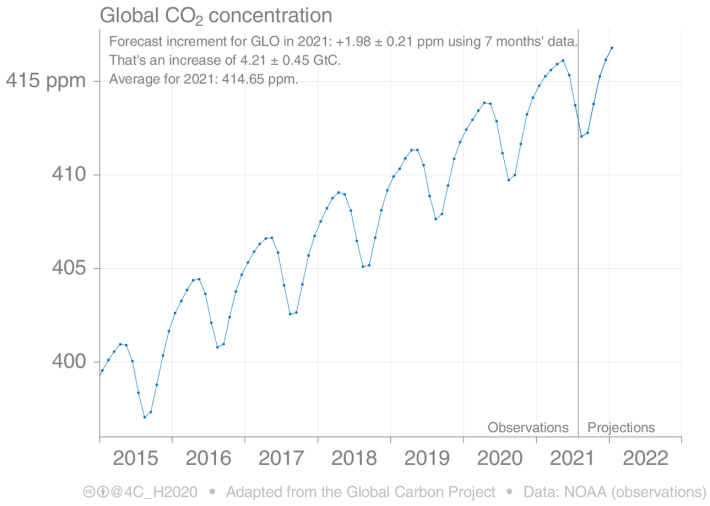

Figure 3. The projection of CO_2 concentration takes into account the increasing trend and seasonal cycle.

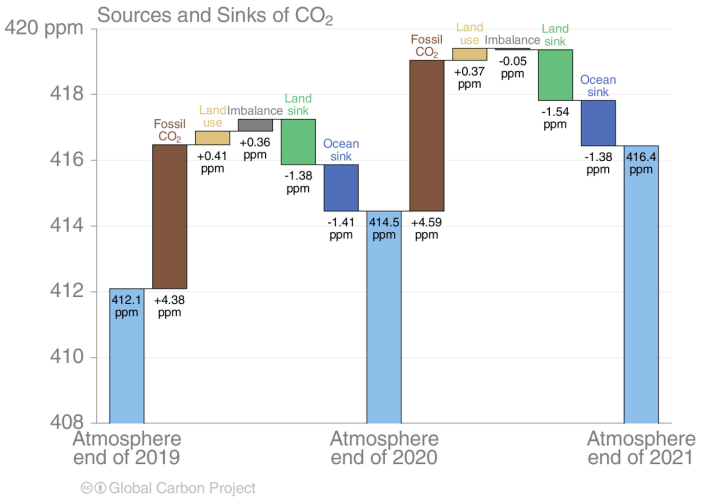

Figure 4. Drivers of the increase in atmospheric CO_2 from 2019 to 2020 and 2020 to 2021.

REMAINING CARBON BUDGET

- The global average temperature will continue to rise as a result of continued emissions and will keep rising until emissions reach net-zero.
- Continued emissions have decreased the remaining carbon budget. If emissions remain at 2021 levels, the amount of carbon that can be emitted for a 50% chance to keep global warming below 1.5˚C or 2˚C will be 11 years and 32 years, respectively (total budget remaining: 420 and 1,270 $GtCO_2$).
- To achieve net-zero CO_2 emissions by 2050, the emissions must decrease by about 1.4 $GtCO_2$ every year, comparable to the COVID-19-induced drop of 1.9 $GtCO_2$ in 2020.

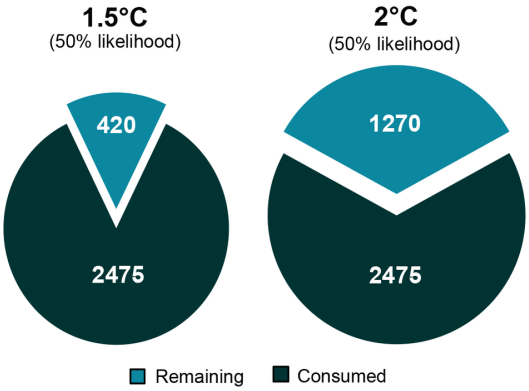

Figure 5. The remaining carbon budget (in $GtCO_2$) for a 50% probability of staying below 1.5°C and 2°C.

SUSTAINABLE GROWTH

- In 23 countries[3] (responsible for about 25% of global emissions), there have been reductions in fossil CO_2 emissions in the past decade (2010-2019), in parallel to economic growth. This is primarily driven by the transition to cleaner sources of energy displacing fossil fuels.
- Decarbonisation has also helped to slow down emission growth in China, but it has proven to be insufficient in countries such as India, where the growing energy demand offsets the benefits of decarbonisation.

