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TRENDS IN GLOBAL CO_2 AND TOTAL GREENHOUSE GAS EMISSIONS

2019 Report

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In this version, corrections have been made in Tables A.2 and B.5 that came to light after publication on 2 February 2020 and in the accompanying dataset. The corrections are described in file https://www.pbl.nl/sites/default/files/downloads/pbl-2020-trends-in-global-co2-and-total-greenhouse-gas-emissions-2019-report-list-of-errata_4068.pdf.

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Summary

Growth in global greenhouse gas emissions in 2018 highest since 2011

In 2018, the growth in total global greenhouse gas (GHG) emissions (excluding those from land-use change) resumed at a rate of 2.0%, reaching 51.8 gigatonnes of CO_2 equivalent[1] ($GtCO_2$ eq) after six years, with a somewhat lower annual growth of around 1.3% (Figure S.1). The 2018 global GHG emissions amounted to 55.6 $GtCO_2$ eq when also including those from land-use change (which are estimated at a very uncertain 3.8 $GtCO_2$ eq). This increase occurred while global economic growth in 2018 continued at about the average annual rate of 3.4% since 2012. Present GHG emissions that exclude those from land-use change are about 57% higher than in 1990 and 43% higher than in 2000.

In 2018, the 2.0% (1.0 $GtCO_2$ eq) increase in global GHG emissions was mainly due to a 2.0% increase in global fossil carbon dioxide (CO_2) emissions from fossil-fuel combustion and those from industrial non-combustion processes including cement production. Global emissions of methane (CH_4) and nitrous oxide (N_2O) increased by 1.8% and 0.8%, respectively. Global emissions of fluorinated gases (so-called F-gases) continued to grow by an estimated 6% in 2018, thereby also contributing to the 2.0% growth in total GHG emissions. The 2.0% growth in GHG emissions is higher than the annual average increase of 1.2% since 2012, but lower than the 2.5% increase over the first decade of this century (Figure S.1). Fossil CO_2 emissions are the largest source of global GHG emissions, with a share of about 72%, followed by CH_4 (19%), N_2O (6%) and F-gases (3%). The GHG emission growth over the past years and the higher rate of 2.0% in 2018 are quite similar to the increase in CO_2 emissions, which contribute almost three quarters to total GHG emissions (excluding those from land-use change).

On a global level, the year 2018 was among the five warmest years (2014–2018) since records began in 1880. Of the 10 warmest years since 1880, 9 occurred since 2005. In 2018, temperatures across much of the world were warmer to much warmer than average. Record warm temperatures were measured across much of Europe, the Middle East, New Zealand and parts of Asia. A heatwave of unprecedented intensity and duration struck Europe, from 18 to 22 April. France, Germany and Switzerland had their warmest year since national records began. The Netherlands had its second warmest year on record (with 2014 being the record year). The departure from the average global temperature level was 0.97 °C above the 1880–1900 average, just slightly below those of the years 2015–2017 (NOAA, 2019).

In 2018, GHG emissions increased in four of the largest emitting countries, and decreased in EU and Japan

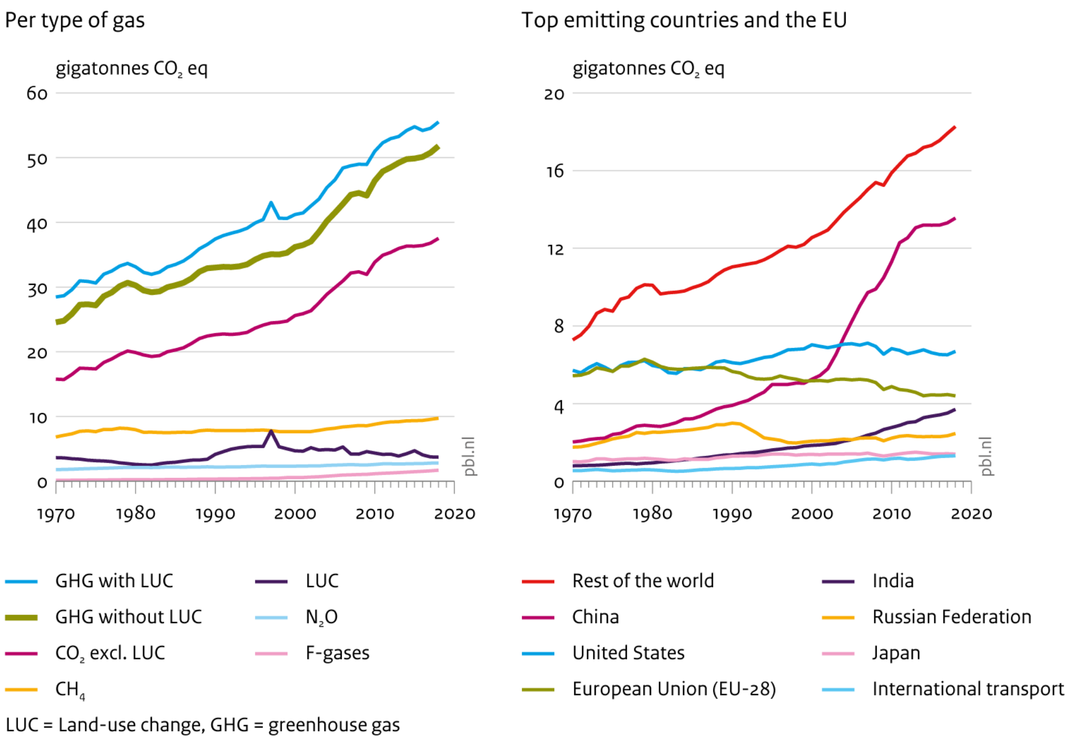
The five largest emitters of GHG, together accounting for 62%, globally, are China (26%), the United States (13%), the European Union (more than 8%), India (7%), the Russian Federation (5%) and Japan (almost 3%). These countries also have the highest CO_2 emission levels (Figure S.1). In 2018, a real increase in GHG emissions was shown in four of these

[1] GHG emissions, without including land-use change, are based on EDGARv5 (this report) and those that include CO_2 emissions from land-use change are from Houghton and Nassikas (2017). The 3.8 $GtCO_2$ eq includes 0.2 $GtCO_2$ eq in CH_4 and data on N_2O from forest fires was taken from the GFED 4.1s data set. For CH_4, N_2O and F-gases, we used the Global Warming Potential (GWP) metric for 100 years from the Fourth Assessment Report (AR4) of the IPCC. The historical GHG emission trends (excluding those from land-use change) from the EDGAR database are also presented in UNEP's Emissions Gap Report 2019 (UNEP, 2019).

countries: China (+1.9%), India (+5.5%), the United States (+2.7%) and the Russian Federation (+5.1%), whereas emissions decreased in the European Union (-1.5%) and Japan (-1.2%) (ranked according to the largest absolute changes). However, the increase in the rest of the world was even more substantial than in the individual, largest emitting countries. This is different from the recent past when China's emission growth eclipsed the increases elsewhere.

Figure S.1

Global greenhouse gas emissions



Source: GHG excl. LUC EDGAR v5.0 FT2018
LUC: Houghton and Nassikas 2017

Source: EDGAR v5.0 FT2018 (without land-use change).
both: F-gas: EDGAR v4.2 FT2018; incl. savanna fires.

Global CO_2 emissions shows largest increase since 2011

The relatively large 2.0% increase in global GHG emissions in 2018 was mainly due to a 2.0% increase in global carbon dioxide (CO_2) emissions, after six years with a somewhat lower annual growth of around 1.2%. In the decade before 2011, annual CO_2 emission growth was much larger, with an average of about 2.8%, annually (Figure S.1). However, the 2018 CO_2 emission growth rate was well below the average annual growth rate of 2.8%, which occurred in the first decade of the 21st century, when China showed very high annual growth in CO_2 emissions due to its rapid industrialisation.

In 2018, the relatively large increase in global CO_2 emissions of 2.0% to 37.5 $GtCO_2$ (about 66% higher than that of 1990) was mainly due to a larger increase in global coal consumption (1.4%) than in previous years, mainly caused by a strong increase in coal consumption in India (+8.7%, more than twice the rate of 2017), China (+0.9%) and the Russian Federation (+4.9%) (ranked according to the largest absolute changes). Other countries contributing to the global increase in coal consumption in 2018 were Vietnam (+22.9%), Pakistan (+63%), Indonesia (+7.7%), Kazakhstan (+12.2%) and Turkey (+7.2%). In contrast, coal consumption continued to decrease in the United States (-4.3%) and the European Union (-5.1%) (notably in Germany, Spain, the United Kingdom and the Netherlands), and Japan (-2.1%) (all ranked according to the largest absolute changes).

