

# The PRIMAP-hist national historical emissions time series (1750-2021) (v2.4.2, updated March 2023)

## 1 Recommended citation

Gütschow, J.; Pflüger, M. (2023): The PRIMAP-hist national historical emissions time series v2.4.2 (1750-2021). zenodo. [10.5281/zenodo.7727475](https://doi.org/10.5281/zenodo.7727475).

Gütschow, J.; Jeffery, L.; Gieseke, R.; Gebel, R.; Stevens, D.; Krapp, M.; Rocha, M. (2016): The PRIMAP-hist national historical emissions time series, *Earth Syst. Sci. Data*, 8, 571-603, [doi:10.5194/essd-8-571-2016](https://doi.org/10.5194/essd-8-571-2016)

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## 3 Abstract

The PRIMAP-hist dataset combines several published datasets to create a comprehensive set of greenhouse gas emission pathways for every country and Kyoto gas, covering the years 1750 to 2021, and almost all UNFCCC (United Nations Framework Convention on Climate Change) member states as well as most non-UNFCCC territories. The data resolves the main IPCC (Intergovernmental Panel on Climate Change) 2006 categories. For CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O subsector data for Energy, Industrial Processes and Product Use (IPPU), and Agriculture are available. The “country reported data priority” (CR) scenario of the PRIMAP-hist dataset prioritizes data that individual countries report to the UNFCCC. For developed countries, Annex I in terms of the UNFCCC, this is the data submitted annually in the “common reporting format” (CRF). For developing countries, non-Annex I in terms of the UNFCCC, this is the data available through the UNFCCC DI interface ([di.unfccc.int](http://di.unfccc.int)) with additional country submissions read from pdf and where available xls(x) or csv files. For a list of these submissions please see below. For South Korea the 2021 official GHG inventory has not yet been submitted to the UNFCCC but is included in PRIMAP-hist. PRIMAP-hist also includes official data for Taiwan which is not recognized as a party to the UNFCCC.

Gaps in the country reported data are filled using third party data such as CDIAC, BP (fossil CO<sub>2</sub>), Andrew cement emissions data (cement), FAOSTAT (agriculture), and EDGAR v7.0 (all sectors). Lower priority data are harmonized to higher priority data in the gap-filling process.

For the third party priority time series gaps in the third party data are filled from country reported data sources.

Data for earlier years which are not available in the above mentioned sources are sourced from EDGAR-HYDE, CEDS, and RCP (N<sub>2</sub>O only) historical emissions.

The v2.4 release of PRIMAP-hist reduced the time-lag from 2 to 1 years. Thus we include data for 2021 while the 2.3.1 version included data for 2019 only. For energy CO<sub>2</sub> growth rates from the BP statistical review of world energy are used to extend the country reported (CR) or CDIAC (TP) data to 2021. For CO<sub>2</sub> from cement production Andrew cement data are used. For other gases and sectors EDGAR 7.0 is used since PRIMAP-hist v2.4.1 (v2.4 had to rely on numerical methods).

Version 2.4.2 of the PRIMAP-hist dataset does not include emissions from Land Use, Land-Use Change, and Forestry (LULUCF) in the main file. LULUCF data are included in the file with increased number of significant digits and have to be used with care as they are constructed from different sources using different methodologies and are not harmonized.

The PRIMAP-hist v2.4.2 dataset is a bugfix update of

Gütschow, J.; Pflüger, M. (2023): The PRIMAP-hist national historical emissions time series v2.4.1 (1750-2021). Zenodo. doi:10.5281/zenodo.7585420.

The [Changelog](#) below indicates the most important changes. You can also check the issue tracker on [github.com/JGuetschow/PRIMAP-hist](https://github.com/JGuetschow/PRIMAP-hist) for additional information on issues found after the release of the dataset.

## 4 Use of the dataset and full description

Before using the dataset, please read this document and the article describing the methodology, especially the section on uncertainties and the section on limitations of the method and use of the dataset.

Gütschow, J.; Jeffery, L.; Gieseke, R.; Gebel, R.; Stevens, D.; Krapp, M.; Rocha, M. (2016): The PRIMAP-hist national historical emissions time series, Earth Syst. Sci. Data, 8, 571-603, doi:10.5194/essd-8-571-2016

Please notify us ([mail@johannes-guetschow.de](mailto:mail@johannes-guetschow.de)) if you use the dataset so that we can keep track of how it is used and take that into consideration when updating and improving the dataset.

When using this dataset or one of its updates, please cite the DOI of the precise version of the dataset used and also the data description article which this dataset is supplement to (see above). Please consider also citing the relevant original sources when using the PRIMAP-hist dataset. See the full citations in the References section further below.

Since version 2.3 we use the data formats developed for the PRIMAP2 climate policy analysis suite: [PRIMAP2 on GitHub](#). The data are published both in the interchange format which consists of a csv file with the data and a yaml file with additional metadata and the native NetCDF based format. For a detailed description of the data format we refer to the [PRIMAP2 documentation](#).

We have also included files with more than three significant digits. These files are mainly aimed at people doing policy analysis using the country reported data scenario (HISTCR). Using the high precision data they can avoid questions on discrepancies with the reported data. The uncertainties of emissions data do not justify the additional significant digits and they might give a false sense of accuracy, so please use this version of the dataset with extra care.

## 5 Support

If you encounter possible errors or other things that should be noted, please check our issue tracker at [github.com/JGuetschow/PRIMAP-hist](https://github.com/JGuetschow/PRIMAP-hist) and report your findings there. Please use the tag “v2.4.2” in any issue you create regarding this dataset.

If you need support in using the dataset or have any other questions regarding the dataset, please contact [mail@johannes-guetschow.de](mailto:mail@johannes-guetschow.de).

## 6 Sources

**Global CO<sub>2</sub> emissions from cement production v210723 (Andrew 2022) data, paper** Andrew (2022), Andrew (2019b)

**BP Statistical Review of World Energy** [website](#): British Petroleum (2022)

**CDIAC** [data](#): Gilfillan et al. (2020), [paper](#) Gilfillan and Marland (2021)

**CEDS** [data](#): [paper](#): Hoesly et al. (2020), Hoesly et al. (2018)

**EDGAR versions 4.2 and 4.2 FT2010**: [EDGAR v4.2](#), [EDGAR v4.2 FT2010](#): JRC and PBL (2011), Olivier and Janssens-Maenhout (2012)

**EDGAR version 7.0**: [data](#), [website](#) JRC (2022), Reports: European Commission Joint Research Centre (2022), European Commission Joint Research Centre (2021),

**EDGAR-HYDE 1.4** [data](#): Van Aardenne et al. (2001), Olivier and Berdowski (2001)

**FAOSTAT database** [data](#): Food and Agriculture Organization of the United Nations (2023)

**RCP historical data** [data](#), [paper](#): Meinshausen et al. (2011)

**UNFCCC National Communications and National Inventory Reports for developing countries** [website](#), slightly updated version of [data](#): UNFCCC (2023b), Pflüger and Gütschow (2022)

**UNFCCC Biennial Update Reports** [website](#), [data](#): UNFCCC (2022)

**UNFCCC Common Reporting Format (CRF)** [website](#), [paper](#), [data \(23-01-23\)](#): UNFCCC (2023a) (processed as described in Jeffery et al. (2018a))

**Official country repositories (non-UNFCCC)** \* Taiwan / Republic of China: [website](#), [data](#): Republic of China - Environmental Protection Administration (2022) \* South Korea: [website](#), [data](#): Republic of Korea (2021)

## 7 Files included in the dataset

For each dataset we have three files: the `.nc` file contains the data and metadata in the native PRIMAP2 netCDF based format. The `.csv` file contains the data in a csv format following the specifications of the PRIMAP2 interchange format. The metadata for the interchange format file is included in the `.yaml` file.

- **Guetschow-et-al-2023a-PRIMAP-hist\_v2.4.2\_final\_09-Mar-2023.X**: The main dataset with numerical extrapolation of all time series to 2021 and three significant digits.
- **Guetschow-et-al-2023a-PRIMAP-hist\_v2.4.2\_final\_no\_extrap\_09-Mar-2023.X**: Variant without numerical extrapolation of missing values and not including the country groups mentioned in section [“country”] (three significant digits).
- **Guetschow-et-al-2023a-PRIMAP-hist\_v2.4.2\_final\_no\_rounding\_09-Mar-2023.X**: The main dataset with numerical extrapolation of all time series to 2021 and eleven significant digits.
- **Guetschow-et-al-2023a-PRIMAP-hist\_v2.4.2\_final\_no\_extrap\_no\_rounding\_09-Mar-2023.X**: Variant without numerical extrapolation of missing values and not including the country groups mentioned in section [“country”] (eleven significant digits).
- **PRIMAP-hist\_v2.4.2\_data-description.pdf**: Data description including changelog.
- **PRIMAP-hist\_v2.4.2\_updated\_figures.pdf**: Updated figures from the PRIMAP-hist paper published in ESSD.
- **changes\_PRIMAP-hist\_v2.4.2\_to\_v2.4.1.xlsx**: xls file which lists relative changes per country, gas and main sector for 2015, 2020, 2021, and 1990-2021 (cumulative).

## 8 Notes

- Emissions from international aviation and shipping are not included in the dataset.
- Emissions from Land Use, Land-Use Change, and Forestry (LULUCF) are not included in the main version of this dataset. They are included in the version without rounding as users need to take extra care when using LULUCF data because some of the year-to-year changes in the data come from using different sources or methodology changes within a source rather than changes in actual emissions.

## 9 Data format description (columns)

The PRIMAP-hist data in the comma-separated values (CSV) files is formatted consistently with the PRIMAP2 interchange format.

The data contained in each column are as follows:

### 9.1 “source”

Name of the data source. Here: *PRIMAP-hist\_v2.4.2* with suffixes *\_ne* for no extrapolation and *\_nr* for no rounding.

### 9.2 “scenario (PRIMAP)”

- HISTCR: In this scenario country-reported data (CRF, BUR, UNFCCC DI) are prioritized over third-party data (CDIAC, FAO, Andrew, EDGAR, BP).
- HISTTP: In this scenario third-party data (CDIAC, FAO, Andrew, EDGAR, BP) are prioritized over country-reported data (CRF, BUR, UNFCCC DI)

### 9.3 “provenance”

Provenance of the data. Here: “derived” as it is a composite source.

### 9.4 “country (ISO3)”

ISO 3166 three-letter country codes or custom codes for groups:

Table 1: Additional “country” codes.

Code	Region description
EARTH	Aggregated emissions for all countries.
ANNEXI	Annex I Parties to the Convention
NONANNEXI	Non-Annex I Parties to the Convention
AOSIS	Alliance of Small Island States
BASIC	BASIC countries (Brazil, South Africa, India and China)
EU27BX	European Union post Brexit
LDC	Least Developed Countries
UMBRELLA	Umbrella Group

### 9.5 “category (IPCC2006)”

IPCC (Intergovernmental Panel on Climate Change) 2006 categories for emissions. Some aggregate sectors have been added to the hierarchy. These begin with the prefix *M*.

Table 2: Category descriptions using IPCC 2006 terminology.

Category code	Description
M.0.EL	National Total excluding LULUCF
1	Energy
1.A	Fuel Combustion Activities
1.B	Fugitive Emissions from Fuels
1.B.1	Solid Fuels
1.B.2	Oil and Natural Gas
1.B.3	Other Emissions from Energy Production
1.C	Carbon Dioxide Transport and Storage (currently no data available)
2	Industrial Processes and Product Use (IPPU)
2.A	Mineral Industry
2.B	Chemical Industry

Category code	Description
2.C	Metal Industry
2.D	Non-Energy Products from Fuels and Solvent Use
2.E	Electronics Industry (no data available as the category is only used for fluorinated gases which are only resolved at the level of category 2)
2.F	Product uses as Substitutes for Ozone Depleting Substances (no data available as the category is only used for fluorinated gases which are only resolved at the level of category 2)
2.G	Other Product Manufacture and Use
2.H	Other
M.AG	Agriculture, sum of 3.A and M.AG.ELV
3.A	Livestock
M.AG.ELV	Agriculture excluding Livestock
4	Waste
5	Other

## 9.6 “entity”

Gas categories using global warming potentials (GWP) from either Second Assessment Report (SAR) or Fourth Assessment Report (AR4).

Table 3: Gas categories and underlying global warming potentials

Code	Description
CH4	Methane
CO2	Carbon Dioxide
N2O	Nitrous Oxide
HFCS (SARGWP100)	Hydrofluorocarbons (SAR)
HFCS (AR4GWP100)	Hydrofluorocarbons (AR4)
PFCS (SARGWP100)	Perfluorocarbons (SAR)
PFCS (AR4GWP100)	Perfluorocarbons (AR4)
SF6	Sulfur Hexafluoride
NF3	Nitrogen Trifluoride
FGASES (SARGWP100)	Fluorinated Gases (SAR): HFCs, PFCs, SF <sub>6</sub> , NF <sub>3</sub>
FGASES (AR4GWP100)	Fluorinated Gases (AR4): HFCs, PFCs, SF <sub>6</sub> , NF <sub>3</sub>
KYOTOGHG (SARGWP100)	Kyoto greenhouse gases (SAR)
KYOTOGHG (AR4GWP100)	Kyoto greenhouse gases (AR4)

## 9.7 “unit”

Unit is either  $\langle substance \rangle$  gigagram / a\* where substance is the entity or for CO<sub>2</sub> equivalent units  $CO_2$  gigagram / a\*. The CO<sub>2</sub>-equivalent is calculated according to the global warming potential indicated by the entity (see above).

## 9.8 Remaining columns

Years from 1750-2021.

## 10 Changelog

Throughout this section we use “CR” to refer to the country-reported data priority source and “TP” to refer to the third-party priority source.

## 10.1 v2.4.2 (March 2023)

The v2.4.2 release is a minor bugfix release with no new input data and no changes to methods except for a bugfix affecting source harmonization in special cases.

### 10.1.1 Changes in PRIMAP-hist source creation (v2.4.2)

No changes

### 10.1.2 Changes in data sources and preprocessing (v2.4.2)

No changes

### 10.1.3 Bug fixes and resolved issues (v2.4.2)

v2.4.2 fixed a bug in the generation of the composite source which influenced the harmonization of lower priority sources in some cases including accidental discarding of the last data point of the higher priority source. The bug influenced 2020 and 2021 emissions for Annex I countries and longer periods for non-Annex I countries. For most countries the influence is very small and not noteworthy, but for some country-sectors-gas timeseries with high fluctuations / changes in growth rates the influence is higher. The bug has been introduced in v2.4. We list the changes below.

### 10.1.4 Known problems (v2.4.2)

see [Known problems \(v2.4.1\)](#) below

### 10.1.5 Noteworthy changes (v2.4.2)

Here, we list the most important changes in total and per sector / per gas emissions and their reasons. We limit our analysis to the period of 1990 - 2021 here. The analysis is based on category M.0.EL, and the Kyoto GHG basket using AR4 GWPs. Additionally we look at changes in the last years as these were affected by the bug that this release corrects.

#### 10.1.5.1 Notable changes in total Kyoto GHG (AR4) emissions (1990 - 2021) (v2.4.2)

- **Changes of 20-50% in cumulative emissions** None
- **Changes of 10-20% in cumulative emissions** None
- **Changes of 5-10% in cumulative emissions**
  - **Bosnia and Herzegovina (CR)**: In sector 1.A, CO<sub>2</sub> the last year of data in the UNFCCC DI dataset was not used. As the trend is opposite to the trend in CDIAC, the next priority source, the inclusion of the datapoint in v2.4.2 has high influence on resulting emissions past 2013 in that sector.

**10.1.5.2 Changes for individual years and sectors (v2.4.2)** The bug that was fixed with the release affected only few years in most cases and thus the changes in emissions are not included in the listing above. We discuss the most prominent changes here:

- For 2015 the only country with a M.0.EL Kyoto GHG change of over 1.5% is **Bosnia and Herzegovina** (15%) (see above).
- For 2020 we have 4 countries with changes of over 10%.
  - **Namibia (CR, TP)**,
  - **Greece (CR)**: Growth rates for energy CO<sub>2</sub> are different in CRF2022 and BP2022 data for 2019-2020 (higher reductions in BP than in CRF, thus corrected emissions are higher than emissions in v2.4.1).
  - **Bosnia and Herzegovina (CR)**: see above
  - **Fiji (CR, TP)**. 2016-2017 growth rate in CDIAC is much lower than in BP. CDIAC 2017 data point was not used in v2.4.1 (BP data was used instead), thus emissions were higher in v2.4.1 than in v2.4.2.

- 10 countries have 2020 changes between 5 and 10%: Botswana (CR, TP in M.AG), Denmark (CR in 1, 2, 5), Estonia (CR in 1, 2, 5), Iceland (CR in 1, 2), Malaysia (CR in 1, 2, M.AG), Namibia (CR in M.AG), Papua New Guinea (CR, TP in 1), Qatar (CR, TP in 1), South Sudan (CR, TP in M.AG), Ukraine (CR in 1, 4), and South Africa (CR in 1, 2, M.AG).
- Changes in 2021 emissions are similar to changes in 2020 emissions. For details we refer to the file *changes\_PRIMAP-hist\_v2.4.2\_to\_v2.4.1.xlsx* available with the dataset.

## 10.2 v2.4.1 (February 2023)

The v2.4.1 release updates mainly third party data. Time series are not extended and cover 1750 to 2021. UNFCCC CRF data and data from the DI interface have been updated, however the changes are minor. In the third party data category FAOSTAT has been updated to the 2022 release (Food and Agriculture Organization of the United Nations (2023)) and EDGAR has been updated to v7.0 (JRC (2022)). There have been no updates to data processing.

