Report on progress on reaching European greenhouse gas emission targets

July 2024

EYE-CLIMA

Report of the EYE-CLIMA Horizon Europe Project

GLOBAL CARBON project

Report on progress on reaching European greenhouse gas emission targets

Executive Summary

Independent estimates based on modelling and atmospheric observations show that there has been a decrease in the emissions of CO_2, CH_4 and N_2O over Europe from the 1990s and through the 2010s, consistent with National Greenhouse Gas Inventories (NGHGIs) reported under the United Framework Convention on Climate Change (UNFCCC). Differences between independent estimates and NGHGIs remain considerable for land-based CO_2 removals.

To achieve the common EU27 emission target commitment for 2030, greater rates of emission reduction will be needed compared to those observed over the past three decades, but with strong policy ambitions the targets appear to be achievable. The largest policy risk may be to maintain land-based CO_2 removals.

Future refinements of emission estimation methods based on atmospheric observations will provide useful independent estimates to support climate policy and decision making. Specifically, such refinements include: i) a finer spatial resolution that allows for comparisons to NGHGIs at national and sub-national scales, and ii) resolving emissions for given categories of source sectors.

Introduction

With countries developing their own national emission targets or Nationally Determined Contributions (NDCs), as required by the Paris Agreement under the UNFCCC, it is necessary to monitor and verify whether countries are achieving their targets. At present, target setting and target monitoring relies on the information provided by NGHGIs.

NGHGIs are the official regulatory tool to quantify GHG emissions to the atmosphere. These are prepared by countries following the detailed methodological guidance of the Intergovernmental Panel on Climate Change (IPCC, 2006, 2019). Very simplistically, these are generally based on activity data (e.g., energy consumption, number of animals) multiplied with *Emission Factors* (emission rate per activity) to give emissions. In some sectors, models are also used to directly estimate emissions or emission factors, such as agriculture, forestry, and other land use (AFOLU).

Some emission factors can be estimated accurately (e.g., CO_2 emission from combusting a barrel of oil), while other emission factors can be uncertain. The emissions from a cow, for example, are hard to measure and can vary depending on feed, time, and location. Activity data can also be inaccurate (e.g., barrels of oil combusted) or uncertain (e.g., number of cows in a country).

Consequently, the accuracy of NGHGIs can be limited in some sectors by the accuracy of the emission factors and activity data. Generally, the accuracy of NGHGIs is best for CO_2 emissions from fossil fuel use, and poorest for CH_4, N_2O, and CO_2 emissions from agriculture, forestry, and other land use (AFOLU). Independent validation and verification of NGHGIs is important to guide the inventory agencies in improving the inventories and to guide policy.

One such independent approach is the use of atmospheric observations in *Inverse Modelling*. Atmospheric observations are made routinely from national and international networks of observing stations, as well as from satellites. The measurements reveal what is actually in the atmosphere, and is the integrated signal from many individual sources. The coverage and accuracy of the atmospheric observations strongly determines the sensitivity of this method to detect changes in emissions, such as whether they can identify emission reductions due to the implementation of mitigation measures, and whether given reduction targets are met.

Inverse modelling is generally used by the research community and by some non-governmental organisations (e.g. UNEP's International Methane Emission Observatory). NGHGIs are officially reported to the UNFCCC by national governments, but in the process of making the estimates, inverse modelling can be used for verification and improvement. Inverse modelling has already helped improve emission estimates in some countries, such as for fluorinated gases in the UK. Inverse modelling estimates are also compared with NGHGIs in scientific publications to support inventory agencies and help improve inverse modelling.

What is inverse modelling?

Inverse modelling is a statistical method to determine the best estimate of some unknown variables (in this case the emissions) using indirect observations (the atmospheric concentrations). It relies on being able to relate the emissions to atmospheric concentrations through a model of atmospheric transport and dispersion and the inverse, i.e., being able to relate the changes in atmospheric concentrations to changes in emissions.

