Non-CO_2 Greenhouse Gas Emissions Data for Climate Change Economic Analysis*

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Steven K. Rose and Huey-Lin Lee

1. Introduction

Non-CO_2 (carbon dioxide) greenhouse gas emissions (NCGGs) are responsible for almost a third of historic radiative forcing, and land related activities contribute approximately two thirds of global NCGG emissions. Therefore, modeling of NCGG emissions is essential for projecting climate change and evaluating the net environmental effectiveness of alternative climate change mitigation strategies.

This chapter describes the GTAP NCGG emissions dataset. It highlights NCGG emissions associated with land-based activities, and the heterogeneity of sectoral and regional NCGG emissions. The NCGG dataset complements the GTAP fossil fuel combustion CO_2 emissions database (Lee, 2005) and the forest carbon stock dataset, where the later is described in chapter 2[1] of this volume. Together, the datasets provide a fairly complete GHG emissions and carbon sink profile for each sector within each region.

The GTAP NCGG emissions data were derived from new highly disaggregated country-level emissions source data from the United States Environmental Protection Agency (USEPA) (Rose et al., 2007b). Unlike other NCGG databases, the data was specifically developed for direct integration with economic activity datasets. The detailed USEPA source emissions data and the explicit linking of NCGG emissions directly to

[1] GTAP Working Paper No. 40

emissions drivers (e.g., energy use, land use, fertilizer, capital) during the mapping to the GTAP economic activity dataset, allows for more explicit, realistic, and internally consistent modeling of emissions activity and mitigation technologies and costs. The NCGG dataset was collaboratively developed by USEPA and Purdue University's Global Trade Analysis Project (GTAP). The most current version of the dataset is publicly available on the GTAP website (https://www.gtap.agecon.purdue.edu/).

2. Background

NCGGs include nitrous oxide (N_2O), methane (CH_4), and fourteen fluorinated gases (F-gases) (Table 1).[2] These greenhouse gases (GHGs), along with carbon dioxide, are referred to as the Kyoto basket of greenhouse gases. Like CO_2, NCGGs are gases that trap heat in the Earth's atmosphere. They trap more heat per molecule than CO_2. NCGGs were responsible for 30% of radiative forcing between pre-industrial times and 1990 (IPCC, 2001). USEPA (2006a) projects NCGG growth of 44% from 1990 to 2020, with methane two thirds of 1990 emissions and growing by 35%, and nitrous oxide just under a third of 1990 emissions growing by 41%, while the F-gases in total represent approximately 3% of 1990 emissions growing by almost 300% to become 7% of NCGG emissions by 2020.[3]

[2] In the database, the fourteen F-gases are grouped into four representative groups: CF_4 (Perfluoromethane), HFC-134a (Hydrofluorocarbons, $C_2H_2F_4$), HFC-23 (Hydrofluorocarbons, CHF_3), SF_6 (Sulphur hexafluoride).

[3] Based on carbon dioxide equivalent units computed using the IPCC Second Assessment Report 100-year global warming potentials for reporting inventories (IPCC, 1996).

Table 1. Non- CO_2 greenhouse gases included in the database and their 100-year global warming potential (GWP) (IPCC, 1996)

Gas	GWP
Carbon dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous oxide (N_2O)	310
HFC-23	11,700
HFC-32	650
HFC-125	2,800
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
HFC-4310mee	1,300
CF_4	6,500
C_2F_6	9,200
C_4F_{10}	7,000
C_6F_{16}	7,400
SF_6	23,900

Land use and land based practices represent an important driver of NCGG emissions. In 2000, agricultural land related activities were estimated to produce approximately 50% of global atmospheric methane (CH_4) emissions and 75% of global nitrous oxide (N_2O) emissions. This amounts to a total contribution to all anthropogenic greenhouse gas emissions in 2000 of approximately 14% on a carbon dioxide equivalent basis (USEPA, 2006a). By tying NCGG emissions directly to economic activities, as is done with the dataset described in this chapter, we have an explicit characterization of emissions associated with economic sectors and an economic structure for modeling NCGG emissions. In Figure 1 and Table 2, we see that land related economic sectors are responsible for 60% of global NCGG emissions, with ruminant livestock production contributing the largest share at 25%, and paddy rice second at 8%, followed closely by various crops and non-ruminant livestock.

Figure 1. 2001 global land-use related shares of NCGG emissions

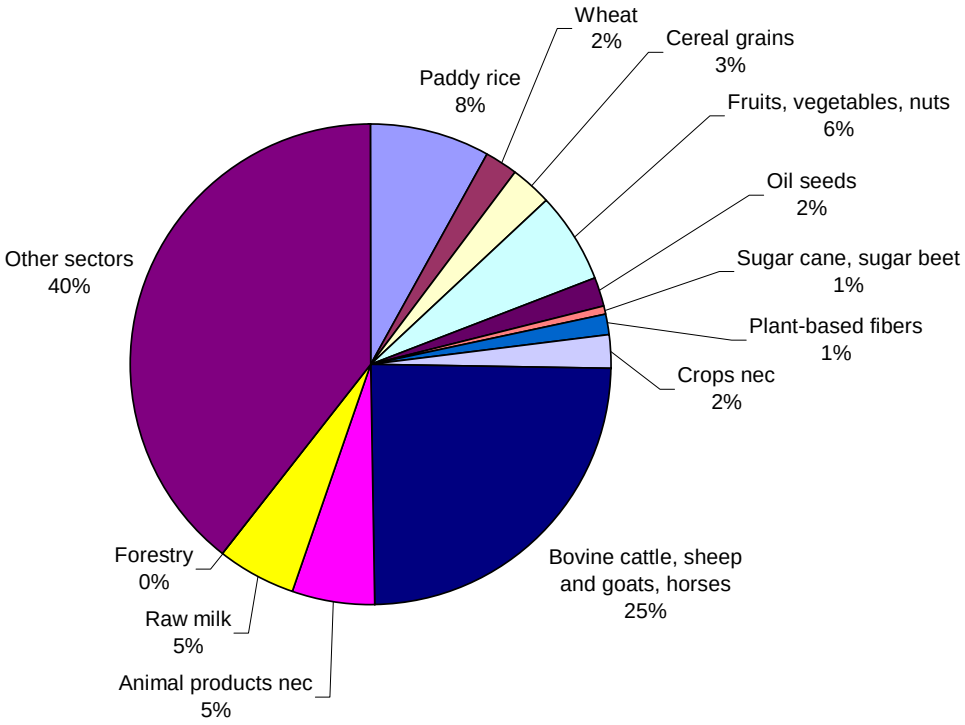


Table 2. 2001 global land-use related NCGG emissions

Sector	MtCeq
Paddy rice	199
Wheat	57
Cereal grains	67
Fruits, vegetables, nuts	150
Oil seeds	49
Sugar cane, sugar beet	18
Plant-based fibers	31
Crops nec	55
Bovine cattle, sheep and goats, horses	609
Animal products nec	136
Raw milk	133
Forestry	0
TOTAL land-use related sectors	***1505***
Other sectors	***976***

NCGGs are important because of both their historic and projected contributions to radiative forcing and climate change, as well as for their climate change mitigation potential, especially as alternatives to fossil fuel combustion CO_2 emissions mitigation. Previous engineering-based studies and project experience through government programs has identified a variety of viable NCGG mitigation technologies and provided estimates of direct project net costs (e.g., USEPA, 2006b). Furthermore, macroeconomic studies have found that NCGG mitigation opportunities offer mitigation flexibility that could lower the costs of achieving emissions reduction quantity objectives, such as for national commitments, cap-and-trade programs, and long-run climate change stabilization (e.g., de la Chesnaye and Weyant, 2006). In addition, Rose et al. (2007a) reports results explicitly isolating potential cost-effective roles for land-based NCGG mitigation, as well as forest sequestration and bioenergy, in dynamic climate change stabilization mitigation portfolios. Meanwhile, public-private partnerships have identified and developed profitable NCGG reduction partnerships (e.g., USEPA's Methane to Markets program,

http://www.epa.gov/methanetomarkets/). Research results and hands-on experience like these have justified the inclusion of NCGG mitigation alternatives in international programs such as the UNFCCC Joint Implementation and Clean Development Mechanism Programs, as well as their explicit inclusion in recently proposed U.S. legislation.

