VERIFY

Observation-based system for monitoring and verification of greenhouse gases

GA number 776810, RIA

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Lead beneficiary:	CICERO
Responsible	CICERO
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Internal reviewer:	Aurélie Paquirissamy (CEA/LSCE)

Changes with respect to the DoA

This deliverable was delayed as it is based on the results of D5.3 Second report - Reconciliation of bottom-up and top-down methods at sub-national scales

Dissemination and uptake
(Who will/could use this deliverable, within the project or outside the project?)

Document freely available on the website of VERIFY targeting more specifically policy makers and experts. All factsheets can also be displayed from the "product" pages of the website.

Short Summary of results (<250 words)

This deliverable is primarily to present the second series of factsheets for the scientific review article on multi-gas GHG budgets. There are four main factsheets for CO_2 land, CO_2 fossil, CH_4, and N_2O. The creation process is undergoing automation to permit the production of all four of these factsheets for every single country and group of countries considered in the project. The first round of factsheets presented the concept for the EU27+UK, while this second round of factsheets advances the automation process (though only presents country samples). The factsheets for each component, and each region, will have a similar design. The top-left will show a figure based on inventories submitted by Member States to the UNFCCC, where decennial changes in the overall trend are broken-down by sector. This is to provide a link to WP1 and to set the remaining figures in context. The top right shows a map of Europe and will highlight the region under consideration to orient the viewer. The bottom part of the figure shows a comparison of sectoral emissions by bottom-up methods and a comparison of the bottom-up and top-down methods. All uncertainties are shown. The full set of country-specific factsheets will be available via the VERIFY web portal, and the factsheets will be updated with each new GHG synthesis.

Evidence of accomplishment
(report, manuscript, web-link, other)

All of the factsheets will be made available on the website which also shows plots used in the synthesis papers (and which serve as the basis for the factsheets).

http://webportals.ipsl.jussieu.fr/VERIFY/FactSheets/

Users can register their email address to receive the name and password to access the site.

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Version	Date	Description	Author (Organisation)
V0	12/03/2021	Creation/Writing	Glen Peters (CICERO)
V1	12/03/2021	Writing/Formatting/Delivery on the Participant Portal	Philippe Peylin and Aurélie Paquirissamy (CEA/LSCE)

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1. Glossary

Abbreviation / Acronym	Description/meaning
GHG	Greenhouse gas

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2. Executive Summary

This deliverable is primarily to present the second round of factsheets for the scientific review articles on multi-gas GHG budgets (essd-2020-367 and essd-2020-376, undergoing review process, revisions to be submitted in March / April).

The VERIFY project collects and disseminates a large amount of information and data on GHG emissions across Europe. This data and information varies in complexity, ranging from high-resolution spatially-explicit maps of GHG fluxes to synthesis plots which compare country-level totals between various data sources on an annual scale to allow for identification of trends and differences. Much of this information is accessible to technical experts, but less understandable to educated professionals outside of this field who may nevertheless rely on this information for decisions.

One goal of the VERIFY project is dissemination of the compiled results to multiple audiences. Three different country-level factsheets are created for this purpose. The factsheets described in this deliverable target experts who wish to see a summary of the information presented in the scientific synthesis articles submitted by WP5, building on the data produced in WP2, WP3, and WP4.

There are four main factsheets separated by greenhouse gas species: CO_2 land, CO_2 fossil, CH_4, and N_2O. Each of the factsheets can be produced for all regions considered in the project. The first round of factsheets only presented the concept for the EU27+UK. The second round of factsheets furthers advance the automation process, though for space requirements, only presents samples for a specific country. The website provides all factsheets for all countries. The factsheets for each component, and each region, will have a similar design. The top-left will show a figure based on UNFCCC inventories, where decennial changes are shown by sector. This is to provide a link to WP1 and context. The top right shows a map of Europe and will either show regional results (EU27+UK) or highlight the region under consideration. The bottom part of the figure shows a comparison of sectoral emissions by bottom-up methods and a comparison of the bottom-up and top-down methods. All uncertainties are shown. Country-specific factsheets will be available via a web portal, and the factsheets will be updated with each new GHG synthesis. There are around 80 countries and sub-regions, four different types of factsheets, and around 320 individual factsheets.

These factsheets provide convenient materials to serve as a focal-point for discussions between members of the VERIFY project and national and regional experts when searching for future research directions.