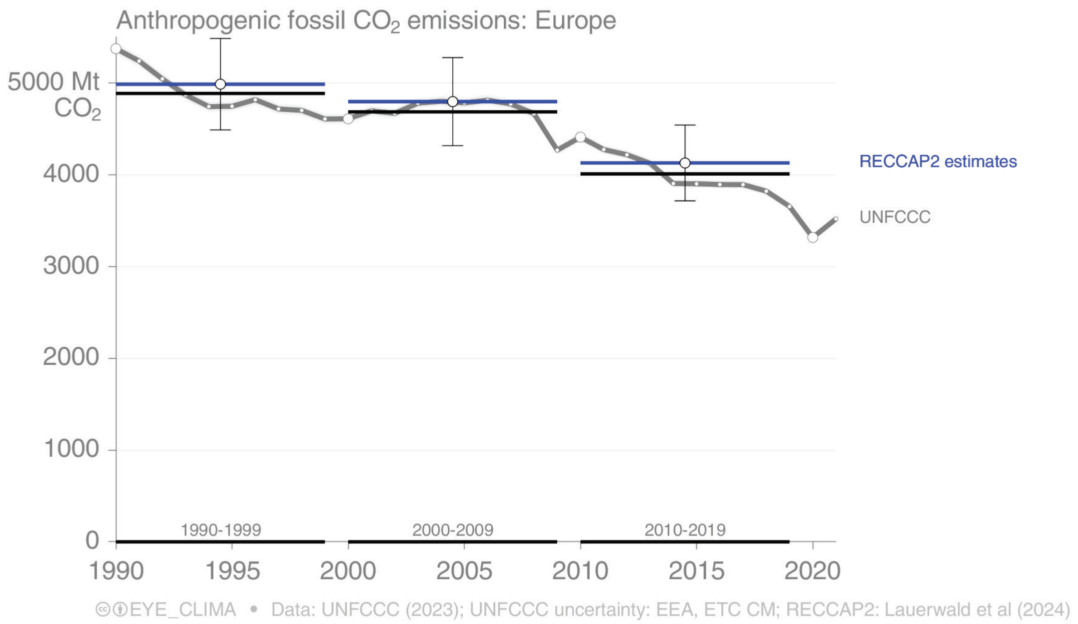
Inverse modelling relies on using a first estimate of the emissions, known as the "prior". Since the problem is under-constrained (there are not enough observations to uniquely constrain the emissions) the statistically most probable solution is found, that is, the emissions that minimise the difference between the modelled and observed atmospheric concentrations.

Analysis of emission trends over the past three decades

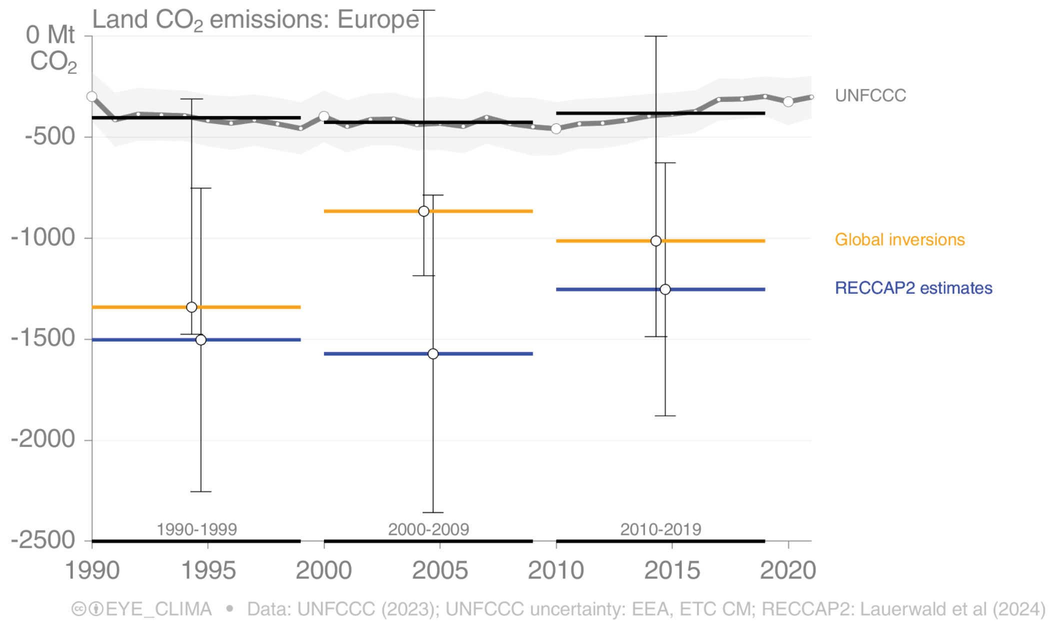
This Progress on Targets report is based on the results of the second Regional Carbon Cycle Assessment Program (RECCAP2), led by the Global Carbon Project (Lauerwald et al., 2024). RECCAP2 analysed European emissions (covering continental Europe, excluding Russia and Turkey) and examined their trends on a decadal time scale, using decadal averages (1990-1999, 2000-2009, and 2010-2019). Decadal averages are used to smooth-out interannual variability (due to weather extremes), which is captured by the inverse modelling but not by NGHGIs.

