ECMWF Anthropogenic CO$_2$ emission uncertainties

CO$_2$ Human Emissions
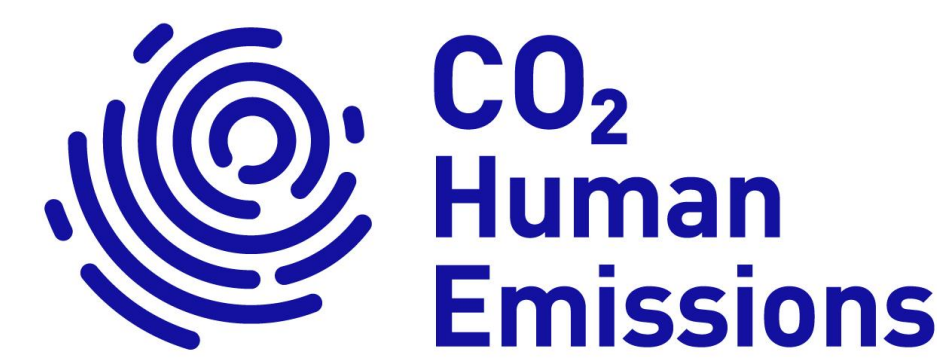
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Background

In **2015** average concentration of **CO$_2$ ~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 greenhouse gases **datasets** of **human emissions** (HE): EDGAR, CDIAC, EIA, IEA, etc.

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

High uncertainty of global total GHG emissions:
i) **increasing** share of **emissions from countries with less developed statistical** infrastructure,
ii) **decreasing** share of **emissions from the well measured activities** (e.g. coal power plants).

Necessity of CO$_2$ HE fluxes **global uncertainties** correct representation on the gridded map – **sector- + fuel- + country-specific approach** is needed.

IPCC → EDGAR → ECMWF grouping

Anthropogenic CO$_2$ emission **dataset** used is **EDGARv4.3.2_FT2015** – based on EDGARv4.3.2 source distribution and CO$_2$ emissions of 2015.

Energy sector is **divided into Super** and **Average power plant** emissions based on CO$_2$ **flux** threshold of **8.3E-06 kg/m^2/s**.

Coal CO$_2$ emissions were calculated **from CH4 emissions** of brown and hard coal from **underground mining** (only grid-boxes with 6 and more zero neighbours were 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 10x10);
- use for CO$_2$ **co-emitting species** (e.g. CH4, CO, NO2).

ECMWF's anthropogenic CO$_2$ 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 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 CO$_2$ emissions in 2015