3. Introduction

The VERIFY project will produce several different factsheets, each with a different content and target audience:

- WP1: Summary of UNFCCC GHG inventories, for policy makers
- WP5: Synthesis of the GHG budgets from the science in WP2, WP3, and WP4, for national and regional technical experts
- WP6: Synthesis of the WP1 and WP5 factsheets (EU27+UK), for policy makers

The WP1 factsheets have been completed (Milestone 2). The WP1 factsheets are per country and show information on GHG trends over time, shares for the latest inventory year, and uncertainty information for the last inventory year. A table and short text summarizes the key inventory results and there is a paragraph summary of each fact sheet. Each country factsheet is around five pages and collated in a single document (of around 140 pages). In addition, these WP1 factsheets are also made available through the VERIFY website: **http://webportals.ipsl.jussieu.fr/VERIFY/FactSheets/** (with a free registration).

The WP5 factsheets are based on the data and model runs in WP2, WP3, and WP4. These factsheets are key summaries of the GHG budget synthesis (D5.9 First scientific review article on multi-gas GHG budgets – AFOLU and D5.3 CO_2 and CH_4 and N_2O syntheses papers recently submitted to ESSD and still undergoing review). These factsheets cover CO_2 from fossil sources, CO_2 from land-use and land-use change, CH_4, and N_2O. The WP5 factsheets are significantly more complex than those in WP1, presenting detailed top-down and bottom-up results that will be updated several times throughout the project. A more systematic approach is needed to develop the WP5 factsheets to avoid them overburdening the project. There also needs to be consistency with the scientific reviews for which the factsheets are based.

The general strategy for the WP5 factsheets is to link them to the analysis conducted for D5.3 and thereby automate their generation for easy updates and online access. The VERIFY web portal contains all the datasets (http://webportals.ipsl.jussieu.fr/VERIFY/) which are then processed into figures and factsheets (http://webportals.ipsl.jussieu.fr/VERIFY/FactSheets/). A user interface allows the user to select the GHG and plot variants and country/region which to plot. A further link allows premade factsheets to be selected, for WP1, WP5, or WP6.

The WP5 factsheets go hand-in-hand with the GHG budget synthesis (also WP5). The factsheets and synthesis should therefore be completed at (approximately) the same time. At the end of each GHG budget synthesis, the factsheets will be "frozen" to provide version control. The figures and factsheets are then updated in the next GHG budget synthesis round, additionally including user feedback on the design and content.

This deliverable shows the general structure, content, and workflow of the factsheets for all countries and regions. Sample factsheets are shown for each GHG for specific countries (EU27+UK and Germany), but the web portal will ultimately have factsheets for all EU countries and regions

studied in the GHG budget synthesis (currently 79 different countries and groups of countries). Note that currently the web portal displays already all figures that will form the individual country factsheets. There are over 300 factsheets in total, making it unrealistic to write specific text and interpretation for each fact sheet. Therefore, we have decided on a strategy that has standardized captions for each of the factsheets. This strategy can be revisited in the third round of factsheets.

The creation of four unique factsheets for 79 different regions and countries would require an unreasonable amount of time to carry out by hand. Therefore, one major innovation for this year is the implementation of a series of computer scripts to automate the creation of each factsheet. This is achievable as the graphics for every region and country have already been created from the data and stored in a single repository, with the country/region name found in the filename. The basic template for each of the four species contains the same text and layout as defined by the typesetting language LaTeX. LaTeX was selected because it allows for the inclusion of graphics through simple text commands, and it is well-known for producing professional-looking manuscripts. Creation of a factsheet using LaTeX presented more challenges as the user has much less control over specific positioning of elements, but we decided the trade-off between format and the ability to easily change graphics was acceptable for this year. By changing the name of the country/region code in each template and recompiling, we are able to produce a customized .pdf file for each country/region using scripts in the bash scripting language.

Apart from the design of the factsheet (positioning of graphics, and spatial requirements for elements which vary across countries/regions), automation of the creation of the maps displayed on each factsheet posed the greatest challenge. Work is still underway to ensure that this is done in a consistent and professional manner. It is clear that what works well for one country/region will not work well for others, and we are seeking to achieve the correct balance among all countries/regions.

Attached to the end of this deliverable are sample fact sheets for the EU28 (EU27+UK) and Germany.