For the CO_2, CH_4 and N_2O budgets, multiple independent estimates, including those based on inverse modelling of atmospheric observations, were analysed to establish the most accurate emissions for Europe. The regional coverage in the RECCAP2 analysis is slightly larger than for UNFCCC reporting (representing ~3% of GHG emissions).

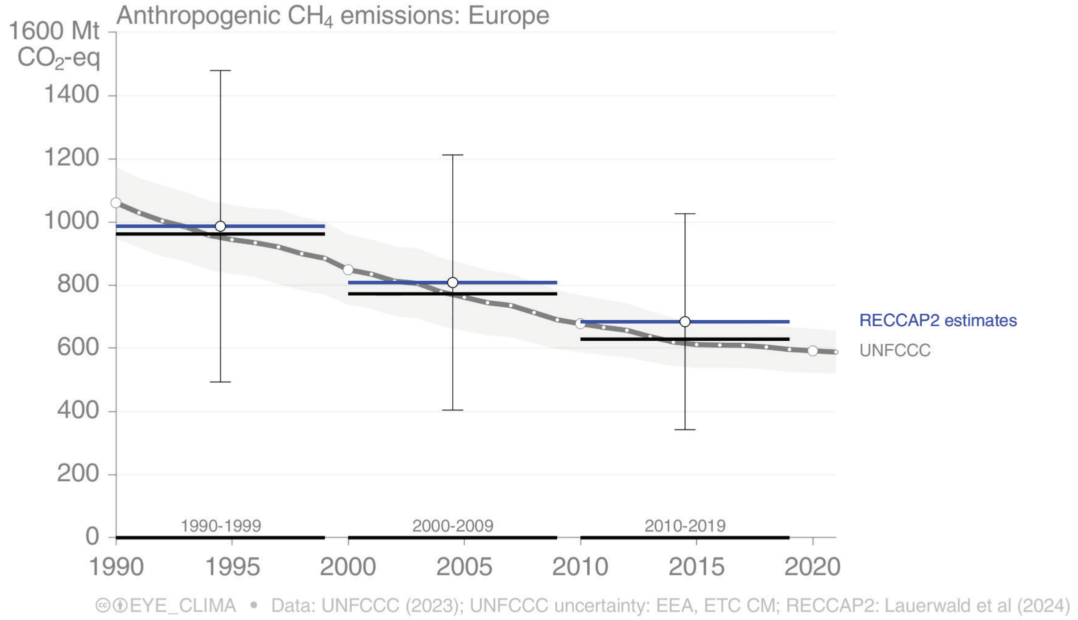
Fossil CO_2 emissions: Considerable reductions in fossil CO_2 emissions were found: a 35% reduction from 1990 to 2021 for the UNFCCC reporting countries covered. These reductions are in line with the independent (mainly inventory-based) estimates used in RECCAP2.



Land CO_2 emissions: The land biosphere was overall a net sink of CO_2, which remained relatively constant within the uncertainties of each dataset. The size of the sink varies considerably between different estimates. The uncertainty ranges of the RECCAP2 analysis and the UNFCCC estimate do not overlap, but estimates from global Inverse Modelling overlap both estimates. Further research is needed to reduce the uncertainty range and provide more confidence in the likely level of CO_2 uptake in Europe.