In order to **compare uncertainty** calculations for **ECMWF groups** based on EDGAR **global** emission budgets **regional** (for European countries only) **more detailed** anthropogenic CO$_2$ emission budgets of 2015 provided by Netherlands Organisation for Applied Scientific Research (**TNO**) were used.
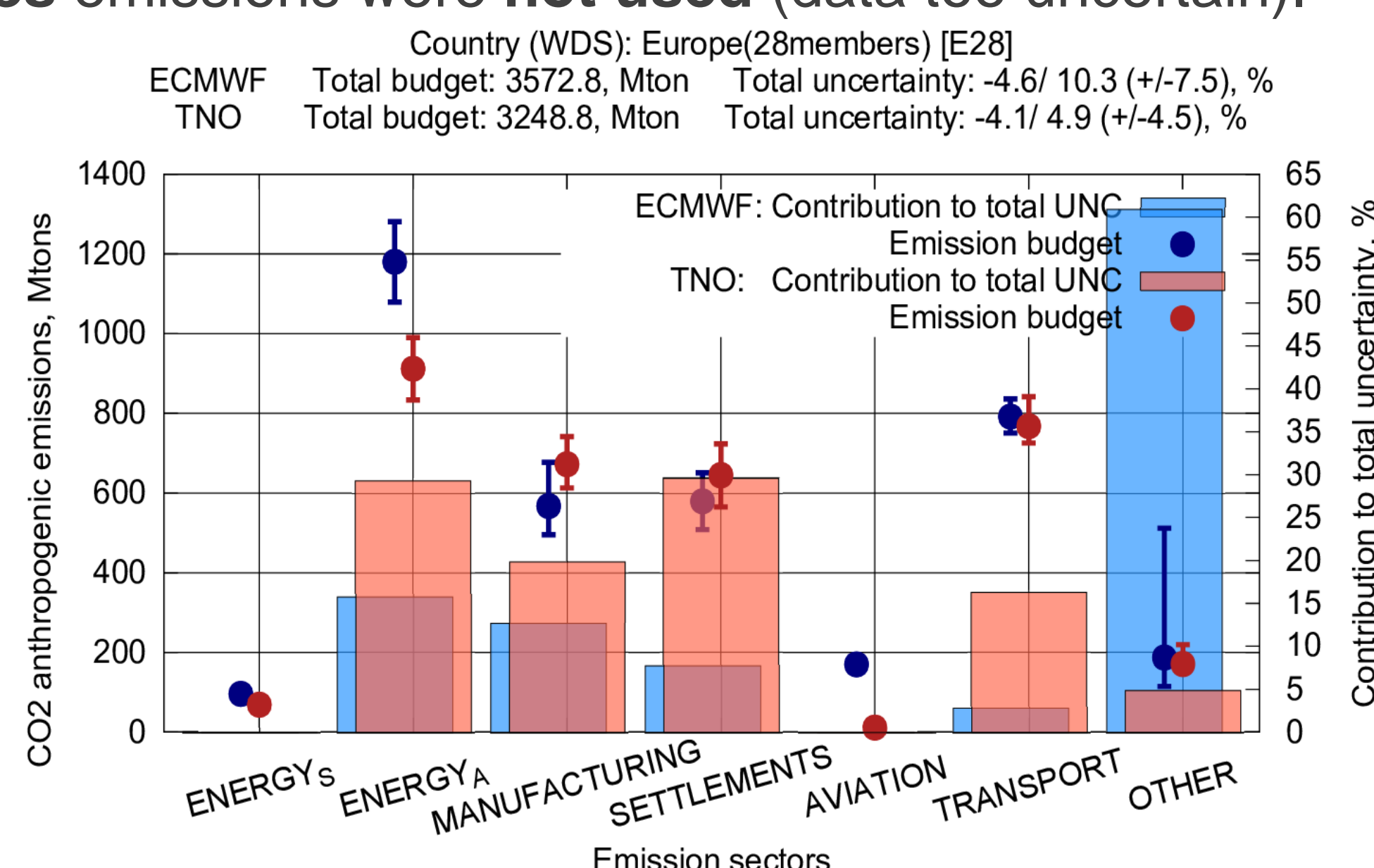
Each **TNO sector** was **matched** with one or several IPCC activity → EDGAR sector → **ECMWF group** for further comparability of obtained results.

All **TNO activities** that **don't result** in CO$_2$ **long-cycle C** production, or, where **IPCC** suggests to **neglect** CO$_2$ emissions when using most basic Tier1 approach for uncertainty calculations, were **omitted**.

For **fuel dependant activities** the most **typical fuel** (or Emission Factor) was used. **Fossil Fuel Fires** emissions were **not used** (data too uncertain).

TNO emission **budgets** are **more detailed** so they are usually **less uncertain** than ECMWF ones. More detailed knowledge about rather uncertain activity budgets prior to combining with more certain ones leads to a reduction in combined CO$_2$ emission uncertainty.

Country (WDS): Europe(28members) [E28]
ECMWF   Total budget: 3572.8, Mton   Total uncertainty: -4.6/ 10.3 (+/-7.5), %
TNO   Total budget: 3248.8, Mton   Total uncertainty: -4.1/ 4.9 (+/-4.5), %