4. Conclusions

This deliverable presented motivations for and examples of summary factsheets based on the scientific synthesis analysis carried out in WP5 of the VERIFY project. There are four main factsheets: CO_2 land, CO_2 fossil, CH_4, and N_2O.

The factsheets are produced for all countries and regions considered in the project, leading to a total of over 300 factsheets. This deliverable explains the process, and only presents samples of the country-level factsheets. The factsheets for each of the four components have similar layouts:
- The top-left shows a figure based on Member State submissions to the UNFCCC, where decennial trends are broken down by subsectors to identify drivers of change. This is to both provide a link to WP1 and also to establish context for the dataset comparisons which follow.
- The top right shows a map of Europe with the region/country of interest shaded in gray to immediately orient the reader.
- The bottom part of the figure shows a comparison of sectoral emissions by bottom-up methods (left) and a comparison of the bottom-up and top-down methods (right). All uncertainties are shown where available.

The country-specific factsheets are compiled through an automated process and made available via a web portal. This will permit the factsheets to be updated with each new GHG synthesis while reducing the amount of human intervention required to assemble 79 factsheets each for four different GHG species. The next deliverable, D5.8 (Third - Fact sheets with national observation-based GHG Budgets from project results), will provide an update of the factsheets (around November 2021).
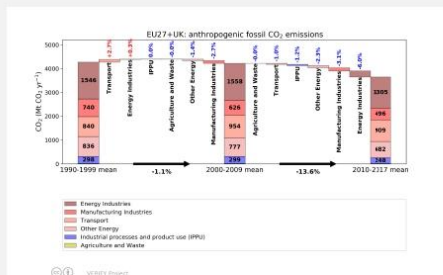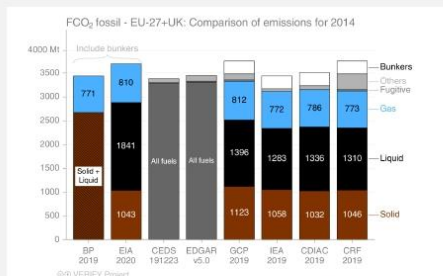
5. Factsheets

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Fact Sheet - E28

March 2021, v2.00

CO2fossil

E28 = EU27 + UK

E28 : Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom

Fossil CO_2 emissions including fossil fuel (coal, oil, and gas) and fossil carbonate (e.g., cement, limestone). The decennial trends show the mean changes by key sectors in UN-FCCC national GHG inventories, averaged over the 1990–1999, 2000–2009, and 2010–2017 time periods, with the contribution of changes (%) shown for each category.

A comparison of fossil CO_2 emissions across different data providers for the latest year (2014) where all datasets are available with the UNFCCC national GHG inventories (last bar). Emissions from international transport ('bunkers') are usually excluded from national totals but shown here based on bunker fuel sales. Breaking down by emission categories facilitates exploration of the reasons for differences, but not all datasets provide this breakdown (grey, 'all fuels').

A comparison of fossil CO_2 emissions across different data providers over time. Differences between datasets are relatively constant over time, representing system boundary differences and the emission categories included. The UNFCCC national GHG inventories are labelled as Common Reporting Format (CRF).
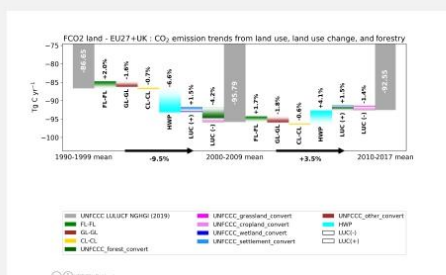

Horizon 2020 Societal challenge 5 :
Climate action, environment,
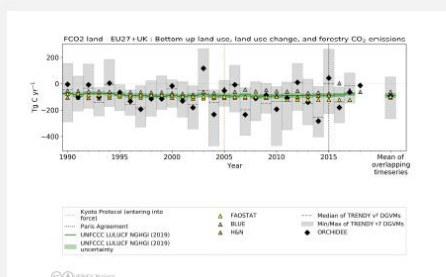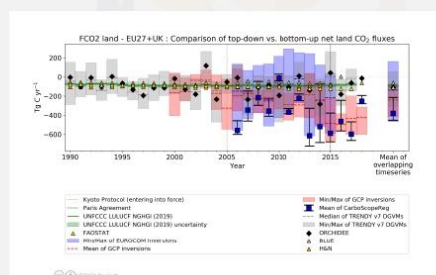resource efficiency and raw materials

