CoCO2
Prototype system for a Copernicus CO_2 service

CoCO2-MOSAIC
Global mosaic PED 2015

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Co-ordinated by ECMWF

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D2.3 CoCO2-MOSAIC: global mosaic PED 2015

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Table of Contents

Figures

Tables

1 Executive Summary

Spatially and temporally explicit bottom-up information of CO_2 anthropogenic emissions is needed to initialize transport models, separate biogenic and anthropogenic emissions, and attribute the exact sources (sectors) of anthropogenic emissions. With this aim, a global Prior Emission Dataset (PED) was developed by CoCO2 Task 2.1 providing spatially consistent anthropogenic emissions for the global assimilation system of WP3. However, the global PED cannot include all the latest information available regionally to keep a methodological consistency at global scale (e.g., with consistent use of spatial proxy data). The goal of this task is to complement the global PED by building a global mosaic of regional CO_2 emission inventories that includes all the latest information available at regional level without the limitation of using consistent methodology and spatially harmonised dataset. The global mosaic PED, hereafter referred as CoCO2-MOSAIC, includes primarily official or widely used information in each region that can be considered as a regionally accepted reference. As so, the CoCO2-MOSAIC will be used to (i) assess the global PED and (ii) analyse the sensitivity of the WP3 global modelling system to changes in the bottom-up emissions used as input (and in particular their spatial disaggregation).

The CoCO2-MOSAIC includes six regional emission inventories and uses three global datasets to gap-fill regions and sectors where regional emission inventories are falling short. The mosaic provides monthly CO_2 fossil fuel (CO2ff) emissions and CO_2 biofuel (CO2bf) emissions for 2015 at $0.1^{\circ}\times0.1^{\circ}$. This report describes the collating and gap-filling methodology used to build the global mosaic, summarizes the final characteristics of the output files, and provides a general overview of the final CO2ff and CO2bf emissions per sector and region. The report also discusses the main limitations of the methodology and the best solutions to mitigate their effects.

The CoCO2-MOSAIC will be released at Zenodo and at the JRC data catalogue with the upcoming scientific paper describing the dataset and comparing the mosaic against global emission inventories.

2 Introduction

2.1 Background

The future Copernicus CO_2 Monitoring and Verification Support (MVS) capacity will exploit the observations from the upcoming CO2M mission, which initially foresees the launch of 2-3 polar-orbiting satellites that will sample XCO_2, XCH_4 and NO_2 at around 2-4 km^2. However, (i) satellites do not measure emissions, they measure total column concentrations and (ii) the signal of anthropogenic emissions in atmospheric concentrations is small (and with much smaller variation) relative to the oscillating signal of natural fluxes between the land and ocean surfaces and the atmosphere.

The assimilation of prior information datasets is needed to solve these challenges. During the last decade, several efforts have been made to produce bottom-up inventories of CO_2 emissions based on multiple sources of activity data, emission factors, and proxy datasets for spatial and temporal disaggregation. Spatially explicit inventories are of particular interest for the data assimilation systems developed in CoCO2 WP3 and WP4, as they can be used to initialize the transport models, to separate biogenic and anthropogenic emissions, and to attribute the exact anthropogenic source of the emissions.

With this goal, global and regional Prior Emission Datasets (PEDs) are built in Task 2.1. The global PED needs to provide spatially and methodologically consistent emissions for the global data assimilation model, which at some regions leads to the exclusion of more detailed information available. Besides, the global PED needs to provide emissions in the shortest time lag possible, whereas emission and activity data used to build bottom-up inventories typically becomes available with a lag of at least 2 years. Thus, producing a spatially and methodologically consistent, near-real time emission dataset may result in a loss of information that needs to be assessed.

The goal of the current task is to build a comprehensive global mosaic of gridded regional CO_2 emission inventories that are primarily official reference data or widely used in each region or country. Regional inventories are assumed to have higher accuracy due to the uptake of local data at much finer spatial resolution and including country-specific activity and emissions information. Compared to the global PED, this mosaic includes all the regional information available, without the limitation of providing spatially and methodologically consistent or near real-time estimations. Therefore, the CoCO2-MOSAIC will be considered as the regionally accepted reference, and so will be used to assess the representativeness of the global PED. The mosaic will be also used in CoCO2 task 3.1 to analyse the sensitivity of the global modelling system to different prior emission information (CoCO2-PED vs. CoCO2-MOSAIC). Besides, despite its lack of methodological consistency for spatial disaggregation, the CoCO2-MOSAIC is expected to be still used for regional atmospheric inversions within the spatial domain of each regional inventory. In a similar way the HTAP_v2.2 mosaic emission dataset (Janssens-Maenhout et al., 2015) has been extensively used by air pollutant models.

2.2 Scope of this deliverable

2.2.1 Objectives of these deliverables

The goal of the current task is to build a global mosaic of gridded regional CO_2 emission inventories that are primarily official references or widely used in the region or country. The global mosaic of regional inventories will serve as a reference to evaluate the representativeness of the global PEDs developed in CoCO2. The mosaic will provide gridded

(0.1°×0.1°) monthly emissions for the inventory year 2015, as this is the last year when latest information was available for most regions. The mosaic differentiates between the CO_2 from fossil fuel (CO2ff, long cycle) and CO_2 from biofuel (CO2bf, short cycle, see Annex 1) components to keep consistency with the IPCC reporting system, where mainly CO2ff is the focus[1].

2.2.2 Work performed in this deliverable

The work of this deliverable has resulted in the following product:

- CoCO2-MOSAIC. A global mosaic of regional emission inventories for CO2ff and CO2bf at 0.1°×0.1° and monthly resolution for 2015. Emissions are split in seven sectors: energy_s (energy production by super-emitters, annual emissions above 7.9e-6 kg/m2/s) and energy_a (energy production by standard emitters, the rest), manufacturing, settlements, transport, aviation, other.

This report is a product user manual, describing the collected datasets, the collating and gap-filling methodologies, and giving an overview of the file structure and resulting CO_2 emissions per sector and region.

2.2.3 Deviations and counter measures

The work plan foresaw a global mosaic for 2015 or 2016 for CO_2 and other GHGs. The year 2015 was chosen as base year as it was the latest year when all regional inventories provided data. Emissions during 2016, 2017 and 2018 have been also processed and will be released in a future stage gap-filling missing years in each region with the last year available.

CoCO2-MOSAIC focuses on CO2ff and CO2bf. We refer to HTAP_v2.2 and HTAP_v3(G. Janssens-Maenhout et al. 2015; Crippa et al. 2022) for CH_4 and other air pollutants.

[1] While liquid and gas biofuel as well as short cycle biomass (crop residues, dung, etc.) are considered carbon neutral, long cycle biomass (forest, woody cropland) are accounted for (being not carbon neutral). A good inventory requires the comprehensive reporting of fossil fuel CO2, and long cycle biomass CO2, and is prescribed as such by IPCC guidelines for national GHG inventory reporting.

3 Regional emission inventories

3.1 CAMS-REG-GHG v5.1

The Copernicus Atmosphere Monitoring Service (CAMS) has been providing consistent estimations of anthropogenic emissions over Europe since 2009, from the former TNO-MAC series to the current CAMS-GLOB-ANT and CAMS-REG inventories at global and regional level, respectively. CAMS datasets cover both air pollutants and GHGs. The global mosaic uses the CAMS-REG-GHG dataset which provides CH_4, CO2ff, CO2bf gridded (0.1°×0.05°) emissions over Europe [30° to 72°N, -30° to 60°E] during 2000-2018 (version 5.1) (Kuenen et al. 2022). Annual CO_2 emissions are calculated at country level for each source category (209 in total). These values are based on the emissions officially reported by European countries in their national inventories. The IIASA GAINS model is used to fill gaps or replace low quality data. EDGAR v4.3.2 emission gridmaps of Janssens-Maenhout et al. (2019) are used in countries outside UNECE-Europe but still within the bounding box of CAM-REG (e.g., North African countries). Emissions are spatially allocated using proxy datasets such as traffic intensity, road network, CORINE land cover, population density, or power plant list, among others, as specified in Kuenen et al. (2022). The 209 emission categories are aggregated into GNFR sectors, an aggregation of the Nomenclature For Reporting (NFR) used by European countries as the basis of reporting gridded emissions of air pollutants. More details on the sector classification can be found at https://www.ceip.at/reporting-instructions.

CAMS-REG-GHG v5.1 is freely available at ECCAD (https://eccad3.sedoo.fr/), but for this task we used a specific version prepared by the CAMS team modifying some GNFR sectors to match better the description of the mosaic sectors (Table 1).

Table 1: Description of CAMS-REG-GHG v5.1 sectors

Sector	Comments
A_PublicPower	
B_Industry	For this version, 1A1b and 1A1c were moved to D_Fugitives
C_OhterStationaryComb	-
D_Fugitives	-
E_Solvents	-
F1_RoadTransport_Exhaust_Gasoline	-
F2_RoadTransport_Exhaust_Diesel	-
F3_RoadTransport_Exhaust_LPG_gas	-
F4_RoadTransport_NonExhaust	-
G_Shipping	Only inland shipping
H_Aviation	Only Landing and Take-off cycles (LTO) in airports
I_OffRoad	-
J_Waste	Waste incineration with energy recovery has been already moved to A_PublicPower
K_AgriLivestock	Sector discarded, as it does not produce CO_2 emissions.
L_AgriOther	-

3.2 DACCIWA v2.0

The DACCIWA project has developed the first inventory of gridded anthropogenic emissions for Africa. The first version, DACCIWA v1.0 (Keita et al. 2021), provided emissions from atmospheric pollutants (BC, OC, CO, NO_X, SO_2 and NMVOCs) considering only combustion sources. Within the framework of CoCO2 Task 2.1, a new DACCIWA v2.0 inventory has been developed covering CO2ff, CO2bf and CH_4, and considering other anthropogenic sources (e.g., fugitive emissions) in addition to fossil fuel combustion. The inventory provides annual emissions from 2015 to 2018 at 0.1°×0.1°.

