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

VERIFY

Observation-based system for monitoring and verification of greenhouse gases

GA number 776810, RIA

Deliverable number (relative in WP)	**D6.5**
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Changes with respect to the DoA
This deliverable was delayed as it is based on the results of D5.9 First scientific review article on multi-gas GHG budgets and on the D5.3, D5.4 and D5.5 reports of the reconciliation of bottom-up and top-down methods at national or regional scales. Besides, the (updated) inventory data collection for Indonesia proved to be challenging and required more time than was initially planned.
Dissemination and uptake **(Who will/could use this deliverable, within the project or outside the project?)**
Factsheets may be used for scientific studies. They may help discussing the applicability of this kind of analysis on a broader scale than Europe. And finally it may also help discussing priorities for further inventory development in Indonesia.
Short Summary of results (<250 words)
This deliverable primarily presents the fact-sheets linked to the first scientific review article on multi-gas GHG budgets. There are four main sheets: CO_2 fossil, CO_2 land, 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, but this deliverable will only present the factsheets for Indonesia. The fact-sheets for each component, and each region, will have a similar design. The upper part of the sheets shows figures based on inventories as submitted to the UNFCCC. This is to provide a link to WP1 and to set the remaining figures in context. The bottom part of the sheets shows a comparison of sectoral emissions by bottom-up methods (left) and a comparison of the bottom-up and top-down methods (right). Min-max ranges give an indication of the uncertainties within the model ensembles. Country-specific factsheets will be available via a web portal, and the factsheets can be updated with new GHG syntheses.
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.**

Version	Date	Description	Author (Organisation)
V0	20/05/2022	Creation/Writing	P.Ruyssenaars (RIVM)
V0.1	24/05/2022	Writing/Formatting/Delivery	A.M.R. Petrescu (VUA)
V1	07/06/2022	Formatting/Delivery on the Participant Portal	Aurélie Paquirissamy (LSCE)

1. Glossary

Abbreviation / Acronym	Description/meaning
BP	The British Petroleum Company
BLUE	Bookkeeping model University of Munich
CH_4	Methane
CO_2	Carbon dioxide
DGVM	Dynamic Global Vegetation Model
EDGAR	Emission Database for Global Atmospheric Research
GAINS	Greenhouse Gas and Air Pollution Interactions and Synergies model
GCP	Global Carbon Project model
GHG	Greenhouse gas
LULUCF	Land Use, Land Use Change and Forestry
N_2O	Nitrous oxide
ORCHIDEE	General ecosystem model from the Laboratoire des Sciences du Climat et de l'Environnement (LSCE)
TRENDY	Model intercomparison project among DGVM's
VERIFY	Verifying greenhouse gas emissions, EU H2020 project, grant agreement no. 776810

VERIFY is a research project funded by the European Commission under the H2020 program. Grant Agreement number 776810.

2. Executive Summary

The VERIFY project collects and disseminates a large amount of information and data on greenhouse gas emissions across Europe and looks into possibilities to apply these developed methodologies to other regions in the world, such as China, US and Indonesia. The available data and information vary in complexity, ranging from high-resolution spatially-explicit maps of greenhouse gas 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; among which this one for Indonesia. 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, in which space-constraints limited the discussion to a single region of Indonesia. Four main factsheets have been produced, separated by greenhouse gas species: CO_2 fossil, CO_2 land, CH_4 and N_2O.

The upper part of each sheet shows a figure based on UNFCCC inventories, where decennial changes are shown by sector. This is to provide a link to WP1 and context. The bottom part of the sheets 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, calculated as the min-max range of the model ensembles. Country-specific factsheets will be available via a web portal, and the factsheets will be updated with each new GHG synthesis.

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 proposed to produce factsheets for USA, China and Indonesia, using the same approach compared to the one used for EU27 and UK countries, but with less detailed data since the project does not produce specific estimations of GHG budgets for these three countries. This deliverable contains a documentation for the factsheet produced for Indonesia.

We provide a short text like in the WP1 factsheets for EU countries, describing changes of emissions in Indonesia from different global estimates, and a synthesis of the GHG budgets for policy makers and the general public (as this deliverable is part of WP6). The part of this factsheet completed to show information on CO_2 emissions trends over time (aggregated sector) is for the latest inventory year. In this case, the information is based on inventory data received from Indonesia that relate to the second Biennial Update Report (2nd BUR published in 2018); and inventory data for the 3rd BUR (published in 2021).
The factsheets cover fossil CO_2emissions, CO_2 from land (referring here to the Land Use and Land Use Change (LULUCF) sector), CH_4 and N_2O anthropogenic emissions. The factsheets are significantly more complex than an analysis based only on bottom-up emissions as they represent top-down results from ensemble of global inversions and bottom-up results from different global inventories, that can be updated when new estimates become available.
It should be noted that on the basis of the UNFCCC guidelines, countries do not report emissions of non-anthropogenic sources. This means there will be a discrepancy with the top down emissions, that are calculated on the basis of measurements that do include non-anthropogenic sources.

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 webportal 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 syntheses (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. Sample factsheets are shown for each GHG, but design, content, and summaries will be all be finalized with the final GHG budget synthesis (D5.10). This deliverable shows factsheets for Indonesia, but the web portal will ultimately include factsheets for all EU countries and regions studied in the GHG budget synthesis (currently 79).

Sample factsheets by greenhouse gas

4.1. CO_2 from fossil sources

CO_2 emissions in Indonesia are dominated by the energy sector, as shown in figure 1. About 90% of reported CO_2 emissions from fossil sources in 2016 is related to the energy sector. Data in figure 1 is based on the 2nd Biennual Update Report (BUR) from Indonesia (Rep. of Indonesia, 2018). Over the period 2000-2012, energy consumption increased. After 2012, energy consumption more or less stabilized. Emission of other sectors show a relatively stable trend, and represent only a small share of the total CO_2 emissions from Indonesia.