IPCC methodology & input data chain

70 IPCC activities

2 types: countries with well/less developed statistical systems
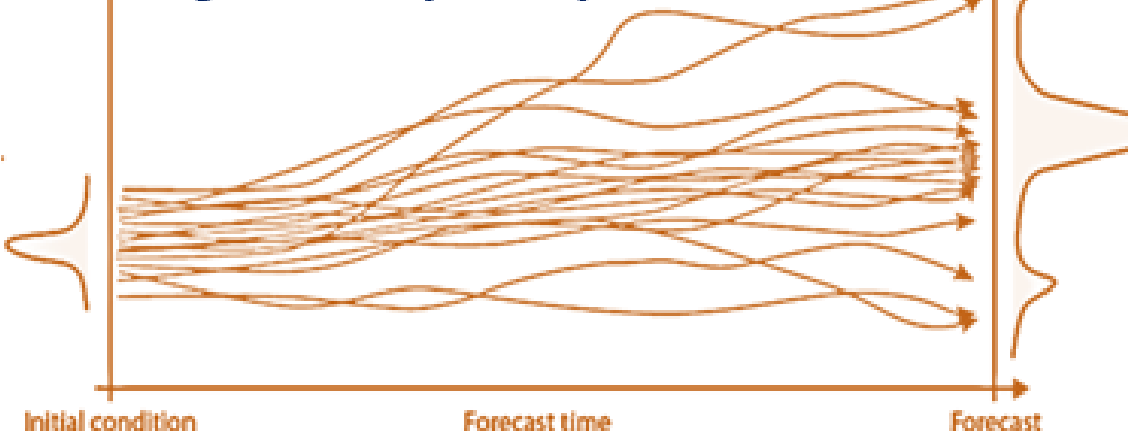- Emission Factor (or Estimation Parameter) uncertainty [EF]
- Activity Data uncertainty [AD]
- Combined uncertainty (with error propagation method)

Original cluster

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

Emissions Database for Global Atmospheric Research (EDGAR): anthropogenic emissions of greenhouse gases and air pollutants on spatial grid

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
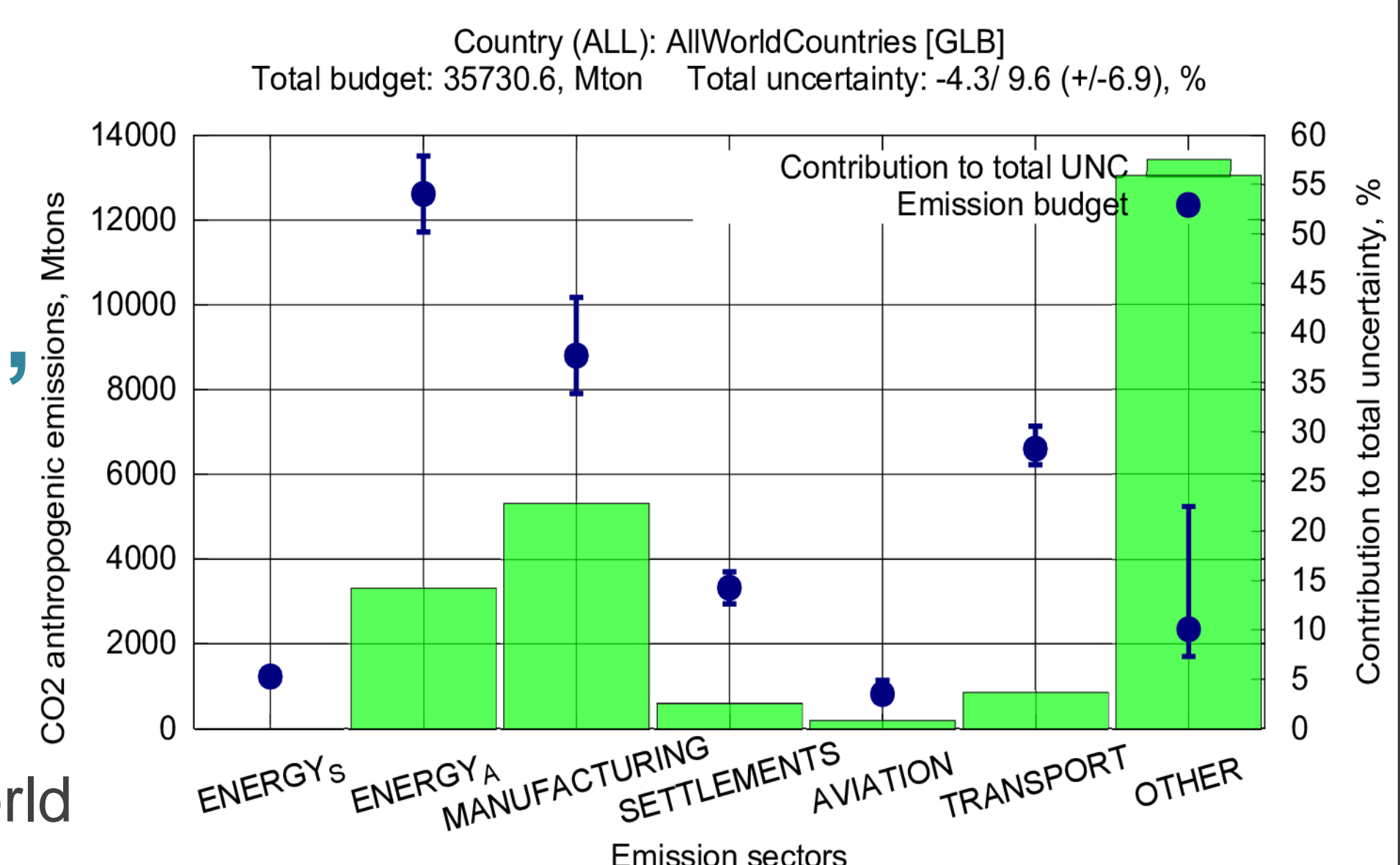- log-normal mean
- log-normal standard deviation