Activity data come primarily from the United Nations Statistics Division (UNSTAT) database (http://data.un.org/Explorer.aspx). CO_2 emission factors derived from field measurements (Keita et al. 2018) were used for residential, commercial, road transport and open waste burning. The CH_4 emission factors from Akagi et al. (2011) for charcoal making and solid waste burning and from Doumbia et al. (2019) for gas flaring. The default emission factors from IPCC (2006) were used for other sources. Emissions were spatially allocated using population density, road network and African power plant network given by the Africa infrastructure (https://powerafrica.opendataforafrica.org). DACCIWA v2.0 aggregates the emissions in seven different sectors, which are the same ones defined for the present mosaic (see Table 10). The DACCIWA v2.0 dataset is freely available at ECCAD repository: https://eccad3.sedoo.fr/.

3.3 GEAA-AEI v3.0

The Research Group for Atmospheric and Environmental Studies (GEAA) produces the Argentine Emission Inventory (GEAA-AEI), which provides gridded (0.025°×0.025°) emissions of 12 air pollutants and GHGs (CO_2, CH_4, N_2O) from 1955 to 2020 at monthly resolution (version 3.0) (Puliafito et al. 2021). The inventory is calculated following a bottom-up approach as follows: (i) geolocation of emission sources, (ii) identification of the activity data for each source per sector, (iii) development of a consistent monthly evolution, (iv) application of emission factors, (v) production of the raster files. GEAA-AEI of Puliafito et al. (2021) is freely available at https://doi.org/10.17632/d6xrhpmzdp.2. For this mosaic, the GEAA team prepared a specific version splitting CO_2 emissions in CO2ff and CO2bf, and rearranging some sectors to match better the description of the mosaic sectors (Table 2).

Table 2: Description of GEAA-AEI v3.0 sectors

Sector	Description	IPCC code	Point source
CEN	Thermal power plants	1A1a	yes
WAS	Open urban waste burning	4C	yes
IND_FUE	Industrial own fuel consumption	1A2	no
IND_PRO	Industrial production	2B, 2C	yes
COM	Commercial	1A4a	no
GOV	Governmental	1A4a	no
RES	Residential	1A4b	no
FAG	Fuel use in agriculture	1A4c	no
AVI	National aviation, only LTO	1A3a	no
VEH	Vehicular road transport	1A3b	no
TRE	Railroad	1A3c	no
BAR	Coastal-fluvial navigation (only national bunker)	1A3d	no

REF	Refineries	1A1b	yes
VEN	Venting/flaring in gas/oil production wells	1B2a	yes
FUE	Biomass burning fires: agricultural waste, clearing, intentional/unintentional fires	4F	no

3.4 INEMA v1.0

The Inventario Nacional de Emisiones Antropogénicas (INEMA v1.0) (Álamos et al. 2022) is the first Chilean gridded emission inventory of anthropogenic emissions of air pollutants (NOx, SO_2, CO, VOCs, NH_3, PM10, PM2.5, and BC) and GHGs (CO_2, CH_4). INEMA provides annual gridded (0.01°×0.01°) emissions for the inventory years 2015 to 2017 disaggregated into five different sectors (Table 3). In the energy, industry, and mining sectors, point emissions self-reported by Chilean industrial facilities to the Registro de Emisiones y Transporte de Contaminantes (RETC, https://retc.mma.gob.cl) are used. In residential and transport sectors, emissions are calculated as non-point sources based on firewood consumption and number of vehicles. Possibly some gas or oil use is missing which especially for air pollutants is assumed to be of minor importance.

The spatial allocation of residential and transport emissions is made based on population density and the road network, respectively, as described by Alamos et al. (2022). The current version of the inventory does not split between CO2ff and CO2bf. Energy, Mining and Industry sectors report the sum of CO2ff and CO2bf, while residential is considered to include only CO2bf and Transport only CO2ff (Table 3). INEMA v1.0 is freely available at https://doi.org/10.5281/zenodo.4784286.

Table 3: Description of INEMA v1.0 sectors

Sector	CO2	Description	IPCC code
Energy	CO2ff + CO2bf	RTEC point sources: production and distribution of fuels and the generation of electric energy.	1A1
Mining	CO2ff + CO2bf	RTEC point sources: Production and smelting of metals	2C1-4
Industry	CO2ff + CO2bf	RTEC point sources: remaining point sources outside the 'Energy' and 'Mining' sectors.	1A2, 2* (excluding 2C)
Residential	CO2bf	Combustion of biomass for heating, cooking, and heating water.	1A4b
Transport	CO2ff	Exhaust emissions from vehicles traveling on public routes nationwide in urban and interurban area. Rail, air, and sea modes are not included, nor are off-road machinery.	1A3b

3.5 REAS v3.2.1

The Regional Emission inventory in ASia (REAS) series provides long-term emissions from major anthropogenic air and climate pollutants over East, South and South-East Asia. The latest version available is REAS v3.2.1 (Kurokawa and Ohara 2020), a long-term (1950-2015) gridded (0.25°×0.25°) inventory that provides monthly emissions of SO_2, NO_x, CO, NMVOCs, NH_3, PM10, PM2.5, BC, OC, CO2ff, CO2bf.. REAS v3 is produced following a bottom-up approach. Annual activity data at country level are collected from different international and national statistics and national emission inventories. Emissions factors from research papers and from national inventories are used. Annual emissions per country are spatially allocated with proxy datasets such as HYDE 3.2.1 total population gridmaps (residential sector) or EDGARv4.3.2 transport emission gridmaps (transport sector). The position of industry and power plant emissions was checked manually and with global databases, and large power plants were made available as point sources. Monthly emissions were estimated also using proxy datasets such as monthly energy production statistics, monthly industrial production statistics, or monthly surface temperature. Table 4 shows the sectors available for CO_2. The emissions are split in CO2ff and CO2bf, but some sectors only report CO2ff emissions.

Table 4: Description of REAS v3.2.1 sectors

Sector	Description	CO2
POWER_PLANTS_POINT	Power and heat plants as point sources.	CO2ff
POWER_PLANTS_NON-POINT	Power and heat plants as non-point sources	CO2ff, CO2bf
INDUSTRY	Industry (emissions both from fuel combustion and industrial processes)	CO2ff, CO2bf
DOMESTIC	Residential, commerce and public services, agricultural equipment, and others (fishing is not included)	CO2ff, CO2bf
ROAD_TRANSPORT	Road transport (cars, buses, trucks, motorcycles, and other on-road vehicles)	CO2ff
OTHER_TRANSPORT	Railway, and other off-road transports (navigation is not included)	CO2ff

REAS v3.2 is freely available at the Japanese National Institute for Environmental Studies (NIES) website: https://www.nies.go.jp/REAS/index.html#REASv3.2.1

3.6 VULCAN v3.0

The Vulcan Project provides a gridded inventory of anthropogenic CO_2 emissions from fossil fuel combustion and cement production inside the USA. VULCAN v3.0 (Gurney et al. 2020) is the last version available and it estimates CO2ff emissions at 1×1km and hourly resolution for the inventory years from 2010 to 2015. The current version of the VULCAN inventory does not include CO2bf emissions (CO2bf will be added in the upcoming v4.0).

Table 5: Description of VULCAN v3.0 sectors

Sectors	Description/Comments
Electricity production	15566 electricity production facilities, all geolocated to its physical location.
Industrial	Non-point source derived from the USA National GHG Inventory (NGHGI), spatially distributed using total building area and energy use intensity (EUI). Point sources geolocated to each individual facility.
Cement	Geolocated to each individual facility.
Commercial	Non-point source derived from USA NGHGI, spatially distributed using total building area and energy use intensity. Point sources geolocated to each individual facility.
Residential	Non-point source derived from USA NGHGI, spatially distributed using total building area and energy use intensity.
On road	Derived from USA NGHGI, distributed in space and time using traffic data.

Nonroad	Mobile sources travelling off-road except locomotives, airplanes and CMVs
Commercial Marine Vessels (CMV)	Manoeuvring, hoteling, cruise, and reduced speed zone travel and are specific to geographically located ports and shipping lanes that extend 12 nautical miles from the shoreline
Airport	Taxi & take-off/landing sequences up to 3000” (927 m).
Rail	Emissions from diesel-powered locomotives, distributed in space using freight data.

CO_2 emissions are estimated at the native spatial-temporal resolution of emission points, lines and polygons depending on the characteristics of the input data sources. Additional spatial and temporal distribution (downscaling, interpolation, proxy surrogates) are needed to achieve hourly resolution for six complete calendar years (2010–2015) at the spatial resolutions of a USA Census block-group or finer (e.g., points, lines) and at 10 different sectors (Table 5). The inventory includes the expanded uncertainty (coverage probability of 95%) of the CO2 emissions at pixel level (with pixel sizes of 1kmx1km).