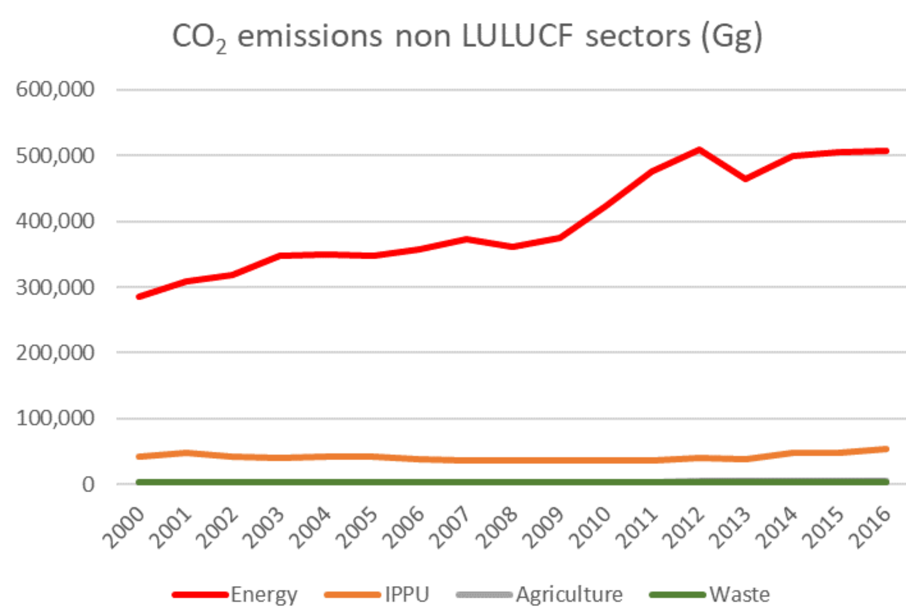

Figure 1: Sectoral emission trends Indonesia

Zooming in on the energy sector, figure 2 shows the trend in relative share per subsector over the period 2000-2016. The relative share of the sector 1A1 Energy industries varies between 21% (in 2000) and 46% (in 2016); an increasing trend of about 1% per year. In absolute terms, the CO_2 emissions of the energy industries were 2.75 times higher in 2016 compared to 2000. According to the 2nd BUR, the road transport sector is the only other sector with increasing relative share. In 2016, the road transport related CO_2 emissions were 2.3 time higher than the emissions in 2000.

This is clarified in the 2nd BUR by a substantial economic growth (e.g. 5.4 % per year over the period 2010-2016 and a growing population; 1.36% per year over 2010-2016).

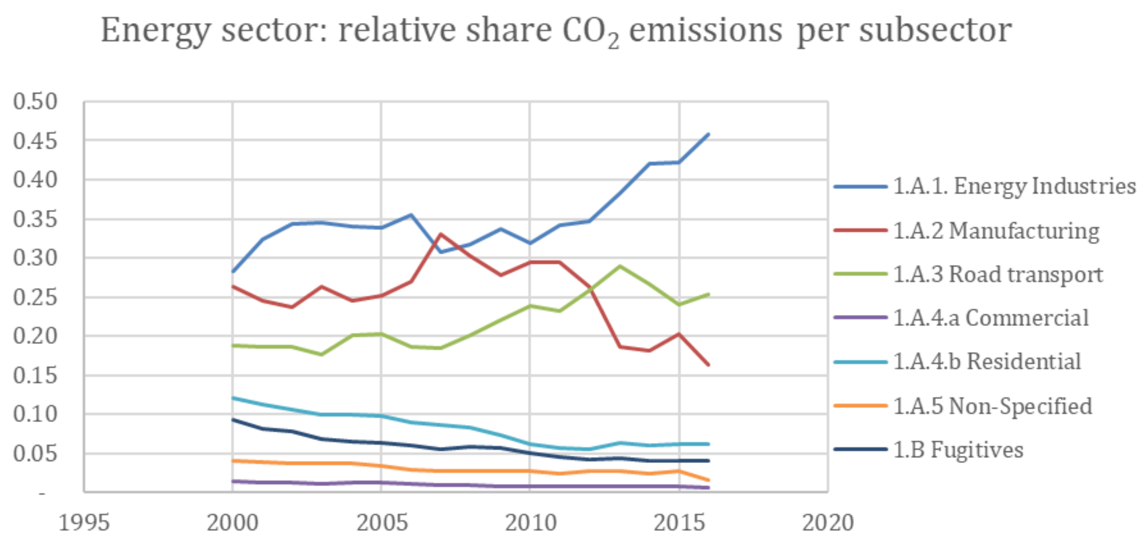

Figure 2: Emission in the energy sector: subsectoral CO_2 emission trends in Indonesia

The emissions reported by Indonesia are for this factsheet compared with other available datasets. This comparison also includes the dataset provided by Indonesia to the 3rd Biennual Update Report, that became available in 2021 (Republic of Indonesia, 2021).
For this factsheet, a number of datasets were consulted, as shown in figure 3. The comparison was made for the Energy sector only.

Some remarks:
Figure 3 includes the inventory dataset that is based on the 2020 inventory.
The consulted datasets show a comparable trend over the period 1990 – 2020. The actual Indonesian inventory dataset based on the BUR's, is available for the timeseries 2000 – 2019. Compared to the other available datasets, the Indonesian inventory is at the high end of the emission range that the datasets show.
In the period after 2000 some datasets show anomalies (that are not observed in the inventory data); such as PRIMAP-TP and CDIACv2021 for 2010 and 2013-2014. CDIAC relies on error-prone supply-side data: production, imports, exports. PRIMAP-hist TP prioritizes third-party sources over official sources. In this case probably CDIAC data is followed.

The IDN UNFCCC 2021 3rd BUR Energy emissions trends show a constant increasing trend. Between 1990 and 2019 a net increase in emissions by 116 % is noted. EDGARFT2020, BP and GCP indicate for 2020 a substantial decrease in 2020 of 11-13 % in the energy sector related emissions compared to 2019. This might relate to global economic impacts of Covid-19.