The lower growth rate in global CO_2 emissions in 2015 and 2016 (0.0% and +0.3%, respectively) was mainly due to declining global coal consumption, caused by three years of decreasing coal consumption in China (in 2014 to 2016 only), in the United States and the European Union, mainly because of increased renewable power generation, in particular, wind and solar power, and power plant fuel switches from coal to natural gas. The decrease in coal consumption continued in the United States and European Union in 2017 and 2018. Changes in coal consumption in China are important, as China accounts for half of the global coal consumption, and because global coal combustion accounts for about 40% of global CO_2 emissions.

In 2018, global consumption of oil products and natural gas continued to increase, by a respective 1.2% and 5.3%. The absolute increase in global oil consumption was led by China (+5.0%), the United States (+2.1%) and India (+5.1%), followed by Indonesia (+5.3%), Australia (+4.4%) and Iraq (+7.7%). In contrast, oil consumption decreased in Saudi Arabia (-3.6%), Japan (-2.9%) and Pakistan (-16.6%) and the European Union, in particular in Germany (-5.1%). The increase in global natural gas consumption concerned mainly the United States (+10.5%), China (+17.7%), the Russian Federation (+5.4%) and Iran (+7.4%) (ranked according to the largest absolute changes).

In 2018, global energy demand increased by about 2.1%. More than half of this increase was met by fossil fuels and the rest by renewables plus nuclear power. Since 2010, renewable and nuclear power increased their share in total power generation by 3 percentage points, to almost 36%.

Global CH_4 emissions again increase after five years of slow growth

In 2018, global methane emissions continued to increase by 1.8%, to a total of 389 $MtCH_4$ (9.7 $GtCO_2$ eq). This is 24% more than in 1990. In 2017, methane emissions also saw a 1.8% increase, which was markedly greater than in the four preceding years, when the average annual growth was 0.6%. For methane, too, in the decade before 2011, the growth in anthropogenic emissions was larger, of on average about 1.3%, annually (Figure S.1).

Sources that contributed the most to the net increase in global CH_4 emissions in 2018 were (in decreasing order of absolute changes): coal production (+5.0%), natural gas production (+4.5%), livestock farming (+1.5%) — particularly sheep (+9.3%) and cattle (+0.7%) — and waste water (1.2%). With a 2.3% increase in CH_4 emissions, China (+2.3%) accounts for one fifth of the net increase in global methane emissions, followed by Indonesia (+5.0%), the United States (+2.6%), India (+1.7%), the Russian Federation (+2.5%) and Brazil (+1.1%) (all ranked according to the largest absolute changes).

Global N_2O emissions and F-gas emissions continue to grow

For 2018, the growth rate of global N_2O emissions was estimated at 0.8%, reaching a total of 9.5 MtN_2O (2.8 $GtCO_2$ eq). Since 2011, global nitrous oxide emissions show an emission pattern that is similar to that of methane, except that the 2018 emission increase was one percentage point lower than that of CH_4 (Figure S.1). This means that, after an increase of 2.2% in 2017, the annual growth rate was back at the level of the years 2014–2016. Current global emission levels are 28% higher than in 1990. Increases in N_2O emissions from the largest sources, notably the use of synthetic nitrogen fertilisers (+2.9%), manure in pastures, rangeland and paddocks (+1.3%) and N-fixing crops (+6.9%) contributed most to global N_2O emission changes in 2018. With a 4.2% increase, Brazil accounts for the largest contribution to the global N_2O increase, followed by India (+1.6%), the United States (+0.9%), China (+0.6%) and Turkey (+5.2%). In contrast, Australia saw an 8.9% decrease, mainly due to fewer emissions from savannah burning in 2018, after a peak in 2017.

F-gases, as a group, show an annual global growth rate of 5.9% in 2018, which is somewhat higher than the average 4.4% annual increase over the 2011–2016 period. For 2018, global total F-gas emissions are estimated at 1.7 $GtCO_2$ eq worldwide, which is almost five times the emissions in 1990, when HFC emissions from the use of these substances were non-existent. At present, emissions from HFCs used as a substitute for CFCs — as CFCs are phased out to protect the ozone layer — together with HFC-23 by-product emissions from the production of HCFC-22, make up more than 80% of present total F-gas emissions, while the remainder of F-gas emissions are those of SF_6 (13%) and PFCs 6%). The largest absolute increase in 2018 was seen in the estimated increase in emissions of by-product HFC-23 (+16%) and those from the use of HFCs (+3.5%). The country that contributed most to the estimated 2018 increase was the Russian Federation, followed by China, Turkey and the United States. It should be noted that the F-gas emissions, while reasonably accurate at a global level, are very uncertain at a national level, due to the methodology used for EDGAR v4.2 FT2018, which mainly relies on top-down estimates distributed to individual countries using various proxies.

Methodology

The calculation of these emissions was based on the EDGAR database version v5.0 FT2018 for CO_2 from the use of fossil fuel and carbonates (e.g. in cement clinker production and lime production) (Crippa et al., 2019)[3], mainly based on IEA energy statistics (IEA, 2017a), and the new version v5.0 for methane and nitrous oxide that was released this year (see Annex I in Crippa et al., 2019)[2].

The EDGAR v5.0 database covers the years 1970-2015 and includes comprehensive activity statistics and emission factor data up to 2015. In this report, we used the EDGAR v4.2 FT2010 dataset for F-gases, since a comprehensive and consistent new data set for all F-gases is not yet available.

For CO_2 emissions in 2016, 2017 and 2018, a fast-track (FT) method was used as described in Olivier et al. (2017 and reported in Crippa et al. (2019)[3]. For 2016, the CO_2 emissions from fossil fuel combustion, national trends in coal, oil product and natural gas consumption were based on the latest detailed IEA statistics on 2015 and 2016 (IEA, 2018). For 2017 and 2018, the FT estimates were based on the latest BP coal, oil and natural gas consumption statistics on 2016 to 2018 (BP, 2019).

For methane and nitrous oxide emissions over the 2016–2018 period, we mainly used an FT method for about 80% to 90% of global emissions, based on detailed agricultural statistics from FAO (CH_4 and N_2O), fuel production and transmission statistics from IEA and BP (CH_4), for so-called Annex-I countries (industrialised countries under the UN Climate Convention) supplemented with data on coal production (CH_4 recovery) and the production of chemicals (N_2O abatement) (UNFCCC, 2019). For agricultural statistics, extrapolation was used for many sources where international statistics are not yet available for 2018.

For F-gases, we used an FT method for Annex-I countries, for the most important gases and sources, using the reported emission trends in 2010–2017 (UNFCCC, 2019). For the

[2] The EDGAR v5.0 dataset does not include CH_4 and N_2O emissions from savannah burning. For our report, these emissions were added on the basis of the FAO data set for this source category.
[3] A small difference with the Crippa et al. (2019) data can be found in the CO_2 emissions from cement production in 2016–2018, where PBL uses updated emission factors resulting in 1.0% lower global total CO_2 emission level in 2018 (0.36 $GtCO_2$ lower).

remaining countries and years, for F-gases, we generally used extrapolation, since international statistics are not available[4].

We stress that the F-gas emissions, while reasonably accurate at a global level, are very uncertain on national levels, due to the methodology used for EDGAR v4.2 FT2010, which mainly relies on top-down estimates distributed to individual countries using various proxies. methodology used for EDGAR v4.2 FT2018, that mainly relies on top-down estimates distributed to individual countries using various proxies.

Most comprehensive data set

This is the most comprehensive report on global GHG emissions up to 2018, with detailed data on all GHG emissions. Other studies focus on CO_2 emissions only, which make up around three quarters of total GHG emissions, and/or present shorter historical time series.

[4] This analysis is based primarily on GHG emission data (CO_2 from fossil-fuel use and industrial processes, CH_4, N_2O and fluorinated gases), but excluding CO_2 from land-use change using data from EDGAR v5.0 FT2018. The largest changes, compared to v4.3.2 GHG FT2017 (Olivier et al., 2018), concern the CH_4 and N_2O emissions, since these data sets have been updated in v5.0 from 2012 to 2015). This includes new statistics and several revisions on previous years. In general, for non-CO_2 sources, updated international statistics from IEA, BP (2019), USGS, FAO, IFA, IRRI, UNFCCC (CRF) and other sources were used to estimate the trends for 2015–2018 emissions of CH_4 and N_2O. For more details on the methodologies and data sources used, please see Annex I in Crippa et al. (2019).

1 Introduction

This report presents recent trends, up to 2018, in greenhouse gas (GHG) emissions, for both carbon dioxide (CO_2) and non-CO_2 GHG emissions. We calculated these emissions based on the EDGAR database version 5.0 for CO_2 from fossil fuel use and carbonate uses (such as cement clinker production and lime production) (Crippa et al., 2019)[5], mainly based on the IEA energy statistics (IEA, 2017a), and the new version 5.0 for methane (CH_4) and nitrous oxide (N_2O) released this year (Crippa et al., 2019). The EDGAR v5.0 database covers the years 1970-2015 and includes comprehensive activity statistics and emission factor data up to 2015. For 2016, 2017 and 2018 a fast-track (FT) method was used for CO_2 emissions (as described in Olivier et al., 2017 and Crippa et al., 2019). For CO_2 emissions from fossil fuel combustion, the 2016 emissions were based on the 2016/2015 trends by fuel type and country in IEA (2018)[6] and the 2017 and 2018 emissions are based on the trends 2016-2017-2018 for coal, oil and natural gas consumption by country in BP (2019). For the methane (CH_4) and nitrous oxide (N_2O) emissions from 2016 to 2018, we mainly used a fast-track method for about 80% to 90% of global emissions[7].