VULCAN v3.0 is freely available at NASA’s Land Process Distributed Active Archive Center (DAAC): https://doi.org/10.3334/ORNLDAAC/1741

4 Global emission inventories and auxiliary datasets

4.1 EDGAR v6.0

EDGAR is a global gridded (0.1°×0.1°) emission inventory providing anthropogenic emissions of GHGs (CO2ff, CO2bf, CH_4, N_2O, F-gases) and air pollutants from 1970 to 2018 (version 6.0) (Crippa et al. 2021). Emissions of each species are calculated at country level per sector and year using country specific activity data and emission factors. Emissions are spatially allocated using proxy datasets that may vary over time such as the location of energy and manufacturing facilities, road networks, shipping routes, human and animal population density and agricultural land use, among others. Year-to-year variations are modelled using international annual statistics. Finally, monthly profiles are derived with specific proxy data for each sector and country/region.

CO_2 emissions are available separately for CO2ff (*CO2_excl_short-cycle_org_C*) and CO2bf (*CO2_org_short-cycle_C*) at 21 categories. EDGAR categories are the basis of the mosaic sectors and are fully described in Table 10. EDGAR v6.0 is freely available at https://edgar.jrc.ec.europa.eu/dataset_ghg60.

4.2 CAMS-GLOB-SHIP v3.1

CAMS-GLOB-SHIP (Jalkanen, Johansson, and Kukkonen 2016; Granier et al. 2019) provides gridded (0.1°×0.1°) shipping emissions at global scale from 2000 to 2018 for NO_x, SO_x, CO, CO_2, VOC, EC, OC, Ash and SO_4. The emissions are estimated by combining (i) global ship activity recorded in Automatic Identification Systems (AIS), (ii) data for vessel technical description, and (iii) the Ship Traffic Emission Assessment Model (STEAM developed by the Finnish Meteorological Institute (FMI) by Johansson et al., 2018). Shipping emissions are provided separately for ships at sea areas and those at inland waters (Table 6).

CAMS-GLOB-SHIP v3.1 is freely available at the Copernicus Atmosphere Data Store: https://ads.atmosphere.copernicus.eu/cdsapp#!/home.

Table 6 Description of CAMS-GLOB-SHIP categories

Sector	Description
sea	Ships at sea areas
inland	Ship at inland waters

4.3 CAMS-GLOB-TEMPO v3.1

CAMS-TEMPO (Guevara et al. 2021) dataset provides monthly, weekly, daily, and hourly temporal profiles for air pollutants (NO_x, SO_x, NMVOC, NH_3, CO, PM10, PM2.5) and GHGs (CO_2 and CH_4). Two versions are available: CAMS-GLOB-TEMPO at global scale and CAMS-REG-TEMPO at European level, matching the spatial coverage and resolution of CAMS-GLOB-ANT and CAMS-REG inventories, respectively.

The temporal profiles are normalized weight factors for each hour, day of the week, and month of the year for each sector and species. Temporal profiles can also vary spatially (per country or grid cell) and/or temporally (from year to year) depending on the input data availability for the species and the temporal resolution considered. The temporal weight factors are calculated by combining national and local statistical information linked to emission variability (e.g., electricity statistics, traffic activity) and existing meteorology-dependent parametrizations to account for the influences of sociodemographic factors and climatological conditions. For the CoCO2-MOSAIC, CAMS-GLOB-TEMPO monthly factors were used (Table 7).

Table 7: CAMS-GLOB-TEMPO monthly factors

Sector	Spatial resolution	Year dependent	Pollutant dependent
Energy industry	Country	no	yes
Residential/commercial	Gridded	yes	no
Manufacturing industry	Country	no	no
Road transport	Gridded	no	no
Agriculture – NH3/NOx	Gridded	yes	-
Agriculture – other	Fixed	no	-

CAMS-TEMPO if freely available at ECCAD: https://eccad3.sedoo.fr.

Table 8: Summary of the regional emission inventories integrated in the CoCO2-MOSAIC.

Inventory	Spatial coverage	Temporal coverage	Spatial resolution	Temporal resolution	CO_2	Reference
CAMS-REG-GHG v5.1	Europe [30 to 72N, -30 to 60E]	2000-2018	0.1°×0.05°	monthly	ff, bf	(Kuenen et al. 2022)
DACCIWA v2.0	Africa	2010-2022	0.1°×0.1°	annual	ff, bf	(Keita et al. 2021)
GEAA-AEI v3.0	Argentina	1995-2020	0.025°×0.025°	monthly	ff, bf	(Puliafito et al. 2021)
INEMA v1.0	Chile	2015-2017	0.01°×0.01°	annual	ff, bf	(Álamos et al. 2022)
REAS v3.2.1	Southeast Asia	1950-2015	0.25°×0.25°	monthly	ff, bf	(Kurokawa and Ohara 2020)
VULCAN v3.0	USA	2010-2015	1×1km	hourly	ff	(Gurney et al. 2020)

Table 9: Summary of global datasets used for gap-filling and temporal disaggregation

Inventory	Spatial coverage	Temporal coverage	Spatial resolution	Temporal resolution	CO_2	Reference
EDGAR v6.0	global	1970-2018	0.1°×0.1°	monthly	ff, bf	https://edgar.jrc.ec.europa.eu/index.php/dataset_ghg60 http://data.europa.eu/89h/97a67d67-c62e-4826-b873-9d972c4f670b (Greet Janssens-Maenhout et al. 2019; Crippa et al. 2021)
CAMS-GLOB-SHIP v3.1	global	2000-2018	0.1°×0.1°	monthly	ff	(Jalkanen, Johansson, and Kukkonen 2016; Granier et al. 2019)
CAMS-GLOB-TEMPO v3.1	global	2000-2020	0.1°×0.1°	monthly weekly daily hourly	-	(Guevara et al. 2021)

5 Methodology

The following steps were followed for the development of the global mosaic PED:

- Definition of the characteristics targeted by the global mosaic.
- Development of a default global emission inventory to gap-fill:
    - regions not covered by regional datasets.
    - sectors and/or CO_2 components not provided by the regional datasets.
- Collating and gap-filling regional inventories under the characteristics of the global mosaic in terms of spatial resolution, temporal resolution, and sector aggregation.
- Development of the spatial masks to combine the different inventories.

5.1 Target requirements of the global mosaic

The general characteristics of the global mosaic are:

- Spatial resolution: 0.1°×0.1°.
- Spatial coverage: global.
- Temporal resolution: monthly.
- Temporal coverage: inventory year 2015.
- CO_2 components: CO2ff and CO2bf emissions.
- Sector aggregation: seven groups of sectors as defined in Table 10 based on the 21 emission categories of EDGAR v6.0. The groups are the same as those defined in CHE WP3 (Choulga et al. 2021). The only change is that aviation emissions only include LTO.
- Units: CO_2 emission flux [*kg/m2/s*]

Table 10: Definition of the sectors used in the global mosaic.

sector	IPCC sector	Description	EDGAR sector
ENERGY_S	1.A.1.a (subset)	Power industry (without autoproducers): super emitting power plants (flux > 7.9e-6 kg/m2/s)	ENE
ENERGY_A	1.A.1.a (rest)	Power industry (without autoproducers): standard emitting power plants (flux < 7.9e-6 kg/m2/s)	ENE
	4.C	Solid waste incineration	SWD_INC
MANUFACTURING	1.A.2	Combustion for manufacturing (including autoproducers)	IND
	2.C.1, 2.C.2	Iron and steel production	IRO
	2.C.3, 2.C.4, 2.C.5, 2.C.6, 2.C.7	Non-ferrous metals production	NFE
	2.D.1, 2.D.2, 2.D.4	Non energy use of fuels	NEU
	2.A.1, 2.A.2, 2.A.3, 2.A.4	Non-metallic minerals production (cement, lime, glass, other)	NMM
	2.B.1, 2.B.2, 2.B.3, 2.B.4, 2.B.5, 2.B.6, 2.B.8	Chemical processes	CHE
SETTLEMENTS	1.A.4 1.A.5.a, 1.A.5.b.i, 1.A.5.b.ii	Energy for buildings	RCO
AVIATION	1.A.3.a_LTO	Aviation landing & take off; typical fuel: jet kerosene	TNR_aviation_LTO
TRANSPORT	1.A.3.b	Road transportation; typical fuel: most typical emission factor uncertainty	TRO_noRES
	1.A.3.d	Shipping; typical fuel: composition of 80% diesel and 20% residual fuel oil	TNR_Ship (replaced by CAMS-GLOB-SHIP)
	1.A.3.c, 1.A.3.e	Railways, pipelines, off-road transport; typical fuel: railways - diesel, off-road transport – most typical emission factor uncertainty	TNR_Other
OTHER	1.A.1.b, 1.A.1.c, 1.A.5.b.iii, 1.B.1.c, 1.B.2.a.iii.4, 1.B.2.a.iii.6, 1.B.2.b.iii.3	Oil refineries and transformation industry	REF_TRF
	1.B.2.a.ii, 1.B.2.a.iii.2, 1.B.2.a.iii.3, 1.B.2.b.ii, 1.B.2.b.iii.2, 1.B.2.b.iii.4, 1.B.2.b.iii.5, 1.C	Fuel exploitation	PRO
	1.B.1.a	Coal production (*no CO_2 emissions)	COL
	3.C.2, 3.C.3, 3.C.4, 3.C.7	Agricultural soils	AGS
	2.D.3, 2.B.9, 2.E, 2.F, 2.G	Solvents and products use	PRU_SOL

5.2 Default global inventory

The default global inventory is based on EDGAR 6.0. The only modification was the replacement of EDGAR shipping emissions (TRO_Ship) by CAMS-GLOB-SHIP v3.1 emissions due to the superior accuracy of the latter. Particularly, shipping emissions are the sum of CAMS-GLOB-SHIP *inland* and *sea* emissions. All CAMS-GLOB-SHIP emissions correspond CO2ff. CO2bf shipping emissions are negligible. Both EDGAR and CAMS-GLOB-SHIP already had the spatiotemporal resolution targeted by the global mosaic, so no harmonization was needed.