### 10.2.1 Changes in PRIMAP-hist source creation (v2.4.1)

#### 10.2.1.1 Methodology changes (v2.4.1) No changes

#### 10.2.1.2 Data source prioritization (v2.4.1)

- Replacement with updated version of the data.

#### 10.2.1.3 Sectors and gases (v2.4.1) No changes

#### 10.2.1.4 Composite source generation methodology (v2.4.1) No changes

#### 10.2.1.5 Special treatment of individual countries (v2.4.1)

- Special treatments for Albania, Andorra, China, Croatia, The Democratic Republic of the Congo, France, Iceland, India, Latvia, Namibia, Pakistan, and Saudi Arabia are still in place (see [Special treatment of individual countries \(v2.4\)](#)).

### 10.2.2 Changes in data sources and preprocessing (v2.4.1)

#### 10.2.2.1 Input source updates (v2.4.1)

- CRF data have been updated to incorporate the [2022 submissions until Jan 23, 2023](#) with the [final 2021 submissions](#) as backup to fill potentially missing 2022 data. The last data year is now 2020 for all categories and gases. Updates vs the 2022 data used in v2.4 (2023.09.26) are: Croatia, Liechtenstein, Luxembourg, Poland, Portugal, Romania, Slovakia, and Slovenia. Changes are mostly for individual sectors and years and only have a small effect on aggregate emissions.
- UNFCCC “Detailed Data by Party” has been updated to data available by Jan 23, 2022 (no changes since Oct 2022). Since the version used in PRIMAP-hist v2.4 (Pflüger and Gütschow (2022)) we have the following changes :
  - Bahamas: Waste CH<sub>4</sub> data point in 2000 with very high emissions has been changed. Emissions are now lower.
  - Chad has added data
  - Dominican Republic: Added single data point timeseries which are 0. No effect on PRIMAP-hist
  - Georgia: corrected data
  - Indonesia: Added a single data point timeseries which is 0. No effect on PRIMAP-hist
  - Israel: Data for some agricultural sectors has been removed.
  - Moldova: added data but just timeseries which are 0
  - Pakistan: Added to may sector/gas combinations but the data is not sufficient to be used in PRIMAP-hist as it covers only 2015.
  - Sri Lanka: Adjusted 1994 data for some categories and gases. No effect on PRIMAP-hist as the data is currently not used.
- EDGAR: Version 7.0 of the EDGAR dataset now covers 1970 - 2021. Data for the latest years are based on a “fast-track” approach which in the case of energy CO<sub>2</sub> is the extension of emissions with energy CO<sub>2</sub> growth rates from BP (the same approach taken in PRIMAP-hist). For other

sectors proxy data and numerical methods are used. For non-CO<sub>2</sub> the methodology has not been published yet. Emissions estimates for several countries and sector/gas combinations have changed, however for most sectors not in a systematical way but on a per country, sector and gas level (sometimes changes for countries in the same region are similar). Where these changes impact aggregate emissions we describe them in the [Noteworthy changes \(v2.4.1\)](#) section below.

- FAOSTAT: Most timeseries are extensions of last years data. However, a few sector / gas combinations have systematical changes. 3.A.2 for N<sub>2</sub>O is systematically higher than in previous FAOSTAT releases. The agricultural sector as a whole however is unchanged for many countries and the higher emissions in 3.A.2 are contrasted by lower emissions in 3.C(4/5). Thus these changes are likely due to a reassignment of sector to emissions from some manure related activity. Other changes affect only individual countries. Where these changes impact aggregate emissions we describe them in the [Noteworthy changes \(v2.4.1\)](#) section below.

#### 10.2.2.2 Changes in preprocessing (v2.4.1) No changes

#### 10.2.3 Bug fixes and resolved issues (v2.4.1)

#### 10.2.4 Known problems (v2.4.1)

- SF<sub>6</sub> emissions in the TP time series are too low for some countries. This issue has only partly been fixed. The inclusion of sector 2.F.8.b has decreased emissions for some countries as EDGAR v4.2 is scaled to match v4.2 FT2010 if it is present, and for those countries 2.F.8.b is the only sector with data in v4.2 FT 2010. For Iceland the 2.F.8.b data are clearly wrong and several orders of magnitude too high. ([issue #19](#))
- FAO data for synthetic fertilizers do not cover the full period (1961 - 2018) for several countries. In the 2020 release data for some countries were removed leading to changed emission estimates. Some time series start later than 1961, while others have gaps. We currently use the summed “Agricultural Soils” data from the FAO emissions total domain. We plan to use detailed FAO data processing in v2.5 again and solve this issue. ([issue #22](#))
- In v2.2 there was a problem with scaling of historical CO<sub>2</sub> emissions especially for 1.B.2 and the USA. The new scaling algorithm has alleviated this problem, but it is not completely solved. Countries affected are Belize, Morocco, Mexico, Turkey, USA. ([issue #34](#))
- Process emissions from lime production (2.A.2) are currently not included in the third party priority (TP) scenario, as we use Andrew cement data as a proxy for sector 2.A. To include lime process emissions sub-sector resolution of 2.A would have to be introduced. ([issue #38](#))
- Despite the new algorithm for scaling of early emissions data to the more recent sources described in [Methodology changes \(v2.3\)](#) the scaling of CEDS data is in some cases problematic e.g. when the CEDS data shows a strongly decreasing trend before the matching year (see e.g. Saint Lucia CH<sub>4</sub> in 1.B.1). ([issue #40](#))
- EDGAR data for N<sub>2</sub>O, 1.B.1 is very limited for some countries, thus extrapolation generates most of the data for those countries. The main problem is Croatia, however it’s not relevant on the level of aggregate emissions. ([issue #42](#))
- Burkina Faso (CR time series): 0 value in UNFCCC DI for 1.A, CH<sub>4</sub> lead to very low emssion. Other values for that year don’t fit the rest of the time series either. (see [issue #53](#))
- Palau (CR timeseries): UNFCCC data for M.AG.ELV, CH<sub>4</sub> has a very high peak. Investigate the source of the data to check if it is correct. (see [issue #54](#))
- Georgia (CR, TP timeseries): Datapoints added in UNFCCC DI data for waste CH<sub>4</sub>, N<sub>2</sub>O, Other CO<sub>2</sub>, N<sub>2</sub>O, which are very low. Investigate the source of the data to check if it is correct. (see [issue #55](#))
- For some countries some timeseries start later than 1750, so long range historical data (CEDS etc.) are (partly) missing. This is the case for small countries, e.g. Andorra, Monaco (CO<sub>2</sub>, different sectors). (see [issue #56](#))
- For Azerbaijan, HFC emissions drop to almost 0 in 2013 in the UNFCCC DI data. The data used in PRIMAP-hist are consistent with the data in the UNFCCC DI portal. Check if there is a GWP error in the 2013 data in the DI portal. 2013 values for some other sectors / gases also deviate from the trend of the other data points. (see [issue #53](#))
- The “Other” sector is missing in the CRF data available in the [UNFCCC\\_non-AnnexI\\_data repository](#). This affects Switzerland and New Zealand. (see [issue #53](#))
- For problems that were found after the release of the dataset, please consult the issue tracker



[github.com/JGuetschow/PRIMAP-hist](https://github.com/JGuetschow/PRIMAP-hist). If you encounter a problem please add an issue or contact the authors directly.

## 10.2.5 Noteworthy changes (v2.4.1)

Here, we list the most important changes in total and per sector / per gas emissions and their reasons. We limit our analysis to the period of 1990 - 2021 here. The analysis is based on category M.0.EL, and the Kyoto GHG basket using AR4 GWPs.

### 10.2.5.1 Notable changes in total Kyoto GHG (AR4) emissions (1990 - 2021) (v2.4.1)

- **Changes of 20-50% in cumulative emissions**
  - **CHAD (CR)**: The new UNFCCC data that are available for the agricultural sector are much lower than the FAO data used before.
  - **Timor-Leste (CR, TP)**: EDGAR v7.0 data differ from EDGAR 6.0 for recent years in sector 1.B.2 which is a major sector for Timor-Leste.
- **Changes of 10-20% in cumulative emissions**
  - **Saint Helena, Ascension, and Tristan da Cunha (CR, TP)**: EDGAR v7.0 and current FAOSTAT data contain no agricultural data for Saint Helena, Ascension, and Tristan da Cunha. As there are no country reported data there is no AFOLU data for Saint Helena, Ascension, and Tristan da Cunha in PRIMAP-hist v2.4.1.
- **Changes of 5-10% in cumulative emissions**
  - **Ghana (CR, TP)**: The new EDGAR data has considerably increased estimates for fugitive emissions in the latest years for all gases leading to strong increases in M.0.EL KyotoGHG emission estimates for the latest years.
  - **Haiti (TP)**: EDGAR 6.0 data for 1.B.1 was much lower before 2005 than after 2005. In v7.0 the data before 2005 are similar to the data after 2005 and in consequence the emissions in PRIMAP-hist (TP) are higher before 2005 as well. CH<sub>4</sub> and N<sub>2</sub>O are affected.
  - **Papua New Guinea (CR, TP)**: Updated EDGAR fugitive emissions (1.B.2) are much lower for recent years than emissions in EDGAR 6.0, leading to overall lower emissions in recent years in PRIMAP-hist v2.4.1.
  - **Sierra Leone (CR, TP)**: The updated FAO data are lower for category 3.C.1, leading to lower agricultural emissions in PRIMAP-hist v2.4.1; The new EDGAR data have adjusted estimates for recent years and lowered emissions estimates in 1.A for CO<sub>2</sub>. As we don't have country reported data for Sierra Leone, this affects the CR and TP time series equally.
  - **Vanuatu (CR, TP)**: FAO emissions data have been corrected downwards for recent years. As we don't have country reported data for Vanuatu this affects the CR and TP timeseries equally.

## 10.3 v2.4 (October 2022)

The v2.4 release updates mainly country reported data and extends the time series by two years to 2021. New and updated input data sources are UNFCCC data for AnnexI and non-AnnexI data, BP data (British Petroleum (2022)), and cement process emissions data (Andrew (2022)). UNFCCC data are now read from xlsx and pdf files using the new PRIMAP2 software (<https://github.com/pik-primap/primap2>) which enable processing of non-numerical flags and enables a more precise treatment of sectors where no data are reported (see [Changes in preprocessing \(v2.4\)](#)).

### 10.3.1 Changes in PRIMAP-hist source creation (v2.4)

#### 10.3.1.1 Methodology changes (v2.4) No changes

#### 10.3.1.2 Data source prioritization (v2.4)

- We now use BP data also for flaring emissions.
- Replacement with updated version of the data.

#### 10.3.1.3 Sectors and gases (v2.4) No changes

#### 10.3.1.4 Composite source generation methodology (v2.4)

- Two changes have been introduced in the combination of sources regarding zero data. They were necessary because the new processing of non-numerical flags in the UNFCCC data produced a lot of all-zero time series.
  - If a time series is zero at the boundary but a lower priority time series is non-zero the time series will be completed with zero instead of the non-zero data from the lower priority time series. This is also used for extrapolation with the long-term historical timeseries (CEDS, RCP, EDGAR-HYDE)
  - If time-series is non-zero at the boundary but a lower priority time series which should be used to extend it is all zero the lower priority time series will not be used.

#### 10.3.1.5 Special treatment of individual countries (v2.4)

- Latvia: Scaling of CRF data to EDGAR data for CH<sub>4</sub>, 2.C gives huge emissions as CRF is near zero in scaling year 2013. We use unscaled CRF data for 2014 - 2020 (TP time series).
- Pakistan: Scaling EDGAR data to BP data for CO<sub>2</sub>, 1.B.2 gives huge emissions. We use unscaled 2002 - 2011 EDGAR values (TP time series).
- Special treatments for Albania, Andorra, China, Croatia, The Democratic Republic of the Congo, France, Icenad, India, Namibia, and Saudi Arabia are still in place (see [Special treatment of individual countries \(v2.3.1\)](#)).

### 10.3.2 Changes in data sources and preprocessing (v2.4)

#### 10.3.2.1 Input source updates (v2.4)

- CRF data have been updated to incorporate the [2022 submissions until Sep 27, 2022](#) with the [final 2021 submissions](#) as backup to fill potentially missing 2021 data. The last data year is now 2020 for all categories and gases. Only one country has changes in overall emissions of over 2%: Belarus.
- Data from the Biennial Update Reports (BURs, UNFCCC (2022)) have been updated. We have added the fourth BURs from Argentina and South Africa (2017 data only); third BURs from Colombia, Indonesia (2019 data only), Mexico (2019 data only), Montenegro, Morocco, and Thailand (2019 data only). In total, countries included in our BUR data are
  - first BUR: Indonesia, Montenegro, Mongolia, Mauritania, Oman, and Togo
  - second BUR: Andorra, Argentina, Colombia, Indonesia, Macedonia, Mauritania, Mexico, Moldova, Montenegro, Morocco, Namibia, and South Africa
  - third BUR: Argentina, Andorra, Colombia, Indonesia (2019 data only), Malaysia, Mexico (2019 data only), Montenegro, Morocco, Namibia, South Africa (2015 data only), Thailand (2019 data only), and Viet Nam
  - fourth BUR: Argentina, Chile, Namibia, Singapore, South Africa (2017 data only)
  - BUR data from countries reporting in IPCC1996 categories are included via the UNFCCC detailed data by party interface (see below).
- UNFCCC “Detailed Data by Party” has been updated to data available by Oct 10, 2022 (Pflüger and Gütschow (2022)): since the version used in PRIMAP-hist v2.3.1 we have the following changes:
  - Bahamas has updated data for year 2000.
  - Burkina Faso has added data for 2007-2017 for most sectors and gases.
  - Georgia has updated data for 1990 and 2017.
  - India has slightly updated data for 2010 and 2016 (some data points were updated and some missing sectors were added).
  - Israel has added data for 2019 and adjusted data for earlier years.
  - Jordan has added data for 2000 and 2016.
  - Republic of Korea has added data for 2017 and 2018.
  - Paraguay has added data for 2017.
  - Sri Lanka has slightly updated data for 1994. Some data points have been removed (e.g. CH<sub>4</sub>, category 2, 2000)
  - Togo has updated data for 2000, 2005 and added data for 2010-2018 (KYOTOGHG only). Other time series were removed completely.
  - Uruguay has added data for 2019 and updated data for earlier years in several sectors
  - Due to processing of non-numerical flags, data for several sectors are now explicitly 0 instead of missing for the following countries: Afghanistan, Albania, Armenia, Azerbaijan, Bhutan, Chile,

China, Cote d'Ivoire, Cuba, Dominica, Dominican Republic, Ecuador, Eritrea, Guinea-Bissau, Guyana, Honduras, Jamaica, Lebanon, Liberia, Maldives, Marshall Islands, Moldova, Mongolia, Nauru, Palau, Palestinian Territory, Saint Vincent and the Grenadines, San Marino, Sao Tome and Principe, Solomon Islands, Timor-Leste, Tuvalu, Uganda, Rwanda, Uzbekistan, Vanuatu, Viet Nam. These additions are in the raw data, preprocessing removes some data. For changes in preprocessed data see section [Changes in preprocessing v2.4] below.

- BP fossil CO<sub>2</sub> data have been updated to the 2022 release (British Petroleum (2022)), last used data year is 2021.
  - 2019 data has been updated for several countries.
- Cement process CO<sub>2</sub> emissions data have been updated from v210723 used in PRIMAP-hist v2.3.1 to v220919 (Andrew (2022)).
- We have updated some country reported data that are not (yet) officially submitted to the UNFCCC. These are:
  - 2021 inventory for South Korea (Republic of Korea (2021)): Official South Korea national inventory which has not (yet) been submitted to the UNFCCC.
  - 2022 inventory report for Taiwan (Republic of China - Environmental Protection Administration (2022)). As Taiwan is not a member of the UNFCCC this data can not become official UNFCCC data, but as it is officially reported by the Taiwanese government we treat it as country reported data.

### 10.3.2.2 Changes in preprocessing (v2.4)

- All UNFCCC data (CRF, BUR, NIR, DI interface) is now read using PRIMAP2 which enables a detailed treatment of flags like “NE”, “IE” etc. We map flags that indicate data are included in other sectors or the sector does not exist for the country (e.g. “IE”, “NA”) to 0 to indicate that there should be no non-zero data while we map flags indicating data are missing (e.g. “NE”) to NaN to enable filling these gaps from other sources. This has altered the emissions estimates for several countries, especially smaller countries which do not have all types of industries. Despite the changes on subsector level the impacts on overall Kyoto GHG emissions are small. In consequence
  - This mostly affect AnnexI countries, but also some non-AnnexI countries, e.g. South Korea
  - This mostly affects small countries (e.g. Monaco) as they are more likely to not have certain sectors (usually industrial sectors, but for Monaco actually agriculture).
  - Sector 1.B.1 (fugitive emissions from solid fuels), CH<sub>4</sub> is zero for many countries now
  - Agriculture excluding livestock (M.AG.ELV), CH<sub>4</sub> is zero for several countries now.
  - For several countries IPPU subsectors (2.X) are zero for the whole period or just some years (esp 2.B). All gases are affected.
  - NF<sub>3</sub> time series now often start explicitly with 0. For these countries historical extrapolation is now also 0.