For F-gases we used in this report the EDGAR v4.2 FT2010 dataset that covers the years 1970-2010, since a new comprehensive and consistent dataset for all F-gases is not yet available. For later years we used a fast-track method for so-called Annex I countries (industrialised countries under the UN Climate Convention), using reported emission trends for the most important F-gases and sources for 2010-2017 (UNFCCC, 2019). For the remaining countries and years, we generally used for F-gases extrapolation since international statistics are not available. This also applies to most CH_4 and N_2O emissions in 2018.

Please note that the EDGAR v5.0 dataset does not cover CH_4 and N_2O emissions from savannah burning. Therefore, for this report the EDGAR v5.0 emission data were completed to cover all sources of anthropogenic GHG emissions (except for those from land-use change) with the dataset on CH_4 and N_2O emissions from savannah burning up to 2017, as reported by the *Food and Agriculture Organization* (FAO)[8].

[5] A small difference with the Crippa et al. (2019) data can be found in the CO_2 emissions from cement production in 2016-2018, where PBL uses corrected/updated emission factors resulting in 1.0% higher global total CO_2 emission level in 2018 (0.36 $GtCO_2$ higher).

[6] This IEA dataset was the most recent available at the time of this study. Very recently the new version IEA (2019b) has been released covering energy statistics up to and including 2017.

[7] This analysis is based primarily on GHG emission data (CO_2 from fossil fuel use and industrial processes, CH_4, N_2O and fluorinated gases), but excluding CO_2 from land use change, using data from EDGAR v5.0 GHG FT2018 except for F-gases. The largest changes compared to v4.3.2 GHG FT2017 (Olivier et al., 2018) are in the CH_4 and N_2O emissions, since these datasets have been updated in v5.0 from 2012 to 2015). Version v5.0 includes new statistics and several revisions to previous years. In general, for non-CO_2 sources, we used updated international statistics from IEA, BP, USGS, FAO, IFA, IRRI, UNFCCC (CRF) and other sources to estimate the trends for 2015–2018 emissions of CH_4 and N_2O. For more details on the methodologies and data sources used for v5.0, please see Annex I in Crippa et al. (2019), Olivier et al. (2017), and see Maenhout et al. (2019) for a description of methods and data sources used in v4.3.2, also largely used in v5.0.

[8] The UN Food and Agriculture Organization (FAO) has compiled data on savannah burning emissions, for 1990–2017, using data on monthly burned area, per 0.25°x0.25° grid cell, for five land-cover types from the GFED4.1s data set (Van der Werf et al., 2017), multiplied by biomass consumption per hectare and tier 1 emission factors from IPCC (2006), aggregated at country level. The GFED data cover the 1996–2018 period. For the years before 1996, FAO used the average of the 1996 to 2014 values. For details, see (a) Data set Information at http://fenixservices.fao.org/faostat/static/documents/GH/GH_e.pdf, (b) Metadata at http://www.fao.org/faostat/en/#data/GH/metadata.

We stress that the F-gas emissions, while reasonably accurate at global level, are very uncertain at country level, due to the methodology used for EDGAR v4.2 FT2010, that mainly relies on top-down estimates distributed to individual countries using various proxies.

Non-CO_2 emissions constitute a significant fraction of global GHG emissions. For climate policies, this refers to methane (CH_4), nitrous oxide (N_2O) and the so-called F-gases (HFCs, PFCs, SF_6 and NF_3). To our knowledge, this report is the first to provide estimates of total global GHG emissions including 2018, based on detailed activity data on most of the sources for these years, whereas the 2016-2018 figures we estimated using a Fast-Track approach[9].

For *global* net CO_2 emissions from land use, land-use change and forestry (LULUCF), we used data recently generated in the *Global Carbon Project* (GCP) (Houghton et al., 2012) through 2015 (Houghton and Nassikas, 2017), which include data on CO_2 emissions from forest and peat fires, from the *Global Fire Emissions Database* version GFED4.1s through 2018 (Van der Werf et al., 2017)[10]. Those data are inherently very uncertain and therefore typically not included in emission totals of countries (e.g. as reported by countries under the UN Climate Convention) (UNFCCC, 2011). For the comprehensive overview of all GHG emissions and removals, we included them in the main figure (Figure 2.1) to illustrate their share in overall, total global anthropogenic GHG emissions. However, discussions on emission data focus on those derived from the EDGAR database, which excludes LULUCF emissions. For more information on this subject, we refer to the *Global Carbon Project* (2018) and its new 2019 release.

In addition to the global trends, the focus of this report is also on the top 5 emitting countries and the European Union as a whole, and on the global total and the countries that were largely responsible for the global emissions changes in 2018. Uncertainty about non-CO_2 emission data is typically much larger than about CO_2 emissions (excluding forest and other land-use-related emissions, 'LULUCF'). This is because these sources are much more diverse and emissions are determined by technological or other source-specific factors, whereas for CO_2, the emission factors are mainly determined by the fossil fuel type and carbon content of fuels and carbonates.

Chapter 2 discusses the global emission trends, focussing on trends of emissions and drivers in the present decade (2010-1018). Firstly, we discuss the most important variables driving the volume of the GHG sources and which of those is covered by the international statistics used for our fast-track emission estimates, for the years 2016 to 2018. Section 2.1 discusses the global total GHG emissions, with a focus on CO_2 and on the group of non-CO_2 greenhouse gases and their relation with GDP. Section 2.2 presents the main trends in CO_2 emissions, showing key trends in the use of main fossil fuels and cement production in the largest countries. Section 2.3 discusses the main trends in non-CO_2 GHG emissions and illustrates with the recent trends in key drivers of these emissions in the largest countries: fossil fuel production, cattle stock, rice cultivation (drivers for CH_4), and the use of synthetic fertilisers and manure used as fertiliser (drivers for N_2O).

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[9] Other work on historical time series of anthropogenic GHG emissions, up to 2005 or 2014, includes US Environmental Protection Agency (EPA) on global non-CO_2 greenhouse gas emissions for 1990–2005 (US EPA, 2012); the CAIT database for greenhouse gas emissions for 1990-2014, compiled by the WRI (2016); and the PRIMAP-hist data set for 1850–2014, developed at the Potsdam Institute for Climate Impact Research (PIK) (Gütschow et al., 2016).

[10] The H&N time series was extended for 2016 to 2018 with preliminary numbers based on fire counts through 2018: for 2016 and 2017 numbers from GBC (2018) and our own estimate for 2018 based on numbers from GFED4.1s (same number as selected for 2017). Total LULUCF emissions presented here includes 0.2 $GtCO_2$ eq for fire emissions from CH_4 and N_2O taken from the GFED 4.1s dataset (also preliminary numbers).

Chapter 3 provides more detailed information on the five largest emitting countries and the European Union, using the same approach as in Sections 2.1 to 2.3.

This report focuses on trend analysis and identification of the key drivers of CO_2, CH_4 and N_2O emissions, rather than analysing more aggregate drivers, such as Gross Domestic Product (GDP), energy use per unit of GDP, and CO_2 emissions per unit of energy. The 2017 report provides more details on the methodology used for estimating non-CO_2 emissions (Olivier et al., 2017), in Box 1.1 and Appendix D of that report. That report also discusses the quality and completeness of CH_4 and N_2O emission data by comparing emissions in the former EDGAR data set v4.3.2 with total CH_4 and N_2O emissions from the officially reported national emissions.

Box 1.1 Coverage of EDGAR v5.0 and the JRC booklet 2019

The 2019 JRC booklet, by Crippa et al. (2019), shows the time series of global greenhouse gas emissions, for all countries around the world and the European Union as a whole, using data from EDGAR v5.0 on 1970–2015, which are identical or very similar to the data used for this report:

- The CO_2 emissions presented separately in the JRC booklet show the trend for individual countries from 1990 to 2018, as compiled according to the FT method for 2016-2018, used in both this report and Crippa et al. (2019). However, there is a small difference with Crippa et al. (2019) in the CO_2 emissions from cement production for 2016–2018, where PBL uses updated emission factors resulting in a 1.0% lower global total CO_2 emission level in 2018 (0.36 $GtCO_2$ lower) than in the JRC booklet.

