DEVELOPMENT OF THE VERSION 9 NON-CO_2 GHG EMISSIONS DATABASE

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1. Introduction

In this document, we describe the methodology we use to develop the non-CO_2 greenhouse gas (GHG) emissions dataset for the GTAP Version 9 Database.[1] This new release of the GTAP database has a new base year, 2011. This new dataset provides emissions for 24 non-CO_2 emissions categories with 119 unique emissions subcategories for 244 countries. Emissions by region and economic sector, as well as emissions driver, for three major non-CO_2 gases (or groups of gases) are provided - CH_4, N_2O, and the group of fluorinated gases (F-gases), including CF_4, HFCs, and SF_6. Emissions come from three emissions drivers: consumption (by consumers and firms), endowment use (land and capital), and output.

The GTAP Version 6 non-CO_2 emissions dataset (Rose and Lee, 2009) which has 2001 as base year is generated from the dataset in Rose et al. (2010b) which is a highly detailed dataset of 2001 emissions developed from reported Annex 1 and non-Annex 1 country inventories, and estimated emissions for non-Annex 1 countries[2]. The detailed data readily lends itself to cleaner

[1] Narayanan et al. (2014)

[2] Annex I country emissions – except Russia - were extracted from the United Nations Framework Convention on Climate Change (UNFCCC) Common Reporting Framework (CRF) and National Inventory submissions. Emissions estimates for Russia were obtained from Russia's Third National Communication (IACRFCC, 2002). The main source for the Non-Annex I country emissions was National inventories. For the non-Annex I countries without national inventories, the EDGAR database 3.2 (Olivier, 2002) and Asia Least-Cost Greenhouse Gas Abatement Strategy (ALGAS) country reports were used.

mappings to economic activity. These 2001 data were also based on official reported country emissions as much as possible, rather than estimates based on standardized emissions estimation approaches applied to all countries and sectors. However, building the detailed 2001 dataset was resource intensive, and the effort has not been updated since for subsequent years consistent with the GTAP dataset releases. Instead, emissions growth approaches have been used for Versions 7 and 8 which have 2004 and 2007 as base years, respectively.

The Version 7 emissions dataset (Rose et al., 2010a) is developed by extrapolating the Rose et al. (2010b) detailed data to 2004 using CH_4 and N_2O emissions growth rates derived from EPA (2006) projections; and, in the case of F-gases, economic output growth rates derived from Versions 6 and 7 of the GTAP economic activity datasets.

The methodology used for Version 8 (Ahmed et al., 2014) is a growth rate approach that takes advantage of the detailed 2001 raw data of Rose et al. (2010b), and applies growth rates derived from two global emissions datasets: EDGAR and FAOSTAT. Specifically, a modified version of the methodology used for the Version 7 emissions dataset is used to extrapolate Rose et al. (2010b) using growth rates derived from country and source level emissions estimates for methane (CH_4), nitrous oxide (N_2O), and fluorinated gases (F-gases) from the Emission Database for Global Atmospheric Research (EDGAR) Version 4.2 (2011) dataset for non-agricultural emissions activities, and from the new FAO GHG emissions dataset for agricultural emissions activities.

Here, for the Version 9 emissions dataset, the basic idea of our methodology is to use data from the EDGAR Version 4.2 (2011) dataset for non-agricultural activities, and from FAOSTAT (2014) emissions dataset for agricultural activities directly as inputs into the build.[3] One issue with the EDGAR dataset is that the last available year is currently 2010, thus we project these to the new 2011 base year with the emissions growth approach which is described in the following section of this report. Basically, the emission growth approach offers to use the country, category, and GHG specific emission growth rates from year 2007 to 2010 to extrapolate the dataset from year 2010 to 2011. The FAO dataset, on the other hand, has data through 201x. The EDGAR and FAOSTAT

[3] United Nations Framework Convention on Climate Change (UNFCCC) also provide non-CO2 emissions data. However in this version, we do not utilize that dataset because (1) mapping regarding emission source is not complete, (2) the available data in the website is difficult to process, (3) dataset is updated regularly only for Annex I parties, and finally (4) CF_4 emissions data are not included in the dataset.

emissions datasets are based on globally standardized methods, not official government reported emissions. However, they are updated regularly and hence the construction in the GTAP database can be standardized. The downside of using these datasets directly as inputs into the build is that there is cruder mapping to drivers and sectors. And, the resulting data do not necessarily align with official reports.

The report is organized as follows. Sections 2 and 3 describe the methodology used to process the available data in the EDGAR and FAOSTAT datasets, respectively. Section 4 describes the characteristics of the dataset we obtain as a result of our methodology. Section 5 presents some results.

2. Methodology for The EDGAR Version 4.2 (2011)

The data available in EDGAR Version 4.2 (2011) are used to estimate emissions for the non-agricultural activities. Table 1 lists the IPCC codes and their descriptions of the data available in the dataset[4]. As listed in Table 1, the EDGAR Version 4.2 (2011) dataset covers data on emissions from both agricultural and non-agricultural activities. However, we use the emissions data only for non-agricultural activities. The data about emissions from agricultural activities are obtained from FAOSTAT (2014) GHG emissions dataset which provides not only data for year 2011 but also has broader commodity coverage.

In our methodology, the first step is to map the Rose et al. (2010b) detailed emissions categories to emissions categories in the EDGAR (2011) dataset. This mapping is provided in Table 2. There are 16 top-level emissions categories, listed in the first column of Table 2, with 65 subcategories, listed in the third column of the table. The fifth column of the table lists the related IPCC emissions inventory codes. For instance, the data for "Aluminum Production CF4" emissions category is obtained from the EDGAR process emissions of primary aluminum production CF_4

[4] For IPCC codes 2C4, 7B, and 7C, the data have multiple descriptions. Those data with the same IPCC code but multiple descriptions are aggregated in our dataset.

emissions data ("2C3" IPCC code). The last two columns of Table 2 represent the number of countries with nonzero data and the corresponding GTAP sector, respectively.

2.1. Limitations with the EDGAR Emissions Dataset and Our Solutions:

a. Notice in Table 2 that because of insufficient disaggregation in the EDGAR dataset in ADNI and OLGS emissions categories, the subcategories of these categories have the same IPCC code. For these two emissions categories - ADNI and OLGS – the data are distributed among the subcategories according to the regional weights obtained from the GTAP Version 8 non-CO_2 emissions dataset.

b. As presented in Table 2, there are cases where available data in the EDGAR dataset are more disaggregated than what is needed. For instance, for the "Combined stationary and mobile combustion" (STATMOB) subcategory of the "Stationary and Mobile Combustion CH_4" (SMCH) category, the IPCC code of the required data is 1A but the data in the EDGAR emission dataset are disaggregated into nine groups: 1A1a, 1A1bc, 1A2, 1A2b, 1A3a, 1A3c, 1A3d, 1A3e, 1A4. In these cases, the data for the sum of the EDGAR categories is used.

c. As marked with " * " in Table 2, there are three emission categories that are problematic: "Other Industrial Non-Agricultural Sources CH_4" (INCH), "Other Industrial Non-Agricultural Sources N_2O" (INN2), and "ODS Substitutes HFC-134a" (ODS). As marked on Table 2, data for some of the subcategories of these categories are not available in EDGAR (2011). For those subcategories, the data available in GTAP Version 6 non-CO_2 emissions dataset are extrapolated from 2001 to 2011 with the help of the GDP growth approach as described below.

GDP Growth Approach

In this approach, we use the annual GDP growth rate to project the emissions data from 2001 to 2011. Thus, the projected data can be obtained by

$$E_{2011}(reg) = E_{2001}(reg) * \prod_{i=2001}^{2010} [gdp_{i+1/i}(reg) + 1]$$

where $gdp_{i+1/i}(reg)$ is the country specific annual GDP growth rate from year *i+1* to *i* for $i \in [2001,2010]$ which is obtained from the World Bank (World Development Indicators, 2014)[5].

d. As mentioned above, another obstacle with use of EDGAR (2011) dataset is that the most recent data available are from 2010 for all emissions categories. At the moment, we do not know when the data in EDGAR will be updated to include 2011. Therefore, we use the existing data by extrapolating it to 2011 with the help of emissions growth approach presented below. As described above, 2011 emissions data are developed at the subcategory level. The data are then mapped into the GTAP Version 9 region and sector aggregation.