5.3 Harmonization of regional emission inventories

5.3.1 Spatial re-gridding

The spatial grid of the global mosaic has a spatial resolution of 0.1°×0.1°. The upper-left corner of the upper-left pixel is at [-180.0°,-90.0°]. The regional emission inventories were re-projected as follows:

Table 11: Spatial harmonization of regional emission inventories

Inventory	Original resolution	Method
CAMS-REG-GHG v5.1	0.1˚×0.05˚	The regional grid is aligned with the mosaic grid, so raw emissions were directly averaged into the mosaic pixels.
DACCIWA v2.0	0.1˚×0.1˚	-
GEEA-AEI v3.0	0.025˚×0.025˚	The regional grid is aligned with the mosaic grid, so raw emissions were directly averaged into the mosaic pixels. Sectors providing source emissions were averaged over the 0.1˚×0.1˚ pixel containing the source.
INEMA v1.0	0.01˚×0.01˚	The regional grid is aligned with the mosaic grid, so raw emissions were directly averaged into the mosaic pixels.
REAS v3.2	0.25˚×0.25˚	First, emissions were downscaled from 0.25˚x0.25˚ to 0.05˚x0.05˚ grid by just replicating the emission fluxes except for 0.25˚x0.25˚ pixels containing sea & land. At coastal pixels, emission fluxes were re-calculated assuming that emissions over the 0.05˚x0.05˚ sea pixels are zero (REAS does not provide shipping emissions). Then, 0.05x0.05 emissions fluxes were directly averaged into the mosaic grid. Power plant emissions were available as point sources, so they were directly averaged over the 0.1˚x0.1˚ pixel containing the power plant.
VULCAN v3.0	1km×1km	The VULCAN team aggregated point, line, and polygon emissions to the mosaic grid to minimize re-projection errors.

5.3.2 Temporal (re-)distribution

The global mosaic provides monthly CO_2 emission fluxes during 2015.

- Inventory year 2015: latest year in which all regional inventories provide CO_2 emissions.
- Resolution (monthly): All inventories provide monthly emissions except DACCIWAv2.0 and INEMAv1.0. In these two regions, monthly emissions were estimated using the monthly weight factors from CAMS-GLOB-TEMPO v3.1. Flat profiles were used in sectors not covered by CAMS-GLOB-TEMPO.

Table 12: CAMS-GLOB-TEMPO v3.1 monthly weight factors used for INEMA and DACCIWA.

Global mosaic sector	CAMS-GLOB-TEMPO v3.1 monthly weight factor
energy_s	*FM_ene_co2*
energy_a	*FM_ene_co2*
manufacturing	*FM_ind*
settlements	*FM_res*
transport	*FM_tro*
aviation	flat profile
other	flat profile

5.3.3 Unit conversion

The global mosaic PED provides CO2ff and CO2bf emission fluxes [$kg/m^2/s$] but some regional datasets provide total emissions [*kg/year*]. Conversion to the standard unit used for the global mosaic PED [$kg/m^2/s$] was performed for the latter ones, using the cell area layer included in the mosaic output file. When the inventory provided point sources (e.g., power plants), the emissions were averaged over the entire pixel.

VULCAN 3.0 provides emissions as kg C instead of kg CO_2. Carbon emissions were transformed into CO_2 emission based on the atomic mass of Carbon within CO_2 (12/44).

5.3.4 Sector (re-)aggregation

The global mosaic provides emissions of CO2ff and CO2bf aggregated in seven groups of sectors. The definition of biofuels follows that provided by the International Energy Agency (IEA) (Appendix A). However, in practice, the split between CO2ff and CO2bf was made by each regional inventory, and we just verified the consistency of regional methodologies with the IEA definition.

The emission categories of regional inventories were aggregated into the mosaic sectors as shown in Table 13. Some inventories were also gap-filled when the emissions were missing a CO_2 component and/or sector. Before gap-filling, we analysed with EDGARv6.0 if the category & CO_2 component was missing due to its negligible contribution. We only gap filled a missing category/component if its contribution to the sector was above 1%. The main modifications were made in the following inventories:

INEMA v1.0:

- **Energy, mining & residential**: CO2ff and CO2bf were reported together and the exact contribution of CO2ff and CO2bf at pixel level was not available. To solve this, the INEMA team calculated the CO2ff/CO2bf fraction per sector and Chilean region (16 in total) based on annual emissions from the Registro de Emisiones y Transporte de Contaminantes (RTEC). The regional ratios were then applied at pixel level to split CO2ff and CO2bf.
- **Open waste burning**: CO2ff and CO2bf emissions are not included, but according to EDGAR v6.0 data they can be neglected (<0.1% of energy emissions).

- **Residential**: INEMA only reports CO2bf from wood combustion. CO2ff was gap-filled with the default global inventory due to its significant contribution in total CO2 emissions (~30%)
- **Transport**: INEMA only reports CO2ff. The contribution of CO2bf transport emissions over Chile is less than 0.1% according to EDGAR v6.0, so CO2bf transport emissions can be neglected.

REAS v3.2.1

- **Open waste burning:** According to EDGARv6.0 SWD_INC, CO2bf emissions from open waste burning account for 3.3% of the total energy emissions within the REAS spatial domain. Therefore, we gap-filled them with EDGARv6.0 SWD_INC.
- **Shipping & aviation:** CO_2 emissions were missing in both sectors. They were gap-filled with the global default inventory.
- **Road transport**: REAS only provides CO2ff emissions for the transport sector (ROAD_TRANSPORT + OTHER_TRANSPORT). The overall contribution of CO2bf for ‘road transport’ over all REAS countries is around 1%, reaching a 7% in Thailand and Philippines according to EDGAR v6.0. Thus, we gap-filled the road transport CO2bf emissions with the global default inventory.

VULCAN v3.0:

- **Open waste burning**: CO2ff emissions not included, but according to EDGARv6.0 they are negligible (<0.1% of energy emissions).
- **CO2bf** emissions were missing in all the sectors. We gap-filled all the sectors except the ‘other’ with EDGARv6.0

Table 13 Aggregation and gap-filling (red) of regional inventory sectors to the mosaic sectors. CO2ff (ff) and CO2bf (bf) components are specified in those inventories not providing separate estimations of both components in all categories.

MOSAIC	EDGAR 6.0	CAMS-REG-GHG 5.1	DACCIWA 2.0	GEAA-AEI 3.0	INEMA 1.0	REAS 3.2.1	VULCAN 3.0
energy_s	ENE	A_PublicPower	energy_s	CEN	Energy (ff +bf)	POWER_PLANT_NON_POINT (ff, bf) POWER_PLANT_POINT (ff)	elec_prod (ff)
energy_a	ENE	A_PublicPower	energy_a	CEN	Energy (ff + bf)	POWER_PLANT_NON_POINT (ff, bf) POWER_PLANT_POINT (ff)	elec_prod (ff)
	SWD_INC	J_Waste		WAS	-	gap-filled (ff, bf)	-
manufacturing	IND IRO NFE NEU NMM CHE	B_Industry	Manufacturing	IND_FUE IND_PRO	Industry (ff + bf) Mining (ff + bf)	INDUSTRY (ff, bf)	industrial (ff) cement (ff)
settlements	RCO	C_OtherStationaryComb	Settlements	COM GOV RES FAG	Residential (bf) gap-filled (ff)	DOMESTIC (ff, bf)	commercial (ff) residential (ff)
aviation	TNR_aviation_LTO	H_Aviation (LTO)	Aviation (LTO)	AVI (LTO)	gap-filled (ff)	gap-filled (ff)	airport (ff) (*LTO up 915m)
transport	TRO_noRes	F1_RoadTransport_exhaust_gasoline F2_RoadTransport_exhaust_diesel F3_ReadTransport_Exhaust_LPG_gas F4_RoadTransport_NonExhaust	Transport	VEH	Transport (ff)	ROAD_TRANSPORT (ff) gap-filled (bf)	onroad (ff)
	CAMS-GLOB-SHIP	G_Shipping		BAR	gap-filled (ff)	gap-filled (ff)	cmv (ff)
	TNR_Other	I_Offroad		TRE	gap-filled (ff)	OTHER_TRANSPORT (ff)	railroad (ff) nonroad (ff)
other	REF_TRF PRO COL AGS PRU_SOL	D_Fugitives E_Solvents L_AgriOther	Other	REF VEN	-	-	-
		Excluded: K_AgriLivestock (no CO_2 emissions)		excluded: FUE (accounted in AFOLU)	*CO2ff & CO2bf split with regional ratios RETC 2020		CO2bf gap-filled (except OTHER)

5.4 Masks

The following spatial masks were used to produce the global mosaic:

- **Country mask**, to facilitate the aggregation of the emissions by country for the comparison against NGHGIs.
- **Inventory mask**, to build the global mosaic.

5.4.1 Country mask

The country mask is the basis of all the spatial masks, making the mosaic internally consistent. The country mask was derived from the Geographic Information System of the COmmission (GISCO) 2020 dataset (EUROSTAT 2020), which is the latest country definition provided by the European Commission. GISCO defines the administrative boundaries at country level of the world and is based on the geometry from EBM v2020 (Reference Date 31.12.2018) of EuroGeographics for the members of Eurogeographics, and GISCO Countries 2020.