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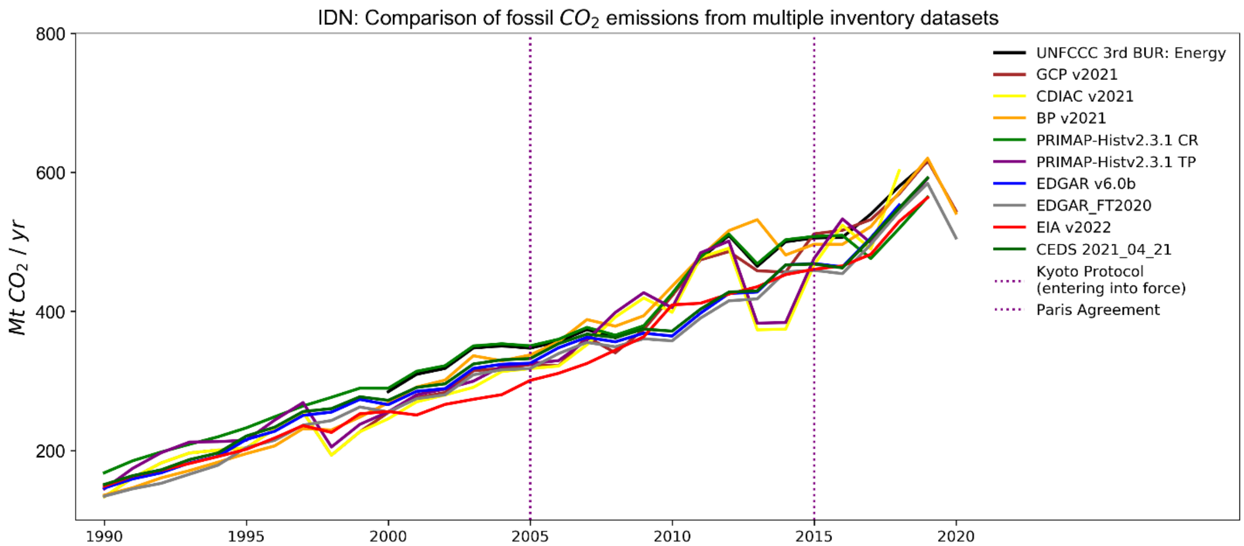

Figure 3: Comparison of Indonesia fossil CO_2 emissions from multiple inventory datasets (methodology and data collected following Andrew et al., 2020).

4.2. CO_2 from land use

In accordance to the 2nd BUR, figure 4 shows that emissions from LULUCF are a predominant source of CO_2 emissions in Indonesia. LULUCF emissions are related to deforestation and forest degradation. However, most important emission sources in this category are peat decomposition and peat fires, that constitute about 70% of the emissions for this sector in 2016.

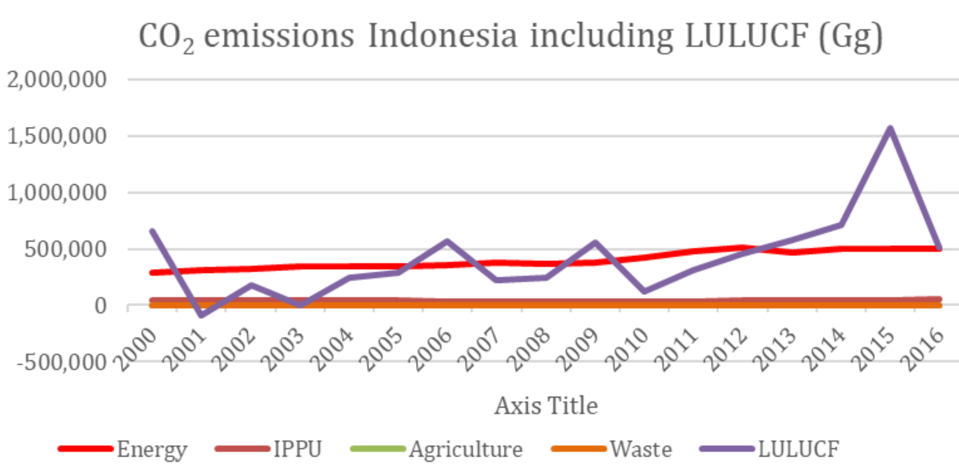

Figure 4: CO_2 emissions Indonesia including the LULUCF sector, based on BUR-2

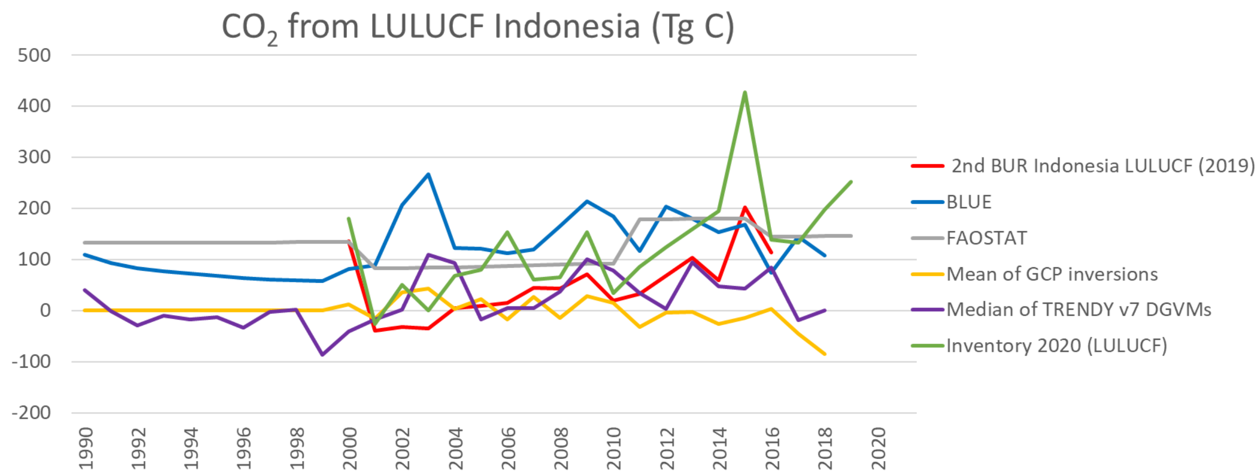

Figure 5: Comparison of different BU datasets for the LULUCF sector in Indonesia.

Figure 5 shows the comparison of different datasets for the LULUCF sector in Indonesia. It includes both the dataset presented by the 2nd BUR (2018) and the inventory dataset for 2020, used for the 3rd BUR (2021). This figure not only shows substantial differences between all datasets, but also between the dataset of 2nd BUR and 3rd BUR. Probably these differences can be explained by a change in methodology, as also found by a study of Austin et al., (2018), that attributes the potential reasons for the differences to input data and estimation methods, including the definitions and assumptions used for setting accounting boundaries, including emitting activities, incorporating fluxes from various carbon pools, and handling legacy fluxes.

Major source for uncertainty in the inventory data relates to peat decomposition and peat fires, that are a specific feature for Indonesia. One of the factors determining the uncertainty, is the thickness of the peat layers in Indonesia. Austin (2018) concludes that the largest changes stem from the inclusion of legacy GHG emissions due to peat drainage (which increased emissions by at least +94% compared to the reference), methane emissions due to peat fires (+35%), and GHG emissions from belowground biomass and necromass carbon pools (+61%), modifications to assumptions of the mass of fuel burnt in peat fire events (+88%), and accounting for regrowth following a deforestation event (−31%). These differences cumulatively explain more than half of the observed difference among inventory estimates.