### 10.3.3 Bug fixes and resolved issues (v2.4)

- For some countries (at least Taiwan) the extrapolation of energy CO<sub>2</sub> data gave a result not in line with the BP growth rates ([issue #49](#)). Fixed now.
- We now process non-numerical flags in country reported data. This closes [issue #45](#) and [issue #43](#)

### 10.3.4 Known problems (v2.4)

- SF<sub>6</sub> emissions in the TP time series are too low for some countries. This issue has only partly been fixed. The inclusion of sector 2.F.8.b has decreased emissions for some countries as EDGAR v4.2 is scaled to match v4.2 FT2010 if it is present, and for those countries 2.F.8.b is the only sector with data in v4.2 FT 2010. For Iceland the 2.F.8.b data are clearly wrong and several orders of magnitude too high. ([issue #19](#))
- FAO data for synthetic fertilizers do not cover the full period (1961 - 2018) for several countries. In the 2020 release data for some countries were removed leading to changed emission estimates. Some time series start later than 1961, while others have gaps. As data are summed with other sectors before use in PRIMAP-hist the gaps and boundaries are not filled with data from other sources. ([issue #22](#))

- In v2.2 there was a problem with scaling of historical CO<sub>2</sub> emissions especially for 1.B.2 and the USA. The new scaling algorithm has alleviated this problem, but it is not completely solved. Countries affected are Belize, Morocco, Mexico, Turkey, USA. ([issue #34](#))
- Process emissions from lime production (2.A.2) are currently not included in the third party priority (TP) scenario, as we use Andrew cement data as a proxy for sector 2.A. To include lime process emissions sub-sector resolution of 2.A would have to be introduced. ([issue #38](#))
- Despite the new algorithm for scaling of early emissions data to the more recent sources described in [Methodology changes \(v2.3\)](#) the scaling of CEDS data is in some cases problematic e.g. when the CEDS data shows a strongly decreasing trend before the matching year (see e.g. Saint Lucia CH<sub>4</sub> in 1.B.1). ([issue #40](#))
- EDGAR data for N<sub>2</sub>O, 1.B.1 is very limited for some countries, thus extrapolation generates most of the data for those countries. The main problem is Croatia, however it's not relevant on the level of aggregate emissions. ([issue #42](#))
- Burkina Faso (CR time series): 0 value in UNFCCC DI for 1.A, CH<sub>4</sub> lead to very low emissions. Other values for that year don't fit the rest of the time series either. (see [issue #53](#))
- Palau (CR timeseries): UNFCCC data for M.AG.ELV, CH<sub>4</sub> has a very high peak. Investigate the source of the data to check if it is correct. (see [issue #54](#))
- Georgia (CR, TP timeseries): Datapoints added in UNFCCC DI data for waste CH<sub>4</sub>, N<sub>2</sub>O, Other CO<sub>2</sub>, N<sub>2</sub>O, which are very low. Investigate the source of the data to check if it is correct. (see [issue #55](#))
- For some countries some timeseries start later than 1750, so long range historical data (CEDS etc.) are (partly) missing. This is the case for small countries, e.g. Andorra, Monaco (CO<sub>2</sub>, different sectors). (see [issue #56](#))
- For Azerbaijan, HFC emissions drop to almost 0 in 2013 in the UNFCCC DI data. The data used in PRIMAP-hist are consistent with the data in the UNFCCC DI portal. Check if there is a GWP error in the 2013 data in the DI portal. 2013 values for some other sectors / gases also deviate from the trend of the other data points. (see [issue #53](#))
- The "Other" sector is missing in the CRF data available in the [UNFCCC\\_non-AnnexI\\_data repository](#). This affects Switzerland and New Zealand. (see [issue #53](#))
- For problems that were found after the release of the dataset, please consult the issue tracker [github.com/JGuetschow/PRIMAP-hist](https://github.com/JGuetschow/PRIMAP-hist). If you encounter a problem please add an issue or contact the authors directly.

### 10.3.5 Noteworthy changes (v2.4)

Here, we list the most important changes in total and per sector / per gas emissions and their reasons. We limit our analysis to the period of 1990 - 2021 here. The analysis is based on category M.0.EL, and the Kyoto GHG basket using AR4 GWPs.

#### 10.3.5.1 Notable changes in total Kyoto GHG (AR4) emissions (1990 - 2021) (v2.4)

- **Changes of 20-50% in cumulative emissions**
  - **Burkina Faso (CR):** 0 value in UNFCCC DI for 1.A, CH<sub>4</sub> lead to very low emission. Other values for that year don't fit the rest of the time series either. (see [issue #53](#))
  - **Monaco (CR):** Large drop in emissions estimates due to updated CRF processing. 1.B.1, CH<sub>4</sub> is now 0 (CRF processing). high impact on category 1 CH<sub>4</sub> emissions. similar for 2.B, 2.C, 3.A. CH<sub>4</sub> now only a fraction of v2.3.1 emissions. For CO<sub>2</sub> 2.A, 2.B, 2.C are affected. All agricultural emissions now 0; N<sub>2</sub>O now 0 for 2.B; PFCs much lower as 0 in first years and extrapolate with 0
  - **Palau (CR)** UNFCCC data for M.AG.ELV, CH<sub>4</sub> has a very high peak. No other changes. Investigate the source of the data to check if it is correct. (see [issue #54](#))
- **Changes of 10-20% in cumulative emissions**
  - **Azerbaijan (TP):** BP flaring CO<sub>2</sub> emissions (1.B.2) are much higher than EDGAR which was used before. F-gases drop to 0 in DI data
  - **Estonia (CR):** Several changes in subsectors / gases. Most important change is that 1.B CO<sub>2</sub> is now 0 (CRF processing) other changes are: CH<sub>4</sub> in 2, 2.C, now 0 (CRF processing); 1.A, N<sub>2</sub>O lower (CRF update); 3.A, M.AG.ELV, N<sub>2</sub>O lower (CRF update)
  - **Montenegro (CR, TP 2-5%):** New BUR with updated emission estimates in several sectors
- **Changes of 5-10% in cumulative emissions**

- **Georgia (CR, TP)**: Datapoints added in UNFCCC DI data for waste CH<sub>4</sub>, N<sub>2</sub>O, Other CO<sub>2</sub>, N<sub>2</sub>O, which are very low. Investigate the source of the data to check if it is correct. (see [issue #55](#))
- **Morocco (CR)**: New BUR with changed emissions estimates in several sectors.
- **Changes of 2-5% in cumulative emissions**
  - **Colombia (CR)**: New BUR with changed emissions estimates in several sectors.
  - **Libya (CR, TP)**: BP now used for 1.B.2, Andrew cement data updated.
  - **Macao (CR, TP)**: Changes in data processing led to differences in gap filling in 2.A
  - **Oman (CR, TP)**: BP now used for 1.B.2
  - **Paraguay (CR)**: New and updated UNFCCC DI data with changes in several sectors.
  - **Russia (CR, TP)**: Smaller changes in several sectors due to updated CRF data and the CRF data processing changes.
  - **Syria (CR, TP)**: BP now used for 1.B.2
  - **Turkmenistan (CR)**: BP now used for 1.B.2 (same changes in TP time series, but below 2% change in cumulative KYOTO GHG emissions)
  - **Trinidad and Tobago (CR, TP)**: BP now used for 1.B.2

## 10.4 v2.3.1 (September 2021)

The v2.3.1 release is a minor bugfix update of the v2.3 version. The only new data source included is updated cement process emissions data (Andrew (2021)).

### 10.4.1 Changes in PRIMAP-hist source creation (v2.3.1)

10.4.1.1 **Methodology changes (v2.3.1)** No changes

10.4.1.2 **Data source prioritization (v2.3.1)** No changes

10.4.1.3 **Sectors and gases (v2.3.1)** No changes

10.4.1.4 **Composite source generation methodology (v2.3.1)** No changes

#### 10.4.1.5 Special treatment of individual countries (v2.3.1)

- Iceland: SF<sub>6</sub> emissions from EDGAR v4.2 are several orders of magnitude too high and thus removed.
- Saudi Arabia: Scaling of UNFCCC data to EDGAR in category 2.C, CO<sub>2</sub> leads to very high emissions in recent years. To avoid this scaling artifact UNFCCC data are extrapolated linearly.
- Special treatments for Albania, Andorra, China, Croatia, the Democratic Republic of the Congo, France, India, and Namibia are still in place (see [Special treatment of individual countries \(v2.3\)](#)).

### 10.4.2 Changes in data sources and preprocessing (v2.3.1)

#### 10.4.2.1 Input source updates (v2.3.1)

- Cement process CO<sub>2</sub> emissions data have been updated from v210505 used in PRIMAP-hist v2.3 to v210723.

#### 10.4.2.2 Changes in preprocessing (v2.3.1)

- Andrew cement data does not contain the -9999 values any more since v210505 which were mapped to NaN. We now also treat the zero only timeseries as 0 and not as NaN. This change is effective since PRIMAP-hist v2.3 but was missing in the v2.3 CHANGELOG.

### 10.4.3 Bug fixes and resolved issues (v2.3.1)

- Georgia: UNFCCC data are wrong for waste and LULUCF CH<sub>4</sub>, in 1990 and 2017. GWP is applied in the inventory table but the unit given suggests data are in native units (as it actually is for all other sectors). ([issue #39](#))

- Missing countries in CEDS: Some small countries are missing in CEDS and currently lack early emissions data for CO<sub>2</sub> and CH<sub>4</sub> in some sectors. The issue has been fixed using growth rates of the RC10 regions containing these countries. Countries affected are Anguilla, Andorra, Antarctica, Monaco, Nauru, Saint Helena, Ascension and Tristan da Cunha, San Marino, Tuvalu, and Vatican City State. ([issue #41](#))
- EDGAR v4.2 data for Iceland has been removed. Sector 2.F.8.b data are several orders of magnitude too high. ([issue #19](#))
- Error in Taiwanese country reported data has been fixed. Some time series we contained twice in the csv data file and included twice in sectors sums. This has been fixed.
- A bug in BUR data processing for f-gases has been fixed and now Montenegro's BUR HFC emissions are used.
- Saudi Arabia's CO<sub>2</sub> emissions from sector 2.C have been fixed. EDGAR data are now extrapolated to avoid scaling artifacts. ([issue #46](#))

#### 10.4.4 Known problems (v2.3.1)

- SF<sub>6</sub> emissions in the TP time series are too low for some countries. This issue has only partly been fixed. The inclusion of sector 2.F.8.b has decreased emissions for some countries as EDGAR v4.2 is scaled to match v4.2 FT2010 if it is present, and for those countries 2.F.8.b is the only sector with data in v4.2 FT 2010. For Iceland the 2.F.8.b data are clearly wrong and several orders of magnitude too high. ([issue #19](#))
- FAO data for synthetic fertilizers do not cover the full period (1961 - 2018) for several countries. In the 2020 release data for some countries were removed leading to changed emission estimates. Some time series start later than 1961, while others have gaps. As data are summed with other sectors before use in PRIMAP-hist the gaps and boundaries are not filled with data from other sources. ([issue #22](#))
- In v2.2 there was a problem with scaling of historical CO<sub>2</sub> emissions especially for 1.B.2 and the USA. The new scaling algorithm has alleviated this problem, but it is not completely solved. Countries affected are Belize, Morocco, Mexico, Turkey, USA. ([issue #34](#))
- Process emissions from lime production (2.A.2) are currently not included in the third party priority (TP) scenario, as we use Andrew cement data as a proxy for sector 2.A. To include lime process emissions sub-sector resolution of 2.A would have to be introduced. ([issue #38](#))
- Despite the new algorithm for scaling of early emissions data to the more recent sources described in [Methodology changes \(v2.3\)](#) the scaling of CEDS data is in some cases problematic e.g. when the CEDS data shows a strongly decreasing trend before the matching year (see e.g. Saint Lucia CH<sub>4</sub> in 1.B.1). ([issue #40](#))
- EDGAR data for N<sub>2</sub>O, 1.B.1 is very limited for some countries, thus extrapolation generates most of the data for those countries. The main problem is Croatia, however it's not relevant on the level of aggregate emissions. ([issue #42](#))
- For problems that were found after the release of the dataset, please consult the issue tracker [github.com/JGuetschow/PRIMAP-hist](https://github.com/JGuetschow/PRIMAP-hist). If you encounter a problem please add an issue or contact the authors directly.

#### 10.4.5 Noteworthy changes (v2.3.1)

Here, we list the most important changes in total and per sector / per gas emissions and their reasons. We limit our analysis to the period of 1990 - 2019 here. The analysis is based on category M.0.EL, and the Kyoto GHG basket using AR4 GWPs.

##### 10.4.5.1 Notable changes in total Kyoto GHG emissions (1990 - 2019) (v2.3.1)

- **Countries removed**
  - **Curacao** (CR and TP): Curacao was included in v2.3 as an individual country. Due to the very limited data we now again include Curacao only as part of the former Netherlands Antilles.
- **Changes of 50-100% in cumulative emissions**
  - **Iceland** (TP only): EDGAR 4.2FT2010 SF<sub>6</sub> Emissions for sector 2.F.8.b have been removed (see [Bug fixes and resolved issues \(v2.3.1\)](#) section).
- **Changes of 20-50% in cumulative emissions**

- **Georgia** (CR only): The bug from v2.3 has been fixed. See [Bug fixes and resolved issues \(v2.3.1\)](#) section.
- **Taiwan** (CR only): The bug from v2.3 has been fixed. See [Bug fixes and resolved issues \(v2.3.1\)](#) section.

#### 10.4.5.2 Changes for individual categories / gases (v2.3.1)

- The updated cement process emissions data (Andrew (2021)) have changed emissions estimates in sector 2.A for several countries.
- When including the full range of years we also have noteworthy changes for the countries which are not included in CEDS and had missing data in v2.3.

### 10.5 v2.3 (July/August 2021)

The v2.3 release is an update of the v2.2 version. The methodology is mainly unchanged, but the input sources have been updated where available and CEDS (Hoesly et al. (2020)) has been added as emissions source for pre-1960/70 historical data replacing RCP and EDGAR-HYDE for CH<sub>4</sub> and CO<sub>2</sub>. The time series now start in 1750 instead of 1850. Additionally, some bugs have been fixed.

#### 10.5.1 Changes in PRIMAP-hist source creation (v2.3)

##### 10.5.1.1 Methodology changes (v2.3)

- For extrapolation of CH<sub>4</sub> and CO<sub>2</sub> data we now use CEDS data (Hoesly et al. (2020)).
- The dataset now begins in 1750 instead of 1850. For several sectors and gases this means no change in cumulative emissions as emissions in 1850 were zero because the relevant emissions sources did not exist yet.
  - F-gases are 0 in 1850 and thus are extended using 0.
  - For N<sub>2</sub>O, which is not included in the CEDS dataset, we use EDGARHYDE and RCP back until 1850 and a sector specific approach for 1750 - 1849:
    - \* Category 2 and subsectors are 0 in 1850 and thus extrapolated with 0 for all gases.
    - \* Category 1 and subsectors are extrapolated using CO<sub>2</sub> emissions data as a proxy
    - \* Categories 3.A (Livestock) 3.MAG.ELV (Agriculture excluding livestock), and 4 (Waste) are extrapolated using CH<sub>4</sub> emissions growth rates as a proxy.
  - For all gases LULUCF emissions are extrapolated such that they reach 0 in 1750. As large scale deforestation took place in the now industrialized countries in this time frame, proper data would be a valuable improvement.
- For consistency of cumulative emissions with CEDS we do not use just the growth rates of CEDS to extend the near term data, but use a transition period of 25 years where emissions are scaled from the near term value to the CEDS value (technically CEDS data are scaled with a scaling factor that approaches 1 linearly within 25 years). This is especially important for sectors where CEDS shows higher emissions in the early 20th century than in ~1970 where the scaling to recent data takes place (e.g. 2.C Metal industry). In cases where CEDS emissions are much higher than the more recent emissions this scaling is clearly visible, but we prefer this over large changes in historical emissions due to unlimited scaling.

##### 10.5.1.2 Data source prioritization (v2.3)

- No changes except the inclusion of CEDS data described above and replacement of data sources through updated versions (see section [Input source updates \(v2.3\)](#) below)

##### 10.5.1.3 Sectors and gases (v2.3) No changes

##### 10.5.1.4 Composite source generation methodology (v2.3) No changes

##### 10.5.1.5 Special treatment of individual countries (v2.3)

- France and Croatia: Special treatment for sector 1.B.2 and gases N<sub>2</sub>O and CO<sub>2</sub>. Scaling of EDGAR v6.0 data to CRF would give huge emissions. We use linear extrapolation of CRF data for 1980 - 2000.

- India: Emissions for f-gases in UNFCCC data are very low for 2010. This leads to scaling issues. We replace the data by NaN to use alternative sources.
- Namibia: According to Robbie Andrew cement production has only started in 2011 in Namibia. Thus CDIAC cement emissions before 2011 are not realistic and we add 0 explicitly in the Andrew dataset. BUR data for 2.A is non-zero. As 2.A contains not only cement production emissions but also emissions from other mineral industry this is fine. But CDIAC and Andrew data cover only cement and thus should be zero.
- Special treatments for Albania, Andorra, China, and the Democratic Republic of the Congo are still in place (see v2.2).