Despite all this, sector-level and economy-wide NCGG emissions and mitigation modeling is still relatively unsophisticated. In large part, because modelers have focused their efforts on modeling energy and industrial fossil fuel CO_2 emissions based on fuel combustion (Hourcade et al., 2001). As that modeling has advanced and global NCGG emissions and cost data have become available, the modeling community has shifted its attention to the other categories of emissions—NCGGs, non-combustion CO_2, and land-use and land-use change CO_2. The initial modeling, built off aggregated databases and aggregated and partially integrated representations of mitigation responses, established that NCGG mitigation could be a substantial part of a cost-effective strategy (de la Chesnaye and Weyant, 2006). However, more explicit evaluation of NCGG mitigation technologies and the impact of NCGG mitigation decisions within and across sectors and regions calls for more disaggregated consistent emissions source data that is integrated more directly with the economic activity generating the emissions.

The GTAP NCGG database was developed to fill this need and facilitate more refined modeling and evaluation of NCGG emissions and mitigation potential. For each region, the dataset provides disaggregated source-level NCGG emissions for each economic sector and regional household. Furthermore, the sector emissions are tied to emissions drivers: factor inputs (endowments), intermediate inputs, or output. Household

emissions are tied to intermediate input use, specifically energy use. The NCGG emissions are reported in terms of the 87 GTAP regions, 57 sectors, and regional households associated with version 6 of the GTAP database.

The NCGG database is one part of a GTAP/EPA development effort designed to improve international climate modeling by developing key climate related datasets that are both internally consistent and integrated with core economic activity datasets. A number of complementary resources are currently available, some products of the GTAP/EPA project, including GTAP datasets for fossil fuel combustion CO_2 emissions, land-use and land-cover, forest carbon; and USEPA datasets for country-level historical and near-term NCGG projections, and NCGG emissions abatement costs estimates. See Rose et al. (2007c) for an overview of these resources. Furthermore, development efforts are on-going that will yield additional GTAP/EPA products and improvements in the future. Additional data products will include a global soil carbon dataset and, as discussed below, incorporation of additional emissions categories, including non-fossil fuel combustion CO_2 emissions, as well as additional biomass burning and biomass combustion CO_2 and non-CO_2 emissions.

The remainder of this chapter is organized as follows. The next section describes the methodologies employed in developing the GTAP NCGG dataset. The remaining sections provide an overview of the data and discuss modeling opportunities. Land-based NCGG emissions are emphasized throughout.

3. Methodology

This section describes the NCGG input data for the GTAP NCGG dataset and the methods employed in mapping the data. Each NCGG emissions source (subcategory) from the input data set for each country was allocated to the corresponding GTAP sector(s) or regional household and then directly to an appropriate unique economic activity emissions driver within each sector/household. This methodology ensures that GTAP NCGG emissions totals are consistent with the original sources, while emissions-driver relationships are customized to the economic model structure.

3.1 USEPA NCGG emissions input data

The US Environmental Protection Agency (USEPA) developed a detailed non-CO_2 and non-fossil fuel combustion CO_2 ("Other CO_2") greenhouse gas emissions database specifically for use by global economic models (Rose et al., 2007b). The dataset's disaggregated emissions structure maps directly to countries and economic sectors and facilitates utilization of available input activity quantity data, such as energy volumes and land-use acreage in both the mapping of emissions into GTAP as well as emissions modeling.

Other global emissions datasets have provided valuable regional and global estimates (e.g., USEPA, 2006a; Olivier, 2002); however, estimated emissions have been developed and presented according to IPCC source categories that aggregate across countries, and more importantly, aggregate across economic sectors and activities; thereby, making it difficult to model actual emitting activities and abatement strategies. The Rose et al. (2007b) NCGG emissions categories and subcategories are also based on

IPCC emissions inventory categories and subcategories (IPCC, 1997a); however, the data is substantially more disaggregated than other datasets. The 2001 base year of the new dataset corresponds to the base year of the GTAP version 6 database. The database provides emissions for 29 non-CO_2 and Other CO_2 GHG emissions categories with 153 unique emissions sources (subcategories) for 226 countries. The other datasets provide emissions for more aggregated regions and do not provide emissions by subcategories. Annex 1 country emissions were extracted from national UNFCCC Common Reporting Framework and National Inventory submissions. Non-Annex 1 country emissions were primarily drawn and, when possible, disaggregated from available National Inventories. When National Inventories were not available or specific emissions categories were not represented, other data sources and methods were called upon: the EDGAR 3.2 database by RIVM/TNO[4] (biomass burning, Other CO_2), ALGAS country reports;[5] or, estimated using IPCC inventory methods or extrapolated from 2000 estimates. See Rose et al. (2007b) for more detailed descriptions of the methods used in developing the data in each of the USEPA NCGG emissions subcategories.

3.2 Mapping USEPA NCGG data to GTAP

Table 3 provides a summary of the emissions categories and subcategories represented in the GTAP NCGG dataset. Most, but not all, of the USEPA categories and subcategories were mapped into GTAP. Specifically, 24 categories and 119 subcategories

[4] EDGAR (Emission Database for Global Atmospheric Research), Version 3.2 (Olivier, 2002)
[5] ALGAS (Asia Least-Cost Greenhouse Gas Abatement Strategy)

were mapped into GTAP. The 5 USEPA NCGG emissions categories and 34 subcategories not currently mapped into GTAP include:

a. Specific biomass burning N_2O and CH_4 emissions not uniquely attributable to anthropogenic activity (middle and high latitude forest fires, middle and high latitude grassland fires, indirect N_2O from tropical forest fires, tropical forest fires).
b. Biomass burning tropical forest fire deforestation N_2O, CH_4, and CO_2 emissions. Currently omitted because the emissions are associated with land-use change, and the GTAP land-use database (Lee et al., 2005) does not provide land-use change data. Please note however that GTAP forest carbon stock data is available that is consistent with the GTAP forest inventory dataset (see the previous chapter[6]). This data will allow for modeling changes of forest carbon.
c. Biomass combustion N_2O, CH_4, and CO_2 emissions. Omitted from mapping because the GTAP energy database does not currently include biomass energy volumes.
d. Methane from underground storage and geothermal energy. Only one country reported emissions in each of these subcategories, and the emissions were modest: Latvia (underground storage emissions of 0.33 Gg), and New Zealand (geothermal emissions of 2.47 Gg).
e. Other CO_2 emissions not attributable to fossil fuel combustion. This includes fugitive and combustion CO_2 emissions from the chemical

[6] GTAP Working Paper No. 42

industry and metal production, fugitive CO_2 emissions from oil production/transmission/handling, and CO_2 emissions associated with cement production. The first of these three categories was omitted due to concerns about double counting with the GTAP CO_2 combustion emissions database. The second and third will be added to the GTAP emissions database in the future.

Overall, the omitted emissions subcategories will be added to the database in the future as methodologies are developed and activity data becomes available. The USEPA emissions data omitted from the GTAP mapping are described in Rose et al. (2007c) and can be obtained from USEPA (Rose et al., 2007b).

Each of the USEPA emissions subcategories was individually mapped to the GTAP version 6 database's region and sector structure (87 regions, 57 sectors), and regional households (Table 3). For each of the USEPA emissions subcategories, the relevant set of emitting GTAP sectors was identified from a careful matching of IPCC emissions source definitions and driver descriptions (IPCC, 1997a, 1997b, 2000, 2003) to the underlying United Nations Central Product Classification (CPC) and International Standard Industrial Classification (ISIC) definitions associated with the GTAP sectors (see Appendix A for the CPC and ISIC codes associated with the GTAP sectors).

Many USEPA emissions subcategories mapped directly to individual GTAP sectors for each country (Table 3). However, disaggregation methodologies were required for subcategories that mapped to multiple GTAP sectors and/or when there were multiple emitting activities (e.g,, CH_4 and N_2O emissions from combustion of coal, natural gas, and oil in GTAP energy sectors col, oil, gas, p_c, ely, and gdt). Where possible, GTAP

input activity data was exploited for subcategory emissions disaggregation across sectors in order to integrate the datasets, thereby providing greater consistency across datasets.

There were four cases where an USEPA emissions category/subcategory did not map directly to a GTAP sector or country. In each case, shares were developed, either sector shares or country shares.

- Case 1: Category/subcategory maps to multiple GTAP sectors and there is only one emitting activity
- Case 2: Category/subcategory maps to multiple GTAP sectors and there are multiple emitting activities
- Case 3: Category/subcategory maps to multiple GTAP sectors but emissions source is poorly defined – this case applies only to livestock related subcategory designations of "UNKNOWN."
- Case 4: Category/subcategory includes aggregated regional emissions for a few smaller emitting countries that could not be disaggregated – this case applies only to two USEPA emissions categories—agricultural soils and pasture, range, and paddock.

For cases 1 and 2, GTAP base year activity and IPCC emissions factor data are applied when available. If not available, other methods were employed, such as using GTAP production shares. See Rose et al. (2007c) for a complete description of the mapping methodologies and the specific mapping and disaggregation handling for each subcategory.

