

Background

In 2015 average concentration of CO₂ ~40% higher than in mid-1800s - average growth of 2 ppm/year in last 10 years.

Fossil-fuel emissions are concentrated in cities or close to power plants - largest sources are electricity & heat production and road transport.

Global gridded CO₂ emission datasets of human emissions (HE): CDIAC, ODIAC, EDGAR, FFDAS, CEDS, PKU-FUEL, etc.

Uncertainty of global inventory is determined by the data quality of the largest emitting countries.

High uncertainty of global total GHG emissions:

- increasing share of emissions from countries with less developed statistical infrastructure,
- decreasing share of emissions from the well measured activities (e.g. coal power plants).

Necessity of CO₂ HE fluxes global uncertainties correct representation on the gridded map – sector- + fuel- + country-specific approach is needed.

IPCC → EDGAR → ECMWF grouping

Anthropogenic CO₂ emission dataset used is EDGAR (v4.3.2_FT2015 & v4.3.2) – CO₂ source distribution of 2012 and emissions of 2015 & 2012.

Initial dataset is updated with improved apportionment of the energy sector and energy usage for manufacturing.

Updated energy sector is divided into Super and Average power plant emissions based on CO₂ flux threshold of 7.9·10⁻⁶ kg·m⁻²·s⁻¹.

Coal CO₂ emissions are calculated from CH₄ emissions of brown and hard coal from underground mining (only grid-boxes with 6 and more zero neighbours are used) multiplied by (5.9/18.0) ratio.

Fossil Fuel Fires sector is not used as data in this sector is quite uncertain.

All 70 IPCC activities, used in EDGAR sectors, are combined into 7 ECMWF groups taking into account:

- activity type (point sources, 3D field, etc.);
- amount of knowledge for the activity (uncertainty value);
- geographical distribution (e.g. over urban areas only);
- size of covariance matrix (optimal size is less than 10·10);
- use for CO₂ co-emitting species (e.g. CH₄, CO, NO₂).

ECMWF's anthropogenic CO₂ emission group uncertainties are based on:

- emission budgets per country per group;
- uncertainty basic values from IPCC Tier 1 approach based on error propagation method (+ correction if half-range uncertainty ≥ 100 & ≤ 230%):
 - ✓ separate values for countries with well (WDS) and with less well developed statistical systems (LDS);
 - ✓ taking into account most typical fuel values:
 - aviation – Jet Kerosene; railways – Diesel;
 - road/off-road transport – typical uncertainty for Emission Factor;
 - shipping – 80% Gas / Diesel Oil & 20% Residual Fuel Oil.
- way of defining lognormal distribution for non-negative emissions (applied if lower half-range of uncertainty ≥ 50%).