Perturbation cluster

Ensemble Prediction System (EPS)

Initial condition   Forecast time   Forecast

ENS perturbations

ENS perturbations of CO2 anthropogenic emissions
- per country (main assumption: full correlation within a country)
- per group

IPCC → EDGAR → ECMWF uncertainties

№	ECMWF group	EDGAR sector	EDGAR sector note	WDS countries Lower	WDS countries Upper	LDS countries Lower	LDS countries Upper
1	ENERGY_S	ENE	Power industry: SUPER emitting power plants	8.60	3.00	12.21	3.00
2	ENERGY_A	ENE	Power industry: AVERAGE emitting power plants	8.60	8.60	12.21	12.21
		SWD_INC	Solid waste incineration	40.31	40.31	41.23	41.23
3	MANUFACTURING	IND	Combustion for manufacturing	8.60	8.60	12.21	12.21
		IRO	Iron and steel production	37.08	37.08	37.08	37.08
		NFE	Non-ferrous metals production	73.17	73.17	73.17	73.17
		NEU	Non energy use of fuels	121.72	121.72	124.04	124.04
		NMM	Non-metallic minerals production	70.93	70.93	93.02	93.02
		CHE	Chemical processes	107.76	89.88	107.76	89.88
4	SETTLEMENTS	RCO	Energy for buildings	12.21	12.21	25.96	25.96
5	AVIATION	TNR_Aviation_CRS	Aviation cruise	5.54	6.44	50.06	106.79
		TNR_Aviation_CDS	Aviation climbing&descent	5.54	6.44	50.06	106.79
		TNR_Aviation_LTO	Aviation landing&takeoff	5.54	6.44	50.06	106.79
6	TRANSPORT	TRO	Road transportation	5.39	5.39	7.07	7.07
		TNR_Ship	Shipping	5.43	5.12	50.04	50.01
		TNR_Other	Railways, pipelines, off-road transport	50.33	106.87	50.54	106.99
7	OTHER	REF_TRF	Oil refineries and Transformation industry	54.35	149.29	57.70	151.43
		PRO	Fuel exploitation	191.10	339.06	210.90	364.47
		COL	Coal production	115.81	300.54	115.81	300.54
		AGS	Agricultural soils	70.71	0.00	70.71	0.00
		PRU_SOL	Solvents and products use	25.00	25.00	50.00	50.00

Global human CO$_2$ emissions in 2015: budget, uncertainties & contributions

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

Country (ALL): AllWorldCountries [GLB]
Total budget: 35730.6, Mton   Total uncertainty: -4.3/ 9.6 (+/-6.9), %

References

Janssens-Maenhout, G., Crippa, M., Guizzardi, D., Muntean, M., Schaaf, E., Dentener, F., Bergamaschi, P., Pagliari, V., Olivier, J., Peters, J., van Aardenne, J., Monni, S., Doering, U., Petrescu, R., Solazzo, E., and Oreggioni, G.: EDGAR v4.3.2 Global Atlas of the three major Greenhouse Gas Emissions for the period 1970–2012, Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2018-164, in review, 2019.

2006 IPCC Guidelines for National Greenhouse Gas Inventories.

2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Acknowledgements