Table 3. Mapping NCGG categories and subcategories to GTAP v6 sectors and emissions drivers

Category	Subcategory	GHG	GTAP sector	Emissions driver(s)
Adipic and Nitric Production	Adipic Acid Production	N2O	crp	Output
	Nitric Acid Production	N2O	crp	Output
Agricultural Soils	Crop soils only - pasture, range, paddock disaggregated into its own category (below)	N2O	pdr, wht, gro, v_f, osd, c_b, pfb, ocr	Input (crp)
Biomass Burning	Agricultural Waste Burning	CH4 & N2O	pdr, wht, gro, v_f, osd, c_b, pfb, ocr	Output
	Savannah and Shrubs Fires	CH4 & N2O	ctl	Endowment (land)
Fugitives from Coal Mining Activities		CH4	col	Output
Fugitives from Oil and Natural Gas Systems	Natural gas - distribution	CH4	gdt	Output
	Natural gas - exploration	CH4	gas	Output
	Natural Gas - flaring	CH4	gas	Output
	Natural gas - leakage	CH4	gdt	Output
	Natural gas - leakage at industrial plants and power stations	CH4	gdt	Output
	Natural gas - leakage at residential and commercial sectors	CH4	gdt	Output
	Natural gas - production/processing	CH4	gas, gdt	Output
	Natural gas - transmission	CH4	otp	Output
	Natural Gas - venting	CH4	gas	Output
	Oil - distribution of products	CH4	p_c	Output
	Oil - exploration	CH4	oil	Output
	Oil - flaring	CH4	oil	Output
	Oil - other	CH4	oil	Output
	Oil - production	CH4	oil	Output
	Oil - refining and storage	CH4	p_c	Output
	Oil - transport	CH4	otp	Output
	Oil - venting	CH4	oil	Output
Human Sewage		N2O	osg	Output
Landfilling of Solid Waste		CH4	osg	Output
Livestock Enteric Fermentation	BUFFALO	CH4	ctl	Endowment (capital)
	CAMEL (includes reportings for camels, alpaca, llamas, and camelids)	CH4	ctl	Endowment (capital)
	DAIRY_CATTLE	CH4	rmk	Endowment (capital)
	GOAT	CH4	ctl	Endowment (capital)
	HORSE	CH4	ctl	Endowment (capital)
	MULE/ASS	CH4	ctl	Endowment (capital)
	NON-DAIRY_CATTLE (includes reportings for non-dairy cattle, deer, and reindeer)	CH4	ctl	Endowment (capital)
	OTHER (includes reportings for fur bearing animals, ostrich, emus, rabbits, and "other")	CH4	oap	Endowment (capital)
	POULTRY (includes reportings for chickens, ducks, geese, turkeys, and "poultry")	CH4	oap	Endowment (capital)
	SHEEP/LAMB	CH4	ctl	Endowment (capital)
	SWINE	CH4	oap	Endowment (capital)
	UNKNOWN (not specified in reporting)	CH4	ctl, oap, rmk	Endowment (capital)

Category	Subcategory	GHG	GTAP sector	Emissions driver(s)
Livestock Manure Management	BUFFALO	CH4 & N2O	ctl	Endowment (capital)
	CAMEL (includes reportings for camels and camelids)	CH4 & N2O	ctl	Endowment (capital)
	DAIRY_CATTLE	CH4 & N2O	rmk	Endowment (capital)
	GOAT	CH4 & N2O	ctl	Endowment (capital)
	HORSE (includes reportings for horses and combined reportings that include horses/goats/asses/mules/rabbits(	CH4 & N2O	ctl	Endowment (capital)
	MULE/ASS	CH4 & N2O	ctl	Endowment (capital)
	NON-DAIRY_CATTLE (includes reportings for non-dairy cattle, 1 to 3 year cattle, fat calves. deer, and equidea)	CH4 & N2O	ctl	Endowment (capital)
	OTHER (includes reportings for fur bearing animals and rabbits)	N2O	oap	Endowment (capital)
	POULTRY (Includes reportings for chickens, boilers, hens, ducks, geese, turkeys, and "poultry")	CH4 & N2O	oap	Endowment (capital)
	SHEEP/LAMB	CH4 & N2O	ctl	Endowment (capital)
	SWINE (includes reportings for swine, pig, and sow)	CH4 & N2O	oap	Endowment (capital)
	UNKNOWN (not specified in reporting)	CH4 & N2O	ctl, oap, rmk	Endowment (capital)
Other Industrial Non-Agricultural Sources	Mineral production	CH4	nmm	Output
	Chemical production	CH4	crp	Output
	Chemical production	N2O	crp	Output
	Iron, steel, & ferroalloys production	CH4	i_s	Output
	Iron, steel, & ferroalloys production	N2O	i_s	Output
	Aluminum & non-ferrous Production	CH4	nfm	Output
	All metal production	CH4	i_s, nfm	Output
	Other	CH4	omf, ppp	Output
	Other	N2O	omf, ppp	Output
Pasture, Range, and Paddock	BUFFALO	N2O	ctl	Endowment (capital)
	DAIRY_CATTLE	N2O	rmk	Endowment (capital)
	GOAT (includes reportings for goats and combined reportings that include goats/horses/deer/buffalo/donkeys/mules/emus/alpaca/camels)	N2O	ctl	Endowment (capital)
	HORSE (includes reportings for horses and combined reportings that include horses/goats/asses/mules/rabbits)	N2O	ctl	Endowment (capital)
	MULE/ASS	N2O	ctl	Endowment (capital)
	NON-DAIRY_CATTLE (includes reportings for non-dairy cattle, 1 to 3 year cattle, fat calves. deer, and equidea)	N2O	ctl	Endowment (capital)
	OTHER (includes reportings for fur bearing animals and rabbits)	N2O	oap	Endowment (capital)
	POULTRY	N2O	oap	Endowment (capital)
	SHEEP/LAMB	N2O	ctl	Endowment (capital)

Category	Subcategory	GHG	GTAP sector	Emissions driver(s)
Rice Cultivation		CH4	pdr	Endowment (land)
Stationary and Mobile Combustion	Stationary Combustion: Energy Industries	CH4 & N2O	col, oil, gas, p_c, ely, gdt	Inputs (refined oil (ep_c), coal (ecol), natural gas (egdt))
	Stationary Combustion: Total Industry Sector	CH4 & N2O	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	Inputs (refined oil (ep_c), coal (ecol), natural gas (egdt))
	Mobile Combustion: Total Transport Sector	CH4 & N2O	otp, wtp, atp	Inputs (refined oil (ep_c), coal (ecol), natural gas (egdt))
	Stationary and Mobile Combustion: Agriculture	CH4 & N2O	Crop sectors 1-8, livestock sectors 9-12, forestry, fishing	Inputs (refined oil (ep_c), coal (ecol), natural gas (egdt))
	Stationary Combustion: Commercial and Public Services	CH4 & N2O	wtr, trd, cmn, ofi, isr, obs, ros, osg	Inputs (refined oil (ep_c), coal (ecol), natural gas (egdt))
	Stationary Combustion: Residential	CH4 & N2O	households	Inputs (refined oil (ep_c), coal (ecol), natural gas (egdt))
	Non-specified Other	CH4 & N2O	osg	Inputs (refined oil (ep_c), coal (ecol), natural gas (egdt))
Wastewater Treatment		CH4	osg	Output
Aluminum Production	Aluminum Production	CF4	nfm	Output
Electrical Transmission and Distribution	Electrical Transmission and Distribution	SF6	ely	Output
HCFC-22 Production	HCFC-22 Production	HFC-23	crp	Output
Magnesium Manufacturing	Magnesium Manufacturing	SF6	nfm	Output
ODS Substitutes	Aerosols (MDI)	HFC-134a	crp	Output
	Aerosols (Non-MDI)	HFC-134a	crp	Output
	Fire Extinguishing	HFC-134a	crp	Output
	Foams	HFC-134a	crp	Output
	Refrigeration/AC	HFC-134a	ele	Output
	Solvents	HFC-134a	crp	Output
Semiconductor Production	Semiconductor Production	CF4	ele	Output

3.3 Mapping to GTAP emissions drivers

Tying emissions as closely as possible to emissions drivers allows for a more refined representation of abatement technologies and responses. For instance, there are many NCGG emissions that are closely related to input use. Nitrous oxide emissions from fertilizer usage and methane emissions from livestock are two obvious examples. With emissions tied to particular inputs, inputs can be adjusted to manage emissions while production is maintained via input substitution. When it is difficult to tie emissions

directly to input usage due to a lack of (a) input use data, (b) scientific understanding of emissions generation processes, or (c) econometric production cost estimates, emissions are tied to the aggregate output of the sector.