A comparison of bottom-up datasets and top-down inversions show some remarkable differences (see figures 5 and 6):

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Inventory datasets in figure 5, as well as the results of bookkeeping models (DGVMs) suggest that the LULUCF sector is a (substantial) source in Indonesia. GCP inversions show that the LULUCF sector is a (substantial) sink category in Indonesia.

At the same time, the min/max of the inversions show that there are substantial uncertainties related to this sector. Also the bottom-up inventories are highly uncertain, as indicated above.

During a VERIFY knowledge transfer workshop in 2021[1], the mismatch between Top Down and Bottom UP estimates were for biomass use explained in the delayed effect of internationally traded commodities cultivated on the deforested areas (see also Xu et al., 2022).

Moreover, the bottom-up estimates of biomass fires are not very reliable (and show large changes of the years – related to changes in methodology and year to year differences in a.o. weather conditions).

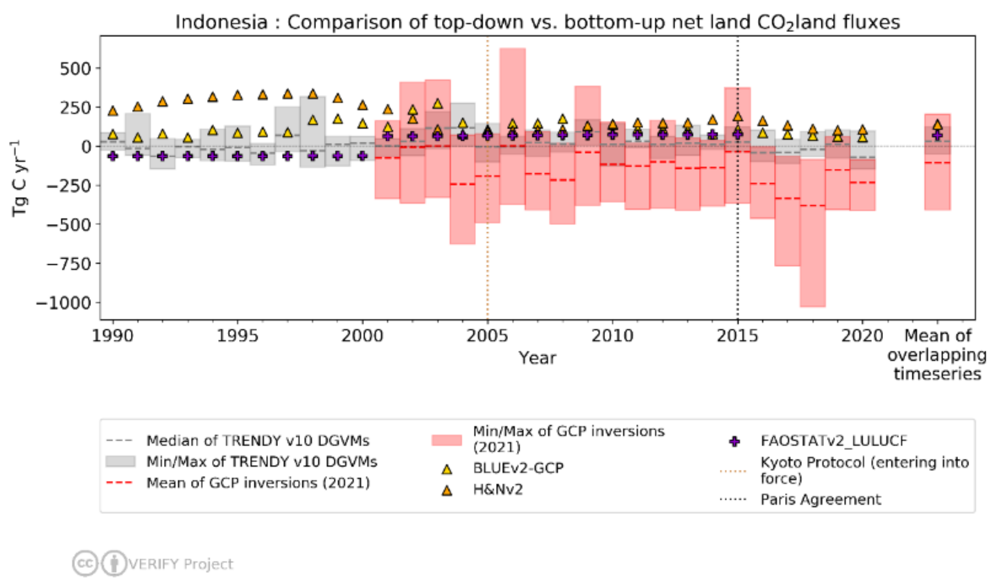

Figure 6: Comparison of bottom-up datasets and top-down inversions for the LULUCF sector in Indonesia.

4.3. CH_4 emissions

According to the Indonesian inventory (3rd BUR, figure 7), the waste sector is the most important sector for CH_4 emissions in Indonesia. The relative share of emissions of this sector is also increasing compared to the other sectors. Emissions in this sector are about 1.75 times higher in 2019 compared to 2000.

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[1] D6.6 : Knowledge transfer workshop with US, China, Indonesia (ipsl.fr)

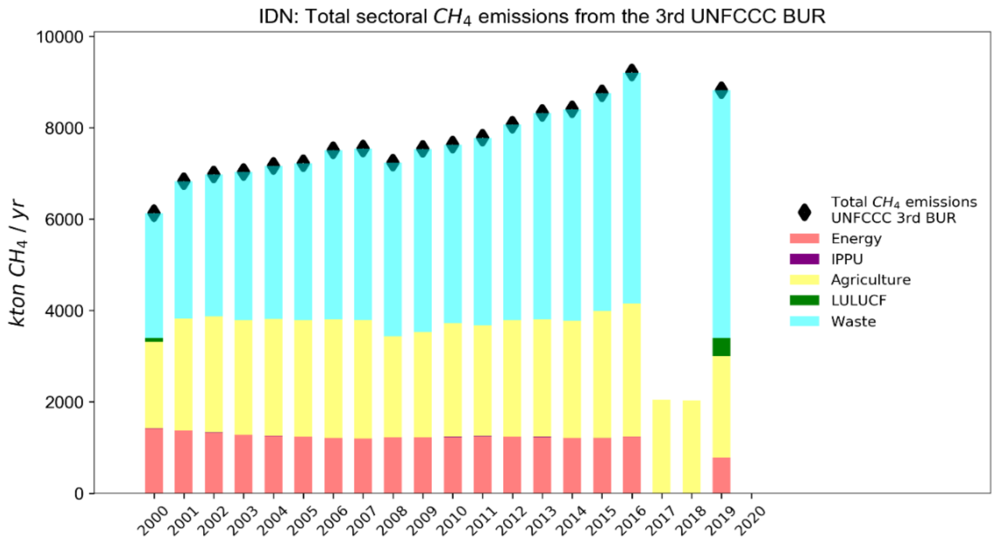

Figure 7: Sectoral CH_4 emissions in Indonesia for 2000 -2019. For 2017 and 2018 detailed information per
sector was only available for Agriculture.

The 2nd and 3rd BUR datasets are comparable, except that the 3rd BUR includes 3 more years (2017-2019). A comparison of the inventory data (BUR 2) applied for this factsheet, and other bottom up datasets, shows the following.