Emission Growth Approach

The emission growth approach offers to use the country, category, and GHG specific emission growth rates from year 2007 to 2010 to extrapolate the dataset from year 2010 to 2011. For that purpose, in the first step, we calculate the emissions growth rate from 2007 to 2010. In the second step, we apply the calculated emission growth rate to 2010 emissions data to obtain 2011 data. Thus, as the first step, the emission growth rate can be obtained by

$$gr(reg, cat, gas) = \left(\frac{E_{2010}(reg, cat, gas)}{E_{2007}(reg, cat, gas)}\right)^{1/3} - 1$$

where gr is the country, category, and GHG specific emission growth rate, and $reg, cat,$ and gas are the region, category and GHG sets, respectively. $E_i(reg, cat, gas)$ is the country, category, and GHG specific emissions level in year *i*. Thus, as the second step, the emissions data can be projected from 2010 to 2011 by

$$E_{2011}(reg, cat, gas) = [r(reg, cat, gas) + 1]^4 * E_{2007}(reg, cat, gas)$$

[5] 37 GTAP countries are not covered in the World Development Indicator (2014). For those countries, the world average annual GDP growth rate is used. The other two alternative to the world average would be regional average, and income level average GDP growth rates which are left for the future improvements.

3. Methodology for The FAOSTAT (2014) GHG Emissions Dataset

The data available in FAOSTAT (2014) GHG emissions dataset are used to estimate emissions for the agricultural activities. Similar to the methodology used for the EDGAR (2011) dataset, the first step is to map the Rose et al. (2010b) detailed emissions categories to emissions categories in FAOSTAT emissions dataset. This mapping is provided in Table 3. There are 8 top-level emissions categories with 54 subcategories. The fifth column of the table lists the related GHG emissions dataset within the FAOSTAT (2014). The FAOSTAT dataset provides emissions by both livestock and crop types. The sixth column of Table 3 represents the number of countries with nonzero data. The final column of Table 3 presents the mapping between the emissions subcategories and the GTAP Version 9 dataset's sector structure (57 sectors[6]). As described above, 2011 emissions data is developed at the subcategory level. The data are then mapped into the GTAP Version 9 region and sector aggregation.

The livestock related categories are "Livestock Enteric Fermentation CH_4", "Livestock Manure Management, both CH_4 and N_2O", and "Pasture, Range and Paddock N_2O" and these categories are disaggregated into twelve specific livestock categories. For the Enteric Fermentation and Manure Management categories, the data of each subcategory is obtained from the corresponding livestock data. The emissions data for the Pasture, Range, and Paddock category is obtained from aggregation of the FAO "Manure applied to Soil" and "Manure left on Pasture" emissions data. The agricultural soil emissions are disaggregated into cropland emissions and livestock related emissions from pasture, ranges, and paddocks.

The crop related categories in Version 9 dataset are "Biomass Burning, both CH_4 and N_2O", "Cropland Soils N_2O" and "Rice Cultivation CH_4". The emissions data for the Cropland Soils category is calculated from aggregation of the FAO "Synthetic Fertilizers" and "Cultivated Organic Soils" emissions data. The emissions data for the "Agricultural residue burning" subcategory of the "Biomass Burning" emissions category is obtained from the FAO "Burning Crop Residues" emissions data. The emissions data for the "Savanna burning" subcategory of the "Biomass Burning" emissions category is obtained from the FAO "Burning Savana" emissions data.

[6] See Table 5 for the list of GTAP sectors.

4. The Final Output

The GTAP Version 9 non-CO_2 GHG emissions dataset is provided in a header file with four headers (NCQO, NCQE, NCQF, and NCQP) each of which represents a source of emissions in the GTAP database. Table 4 illustrates the mapping between the 24 emission categories - 16 non-agricultural and 8 agricultural top-level emissions categories - and these four sources of emissions.

The available non-CO_2 emissions data in both EDGAR and FAOSTAT datasets are measured in gigagrams. In GTAP dataset, the data are provide in both gigagrams and million metric tons of CO_2 equivalent (M. ton CO2-e). Table 7 lists the global warming potentials (GWP)[7] used to convert the GHG emissions data collected from EDGAR and FAOSTAT datasets into CO_2-e.

a. Data on non-CO_2 emissions associated with output by industries (NCQO)

The header $NCQO(g,p,r)$ contains the data on non-CO_2 emissions associated with output by industries. The data are indexed by gas, industry, and region. The gas set ($g \in GHG\_COMM$) has three elements: CH_4, N_2O, and F-gas. The industry set ($p \in PROD\_COMM$) contains the standard 57 GTAP sectors[8] plus capital good industry (*CGDS*). The country set ($r \in REG$), which contains 140 regions, is an aggregation of the standard 244 GTAP countries.[9]

$$NCQO(g,p,r) = \begin{cases} CH4\_QO(t,r) & for\ g = CH_4 \ \ \&\ p = t \in TRAD\_COMM \\ N2O\_QO(t,r) & for\ g = N_2O \ \ \&\ p = t \in TRAD\_COMM \\ FGAS\_QO(t,r) & for\ g = FGAS\ \&\ p = t \in TRAD\_COMM \\ 0 & for\ p = "CGDS" \end{cases}$$

where

- $CH4\_QO(t,r) = \omega_{bbch\_agres}(t,r) * BBCH_{AGRES}(t,r) + \omega_{inch}(t,r) * INCH(t,r) + \omega_{olgs}(t,r) * OLGS(t,r) + COAL(t,r) + LNDF(t,r) + WWTR(t,r)$

- $N2O\_QO(t,r) = ADNI(t,r) + \omega_{bbn2\_agres}(t,r) * BBN2(t,r) + HUMS(t,r) + \omega_{inn2}(t,r) * INN2(t,r)$

[7] According to the USEPA, the global warming potential (GWP) represents how much a given mass of a chemical contributes to global warming over a given time period compared to the same mass of carbon dioxide. Carbon dioxide's GWP is defined as 1.

[8] See Table 5 for the description of the GTAP sectors.

[9] Table 6 provides the concordance between 140 regions and 244 countries.

- $FGAS\_QO(t,r) = ALUM(t,r) + ELTD(t,r) + HF22(t,r) + MAGN(t,r) + ODS(t,r) + SEMI(t,r)$

with $\omega_i(t,r)$ cost shares in which

$$\omega_i(t,r) = \frac{PRODUCTION_i(t,r)}{\sum_t PRODUCTION_i(t,r)}$$

$$for\ i \in \{bbch\_agres, bbn2\_agres, inn2, inch, olgs\}$$

b. Data on non-CO_2 emissions associated with endowment by industries (NCQE)

The header $NCQE(g,w,p,r)$ contains the data on non-CO_2 emissions associated with endowment by industries. The data in this header are indexed by gas ($g \in GHG\_COMM$), endowment ($w \in ENDW\_COMM$), industry ($p \in PROD\_COMM$), and region ($r \in REG$). The endowment set contains eight elements: land, capital, natural resources, and five types of labor endowments (technical and professional workers, clerks, service and shop floor workers, officers and managerial professionals, agricultural and other low skilled workers).[10]

$$NCQE(g,w,p,r) = \begin{cases} 0 & for\ \forall g \in GHG\_COMM, w \in ENDW\_COMM \backslash \{land, capital\} \\ CH4\_ENDW("land",t,r) & for\ g = CH_4\ \&\ w = land\ \&\ p = t \in TRAD\_COMM \\ CH4\_ENDW("capital",t,r) & for\ g = CH_4\ \&\ w = capital\ \&\ p = t \in TRAD\_COMM \\ N2O\_ENDW("land",t,r) & for\ g = N_2O\ \&\ w = land\ \&\ p = t \in TRAD\_COMM \\ N2O\_ENDW("capital",t,r) & for\ g = N_2O\ \&\ w = capital\ \&\ p = t \in TRAD\_COMM \\ FGAS\_ENDW("land",t,r) & for\ g = FGAS\ \&\ w = land\ \&\ p = t \in TRAD\_COMM \\ FGAS\_ENDW("capital",t,r) & for\ g = FGAS\ \&\ w = capital\ \&\ p = t \in TRAD\_COMM \\ 0 & for\ p = "CGDS" \end{cases}$$

where

- $CH4\_ENDW("land",t,r) = \omega_{bbch\_savan}(t,r) * BBCH_{SAVAN}(t,r) + \omega_{rice}(t,r) * RICE(t,r)$

[10] Since the unskilled labor, skilled labor, and natural resources are not associated with any kind of emissions, emission values for those elements are zero.