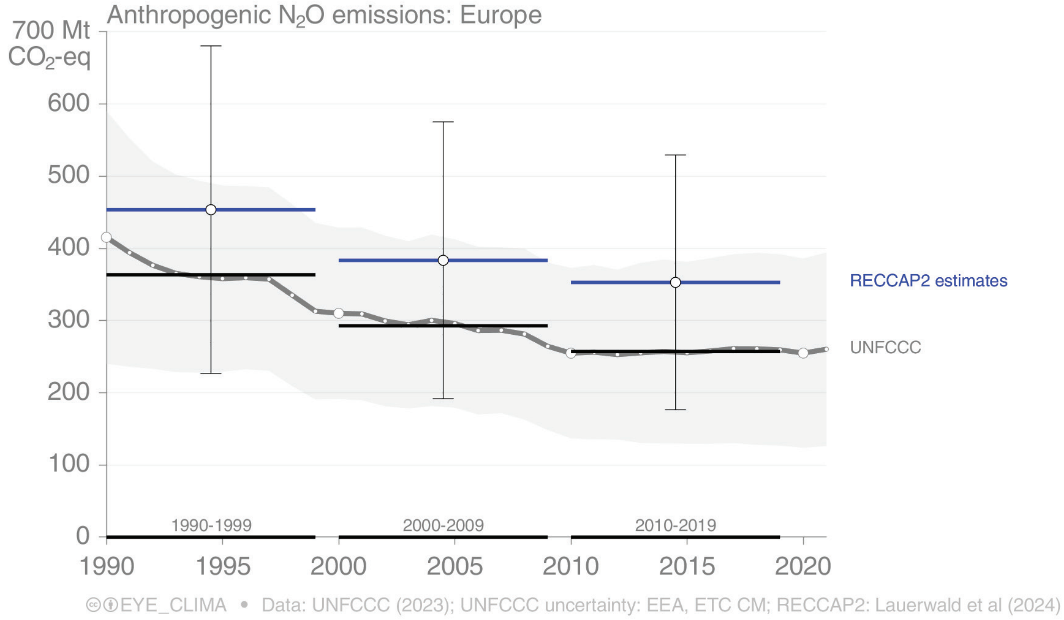


Anthropogenic CH_4 emissions: European CH_4 emissions reduced by about 45% from 1990 to 2021 according to the UNFCCC estimates, which is in line with the RECCAP2 analysis. From the 1990s to the 2000s, the reductions occurred across all sectors, but in the 2000s to the 2010s, emissions from energy, industry and waste continued to decrease at a similar pace, while reductions in emissions from agriculture slowed considerably. There are large CH_4 emissions from natural sources, but there are not reported in the UNFCCC inventories and hence not shown here.



Anthropogenic N_2O emissions: European N_2O emissions were reduced 37% from 1990 to 2021 according to the UNFCCC estimates. This reduction is consistent with the RECCAP2 estimates, although there is disagreement with the level of the emissions between the different estimates.

The strongest reductions in N_2O were seen in industrial emissions, amounting to about two thirds of the total reduction between the 1990s and 2000s, and about 90% of the total reduction between the 2000s and 2010s, although the uncertainties in the



industrial emissions estimate are large.

The RECCAP2 uncertainty assessment is based on discrepancies between different estimates but it does not provide uncertainty information on trends. Generally, the uncertainty in the trends will be smaller than those for the absolute value.

The uncertainty in these estimates is assessed by Lauerwald et al. (2024) as moderate (±50%) for the land-biosphere CO_2 sink and CH_4 and N_2O emissions, but low (±10%) for fossil CO_2 emissions.

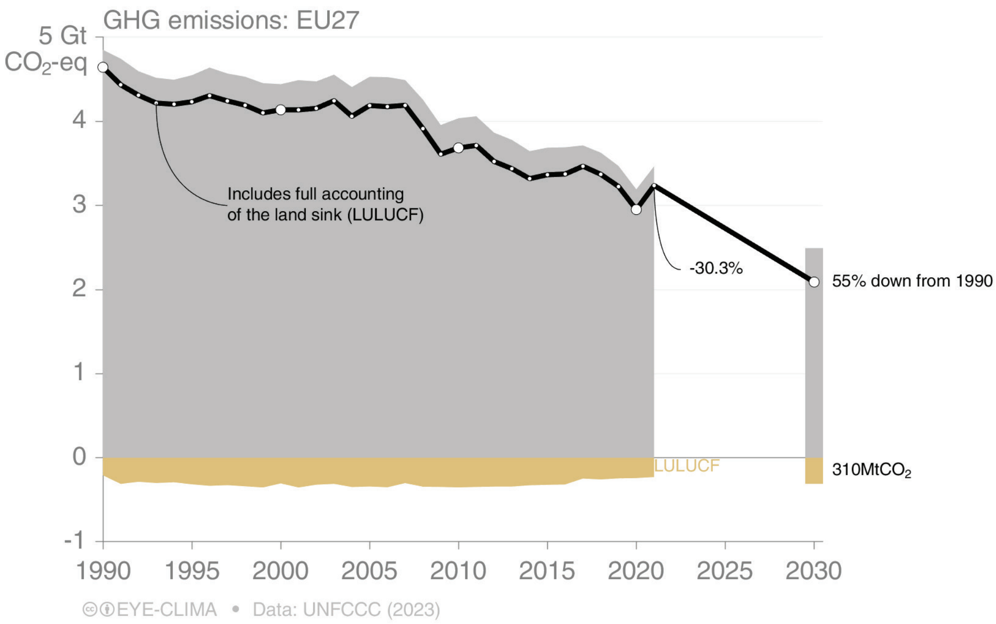
Evaluating emission reduction targets

The comparisons between the UNFCCC and RECCAP2 estimates were for Europe and show broad consistency, except for land-based CO_2 emissions. Emission reduction targets, however, are based on legal entities and do not cover Europe as a whole.