GISCO 2020 labels countries with their ISO Alpha-3 codes and their English name. For rasterization, the ISO Numeric (3-digit) code of each country was used. ISO Numeric codes were not available for regions defined by the European Commission as under conflict (14 in total). These regions were coded with four digits, from 1000 to 1014, as specified in the metadata.csv file

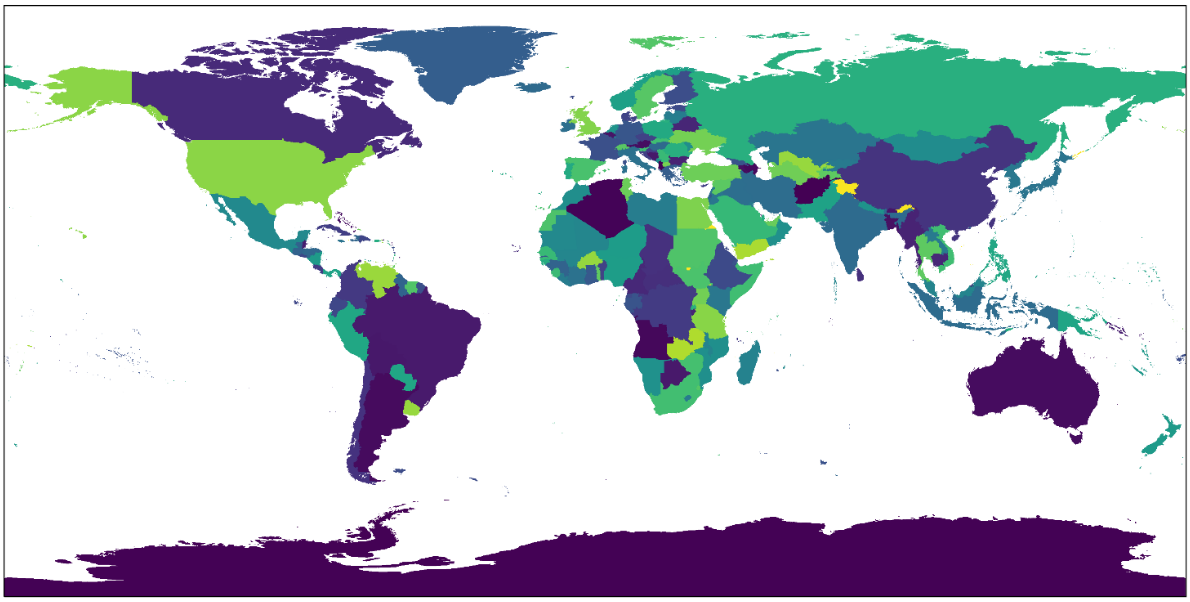

Figure 1: Overview of the country mask (*mask_country*)

The rasterization was made with the highest resolution shapefile provided by GISCO (1m). Different rasterization procedures were applied at coastal borders, and borders between countries (Fig 2). At coastal borders, all the pixels touched by the coastal line were considered as land an assigned to the corresponding country. At country borders, pixels touched by more than one country were assigned to the country covering most of the border pixel. Note that this introduces a small error when aggregating emissions by country in those countries having significant emissions near their borders and in particular when the neighbouring countries are considerably different in size and so in emissions total.

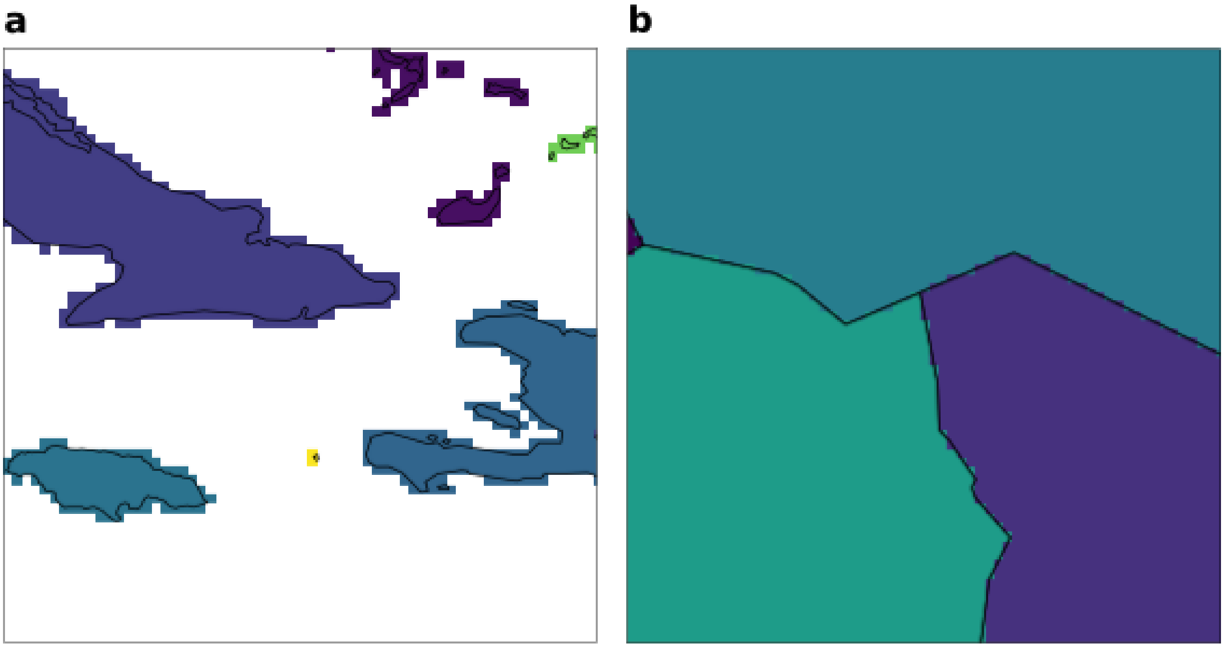

Figure 2 Masking procedure applied at (a) coastal pixels and (b) borders between countries.

5.4.2 Inventory mask

The inventory mask is the basis of the global mosaic, assigning each pixel to one of the source inventories. The mask is also made available in the output file, so users can verify the origin of the CO_2 emissions at pixel level.

The inventory mask was developed from the country mask. In each country, regional inventories were used only if they covered the whole country (excluding oversea territories). Therefore, the original spatial extent of some regional inventories differs from their spatial extent in the mosaic, as countries partly covered by regional inventories were fully gap-filled with the default global mosaic.

The spatial extent of regional inventories was limited to inland and coastal pixels (all pixels touching some land), as this is the coverage typically provided at regional level. Pixels fully covered by sea were assigned to the default global inventory (shipping emissions from CAMS-GLOB-SHIP). In some regional inventories such as DACCIWA, the emissions at some coastal pixels were missing (depending on the portion of land covered by the coastal pixel). Some of those pixels had nonzero emissions according to CAMS-GLOB-SHIP. Thus, these pixels were gap-filled with CAMS-GLOB-SHIP in order to guarantee the continuity of shipping emissions between coastal and sea pixels.

The exact list of countries covered by each inventory is described in Table 14. The table also show the numerical ID assigned to each regional inventory to facilitate the storage of the mask as NetCDF.

Table 14: Description of countries covered by each regional inventory

Inventory ID	Inventory name	Countries
1	CAMS-REG-GHG v5.1	ALB, ARM, AUT, AZE, BEL, BGR, BIH, BLR, CHE, CYP, CZE, DEU, DNK, ESP, EST, FIN, FRA, GBR, GEO, GRC, HRV, HUN, IRL, ISL, ITA, KOS, LTU, LUX, LVA, MDA, MKD, MLT, MNE, NLD, NOR, POL, PRT, ROU, SRB, SVK, SVN, SWE, TUR, UKR, LBN, PSE, SYR
2	DACCIWA v2.0	DZA, AGO, BEN, BWA, BFA, BDI, CMR, CPV, CAF, TCD, COM, COG, COD, CIV, DJI, EGY, GNQ, ERI, ETH, GAB, GMB, GHA, GIN, GNB, KEN, LSO, LBR, LBY, MDG, MLI, MWI, MRT, MUS, MYT, MAR, MOZ, NAM, NER, NGA, REU, RWA, STP, SEN, SYC, SLE, SOM, ZAF, SSD, SDN, SWZ, TZA, TGO, TUN, UGA, ESH, ZMB, ZWE, XF, XG, XO, XU, XV
3	GEAA-AEI v3.0	ARG
4	IENEMA v1.0	CHL
5	REAS v3.2.1	MNG, KOR, PRK, JPN, CHN, PHL, IDN, TWN, BRN, SGP, MYS, IND, KHM, VNM, LAO, THA, MMR, BTN, BGD, NPL, LKA, MDV, PAK, AFG, TLS, XH, XA, XB, XC, XD, XE, XM, XN
6	VULCAN v1.0	USA
0	EDGAR v6.0 (default)	All countries not covered by regional inventories, and sea pixels. Sea pixels are masked as -1 in mask_country.