- The CO_2 emissions from fossil fuel combustion in v5.0 were calculated using the same fuel statistics as those of the *International Energy Agency* (IEA,2017a). For the CO_2 Fast Track 2018, the trend in fossil fuel combustion emissions from fuel consumption from IEA was used, which was available for 2016, and the trend in BP main fossil fuel consumption up to 2018. For more details on the FT methodology for CO_2, see Annex I in Crippa et al. (2019).

- The 2019 JRC booklet reports trends up to 2015 for the non-CO_2 gases CH_4, N_2O and the F-gases — and thus for total greenhouse gases — as included in the new EDGAR v5.0 data set (which excludes CH_4 and N_2O emissions from savannah burning).
- For F-gases, a partly new data set was compiled by JRC, as was used in the JRC booklet, which is somewhat different than the data set used in this report. For more details of the EDGAR v5.0 data set on F-gases used by JRC, we refer to Annex II in Crippa et al. (2019).

2 Trends in global emissions

2.1 Introduction

Our analysis focuses on the identification of key trends and the main direct drivers that determine the changes in the quantity of CO_2, CH_4 and N_2O emissions, both globally and for the five largest emitting countries and the European Union, as a whole. These gases, currently, contribute a respective 72%, 19% and 6% to global total GHG emissions excluding land use, with F-gases accounting for the remaining 3%. Table 2.1 summarises the main drivers of emissions and their share in global emissions. For the smaller remaining sources, also proxies have been used (e.g. statistics for other livestock) or trend extrapolation (e.g. for landfills and waste water). For details, see Olivier et al. (2017).

Table 2.1 Key drivers of greenhouse gas emissions excluding land-use and global shares

Type of gas	Share gas in GHG	**Main source drivers/** Other source drivers	Share in gas total	Year of statistics
CO_2	**72%**	**Coal combustion**	39%	2018
		Oil combustion	31%	2018
		Natural gas combustion	18%	2018
		Cement clinker production	4%	2017
		Subtotal drivers of CO_2	**92%**	
CH_4	**19%**	**Cattle**	21%	2017
		Rice production	10%	2018
		Natural gas production (including distribution)	14%	2018
		Oil production (including associated gas venting)	9%	2018
		Coal mining	10%	2018
		Landfill: municipal solid waste generation ~ food consumption	10%	2013
		Waste water	11%	
		Subtotal drivers of CH_4	**85%**	
N_2O	**6%**	**Cattle** (droppings on pasture, range and paddock) *	23%	2017
		Synthetic fertilisers (N content) *	13%	2017
		Animal manure applied to soils *	5%	2017
		Crops (share of N-fixing crops, crop residues and histosols)	11%	2017
		Fossil fuel combustion	11%	2018
		Manure management (confined)	4%	2017
		Indirect: atmospheric deposition & leaching and run-off (NH_3)*	9%	2017
		Indirect: atmospheric deposition (NO_x from fuel combustion)	7%	2018
		Subtotal drivers of N_2O, incl. other, related drivers (*)	**83%**	
F-gases	**3%**	HFC use (emissions in CO_2 eq)	61%	NA/2017 **
		HFC-23 from HCFC-22 production (emissions in CO_2 eq)	22%	NA/2017 **
		SF_6 use (emissions in CO_2 eq)	14%	NA/2017 **
		PFC use and by-product (emissions in CO_2 eq)	3%	NA/2017 **
		Subtotal drivers of F-gases	**100%**	

* Activity data compiled by FAO cf. IPCC source category definitions.
** Statistics for Annex I countries only, reporting annually to UNFCCC (CRF files): up to year t-1.
Sources: EDGAR v5.0 for CO_2, CH_4 and N_2O (1970–2015); EDGARv4.2 FT2010 for F-gases (1970–2010); FT2018 for all.

As we only use the fast-track methodology based on indicators of volume trends for estimating the emissions in the last three years (at maximum), we assume that these non-volume effects impacting emissions, such as changes in feed and food, are relatively small on a year-by-year basis. Most of these changes are not further discussed in this report. For more information on this we refer to the detailed National Inventory Reports that are submitted annually by most industrialised countries to the UN Climate Secretariat (UNFCCC, 2019).

The direct drivers of CO_2 are the combustion of coal, oil and natural gas, representing 89% of global CO_2 emissions, with respective shares of 39%, 31% and 18%. Calcination in cement clinker production accounts for another 4% (Table 2.1). Fossil-fuel-related CO_2 emissions can only be significantly reduced by switching to other energy sources, notably renewable sources such as hydropower, wind, solar and nuclear power and sustainably produced biofuels. Additional reductions may be achieved through energy-efficiency improvements. Furthermore, CO_2 capture from flue gases and storage underground (CCS) may contribute to reducing the seemingly ever-increasing CO_2 concentrations in the atmosphere (Global CCS Institute, 2019).

For CH_4, there are three large groups of sources: agriculture, fossil fuel production and waste/waste water. In agriculture, ruminant livestock, particularly cattle, and rice production are the largest global sources. With a share of three quarters of all ruminant-related CH_4 emissions (31%), those from cattle alone are responsible for 21% of current global CH_4 emissions. Rice cultivation on flooded rice fields is another agricultural source, where anaerobic decomposition of organic material produces methane, accounting for 10% of CH_4 emissions. Other large CH_4 sources are coal production, natural gas production and transmission as well as oil production (including vented associated gas that consists mostly of CH_4, if it cannot be utilised). Together, fossil fuel production and transmission account for another third of global methane emissions, with each fuel having roughly equal share. The third largest source is human waste and waste water. These are other sources where anaerobic decomposition of organic material produces methane. When biomass waste in landfills and organic substances in domestic and industrial waste water are decomposed by bacteria in anaerobic conditions, substantial amounts of methane are generated. Landfill and waste water are both estimated at shares of about 10%. For these emissions, food supply as a driver would be a good indicator; however, FAO statistics on food balances are lagging several years behind (Table 2.1).

For N_2O, agricultural activities are the main emission source, with a share of almost 65%. The animal droppings on pastures, rangeland and paddocks are by far the largest global source of nitrous oxide, with an estimated share of 23%, and the use of synthetic nitrogen fertiliser is the second-largest source, accounting for 13%, at present. Indirect N_2O emissions from agricultural activities contribute another 9%. Together, these sources account for 50% of global emissions, including 4% from animal manure applied to agricultural soils as fertiliser (Table 2.1).

F-gas emissions consist of HFCs, PFCs, SF_6 and NF_3. With a share of almost three-quarters, emissions from the *use* of these gases are by far the largest source. Other sources are inadvertent *by-product* emissions of HFC-23 during the production of HCFC-22 and PFCs emissions that arise from primary aluminium production. At present emissions of HFCs and SF_6 are the largest global sources of fluorinated gases with shares of 81% and 13% (PFCs only 6%). Total F-gas emissions from the *use* of these gases, in particular HFCs, have substantially increased since 2005 with about 4% per year, as industrialised countries show in their detailed GHG emission trend reports through 2017 (UNFCCC, 2019). This is an important source of data for F-gases, as there are no global statistics for their use and emissions. We recall the very large uncertainties in F-gas emissions at country level (see introduction of Appendix B).

Other than by reducing the volumes of livestock and fertilisers used, CH_4 and N_2O emissions may also be partly reduced by changes in animal feed, optimising nitrogen fertiliser use on arable land, and changes in human food preferences for meat, fish and vegetables, and reduction in losses over the entire food chain, from primary production by farmers to final consumption. Moreover, methane generated in fossil fuel production and in landfill and waste water may be reduced by recovering CH_4 and either use it as biogas for energy purposes or by flaring it.

2.2 Global trends in total greenhouse gas emissions

In 2018, the growth in total global GHG (GHG) emissions (excluding those from land-use change resumed at a rate of 2.0% (±1%), reaching 51.8 gigatonnes of CO_2 equivalent[11] [12] ($GtCO_2$ eq) after six years (since 2012), with a somewhat lower annual growth of 1.3% on average and compared with the much higher average annual growth rate of 2.5% in the first decade of this century (Figure 2.1). This new time series marks the end of global emissions peaking in 2015 and 2016.

This increase occurred while the 3.4% global economic growth in 2018 continued at about the average annual growth rate of 3.4% since 2012. Present GHG emissions are about 57% higher than in 1990 and 43% higher than in 2000. The 2018 GHG emissions amounted 55.6 $GtCO_2$ eq when also including those from land-use change emissions (which are estimated at a very uncertain 3.8 $GtCO_2$ eq).

The year 2018 was a remarkable year, again, because it was globally among the five warmest years (2014-2018) since records began in 1880. Of the 10 warmest years since 1880, 9 occurred since 2005. In 2018, temperatures across much of the world were warmer to much warmer than average. Record warm temperatures were measured across much of Europe, the Middle East, New Zealand and parts of Asia. A heatwave of unprecedented intensity and duration struck Europe, from April 18–22. France, Germany and Switzerland had their warmest year since national records began. The Netherlands had its second warmest year on record (with 2014 being the record year). The departure from the average global temperature level was 0.97 ^{o}C above the 1880–1900 average, just slightly below those of the years 2015–2017 (NOAA, 2019).