The detailed specification of the GTAP endowment, intermediate input ("Input"), or output driver for each subcategory is listed in the last column of Table 3. In most cases, all the emissions associated with a category were assigned to the same type of driver. For biomass burning emissions, the specific subcategories were assigned unique drivers. For stationary and mobile combustion emissions, emissions were disaggregated and tied to each of the fossil fuel combustion activities.

It is important for modelers to recognize that specific emissions generation processes are obscured by these aggregated emissions-driver relationships. For instance, manure emissions depend on, among other things, the number of animals and the manure management system. Variation in either element of production across regions is represented by differences in capital in the GTAP database. Base year regional differences in the combination of animal number and manure management will be captured in the relationship between emissions and capital. However, the relationship will change over time due to autonomous and policy-driven technological change. Modelers need to be mindful of dynamics in the emissions-driver relationships to avoid unrealistic growth in future emissions and to appropriately apply mitigation technologies. See Hertel et al. (2006) and chapter 6[7] in this volume, which utilize the GTAP NCGG emissions database and USEPA (2006b) mitigation cost data, to develop and apply an initial detailed NCGG mitigation modeling framework specifically for agricultural activities.

[7] GTAP Working Paper No. 44

4. NCGG Data Overview

This section provides a graphical overview of the GTAP NCGG emissions database. Below are a variety of figures that were selected to give the reader a feel for the structure of the emissions data and level of disaggregation. The first set of figures illustrates global NCGG emissions by sector, region, and gas (Figures 2-3). Figure 2 illustrates that by far the largest NCGG emitting economic activity globally is the production of ruminant livestock (e.g., non-dairy cattle, sheep, goats, and horses) which generates enteric methane emissions as well as manure methane and nitrous oxide emissions. The next largest emitting activity is the provision of public services, where methane and nitrous oxide emissions are generated from wastewater, human sewage, and landfill activities, as well as stationary fossil fuel combustion processes.

Figure 3 identifies the top NCGG emitting regions: China ("chn"), the United States ("usa"), India ("ind"), and Brazil ("bra"). As was true for sectors (Figure 2), the distribution of gases across regions varies significantly. Noticeably, F-gases are a relatively small part of the global carbon equivalent emissions and are concentrated in the relatively few countries responsible for the vast majority of electronics, metals, and chemicals production.

The second set of figures (Figures 4 and 5) delve deeper into the data, presenting the NCGG *subcategory* emissions for two illustrative regions—the United States and China. Here we see that the data suggests that NCGG emissions come from a larger set of sectors in the US economy than in the Chinese economy; the F-gases are much more prominent proportionally in the US economy (electronic equipment manufacturing in particular); while paddy rice, ruminant livestock, non-ruminant livestock, and coal

production are more dominant emitting activities in the Chinese economy. Waste handling (wastewater, human sewage, and landfills) is a large NCGG emissions source in both economies. Fugitive CH_4 and stationary and mobile combustion CH_4 and N_2O emissions, as well as dairy cattle CH_4 and N_2O emissions are noticeable in the US data, and almost non-existent in the Chinese data.

Figure 6 illustrates an additional dimension of the dataset that ties sector-level emissions to emissions drivers. Specifically, Figure 6 presents the USA NCGG emissions by sector in terms of emissions driver groups—endowments, intermediate inputs, and output. For instance, the "otp" sector includes both land transportation as well as pipeline transmission activities. NCGG fossil fuel combustion related emissions are attributed to output, while fugitive methane emissions occurring during transmission of fuels over pipelines is associated to fuel input levels. In land related economic sectors, NCGG emissions are mapped primarily to inputs, such as intermediate inputs like fertilizer use, and endowments like livestock capital stock and acreage. To simplify Figure 6, the subcategory emissions in each sector were aggregated by emissions driver.

5. Conclusion

NCGG emissions are important factors in climate change and should be considered for proper evaluation of the net environmental effectiveness of climate change policies. Furthermore, NCGGs mitigation technologies can add "what" flexilibility to "when" and "where" mitigation flexibility in achieving climate change goals. As a result, analysts will want to consider the potential emissions and mitigation impacts of NCGGs in the design of cost-effective policies. The disaggregated globally consistent NCGG

dataset presented in this chapter was designed to facilitate more sophisticated assessment of the climate change role and mitigation opportunities associated with NCGGs. With greater country and emissions source resolution, the data was directly integrated with economic activity and specific emissions drivers; thereby, providing a better characterization of differences in sectoral and regional NCGG profiles and allowing for more refined evaluation of heterogeneous regional and sectoral production and consumption responses.

Figure 2. 2001 global NCGG emissions by sector and gas (MtCeq)

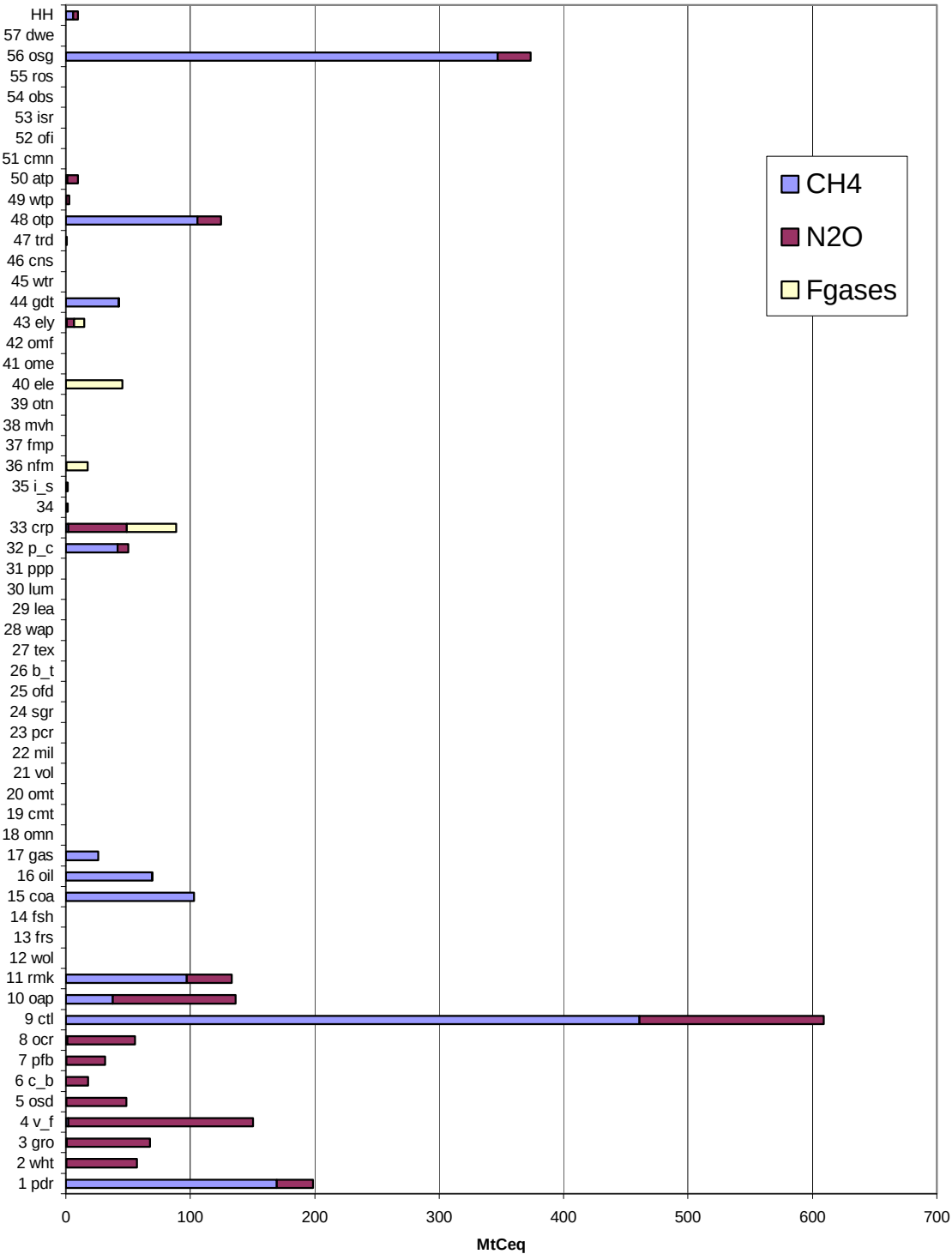


Figure 3. 2001 global NCGG emissions by region and gas (MtCeq)