Fact Sheet - E28

March 2021, v2.00

CO2land

E28 = EU27 + UK

E28 : Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom

Land-based CO_2 emissions in UNFCCC national GHG inventories (LULUCF sector) include CO_2 emissions from managed land: land that remains in the same category (forestland (FL-FL), grassland (GL-GL), cropland (CL-CL)), land that is converted (land-use change), and harvested wood products (HWP). The decennial trends show the mean changes by key categories, averaged over the 1990–1999, 2000–2009, and 2010–2017 time periods, with the contribution of changes (%) shown for each category.

A comparison of different estimates of the CO_2 land fluxes from different bottom-up sources. The grey bars represent the individual model data for eight dynamic global vegetation models (DGVMs). The UNFCCC national GHG inventories include Forest Land, Cropland, Grassland, Wetlands, Settlements, and Other Land from conversions, in addition to harvested wood products. The FAOSTAT estimate includes Forest Land, including afforestation and deforestation as conversion of forest land to other land types). The relative error on the UNFCCC value is computed with the error propagation method (95% confidence interval). The means are calculated for the 1990-2015 overlapping period.

Comparison of bottom-up and top-down CO_2 land estimates. The green line represents the UNFCCC national GHG inventories. The bottom-up estimates belong to bookkeeping models (BLUE, H&N), the grey shade is from dynamic global vegetation models, with ORCHIDEE and FAOSTAT (Forest Resource Assessment) shown separately. The top-down estimates are from the ensembles Global Carbon Budget 2019 (red), EUROCOM (blue) and CarboScopeReg (box with whiskers). The relative error on the UNFCCC value is computed with the error propagation method (95% confidence interval). The time series mean overlapping period is 2006–2015. The colored area represents the min/max of model ensemble estimates.
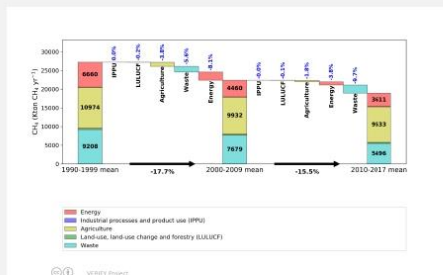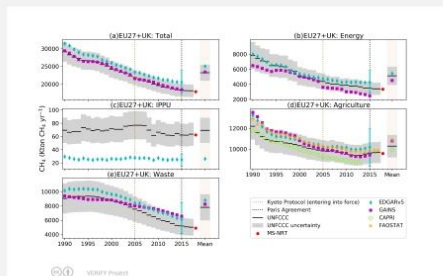

Horizon 2020 Societal challenge 5 :
Climate action, environment,
resource efficiency and raw materials

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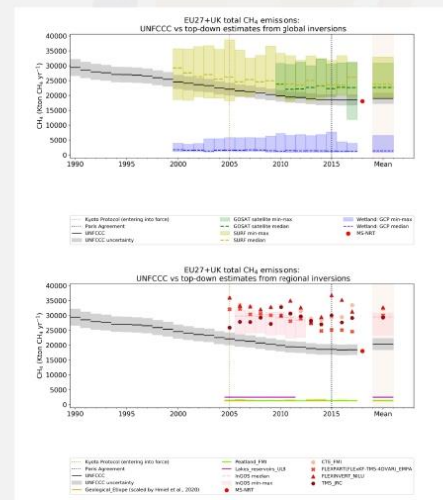# Fact Sheet - E28

March 2021, v2.00

CH4

E28 = EU27 + UK

E28 : Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom

The contribution of changes (%) in anthropogenic CH_4 emissions in the five UNFCCC sectors to the overall change in the decadal mean, as reported in the UNFCCC national GHG inventories. The three stacked columns represent the average CH_4 emissions from each sector during three periods (1990–1999, 2000–2009 and 2010–2017) and percentages represent the contribution of each sector to the total reduction percentages (black arrows) between periods.

Total sectoral anthropogenic CH_4 emissions (excluding LU-LUCF) from UNFCCC national GHG inventories compared to a bottom-up inventory (EDGAR v5.0) and scenario approach (GAINS), with specific models for agriculture only (CAPRI, FAOSTAT). The relative error on the UNFCCC value is computed with the error propagation method (95% confidence interval). The means represent the common overlapping period 1990–2015 (to 2013 for agriculture).