That the warmest years globally are concentrated in recent years rather than more evenly distributed over time is also confirmed by the annual number of so-called *Heating Degree Days* in the United States and the European Union, which is used as estimator of the demand for space heating and by so-called *Cooling Degree Days* in the United States, which is used to estimate the electricity demand for air-conditioning (see Sections 3.2 and 3.3).

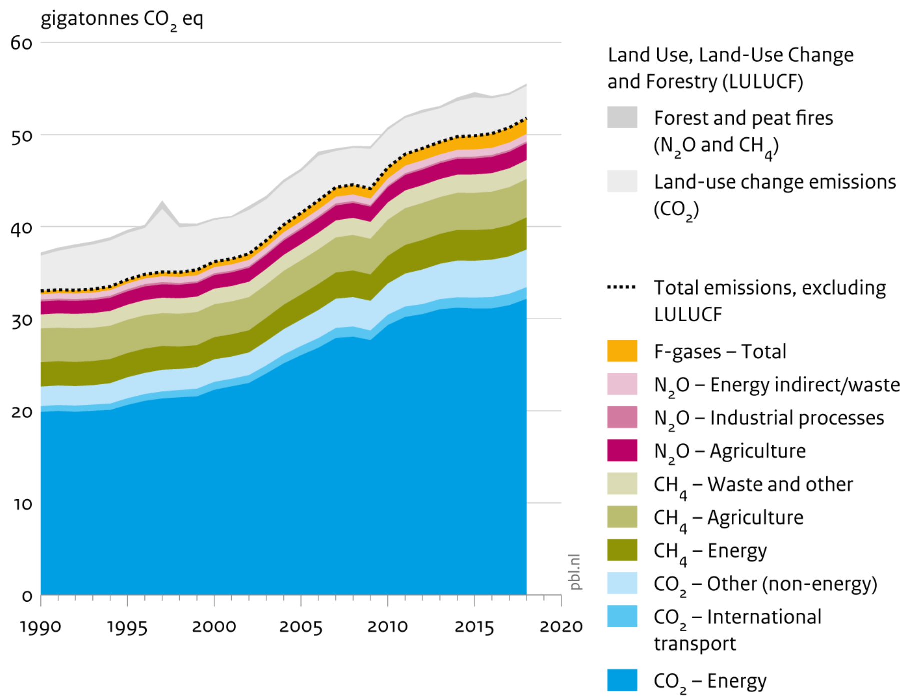
The annual growth rate of 2.0% in 2018 was twice as high as the average growth since 2012, when the average greenhouse gas emission growth was also 1.0% per year (Figure

[11] Unless stated otherwise, we use in this report for CH_4, N_2O and the F-gases the *Global Warming Potential* (GWP) metric from the Fourth Assessment Report (AR4) of the IPCC (2007), which is also used by industrialised countries in their annual national emissions inventory reports submitted to the UNFCCC (so-called Annex I countries). The time horizon of the GWPs used is 100 years. Please note that developing countries officially report their emissions using GWPs from the Second Assessment Report (SAR) of the IPCC. The largest difference is in the GWP of CH_4: the GWP value is 25 in the AR4 and 21 in the SAR, so almost one fifth larger.

[12] The historical EDGAR GHG emission trends in this report were also presented in UNEP's Emissions Gap Report 2019, (UNEP, 2019).

2.1). In 2003, global greenhouse gas emissions growth accelerated to 3.9% and remained high through 2007 (the average increase was 3.6% over these years), which was related to the fast industrialisation of China, since the country became a member of the World Trade Organization (WTO) (Figure 2.1). Please note that the global economic crisis was in 2008–2009. In our analysis of recent trends in emissions and drivers, we focus on the 2010–1018 period and include the first decade of this century, for a broader perspective.

Figure 2.1
Global greenhouse gas emissions, per type of gas and source, including LULUCF



Source: CO2, CH4, N2O excl. land-use change: EDGAR v5.0 FT2018; incl. savannah fires FAO; F-gas: EDGAR v4.2 FT2018
GHG from land-use change: CO2 from Houghton & Nassikas 2017, CH4 and N2O from GFED4.1s 2019

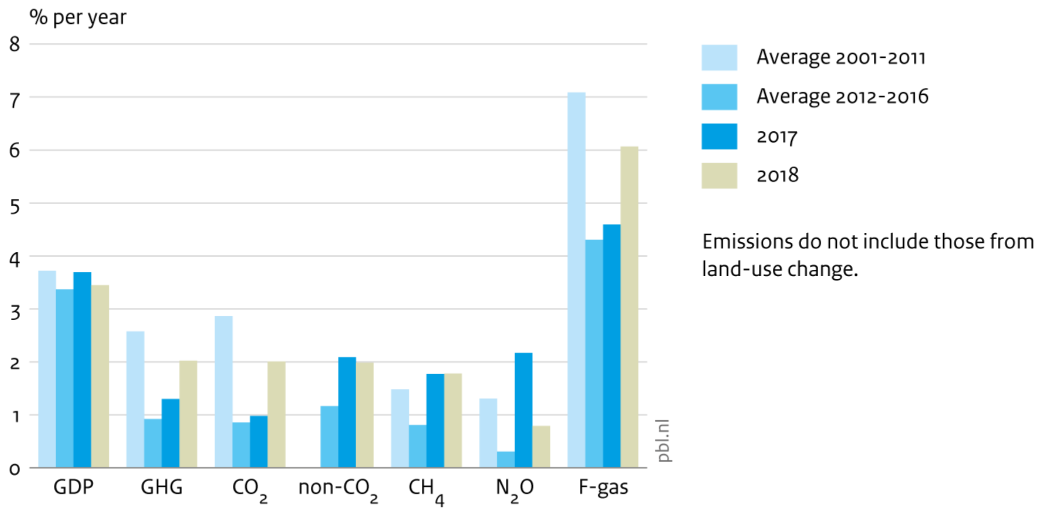
The slowdown of the emissions growth since 2012, that was reported some years ago, had led to speculation whether global GHG emissions are now 'plateauing' or 'peaking' at around 50 $GtCO_2$ eq and whether we may expect global GHG emissions to decrease soon, but now we see in recent years the same growth rate again (1.3% in 2017 and 3.0% in 2018) as the annual average that we saw in the years 1987-1996. In the last three decades of the 20th century, the average global GHG emission increase of 1.3% per year was mainly driven by the 1.6% average annual growth in CO_2 emissions since 1970. Thus, apart from short interruptions in years of global recessions, global GHG emissions have been increasing steadily in the decades since, e.g. from 24.6 gigatonnes in CO_2 equivalent ($GtCO_2$ eq) in 1970, via 33.0 $GtCO_2$ eq in 1990 to 37.1 $GtCO_2$ eq in 2002. Subsequently, in the next decade global emissions accelerated annual growth of 2.5% on average led to 47.9 $GtCO_2$ eq in 2011, after which emissions increased at a much slower rate of 1.0% on average to the present 51.8 $GtCO_2$ eq in 2018.

Note that for climate policy purposes the emissions in 1990 are relevant as it is the default base year for the UN Climate Convention, 2005 is the base year for some national targets (such as for the European Union), further 2010 (more precisely the average of 2008-2012) was the target year for the first commitment period of the Kyoto Protocol. Further analysis may show the extent to which recent global and national GHG trends estimated in this report are in keeping with the total national GHG emission trends as expected from analyses of pledges of countries under the Paris Agreement (see UNEP, 2019; Kuramochi et al., 2019; PBL, 2019).

Annual change in global GDP and total greenhouse gas emissions

Figure 2.2 shows annual changes, for the 2010–2018 period, in global *Gross Domestic Product* (GDP) and global emissions of total greenhouse gases and for each individual gas (but aggregating the fluorinated gases in one group, the so-called F-gases). It shows that, while the average growth in the world economy has been fairly constant since 2010, annual growth in total greenhouse gas emissions saw a distinct drop to 0.2% in 2015. Conversely, 2011 saw a large annual growth in global greenhouse gas emissions of 3.1%, whereas global GDP showed only a slightly elevated annual growth (3.9%). In 2018, the relatively high increase in global greenhouse gas emissions of 2.0% was not accompanied by a very high GDP growth (3.4%). Annual CO_2 growth, in this decade, was very similar to the increase in annual total greenhouse gas. For non-CO_2 emissions, this was less for several years, except for 2017 and 2018, when it was also 2.0%. We observed that the annual increases in GDP and in emissions were not well correlated, although as a rule the emission change in percentages was smaller, for all years and periods shown, than the change in GDP.