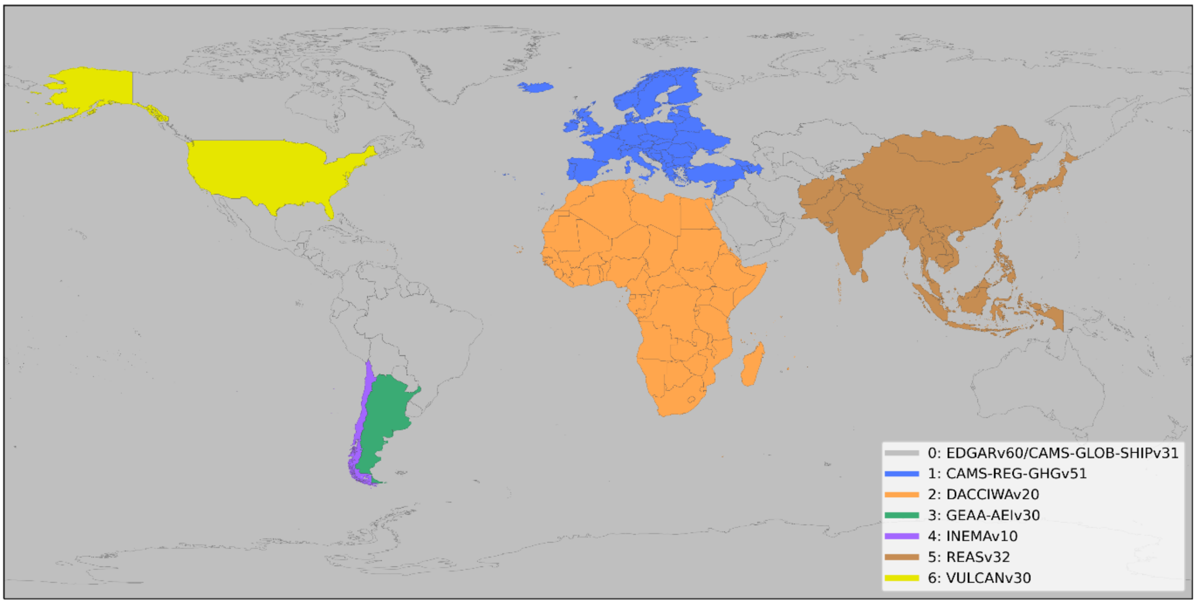

Figure 3 Overview of the inventory mask (*mask_inventory*)

6 Overview of the global mosaic

6.1 Summary

Table 15: Summary of the global mosaic PED

Product family	anthropogenic emissions
Species	CO2ff, CO2bf
Spatial coverage	global
Temporal coverage	2015
Spatial resolution	0.1° × 0.1°
Temporal resolution	monthly
Sectors	energy_s energy_a manufacturing settlements transport aviation other
Source inventories	0: default inventory (EDGAR v6.0/CAMS-GLOB-SHIP v3.1) 1: CAMS-REG-GHG v5.1 2: DACCIWA v2.0 3: GEAA-AEI v3.0 4: INEMA v1.0 5: REAS v3.2.1 6: VULCAN v3.0
Data format	NetCDF

6.2 File description

The global mosaic is provided as NetCDF files. Each file contains the monthly emissions for the seven sectors for one year and one CO_2 component (either CO2ff or CO2bf). Each file is internally structured as follows:

- General attributes of the global mosaic and the file.
- 3 dimensions [time, lat, lon]
- 7 data layers [time, lat, lon], with the monthly emissions of each of the 7 sectors.
- 3 auxiliary layers [lat, lon]:
    - *mask_country*: ISO numeric code.
    - *mask_inventory*: Numerical ID of the source inventory used in each grid cell.
    - *cell_area*: area of each grid cell [m2], to facilitate the spatial aggregation of cell fluxes.

CoCO2-MOSAIC-v1.0 |- CoCO2-MOSAIC-v1.0_01x01_1M_2015_CO2ff.nc |- CoCO2-MOSAIC-v1.0_01x01_1M_2015_CO2bf.nc |- metadata.csv

Figure 4Description of the file system

The metadata.csv file contains one entry for each GISCO 2020 country specifying: [*iso_alpha3*, *iso_numeric*, *name*, *name_engl*, *inventory*, *inventory_id]*.

Table 16: Description of the NetCDF dimensions

Dimension	Units	Data type
Lat	*deg N*	single
Lon	*deg E*	single
Time	*days since 1900-01-01*	int32

Table 17: Description of the NetCDF data layers

Layer	Dimensions	Units	Data type	Fill value	Description
mask_country	[lat, lon]	-	int16	-	Country ISO numeric code (3-digit). Regions defined under conflict by EUROSTAT 2020 don't have an ISO Code, so a 4-digit code was assigned (see metadata.csv)
mask_inventory	[lat, lon]	-	int8	-	Numerical ID of the inventory. Attributes. - *flag_value*: inventory numerical ID - *flag_meaning*: inventory name - *flag_year*: inventory year
cell_area	[lat, lon]	m^2	float64	-	Area of each grid cell.
energy_s	[time, lat, lon]	$kg/m^2/s$	float32	-1e30	Emission flux in the energy_s sector.
energy_a	[time, lat, lon]	$kg/m^2/s$	float32	-1e30	Emission flux in the energy_a sector.
manufacturing	[time, lat, lon]	$kg/m^2/s$	float32	-1e30	Emission flux in the manufacturing sector.
settlements	[time, lat, lon]	$kg/m^2/s$	float32	-1e30	Emission flux in the settlements sector.
transport	[time, lat, lon]	$kg/m^2/s$	float32	-1e30	Emission flux in the transport sector.
aviation	[time, lat, lon]	$kg/m^2/s$	float32	-1e30	Emission flux in the aviation sector.
other	[time, lat, lon]	$kg/m^2/s$	float32	-1e30	Emission flux in the other sector.

6.3 Overview of the CO2 emissions

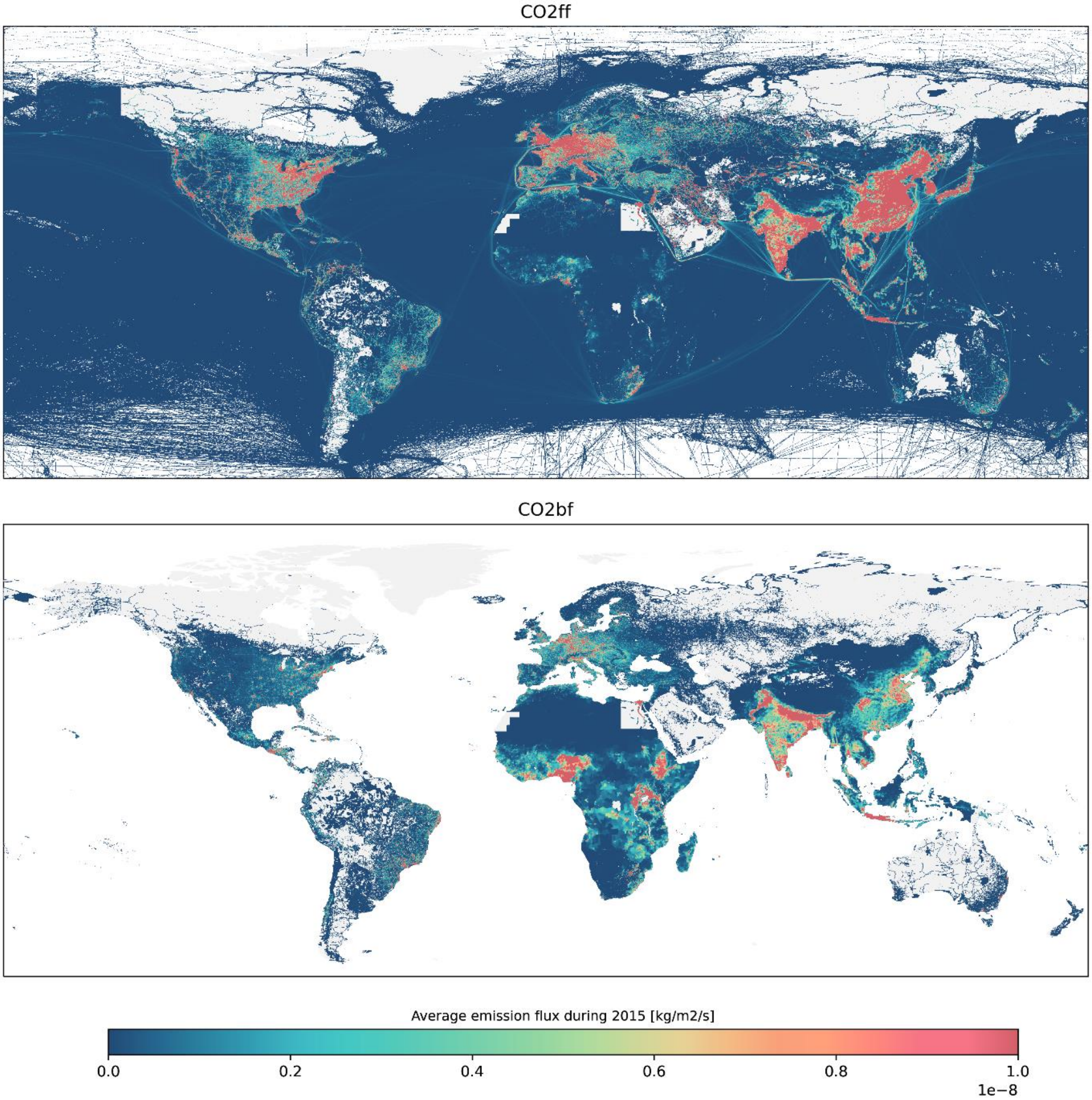

Figure 5 Total CO2ff and CO2bf anthropogenic emissions for the inventory year 2015