- $CH4\_ENDW("capital", t, r) = \omega_{efrm}(t,r) * EFRM(t,r) + \omega_{mnch}(t,r) * MNCH(t,r)$
- $N2O\_ENDW("land", t, r) = \omega_{bbn2\_savan}(t,r) * BBN2(t,r)$
- $N2O\_ENDW("capital", t, r) = \omega_{mnn2}(t,r) * MNN2(t,r) + \omega_{prpd}(t,r) * PRPD(t,r)$
- $FGAS\_ENDW("land", t, r) = FGAS\_ENDW("capital", t, r) = 0$

with $\omega_j(t,r)$ land input shares

$$\omega_j(t,r) = \frac{LAND_j(t,r)}{\sum_t LAND_j(t,r)} \qquad for\ j \in \{bbch\_savan, bbn2\_savan, rice\}$$

and $\omega_k(t,r)$ capital input shares

$$\omega_k(t,r) = \frac{CAPITAL_k(t,r)}{\sum_t CAPITAL_k(t,r)} \qquad for\ k \in \{efrm, mnch, mnn2, prpd\}$$

c. Data on non-CO_2 emissions associated with input use by industries (NCQF)

The data in header $NCQF(g,t,p,r)$ are indexed by gas ($g \in GHG\_COMM$), flow ($t \in TRAD\_COMM$), industry ($p \in PROD\_COMM$), and region ($r \in REG$). The flow set contains the standard 57 GTAP sectors. The header NCQF provides data on non-CO_2 emissions associated with input use by industries.

$$NCQF(g,t,p,r) = \begin{cases} CH4\_TRAD(t,t,r) & for\ g = CH_4\ \&\ p = t \in TRAD\_COMM \\ N2O\_TRAD(t,t,r) & for\ g = N_2O\ \&\ p = t \in TRAD\_COMM \\ FGAS\_TRAD(t,t,r) & for\ g = FGAS\ \&\ p = t \in TRAD\_COMM \\ 0 & for\ p = "CGDS" \end{cases}$$

where

- $CH4\_TRAD(t,t,r) = \begin{cases} 0 & for\ f \notin FOSSILFUEL \\ \omega_{smch}(f,t,r) * SMCH(t,r) & for\ f \in FOSSILFUEL \end{cases}$
- $N2O\_TRAD(t,t,r) =$

$$\begin{cases} 0 & for\ f \notin FOSSILFUEL\ and\ f \notin FERTILIZER \\ N2O\_TRAD\_FF(f,t,r) + N2O\_TRAD\_Z(z,t,r) & for\ f \in FOSSILFUEL, z \in FERTILIZER \end{cases}$$

  - $N2O\_TRAD\_FF(f,t,r) = \omega_{smn2}(f,t,r) * SMN2(t,r)$

- $N2O\_TRAD\_Z(z,t,r) = \omega_{soil}(t,r) * SOIL(t,r)$

- $FGAS\_TRAD(t,t,r) = 0$

with $\omega_s(f,t,r)$ fossil fuel input share used by firms

$$\omega_s(f,t,r) = \frac{EVOLUME_s(f,t,r)}{\sum_e \sum_t EVOLUME_s(f,t,r)} \qquad for\ s \in \{smch, smn2\}$$

and $\omega_{soil}(t,r)$ fertilizer input share used by firms

$$\omega_{soil}(t,r) = \frac{FERT\_USE(t,r)}{\sum_t FERT\_USE(t,r)}$$

d. Data on non-CO_2 emissions associated with input use by households (NCQP)

The header $NCQP(g,t,"HH",r)$ provides data on non-CO_2 emissions associated with input use by households. The data are indexed by gas ($g \in GHG\_COMM$), flow ($t \in TRAD\_COMM$), and region ($r \in REG$).

$$NCQP(g,t,"HH"r) = \begin{cases} CH4\_HH(t,r) & for\ g = CH_4 \\ N2O\_HH(t,r) & for\ g = N_2O \\ FGAS\_HH(t,r) & for\ g = FGAS \end{cases}$$

where

- $CH4\_HH(t,r) = \begin{cases} 0 & for\ f \notin FOSSILFUEL \\ \omega_{smch}(f,"HH",r) * SMCH(t,r) & for\ f \in FOSSILFUEL \end{cases}$

- $N2O\_HH(t,r) = \begin{cases} 0 & for\ f \notin FOSSILFUEL \\ \omega_{smn2}(f,"HH",r) * SMN2(t,r) & for\ f \in FOSSILFUEL \end{cases}$

- $FGAS\_HH(t,"HH",r) = 0$

with $\omega_s(f,"HH",r)$ fossil fuel input share used by households

$$\omega_s(f,"HH",r) = \frac{EVOLUME_s(f,"HH",r)}{\sum_e \sum_t EVOLUME_s(f,"HH",r)} \qquad for\ s \in \{smch, smn2\}$$

5. Results

In this Version 9 dataset, total global emissions of non-CO_2 greenhouse gases are 12,765 M. ton CO_2-e in 2011, with methane (CH_4) accounting for 69%, nitrous oxide (N_2O) accounting for 25% and F-gases accounting for 5% of total emissions (Figure 1). In the GTAP dataset, non-CO_2 emissions are associated with four classes of economic drivers: output, primary factors (land, labor and capital), intermediate inputs (e.g., fertilizers), and household consumption. Figure 2 shows that the main driver of global non-CO_2 emissions is output related emissions (40%). It is followed by the primary factor use related emissions with 33%. The share of global non-CO_2 emissions related to intermediate input use by industries and households are 22% and 5%, respectively.

Figure 3 shows that agriculture accounts for 44% of global non-CO_2 emissions. Figures 4, 5, and 6 depict sector emissions for each gas group by GTAP sector. In the case of nitrous oxide (N_2O), the dominant sources of emissions are the agricultural sectors, with beef cattle (26%) and fruits and vegetables (10%) leading the way. In the case of methane emissions (CH_4), beef cattle (20%) and other government services (e.g., landfills) lead the way (20%), followed by fugitives from coal mining activities (15%). Figure 5 shows that emissions of F-gases are confined to three manufacturing sectors in GTAP (crp, nfm, ele), along with electricity production and distribution (ely).

Figure 7 presents the top ten non-CO_2 emitting regions. China is the most emitting region by far with 21%. It is followed by India and the US with 10% and 8%, respectively. The top three N_2O emitting regions are China (19%), India (10%) and the US (10%). The top four CH_4 emitting regions are China, India, Russia and the US with 21%, 10%, 7%, and 6% respectively. For F-gases, China, and the US are the largest emitters with 27%, and 23%, respectively.

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Table 1 – Description of IPCC codes of the data in EDGAR Version 4.2 (2011)

IPCC	Description
1A1a	power plants
1A1bc	other transformation of solid fuel and energy carriers
1A2	industrial combustion for manufacturing
1A2b	road transport
1A3a	domestic aviation
1A3c	railway
1A3d	inland waterway
1A3e	non-road other transport
1A4	heating/cooling/electrical equipment of buildings
1B1	coal mining and solid fuel transformation
1B2	oil and gas production
2B	process emissions of chemical industry
2C	process emissions of iron & steel industry
2C3	process emissions of primary aluminum production
2C4	process emissions of SF6 used in aluminum production process emissions of SF6 used in magnesium foundries
2E	Byproduct emissions of production of halocarbons and sulphur hexafluoride
2F1a	Consumption of halocarbons and sulphur hexafluoride: refrigerator and air conditioning
2F2	Consumption of halocarbons and sulphur hexafluoride: foam blowing
2F3	Consumption of halocarbons and sulphur hexafluoride: fire extinguishers
2F4	Consumption of halocarbons and sulphur hexafluoride: aerosols
2F7a	Consumption of halocarbons: semiconductors manufacturing
2F7b	Consumption of halocarbons: flat panel display production
2F7c	Consumption of halocarbons: photovoltaic cells manufacturing
2F8	Consumption of halocarbons: electrical equipment
2F8b	Consumption of halocarbons: electrical equipment use
2F9	Other F-gas use and SF6
2F9a	Other F-gas use and SF6 : adiabatic prop: shoes and others
2F9b	Other F-gas use and SF6 : adiabatic prop: tyres
2F9c	Other F-gas use and SF6 : sound proof windows
2F9d	Other F-gas use and SF6 : accelerators
2F9e	Other F-gas use and SF6 : AWACS, other military, misc.
2F9f	Other F-gas use and SF6 : unknown SF6 use
3D	solvent and product use (non-specified)
4A	enteric fermentation of cattle
4B	manure management of cattle
4C	rice cultivation
4D	direct agricultural soil emissions (fertilizers, manure, crop residues)
4D3	indirect emissions from agriculture (leaching and run-off)

Table 1 – Description of IPCC codes of the data in EDGAR Version 4.2 (2011) (cont'd)