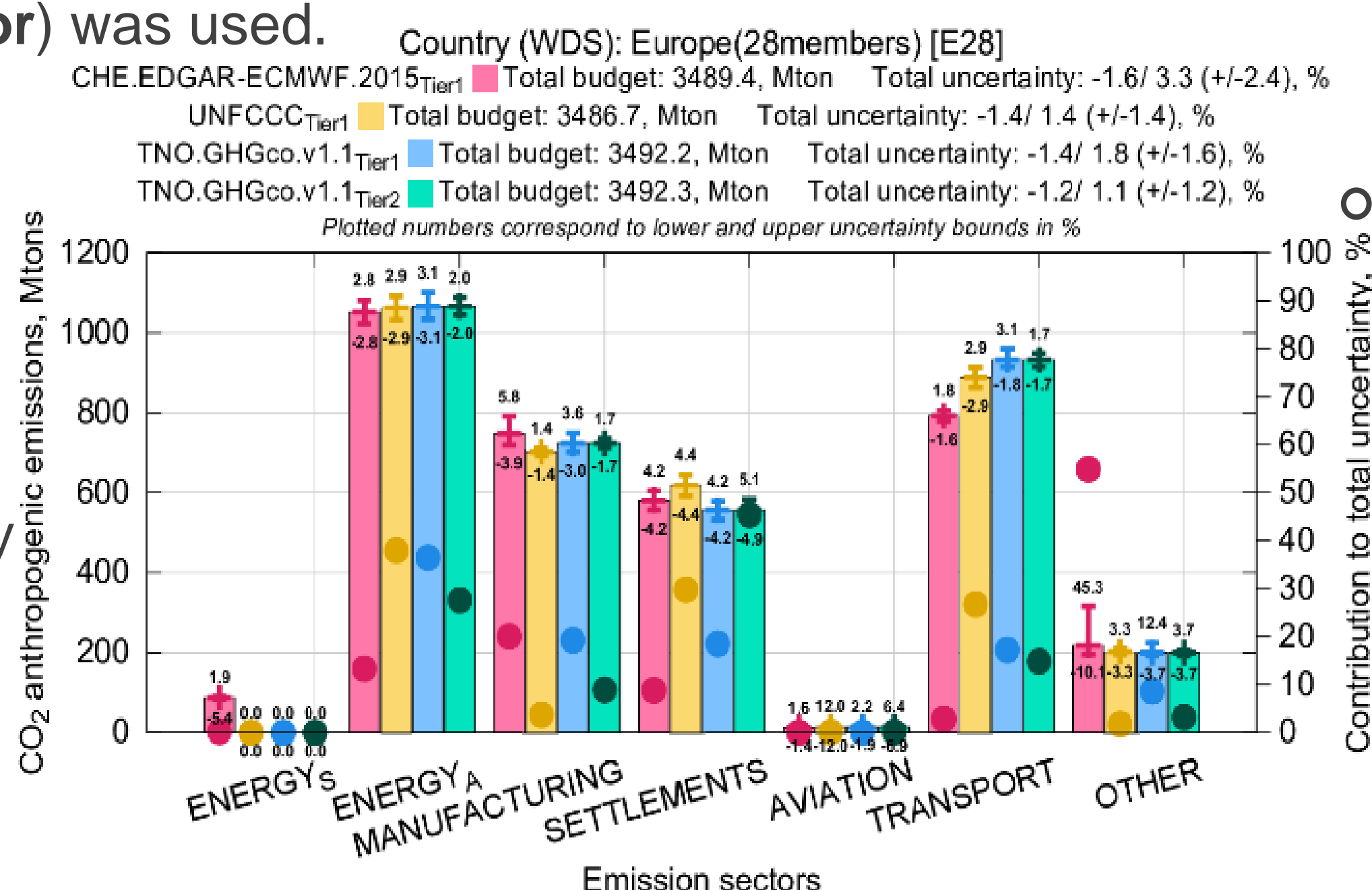
European human CO₂ emissions in 2015

In order to compare uncertainty calculations for ECMWF groups based on EDGAR global emission budgets national more detailed anthropogenic CO₂ emission budgets of 2015 provided by Netherlands Organisation for Applied Scientific Research (TNO) and United Nations Framework Convention on Climate Change (UNFCCC) are used.

Each TNO/UNFCCC sector is matched with one or several IPCC activity → EDGAR sector → ECMWF group for further comparability of obtained results.

Activities that don't result in CO₂ long-cycle C production or that IPCC suggests to neglect when using most basic Tier1 approach for uncertainty calculations, are omitted. For fuel dependant activities the most typical fuel (or Emission Factor) was used.

ECMWF uncertainties are the highest ones, UNFCCC & TNO_{Tier2} - the lowest ones – their emission budgets are more detailed so more certain in general. Mainly uncertainties differ in fuel dependent groups (e.g. due to biofuels as ECMWF is not taking them into account).



IPCC methodology & input data chain

70 IPCC activities

2 types: countries with well/less developed statistical systems

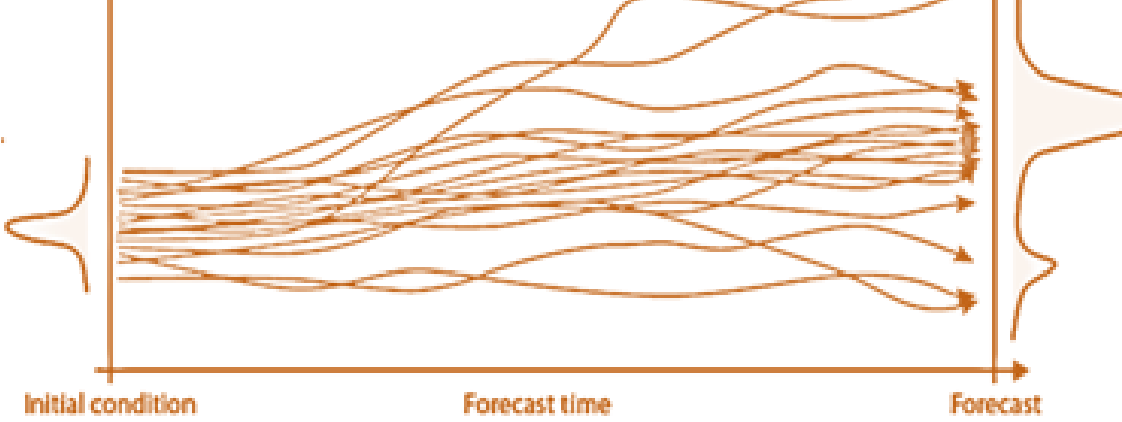
- Emission Factor (or Estimation Parameter) uncertainty [EF]
- Activity Data uncertainty [AD]