Figure 2.2
Annual changes in global GDP and global greenhouse gas emissions, 2001–2018



Source: GDP: World Bank, IMF; GHG: EDGAR v5.0 (EC-JRC/PBL, 2019) FT2018, except F-gas: EDGAR v4.2 FT2018

When looking at the separate greenhouse gases, we can see which gases were mainly responsible for the total GHG trend in this decade (Figure 2.2). It shows that the 11.6% increase in GHG in 2018 compared to 2010 is due mainly to a 10.9% increase in CO_2 and also a 13.6% increase in no-CO_2 gases. The GHG emissions increase in 2018 of 2.0% was mainly due to a 2.0% increase in global CO_2 emissions from fossil fuel combustion and those from industrial non-combustion processes including cement production, which contribute almost three quarters to total GHG increase in 2018, but also non-CO_2 emissions retained their relatively large annual increase of 2.0% in 2018. In contrast, the low GHG emission growth in 2015 of about 0.2% is mainly due to null CO_2 growth in this year, which is mainly caused by a declining global coal consumption, notably in China, the United States and the European Union.

The emissions of the other greenhouse gases CH_4, N_2O and F-gases increased in 2018 by 1.8%, 0.8% and 5.9%, respectively. Although most of global GHG emissions consist of CO_2 (about 72%), methane, nitrous oxide and fluorinated gases (so-called F-gases) also make up significant shares (19%, 6% and 3%, respectively). From the shares and increases in 2015 we can infer that it was mainly the low 0.4% change in CH_4 emissions that caused the lower annual growth of 0.8% non-CO_2 greenhouse gases in 2015.

These percentages for the share in total GHG emissions do not include net emissions from land use, land-use change and forestry (LULUCF), which are usually accounted for separately, because they are inherently very uncertain and show large interannual variations that reflect the periodically occurring strong El Niňo years, such as in 1997–1998 and 2015–2016, as shown by the grey area above the dashed line in Figure 2.1. When including LULUCF emissions — for 2018 estimated at about 3.8 $GtCO_2$ eq — estimated global total GHG emissions come to 55.6 $GtCO_2$ eq. in 2018.

Increase in atmospheric CO_2 concentration in 2018 among highest in recent years

The year 2018 was a remarkable year, not so much for the annual mean CO_2 concentration in the atmosphere, which reached 408.5 ppm, but for the 2.86 ppm net increase in atmospheric CO_2 concentration from 1 January through 31 December 2018, as this was the fourth largest increase since measurements began at Mauna Loa (Hawaii) in 1959. The years with the largest increases were 2016, 2015 and 1998, however the uncertainty ranges of the increases in these four years overlap (NOAA/ESRL, 2019).

The annual increase in CO_2 in the atmosphere was mainly driven by the dozens of gigatonnes in CO_2 emissions from fossil fuel combustion and those from calcination of carbonates found in limestone, when used to produce lime or cement clinker and by CO_2 emissions from large-scale forest fires, whereas the net increase in atmospheric CO_2 was also strongly mitigated by the net carbon uptake by the oceans and growing vegetation. Thus, there is no one-to-one relationship between the net increase in annual mean CO_2 concentrations and annual CO_2 emissions from fossil fuels.

2.3 Global trends in CO_2 emissions

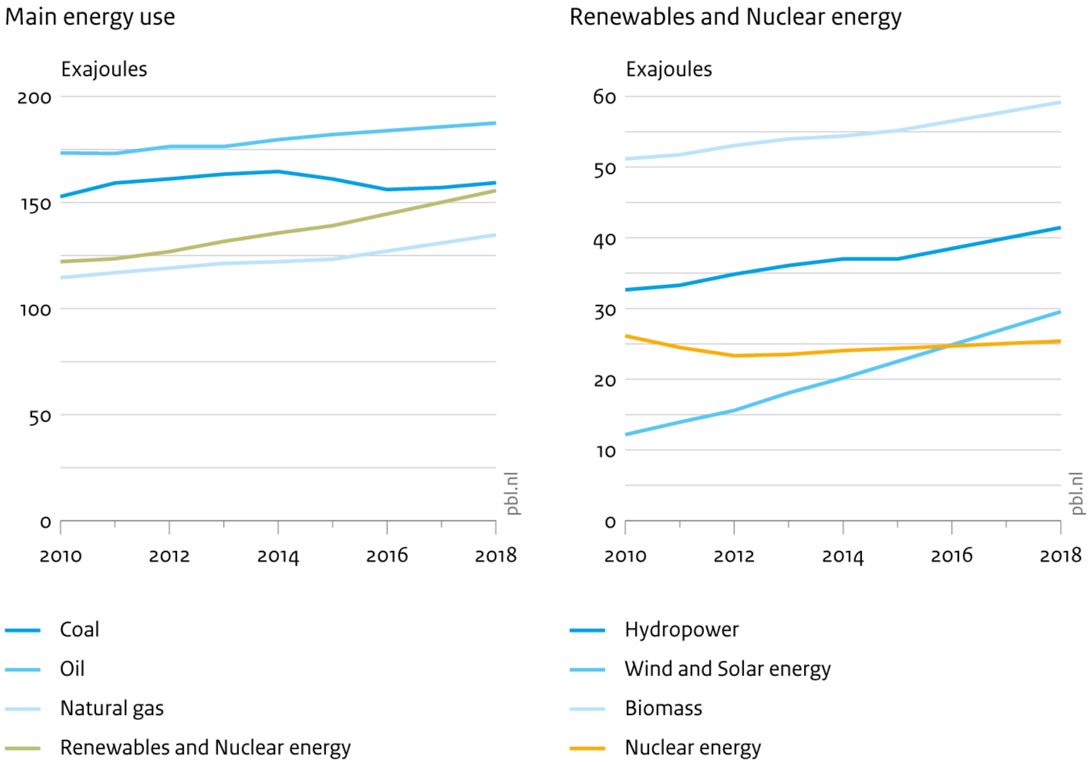
We recall that, while CO_2 emissions are mainly based on detailed IEA fuel statistics, the CO_2 emission trends in 2017 and 2018 are mainly based on BP statistics for coal, oil and natural gas consumption. Very recent CO_2 emissions are also discussed in studies by IEA (2019a) and JRC (Crippa et al., 2919).

In the 1970–2003 period, global CO_2 emissions (excluding those from land use change) increased by 1.6% per year on average. From 2003 to 2011 the emissions growth accelerated to 3.2% per year on average driven by China's fast industrialisation since 2002. However, during the years 2012 to 2014 global annual growth slowed down to about 1.3% per year and in 2015 CO_2 emissions remained constant.

However, in 2016, global CO_2 emissions started to increase again; by 0.3% in 2016, 1.0% in 2017 and 2.0% in 2018. This rebound was mainly due to a new rise in global **coal consumption** of 0.2% in 2017 and 1.4% in 2018, after three years of decreases (Figure 2.3, left graph). In Figure 2.3, these annual changes are hardly visible. In the left part of Figure 2.3, however, global fossil fuel production with a more detailed scale on the Y-axis, clearly shows the annual changes. In 2018, globally, oil made up 29% of Total Primary Energy Supply (TPES), for coal this was 25%, renewables plus nuclear was 24% and natural gas was 21% (IEA, 2019b; BP, 2019). In other words, 76% of the world's energy supply still consisted of fossil fuels. Globally, with a share of 9%, biomass was by far the largest non-fossil energy type. This refers to solid biomass burned in power plants, modern biofuels used in transport and traditional biofuels used for cooking and space heating, such as fuelwood, charcoal and biogas.

This decline in global coal production and consumption was caused by three years of decreasing coal consumption in China and declines in the United States and the European Union, mainly from power plants switching fuel to natural gas and increased global renewable power generation, in particular, wind and solar power (Figure 2.3, right side) (IEA, 2019a; BP, 2019). As shown in the left part of this figure, renewable power plus nuclear power, albeit steadily rising, still made up a very small part of the global energy mix.

Figure 2.3
Trends in global energy use, 2010-2018



Source: IEA, BP

The increase in 2018 in global **coal** consumption was mostly due to large absolute increases in India (8.7%, twice the increase in 2017) and China (0.9%). About two thirds of the global growth was in India and about 30% in China. Together, the changes in all other countries come almost to zero. Other countries that saw relatively large absolute increases in coal consumption are Vietnam (+22.9%), Pakistan (+63%) and Indonesia (+7.7%), as well as Kazakhstan (+12.2%) and the Russian Federation (+4.9%) (ranked in order of the largest absolute changes)[13]. In contrast, coal consumption in the European Union and United States continued to decrease, by 4.3% and 5.1%, respectively (particularly in Germany and Spain). Also, in Canada and Japan, coal use continued to decline in 2018. Apart from India and China, together, the mentioned increases and decreases in other countries contributed about 40% to the net increase, effectively cancelling total changes in these countries and the European Union.

[13] This ranking according to the largest absolute changes, indicating change in percentage, is used throughout the report, in lists of countries or source categories.