## 10.5.2 Changes in data sources and preprocessing (v2.3)

### 10.5.2.1 Input source updates (v2.3)

- CRF data have been updated to the 2021v1 release (Gütschow et al. (2021b)) with the 2020v2 release (Gütschow et al. (2021a)) used as backup to fill potentially missing 2021 data. We have included data updates from Poland and Romania, which were published after the release of 2021v1. The last data year is now 2019 for all categories and gases. Only three countries have changes in overall emissions of over 2%: Kazakhstan, Latvia, and Romania.
- Data from the Biennial Update Reports (BURs, UNFCCC (2021) ) have been updated. We have added the first BUR of Oman, second BUR of Mauritania, the third BURs of Viet Nam and Malaysia, and the fourth BURs of Chile, Namibia, and Singapore. From the third BUR of South Africa we have included the 2015 data only, as data for the other years lacks sectoral and gas resolution. In total, countries included in our BUR data are
  - first BUR: Indonesia, Montenegro, Mongolia, Mauritania, Oman, and Togo
  - second BUR: Andorra, Argentina, Colombia, Indonesia, Macedonia, Mauritania, Mexico, Moldova, Montenegro, Morocco, Namibia, and South Africa
  - third BUR: Argentina, Andorra, Malaysia, Namibia, South Africa (2015 data only) and Viet Nam
  - fourth BUR: Chile, Namibia, Singapore
  - BUR data from countries reporting in IPCC1996 categories are included via the UNFCCC detailed data by party interface (see below).
- UNFCCC “Detailed Data by Party” has been updated to data available by July 31st, 2021 (Gieseke and Gütschow (2021)): since the version used in PRIMAP-hist v2.3 we have the following changes:
  - Brazil has added data for 2016. Data for other years have been adjusted (BUR4).
  - Bhutan has added data for 2015
  - India has added data for 2016 (BUR3)
  - Chile has added data for 2016. Data for other years have been adjusted (BUR4). Chile’s BUR4 data are included both in the BUR source and in the UNFCCC source.
  - Georgia has added data for 2017 and adjusted data for 1990 (The data are from the NIR accompanying the latest National Communication). The data has a GWP error in CH<sub>4</sub>, see [Known problems \(v2.3\)](#) section below.
  - Liberia has added data for 2012 (BUR1)
  - Paraguay has added data for 2013
  - Several countries have removed data from “other” subcategories. This usually affects the year 1994 where data were often put in “other” subcategories, likely because they didn’t fit the IPCC1996 categories.
    - For Afghanistan GWP weighted time-series have been adjusted.
    - For Sierra Leone all data have been removed.
    - For Pakistan all N<sub>2</sub>O and CH<sub>4</sub> data have been removed.

These additions are in the raw data, preprocessing removes some data. For changes in preprocessed data see section [Changes in preprocessing v2.3] below.

- BP fossil CO<sub>2</sub> data have been updated to the 2021 release (British Petroleum (2021)), last used data year is 2019.
- FAOSTAT data have been updated to include all data available by June 25th, 2021 (Food and Agriculture Organization of the United Nations (2021)). For all sectors and gases the last used year is now 2019. The new FAO data are mainly an extension of the version used in PRIMAP-hist v2.2 (Food and Agriculture Organization of the United Nations (2020)). Changes are limited so single countries and mainly to the most recent years.



- EDGAR data have been updated from v5.0 to v6.0. Data in most sectors and for most gases have changed for many countries. Those changes affect several countries and especially the TP time series for all sectors except agriculture and CO<sub>2</sub> for sectors 1.A and 2.A. The data changes in the fugitive emissions categories 1.B.1 and 1.B.2 are especially high and highly affect overall emissions for several developing countries with comparatively large fossil fuel extraction or processing sectors. A further category with high changes is waste (4) which impact several developing countries where emissions from waste have a high contribution to total emissions. We discuss impacts on countries' total emissions in the [Noteworthy change (v2.3)] section.
- CDIAC data have been updated to CDIAC-FF 2020 (Gilfillan et al. (2020)): For most countries the category 1.A time series have been extended but existing data have not been changed. For some smaller developing countries existing time series have been adjusted. We discuss changes in the [Noteworthy changes \(v2.3\)](#) section when they impact country results. Categories 2.A (Cement) and 1.B (flaring) are no longer used in PRIMAP-hist. For Cement we use the Andrew data. CDIAC flaring data also contains venting emissions by considering 100% oxidation of vented Methane and thus leads to some double counting of venting emissions.
- We have added some country reported data that are not (yet) officially submitted to the UNFCCC. These are:
  - 2020 inventory for South Korea (Republic of Korea (2020)): Official South Korea national inventory which has not (yet) been submitted to the UNFCCC.
  - 2020 inventory report for Taiwan (Republic of China - Environmental Protection Administration (2020)). As Taiwan is not a member of the UNFCCC this data can not become official UNFCCC data, but as it is officially reported by the Taiwanese government we treat it as country reported data. This closes [issue #20](#).

#### 10.5.2.2 Changes in preprocessing (v2.3)

- The processing of f-gas emissions in BUR data has been improved to calculate baskets from individual gases where these are available. This has a slight impact on HFCs and PFCs as these baskets were converted between different GWP values using default factors in earlier version of PRIMAP-hist.

#### 10.5.3 Bug fixes and resolved issues (v2.3)

- Downscaling of 1.B.1 CH<sub>4</sub> data from Sudan to Sudan and South Sudan has been fixed ([issue #24](#))
- The low UNFCCC agricultural N<sub>2</sub>O data for Albania listed as a possible bug for v2.2 is consistent with Albania's third national communication. ([issue #23](#))
- Taiwan is now included with official data in the country reported scenario. ([issue #20](#))

#### 10.5.4 Known problems (v2.3)

- SF<sub>6</sub> emissions in the TP time series are too low for some countries. This issue has only partly been fixed. The inclusion of sector 2.F.8.b has decreased emissions for some countries as EDGAR v4.2 is scaled to match v4.2 FT2010 if it is present, and for those countries 2.F.8.b is the only sector with data in v4.2 FT 2010. For Iceland the 2.F.8.b data are clearly wrong and several orders of magnitude too high. ([issue #19](#))
- FAO data for synthetic fertilizers do not cover the full period (1961 - 2018) for several countries. In the 2020 release data for some countries were removed leading to changed emission estimates. Some time series start later than 1961, while others have gaps. As data are summed with other sectors before use in PRIMAP-hist the gaps and boundaries are not filled with data from other sources. ([issue #22](#))
- In v2.2 there was a problem with scaling of historical CO<sub>2</sub> emissions especially for 1.B.2 and the USA. The new scaling algorithm has alleviated this problem, but it is not completely solved. Countries affected are Belize, Morocco, Mexico, Turkey, USA. ([issue #34](#))
- Process emissions from lime production (2.A.2) are currently not included in the third party priority (TP) scenario, as we use Andrew cement data as a proxy for sector 2.A. To include lime process emissions sub-sector resolution of 2.A would have to be introduced. ([issue #38](#))
- Georgia: UNFCCC data are wrong for waste and LULUCF CH<sub>4</sub>, in 1990 and 2017. GWP is applied in the inventory table but the unit given suggests data are in native units (as it actually is for all other sectors). ([issue #39](#))

- Despite the new algorithm for scaling of early emissions data to the more recent sources described in [Methodology changes \(v2.3\)](#) the scaling of CEDS data is in some cases problematic e.g. when the CEDS data shows a strongly decreasing trend before the matching year (see e.g. Saint Lucia CH<sub>4</sub> in 1.B.1). ([issue #40](#))
- Missing countries in CEDS: Some small countries are missing in CEDS and currently lack early emissions data for CO<sub>2</sub> and CH<sub>4</sub> in some sectors. These are Anguilla, Andorra, Antarctica, Curacao, Monaco, Nauru, Saint Helena, Ascension and Tristan da Cunha, San Marino, Tuvalu, and Vatican City State. ([issue #41](#))
- EDGAR data for N<sub>2</sub>O, 1.B.1 is very limited for some countries, thus extrapolation generates most of the data for those countries. The main problem is Croatia, however it's not relevant on the level of aggregate emissions. ([issue #42](#))
- For problems that were found after the release of the dataset, please consult the issue tracker [github.com/JGuetschow/PRIMAP-hist](https://github.com/JGuetschow/PRIMAP-hist). If you encounter a problem please add an issue or contact the authors directly.

### 10.5.5 Noteworthy changes (v2.3)

Here, we list the most important changes in total and per sector / per gas emissions and their reasons. As we have changed the data source for early emissions and thus have changes for a lot of countries in earlier years we limit our analysis to the period of 1990 - 2019 here. The analysis is based on category M.0.EL, and the Kyoto GHG basket using AR4 GWPs.

#### 10.5.5.1 Notable changes in total Kyoto GHG emissions (1990 - 2019) (v2.3)

- **Countries added**
  - **Curacao** (CR and TP): Very limited data are now available. Fugitive emissions for CH<sub>4</sub> and CO<sub>2</sub>. CR and TP timeseries are identical.
- **Changes over 100% in cumulative emissions**
  - **Iceland** (TP only): EDGAR 4.2FT2010 SF<sub>6</sub> Emissions for sector 2.F.8.b are wrong (several magnitudes too high). They were not used before the EDGAR SF<sub>6</sub> fix (see [Known problems \(v2.3\)](#)).
- **Changes of 50-100% in cumulative emissions**
  - **Bahrain** (CR and TP): New EDGAR v6.0 data for CH<sub>4</sub> in sector 1.B is much higher than earlier data leading to changes in total CH<sub>4</sub> emissions of over 100% in the period of 1990-2019. Further contributions from CH<sub>4</sub>, sector 4 (waste).
  - **Botswana** (TP only): EDGAR 6.0 data for CH<sub>4</sub> from category 4 (waste) is at least two orders of magnitude lower than EDGAR 5.0 data and now at the same levels as EDGAR v4.3.2 data. Contributions to the overall emissions change from other sectors are small.
  - **Georgia** (CR only): The changes are mostly due to the bug in the UNFCCC data mentioned in the [Known problems \(v2.3\)](#) section.
  - **Equatorial Guinea** (CR and TP): EDGAR v6.0 data for fugitive emissions from oil and natural gas (category 1.B.2) are between 50 and 100% higher than emissions estimates in EDGAR v5.0. As this is the most important sector for Equatorial Guinea the impact on total emissions is large. A further contribution comes from CO<sub>2</sub> in fossil fuel combustion for energy use (1.A) where new CDIAC data are significantly higher than older data. As we have no country reported data for Equatorial Guinea, the CR and TP time series are identical.
  - **Timor-Leste** (CR and TP): EDGAR v6.0 data for fugitive emissions from oil and natural gas (category 1.B.2) are between 50 and 100% higher than emissions estimates in EDGAR v5.0. As this is the most important sector for Timor-Leste the impact on total emissions is large. A further contribution comes from CO<sub>2</sub> in fossil fuel combustion for energy use (1.A) where new CDIAC data are significantly higher than older data. As we have no country reported data for Timor-Leste, the CR and TP time series are identical.
  - **Taiwan (Republic of China)** (CR): Country reported data are included for the first time and differs significantly from third party data for several sectors and gases. For some sectors and gases (e.g. CH<sub>4</sub> in category 2), sectoral detail is not sufficient for inclusion in PRIMAP-hist and thus third party data are used for the CR time series. Double counting of data contained in csv file twice leads to overestimation of emissions.
- **Changes of 20-50% in cumulative emissions**

- **Belarus** (TP only): EDGAR 6.0 data for CH<sub>4</sub> from category 4 (waste) is an order of magnitude lower than EDGAR 5.0 data and now below EDGAR v4.3.2 levels. Contributions to the overall emissions change from other sectors are small.
- **Cameroon** (CR and TP): EDGAR v6.0 CH<sub>4</sub> data for fugitive emissions from oil and natural gas (category 1.B.2) are between 20 and 50% lower than emissions estimates in EDGAR v5.0. As we have no country reported data for Cameroon, the CR and TP time series are identical.
- **Republic of the Congo** (CR and TP): EDGAR v6.0 data for fugitive CH<sub>4</sub> emissions from oil and natural gas (category 1.B.2) are between 20 and 50% higher than emissions estimates in EDGAR v5.0. CO<sub>2</sub> emission estimates for the same sector have increased by over 100% because in PRIMAP-hist v2.3 we use EDGAR v6.0, while we used CDIAC 2017 in v2.2. Contributions to the overall emissions change from other sectors are small. As we have no country reported data for the Republic of the Congo, the CR and TP time series are identical.
- **Gabon** (CR and TP): EDGAR v6.0 data for fugitive CH<sub>4</sub> emissions from oil and natural gas (category 1.B.2) are between 20 and 50% higher than emissions estimates in EDGAR v5.0. CO<sub>2</sub> emission estimates for the same sector have increased strongly because in PRIMAP-hist v2.3 we use EDGAR v6.0, while we used CDIAC 2017 in v2.2. Contributions to the overall emissions change from other sectors are small. As we have no country reported data for Gabon, the CR and TP time series are identical.
- **Kiribati** (CR (TP 10-20% change)): Waste CH<sub>4</sub> emissions, which are the major source for CH<sub>4</sub> emissions are around 30% lower in EDGAR v6.0 than in v5.0. Fugitive emissions from EDGAR now include CH<sub>4</sub> from solid fuels (1.B.1) but no longer from oil and natural gas (1.B.2). Further changes come from fossil fuel combustion for energy use (1.A) where CDIAC 2020 emissions differ from the 2017 version used in PRIMAP-hist v2.2 for recent years. The latter change is less relevant for the TP scenario as scaling amplifies the changes in the CR scenario.
- **Lao People’s Democratic Republic** (CR and TP): Main drivers are CO<sub>2</sub> emissions from fossil fuel combustion for energy use (1.A) where CDIAC 2020 emissions are much higher than the 2017 version after 2006. CH<sub>4</sub> emissions from waste are a bit lower while N<sub>2</sub>O emissions are higher after 2000 (EDGAR v6.0 vs v5.0). Cement process CO<sub>2</sub> emissions have also increased, but only for the last years. Contributions from other sectors are small. As we have no country reported data for Lao People’s Democratic Republic, the CR and TP time series are identical.
- **Marshall Islands** (TP only): CO<sub>2</sub> Emissions from fossil fuel combustion for energy use (1.A) where CDIAC 2020 emissions are much higher than the 2017 version.
- **Solomon Islands** (CR and TP): CO<sub>2</sub> Emissions from fossil fuel combustion for energy use (1.A) where CDIAC 2020 emissions are much higher than the 2017 version. As we have no country reported data for the Solomon Islands, the CR and TP time series are identical.
- **Changes of 10-20% in cumulative emissions**
  - **Aruba** (CR and TP): Aruba has large changes in all top-level sectors with especially high changes (>100%) in the agricultural sector. The reasons for the changes are manifold. EDGAR data has changed, especially for CH<sub>4</sub> in sector 1.B.2; Aruba is no longer included in the FAO data and thus EDGAR data are used for the agricultural sector; CDIAC data for fossil fuel CO<sub>2</sub> has changed as well. As we have no country reported data for Aruba, the CR and TP time series are identical.
  - **Antigua and Barbuda** (CR and TP): Large changes in sectors 1, 4, and 5 for different gases mainly introduced by changes in EDGAR data. Fugitive emissions (1.B) are no longer covered by EDGAR for Antigua and Barbuda. As we have no country reported data for Aruba, the CR and TP time series are identical.
  - **Bahamas** (CR and TP): EDGAR data for waste CH<sub>4</sub> has increased by over 100% from v5.0 to v6.0. It is the dominant source of CH<sub>4</sub> emissions for the Bahamas. Changes in other sectors only give small contributions to changes in total emissions. As we have no country reported data for the Bahamas, the CR and TP time series are identical.
  - **Comoros** (CR and TP): EDGAR data for waste CH<sub>4</sub> has increased by over 100% from v5.0 to v6.0. It is the main source of CH<sub>4</sub> emissions for Comoros. Changes in other sectors only give small contributions to changes in total emissions. As we have no country reported data for Comoros, the CR and TP time series are identical.
  - **Iraq** (CR and TP): The two main sources for changes are sectors 1.B.2 and 4 for CH<sub>4</sub> where EDGAR data has changed significantly. Changes in other sectors only give small contributions to changes in total emissions. As we have no country reported data for Iraq, the CR and TP

time series are identical.

- **Saint Lucia** (TP only): Fugitive emissions from EDGAR now include CH<sub>4</sub> from solid fuels (1.B.1) but no longer from oil and natural gas (1.B.2). The main source of changed emissions is however Waste CH<sub>4</sub> where emissions have decreased from EDGAR v5.0 to v6.0. Outside the 1990-2019 year range we have to note a peak in fugitive CH<sub>4</sub> around 1950 coming from CEDS data.
- **Moldova** (TP only): The main source of changes in overall emissions is CH<sub>4</sub> from the waste sector. EDGAR v6.0 emissions are much lower (around 70%) than v5.0.
- **Malaysia** (CR only): The inclusion of the new BUR3 data has changed emissions estimates for many gases and sectors.
- **Nigeria** (CR and TP): The main sources of differences are CO<sub>2</sub> and CH<sub>4</sub> from category 1.B.2 (fugitive emissions from oil and natural gas) where EDGAR emissions estimates have changed strongly from version 5.0 to 6.0 and CDIAC data has been replaced by EDGAR for CO<sub>2</sub>.
- **Niue** (CR and TP): The changes originate from CO<sub>2</sub> in category 1.A. CDIAC data shows reduced emissions for the last years and is not in line with the trend from downscaled BP data used in previous PRIMAP-hist versions. We have to note here that CDIAC data for Niue has a very coarse resolution and oscillates between 1 and 3 ktC with 2 ktC as the only intermediate value.
- **British Virgin Islands** (CR and TP): The main data change is higher CO<sub>2</sub> emissions in 1.A from changed CDIAC data. Outside the 1990-2019 year range we have to note a peak in fugitive CH<sub>4</sub> around 1950 coming from CEDS data. As we have no country reported data for the British Virgin Islands, the CR and TP time series are identical.

**10.5.5.2 Changes for individual categories / gases (v2.3)** Most of the changes for individual categories and gases have already been described in the [Input source updates \(v2.3\)](#) section above.

As we have changed the data source for early emissions of CO<sub>2</sub> and CH<sub>4</sub> from RCP (using growth rates) to CEDS we have changes in several sectors that affect several countries. On a global level the most affected sectors are 1.A and M.AG.ELV for CH<sub>4</sub> and 1.B.1, 2.C, 2.D, 2.G, 2.H, 4, M.AG for CO<sub>2</sub>.