Combined uncertainty (with error propagation method)

Original cluster

Intergovernmental Panel on Climate Change (IPCC): 2006 IPCC Guidelines for National Greenhouse Gas Inventories (+ its 2019 Refinements)

Ensemble Prediction System (EPS)



ENS perturbations

ENS perturbations of CO₂ anthropogenic emissions

- per country (main assumption: full correlation within a country)
- per group

20 EDGAR sectors

Pre-processing

- Energy [ENE] => SuperPlant + AveragePlant
- Brown coal CH₄ + Hard coal CH₄ => Coal CO₂ from underground mining [COL]

2 types: countries with well/less developed statistical systems

- Combined uncertainty (with error propagation method)

Corrected (systematic underestimation by error propagation method)

Pre-processing Country emission budget

242 countries + 1 ocean

- Log-normal uncertainty distribution

Mapping cluster

7 ECMWF groups

242 countries + 1 ocean

- Combined uncertainty (with error propagation method)

Post-processing

- log-normal mean
- log-normal standard deviation

Perturbation cluster

IPCC → EDGAR → ECMWF uncertainties

№	ECMWF group	EDGAR sector	EDGAR sector note	Emission global budget 2015, Mton	Prior uncertainties, %			
					WDS countries Lower	WDS countries Upper	LDS countries Lower	LDS countries Upper
1	ENERGY_S	ENE	Power industry: SUPER emitting power plants	13'704	8.6	3.0	12.2	3.0
2	ENERGY_A	ENE	Power industry: AVERAGE emitting power plants		8.6	8.6	12.2	12.2
3	MANUFACTURING	SWD_INC	Solid waste incineration	137	40.3	40.3	41.2	41.2
		IND	Combustion for manufacturing	6'183	8.6	8.6	12.2	12.2
		IRO	Iron and steel production	234	37.1	37.1	37.1	37.1
		NFE	Non-ferrous metals production	91	73.2	73.2	73.2	73.2
		NEU	Non energy use of fuels	10	121.7	121.7	124.0	124.0
		NMM	Non-metallic minerals production	1'748	70.9	70.9	93.0	93.0
4	SETTLEMENTS	CHE	Chemical processes	534	107.8	89.9	107.8	89.9
		RCO	Energy for buildings	3'322	12.2	12.2	26.0	26.0
5	AVIATION	TNR_Aviation_CRS	Aviation cruise	412	5.5	6.4	50.1	106.8
		TNR_Aviation_CDS	Aviation climbing&descent	306	5.5	6.4	50.1	106.8
		TNR_Aviation_LTO	Aviation landing&takeoff	98	5.5	6.4	50.1	106.8
6	TRANSPORT	TRO	Road transportation	5'530	5.4	5.4	7.1	7.1
		TNR_Ship	Shipping	819	5.4	5.1	50.0	50.0
		TNR_Other	Railways, pipelines, off-road transport	255	50.3	106.9	50.5	107.0
7	OTHER	REF_TRF	Oil refineries and Transformation industry	1'917	54.4	149.3	57.7	151.4
		PRO	Fuel exploitation	258	191.1	339.1	210.9	364.5
		COL	Coal production	7	115.8	300.5	115.8	300.5
		AGS	Agricultural soils	99	70.7	0.0	70.7	0.0
		PRU_SOL	Solvents and products use	61	25.0	25.0	50.0	50.0

Global uncertainty at 2σ, %

CDIAC	±8.4 %
CHE_EDGAR-ECMWF_2015	±7.1 % (-4.7/+9.6 %)
EDGAR	±9.0 %
Global Carbon Project	±10.0 %
BP, CEDS, EIA, IEA	no quantitative assessment of uncertainty associated with its emissions dataset

Good agreement globally with reported country and world total and per sector emission budgets.

Freely available global gridded (0.1°×0.1° resolution) yearly and monthly anthropogenic CO₂ emission & uncertainties data CHE EDGAR-ECMWF 2015 per 7 emission groups at <https://doi.org/10.5281/zenodo.3712339>.

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- 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.
- CHE open-access deliverables: <https://www.che-project.eu/resources>.

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