IPCC	Description
4E	Savannah burning
4F	field burning of agricultural residues
5A	Forest fires
5C	Grassland fires
5D	Wetland/peat fires and decay
5F2	Forest fires decay
6A	solid waste disposal in landfills
6B	waste water treatment
6C	waste incineration
6D	other solid waste disposal (hazardous, compost)
7A	fossil fuel fires: coal (underground) and oil (Kuwait)
7B	Indirect N2O from non-agricultural NOx (emitted in cat. 1A4 - res.) Indirect N2O from non-agricultural NOx (emitted in cat. 1A2 -ind. comb.) Indirect N2O from non-agricultural NOx (emitted in cat. 1A3 - transport) Indirect N2O from non-agricultural NOx (emitted in cat. 1A1 -PP) Indirect N2O from non-agricultural NOx (emitted in cat. 5 - forest fires)
7C	Indirect N2O from non-agricultural NH3 (emitted in cat. 1A2 - ind.comb.) Indirect N2O from non-agricultural NH3 (emitted in cat. 1A3 - transport) Indirect N2O from non-agricultural NH3 (emitted in cat. 5 - forest fires) Indirect N2O from non-agricultural NH3 (emitted in cat. 1A4 - res.) Indirect N2O from non-agricultural NH3 (emitted in cat. 1A1 - PP)

Table 2 - Emissions Categories and Their Subcategories for the data from EDGAR Version 4.2 (2011)

Category Code	Category	Subcategory Code	Subcategory	IPCC Code	# countries	GTAP sector
ADNI	Adipic Acid and Nitric Acid Production N_2O	ADIPAC	Adipic acid production	2B	70	crp
		ADIPNIT	Adipic acid and nitric acid production (combined)			crp
		NITACID	Nitric acid production			crp
ALUM	Aluminum Production CF_4	ALUM	Aluminum production	2C3	49	nfm
COAL	Fugitives from Coal Mining Activities CH_4	MPM_COAL_SC	Fugitives from coal mining activities	1B1	205	col
ELTD	Electrical Transmission and Distribution SF_6	ELTD	Electrical transmission and distribution	2F7a	21	ely
				2F7b		
				2F7c		
HF22	HCFC-22 Production HFC-23	HF22	HCFC-22 production	2E	20	crp
HUMS	Human Sewage N_2O	HUMS	Human Sewage	6B	191	osg
INCH	Other Industrial Non-Agricultural Sources CH_4	ALLMTL	Metal production listed under "other"	2C	60	i_s, nfm
		ALMNFER	Aluminum production	2C	60	nfm
		CHMIND	Chemical industry	2B	72	crp
		IRNSTL	Ferroalloys production and iron and steel production	2C	60	i_s
		MINPROD	Mineral production	N/A	*	nmm
		OTHER	Other (not specified)	N/A	*	omf, ppp
INN2	Other Industrial Non-Agricultural Sources N_2O	CHMIND	Chemical industry	2B	70	crp
		IRNSTL	Ferroalloys production and iron and steel production	2C	**	i_s
		OTHER	Other (not specified)	N/A	*	omf, ppp
LNDF	Landfilling of Solid Waste CH_4	LNDF	Landfilling of solid waste	6A	217	osg
MAGN	Magnesium Manufacturing SF6	MAGN	Magnesium manufacturing	2C4	33	nfm

Table 2 - Emissions Categories and Their Subcategories for the data from EDGAR Version 4.2 (2011) (cont'd)

Category Code	Category	Subcategory Code	Subcategory	IPCC Code	# countries	GTAP sector
ODS	ODS Substitutes HFC-134a	AEROMDI	Aerosols (MDI)	2F4	64	crp
		AERONON	Aerosols (Non-MDI)	2F4	64	crp
		FIREXT	Fire extinguishing	2F3	**	crp
		FOAM	Foams	2F2	63	crp
		REFAC	Refrigeration/AC	2F1	63	ele
		SOLV	Solvents	N/A	N/A	crp
OLGS	Fugitives from Oil and Natural Gas Systems CH_4	NATGAS_DIST	Natural gas - distribution	1B2	232	gdt
		NATGAS_EXP	Natural gas - exploration			gas
		NATGAS_FLR	Natural gas - flaring			gas
		NATGAS_LK	Natural gas - leakage			gdt
		NATGAS_LKIND	Natural gas - leakage at industrial plants and power stations			gdt
		NATGAS_LKRES	Natural gas - leakage at residential and commercial sectors			gdt
		NATGAS_PROD	Natural gas - production/processing			gdt, gas
		NATGAS_TRANS	Natural gas - transmission			otp
		NATGAS_VNT	Natural gas - venting			gas
		OIL_DIS	Oil - distribution of products			p_c
		OIL_EXP	Oil - exploration			oil
		OIL_FLR	Oil - flaring			oil
		OIL_OTH	Oil - other			oil
		OIL_PROD	Oil - production			oil
		OIL_REF	Oil - refining and storage			p_c
		OIL_TRANS	Oil - transport			otp
		OIL_VNT	Oil - venting			oil
		OILGAS	Fugitives from Oil and Natural Gas Systems			gdt, oil,gas, p_c, otp
		OILGAS_FLR	Oil & Natural Gas - flaring			oil, gas
		OILGAS_VNT	Oil & Natural Gas - venting			oil, gas

Table 2 - Emissions Categories and Their Subcategories for the data from EDGAR Version 4.2 (2011) (cont'd)

Category Code	Category	Subcategory Code	Subcategory	IPCC Code	# countries	GTAP sector
SEMI	Semiconductor Production CF_4	SEMI	Semiconductor production	2F7a 2F7b 2F7c	28	ele
SMCH	Stationary and Mobile Combustion CH_4	STATMOB	Combined stationary and mobile combustion	all 1A's	223	all GTAP sectors except "dwe"
		STM_AG	Stationary and mobile combustion – other sectors agriculture	1A4	223	pdr, wht, gro, v_f, osd, c_b, pfb, ocr, ctl, oap, rmk, wol, frs, fsh
		STM_CPS	Stationary combustion – commercial and public services	1A4	223	wtr, trd, cmn, ofi, isr, obs, ros, osg
		STM_EN	Stationary combustion – energy industries	1A1a, 1A1bc	201	coa, oil, gas, p_c, ely, gdt
		STM_IND	Stationary combustion – total Industry sector	1A2	205	omn, cmt, omt, vol, mil, pcr, sgr, ofd, b_t, tex, wap, lea, lum, ppp, crp, nmm, i_s, nfm, fmp, mvh, otn, ele, ome, omf, cns
		STM_MO	Mobile combustion – total transport sector	1A3's	182	otp, wtp, atp
		STM_OTH	Stationary and mobile combustion – other sectors	1A4	223	pdr, wht, gro, v_f, osd, c_b, pfb, ocr, ctl, oap, rmk, wol, frs, fsh, wtr, trd, cmn, ofi, isr, obs, ros, osg, HH
		STM_RES	Stationary combustion – residential	1A4	223	HH
		STM_UNSOTH	Other (not specified)	all 1A's	223	osg

Table 2 - Emissions Categories and Their Subcategories for the data from EDGAR Version 4.2 (2011) (cont'd)

Category Code	Category	Subcategory Code	Subcategory	IPCC Code	# countries	GTAP sector
SMN2	Stationary and Mobile Combustion N_2O	STATMOB	Combined stationary and mobile combustion	all 1A's	223	----
		STM_AG	Stationary and mobile combustion – other sectors agriculture	1A4	223	pdr, wht, gro, v_f, osd, c_b, pfb, ocr, ctl, oap, rmk, wol, frs, fsh
		STM_CPS	Stationary combustion – commercial and public services	1A4	223	wtr, trd, cmn, ofi, isr, obs, ros, osg
		STM_EN	Stationary combustion – energy industries	1A1a, 1A1bc	201	coa, oil, gas, p_c, ely, gdt
		STM_IND	Stationary combustion – total Industry sector	1A2	223	omn, cmt, omt, vol, mil, pcr, sgr, ofd, b_t, tex, wap, lea, lum, ppp, crp, nmm, i_s, nfm, fmp, mvh, otn, ele, ome, omf, cns
		STM_MO	Mobile combustion – total transport sector	1A3's	182	otp, wtp, atp
		STM_OTH	Stationary and mobile combustion – other sectors	1A4	223	pdr, wht, gro, v_f, osd, c_b, pfb, ocr, ctl, oap, rmk, wol, frs, fsh, wtr, trd, cmn, ofi, isr, obs, ros, osg, HH
		STM_RES	Stationary combustion – residential	1A4	223	HH
		STM_UNSOTH	Other (not specified)	all 1A's	223	osg
WWTR	Wastewater Treatment CH_4	WWTR	Wastewater treatment	6B	223	osg

* There are no data with that IPCC code in the EDGAR dataset. Thus, the data are obtained from the GTAP Version 6 non-CO2 dataset by extrapolating the dataset from 2001 to 2011 with the help of GDP growth approach.

** Data with that IPCC code seem to exist in the EDGAR dataset but the set is empty. Thus, the data are obtained from the GTAP Version 6 non-CO2 dataset by extrapolating the dataset from 2001 to 2011 with the help of GDP growth approach.