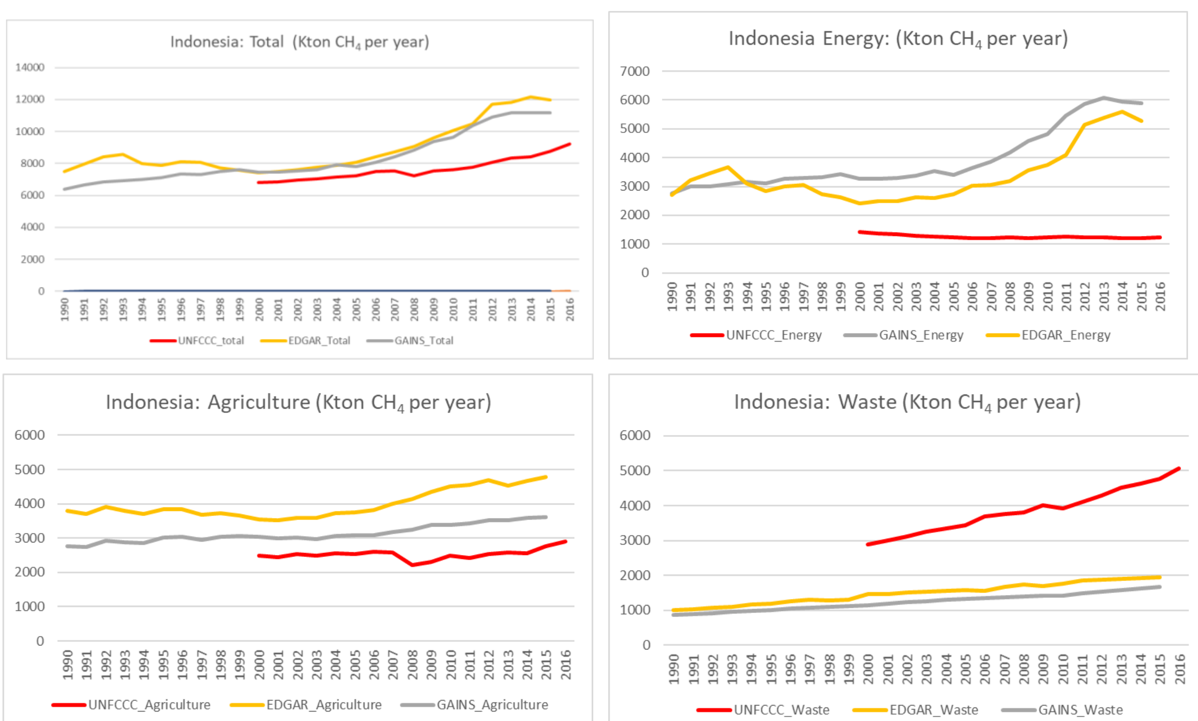

Figure 8: CH_4 emissions in Indonesia: comparison between bottom-up datasets (based on the 2nd BUR)

Figure 8 shows that:
Both GAINS and EDGAR indicate that the sector agriculture and energy have higher emissions over the whole timeseries than reported by Indonesia.
Both GAINS and EDGAR show substantially lower emissions for the waste sector than Indonesia (ca 60% lower than what is reported by Indonesia); also the trend is much lower.
Following GAINS and EDGAR, the Energy sector is the most important sector for CH_4 emissions in Indonesia. It should be noted that the Indonesian inventory is not complete for the sectors coal mining and oil and gas. These are relevant source sectors for Indonesia.

Figure 9 shows a comparison of bottom-up estimates with top-down inversions based on in-situ measurements (SURF) and satellite data (GOSAT). The min-max ranges in this figure suggest substantial
uncertainties in the inversions. Looking at the mean over the time series, it can be concluded that the
bottom-up results lay in the same range as the top-down results. Also the trends are comparable; though
the time series for the GOSAT inversions may be a bit short.

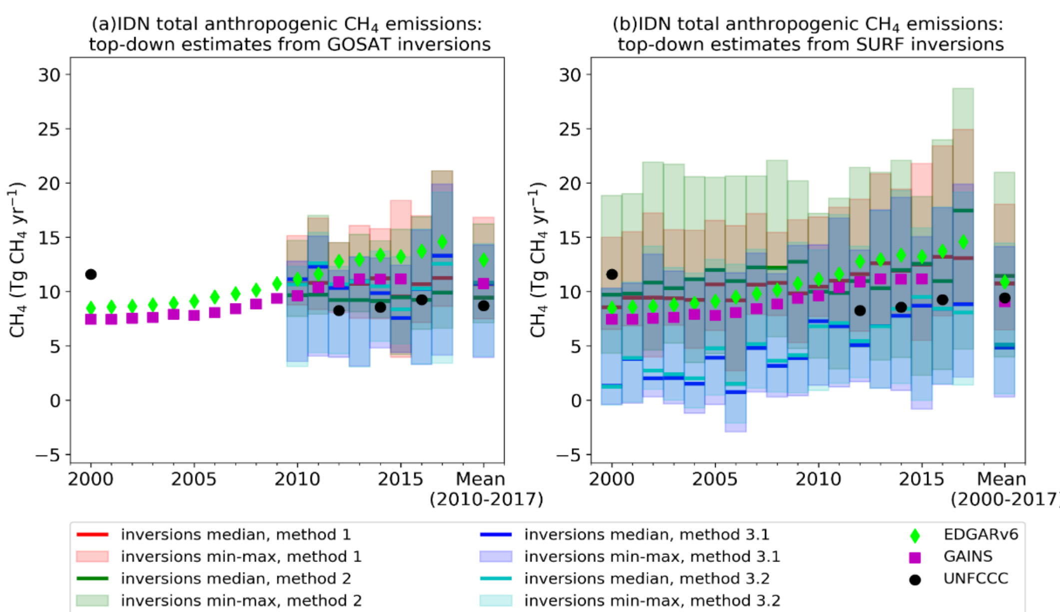

Figure 9: Top-down and bottom-up comparisons of CH_4 emissions in Indonesia.

4.4. N_2O emissions

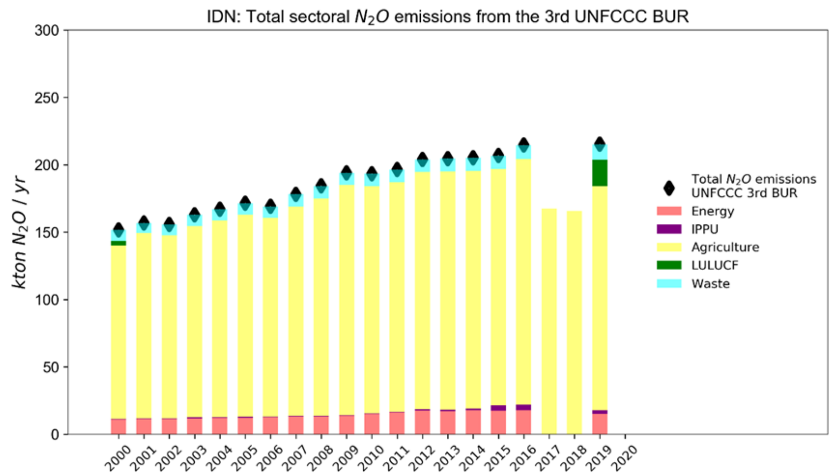

Figure 10: N_2O emissions in Indonesia per sector, for the 2000-2019 period.