Coal-fired power plants are by far the largest user of coal. For more details on new coal plants, plants under construction, planned or retired, we refer to Shearer et al. (2019). They conclude that, in 2018, the number of coal-fired power plants under development again dropped steeply, with a 20% drop in newly completed coal plants (53% in the past three years), a 39% drop in newly started construction (84% in the past three years), and a 24% drop in plants' pre-construction activities (69% over the past three years). Moreover, in 2018, retirements of coal plants continued at a high rate. With 17,000 MW retired in 2018, the United States accounted for over half of global retirements. China and India accounted for 8,000 MW and 2,000 MW, respectively.

Global consumption of oil products and natural gas continued to increase, by 1.2% and 5.3% in 2018. The increase in global **oil consumption** was led by China (+5.0%), the United States (+2.1%) and the Russian Federation (+5.1%), together accounting for all of the net increase. Countries showing relatively large absolute decreases are Saudi Arabia (-3.6%), Germany (-5.1%), Japan (-2.9%) and Pakistan (-16.6%). In addition, Mexico, Venezuela and Egypt also saw decreases in oil consumption (in order of largest absolute changes).

The increase in global **natural gas consumption** in 2018 was led by the United States (+10.5%), China (+17.7%) and the Russian Federation (+5.4%), accounting for more than two thirds of the net global increase. Other countries that saw an increase in natural gas consumption are Iran, South Korea, India and Canada. Countries showing relatively large absolute decreases are Venezuela, Turkey and the European Union (particularly, Italy, France and Germany). For more details on these countries and the European Union we refer to Chapter 3.

Globally, CO_2 emissions from the residential and commercial buildings sector are only 10% of global total CO_2 emissions from fossil fuel combustion and almost one quarter of global gas consumption is used in this sector. Natural gas is the fuel of choice for space heating and other heating purposes, causing 45% of CO_2 emissions from the buildings sector, with oil as second fuel, leading to 37% of the sector's CO_2 emissions (IEA, 2018). From these statistics it is clear that for countries with cold winters the demand for natural gas will vary also because of differences in demand for space heating in winter months, e.g. the United States and north-western European countries. The US Energy Information Administration (EIA) estimates that in the Reference case, in non-OECD countries the use of fossil fuels in this sector will in increase by about 50% by 2050, but their use of electricity will jump five-fold from present level (EIA, 2019i).

The increase in global CO_2 emissions, in 2018, was closely related to the trends in primary energy demand and in the energy mix. In 2018, energy demand increased by 22 EJ, which was met for 50% by fossil fuels and 50% by renewable and nuclear power. Taking a somewhat longer view, total primary energy supply (TPES[14]) increased from 2010 to 2018 by 84 EJ or 15% (from 563 EJ to 646 EJ). Over those years, the shares of fossil fuels decreased from 78.3% to 75.1% (up 45 EJ: coal +6.5, oil +15.1, natural gas +23.3 EJ), renewables increased from 17.1% to 20.9% (up 3.9 percentage points: hydropower +0.4%, biomass +0.1%, wind and solar power +3.4% percentage points), and nuclear energy decreased from 4.6% to 3.9%).

However, with increasing energy demand, for peaking and curbing CO_2 emissions, it is not enough to have higher growth rates of renewable and nuclear energy. As long as their shares

[14] TPES, or Total Primary Energy Supply, is the total amount of energy consumption of a country (or the world). It is calculated as in BP (2018): using a substitution method for nuclear, hydropower and other non-biomass renewable power and assuming 38% conversion efficiency in all these cases. This is different from the definition that the IEA uses in her publications in that they use different percentages for non-combustion power sources.

in total energy supply are too small, a growth in total energy demand will also imply continued growth in fossil fuel use, thereby increasing total CO_2 emissions. Global electricity demand increased by 3.7% in 2018. About half of this increase was met by increased renewable and nuclear power, almost two thirds of which consisted of wind and solar power, a quarter hydropower and the remainder nuclear power. Thus, the other half of the global growth in power generation was still met by fossil fuels, half of which by natural gas and almost two thirds by coal (the small use of oil in power generation decreased further). And then there was the demand for fossil fuels in other sectors, such as industry, transport and the residential and commercial sectors.

CO_2 from non-energy uses

Above, we discussed CO_2 emissions emitted from the combustion of fossil fuels, which accounted for most of the CO_2 emissions (89%, excluding those from LULUCF). This is indeed the main cause of the rise of global CO_2 emissions. The remaining 11% was made up from various sources, partly related to fossil fuel production or use and partly to the use of limestone and dolomite (from the oxidation of the carbonates of which they are composed):

- limestone use in **cement clinker production** (4.1%); this refers only to the non-combustion process part in cement production);
- **non-energy use of fossil fuels** (4.0%), e.g. natural gas, naphtha or LPG as chemical feedstock or coke used primarily as reducing agent in blast furnaces;
- **other use of limestone and dolomite** (1.1%); covers CO_2 from carbonate oxidation processes such as in lime production;
- **solid fuel transformation** (1.0%), notably coke production from coking coal;
- **gas flaring** of natural gas that is not used at oil and natural gas production sites (0.7%).

CO_2 emissions from cement production was the only CO_2 source that saw global emissions decline by 2.6% in 2018, which was a continuation of the 1.3% decrease in 2017. This was largely due to similar decreases in global cement production, with China as the largest contributor due to its very large share of 55% in global cement production. In 2018, China was the only large country to see decreases; in 2017, India and Japan also showed decreases.

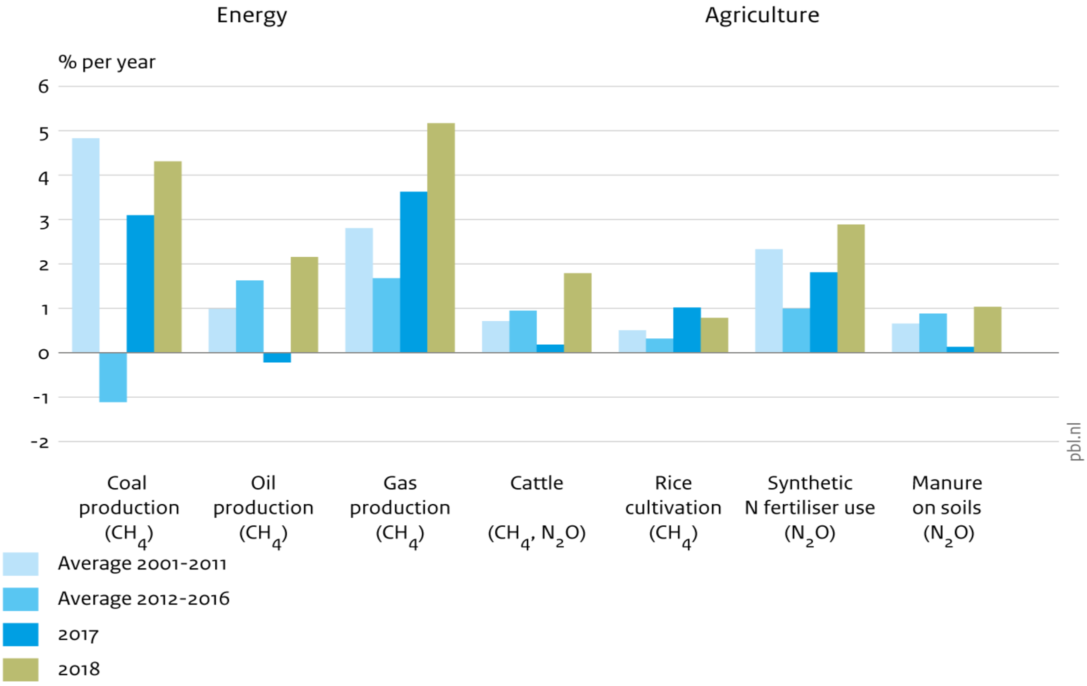
We recall that the time series data for global CO_2 emissions have been revised and updated since the 2018 report mainly for 2016 and 2017 for which a fast-track approach was used, since 1970-2015 emissions were used from EDGAR v5.0 for CO_2 emissions that was also used last year (Olivier and Peters, 2018). Global total CO_2 emissions in 2015 are now 36.3 $GtCO_2$, which is only 0.4% lower than the estimate of 36.4 $GtCO_2$ presented last year for 2015. These changes are mainly due to a significant revision of CO_2 emissions, in recent years, from gas flaring due to a revision of the volume of gas flared as derived from satellite observations of gas flares (in 2015 by 21%;) and small revisions/corrections in CO_2 emissions from non-energy use of fuels (in 2015 by -3.5%). Similar small revisions for these sources were made for the years before 2015. According to Bamji (2019), in 2018, gas flaring emissions increased by 3%, partly due to a 33% increase in oil production in the United States, with almost 50% higher associated flaring emissions and soaring gas flaring in Venezuela. These are data from the Global Gas Flaring Reduction Partnership (GGFR), an initiative managed by the World Bank (2019b).