## 10.6 v2.2 (November 2019)

The 2.2 release is a minor update of the v2.1 version. The methodology is unchanged, only the input sources have been updated where available. Additionally some bugs have been fixed.

### 10.6.1 Changes in PRIMAP-hist source creation

**10.6.1.1 Data source prioritization** No changes except replacement of data sources through updated versions (see section [Input source updates](#) below)

**10.6.1.2 Sectors and gases** No changes

**10.6.1.3 Composite source generation methodology** No changes

#### 10.6.1.4 Special treatment of individual countries

- **Albania:** In categories IPC2A and IPC2C scaling of EDGAR data to UNFCCC data gives huge emissions because of data discrepancies in the scaling period. We extrapolate UNFCCC data for sectors IPC2A (years 1992 - 2000) and IPC2C (years 1980 - 2000 and 2007 - 2018) to avoid scaling artifacts.
- **Andorra:** In the Waste sector (IPC4) scaling of BUR data to EDGAR432 data gives huge emissions as BUR data are near zero in the scaling year 2012. We use linear extrapolation instead of BUR data.
- **China:** Scaling EDGAR N<sub>2</sub>O emissions from IPC2B to fill the gap between 1994 and 2010 in UNFCCC data gives huge emissions as EDGAR drops to near zero in 2010 while UNFCCC is non-zero. We interpolate and extrapolate UNFCCC data linearly instead of using EDGAR to fill missing years (only after 1994).

- Democratic Republic of the Congo: For CO<sub>2</sub> emissions in IPC1, scaling of EDGAR to UNFCCC gives huge emissions. We extrapolate UNFCCC data for 2004 and 2005 linearly to create a matching point that does not create these artifacts.
- Namibia: In the mineral industry sector (IPC2A) scaling of CDIAC data to ANDREWv4 data gives huge emissions as CDIAC is near zero 2010 and before, while ANDREW is non-zero in 2011 and the following years. We use CDIAC data directly for 1994 to 1998.

## 10.6.2 Changes in data sources and preprocessing

### 10.6.2.1 Input source updates

- BP fossil CO<sub>2</sub> data have been updated to the 2020 release (British Petroleum (2020)), last used data year is 2018.
- CRF data have been updated to the 2020 submissions (Gütschow et al. (2020b) + updated data from Hungary).
- Data from the Biennial Update Reports (BURs, UNFCCC (2020) ) have been updated. We have added the second BUR from Morocco and the third BUR from Argentina. Data from the third BURs of Chile and Brazil are (at least partly) included in the UNFCCC detailed data by party interface as their data used a mixture of IPCC 1996 and IPCC 2006 categories. Data from the South African third BUR are currently not included, as data detail is not sufficient and downscaling to gases did not provide results consistent with available national total individual gas time series. In total, countries included in our BUR data are
  - first BUR: Indonesia, Montenegro, Mongolia, Mauritania, and Togo
  - second BUR: Andorra, Argentina, Colombia, Indonesia, Macedonia, Mexico, Moldova, Montenegro, Morocco, Namibia, and South Africa
  - third BUR: Argentina, Andorra, and Namibia
- CRF data have been updated to the 2020 release (Gütschow et al. (2020b), as of January 11, 2021) with the 2019 release (Gütschow et al. (2020a)) used as backup for missing 2020 data. The last data year is now 2018 for all categories and gases.
- FAOSTAT data have been updated to include all data available by December 22nd, 2020 (Food and Agriculture Organization of the United Nations (2020)). For all sectors and gases the last used year is now 2018. The new FAO data show significant changes in emissions estimates in the following sectors: IPC3A1 - enteric fermentation and IPC3A2 - manure management before 1990 for some countries; IPC3C1AG - agricultural biomass burning (especially savanna burning): changes for most countries; IPC3C4 - direct N<sub>2</sub>O from managed soils: changes for a some countries; IPC3C5 - indirect N<sub>2</sub>O from managed soils: large changes for some countries;
- UNFCCC “Detailed Data by Party” has been updated to data available by December 8th, 2020 (Gieseke and Gütschow (2020)): South Sudan has been added to the source. Burundi, Botswana, China, Dominica, Honduras, Israel, South Korea, Kuwait, Maldives, Palau, Pakistan, Sao Tome and Principe, Tonga, and Uruguay have added and updated datapoints. A few countries have also removed individual datapoints: China, Pakistan, Sao Tome and Principe, and Uruguay. These additions are in the raw data, preprocessing removes some data. For changes in preprocessed data see section [Changes in preprocessing](#) below.
- EDGAR data have been updated from v4.3.2 to v5.0. EDGAR v5.0 use IPCC2006 categories which leads to reallocation of emissions between subsectors of IPC2

### 10.6.2.2 Changes in preprocessing

- We have reduced the requirement for UNFCCC data from needing to cover a period of 11 years to 6 years. However, for several countries the data was not suitable to be used as a first priority source (e.g. too many fluctuations) and had to be excluded. After this change the countries Burundi, Belize, Barbados, Botswana, Democratic Republic of the Congo, Eritrea, Honduras, Haiti, Maldives, Myanmar, Palau, and Tonga are added to the UNFCCC data used in PRIMAP-hist.
- We have reduced the requirement for BUR data from needing to cover a period of 11 years to 6 years. This allowed for the inclusion of Morocco’s second BUR.

### 10.6.3 Bug fixes

None

#### 10.6.4 Known problems

- SF<sub>6</sub> emissions in the TP time series are too low. Some sectors from EDGAR data are not read into the PRIMAP-software properly. [issue #19](#).
- FAO data for synthetic fertilizers do not cover the full period (1961 - 2018) for several countries. In the 2020 release data for some countries were removed leading to changed emission estimates as data are summed with other sectors before use in PRIMAP-hist. Some time series start later than 1961, while others have gaps. As data are summed with other sectors before use in PRIMAP-hist the gaps and boundaries are not filled with data from other sources. [issue #22](#)
- UNFCCC agricultural N<sub>2</sub>O data for Albania are very low. [issue #23](#)
- Due to a bug IPC1B1 (venting) CH<sub>4</sub> data from EDGAR v5.0 has not been downscaled from Sudan to Sudan and South Sudan. Thus all CH<sub>4</sub> emissions from sector IPC1B1 are attributed to Sudan. [issue #24](#)
- For problems that were found after the release of the dataset, please consult the issue tracker [github.com/JGuetschow/PRIMAP-hist](https://github.com/JGuetschow/PRIMAP-hist).

#### 10.6.5 Noteworthy changes

Here, we list the most important changes in total and per sector / per gas emissions and their reasons. The changes due to bugs fixed and discussed in the [Bug fixes](#) section above are omitted here.

##### 10.6.5.1 Notable changes in total Kyoto GHG emissions

- **Countries removed**
  - **Pitcairn Islands** (CR and TP): Data for Pitcairn Islands are not included in EDGAR any more since v5.0. As this was the only source there are currently no recent data available at all.
- **Changes over 100% in cumulative emissions**
  - **Barbados** (CR only) UNFCCC data are included for the first time and differ strongly from third party data for CH<sub>4</sub>, IPC4 (waste) and the agricultural sectors (IPC3A, IPCMAGELV).
  - **Botswana** (TP only) New EDGAR 5.0 data for IPC4 (waste) differ strongly from older EDGAR data. In the CR dataset UNFCCC data are included for the first time. These data are similar to the older EDGAR data and thus there are only small changes below 10% in the CR time series.
- **Changes of 50-100% in cumulative emissions**
  - **Belize** (CR only): Changes in a few sectors due to the inclusion of UNFCCC data for the first time. Most important is IPC4 (waste). Smaller changes in several sectors due to new EDGAR and FAO data.
  - **Democratic Republic of the Congo** (CR only): UNFCCC data are included for the first time especially impacting energy (IPC1) emissions.
  - **Myanmar** (CR only): UNFCCC data have been included for the first time. They differ strongly from third party data for N<sub>2</sub>O and CH<sub>4</sub>.
  - **Palau** (CR, TP): UNFCCC data have been included for the first time. They differ strongly from third party data for several sectors and gases. EDGAR v5.0 data also differ from EDGAR v4.3.2 used in PRIMAP-hist v2.1.
  - **South Sudan** (CR, TP): due to a bug IPC1B1 (venting) CH<sub>4</sub> data from EDGAR v5.0 have not been downscaled from Sudan to Sudan and South Sudan. Thus all CH<sub>4</sub> emissions from IPC1B1 are attributed to Sudan.
  - **Sudan** (CR, TP): due to a bug IPC1B1 (venting) CH<sub>4</sub> data from EDGAR v5.0 have not been downscaled from Sudan to Sudan and South Sudan. Thus all CH<sub>4</sub> emissions from IPC1B1 are attributed to Sudan.
  - **Tokelau** (CR, TP): EDGAR v5.0 data differ strongly from EDGAR v4.3.2. Some sectors and gases have changed, other have no data at all in v5.0 despite having data in v4.3.2. CR and TP time series are identical as there are no country reported data.
- **Changes of 20-50% in cumulative emissions**
  - **Albania** (CR only): For some sectors UNFCCC data cover only a period of less than 11 years. Thus these time series have been included for the first time changing especially N<sub>2</sub>O from all agricultural sectors to very low values. See also [Known problems](#) section.
  - **Burundi** (CR (TP 10-20% change)): New EDGAR data (e.g. CH<sub>4</sub> in IPC1 and subcategories) and also extended UNFCCC data which are included for the first time (e.g. CH<sub>4</sub>, IPC4). CH<sub>4</sub>

emissions in IPC3A are much higher than in v2.1 for the last years. This comes from updated FAO data.

- **Georgia** (TP only): New EDGAR data impact CH<sub>4</sub> emissions in IPC1B and IPC4, and CO<sub>2</sub> emissions in IPC2D,G,H. Some new sectors from UNFCCC data, e.g. N<sub>2</sub>O emissions from IPC2H.
- **Hungary** (TP only): The highest changes are for CH<sub>4</sub> in IPC4 (>100%, from EDGAR), and IPC2 (20-50% range, from changes in EDGAR which are amplified by the scaling to CRF) and CO<sub>2</sub> in IPC4 (20-50% range, from CRF data). There are several other small changes as several input sources have changed (e.g. N<sub>2</sub>O in IPC1B2).
- **Jamaica** (CR only): Inclusion of UNFCCC data have changed emission estimates in several sectors, most notably in the agricultural sectors (IPC3A, IPCMAGELV) and the waste sector (IPC4).
- **Tonga** (CR only): Inclusion of UNFCCC data have changed emission estimates in several sectors, most notably in the waste sector (IPC4).
- **Changes of 10-20% in cumulative emissions**
  - **The Bahamas** (CR, TP): New EDGAR data introduce changes in several sectors (e.g. CH<sub>4</sub> for IPC1 and IPC4; CO<sub>2</sub> for IPC1B and IPC2 subsectors; N<sub>2</sub>O for IPC1). CR and TP time series are identical.
  - **Belarus** (TP only): The source for the largest changes are the new EDGAR data, especially CH<sub>4</sub> from IPC4. CRF data have also updated estimates of historical emissions but the changes are smaller.
  - **Central African Republic** (TP only): Changes in EDGAR data, especially CO<sub>2</sub> for IPC2 and subsectors.
  - **Cyprus** (TP only): Changes in EDGAR data, especially CH<sub>4</sub> for IPC4; CO<sub>2</sub>, IPC2 and subsectors.
  - **Finland** (TP only): Changes in EDGAR data, especially CH<sub>4</sub> for IPC4.
  - **Moldova** (TP only): Changes in EDGAR data, especially CH<sub>4</sub> for IPC4.
  - **Maldives** (CR only): Due to additional UNFCCC data the CR time series now differ from TP (only for a few sector - gas combinations).
  - **Marshall Islands** (TP only): Changes in EDGAR data, especially CH<sub>4</sub> for IPC4.
  - **Sierra Leone** (CR, TP): Changes in EDGAR CH<sub>4</sub> and N<sub>2</sub>O in IPC1 and subcategories.
  - **Timor-Leste** (CR and TP): Changes in EDGAR CH<sub>4</sub> for IPC1 and subcategories, CH<sub>4</sub> in IPC4, and N<sub>2</sub>O in IPC5.
- **Other changes / notes**
  - **Fiji**: Fiji has a sudden drop in CH<sub>4</sub> emissions in 2015. The drop originates from FAO cattle enteric fermentation and manure management emissions.
  - **Syria**: BP and EDGAR data disagree for the development in the latest years for CO<sub>2</sub> in IPC1A.

**10.6.5.2 Changes for individual categories / gases / sources** Here, we group the changes by their cause and not by country, as several countries are affected in the same way. Not all changes that are large for a sector and gas combination are listed, because that sector and gas combination might not play a significant role in a country's total emissions.

- **EDGAR data update** The updated EDGAR data have changed emissions estimates for most sectors, gases and countries. Additionally they are now published in IPCC 2006 sectors leading to reassignment of emissions in subsectors of IPC2 compared to the EDGAR v4.3.2 data. Those changes affect several countries and especially the TP time series for all sectors except agriculture, CO<sub>2</sub> for IPC1A and IPC2A.
- **FAO data update** The new FAO data show significant changes in emissions estimates in the following sectors:
  - IPC3C1AG - agricultural biomass burning, especially savanna burning: while data have changed for all countries the relative changes differ strongly. Where savanna burning is a larger factor of total CH<sub>4</sub> and N<sub>2</sub>O emissions this can influence total emissions noticeably.
  - IPC3C4 / IPC3C5 - direct / indirect N<sub>2</sub>O from managed soils: for some countries fertilizer use data cover a shorter period of time now. This leads to lower agricultural emissions as data are summed with other sectors before use in PRIMAP hist. See also **Known problems** section.
- **CRF data update** A few countries have increased their historical emissions estimates (over 2%

increase in cumulative emissions). These are

- **Belarus:** major change is in CH<sub>4</sub> for IPC3A
- **Iceland:** major change is in CH<sub>4</sub> for IPC3 and IPC4
- **Kazakhstan:** changes in several sectors and gases; the major change is CO<sub>2</sub> for IPC1B
- **Malta:** changes in several sectors and gases; the major change is CO<sub>2</sub> for IPC1A
- **New Zealand:** major change is in N<sub>2</sub>O for IPCMAGELV
- **UNFCCC data update** Most of the countries with newly included or changed UNFCCC data are already listed in the [Notable changes in total Kyoto GHG emissions](#) section above. Additionally we have:
  - **Eritrea:** UNFCCC data only used for few sectors / gases. Large changes in CH<sub>4</sub> for IPC4, other sectors have smaller changes.
  - **Honduras:** Most sectors / gases have changed emissions estimates of different magnitude.
  - **Haiti:** Most sectors / gases have changed emissions estimates of different magnitude.
- **BUR data update** Morocco’s second BUR and Argentina’s third BUR have been added.

## 10.7 v2.1 (November 2019)

The 2.1 release is a minor update of the v2.0 version. The methodology is unchanged, only the input sources have been updated where available. Additionally some bugs have been fixed.

### 10.7.1 Changes in PRIMAP-hist source creation

#### 10.7.1.1 Data source prioritization

- Data from the third BUR reports have been included as first priority source for non-Annex I parties.

#### 10.7.1.2 Sectors and gases No changes

#### 10.7.1.3 Composite source generation methodology No changes

#### 10.7.1.4 Special treatment of individual countries

- Andorra: In the Waste sector (IPC4) scaling of BUR data to EDGAR432 data gives huge emissions as BUR data are near zero in the scaling year 2012. We use linear extrapolation instead of BUR data.
- Namibia: In the mineral industry sector (IPC2A) scaling of CDIAC data to ANDREWv4 data gives huge emissions as CDIAC is near zero 2010 and before, while ANDREW is non-zero in 2011 and the following years. We use CDIAC data directly for 1994 to 1998.

### 10.7.2 Changes in data sources and preprocessing

#### 10.7.2.1 Input source updates

- We have included Andrew Cement data (v4, Andrew (2019a)), which replace v2 used in PRIMAP-hist v2.0.
- BP fossil CO<sub>2</sub> data have been updated to the 2019 release (British Petroleum (2019)), last used data year is 2017.
- Data from the Biennial Update Reports (BURs, UNFCCC (2019b)) have been updated. We have added the second BURs from Colombia, Indonesia, Mexico, Moldova, and Montenegro. We have also added the third BURs from Andorra and Namibia. Data from the third BURs of Chile and Brazil are (at least partly) included in the UNFCCC detailed data by party interface as their data used a mixture of IPCC 1996 and IPCC 2006 categories. Data from the South African third BUR are currently not included, as data detail is not sufficient and downscaling to gases did not provide results consistent with available national total individual gas time series. In total, countries included in our BUR data are
  - first BUR: Indonesia, Montenegro, Mongolia, Mauritania, and Togo
  - second BUR: Andorra, Argentina, Colombia, Indonesia, Macedonia, Mexico, Moldova, Montenegro, Namibia, and South Africa
  - third BUR: Andorra and Namibia



- CRF data have been updated to the 2019 release (UNFCCC (2019a), as of October 31, 2019) with the 2018 release used as backup for missing 2019 data. The last data year is now 2017 for all categories and gases.
- FAOSTAT data have been updated to include all data available by September 30th, 2019 (Food and Agriculture Organization of the United Nations (2019)). For all sectors and gases the last year is now 2017. The new FAO data shows significant changes in emissions estimates in the following sectors: IPC3C4 - direct N<sub>2</sub>O from managed soils; IPC3C1AG - agricultural biomass burning.
- UNFCCC “Detailed Data by Party” has been updated to data available in August 1st, 2019 (Gieseke and Gütschow (2019)): Jamaica, Mali, and Yemen have been added to the source. Azerbaijan, Brazil, Chile, Malaysia, Mexico, Chad, United Arab Emirates, and Uruguay have extended and / or updated data.