Anthropogenic CH_4 emissions from top-down global (top) and regional (bottom) inversions compared with UNFCCC national GHG inventories (black line). The time series mean was computed for the common period: 2010–2016 (top) and 2006–2012 (bottom).
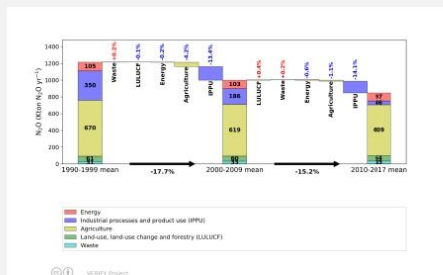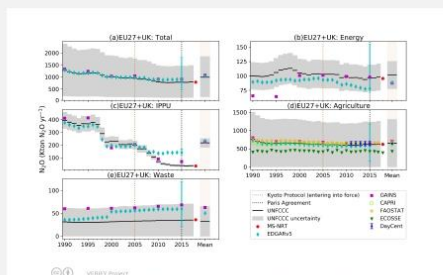
Horizon 2020 Societal challenge 5 : Climate action, environment, resource efficiency and raw materials

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Fact Sheet - E28
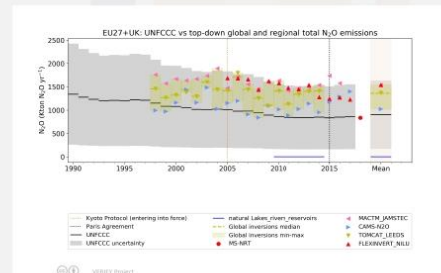
March 2021, v2.00

N2O

E28 = EU27 + UK

E28 : Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom

The contribution of changes in anthropogenic N_2O emissions in the five UNFCCC sectors to the overall change in decadal mean, as reported in UNFCCC national GHG inventories. The three stacked columns represent the average N_2O emissions from each sector during three periods (1990–1999, 2000–2009 and 2010–2017) and percentages represent the contribution of each sector to the total reduction percentages between periods.

Anthropogenic sectoral N_2O emissions from UNFCCC national GHG inventories (black line) compared to global bottom-up inventories (EDGAR v5.0, GAINS) and models for agriculture (CAPRI, FAOSTAT, DayCent and ECOSSE). UNFCCC and EDGAR uncertainty (for 2015 only) was computed with the error propagation method (95% confidence interval). Last reported year in this study refers to 2017 (UNFCCC, FAOSTAT), 2015 (EDGAR v5.0, DayCent), 2015 (GAINS, every 5 years), 2013 (CAPRI), 2018 (ECOSSE).

Total N_2O emissions from UNFCCC national GHG inventories (black line) compared to FLEXINVERT regional inversion over Europe and Global Carbon Project inversions (TOMCAT, CAMS-N2O and MIROC4-ACTM). UNFCCC and EDGAR uncertainty (for 2015 only) was computed with the error propagation method (95% confidence interval). Last reported year in this study refers to 2014 (TOMCAT), 2016 (MIROC4-ACTM), 2017 (UNFCCC, FLEXINVERT and CAMS-N2O). The time series mean was computed for the overlapping period 2005–2014.

Horizon 2020 Societal challenge 5 :
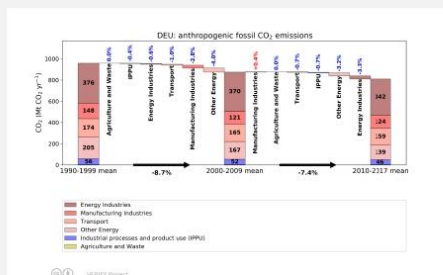Climate action, environment,
resource efficiency and raw materials

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Fact Sheet - DEU
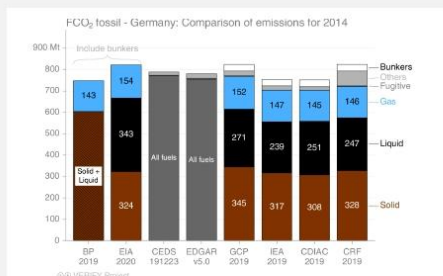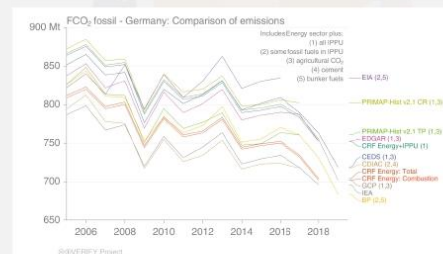*March 2021, v2.00*