[3] Barbados, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Israel, Japan, Luxembourg, North Macedonia, Malta, Mexico, Netherlands, Slovakia, Slovenia, Solomon Islands, Sweden, Switzerland, Tuvalu, United Kingdom and the USA. See https://enactivescience.com/gcp2021/ for all countries and different time-periods.

[4] More information in the 4C Science Summary "The increase in CO_2-induced global warming will only stop when humans stop adding CO_2 to the atmosphere"

NET ZERO PATHWAYS

- The global average temperature remains roughly constant after human-induced CO_2 emissions reach zero.[4]
- The commitment to achieve net-zero emissions by 2050 brings attention to the final goal, but less attention on the journey to net zero. There are multiple pathways to net zero emissions in 2050, which can have different cumulative emissions and thereby temperature implications (Fig. 6). Ambitious 2030 commitments and year-by-year achievements are fundamental for reaching the 2050 objective, with less CO_2 accumulated in the atmosphere and lower temperatures.
- If emissions are drastically reduced to keep within the remaining carbon budget consistent with a 50% probability of 1.5˚C of global warming (420 $GtCO_2$), net zero should be reached by 2043 (Fig. 6, grey line).
- A linear decline in emissions to reach net zero in 2050 exceeds that remaining carbon budget, which would need to be compensated with more ambitious short-term CO_2 and non-CO_2 reductions (faster than linear), or CO_2 removal post-2050 to compensate for the budget overshoot (Fig. 6, black line).
- Delaying action until 2030 would require steeper reductions between 2030 and 2050, leading to an additional 0.2˚C warming from CO_2 emissions and further additional warming if there are insufficient reductions in non-CO_2 emissions (Fig. 6, red line).
- The cumulative nature of CO_2 emissions dictates the necessity of more rapid-short term action, as any delay simply accumulates more CO_2 in the atmosphere and leads to higher temperature outcomes.

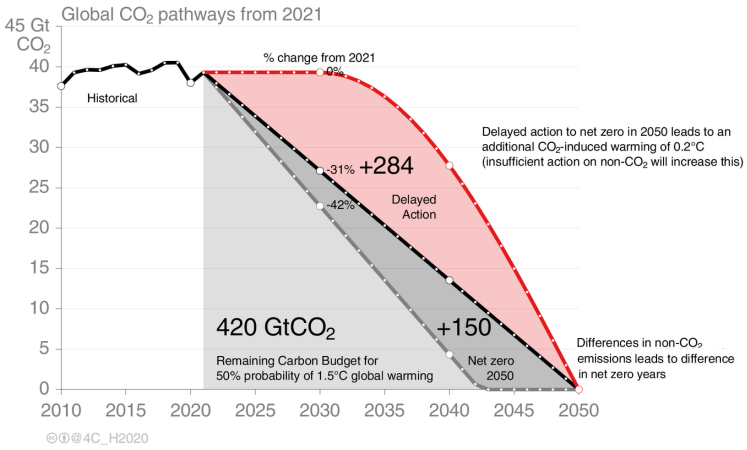

Figure 6. There are different idealised pathways to net zero. A pathway with 'delayed action' (red), but still reaching net-zero in 2050, leads to higher temperature outcomes than a pathway straight to net-zero (black). The grey pathway has cumulative CO_2 emissions of 420 $GtCO_2$, consistent with a 50% chance of keeping warming below 1.5°C. The carbon budgets shown here assume reductions in non-CO_2 emissions consistent with reductions in CO_2 emissions.

POLICY IMPLICATIONS

- The rebound in global fossil CO_2 emissions in 2021 reflects a return towards the pre-COVID fossil-based economy. Investments in the green economy in the post-COVID recovery plans of some countries have been insufficient so far, on their own, to avoid a substantial return close to pre-COVID emissions.
- A further rise in fossil CO_2 emissions in 2022 cannot be ruled out if the road transport and aviation sectors return oil use to its pre-pandemic activity, without reductions in coal or gas use to compensate for the growth in oil. There remains an opportunity for economic incentives and climate policy to avoid growth in emissions in 2022.
- The policy implementation timing is pivotal in the fight for climate change. Reaching net zero CO_2 emissions is necessary to stop temperatures rising, but the pathway leads to a different temperature level. A more ambitious pathway towards net zero reduces cumulative CO_2 emissions and the consequent warming. It is not only about the destination (net zero), but also the journey (pathway).

Acknowledgement

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References

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- *Global Carbon Project. Global Carbon Budget 2021. https://www.globalcarbonproject.org/carbonbudget/*
- *Andrew R. (2021). Figures from the Global Carbon Budget 2021. https://robbieandrew.github.io/GCB2021/index.html*

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