#### 10.7.2.2 Changes in preprocessing

- The EDGAR v4.3.2 data source contains some time series with only a single or very few data points. These have been removed as we do not use single data point time series. This has affected several countries, though only slightly as the time series with missing data are in sectors with low emissions.

#### 10.7.3 Bug fixes

- In earlier versions of PRIMAP-hist, the FAO time series for savanna burning and burning of agricultural residues were mixed up. As they are summed for use in the PRIMAP-hist dataset, this does not directly influence the emissions. However, the savanna burning time series starts in 1990 only, and was extrapolated back to 1961 using EDGAR data, and thus in the older version we erroneously used data for burning of agricultural residues instead of data for savanna burning. This has been corrected in v2.1. Several countries, especially African countries, were affected by the change as visible in the [Noteworthy Changes](#) section.
- In the FAO data some time series are published in units of a gas and other in GgCO<sub>2</sub>eq units. In consequence, the livestock (IPC3A) CH<sub>4</sub> TP time series in PRIMAP-hist v2.0 used a CO<sub>2</sub>eq unit. As the global warming potential (GWP) used for the conversion is not stored with the data, this time series was not converted when aggregating the Kytoto GHG baskets. The original time series is in SAR GWPs (100 year GWP for CH<sub>4</sub>: 21) while the AR4 value for CH<sub>4</sub> 100 year GWP is 25. Thus, IPC3A CH<sub>4</sub> was underestimated by a factor of  $21/25 = 0.84$  in the AR4 Kyoto GHG time series. This has been fixed now and all data are now converted to native units before use in the PRIMAP-hist source. The bug has affected all countries in the TP time series (AR4 GWP Kyoto GHG time series only), but total emissions have only changed notably for those countries which have a high share of livestock emissions in total emissions. (issue #4 in the issue tracker)
- In the CRF data some countries report an unspecified mix of HFCs (PFCs). These can not be converted to different GWPs automatically as their mix is unknown. CRF data are reported in AR4 GWPs. Because there was no conversion to other GWPs the emissions reported as unspecified mix of HFCs (PFCs) were only included for AR4 GWPs. Only few countries report unspecified mixes and of these only Japan in quantities sufficient to noticeably affect total emissions (for recent years only).
- The BUR data have no common specifications of units, GWPs, etc used by all countries. Thus, time series presented in CO<sub>2</sub>eq units can use different GWPs throughout the BUR data source. These time series were not in all cases converted to a common GWP leading to GWP conversion errors in PRIMAP-hist v2.0. This has been corrected in v2.1. Affected countries are Argentina and South Africa.
- For a few very small countries, which are included in reporting of larger countries for some sources there was a bug in downscaling of agricultural emissions leading to emissions time series dropping to 0 in 2013. This has been corrected. Affected countries are Monaco, San Marino, Vatican. (issue #3 in the issue tracker)

#### 10.7.4 Known problems

No known problems. For problems that were found after the release of the dataset, please consult the issue tracker [github.com/JGuetschow/PRIMAP-hist](https://github.com/JGuetschow/PRIMAP-hist).

### 10.7.5 Noteworthy changes

Here, we list the most important changes in total and per sector / per gas emissions and their reasons. The changes due to bugs fixed and discussed in the [Bug fixes](#) section above are omitted here.

#### 10.7.5.1 Notable changes in total Kyoto GHG emissions

- **Changes of 20-50% in cumulative emissions**
  - **Central African Republic:** changes in data before 1990 in CR and TP datasets. The changes originate from the extrapolation bugfix in agricultural biomass burning emissions.
  - **Colombia:** the inclusion of data from the second BUR has changed emissions in the CR time series in all sectors with largest changes in the agricultural sector. The TP time series has only small changes coming mostly from the IPC3A FAO GWP bug (AR4 GWP time series only).
  - **Democratic Republic of the Congo:** overall data changes in CR and TP datasets. The changes originate mostly from biomass burning emissions, where FAO data have changed. The extrapolation bugfix has also influenced pre-1990 emission estimates.
  - **Guinea:** overall data changes in CR and TP datasets. The changes originate mostly from biomass burning emissions, where FAO data have changed. The extrapolation bugfix has also influenced pre-1990 emission estimates.
  - **Guinea Bissau:** overall data changes in CR and TP datasets. The changes originate mostly from biomass burning emissions, where FAO data have changed. The extrapolation bugfix has also influenced pre-1990 emission estimates.
  - **Namibia:** changes mainly in the agricultural sectors. The changes originate from new BUR data and new FAO data including the extrapolation bugfix. Changes for the TP source are in the 10-20% range.
  - **South Sudan:** changes in the agricultural sectors. The changes originate from new FAO data including the extrapolation bugfix. As there is no country-reported data, CR and TP datasets are identical.
- **Changes of 10-20% in cumulative emissions**
  - **Angola:** changes in the agricultural sectors. The changes originate from new FAO data including the extrapolation bugfix. As there is no country-reported data, CR and TP datasets are identical.
  - **Botswana:** changes in the agricultural sectors. The changes originate from new FAO data including the extrapolation bugfix. As there is no country-reported data, CR and TP datasets are identical.
  - **Côte d’Ivoire:** changes in the agricultural sectors. The changes originate from new FAO data including the extrapolation bugfix. As there is no country-reported data, CR and TP datasets are identical.
  - **Republic of the Congo:** changes in the agricultural sectors excluding livestock. The changes originate from new FAO data including the extrapolation bugfix. As there is no country-reported data, CR and TP datasets are identical. The changes are smaller for the AR4 GWP time series as they partly cancel with changes introduced by the FAO IPC3A GWP bugfix.
  - **Mali:** changes in several categories for the CR dataset, as the addition of data for 2010 has enabled the use of the country-reported UNFCCC data in the PRIMAP-hist dataset. The TP dataset has changes in the agricultural sector originating from new FAO data including the extrapolation bugfix.
  - **Namibia:** the most important change comes from fixing a scaling bug in IPC2A (Mineral Industry) CO<sub>2</sub> emissions, which lead to an emissions peak in PRIMAP-hist v2.0. Further changes come from the inclusion of the third BUR (CR dataset) and FAO2019 (both datasets).
  - **Papua New Guinea:** changes in emissions estimates from the agricultural sector and from industrial processes (cement). In the agricultural sector, the main source of changes are direct N<sub>2</sub>O emissions from managed soils (IPC3C4) from the FAO dataset. As there is no country-reported data, CR and TP datasets are identical.
  - **Russia:** strong downward correction of emissions from several sectors and gases in the CR source: CH<sub>4</sub>, CO<sub>2</sub>, and N<sub>2</sub>O from fugitive emissions from oil and natural gas (IPC1B2), N<sub>2</sub>O from livestock (IPC3A), CO<sub>2</sub> and N<sub>2</sub>O from agricultural emissions excluding livestock (IPCMAGELV), CH<sub>4</sub> from waste (IPC4). The national inventory report mentions a change in emissions factors as the source of the changes.
  - **Togo:** changes in the agricultural sectors in the CR source. The changes originate from new

FAO data including the bugfix. Changes in the TP source are smaller (5-10% range) as the estimates for agricultural emissions are higher in the CR source and FAO data are scaled to match these higher emissions.

- **Tanzania:** changes in the agricultural sectors excluding livestock. The changes originate from new FAO data including the extrapolation bugfix. As there is no country-reported data, CR and TP datasets are identical.

**10.7.5.2 Changes for individual categories / gases** Here, we group the changes by their cause and not by country, as several countries are affected in the same way. Not all changes that are large for a sector and gas combination are listed, because that sector and gas combination might not play a significant role in a country's total emissions.

- **FAO data update**

- The FAO data update mainly affected emissions excluding livestock. Livestock emissions are largely unchanged.
- Several countries are affected by a change in direct N<sub>2</sub>O emissions from managed soils (IPC3C4):
  - \* much higher emissions: Iceland (TP)
  - \* higher emissions: Burundi (CR, TP), Gabon (CR, TP), UK (TP)
  - \* lower emissions: Armenia (TP), Belize (CR, TP), Canada (TP), Ireland (TP), Malaysia (TP), Nepal (CR, TP), Oman (CR, TP)
  - \* much lower emissions: Estonia (TP), Suriname (CR, TP)
  - \* other changes: Bahrain (peaks removed, CR, TP), Trinidad and Tobago (peaks removed, CR, TP)
- The Update of biomass burning emissions (and the bugfix) affected several countries as well. A lot of them are already mentioned above. Additionally we have
  - \* Australia (CH<sub>4</sub>, N<sub>2</sub>O: TP)
  - \* Ghana (CH<sub>4</sub>, N<sub>2</sub>O: TP)
  - \* Gambia (lower N<sub>2</sub>O: CR, TP)
  - \* Guyana (lower CH<sub>4</sub>, N<sub>2</sub>O: CR, TP)
  - \* Indonesia (slightly lower CH<sub>4</sub>, N<sub>2</sub>O: CR, TP)
  - \* Lesotho (CH<sub>4</sub>, N<sub>2</sub>O: CR, TP)
  - \* Madagascar (CH<sub>4</sub>, N<sub>2</sub>O: TP)
  - \* Mozambique (CH<sub>4</sub>, N<sub>2</sub>O: CR, TP)
  - \* Paraguay (CH<sub>4</sub>, N<sub>2</sub>O: CR, TP)
  - \* Sudan (CH<sub>4</sub>, N<sub>2</sub>O: CR, TP)
  - \* Senegal: (CH<sub>4</sub>, N<sub>2</sub>O: CR, TP)
  - \* Sierra Leone: (CH<sub>4</sub>, N<sub>2</sub>O: CR, TP)
  - \* South Africa: (CH<sub>4</sub>, N<sub>2</sub>O: CR, TP)
  - \* Zambia: (CH<sub>4</sub>, N<sub>2</sub>O: CR, TP)
  - \* Zimbabwe: (CH<sub>4</sub>, N<sub>2</sub>O: CR, TP)
- Other changes
  - \* Kuwait: new peaks in N<sub>2</sub>O from IPCMAGELV
  - \* Chad: different changes through new FAO data. The most important is a strong increase in emissions for the last years for livestock and direct soil N<sub>2</sub>O. (CH<sub>4</sub>, N<sub>2</sub>O: CR, TP)

- **CRF data update**

- Cyprus: lower N<sub>2</sub>O emissions in agriculture without livestock, but not relevant on national total Kyoto GHG level
- Iceland: much lower livestock N<sub>2</sub>O emissions in CR source.
- Kazakhstan: Fugitive emissions from oil and natural gas (IPC1B2) are much higher in CRF 2019 than in the CRF data used fore PRIMAP-hist v2.0. (CR)
- Luxembourg: slight decrease in N<sub>2</sub>O data from agriculture excluding livestock (CR)
- Romania: changed emission for several sectors and gases (CR)
- Turkey: changed emissions for several sectors and gases (CR)
- USA: N<sub>2</sub>O emissions from energy corrected upwards (CR)

- **UNFCCC data update**

- Chile: the new F-gases UNFCCC data are much higher than EDGAR42 used before. There are no HFCs data in EDGAR, thus the TP source also shows higher F-gases emissions. N<sub>2</sub>O data are lower. One problematic data point has been removed.

- United Arab Emirates: changed emission estimates for latest years
- Azerbaijan: drop in agricultural N<sub>2</sub>O data in last years
- Uruguay: new data have changed emissions for several sectors and gases
- Yemen: newly available in UNFCCC (data detail not sufficient for all sectors). The PRIMAP-hist time series show changes in several sectors and gases (CR).
- **BUR data update**
  - Colombia: the new F-gases BUR data are much higher than EDGAR42 used before. No HFCs data in EDGAR, thus the TP source also shows higher F-gases emissions.
  - Moldova: new BUR data replace UNFCCC data and lead to changes for several sectors and gases in the CR time series.
  - Montenegro: new BUR2 data replace BUR1 data and lead to changes for several sectors and gases in the CR time series.

## 10.8 v2.0 (December 2018)

The v2.0 release comes with several important changes. The dataset now uses the sectors from the IPCC 2006 guidelines. It includes new and updated data sources (EDGAR v4.3.2, Andrew 2018 cement data, updated BUR, CRF and UNFCCC data, updated BP and FAO data). This release of PRIMAP-hist does not include LULUCF emissions. We also present two different data sets to highlight discrepancies between data from third-party assessments and data reported by countries. In the “country-reported priority” time series we prioritize country-reported data over third-party data. This is a direct continuation of earlier versions of PRIMAP-hist. These time series has the scenario code “HISTCR”. In the “third-party priority” time series we prioritize data from third-party assessments (e.g. by research institutes, international organizations, or private companies) over the third-party data. The scenario code is “HISTTP”. A new data description paper with detailed methodology description is currently under preparation.

### 10.8.1 Changes in PRIMAP-hist source creation

#### 10.8.1.1 Data source prioritization

- Through the inclusion of new data sources, the source prioritization has changed a little. The “HISTCR” time series, which are the continuation of the previous PRIMAP-hist time series now use the following source prioritization: CRF 2018, CRF 2017, BUR, UNFCCC2018, Andrew2018, CDIAC 2017, FAO2018, EDGAR v4.3.2, EDGAR v4.2 (FT2010), BP2018.
- The new “HISTTP” time series use the same basic prioritization, but with the block of country-reported data sources (CRF, BUR, UNFCCC) at the end of the priority list.

**10.8.1.2 Sectors and gases** The data source now uses the IPCC 2006 sectors. The sectors are listed in section [category] above. The new sectors bring some changes to the categorical resolution.

- In the agricultural sector we now distinguish between emissions from livestock (IPC3A) and agricultural emissions without livestock (IPCMAGELV). Because of the use of manure as fertilizer for crops, this split is not always exactly the same for all data sources. The extrapolation has also changed, as EDGAR-HYDE has individual data for livestock and agricultural emissions without livestock (for CH<sub>4</sub> and for N<sub>2</sub>O we use the combined time series as the individual time series for agriculture without livestock are zero before 1940 for most regions).
- Subsector resolution for IPC1 and IPC2 is now available for all gases except the fluorinated gases, which lack this resolution in some input data sources.

The gas resolution has not been changed. Country- and sector-resolved data for individual HFCs and PFCs are still too scarce to create individual gas time series. However, NF<sub>3</sub> has been added to the time series but data are only available for a few countries.

#### 10.8.1.3 Composite source generation methodology

- When only a few (less than 6) years are added to the time series by a lower priority source (for a specific country / gas / sector), the scaling is not carried out using regression values but the raw data of the time series and the lower priority source in the last year of the time series (first year in case of extension to the past). This method better accounts for short term trends, which are the information we want to obtain from the lower priority source if only a few years are added.

- The the scaling of lower priority time series to higher priority time series has been adjusted for category IPC1B2. Now a trend of 5 years is used instead of a trend of 15 years. This was necessary as several countries showed a steep increase in emissions in the first half of the 1970s, leading to very high starting points of the backwards extrapolation of EDGAR v4.3.2 data.
- The scaling of lower priority sources when filling gaps in higher priority sources has been changed as there were some problems when the lower priority source data showed strong fluctuations in the years of the gap, leading to different scaling factors for the right and the left boundary. Now small gaps (< 5 years), where the quotient of the left and right boundary scaling factors is larger than 2, are linearly interpolated instead of filling with scaled lower priority data.
- The bound on the scaling factor has been removed. Lower priority sources are now strictly used as growth rates.

#### 10.8.1.4 Special treatment of individual countries

- South Sudan and Sudan now have individual data in most data sources. Thus, individual time series are created for the two countries instead of downscaling of a common time series after the source creation, as done before.

### 10.8.2 Changes in data sources and preprocessing

#### 10.8.2.1 Input source updates

- We have included Andrew 2018 (v2) data on CO<sub>2</sub> emissions from cement to replace the CDIAC cement CO<sub>2</sub> emissions. We classify the dataset as third-party data, as it provides an overview over emissions from almost all countries. However, country-reported data (CRF) are also used to create the dataset.
- BP fossil CO<sub>2</sub> data have been updated to the 2018 release, last used data year is 2016.
- Data from the Biennial Update Reports (BURs) have been updated to include all BURs submitted until 1st September 2018 which use IPCC 2006 categories and contain sufficient data to be used in PRIMAP-hist. All data from countries which submitted their BURs in IPCC 1996 categories should be included in the UNFCCC “Detailed Data by Party” source. Countries included in our BUR data are
  - first BUR: Indonesia, Montenegro, Mongolia, Mauritania, Togo
  - second BUR: Andorra, Argentina, Macedonia, Namibia, South Africa
- CRF data have been updated to the 2018 release with the 2017 release used as backup for missing 2018 data. The last data year is now 2016 for all categories and gases
- EDGAR data have been updated to version v4.3.2. The new release shows significant differences in emissions estimates for some sectors and gases. Most prominent is a strong increase in estimates of fugitive emissions from oil and gas production. While this is a small contribution for most developed countries, it is a very important emissions source for oil exporting countries, especially when export of fossil fuels is the main economic sector. The change is justified in the EDGAR v4.3.2 description paper, see Janssens-Maenhout et al. (2017).
- FAOSTAT data have been updated to include all data available by September 2018. Changes in historical emissions are very limited. For most sectors and gases the last year is now 2016. There are some exceptions which need special processing which is explained in the following section.
- UNFCCC “Detailed Data by Party” has been updated to data available by September 2018 (no updates from the cited July version: Gieseke and Gütschow (2018)): several countries are included for the first time with sufficient data to be used in PRIMAP-hist. Some countries have updated and extended data. However, some time series seem to be constructed from data points that were calculated using different methodologies and therefore show large discrepancies. Other data show strong fluctuations or deviate strongly from third-party sources. In several cases we excluded data from use in PRIMAP-hist as we could not identify the source of the fluctuations and discrepancies. Details are presented in the section *Noteworthy Changes* below.