Table 3 - Emissions Categories and Their Subcategories for the data from FAOSTAT (2014) GHG emissions dataset

Category Code	Category	Subcategory Code	Subcategory	Data in FAO	# countries	GTAP sector
BBCH	Biomass Burning CH_4	AGRES	Agricultural residue burning	Burning Crop Residues	212	pdr, wht, gro, v_f, osd, c_b, pfb, ocr
		SAVAN	Savanna burning	Burning Savana		ctl
BBN2	Biomass Burning N_2O	AGRES	Agricultural residue burning	Burning Crop Residues	212	pdr, wht, gro, v_f, osd, c_b, pfb, ocr
		SAVAN	Savanna burning	Burning Savana		ctl
EFRM	Livestock Enteric Fermentation CH_4	BUFFALO	Buffaloes	Enteric Fermentation	215	ctl
		CAMEL_LLAMA	Camels and Llamas (Total)			ctl
		DAIRY_CATTLE	Cattle, dairy			rmk
		GOAT	Goats			ctl
		HORSE	Horses			ctl
		MULE_ASS	Mules and Assses (Total)			ctl
		NONDAIRY_CTL	Cattle, Non-dairy			ctl
		OTHER	All Animals (Total)			oap
		POULTRY	Poultry Birds (Total)			oap
		SHEEP_LAMB	Sheep			ctl
		SWINE	Swine, breeding and Swine, market (Total)			oap
		UKNOWN	All Animals (Total)			ctl, oap, rmk
MNCH	Livestock Manure Management CH_4	BUFFALO	Buffaloes	Manure Management	217	ctl
		CAMEL_LLAMA	Camels and Llamas (Total)			ctl
		DAIRY_CATTLE	Cattle, dairy			rmk
		GOAT	Goats			ctl
		HORSE	Horses			ctl
		MULE_ASS	Mules and Assses (Total)			ctl
		NONDAIRY_CTL	Cattle, Non-dairy			ctl
		OTHER	All Animals (Total)			oap
		POULTRY	Poultry Birds (Total)			oap
		SHEEP_LAMB	Sheep			ctl
		SWINE	Swine, breeding and Swine, market (Total)			oap
		UKNOWN	All Animals (Total)			ctl, oap, rmk

Table 3 - Emissions Categories and Their Subcategories for the data from FAOSTAT (2014) GHG emissions dataset (cont'd)

Category Code	Category	Subcategory Code	Subcategory	Data in FAO	# countries	GTAP sector
MNN2	Livestock Manure Management N_2O	BUFFALO	Buffaloes	Manure Management	217	ctl
		CAMEL_LLAMA	Camels and Llamas (Total)			ctl
		DAIRY_CATTLE	Cattle, dairy			rmk
		GOAT	Goats			ctl
		HORSE	Horses			ctl
		MULE_ASS	Mules and Assses (Total)			ctl
		NONDAIRY_CTL	Cattle, Non-dairy			ctl
		OTHER	All Animals (Total)			oap
		POULTRY	Poultry Birds (Total)			oap
		SHEEP_LAMB	Sheep			ctl
		SWINE	Swine, breeding and Swine, market (Total)			oap
		UKNOWN	All Animals (Total)			ctl, oap, rmk
PRPD	Pasture, Range, and Paddock N_2O	BUFFALO	Buffaloes	Manure applied to Soil & Manure left on Pasture	217	ctl
		CAMEL_LLAMA	Camels and Llamas (Total)			------
		DAIRY_CATTLE	Cattle, dairy			rmk
		GOAT	Goats			ctl
		HORSE	Horses			ctl
		MULE_ASS	Mules and Assses (Total)			ctl
		NONDAIRY_CTL	Cattle, Non-dairy			ctl
		OTHER	All Animals (Total)			oap
		POULTRY	Poultry Birds (Total)			oap
		SHEEP_LAMB	Sheep			ctl
		SWINE	Swine, breeding and Swine, market (Total)			oap
		UKNOWN	All Animals (Total)			ctl, oap, rmk
RICE	Rice Cultivation CH_4	MPM_RICE_SC	Rice Cultivation	Rice Cultivation	122	pdr
SOIL	Cropland Soils N_2O	SOIL	Cropland Soils	Synthetic Fertilizer & Cultivated Organic Soil	233	pdr, wht, gro, v_f, osd, c_b, pfb, ocr, ctl, oap, rmk

Table 4 – Mapping of 24 Emissions Categories into 4 GTAP Emissions Sources

	Output by Industries	Endowment by Industries		Input use by Industries	Input use by Households
		Land	Capital		
CH_4	BBCH_AGRES	BBCH_SAVAN	EFRM	SMCH	SMCH
	COAL	RICE	MNCH		
	INCH				
	LNDF				
	OLGS				
	WWTR				
N_2O	ADNI	BBN2_SAVAN	MNN2	SMN2	SOIL
	BBN2_AGRES		PRPD		
	HUMS				
	INN2				
F-gas	ALUM				
	ELTD				
	HF22				
	MAGN				
	ODS				
	SEMI				

Table 5 – Standard GTAP Sectors

	Code	Description
1	PDR	Paddy rice
2	WHT	Wheat
3	GRO	Cereal grains nec
4	V_F	Vegetables, fruit, nuts
5	OSD	Oil seeds
6	C_B	Sugar cane, sugar beet
7	PFB	Plant-based fibers
8	OCR	Crops nec
9	CTL	Bovine cattle, sheep and goats, horses
10	OAP	Animal products nec
11	RMK	Raw milk
12	WOL	Wool, silk-worm cocoons
13	FRS	Forestry
14	FSH	Fishing
15	COA	Coal
16	OIL	Oil
17	GAS	Gas
18	OMN	Minerals nec
19	CMT	Bovine meat products
20	OMT	Meat products nec
21	VOL	Vegetable oils and fats
22	MIL	Dairy products
23	PCR	Processed rice
24	SGR	Sugar
25	OFD	Food products nec
26	B_T	Beverages and tobacco products
27	TEX	Textiles
28	WAP	Wearing apparel
29	LEA	Leather products
30	LUM	Wood products
31	PPP	Paper products, publishing
32	P_C	Petroleum, coal products
33	CRP	Chemical, rubber, plastic products
34	NMM	Mineral products nec
35	I_S	Ferrous metals
36	NFM	Metals nec
37	FMP	Metal products
38	MVH	Motor vehicles and parts
39	OTN	Transport equipment nec

Table 5 – Standard GTAP Sectors (cont'd)

	Code	Description
40	ELE	Electronic equipment
41	OME	Machinery and equipment nec
42	OMF	Manufactures nec
43	ELY	Electricity
44	GDT	Gas manufacture, distribution
45	WTR	Water
46	CNS	Construction
47	TRD	Trade
48	OTP	Transport nec
49	WTP	Water transport
50	ATP	Air transport
51	CMN	Communication
52	OFI	Financial services nec
53	ISR	Insurance
54	OBS	Business services nec
55	ROS	Recreational and other services
56	OSG	Public Administration, Defense, Education, Health
57	DWE	Dwellings

Table 6 – List of Regions in Version 9 non-CO_2 Emissions Dataset

Number	GTAP Code	Description
1	AUS	Australia - Australia - Christmas Island - Cocos (Keeling) Islands - Heard Island and McDonald Islands - Norfolk Island
2	NZL	New Zealand
3	XOC	Rest of Oceania - American Samoa - Cook Islands - Fiji - French Polynesia - Guam - Kiribati - Marshall Islands - Micronesia Federated States of - Nauru - New Caledonia - Niue - Northern Mariana Islands - Palau - Papua New Guinea - Pitcairn - Samoa - Solomon Islands - Tokelau - Tonga - Tuvalu - United States Minor Outlying Islands - Vanuatu - Wallis and Futuna
4	CHN	China
5	HKG	Hong Kong
6	JPN	Japan
7	KOR	Korea Republic of
8	MNG	Mongolia
9	TWN	Taiwan
10	XEA	Rest of East Asia - Korea Democratic Peoples Republic of - Macao
11	BRN	Brunei Darussalam

Table 6 – List of Regions in Version 9 non-CO_2 Emissions Dataset (cont'd)

Number	GTAP Code	Description
12	KHM	Cambodia
13	IDN	Indonesia
14	LAO	Lao People's Democratic Republic
15	MYS	Malaysia
16	PHL	Philippines
17	SGP	Singapore
18	THA	Thailand
19	VNM	Viet Nam
20	XSE	Rest of Southeast Asia - Myanmar - Timor Leste
21	BGD	Bangladesh
22	IND	India
23	NPL	Nepal
24	PAK	Pakistan
25	LKA	Sri Lanka
26	XSA	Rest of South Asia - Afghanistan - Bhutan - Maldives
27	CAN	Canada
28	USA	United States of America
29	MEX	Mexico
30	XNA	Rest of North America - Bermuda - Greenland - Saint Pierre and Miquelon
31	ARG	Argentina
32	BOL	Bolivia
33	BRA	Brazil
34	CHL	Chile
35	COL	Colombia
36	ECU	Ecuador
37	PRY	Paraguay
38	PER	Peru
39	URY	Uruguay
40	VEN	Venezuela