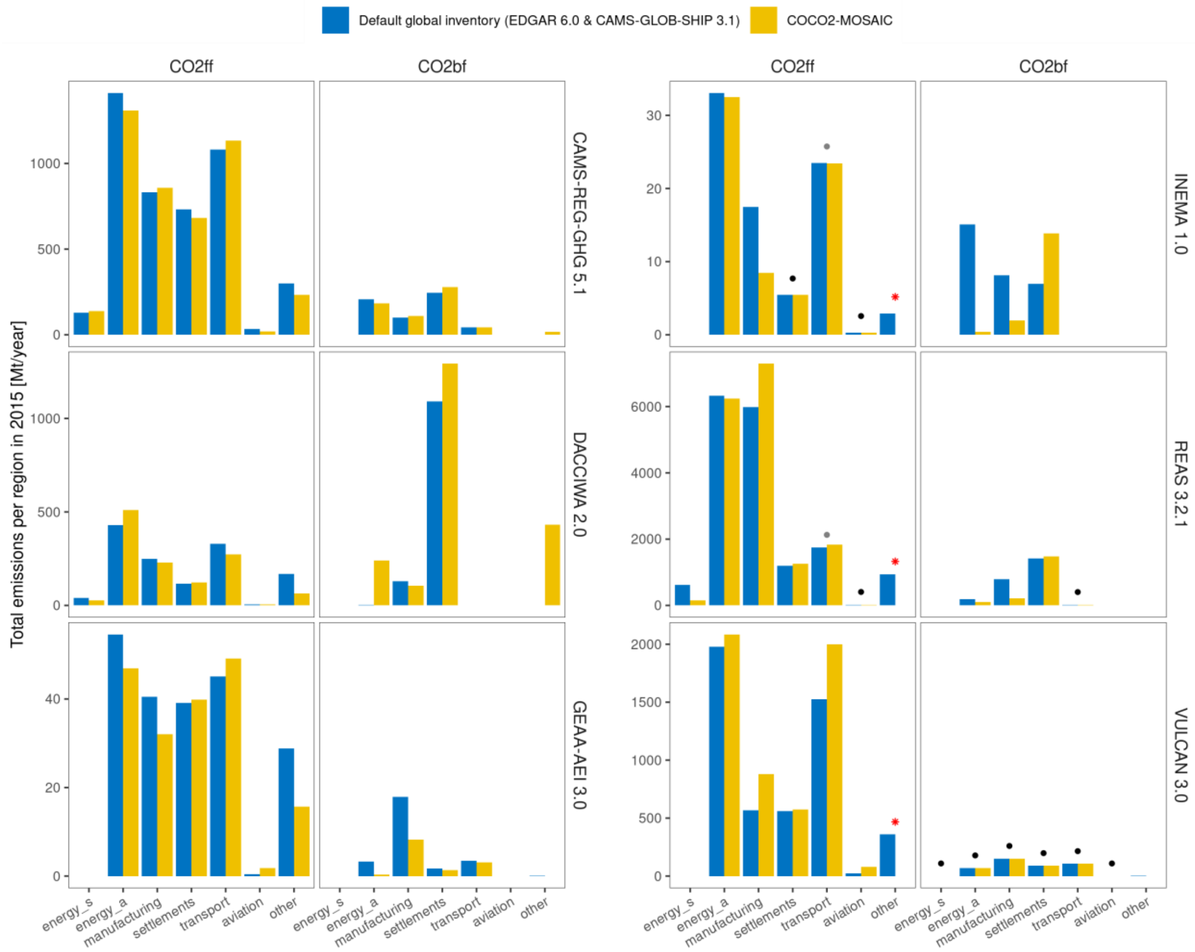

Figure 6 Comparison of the annual emissions of each regional inventory against those from the global default inventory (blue= EDGARv6.0 + CAMS-GLOB-SHIP_3.1; yellow = CoCO2-MOSAIC composed of the regional inventories). Black and grey dots show fully and partly gap-filled sector of EDGARv6.0 for the global mosaic, respectively. Red asterisks denote missing sector in the global mosaic.

We assessed our methodology for collating the total annual emissions of each regional inventory against the total annual emissions provided by the default global dataset over each region (Figure 6). The main goal was to discard any potential issue in re-gridding and re-distribution, conversion between units or re-aggregation amongst sectors. A more detailed analysis of the differences observed, comparing the mosaic against other global inventories and against the CoCO2-PED, will be performed in an upcoming scientific study.

Figure 6 shows that annual emissions from both regional and global inventories are in the same order of magnitude in all the regions and sectors analysed, discarding the presence of major processing errors. As we are comparing total annual emissions per region, the good agreement in some regions is explained due to the use of the same national/international databases by both regional and global inventories.

In general, differences are smaller for CO2ff emissions than for CO2bf. The main discrepancies in CO2ff emissions are observed in the 'other' sector, as this is the most heterogeneous category, and is missing in many cases disaggregated information. Differences between regional inventories and the global dataset are larger for CO2bf emissions, particularly at INEMA, DACCIWA, GEAA-AEI, or REAS regions. This is not surprising as the statistical coverage for the CO2bf sources are known to be more uncertain, also partly because less information is available on biofuel consumption. The net CO2bf emissions are accounted in AFOLU as changes in carbon stocks are more complicated as the current IPCC guidelines for NGHGI of 2006 and its refinement of 2019 show.

We also assessed the monthly profiles by comparing the monthly weight factors of regional and global inventories (Figure 7). Monthly profiles from regional inventories and from the global dataset were compatible in all regions and sectors. The largest intra-annual variability was observed in the settlement sector with monthly factors up to +/- 2. In this sector, regional inventories and the global dataset show similar intra-annual profiles but there are some differences in the magnitude of the factors (e.g., summer season) of which the relative deviation needs further analysis. The sector ‘other’ shows the largest difference in variability between the regional and global inventories, where regional inventories do show a double-peaked inter-annual variability and global inventories remain flat. These observations will be further investigated in the upcoming study.

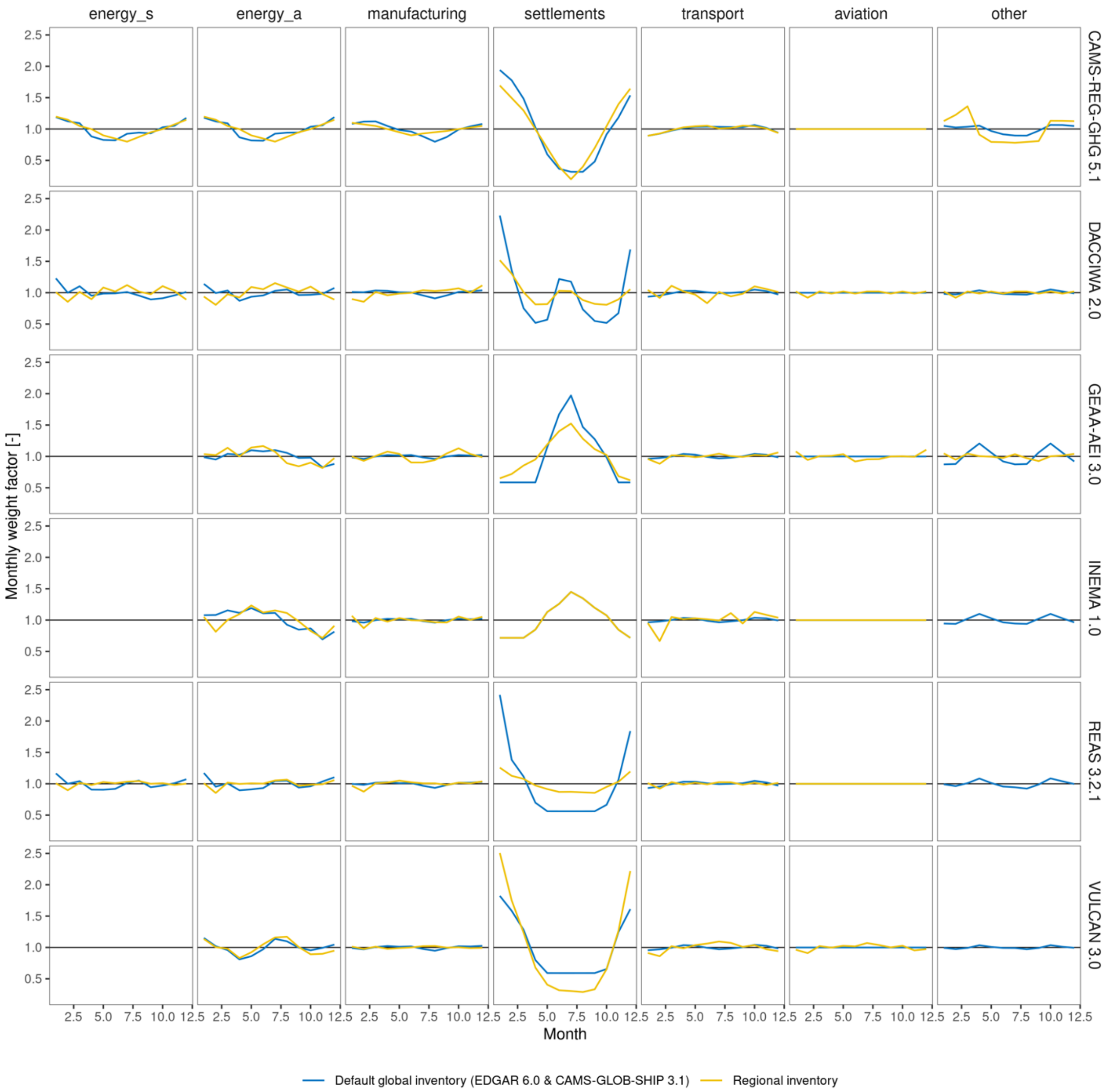

Figure 7 Verification of the monthly profiles. Monthly profiles are weighted with the emissions of each pixel (monthly profile = total monthly emission per region / total annual emissions per region)

6.4 Super emitting pixels

Super emitting pixels were defined using the same threshold applied in the CHE project (7.9e-6 kg/m2/s). Based on this threshold, 26 super emitters were identified in 2015 (Table 18). The CHE project identified 30 super emitters during the same year, using CO_2 emissions from EDGAR 4.2 globally (Choulga et al. 2021). The larger number of super emitters in the CHE study is due to the lower emissions of REAS over South-East countries compared to EDGARv6.0. As a result, some super emitters found by CHE in China, India or South Korea disappeared in the CoCO2 mosaic.