#### 10.8.2.2 Changes in preprocessing

- In earlier versions of PRIMAP-hist, all input sources were extrapolated during sector and gas aggregation where individual subsectors or gases did not cover the full time frame. This has now been replaced by more specific extrapolations for the few cases where extrapolation is needed.

- All data sources not reported in IPCC 2006 sectors are converted to these sectors. These are: FAOSTAT, EDGAR v4.2, EDGAR v4.3.2, EDGAR-HYDE v1.4, RCP, and UNFCCC. BP, CDIAC, and Andrew cement data do not need a conversion as they only cover subsectors which are also present in the 2006 guidelines.
- FAOSTAT data covers the period 1961 to 2016 for most sectors and gases. However, there are a few exceptions that need special treatment:
  - For N<sub>2</sub>O emissions from synthetic fertilizers, the resolved direct and indirect emissions miss 2016 data. We use the net emissions trend to extrapolate direct and indirect emissions. Direct and indirect emissions are mapped to different sectors in the IPCC 2006 categories and are thus needed for the whole time frame.
  - Data for agricultural waste burning are only available from 1990 onwards. In the PRIMAP-hist source creation agricultural waste burning emissions are included in the IPCMAGELV sector. For some countries emissions from this sector are a mayor contribution to the IPCAGELV sector. We thus extrapolate the FAO data with EDGAR v4.3.2 data for the same sector before aggregation of the IPCMAGELV sector.
  - Data for cultivation of organic soils are only available from 1990 onwards. As we have no alternative data source for this sector, we use a constant extrapolation. The data available in FAO are also a constant time series. Implicitly, the same was done in PRIMAP-hist v1.2 as the linear extrapolation of a constant function is a constant extrapolation
- In the BUR data, some tables contained unit errors or ambiguities that had to be corrected. Some countries provided the detailed category and gas information only for selected years and required downscaling to obtain time series usable in PRIMAP-hist
  - SF<sub>6</sub> data for Montenegro have been corrected as they were presented with a wrong unit in the BUR (The unit given is Gg while the data are actually in GgCO<sub>2</sub>eq)
  - Indonesia data need downscaling of IPC1 and IPC2 data to subsectors for 2000 - 2011, where detailed 2012 data are used as downscaling key.
  - Mongolia data only resolve gases for 1990 and 2014 for all sectors. KYOTOGHG time series are provided for all sectors for 1990 - 2014. Some sectors only contain emissions from a certain gas and thus the Kyoto GHG time series can be used to construct an individual gas time series for these sectors. Other sectors need downscaling of Kyoto GHG time series to individual gases using the shares from 1990 and 2014 (linearly interpolated). These sectors are: IPC1 and subsectors and IPC4.
  - Argentina provides data for 1990 - 2014 with gas detail only for 2014. Thus, for all sectors Kyoto GHG data are downscaled to individual gas level using the 2014 shares.
- The UNFCCC “Detailed Data by Party” interface combines data from different country submissions. Sometimes these data have been prepared using different methodologies and guidelines and are inconsistent. When the sectors do not match the IPCC 1996 guidelines used by the interface, the time series are sometimes put into “other” categories. We thus have to remove data points and partial time series for several countries. In other cases we have to downscale data that are not available in the necessary categorical detail using detailed data available for individual years.
- Downscaling of Sudan data to Sudan and South Sudan is now carried out in the individual sources which do not yet contain data for the individual countries (e.g. EDGAR v4.2) or only resolve the individual countries for the time after the separation of Sudan e.g. (FAO, CDIAC).
- The downscaling of the groups for countries not individually resolved in the BP data has been improved. It now uses the trend of emissions shares from CDIAC rather than the shares themselves.

### 10.8.3 Further bug fixes

None.

### 10.8.4 Known problems

- The shorter regression period for category IPC1B2 extrapolation is only applied when extrapolating with EDGAR-HYDE data. However, EDGAR-HYDE data for N<sub>2</sub>O in IPC1B2 starts in 1970, the same year as EDGAR v4.3.2 data. Thus it is not used for extrapolation. In the extrapolation with RCP data the normal regression period is used and thus the starting point of the extrapolation is higher as there was a steep increase in fugitive emissions in the early 1970s.
- Data for the Pitcairn Islands has no CO<sub>2</sub>. All data for the territory comes from EDGAR v4.2 and is very patchy. However, this is not very important as the Pitcairn Islands have only about 50

inhabitants.

- Tokelau CO<sub>2</sub> data are not extrapolated before 1890. Tokelau has no CO<sub>2</sub> IPC1A data and thus needs a special treatment for the CO<sub>2</sub> extrapolation. This will be added in a future version.
- The agricultural sectors (IPC3A, IPCMAG, IPCMAGELV) miss the last years for some countries. To add them in a manner consistent with the rest of the dataset, we use a linear extrapolation with a trend calculated from the last 15 years with data available. This bug will be corrected in the next release.

### 10.8.5 Noteworthy changes

We group the changes by their impact on cumulative IPCM0EL, Kyoto GHG emissions and present the reasons for these changes.

- Changes over 100% in cumulative emissions
  - Brunei Darussalam: EDGAR v4.3.2 shows strong changes compared with EDGAR v4.2 and other sources (especially CH<sub>4</sub>). These changes come from fugitive emissions (IPC1B2, fugitive emissions from oil and natural gas).
- Changes between 50 and 100% in cumulative emissions
  - Republic of the Congo, Gabon, Libya, Nigeria, Oman, Qatar: All countries have large changes in fugitive emissions due to differences in EDGAR v4.3.2 vs. EDGAR v4.2. The main sector is IPC1B2, but other sectors are also affected (e.g., N<sub>2</sub>O from fuel combustion activities (IPC1A), or for Oman emissions from industrial processes and product use (IPC2))
- Changes between 20 and 50% in cumulative emissions
  - Angola, Algeria, Cameroon, Iraq, Kuwait, Saudi Arabia: These countries are impacted by the change in fugitive emissions in the EDGAR data (IPC1B2, CH<sub>4</sub>; for Cameroon also CO<sub>2</sub>; for Iraq also N<sub>2</sub>O from different sectors).
  - Armenia: UNFCCC data are now used. This has changed emissions estimates. Agricultural data from UNFCCC are subject to high fluctuations.
  - Bhutan: Changes in CH<sub>4</sub> and N<sub>2</sub>O from new EDGAR data (IPC1 and subsectors) have reduced emissions estimates.
  - Democratic Republic of the Congo: There are changes for all three major gases. Changes in CO<sub>2</sub> and CH<sub>4</sub> from EDGAR v4.3.2, IPC1B2. Changes in N<sub>2</sub>O from IPC5, which has also changed substantially from EDGAR v4.2 to EDGAR v4.3.2.
  - Equatorial Guinea: Changes come mainly from CH<sub>4</sub>, a bit from N<sub>2</sub>O. They originate from EDGAR v4.3.2, which is also used for CH<sub>4</sub> in IPCMAGELV.
  - Guyana: CH<sub>4</sub> extrapolation before 1960.
  - Lebanon: Changes in CH<sub>4</sub> and N<sub>2</sub>O emissions from UNFCCC data. Changes before 1990 in CO<sub>2</sub>, IPC1B2 from EDGAR v4.3.2 data.
  - Saint Lucia, Madagascar: UNFCCC data have been included, which differs from other sources. (For Saint Lucia especially for N<sub>2</sub>O and CH<sub>4</sub>).
  - Mauritania: Inclusion of BUR data changed emissions estimates. The main source of differences are: N<sub>2</sub>O in IPC4 and IPCMAG, and CH<sub>4</sub> in IPC4.
  - Niger: Inclusion of UNFCCC data introduced changes for all sectors and gases. UNFCCC data are very scarce and fluctuating but somewhat in line with third-party sources and therefore kept.
  - Turks and Caicos Islands: Changes in emissions estimates of all three major gases due to EDGAR v4.3.2.
  - Chad: Changes mainly in emissions estimates of N<sub>2</sub>O and CH<sub>4</sub> from EDGAR v4.3.2. UNFCCC data are only used for IPC4.
  - Tokelau: Changes in emissions estimates of N<sub>2</sub>O and CH<sub>4</sub> from EDGAR v4.3.2.
  - Timor-Leste: Changes mainly in emissions estimates of CH<sub>4</sub> and smaller changes in CO<sub>2</sub> emissions, both from EDGAR v4.3.2.
  - Saint Vincent and the Grenadines: UNFCCC data for agricultural CH<sub>4</sub> and N<sub>2</sub>O are not used any more as they showed large fluctuations and step changes not in line with any other source.
- Changes between 10 and 20% in cumulative emissions
  - Djibouti: EDGAR v4.3.2 has changed emissions estimates of CH<sub>4</sub> and N<sub>2</sub>O significantly.
  - Ecuador: CH<sub>4</sub> emissions estimates have changed for several sectors due to EDGAR v4.3.2.
  - Federated States of Micronesia: cumulative changes mainly from CO<sub>2</sub> (because downscaled BP data are available), but also strong peak changes for CH<sub>4</sub> and N<sub>2</sub>O (from FAO, which had

- very low emission in the last data year in the last revision).
- Georgia: We have removed UNFCCC CH<sub>4</sub> CAT1A data prior to 2000 because they were reported in CAT1A5 (other) and did not match the data for later years, which means that they were likely calculated using a different methodology than data submitted later.
  - Croatia: CH<sub>4</sub> data have changed as IPC3A data in CRF 2018 are significantly higher than in CRF 2017 which was used in PRIMAP-hist v1.2. CO<sub>2</sub> data before 1990 are higher, because the scaling of EDGAR to CRF is not bounded any more. PFCs data have changed, because the CRF data have a gap and the gap filling procedure was adapted.
  - Haiti: CH<sub>4</sub> emissions from IPC1B1 are much higher after 2004 due to EDGAR v4.3.2.
  - Iran: Changes come mainly from CH<sub>4</sub> in IPC1B2, originating from EDGAR v4.3.2. The EDGAR data also introduce changes in N<sub>2</sub>O data for different sectors.
  - Kiribati: The changes come mainly from CH<sub>4</sub>, where IPC4 has been added in EDGAR v4.3.2 and IPC3A, where UNFCCC data are now used. Other gases and sectors changed as well, also due to the inclusion of UNFCCC and EDGAR v4.3.2 data.
  - Mali, Senegal, Mozambique, Tanzania: CH<sub>4</sub> and N<sub>2</sub>O have changed, mostly before 1990: this is due to a new method to extrapolate missing emissions from burning of agricultural residues. In v1.2, linear extrapolation was used, now we use growth rates from EDGAR v4.3.2 (see above).
  - Montenegro: The main change in emissions estimates comes from a modified scaling of EDGAR v4.2 PFCs data to the much higher country-reported data (BUR and UNFCCC).
  - Mongolia: The inclusion of BUR data have introduced changes in several sectors and gases.
  - Paraguay: Inclusion of UNFCCC data, which was not included in v1.2 has changed emissions, primarily N<sub>2</sub>O, where IPCMAGELV is the dominant sector.
  - Sudan and South Sudan: There now are more independent data available for South Sudan, such that we need less downscaling based on economical data. This introduces some changes in emissions, especially for years after 2000. Furthermore, some input data have changed (FAO, EDGAR). The different extrapolation of missing FAO data have also impacted pre-1990 CH<sub>4</sub> and N<sub>2</sub>O emissions especially for South Sudan.
  - Syria: Changes are mainly CH<sub>4</sub>, IPC1B2 and originate from EDGAR v4.3.2 data. N<sub>2</sub>O data have also changed, again because of changes in EDGAR data.
  - Togo: Emissions estimates for all gases have changed because of the inclusion of BUR data.
  - Yemen: CH<sub>4</sub> has changed post-1990 in sector IPC1B2. N<sub>2</sub>O has also changed. Both changes come from EDGAR v4.3.2.
  - South Africa: Higher CH<sub>4</sub> emissions due to the inclusion of BUR data for the agricultural sector, which is much higher than third-party sources.

## 10.9 v1.2 (December 2017)

The v1.2 release uses new input data. CRF data have been updated to the 2017 and 2016 releases, CDIAC and BP data have been updated to their 2017 releases and the UNFCCC Non-Annex I data have been updated to the status of August 2017.

### 10.9.1 Changes in PRIMAP-hist source creation

- The method to fill gaps in time series has been changed. In v1.1, gaps in higher priority time series were linearly interpolated to enable the calculation of trends for the combination of time series from different data sources, even if the time series contained only few data points. This method can not be used any more as we now include UNFCCC data for China, which has data for only three years. Linear interpolation overestimates emissions in the late 1990s, where the Asian financial crisis lead to declining emissions (with a steep increase after the crisis). In v1.2, gaps are filled with data from lower priority time series (where available) in the following way: the linear trend for the gap period is calculated both for the time series with the gap and the time series used to fill the gap. Then the deviation from the the trend is calculated for the time series used to fill the gap. Scaling factors between the two time series are calculated for the left and right boundary of the gap. They are capped using the same bound as for the extension with lower priority time series (a factor of 3 (1/3)). The final time series to fill the gap is constructed as the sum of the linear trend of the higher priority time series and the scaled deviation from trend of the lower priority time series. The scaling uses a linear interpolation between the scaling at the left and right boundaries. This change



affects all countries that have reported only a few years under UNFCCC2017B data, however, for most countries the differences are small. Details are presented in the *noteworthy changes* section.

- Changes in extrapolation trend calculations: in some cases the time span to calculate linear trends for the extrapolation starting points have changed.
  - LULUCF, CO<sub>2</sub>, future extrapolation: FAOSTAT LULUCF data have a change in methodology in 2011 (inclusion of forest degradation and regrowth) leading to abrupt changes in estimates of emissions and removals. To avoid calculating an average over data calculated using different methodologies, we shorten the period to calculate the average to 4 years (2011 - 2014). The average is used to extrapolate data to 2015.
  - LULUCF, all gases: The trend used to calculate the starting point for extrapolations to the past is now calculated over 20 years instead of 30 years to avoid the use of different unharmonized data sources in the trend calculation.
  - BP data are only used to amend a single year to energy CO<sub>2</sub> time series. We therefore no longer use a trend calculation to determine the starting point for the extrapolation, but use the last data point of the higher priority source directly.
- Historical extrapolation for LULUCF, CH<sub>4</sub>: until v1.1, we used EDGARHYDE data for the extrapolation. However, for some regions the EDGARHYDE data have non-zero emissions only between 1960 and 1985 - 1990, which is inconsistent with other sources. We therefore switched to RCP data, which is available on a level of 5 regions. As RCP data are defined starting in 1850, the linear interpolation for 1850 - 1890 is no longer necessary.

## 10.9.2 Changes in data sources and preprocessing

### 10.9.2.1 Input source updates

- CRF data have been updated to the 2017 release with the 2016 release used as backup for missing 2017 data.
  - The last data year is now 2015 for all categories and gases.
  - CRF data since 2015 follow the IPCC 2006 guidelines. Therefore, reported emissions have changed, especially for fugitive emissions and CH<sub>4</sub> and N<sub>2</sub>O from agriculture and land use. See also Jeffery et al. (2018a) and Jeffery et al. (2018b).
  - CDIAC fossil CO<sub>2</sub> data have been updated to the 2017 release, last data year is 2014.
  - BP fossil CO<sub>2</sub> data have been updated to the 2017 release, last used data year is 2015.
  - UNFCCC “Detailed Data by party” has been updated to August 2017: several countries are included for the first time with sufficient data to be used in PRIMAP-hist. Some countries have updated and extended data. However, some time series seem to be constructed from data points that were calculated using different methodologies and therefore show large discrepancies. Other data show strong fluctuations or deviate strongly from third-party sources. In several cases we excluded data from use in PRIMAP-hist, as we could not identify the source of the fluctuations and discrepancies. Details are presented in the *noteworthy changes* section.

### 10.9.2.2 Changes in preprocessing

- CRF 2016 and 2017 data are reported using new tables. The sectors in these tables are similar to but not exactly the IPCC 2006 sectors. The new reporting format makes a conversion to IPCC 1996 sector definitions used for PRIMAP-hist necessary. Depending on the reporting this is not perfectly possible for all countries. However, this mainly influences category 3, which has very small emissions. For details we refer to Jeffery et al. (2018a).

### 10.9.3 Further bug fixes

none

### 10.9.4 Known problems

- For Mauritius, the first data point for CH<sub>4</sub>, category 6 (waste) in the UNFCCC2017 dataset is very low compared to the other data points. This influences the final dataset. As the low data point is in line with EDGAR data we do not remove it.

- There are no CH<sub>4</sub> and N<sub>2</sub>O land use data for Egypt, Grenada, Haiti, and Singapore in PRIMAP-hist v1.1. The only available data source is FAO, which has only zero values in its current version and is thus not used for the PRIMAP-hist source.
- The (former) Netherlands Antilles are not included in the country mask used for Houghton (2008) downscaling, thus there are no Houghton (2008) based data.
- The country mask used in the downscaling of Houghton (2008) data treats Taiwan as a part of China and thus does not deliver data for Taiwan. As none of the data sources used for PRIMAP-hist has land use data for Taiwan, we have no option to downscale Taiwan from China.