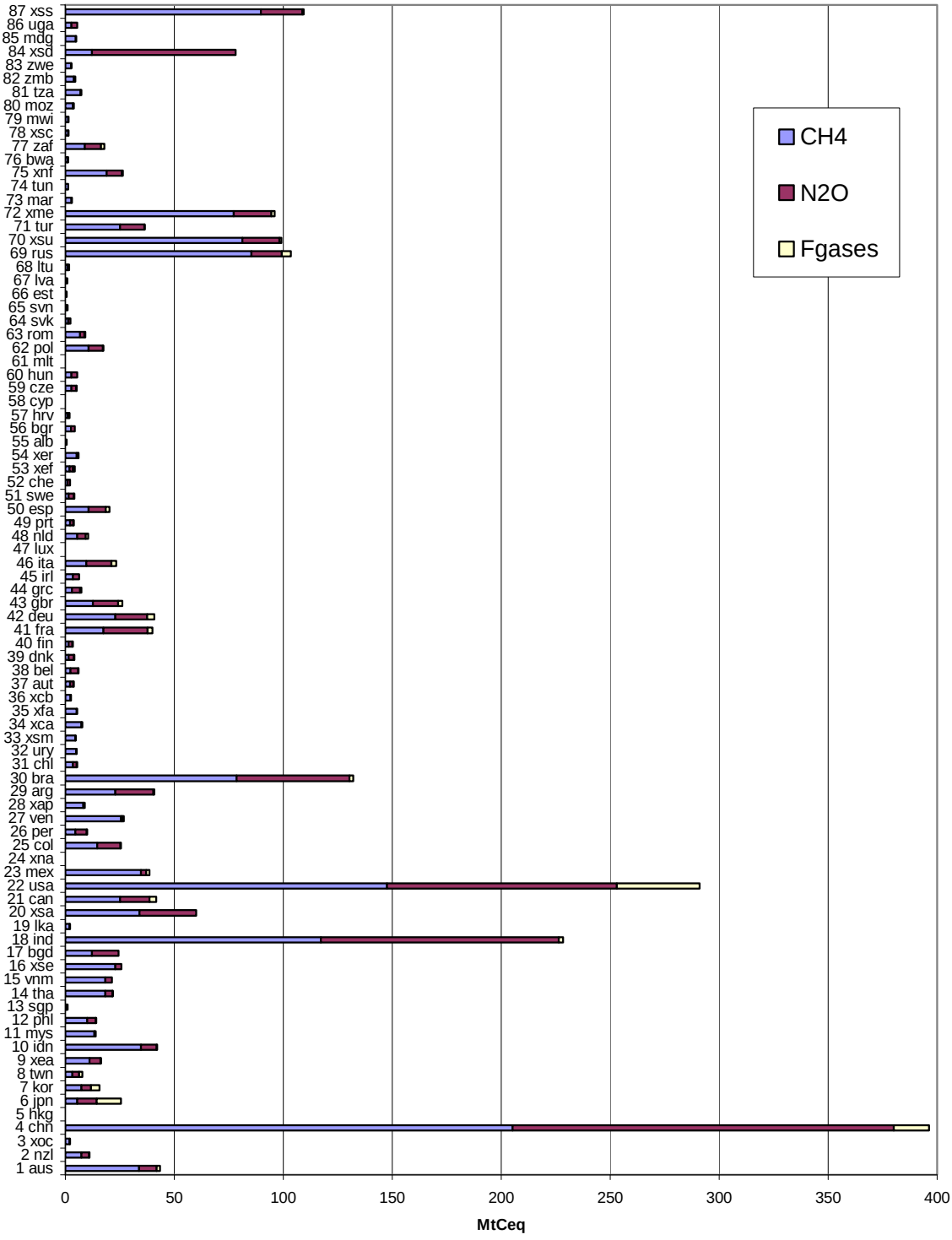


Figure 4. 2001 United States NCGG emissions by sector and source (MtCeq)

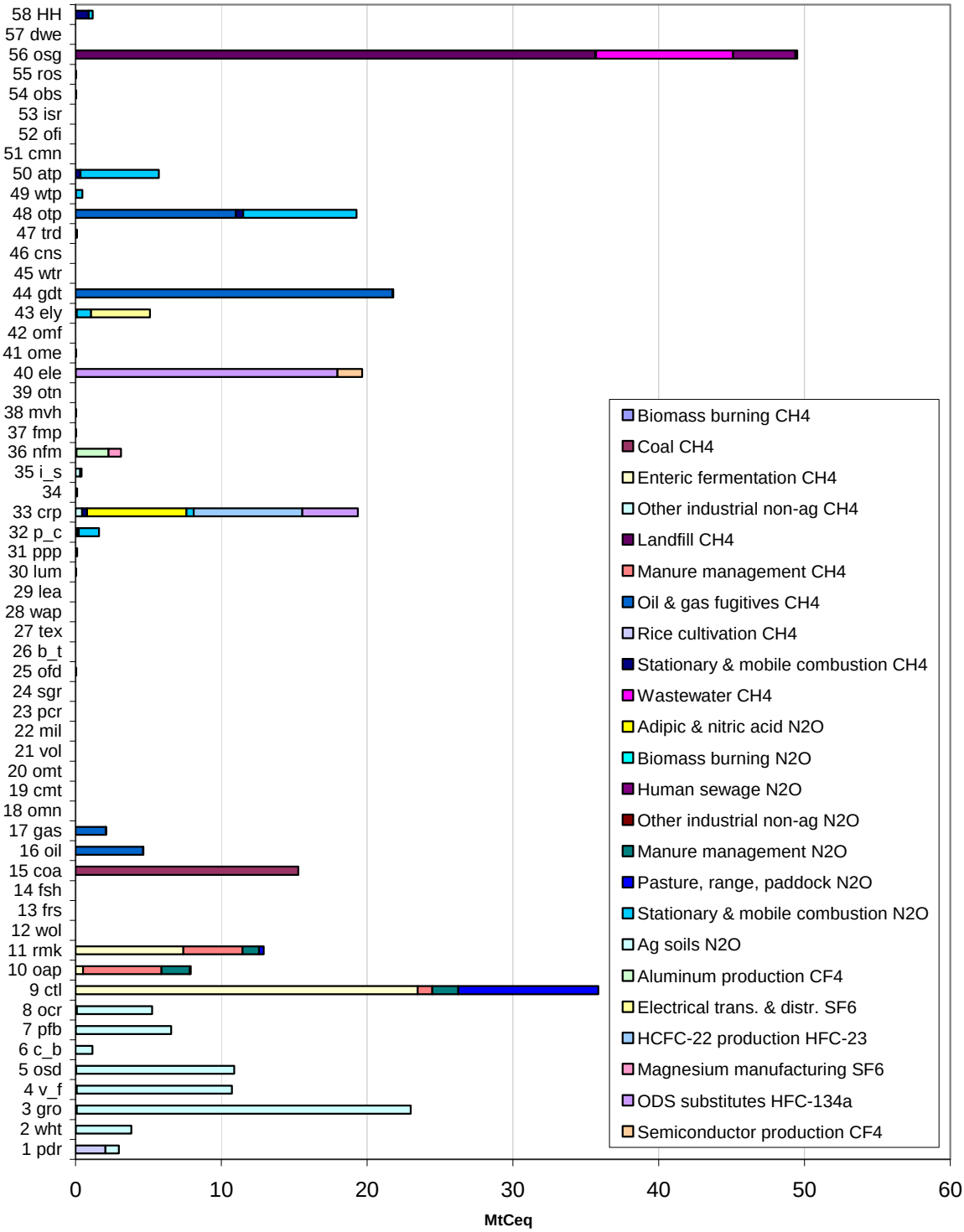


Figure 5. 2001 China NCGG emissions by sector and source (MtCeq)