Table 6 – List of Regions in Version 9 non-CO_2 Emissions Dataset (cont'd)

Number	GTAP Code	Description
41	XSM	Rest of South America - Falkland Islands (Malvinas) - French Guiana - Guyana - South Georgia and the South Sandwich Islands - Suriname
42	CRI	Costa Rica
43	GTM	Guatemala
44	HND	Honduras
45	NIC	Nicaragua
46	PAN	Panama
47	SLV	El Salvador
48	XCA	Rest of Central America - Belize
49	DOM	Dominican Republic
50	JAM	Jamaica
51	PRI	Puerto Rico
52	TTO	Trinidad and Tobago
53	XCB	Caribbean - Anguilla - Antigua & Barbuda - Aruba - Bahamas - Barbados - Cayman Islands - Cuba - Dominica - Grenada - Haiti - Montserrat - Netherlands Antilles - Saint Kitts and Nevis - Saint Lucia - Saint Vincent and the Grenadines - Turks and Caicos Islands - Virgin Islands British - Virgin Islands U.S.
54	AUT	Austria
55	BEL	Belgium
56	CYP	Cyprus
57	CZE	Czech Republic

Table 6 – List of Regions in Version 9 non-CO_2 Emissions Dataset (cont'd)

Number	GTAP Code	Description
58	DNK	Denmark
59	EST	Estonia
60	FIN	Finland
		- Aland Islands
		- Finland
61	FRA	France
		- France
		- Guadeloupe
		- Martinique
		- Reunion
62	DEU	Germany
63	GRC	Greece
64	HUN	Hungary
65	IRL	Ireland
66	ITA	Italy
67	LVA	Latvia
68	LTU	Lithuania
69	LUX	Luxembourg
70	MLT	Malta
71	NLD	Netherlands
72	POL	Poland
73	PRT	Portugal
74	SVK	Slovakia
75	SVN	Slovenia
76	ESP	Spain
77	SWE	Sweden
78	GBR	United Kingdom
79	CHE	Switzerland
80	NOR	Norway
		- Norway
		- Svalbard and Jan Mayen
81	XEF	Rest of EFTA
		- Iceland
		- Liechtenstein
82	ALB	Albania
83	BGR	Bulgaria
84	BLR	Belarus
85	HRV	Croatia
86	ROU	Romania
87	RUS	Russian Federation
88	UKR	Ukraine

Table 6 – List of Regions in Version 9 non-CO_2 Emissions Dataset (cont'd)

Number	GTAP Code	Description
89	XEE	Rest of Eastern Europe - Moldova Republic of
90	XER	Rest of Europe - Andorra - Bosnia and Herzegovina - Faroe Islands - Gibraltar - Guernsey - Holy See (Vatican City State) - Isle of Man - Jersey - Macedonia the former Yugoslav Republic of - Monaco - Montenegro - San Marino - Serbia
91	KAZ	Kazakhstan
92	KGZ	Kyrgyzstan
93	XSU	Rest of Former Soviet Union - Tajikistan - Turkmenistan - Uzbekistan
94	ARM	Armenia
95	AZE	Azerbaijan
96	GEO	Georgia
97	BHR	Bahrain
98	IRN	Iran Islamic Republic of
99	ISR	Israel
100	JOR	Jordan
101	KWT	Kuwait
102	OMN	Oman
103	QAT	Qatar
104	SAU	Saudi Arabia
105	TUR	Turkey
106	ARE	United Arab Emirates
107	XWS	Rest of Western Asia - Iraq - Lebanon - Palestinian Territory Occupied - Syrian Arab Republic - Yemen

Table 6 – List of Regions in Version 9 non-CO_2 Emissions Dataset (cont'd)

Number	GTAP Code	Description
108	EGY	Egypt
109	MAR	Morocco
110	TUN	Tunisia
111	XNF	Rest of North Africa - Algeria - Libyan Arab Jamahiriya - Western Sahara
112	BEN	Benin
113	BFA	Burkina Faso
114	CMR	Cameroon
115	CIV	Cote d'Ivoire
116	GHA	Ghana
117	GIN	Guinea
118	NGA	Nigeria
119	SEN	Senegal
120	TGO	Togo
121	XWF	Rest of Western Africa - Cape Verde - Gambia - Guinea-Bissau - Liberia - Mali - Mauritania - Niger - Saint Helena, ASCENSION AND TRISTAN DA CUNHA - Sierra Leone
122	XCF	Central Africa - Central African Republic - Chad - Congo - Equatorial Guinea - Gabon - Sao Tome and Principe
123	XAC	South Central Africa - Angola - Congo the Democratic Republic of the
124	ETH	Ethiopia
125	KEN	Kenya
126	MDG	Madagascar
127	MWI	Malawi
128	MUS	Mauritius

Table 6 – List of Regions in Version 9 non-CO_2 Emissions Dataset (cont'd)

Number	GTAP Code	Description
129	MOZ	Mozambique
130	RWA	Rwanda
131	TZA	Tanzania United Republic of
132	UGA	Uganda
133	ZMB	Zambia
134	ZWE	Zimbabwe
135	XEC	Rest of Eastern Africa - Burundi - Comoros - Djibouti - Eritrea - Mayotte - Seychelles - Somalia - Sudan
136	BWA	Botswana
137	NAM	Namibia
138	ZAF	South Africa
139	XSC	Rest of South African Customs Union - Lesotho - Swaziland
140	XTW	Rest of the World

Table 7 – Global Warming Potentials (GWP) of non-CO_2 Emissions

Chemical		GWP
	CO_2	1
	CH_4	21
	N_2O	310
F-gas	CF_4	6500
	SF_6	23900
	HFC-22	11700
	HFC-134a	1300

Resource: UNFCCC (http://unfccc.int/ghg_data/items/3825.php)

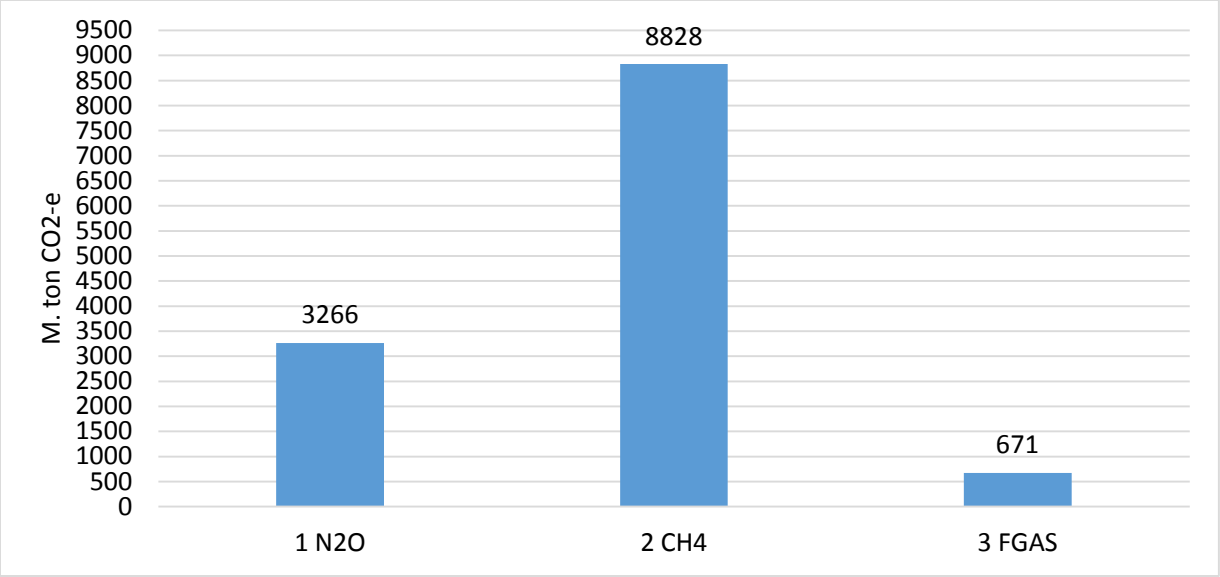

Figure 1: Total non-CO_2 Emissions by Gas (M. ton CO2-e)