According to the Indonesian inventory (3rd BUR, see figure 10), the agriculture sector is the most important sector for N_2O emissions in Indonesia. The relative share of emissions of this sector is also increasing compared to the other sectors. Differences between the datasets corresponding to the 2nd and 3rd BUR are relatively small; except that the 3rd BUR dataset includes 3 additional years (2017-2019). A comparison of the inventory data (2nd BUR) applied for this factsheet, and other bottom-up datasets, shows the following:

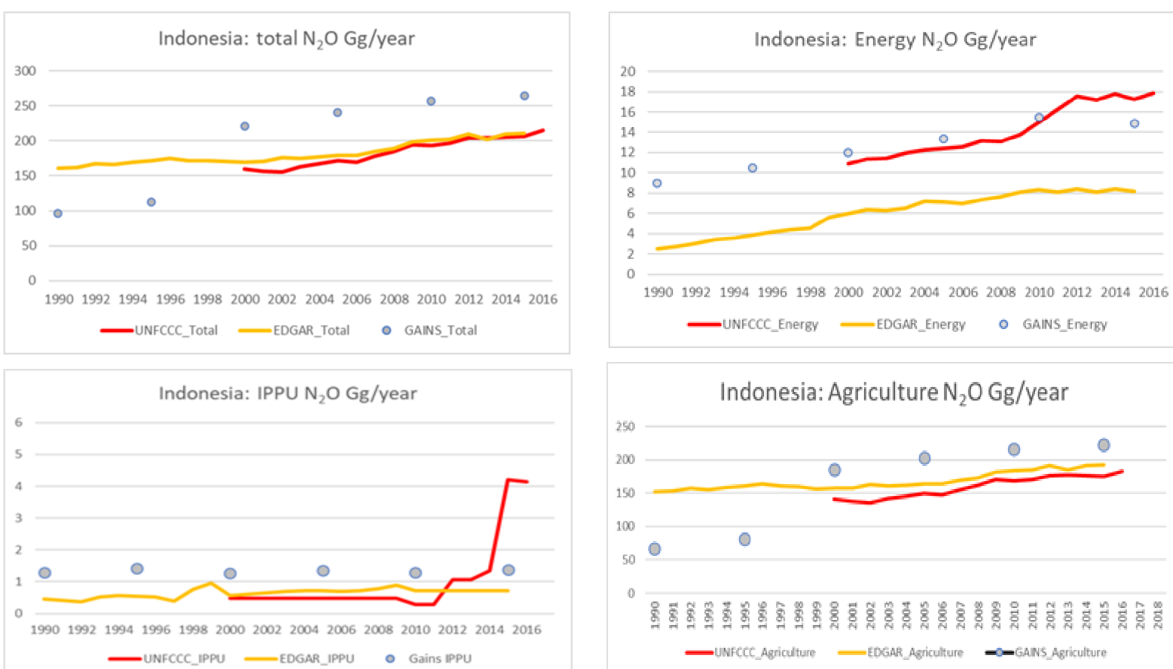

Figure 11: N_2O emissions in Indonesia: comparison between three bottom-up datasets (EDGAR v6.0, GAINS and UNFCCC 2nd BUR).

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Bottom-up inventory datasets comparisons show that total N_2O emissions as reported in the 2nd BUR are in line with the emissions reported by the EDGAR v6.0 dataset. The GAINS total N_2O emissions are about 25% higher. Though emission levels differ, the trends for these datasets shows an increasing comparable development. The 2016 emissions are about 1.35 times higher than the 2000 emissions.

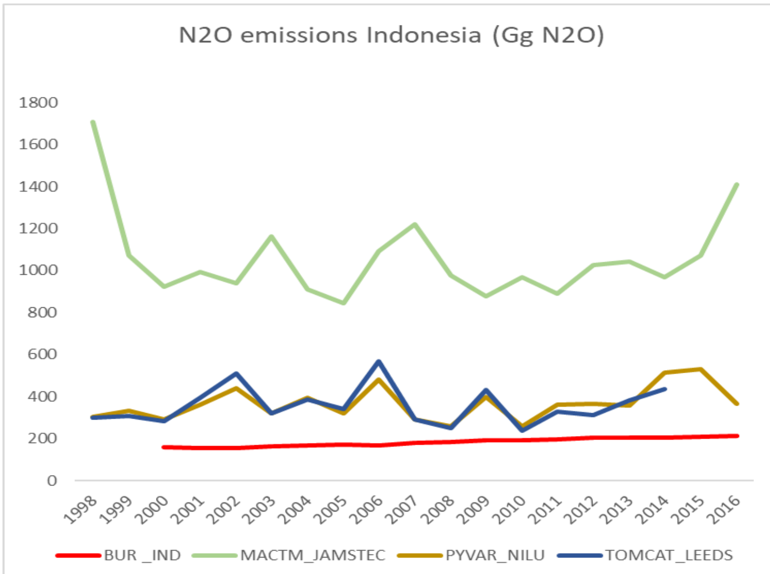


Figure 12: Top-down and bottom-up comparisons of N_2O emissions in Indonesia.

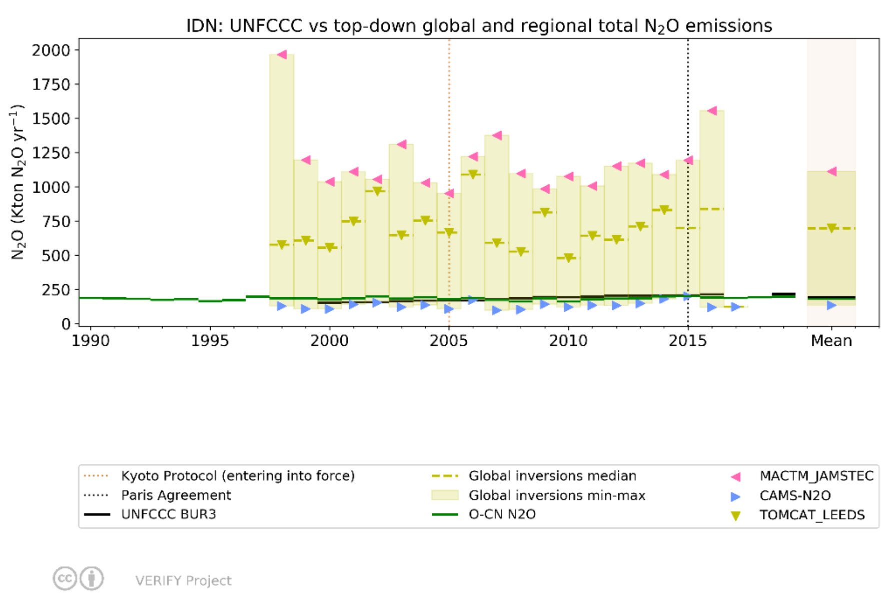


Figure 13: Top-down inversions for N_2O emissions in Indonesia compared to the 3rd UNFCCC BUR data. In green the O-CN natural background N_2O emissions (as pre-industrial).