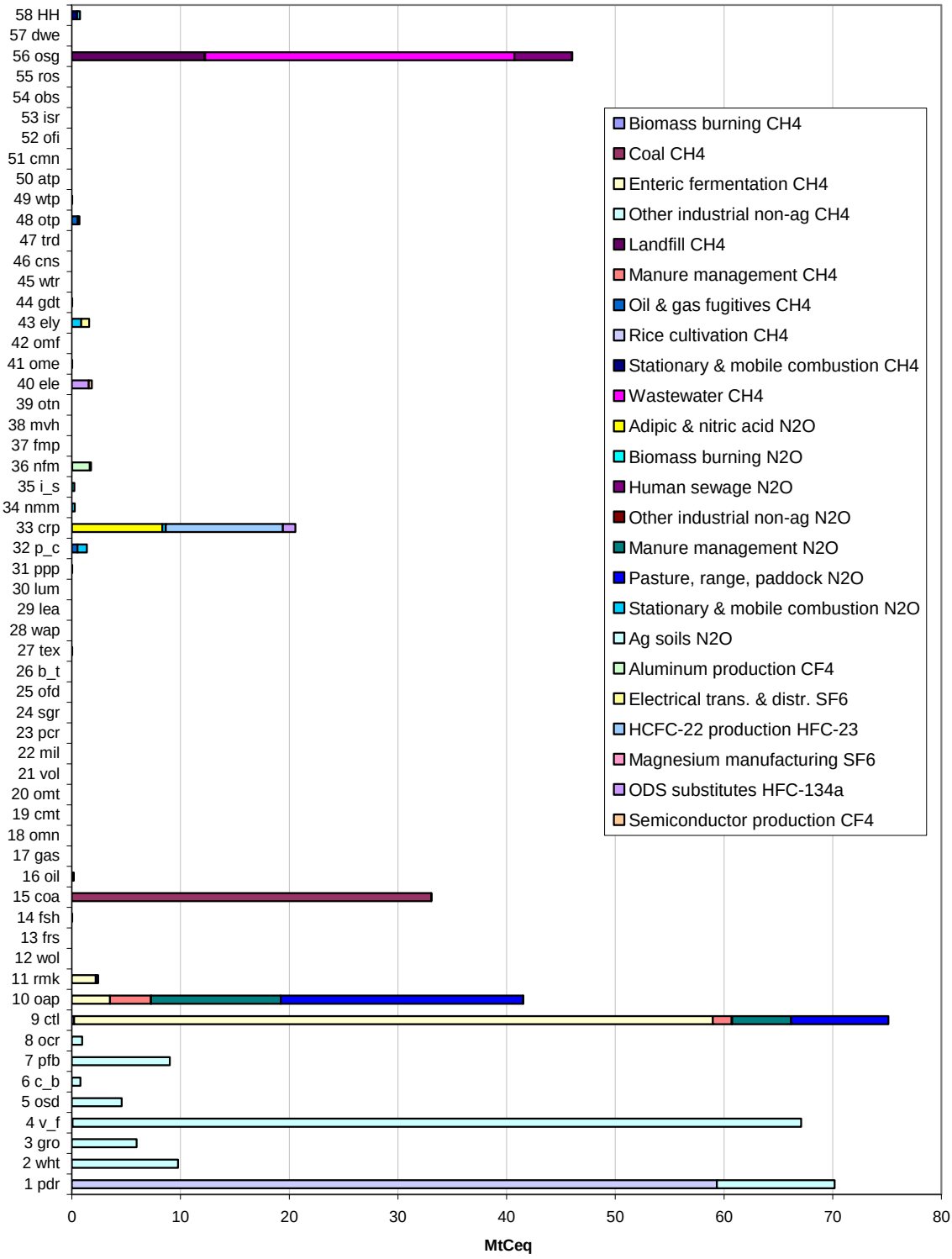
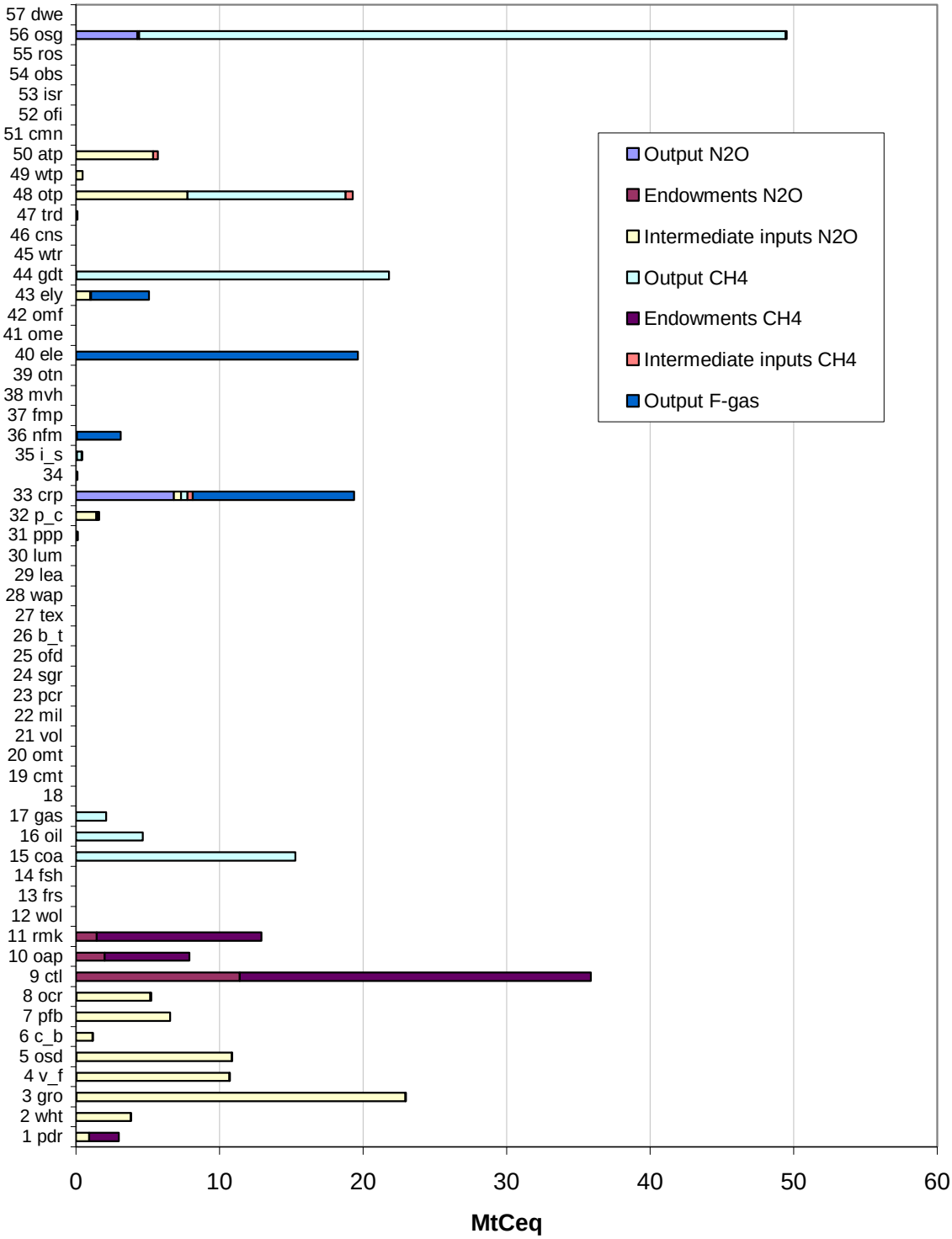


Figure 6. 2001 United States NCGG emissions by sector and emissions driver type (MtCeq)



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Appendix A. GTAP sectoral classification

Source : GTAP database version 6 documentation
(https://www.gtap.agecon.purdue.edu/default.asp)

Tables A1 and A2 below show the sectoral definitions used in version 6.0 of the GTAP data base. The GTAP agricultural and food processing sectors are defined by reference to the Central Product Classification (*CPC*), as shown in table A1. The other GTAP sectors are defined by reference to the International Standard Industry Classification (*ISIC*), as shown in table A2. The ISIC is used for most sectors, because it is the reference point for sectoral classification in most I-O statistics. But for agriculture and food processing, the ISIC does not provide the detail GTAP needs, so CPC is used instead. The CPC was developed by the Statistical Office of the United Nations to serve as a bridge between the ISIC and other sectoral classifications (UN 1990, 1991).

Table A1. GSC2 Sectors defined by Reference to the Provisional CPC

GSC2 Number	Code	CPC Code	Description
1	pdr	0113 0114	Rice, not husked Husked rice
2	wht	0111	Wheat and meslin
3	gro	0112 0115 0116 0119	Maize (corn) Barley Rye, oats Other cereals
4	v_f	012 013	Vegetables Fruit and nuts
5	osd	014	Oil seeds and oleaginous fruit
6	c_b	018	Plants used for sugar manufacturing
7	pfb	0192	Raw vegetable materials used in textiles
8	ocr	015 016 017 0191 0193 0194 0199	Live plants; cut flowers and flower buds; flower seeds and fruit seeds; vegetable seeds Beverage and spice crops Unmanufactured tobacco Cereal straw and husks, unprepared, whether or not chopped, ground, pressed or in the form of pellets; swedes, mangolds, fodder roots, hay, lucerne (alfalfa), clover, sainfoin, forage kale, lupines, vetches and similar forage products, whether or not in the form of pellets Plants and parts of plants used primarily in perfumery, in pharmacy, or for insecticidal, fungicidal or similar purposes Sugar beet seed and seeds of forage plants Other raw vegetable materials
9	ctl	0211 0299	Bovine cattle, sheep and goats, horses, asses, mules, and hinnies, live Bovine semen
			Contd