Here we consider the emission reduction targets for the EU27 only, for which joint NDCs have been prepared, allowing for effort sharing across member countries[1].

The EU includes land-based CO_2 emissions in its targets and has pledged to reduce net GHG emissions to at least 55% in 2030 compared to 1990 and to achieve climate neutrality in 2050.
The EU also has a separate land target, to maintain land-based removals of 310MtCO_2 equivalent in 2030.

Across all greenhouse gases, the EU27 is broadly on track to meet its targets, but this requires an increase in the reduction rates seen in the last decade. Though, more challenging is increasing the land-based CO_2 removals. The land-based CO_2 removals are highly uncertain, and there are signs of a weakening sink in the UNFCCC reported data. It is thus necessary to reverse this trend and strengthen the land-based CO_2 sink to reach the 2030 target.



[1] *The respective contributions by country have been listed in Regulation (EU) 2023/857 of the European Parliament and of the Council.*

Future recommendations

The comparison of atmospheric observation-based emission estimates (via inverse modelling) with NGHGIs, such as in RECCAP2, can lend further confidence to the emission trends (in the case of agreement) or highlight issues in one of the methods, which may require further investigation. Based on this assessment some recommendations for the use of the inverse modelling method to support NGHGIs are:

Emission estimates should be provided with minimal time lag to capture recent changes in trends. The delay of NGHGIs (typically submitted to UNFCCC about 16 months after the end of any given year) should allow sufficient time for inverse modelling results to be provided e.g., for verification of the NGHGI. Comparisons of inverse modelling results and NGHGIs on annual timescales will remain challenging because NGHGIs may not be able to sufficiently reflect changes in emissions due to extreme weather events, which might be captured in emissions from inverse modelling.

Higher spatial resolution in inverse modelling should help improve the emission estimates owing to better representation of atmospheric transport and dispersion, and lead to a better resolution of emissions around country borders.

Analysing periodic sub-annual variations (e.g. seasonal cycles) and the spatial distribution of emissions from inverse modelling may help to distinguish the emissions by source sector, making them a more valuable tool for supporting NGHGIs and policy decisions.

References

IPCC, 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). IGES, Hayama, Japan.

IPCC, 2019. 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Calvo Buendia, E., Tanabe, K., Kranjc, A., Baasansuren, J., Fukuda, M., Ngarize, S., Osako, A., Pyrozhenko, Y., Shermanau, P. and Federici, S. (eds). IPCC, Geneva, Switzerland.

Lauerwald, R., A.Bastos, M.J. McGrath, A.M.R. Petrescu, F. Ritter, R.M. Andrew, A. Berchet, G. Broquet, D. Brunner, F. Chevallier, A. Cescatti, S. Filipek, A. Fortems-Cheiney, G. Forzieri, P. Friedlingstein, R. Fuchs, C. Gerbig, S. Houweling, P. Ke, B.J.W. Lerink, W. Li, X. Li, I.T. Luijkx, G. Monteil, S. Munassar, G.-J. Nabuurs, P.K. Patra, P. Peylin, J. Pongratz, P. Regnier, M. Saunois, M.-J. Schelhaas, M. Scholze, S. Sitch, R.L. Thompson, H. Tian, A. Tsuruta, C. Wilson, J.-P. Wigneron, Y. Yao, S. Zaehle, P. Ciais, W. Li, 2024. Carbon and greenhouse gas budgets of Europe: trends, interannual and spatial variability, and their drivers. Paper submitted to Global Biogeochem Cycles, 2024. https://doi.org/10.22541/essoar.171320253.37867733/v1.

Authors:
Wilfried Winiwarter, IIASA
Glen Peters, CICERO
Rona Thompson, NILU
Ronny Lauerwald, Université Paris-Saclay

Project partners:
NILU (NO)
University of Vienna (AT)
LSCE (FR)
University of Bremen (DE)
FMI (FI)
IIASA (AT)
KIT (DE)
CICERO (NO)
Science Partners (FR)
CITEPA (FR)
University of Crete (GR)
Thünen Institute (DE)
ICOS (FI)
ECMWF (UK)
EMPA (CH)
ETH Zurich (CH)

Acknowledgements:
EYE-CLIMA is funded under the European Union's Horizon programme (grant no. 101081395).

The RECCAP2 Europe results were produced by a large team of researchers in the framework of the Global Carbon Project.

https://eyeclima.eu/

Published 8 July 2024

This project is funded by the European Union
EYE-CLIMA has received funding from the European Union's Horizon Europe research and innovation programme. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. Neither the European Union nor the granting authority can be held responsible for them.

EYE-CLIMA
Verifying emissions of climate forcers

GLOBAL CARBON project