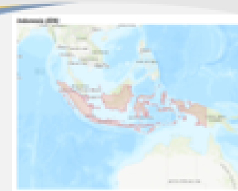
Figures 12 and 13 show the results of comparing top-down global inversions (MACTM_JAMSTEC, PYVAR_NILU and TOMCAT_LEEDS) and bottom up inventories (BUR_IND, the red line in figure 12). The broad min-max range in the inversions in figure 13, shows a significant uncertainty in the inversion results. The data reported in the Indonesian inventory are substantially lower than the results of the inversions. According to the Indonesian experts, the N_2O inventory is still under development (pers. comm.); and data for estimating the N_2O emissions are not collected on an annual basis. The comparison with the inversion result might indeed suggest that the N_2O emission inventory is not complete; and/or the emission sources might be underestimated.

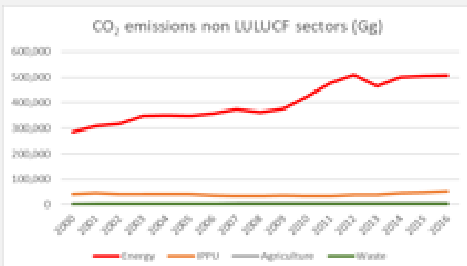
4. Factsheets by greenhouse gas for Indonesia

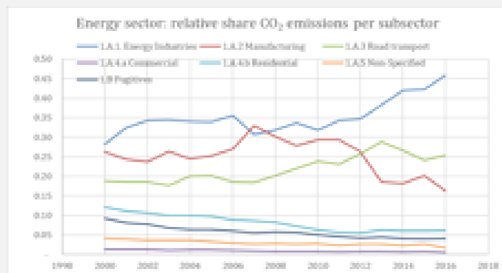
5.1 CO_2 fossil fuel

Fact Sheet – Indonesia
October 2021

CO_2 fossil

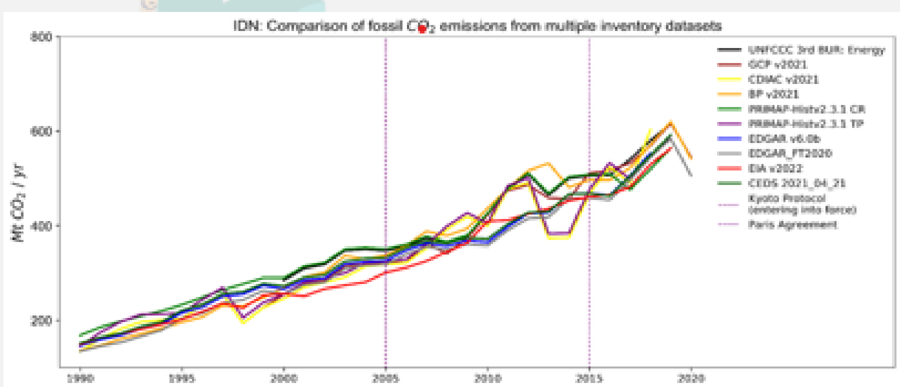






Emissions trends for non LULUCF sectors are determined by the fossil fuel use in the Energy sector representing up to 50% of the total CO_2 emissions in the Indonesian inventory. The emissions **show an increasing trend,** though they are more or less stable in the period 2021-2016.
Main subsectors which contribute to the increase in the past decades are electricity generation and transportation.

Comparison with other bottom-up datasets show comparable trends and may suggest that inventory estimates are at the upper end of the range of different datasets.



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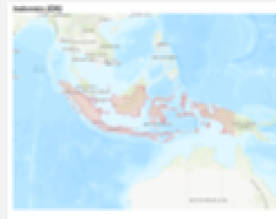
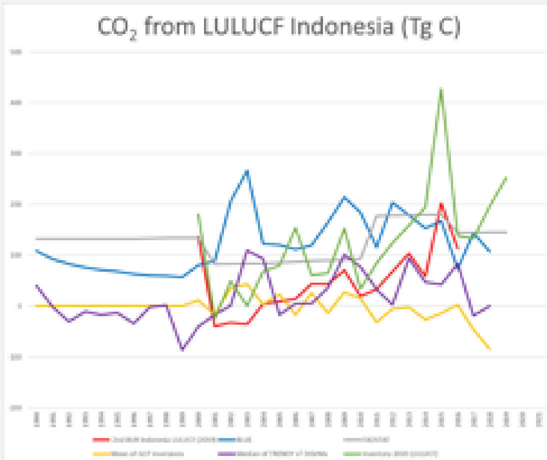
5.2. CO2 land

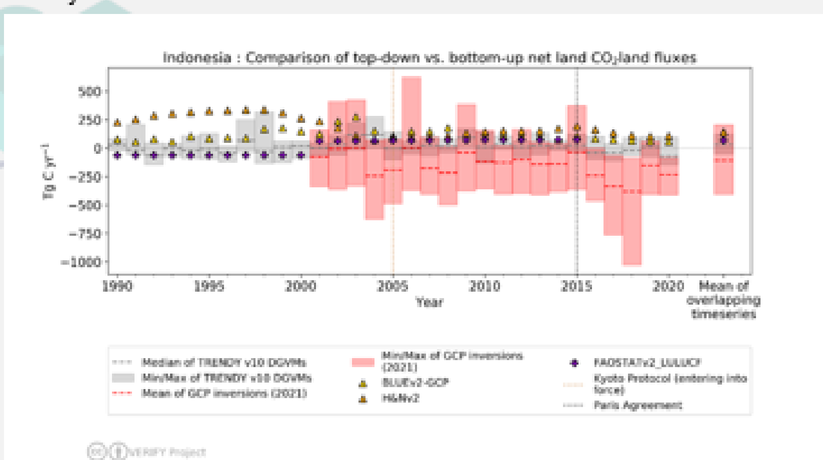
Fact Sheet – Indonesia
October 2021

CO_2 land





The mean of the GCP inversions suggest a small net CO_2 land uptake. The most recent national Indonesian estimate gives a net CO_2 emission (green line). National estimates include highly variable (and uncertain) emissions from peat fires and decomposition (up to 300 Tg CO_2 in 2015). Top down inversion from BLUE **give a higher net CO_2 emission** whereas the trendy inversion is in the range of the inventory.