CO2fossil

DEU

DEU : Germany

Fossil CO_2 emissions including fossil fuel (coal, oil, and gas) and fossil carbonate (e.g., cement, limestone). The decennial trends show the mean changes by key sectors in UN-FCCC national GHG inventories, averaged over the 1990–1999, 2000–2009, and 2010–2017 time periods, with the contribution of changes (%) shown for each category.

A comparison of fossil CO_2 emissions across different data providers for the latest year (2014) where all datasets are available with the UNFCCC national GHG inventories (last bar). Emissions from international transport ('bunkers') are usually excluded from national totals but shown here based on bunker fuel sales. Breaking down by emission categories facilitates exploration of the reasons for differences, but not all datasets provide this breakdown (grey, 'all fuels').

A comparison of fossil CO_2 emissions across different data providers over time. Differences between datasets are relatively constant over time, representing system boundary differences and the emission categories included. The UNFCCC national GHG inventories are labelled as Common Reporting Format (CRF).

Horizon 2020 Societal challenge 5 : Climate action, environment, resource efficiency and raw materials
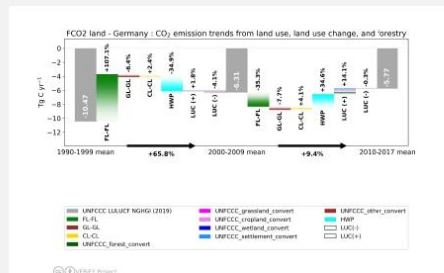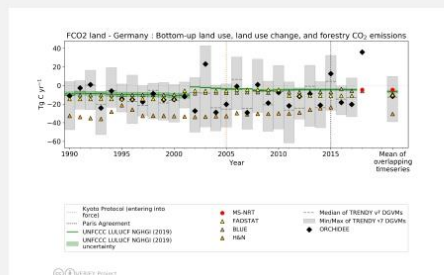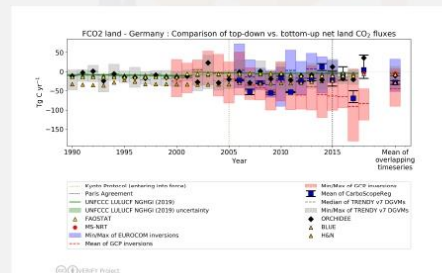
Fact Sheet - DEU

March 2021, v2.00

CO2land

DEU : Germany

Land-based CO_2 emissions in UNFCCC national GHG inventories (LULUCF sector) include CO_2 emissions from managed land: land that remains in the same category (forestland (FL-FL), grassland (GL-GL), cropland (CL-CL)), land that is converted (land-use change), and harvested wood products (HWP). The decennial trends show the mean changes by key categories, averaged over the 1990–1999, 2000–2009, and 2010–2017 time periods, with the contribution of changes (%) shown for each category.

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Comparison of bottom-up and top-down CO_2 land estimates. The green line represents the UNFCCC national GHG inventories. The bottom-up estimates belong to bookkeeping models (BLUE, H&N), the grey shade is from dynamic global vegetation models, with ORCHIDEE and FAOSTAT (Forest Resource Assessment) shown separately. The top-down estimates are from the ensembles Global Carbon Budget 2019 (red), EUROCOM (blue) and CarboScopeReg (box with whiskers). The relative error on the UNFCCC value is computed with the error propagation method (95% confidence interval). The time series mean overlapping period is 2006–2015. The colored area represents the min/max of model ensemble estimates.
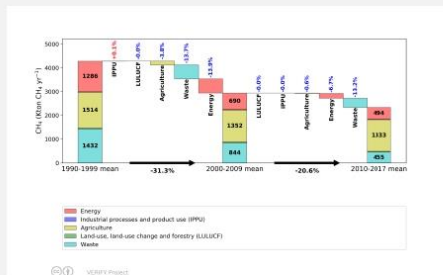
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Fact Sheet - DEU
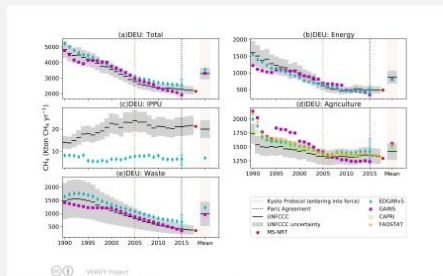
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CH4