### 10.9.5 Noteworthy changes

The noteworthy changes are grouped by dataset or processing which induced the change

- CRF (UNFCCC Annex I)
  - The new reporting guidelines introduce changes in emissions estimates for all countries which vary in strength and sectors affected. Countries with smaller changes are grouped, while for countries with larger changes or changes that are specific to a single country we explain the changes individually. For a more comprehensive discussion of the CRF 2017 data see Jeffery et al. (2018a).
  - Several countries exhibit changes in several sectors where relative changes are large for some sectors and gases but differences in economy-wide GHG emission estimates are small: Canada, Czech Republic, Germany, Denmark, Spain, France, Luxembourg, Netherlands, Norway, New Zealand, Poland, Slovakia, USA.
  - Several countries exhibit changes of emissions estimates which are mainly in the agricultural sector: Greece, Croatia, Hungary, Ireland, Liechtenstein, Lithuania, Latvia, Portugal, Slovenia, Sweden.
  - Australia: Total CH<sub>4</sub> emissions are much lower under the IPCC 2006 guidelines used for CRF 2017 data than under the 1996 guidelines used for CRF 2014 data, which is the basis of v1.1. The largest change is in the agricultural sector. N<sub>2</sub>O emissions are much lower in CRF 2017 than in CRF 2014 as well.
  - Austria: Total CH<sub>4</sub> emissions are higher under the IPCC 2006 guidelines used for CRF 2017 data than under the 1996 guidelines. Total CO<sub>2</sub> emissions are almost unchanged, however, CAT1 emissions decreased significantly while CAT2 emissions increased. Total N<sub>2</sub>O emissions are much lower.
  - Belgium: Total CH<sub>4</sub> emissions are higher under the IPCC 2006 guidelines used for CRF 2017 data than under the 1996 guidelines.
  - Bulgaria: Total CH<sub>4</sub> emissions are much lower in 1990 under the IPCC 2006 guidelines used for CRF 2017 data than under the 1996 guidelines. This leads to different historical emissions. Total N<sub>2</sub>O emissions are much lower.
  - Belarus: Total CH<sub>4</sub> emissions are higher under the IPCC 2006 guidelines used for CRF 2017 data than under the 1996 guidelines. Total N<sub>2</sub>O emissions are significantly lower.
  - Cyprus: Total CH<sub>4</sub> emissions are much lower under the IPCC 2006 guidelines used for CRF 2017 data than under the 1996 guidelines, especially for CAT6. This leads to different historical emissions. Total N<sub>2</sub>O emissions are much lower as well where CAT4 is the main source.
  - Iceland: CH<sub>4</sub> from land use drastically increased under IPCC 2006 guidelines and significantly increased total emissions.
  - Kazakhstan: Changes due to changed data in the industrial processes sector.
  - Monaco: Energy CO<sub>2</sub> is lower in CRF 2017 than in CRF 2014
  - Malta: Changes due to changed data in several sectors and gases.
  - Russia: Increased emissions mostly due to higher non-CO<sub>2</sub> emissions from the energy sector.
  - Turkey: Changes due to changed data, mainly in the waste and agricultural sectors.
  - Ukraine: Lower emissions due to changed data in several sectors and gases
- UNFCCC2017B (UNFCCC for Non-Annex I)
  - for several countries UNFCCC data are available, which were not available for v1.1.
    - \* Countries which now use UNFCCC data but show no strong changes in total emissions: Guatemala, Togo.
    - \* Some countries have newly available UNFCCC data, however, the sector resolution is not sufficient to be used for CO<sub>2</sub> in categories 1 and 2: Albania, Egypt (CAT2 only), Chad.
    - \* Countries with newly available UNFCCC data, where PRIMAP-hist total emissions are

- corrected downward significantly (individual sectors / gases / years can also show increased emissions): Albania, China (especially energy CO<sub>2</sub>), Cuba, Ethiopia, India, Kenya, Niue, Saudi Arabia, Thailand.
- \* Countries with newly available UNFCCC data, where PRIMAP-hist emissions are corrected upward significantly (individual sectors / gases / years can also shown decreased emissions): Morocco, Marshall Islands, Montenegro (post-1990), Malaysia, Saint Vincent and the Grenadines, Lebanon (CAT4).
- Some countries have extended or modified data
  - \* Extended and modified data: Brazil (total emissions corrected downward, but individual sectors / gases corrected upward), Mauritius (small changes), Kyrgyzstan (significant differences for most sectors and gases), Uzbekistan (small changes), Uruguay (lower emissions, mainly from CAT4 and CAT6).
  - \* Extended data: Argentina (recent emissions corrected upward), Bosnia and Herzegovina (recent emissions corrected upward), Peru (no major changes), Singapore (much higher emissions in recent years).
- We excluded some existing and new data. Some data might be included again in future versions of the PRIMAP-hist dataset if discrepancies to other sources and between years can be understood and the data verified.
  - \* Belize: single years show emissions with a factor of 20-50 above the other years and EDGAR data for several sectors and gases. Data removed completely.
  - \* Chile: We exclude the UNFCCC2017B data and only use BUR data as the UNFCCC data contains additional data points which do not fit the BUR data and presumably were generated using a different methodology than used for the BUR data. This impacts emissions estimates for several sectors and gases.
  - \* Central African Republic: single year with emissions which strongly differ from other years (factor of ~100). Presumably using different methodology and from older National Communication. Removed completely, as remaining data only covers a period of 8 years.
  - \* Dominica: single year with emissions which strongly differ from other years (factor of ~100). Presumably using different methodology and from older National Communication. Removed completely, as remaining data only covers a period of 6 years.
  - \* Ecuador: factor ~100 discrepancies with EDGAR and FAO in CAT4, N<sub>2</sub>O. Similar discrepancies in other sectors. As several years are affected, we remove data completely. Emissions are changed compared to v1.1.
  - \* Ethiopia: UN data for CAT1(A4), CH<sub>4</sub>, N<sub>2</sub>O seem to contain a mistake as they are inconsistent with the preceding and following years and the figures in the national communication. The tables in the national communication (The Federal Democratic Republic Of Ethiopia: Ministry of Environment and Forest (2015)) contain the presumably erroneous data. We remove 1997 - 2004 for CAT1, CH<sub>4</sub> and N<sub>2</sub>O.
  - \* Jordan: single year with higher (factor 3) emissions in CAT6 (CH<sub>4</sub>, N<sub>2</sub>O) influencing the CATM0EL KYOTO GHG results. We remove UNFCCC data completely as only 2 data years remaining.
  - \* Kenya: CAT4 N<sub>2</sub>O data are almost 0 in 1994 compared to significant emissions in later years. Potentially using different methodology and from older National Communication. This strongly influences economy-wide emissions and is not in line with other sources. We remove 1994 data. This changes emissions compared to v1.1
  - \* Kiribati: CAT4 N<sub>2</sub>O data are very high for a few years and not in line with EDGAR and FAO. This strongly affects the CAT0 results. We remove UNFCCC data completely.
  - \* Kyrgyzstan: HFCs data seem to have a unit error. HFCs data are removed and EDGAR data are used.
  - \* Niger: scaling of CDIAC due to UNFCCC data are extreme, especially as based on only two data points. We completely remove UNFCCC data.
  - \* Paraguay: strong fluctuations for CH<sub>4</sub> and N<sub>2</sub>O data (CAT4 and CAT6) which dominate the KYOTO GHG time series. We remove UNFCCC data completely.
  - \* Zimbabwe (ZWE): Energy CO<sub>2</sub> is much higher than other sources for one of the three available data points. We remove UNFCCC data completely as only 2 years remaining.
- CDIAC2017
  - Four countries have major adjustments of recent emissions:
    - \* Afghanistan: emissions for energy CO<sub>2</sub> have been corrected downward. In the 2016 release,

2013 emissions were above 20 Mt while for the 2017 release they are roughly 10 Mt. BP data are in line CDIAC and extend the downward trend for 2015. Economy-wide Kyoto GHG emissions are corrected downward by about 1/3rd.

- \* Botswana: Emissions have strongly increased and are much higher than calculated in PRIMAP-hist v1.1. Consequently, 2014 emissions have changed from PRIMAP-hist v1.1 and 2015 emissions have increased further from 2014 emissions (based on BP2017 data).
- \* Mongolia: Emissions for energy CO<sub>2</sub> have been corrected downward. In the 2016 release, 2013 emissions were above 45 Mt while in the 2017 release they are roughly 20 Mt. BP data are in line with CDIAC and extend the downward trend for 2015. Economy-wide Kyoto GHG emissions are corrected downward by about 1/5th.
- \* Tonga: Emissions for 2013 are much lower than in CDIAC2016. This has significantly decreased 2013 and 2014 total emissions.
- CDIAC emissions have changed for several small states, especially small island states, also for historical years. The changes differ in affected years and strength over countries. Some larger countries have been corrected as well. Affected countries are: Anguilla, Antigua and Barbuda, Belize, Cook Islands, Comoros, Cape Verde, Dominican Republic, Fiji, Federated States of Micronesia, Iran, Kiribati, Saint Kitts and Nevis, Lesotho, Macao, Nigeria, Palau, People's Democratic Republic of Korea, Singapore, Suriname, Seychelles, Turks and Caicos Islands, Trinidad and Tobago, Samoa, Yemen, Zimbabwe.
- Additional historical years for Andorra lead to changes in extrapolation with EDGAR-HYDE data for energy CO<sub>2</sub>.
- CDIAC contains data for Tuvalu in the 2017 release. Former releases did not contain data for Tuvalu.
- Processing
  - Gap filling algorithm:
    - \* Singapore: According to CDIAC data, energy CO<sub>2</sub> emissions were decreasing from 2011 to 2007. This was not visible in v1.1, as the gap between 2000 and 2010 in UNFCCC data was interpolated linearly and not filled with CDIAC trends as in v1.2.
    - \* Other countries affected: Armenia, Azerbaijan, Colombia, Costa Rica, Dominican Republic, Peru, Peoples' Democratic Republic of Korea, and Uruguay.

## 10.10 v1.1 (March 2017)

The v1.1 release contains mostly bug fixes. To keep the dataset up to date we also included some updated data sources. The methodology remained unchanged apart from the minor changes described below.

### 10.10.1 Changes in PRIMAP-hist source creation

- South Sudan now has individual data for some sectors. For these sectors, South Sudan is treated as any other country during the source creation, while time series for other sectors and gases are downscaled from Sudan data.
- Sources with scarce data points for several countries (BUR2015, UNFCCC2017) are now interpolated before the creation of the PRIMAP-hist dataset, such that the linear regression used to match lower priority data sources can be computed. Before, the last data point was used directly.

### 10.10.2 Changes in data sources and preprocessing

#### 10.10.2.1 Input source updates

- FAOSTAT data have been updated to the January 2017 version.
  - The last data year is now 2014 for all categories except for forest land emissions where it is 2015. However, for the PRIMAP-hist dataset we use the aggregate land use time series which has 2014 as the last data point.
  - There are significant changes in historical emissions for several countries.
    - \* Land use data for several countries are very different from the 2015 version of FAOSTAT data.
    - \* Manure management CH<sub>4</sub> and N<sub>2</sub>O emissions for a lot of (mostly developed) countries were adjusted down by a large margin. This is not a general adjustment though, as some countries' emissions were adjusted upward, while others remained unchanged.

\* For some economies in transition, pre-1990 emissions are higher than in the 2015 FAOSTAT data.

- CDIAC fossil CO<sub>2</sub> data have been updated to the 2016 release.
- BP fossil CO<sub>2</sub> data have been updated to the 2016 release.
- UNFCCC “Detailed Data by Party” has been updated to January 2017
  - Data have not changed much compared to the version used for PRIMAP-hist v1.0.
  - For Kazakhstan, HFCs and PFCs data for the years 1990 and 1991 with very high emissions were removed from the UNFCCC data repository. In consequence Kazakhstan’s historical (pre-1992) emissions for HFCs and PFCs are much lower in v1.1 than in v1.0.

#### 10.10.2.2 Changes in processing

- FAOSTAT
  - In version 1.0 negative data were removed from the FAOSTAT dataset during processing. This has been fixed. It only affected land use CO<sub>2</sub>. Where data were negative for part of the time series they were replaced by zero, while time series completely consisting of negative data were discarded such that Houghton data were used.
  - In v1.0, single subcategories were linearly extrapolated during category aggregation, such that time series for all categories covered the same time frame. When the linear extrapolation lead to emission estimates of these subcategories to increase backwards in time, the linear regression was replaced with a linear path to zero emissions in the first year with data (1961). In v1.1, this has been changed, such that in those cases a constant extrapolation is used instead of a linear extrapolation to zero. This affects emission estimates from “Field burning of agricultural residues” (IPCC 1996 category 4F) and to a lesser extent subsectors of the “Agricultural soils” sector (IPCC 1996 category 4D). CH<sub>4</sub> and N<sub>2</sub>O emissions are affected. Only a few countries are affected by the change.
- CDIAC
  - A bug in the downscaling of regions to countries was fixed. This affected Indonesia (though not concerning the growth rates used in the PRIMAP-hist dataset, just the absolute values), Timor-Leste, Latvia and Estonia (cement only), and Palau prior to 1992.
  - Downscaling of Italy and San Marino as a region to individual countries now uses EDGAR emissions from appropriate sectors instead of GDP data.
- UNFCCC
  - A bug in the routine that read the csv files exported from the UNFCCC website lead to omitting the second block in the non-standard csv files. This bug has been fixed. Consequently, some countries now have one to three additional data points added at the end of the time series.
  - Data for Viet Nam and Peru are now contained in the UNFCCC dataset with enough data to meet our minimum requirements. UNFCCC data for these two countries are therefore included in PRIMAP-hist v1.1.

#### 10.10.3 Further bug fixes

- In v1.0, a few countries were missing in the downscaled Houghton data. Some countries are still not available as they are missing in the country mask used to convert the gridded vegetation data to countries. For details see Section Known problems below.
- In some cases the Composite Source Generator removed the first or last data point of a time series. This bug has been fixed.

##### 10.10.3.1 Known problems

- For Mauritius, the first data point for CH<sub>4</sub> for different sectors in the UNFCCC 2017 dataset is very low compared to the other data points. This influences the final dataset.
- For Micronesia, the last data point for CH<sub>4</sub> and N<sub>2</sub>O from the agricultural sector (and all subsectors) is very low. This influences the final dataset.
- For Saint Kitts and Nevis, N<sub>2</sub>O emissions from the agricultural sector in the last years are much higher than the rest of the data. This influences the final dataset.
- There are no CH<sub>4</sub> and N<sub>2</sub>O land use data for Egypt, Grenada, Haiti, and Singapore in PRIMAP-hist v1.1. The only available data source is FAO, which has only zero values in its current version and is

thus not used for the PRIMAP-hist source.

- The (former) Netherlands Antilles are not included in the country mask used for Houghton (2008) downscaling, thus there are no Houghton (2008) based data.
- The country mask used in the downscaling of Houghton (2008) data treats Taiwan as a part of China and thus does not deliver data for Taiwan. As none of the data sources used for PRIMAP-hist has land use data for Taiwan we have no option to downscale Taiwan from China.
- Due to the additional year in FAO (2014) some developed countries have very low land use CH<sub>4</sub> emissions in 2014 compared to the period with CRF data. This will be solved in the next revision of PRIMAP-hist where CRF 2015 and CRF 2016 will be used. A number of possible reasons account for the differences between FAO and CRF data, which likely differ between countries. Land-use CH<sub>4</sub> emissions are dominantly from biomass burning. The FAO (Food and Agriculture Organization of the United Nations (2016)) calculate non-CO<sub>2</sub> from biomass burning using the tier 1 methodology of IPCC 2006 guidelines (IPCC (2006)) and activity data from GFED4 (Giglio et al. (2017)). National inventories (CRF 2014) are often based on country specific emissions factors and data for burned areas. The national inventories may also exclude natural disturbances and have different definitions than FAO for managed land areas. Land use N<sub>2</sub>O emissions are subject to similar differences in data.
- UNFCCC data for Ecuador (aggregate sectors and gases) are much higher than third-party data, but only covers a few years. The resulting time series are thus discontinuous.

#### 10.10.4 Noteworthy changes

- Aruba: historical CO<sub>2</sub> emissions are lower than in v1.0 because CDIAC emissions have been adjusted downward for the years prior to 1998.
- Australia, Belize, Botswana, Guinea-Bissau, Namibia, Papua New Guinea, Zimbabwe, Mongolia: changes in CH<sub>4</sub> and/or N<sub>2</sub>O emissions due to the change in extrapolation of FAO data for subsectors of the agricultural sector.
- Bosnia and Herzegovina: pre-1990 CDIAC data have changed, leading to higher pre-1990 CO<sub>2</sub> emissions in PRIMAP-hist.
- Eritrea: historical CO<sub>2</sub> emissions are higher than in v1.0 because CDIAC emissions have been adjusted upward for the years prior to 1998.
- Federated States of Micronesia and Saint Helena, Ascension, and Tristan da Cunha: emissions have increased due to an increase in FAO agricultural CH<sub>4</sub> and N<sub>2</sub>O emissions.
- India: energy related CO<sub>2</sub> is lower starting in 1977 due to changes in CDIAC data.
- Palau, Timor-Leste: higher historical emissions due to the bugfix in CDIAC downscaling.
- Peru: the UNFCCC data that are now used as the first priority source differs from the third-party sources used in PRIMAP-histy v1.0.
- San Marino: changes in historical emissions due to the changed key data for downscaling of San Marino from Italy in CDIAC.
- Sudan, South Sudan: the availability of data for South Sudan changed the time series from the previous time series which, were based on downscaling using population data.
- Vanuatu had zero CO<sub>2</sub> emissions before 1960 in PRIMAP-hist v1.0 because CDIAC2015 had zero data for a few years before 1960. Now, the data are non-zero as these data points are not contained in CDIAC2016.
- For several countries, data for the last two years have changed, as additional data points from updated CDIAC, FAOSTAT, UNFCCC, and BP data replace extrapolated data.
- Land use data for the period of 1991 - 2014 have changed for several countries. The first reason is that we now use Houghton data for all years where they are available and not obtained through extrapolation (see Section 2.4.1 of the data description paper). The second reason is that the FAO data changed massively.

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