GSC2 Number	Code	CPC Code	Description
10	oap	0212	Swine, poultry and other animals, live
		0292	Eggs, in shell, fresh, preserved or cooked
		0293	Natural honey
		0294	Snails, live, fresh, chilled, frozen, dried, salted or in brine, except sea snails; frogs' legs, fresh, chilled or frozen
		0295	Edible products of animal origin n.e.c.
		0297	Hides, skins and furskins, raw
		0298	Insect waxes and spermaceti, whether or not refined or coloured
11	rmk	0291	Raw milk
12	wol	0296	Raw animal materials used in textile
13	for	03	Forestry, logging and related service activities
19	cmt	21111	Meat of bovine animals, fresh or chilled
		21112	Meat of bovine animals, frozen
		21115	Meat of sheep, fresh or chilled
		21116	Meat of sheep, frozen
		21117	Meat of goats, fresh, chilled or frozen
		21118	Meat of horses, asses, mules or hinnies, fresh, chilled or frozen
		21119	Edible offal of bovine animals, swine, sheep, goats, horses, asses, mules or hinnies, fresh, chilled or frozen
		2161	Fats of bovine animals, sheep, goats, pigs and poultry, raw or rendered; wool grease
20	omt	21113	Meat of swine, fresh or chilled
		21114	Meat of swine, frozen
		2112	Meat and edible offal, fresh, chilled or frozen, n.e.c.
		2113	Preserves and preparations of meat, meat offal or blood
		2114	Flours, meals and pellets of meat or meat offal, inedible; greaves
		2162	Animal oils and fats, crude and refined, except fats of bovine animals, sheep, goats, pigs and poultry
21	vol	2163	Soya-bean, ground-nut, olive, sunflower-seed, safflower, cotton-seed rape, colza and mustard oil, crude
		2164	Palm, coconut, palm kernel, babassu and linseed oil, crude
		2165	Soya-bean, ground-nut, olive, sunflower-seed, safflower, cotton-seed, rape, colza and mustard oil and their fractions, refined but not chemically modified; other oils obtained solely from olives and sesame oil, and their fractions, whether or not refined, but not chemically modified
		2166	Maize (corn) oil and its fractions, not chemically modified
		2167	Palm, coconut, palm kernel, babassu and linseed oil and their fractions, refined but not chemically modified; castor, tung and jojoba oil and fixed vegetable fats and oils (except maize oil) and their fractions n.e.c., whether or not refined, but not chemically modified

Table A1. GSC2 Sectors defined by Reference to the Provisional CPC (Continued)			
GSC2 Number	Code	CPC Code	Description
21	vol	2168 2169 217 218	Margarine and similar preparations Animal or vegetable fats and oils and their fractions, partly or wholly hydrogenated, inter-esterified, re-esterified or elaidinised, whether or not refined, but not further prepared Cotton linters Oil-cake and other solid residues resulting from the extraction of vegetable fats or oils; flours and meals of oil seeds or oleaginous fruits, except those of mustard; vegetable waxes, except triglycerides; degras; residues resulting from the treatment of fatty substances or animal or vegetable waxes
22	mil	22	Dairy products
23	pcr	2316	Rice, semi- or wholly milled
24	sgr	235	Sugar
25	ofd	212 213 214 215 2311 2312 2313 2314 2315 2317 2318 232 233 234 236 237 239	Prepared and preserved fish Prepared and preserved vegetables Fruit juices and vegetable juices Prepared and preserved fruit and nuts Wheat or meslin flour Cereal flours other than of wheat or meslin Groats, meal and pellets of wheat Cereal groats, meal and pellets n.e.c. Other cereal grain products (including corn flakes) Other vegetable flours and meals Mixes and doughs for the preparation of bakers' wares Starches and starch products; sugars and sugar syrups n.e.c. Preparations used in animal feeding Bakery products Cocoa, chocolate and sugar confectionery Macaroni, noodles, couscous and similar farinaceous products Food products n.e.c.
26	b_t	24 25	Beverages Tobacco products

n.e.c. Not elsewhere classified

Table A2. GSC2 Sectors defined by Reference to the ISIC, Rev. 3			
GSC2 Number	Code	ISIC3 Code	Description
14	fsh	015	Hunting, trapping and game propagation including related service activities
		05	Fishing, operation of fish hatcheries and fish farms; service activities incidental to fishing
15	col	101	Mining and agglomeration of hard coal
		102	Mining and agglomeration of lignite
16	oil	111	Extraction of crude petroleum and natural gas (part)
		112	Service activities incidental to oil and gas extraction excluding surveying (part)
		103	Mining and agglomeration of peat
17	gas	111	Extraction of crude petroleum and natural gas (part)
		112	Service activities incidental to oil and gas extraction excluding surveying (part)
18	omn	12	Mining of uranium and thorium ores
		13	Mining of metal ores
		14	Other mining and quarrying
27	tex	17	Manufacture of textiles
		243	Manufacture of man-made fibres
28	wap	18	Manufacture of wearing apparel; dressing and dyeing of fur
29	lea	19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
30	lum	20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
31	ppp	21	Manufacture of paper and paper products
		2211	Publishing of books, brochures, musical books and other publications
		2212	Publishing of newspapers, journals and periodicals
		2213	Publishing of recorded media
		2219	Other publishing (photos, engravings, postcards, timetables, forms, posters, art reproductions, etc.)
		222	Printing and service activities related to printing
		223	Reproduction of recorded media
32	p_c	231	Manufacture of coke oven products
		232	Manufacture of refined petroleum products
		233	Processing of nuclear fuel
33	crp	241	Manufacture of basic chemicals
		242	Manufacture of other chemical products
		25	Manufacture of rubber and plastics products
34	nmm	26	Manufacture of other non-metallic mineral products
35	i_s	271	Manufacture of basic iron and steel
		2731	Casting of iron and steel

Table A2. GSC2 Sectors defined by Reference to the ISIC, Rev. 3 (Continued)			
GSC2 Number	Code	ISIC3 Code	Description
36	nfm	272	Manufacture of basic precious and non-ferrous metals
		2732	Casting of non-ferrous metals
37	fmp	28	Manufacture of fabricated metal products, except machinery and equipment
38	mvh	34	Manufacture of motor vehicles, trailers and semi-trailers
39	otn	35	Manufacture of other transport equipment
40	ele	30	Manufacture of office, accounting and computing machinery
		32	Manufacture of radio, television and communication equipment and apparatus
41	ome	29	Manufacture of machinery and equipment n.e.c.
		31	Manufacture of electrical machinery and apparatus n.e.c.
		33	Manufacture of medical, precision and optical instruments, watches and clocks
42	omf	36	Manufacturing n.e.c.
		37	Recycling
43	ely	401	Production, collection and distribution of electricity
44	gdt	402	Manufacture of gas; distribution of gaseous fuels through mains
		403	Steam and hot water supply
45	wtr	41	Collection, purification and distribution of water
46	cns	45	Construction
47	trd	50	Sales, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel
		51	Wholesale trade and commission trade, except of motor vehicles and motorcycles
		521	Non-specialized retail trade in stores
		522	Retail sale of food, beverages and tobacco in specialized stores
		523	Other retail trade of new goods in specialized stores
		524	Retail sale of second-hand goods in stores
		525	Retail trade not in stores
		526	Repair of personal and household goods
		55	Hotels and restaurants
48	otp	60	Land transport; transport via pipelines
		63	Supporting and auxiliary transport activities; activities of travel agencies
49	wtp	61	Water transport
50	atp	62	Air transport
51	cmn	64	Post and telecommunications
52	ofi	65	Financial intermediation, except insurance and pension funding
		67	Activities auxiliary to financial intermediation
53	isr	66	Insurance and pension funding, except compulsory social security
			Contd

Table A2. GSC2 Sectors defined by Reference to the ISIC, Rev. 3 (Continued)			
GSC2 Number	Code	ISIC3 Code	Description
54	obs	70	Real estate activities
		711	Renting of transport equipment
		712	Renting of other machinery and equipment
		713	Renting of personal and household goods n.e.c.
		72	Computer and related activities
		73	Research and development
		74	Other business activities
55	ros	92	Recreational, cultural and sporting activities
		93	Other service activities
		95	Private households with employed persons
56	osg	75	Public administration and defence; compulsory social security
		80	Education
		85	Health and social work
		90	Sewage and refuse disposal, sanitation and similar activities
		91	Activities of membership organizations n.e.c.
		99	Extra-territorial organizations and bodies
57	dwe	n.a.	n.a.

n.a. Not available
n.e.c. Not elswhere classified

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Appendix B. Regions in the GTAP 6 Data Base and Mapping to Standard Countries