Table 18: List of super emitting pixels during 2015. The GPPD column shows if the pixel contains a power plant from the Global Power Plant Database.

Lat[˚]	Lon[˚]	Country	Inventory	CO_2 flux [*kg/m2/s*] x 1e-6	Total CO_2 [*Mt/year*]	GPPD
55.95	37.75	RUS	EDGARv60	24.78	54.37	False
60.35	28.65	RUS	EDGARv60	24.02	46.59	False
55.75	52.45	RUS	EDGARv60	20.40	44.98	False
54.75	20.55	RUS	EDGARv60	17.38	39.28	False
51.25	19.35	POL	CAMS-REG-GHGv51	15.20	37.23	True
37.25	126.45	KOR	REASv32	12.95	40.20	True
51.05	6.65	DEU	CAMS-REG-GHGv51	12.93	31.80	True
51.85	75.35	KAZ	EDGARv60	12.79	30.93	True
57.05	40.35	RUS	EDGARv60	12.05	25.68	True
50.95	6.65	DEU	CAMS-REG-GHGv51	10.99	27.09	True
36.45	126.45	KOR	REASv32	10.01	31.40	True
55.55	37.75	RUS	EDGARv60	9.96	22.07	False
29.45	48.25	KWT	EDGARv60	9.74	33.04	False
51.85	14.45	DEU	CAMS-REG-GHGv51	9.71	23.48	True
34.95	127.85	KOR	REASv32	9.23	29.49	True
-32.35	150.95	AUS	EDGARv60	9.19	30.27	True
69.35	88.25	RUS	EDGARv60	9.16	12.68	True
32.75	44.25	IRQ	EDGARv60	8.89	29.15	True
27.05	49.65	SAU	EDGARv60	8.54	29.61	False
24.65	46.75	SAU	EDGARv60	8.44	29.85	True
25.05	55.05	ARE	EDGARv60	8.43	29.71	False
46.35	40.65	RUS	EDGARv60	8.16	22.02	False
-26.15	28.95	ZAF	DACCIWAv20	7.95	27.77	False
24.25	120.45	CHN	REASv32	7.92	28.10	True
51.45	14.55	DEU	CAMS-REG-GHGv51	7.92	19.32	True
40.35	109.95	CHN	REASv32	7.91	23.53	True

We kept the CHE threshold based on emission fluxes for consistency with the CHE project but note that filtering super emitters by fluxes makes it highly dependent on the pixel area, which progressively decreases towards the poles. For instance, two super emitters (a: RUS 69.35N 88.25E, b: IRQ 32.75N 44.25E) with similar fluxes (a: 9.16e-6, b: 8.89e-6) have very different total emissions (a:12.68 Mt, b:29.15 Mt) due to the high latitude of the Russian pixel.

We also verified the location of super emitting points against the Global Power Plant Database (GPPD) v1.3.0 (Global Energy Observatory KTH Royal Institute of Technology in Stockholm, Enipedia, World Resources Institute 2018). We checked if all super emitting pixels contained a GPPD power plant within the pixel boundaries. Out of the 26 super emitting pixels, 16 contained a GPPD power plant. The 10 pixels that did not contained a power plant were from DACCIWA (x1) and EDGAR (x9). These discrepancies will be further analysed in the upcoming scientific study by using the work done in Task 2.3.b on the improvement of the spatial representation of power plant emissions by considering their exact geographical location.

7 Caveats

The main caveats of the global mosaic are:

- **'aviation' sector**: The aviation sector only includes landing & take-off (LTO) and taxi emissions, which according to EDGAR 6.0 accounts for 12% of total aviation emissions at global scale. Inventories account for LTO and taxi emissions up to 1km (VULCAN goes up to 3000", which is roughly equivalent). Climbing, descent and cruising emissions were excluded because regional inventories only provide LTO emissions. We decided not to gap-filled them with a global dataset (e.g., EDGAR 6.0) due to the lack of spatial consistency between the airport locations given by global and regional datasets. We did not replace the whole aviation sector with a global dataset because the goal of the mosaic is to provide a regional reference. Despite including only LTO, the CoCO2-MOSAIC can still be used as a reference to check airport locations. However, missing aviation emissions need to be accounted if using the mosaic for regional inversions. In the upcoming scientific study, we will evaluate the possibility to complement CoCO2-MOSAIC with an additional file that includes aviation emissions above 1km from EDGAR 6.0 (same spatial resolution) or CAMS-GLOB-AIR (0.5°x0.5°).
- **'other' sector**: this is the sector with more missing information and with more discrepancies between regional inventories. The sector 'other' is a heterogeneous and highly uncertain sector not explicitly available in any of the inventories analysed. It includes diverse activities not accounted in main sectors such as CO_2 emissions from fossil fuel manufacturing (e.g., refineries), fugitive emissions (venting, flaring), liming, urea application and emissions associated with product use. Regional inventories either not account for some of these emissions or include them in one of the main sectors. Besides, they generally do not provide the disaggregation level needed to re-arrange them. We decided not to gap-fill or replace this sector with the default global dataset due to the risk of double-counting emissions already included in one of the main sectors. As a result, this sector is fully missing in INEMA 1.0, REAS 3.2.1 and VULCAN 3.0, and some activities are missing in the other regional inventories. The size of the missing "other" sector will be assessed in a forthcoming study.
- **Spatial inconsistencies**: Another limitation of the mosaic dataset is that for certain sectors/regions, CO2bf and CO2ff emissions are not spatially consistent. For instance, in Chile the residential combustion CO2bf emissions follow the spatial distribution reported by INEMA, whereas the CO2ff follow the spatial distribution of EDGAR. The same applies to the USA: residential CO2ff emissions follow the VULCAN spatial distribution, whereas CO2bf follows the EDGAR distribution.

8 Conclusions

This report provides the Product User Manual for the CoCO2-MOSAIC, a global mosaic of Prior Emission Datasets (PED) for 2015 (CO2ff, CO2bf) derived under CoCO2 Task 2.2 (deliverable 2.3). The report first describes the regional emission inventories used in each region and the global datasets used for gap-filling. Then, the methodology applied to harmonize all the inventories spatially, temporally, per sector is explained, as well as the masking procedure. Finally, the structure of the output files is explained, giving an overview of the results obtained and assessing our methodology for re-gridding, temporal re-distribution, unit conversion and sectoral re-aggregation.

The main data gaps were due to the lack of regional information in countries with significant contribution in global emissions, most notably (ranked from higher to lower emissions) Russia, Canada, Iran, Saudi Arabia, Brazil, Mexico or Australia. These regions were gap-filled with global inventories, but the inclusion of regional information would improve the accuracy of the mosaic as a reference dataset. The CoCO2-MOSAIC could be updated in the future to include new regional datasets, and more recent information in the regions already covered.

The report will be complemented with a scientific description of the emissions per region and sector, and an inter-comparison with other global datasets including the CoCO2-PED (Task 2.1). Within CoCO2, this global mosaic will serve to assess the global PED and to conduct sensitivity analysis in Task 3.1.

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Appendix A– IEA definition of biofuel

IEA definition to identify what belongs to the second category of “biofuel” that generate CO2bf:

Biofuels: Biofuels cover bioethanol, biodiesel, bio-methanol, bio-dimethylether, bio-oil. Liquid biofuels are mainly biodiesel and bioethanol/ETBE used as transport fuels. They can be made from new or used vegetable oils and may be blended with or replace petroleum-based fuels. The natural plant feedstock includes soya, sunflower, and oil seed rape oils. Under some circumstances, used vegetable oils may also be used as feedstock for the process.

Biogas: A gas composed principally of methane and carbon dioxide produced by anaerobic digestion of biomass, comprising

- Landfill gas, formed by the digestion of landfilled wastes.
- Sewage sludge gas, produced from the anaerobic fermentation of sewage sludge.
- Other biogas, such as biogas produced from the anaerobic fermentation of animal slurries and of wastes in abattoirs, breweries, and other agro-food industries.

Black liquor: This is a recycled by-product formed during the pulping of wood in the paper making industry. In this process, lignin in the wood is separated from cellulose, with the latter forming the paper fibres. Black liquor is the combination of the lignin residue with water and the chemicals used for the extraction of the lignin and is burned in a recovery boiler. The boiler produces steam and electricity and recovers the inorganic chemicals for recycling throughout the process.

Peat (and peat briquettes): Combustible soft, porous, or compressed, fossil sedimentary deposit of vegetal origin with high water content (up to 90% in the raw state), easily cut, of light to dark brown colour. Only peat used for energy purposes should be reported.

Solid biomass: Covers organic, non-fossil material of biological origin which maybe used as fuel for heat production or electricity generation. It comprises:

- Charcoal: Covers the solid residue of the destructive distillation and pyrolysis of wood and other vegetal material
- Wood, wood wastes, other solid wastes: Covers purpose-grown energy crops (poplar, willow, etc.), a multitude of woody materials generated by an industrial process (wood/paper industry in particular) or provided directly by forestry and agriculture (firewood, wood chips, bark, sawdust, shavings, chips, black liquor, etc.) as well as wastes such as straw, rice husks, nut shells, poultry litter, crushed grape dregs, etc. Combustion is the preferred technology for these solid wastes. The quantity of fuel used should be reported on a net calorific value basis.

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