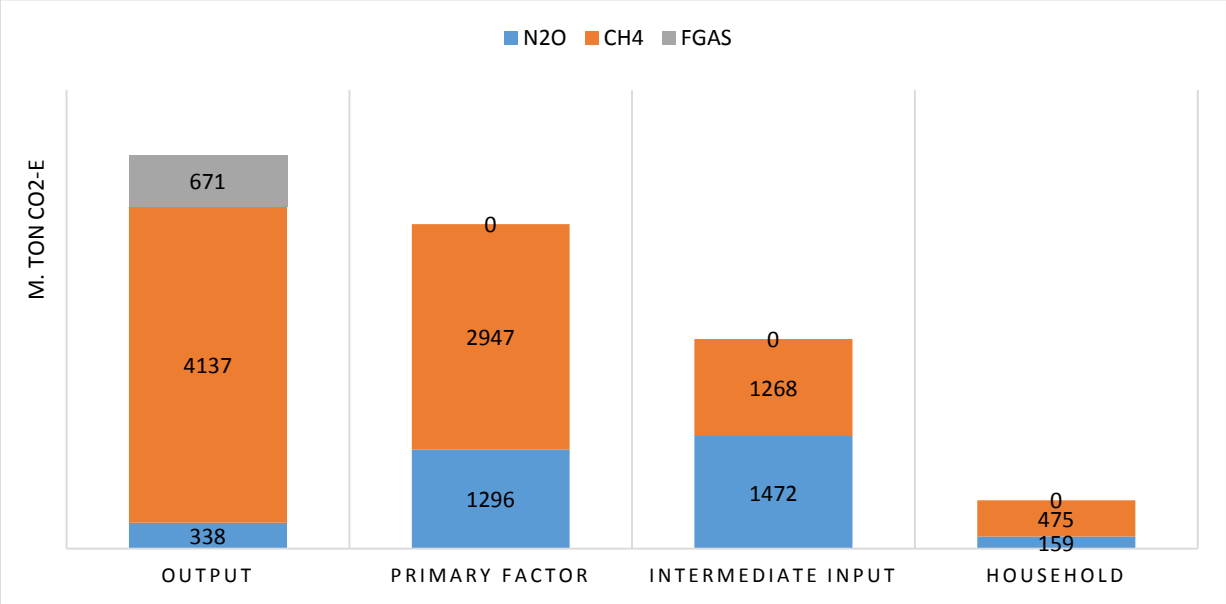

Figure 2: Global non-CO_2 Emission by Economic Driver (M. ton CO2-e)

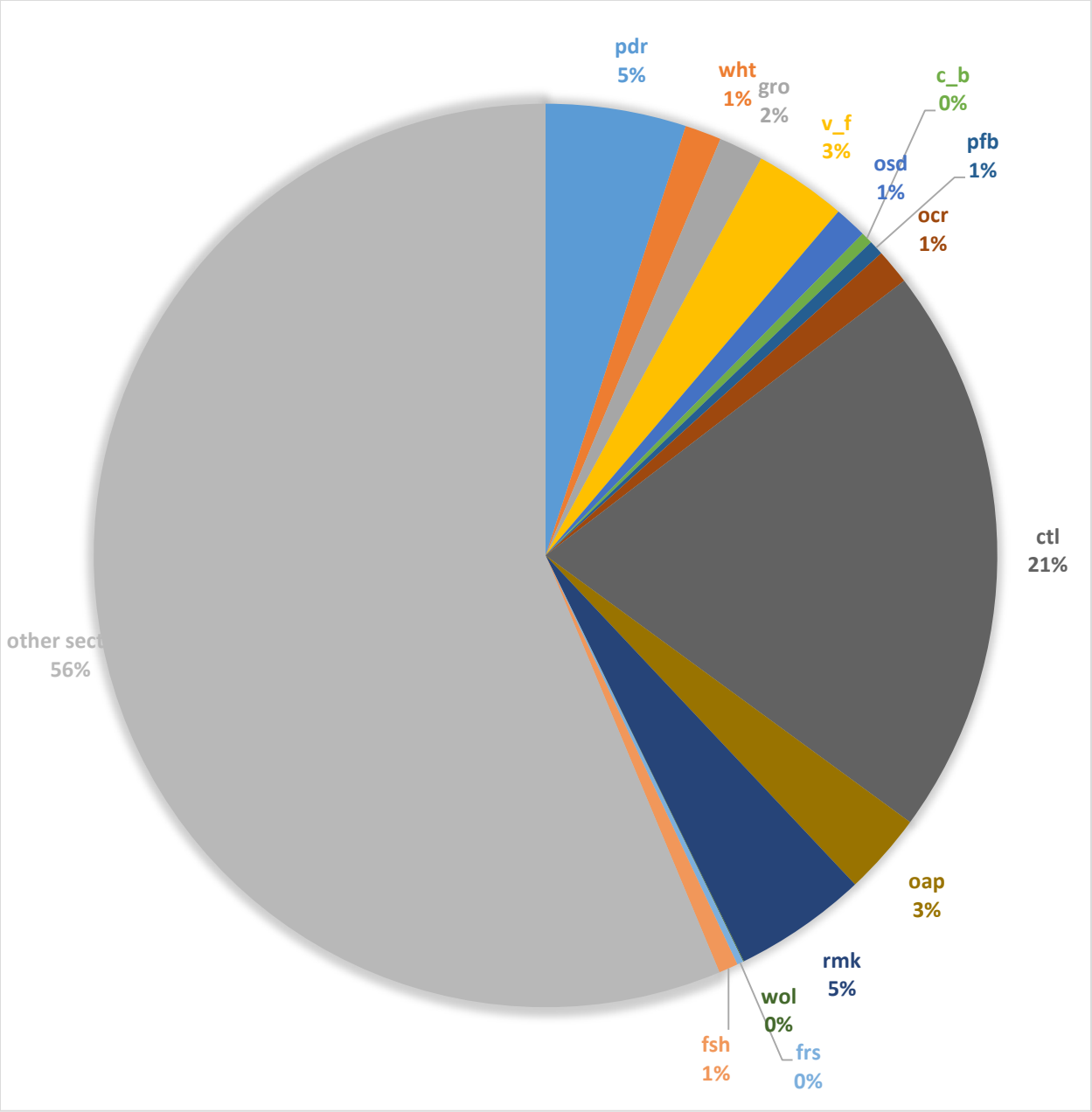

Figure 3: Global non-CO_2 Emissions by GTAP Agricultural Sectors (%)

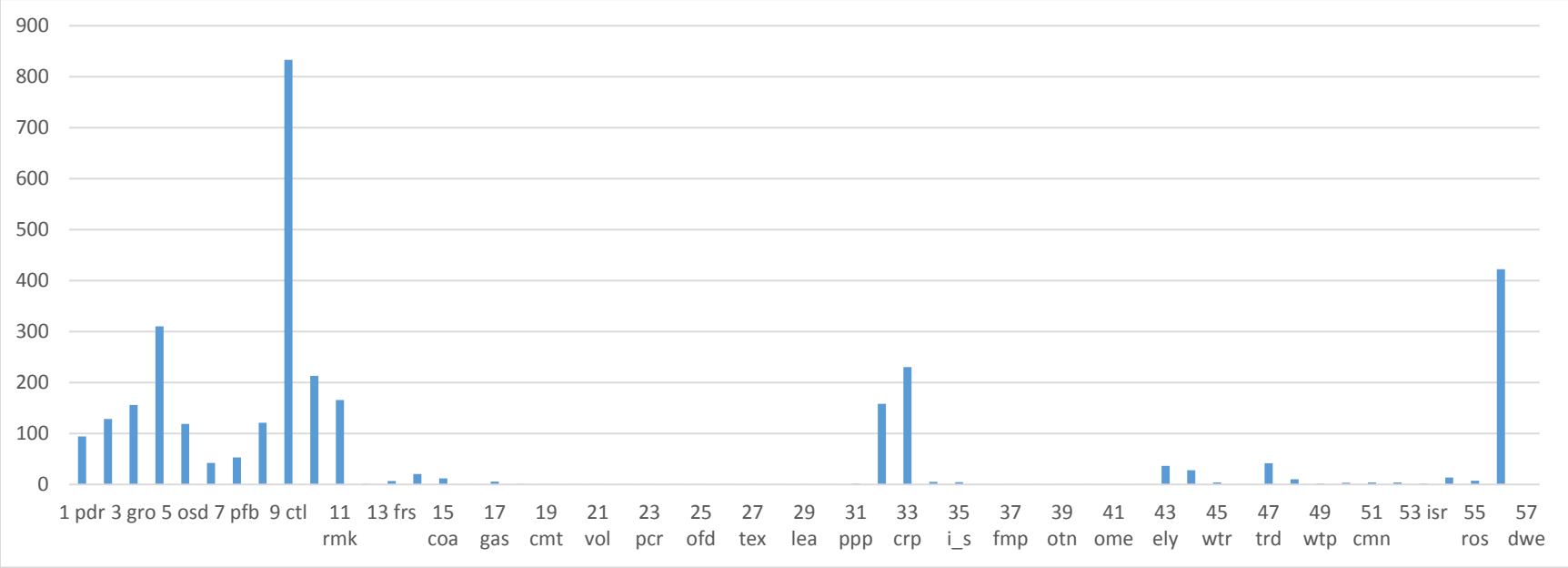

Figure 4: Global N_2O Emissions by GTAP Sector (M. ton CO2-e)