Number	Code	Name	Member Regions (226)	Code
1	AUS	Australia	Australia	AUS
2	NZL	New Zealand	New Zealand	NZL
3	XOC	Rest of Oceania	American Samoa	ASM
			Cook Islands	COK
			Fiji	FJI
			French Polynesia	PYF
			Guam	GUM
			Kiribati	KIR
			Marshall Islands	MHL
			Micronesia, Federated States of	FSM
			Nauru	NRU
			New Caledonia	NCL
			Norfolk Island	NFK
			Northern Mariana Islands	MNP
			Niue	NIU
			Palau	PLW
			Papua New Guinea	PNG
			Samoa	WSM
			Solomon Islands	SLB
			Tokelau	TKL
			Tonga	TON
			Tuvalu	TUV
			Vanuatu	VUT
			Wallis and Futuna	WLF
4	CHN	China	China	CHN
5	HKG	Hong Kong	Hong Kong	HKG
6	JPN	Japan	Japan	JPN
7	KOR	Korea	Korea, Republic of	KOR
8	TWN	Taiwan	Taiwan	TWN
9	XEA	Rest of East Asia	Macau	MAC
			Mongolia	MNG
			Korea, Democratic People's Republic of	PRK
10	IDN	Indonesia	Indonesia	IDN
11	MYS	Malaysia	Malaysia	MYS
12	PHL	Philippines	Philippines	PHL
13	SGP	Singapore	Singapore	SGP
14	THA	Thailand	Thailand	THA
15	VNM	Viet Nam	Viet Nam	VNM

16	XSE	Rest of Southeast Asia	Brunei Darussalam	BRN
			Cambodia	KHM
			Lao People's Democratic Republic	LAO
			Myanmar	MMR
			Timor Leste	TLS
17	BGD	Bangladesh	Bangladesh	BGD
18	IND	India	India	IND
19	LKA	Sri Lanka	Sri Lanka	LKA
20	XSA	Rest of South Asia	Afghanistan	AFG
			Bhutan	BTN
			Maldives	MDV
			Nepal	NPL
			Pakistan	PAK
21	CAN	Canada	Canada	CAN
22	USA	United States of America	United States of America	USA
23	MEX	Mexico	Mexico	MEX
24	XNA	Rest of North America	Bermuda	BMU
			Greenland	GRL
			Saint Pierre and Miquelon	SPM
25	COL	Colombia	Colombia	COL
26	PER	Peru	Peru	PER
27	VEN	Venezuela	Venezuela	VEN
28	XAP	Rest of Andean Pact	Bolivia	BOL
			Ecuador	ECU
29	ARG	Argentina	Argentina	ARG
30	BRA	Brazil	Brazil	BRA
31	CHL	Chile	Chile	CHL
32	URY	Uruguay	Uruguay	URY
33	XSM	Rest of South America	Falkland Islands (Malvinas)	FLK
			French Guiana	GUF
			Guyana	GUY
			Paraguay	PRY
			Suriname	SUR
34	XCA	Central America	Belize	BLZ
			Costa Rica	CRI
			El Salvador	SLV
			Guatemala	GTM
			Honduras	HND
			Nicaragua	NIC
			Panama	PAN
35	XFA	Rest of Free Trade Area of the Americas	Antigua & Barbuda	ATG

			Bahamas	BHS
			Barbados	BRB
			Dominica	DMA
			Dominican Republic	DOM
			Grenada	GRD
			Haiti	HTI
			Jamaica	JAM
			Puerto Rico	PRI
			Saint Kitts and Nevis	KNA
			Saint Lucia	LCA
			Saint Vincent and the Grenadines	VCT
			Trinidad and Tobago	TTO
			Virgin Islands, U.S.	VIR
36	XCB	Rest of the Caribbean	Anguilla	AIA
			Aruba	ABW
			Cayman Islands	CYM
			Cuba	CUB
			Guadeloupe	GLP
			Martinique	MTQ
			Montserrat	MSR
			Netherlands Antilles	ANT
			Turks and Caicos	TCA
			Virgin Islands, British	VGB
37	AUT	Austria	Austria	AUT
38	BEL	Belgium	Belgium	BEL
39	DNK	Denmark	Denmark	DNK
40	FIN	Finland	Finland	FIN
41	FRA	France	France	FRA
42	DEU	Germany	Germany	DEU
43	GBR	United Kingdom	United Kingdom	GBR
44	GRC	Greece	Greece	GRC
45	IRL	Ireland	Ireland	IRL
46	ITA	Italy	Italy	ITA
47	LUX	Luxembourg	Luxembourg	LUX
48	NLD	Netherlands	Netherlands	NLD
49	PRT	Portugal	Portugal	PRT
50	ESP	Spain	Spain	ESP
51	SWE	Sweden	Sweden	SWE
52	CHE	Switzerland	Switzerland	CHE
53	XEF	Rest of EFTA	Iceland	ISL
			Liechtenstein	LIE
			Norway	NOR
54	XER	Rest of Europe	Andorra	AND

			Bosnia and Herzegovina	BIH
			Faroe Islands	FRO
			Gibraltar	GIB
			Macedonia, the former Yugoslav Republic of	MKD
			Monaco	MCO
			San Marino	SMR
			Serbia and Montenegro	SCG
55	ALB	Albania	Albania	ALB
56	BGR	Bulgaria	Bulgaria	BGR
57	HRV	Croatia	Croatia	HRV
58	CYP	Cyprus	Cyprus	CYP
59	CZE	Czech Republic	Czech Republic	CZE
60	HUN	Hungary	Hungary	HUN
61	MLT	Malta	Malta	MLT
62	POL	Poland	Poland	POL
63	ROM	Romania	Romania	ROM
64	SVK	Slovakia	Slovakia	SVK
65	SVN	Slovenia	Slovenia	SVN
66	EST	Estonia	Estonia	EST
67	LVA	Latvia	Latvia	LVA
68	LTU	Lithuania	Lithuania	LTU
69	RUS	Russian Federation	Russian Federation	RUS
70	XSU	Rest of Former Soviet Union	Armenia	ARM
			Azerbaijan	AZE
			Belarus	BLR
			Georgia	GEO
			Kazakhstan	KAZ
			Kyrgyzstan	KGZ
			Moldova, Republic of	MDA
			Tajikistan	TJK
			Turkmenistan	TKM
			Ukraine	UKR
			Uzbekistan	UZB
71	TUR	Turkey	Turkey	TUR
72	XME	Rest of Middle East	Bahrain	BHR
			Iran, Islamic Republic of	IRN
			Iraq	IRQ
			Israel	ISR
			Jordan	JOR
			Kuwait	KWT
			Lebanon	LBN
			Palestinian Territory, Occupied	PSE

			Oman	OMN
			Qatar	QAT
			Saudi Arabia	SAU
			Syrian Arab Republic	SYR
			United Arab Emirates	ARE
			Yemen	YEM
73	MAR	Morocco	Morocco	MAR
74	TUN	Tunisia	Tunisia	TUN
75	XNF	Rest of North Africa	Algeria	DZA
			Egypt	EGY
			Libyan Arab Jamahiriya	LBY
76	BWA	Botswana	Botswana	BWA
77	ZAF	South Africa	South Africa	ZAF
78	XSC	Rest of South African Customs Union	Lesotho	LSO
			Namibia	NAM
			Swaziland	SWZ
79	MWI	Malawi	Malawi	MWI
80	MOZ	Mozambique	Mozambique	MOZ
81	TZA	Tanzania	Tanzania, United Republic of	TZA
82	ZMB	Zambia	Zambia	ZMB
83	ZWE	Zimbabwe	Zimbabwe	ZWE
84	XSD	Rest of Southern African Development Community	Angola	AGO
			Congo, the Democratic Republic of the	COD
			Mauritius	MUS
			Seychelles	SYC
85	MDG	Madagascar	Madagascar	MDG
86	UGA	Uganda	Uganda	UGA
87	XSS	Rest of Sub-Saharan Africa	Benin	BEN
			Burkina Faso	BFA
			Burundi	BDI
			Cameroon	CMR
			Cape Verde	CPV
			Central African Republic	CAF
			Chad	TCD
			Comoros	COM
			Congo	COG
			Cote d'Ivoire	CIV
			Djibouti	DJI
			Equatorial Guinea	GNQ
			Eritrea	ERI
			Ethiopia	ETH

Gabon	GAB
Gambia	GMB
Ghana	GHA
Guinea	GIN
Guinea-Bissau	GNB
Kenya	KEN
Liberia	LBR
Mali	MLI
Mauritania	MRT
Mayotte	MYT
Niger	NER
Nigeria	NGA
Reunion	REU
Rwanda	RWA
Saint Helena	SHN
Sao Tome and Principe	STP
Senegal	SEN
Sierra Leone	SLE
Somalia	SOM
Sudan	SDN
Togo	TGO