DEU : Germany

The contribution of changes (%) in anthropogenic CH_4 emissions in the five UNFCCC sectors to the overall change in the decadal mean, as reported in the UNFCCC national GHG inventories. The three stacked columns represent the average CH_4 emissions from each sector during three periods (1990–1999, 2000–2009 and 2010–2017) and percentages represent the contribution of each sector to the total reduction percentages (black arrows) between periods.

Total sectoral anthropogenic CH_4 emissions (excluding LULUCF) from UNFCCC national GHG inventories compared to a bottom-up inventory (EDGAR v5.0) and scenario approach (GAINS), with specific models for agriculture only (CAPRI, FAOSTAT). The relative error on the UNFCCC value is computed with the error propagation method (95% confidence interval). The means represent the common overlapping period 1990–2015 (to 2013 for agriculture).

Anthropogenic CH_4 emissions from top-down global (top) and regional (bottom) inversions compared with UNFCCC national GHG inventories (black line). The time series mean was computed for the common period: 2010–2016 (top) and 2006–2012 (bottom).

Horizon 2020 Societal challenge 5 :
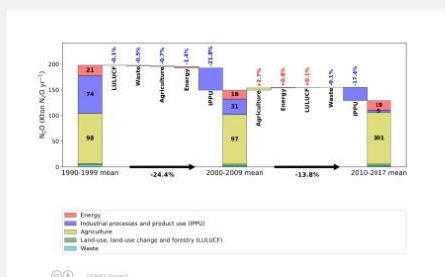Climate action, environment,
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Fact Sheet - DEU
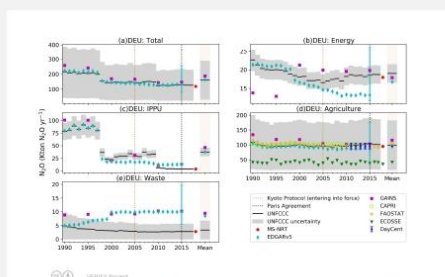
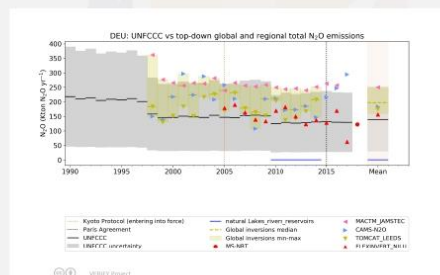*March 2021, v2.00*

N2O

DEU

DEU : Germany

The contribution of changes in anthropogenic N$_2$O emissions in the five UNFCCC sectors to the overall change in decadal mean, as reported in UNFCCC national GHG inventories. The three stacked columns represent the average N$_2$O emissions from each sector during three periods (1990–1999, 2000–2009 and 2010–2017) and percentages represent the contribution of each sector to the total reduction percentages between periods.

Anthropogenic sectoral N$_2$O emissions from UNFCCC national GHG inventories (black line) compared to global bottom-up inventories (EDGAR v5.0, GAINS) and models for agriculture (CAPRI, FAOSTAT, DayCent and ECOSSE). UNFCCC and EDGAR uncertainty (for 2015 only) was computed with the error propagation method (95% confidence interval). Last reported year in this study refers to 2017 (UNFCCC, FAOSTAT), 2015 (EDGAR v5.0, DayCent), 2015 (GAINS, every 5 years), 2013 (CAPRI), 2018 (ECOSSE).

Total N$_2$O emissions from UNFCCC national GHG inventories (black line) compared to FLEXINVERT regional inversion over Europe and Global Carbon Project inversions (TOMCAT, CAMS-N2O and MIROC4-ACTM). UNFCCC and EDGAR uncertainty (for 2015 only) was computed with the error propagation method (95% confidence interval). Last reported year in this study refers to 2014 (TOMCAT), 2016 (MIROC4-ACTM), 2017 (UNFCCC, FLEXINVERT and CAMS-N2O). The time series mean was computed for the overlapping period 2005–2014.

Horizon 2020 Societal challenge 5 :
Climate action, environment,
resource efficiency and raw materials