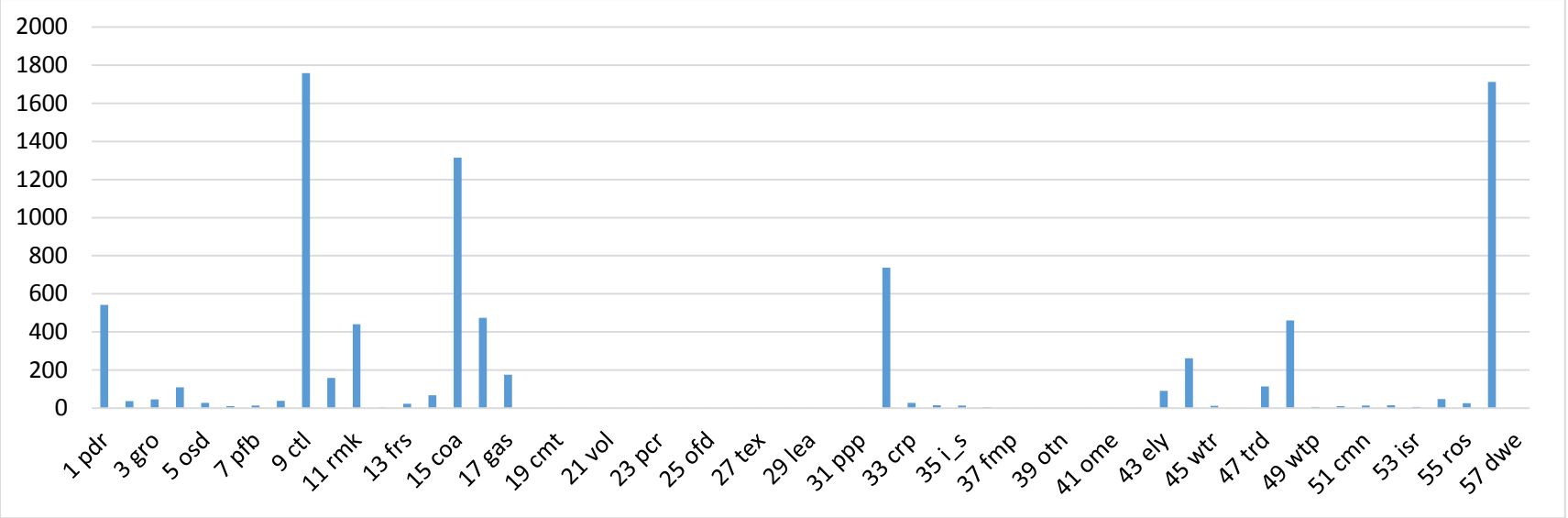

Figure 5: Global CH_4 Emissions by GTAP Sector (M. ton CO2-e)

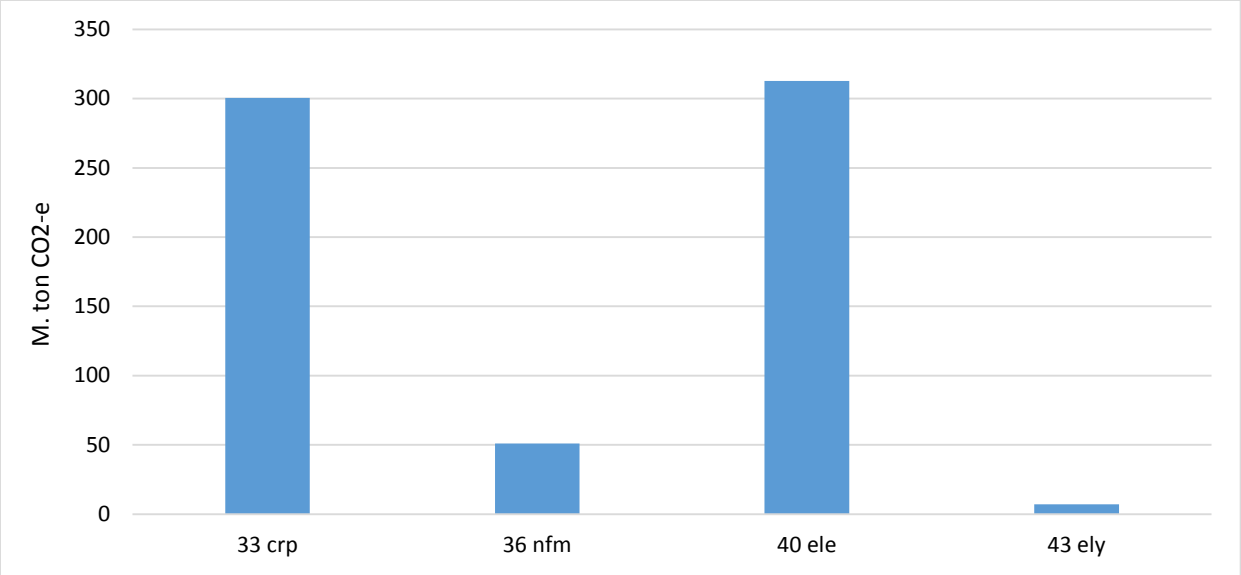

Figure 6: Global F-Gas Emissions by GTAP Sector (M. ton CO2-e)

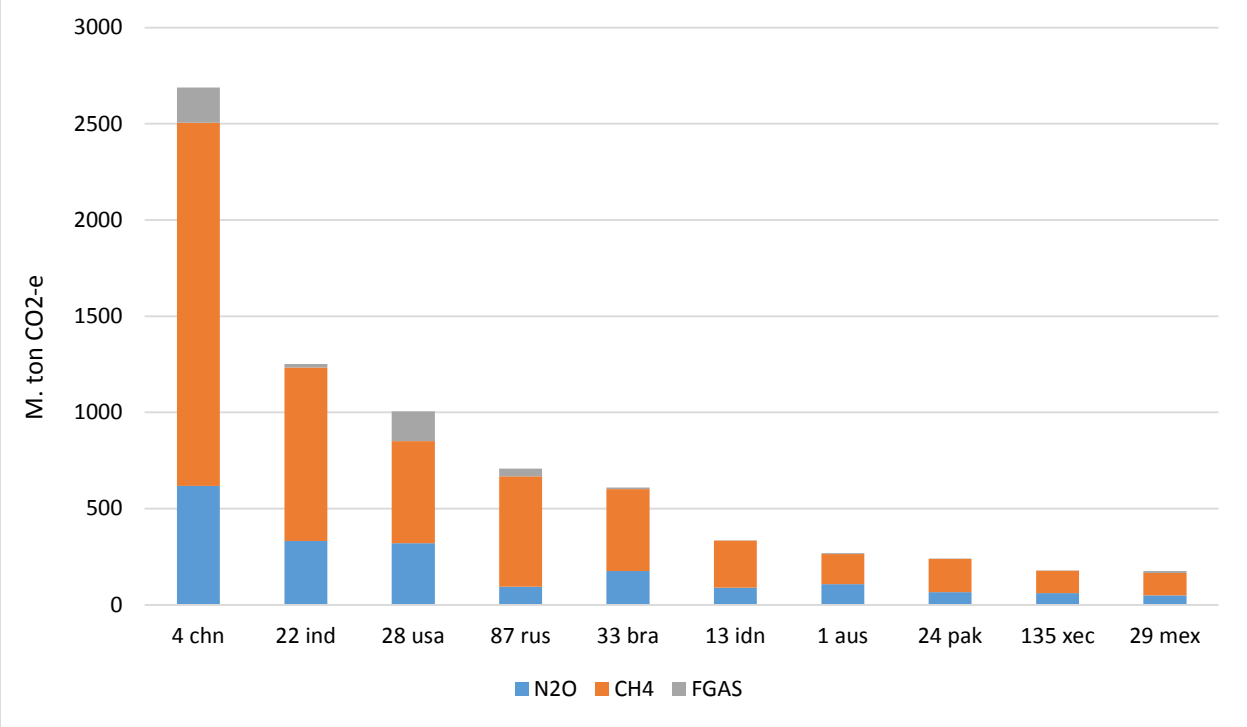

Figure 7: Top 10 non-CO_2 Emitters by gas (M. ton CO2-e)