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Climate action, environment,
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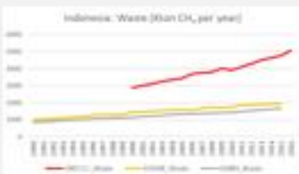
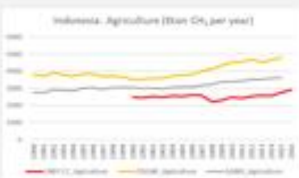
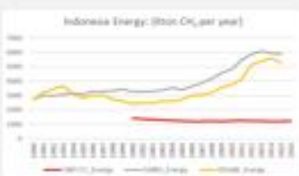
5.3. CH_4

Fact Sheet – Indonesia
October 2021

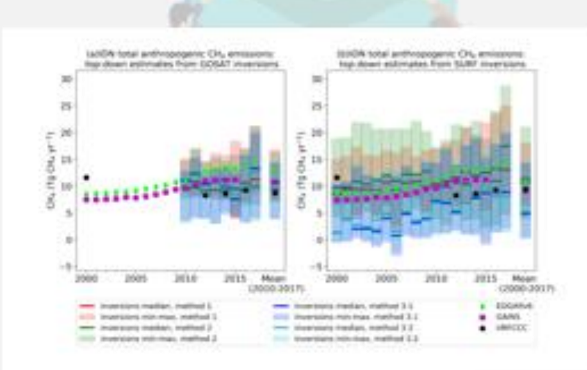
CH_4







CH_4 emissions provided by different global datasets are higher than the national Indonesian inventory. Over the past decades, the inventory shows a lower trend. The inventory shows the waste sector to be the most relevant source, though global datasets suggest the emissions from the energy sector are more important. The inventory for Energy shows a stable trend, noting the inventory is not complete for the, in Indonesia relevant, sectors coal mining and oil and gas.



GOSAT and SURF inversions suggest that inventory data are at the low side. Note that the inventory, other than the inversions, does not include emissions from natural sources (a.o. forest fires). Trends look comparable.

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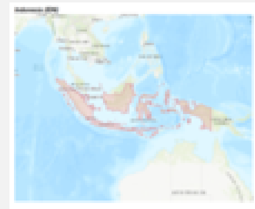
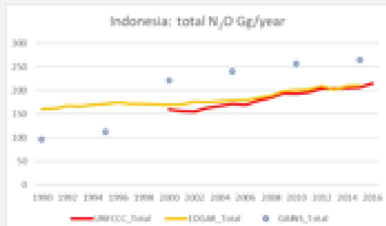
5.4. N_2O

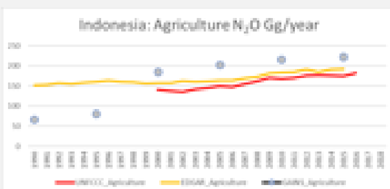
Fact Sheet – Indonesia
October 2021

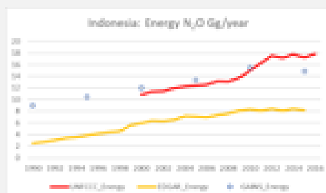
N_2O



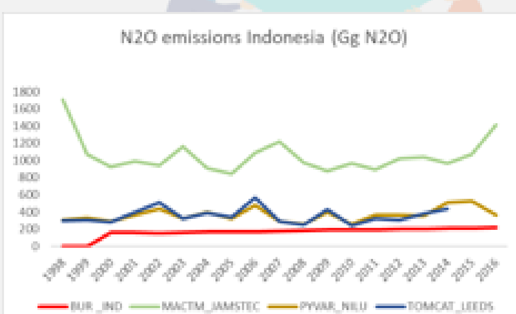


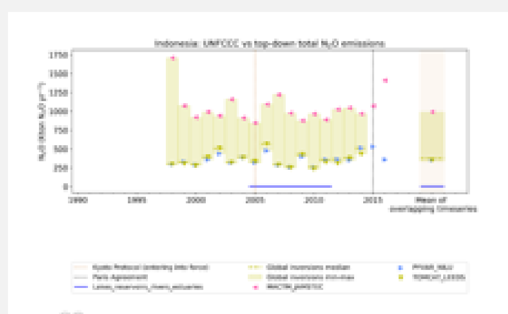
Overall nitrous oxide emissions show **a steady increasing trend after 2000.** Main contributor is the agricultural sector, followed by the Energy sector (with a much lower share in the total emissions).





Comparison of global emission estimates with the inventory Indonesia show similar increasing emission trends. GAINS emission estimates are for the years 2000 onwards significant higher than the inventory. This also holds for agriculture. However GAINS estimates for Energy do align with the emission inventory. For the IPPU sector the inventory is still under construction. Different GCP inversions indicate however a higher N_2O emission from Indonesia than reported in the inventory.





Horizon 2020 Societal challenge 5 :
Climate action, environment,
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5. Conclusions

This deliverable presents results and summary factsheets for Indonesia based on the scientific data analysis carried out in WP5 of the VERIFY project. There are four main factsheets: CO_2 fossil, CO_2 land, CH_4, and N_2O.

Content wise, the inversions for both CH_4 and N_2O suggest that there is reason to assess the methodologies for reported emissions for both compounds. It is noted that the N_2O emissions data are not collected regularly and are therefore highly variable. Besides, the Indonesian inventory is not complete for the coal mining and oil and gas sectors, which represent relevant source sectors for CH_4 emissions in Indonesia. Besides, in accordance with agreed reporting IPCC rules, the inventory does not include the natural emissions of greenhouse gases which may clarify part of the difference between bottom-up and top-down CH_4 estimates.

For CO_2 land, the mismatch of TD observation-based inversions and the BU estimates are for biomass use explained in the delayed effect of consumption due to international trade, which plays an important role in Indonesia. Next to that, bottom-up estimates of biomass burning are not very reliable (and show large changes over the years – that also may relate to changes in the reporting methodologies).

The factsheets for each of the four components are more simplified compared to the factsheets for e.g. EU27 + UK, due to the fact that not all information is available at the same level of detail. Comparable with the European fact sheets, the upper part of the fact sheet shows the inventory based information and some break down to the sectoral level. Besides, the inventory dataset is compared with other datasets. The lower 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. Top-down min-max ranges give an indication of uncertainties in the analysis.

Country-specific factsheets will be compiled through an automated process and made available via a web portal. This will permit the factsheets to be updated for each new GHG synthesis while reducing the amount of human intervention required to assemble 79 factsheets, each for four different GHG species.

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