In using the fast-track method for 2016–2018, fossil fuel trends for coal, oil and natural gas in 2015 and 2016 were obtained from the updated statistics by the International Energy Agency (IEA, 2018) that now covers all years up to 2016, and the updated BP statistics for the trend in 2016/2017/2018 (BP, 2019). The revised global CO_2 emissions were slightly lower than in last year's report, from -0.0 Gt in 1990 (-0.1%), via -0.1 Gt in 2000 (-0.4%) – and somewhat larger for recent years –to +0.7 Gt in 2015 (+2.0%).

2.4 Global emissions of other greenhouse gases

As discussed in the introduction, the non-CO_2 GHG emissions originate from many different sources and are much more uncertain than CO_2 emissions (Figure 2.4). Their uncertainty on a country and global level is of the order of 30% or more, whereas for CO_2 this is about ±5% for OECD countries and ±10% for most other countries (Olivier et al., 2016). Note that due to the large diversity of the emission factors within these sources, and the lack of global statistics for F-gas production and their uses, the annual trends in the emission of CH_4, N_2O and F-gases are much more uncertain than those in CO_2.

Figure 2.4
Annual changes in main drivers of global CH_4 and N_2O emissions, 2001-2018



Source: CH_4: IEA, BP, FAO, IRRI; N_2O: IFA, FAO
Note: Between brackets the greenhouse gas(es) are listed for which the activities are drivers.

Compared to the trend in global CO_2 emissions, the increase in non-CO_2 GHG emissions did not go down as much in 2015 and 2016, namely from 1.9% annual growth over the 2004–2014 period to a growth of 0.8% in 2015 and 1.4% in 2016. And higher growth resumed by 2.1% in 2017 and by 2.1% in 2018. However, methane emissions, which make up two thirds of the non-CO_2 greenhouse gas emissions, showed only a 0.4% growth in 2015 and 2016, after which annual growth resumed at a higher level of 1.8% in 2017 and 2018.

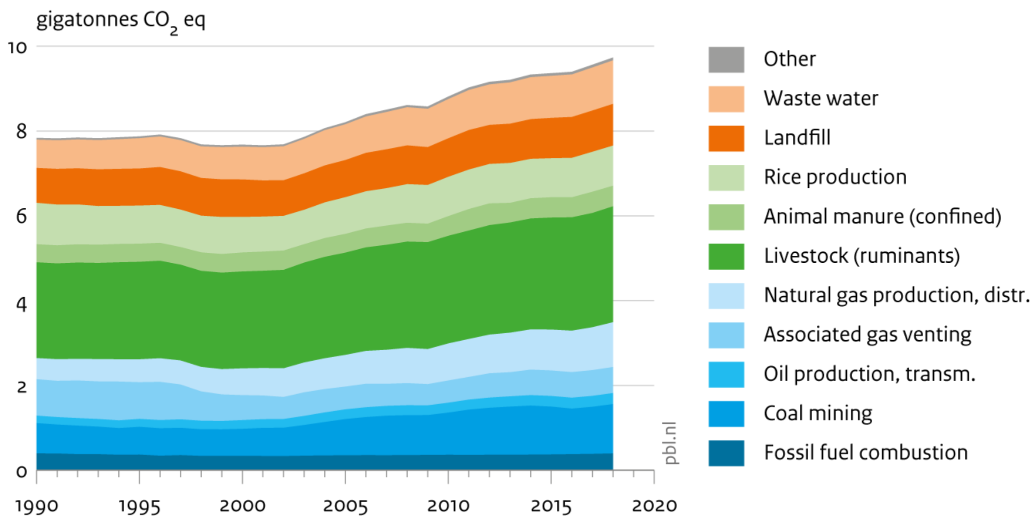
Although varying per country, non-CO_2 emissions constitute a significant share in total GHG emissions. The global share of non-CO_2 greenhouse gases is estimated to have declined from 36% in 1970 to 26.8% in 2013, after which it started to increase, very slowly, to about 27.5% in 2018, because of the slow-down of the annual growth in global CO_2 emissions since 2012.

Methane emissions

The trend in global methane (CH_4) emissions since 1990 is presented in Figure 2.5. It shows that the largest sources are the production and transmission of coal, oil and natural gas, and livestock: when animals ruminate their feed, they emit considerable amounts of methane. So, it is fossil fuel *production*. not fossil fuel *combustion*, that is a large source of CH_4 emissions. Globally, cattle account for two thirds of the CH_4 emitted by livestock, followed by buffalo, sheep and goats that haves shares of about 10%, 7% and 5%, respectively. The third largest source is human waste and waste water: when biomass waste in landfill and organic materials in domestic and industrial waste water decompose by bacteria in anaerobic conditions, substantial amounts of methane are generated. Likewise, rice cultivation in flooded rice fields is another source where anaerobic decomposition of organic material produces methane.

Since the start of the 21st century global CH_4 emissions started to rise again. From 2004 to 2014 they increased by 15.7%, which is 1.6% per year on average. Sources that contributed most to this increase were coal mining (+4.7% per year on average), natural gas production and distribution (+3.1%) and livestock (+0.9%). Countries with the largest absolute increase over these 10 years are China, Indonesia, India and Brazil, whereas the largest decreases occurred notably in the European Union (in particular the United Kingdom and Germany), but also in Argentina, Ukraine and Nigeria.

Figure 2.5
Global methane emissions, per main source



Source: EDGAR v5.0 (EC-JRC/PBL, 2019) FT 2018, incl. savannah fires, based on IEA, BP, FAO, IRRI, UNFCCC, GFED 4.1s

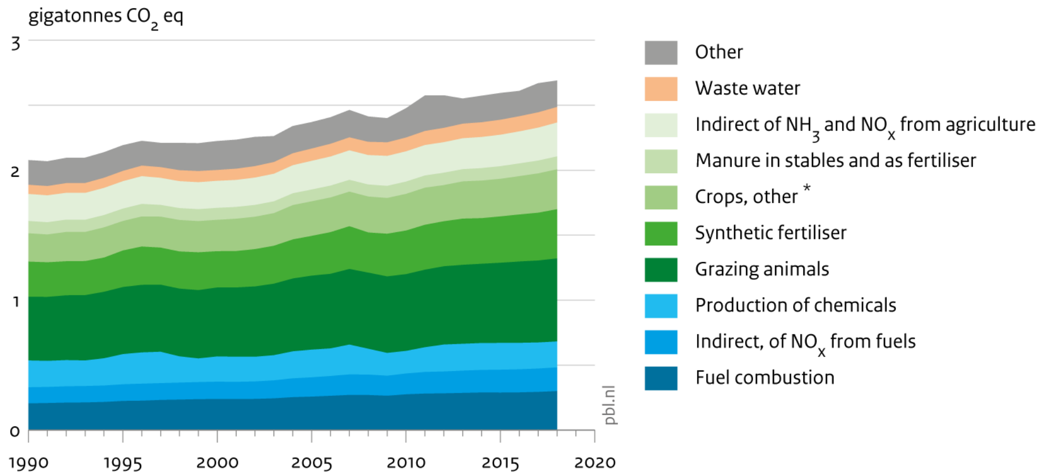
In 2018, the growth rate of methane emissions is estimated at 1.8% to a total of 9.7 $GtCO_2$ eq, which is a continuation of the 1.8% growth in 2017, but markedly higher than in 2015 and 2016 that saw both growth rates of 0.4%, but it is similar to the growth rate in 2012 of 1.5% (Figure 2.5). Present emissions are 24% higher than in 1990, when they were 7.8 $GtCO_2$ eq. Increases in emissions from livestock and from natural gas production contributed most to the global emission increase of 4.3% since 2014, further aided by increases in emissions from waste water handling and landfills, whereas some decreases were seen in emissions from gas venting and savannah burning.

Nitrous oxide emissions

The trend in global nitrous oxide (N_2O) emissions since 1990 is presented in Figure 2.6. It clearly shows that agricultural activities are the largest sources of N_2O accounting for about two-third. The main global sources of N_2O emissions are from manure dropped in pastures, rangeland and paddocks (23%) and the use of synthetic nitrogen fertilisers (13%). More than half of global N fertiliser use is urea. Somewhat smaller sources are other crop-related emissions (from N-fixing crops, crop residues left on the fields and histosols[15]) (together 11%), the indirect N_2O emissions related to NH_3 emissions from agriculture (9%) and animal manure applied to soils (5%). The largest non-agricultural source is fuel combustion (17%, when including indirect emissions of N_2O from NO_x emissions), followed the production of chemicals (7%) and waste water (4%).

For 2018, the growth in global N_2O emissions was estimated at 0.8%, to a total of 2.8 $GtCO_2$ eq, which is similar to those of 2015 and 2016, which saw growth rates of 0.9% and 0.6%, respectively (Figure 2.2). In 2018, emissions were 28% higher than in 1990, when they were 2.2 $GtCO_2$ eq. The increases in N_2O emissions from the largest sources, notably manure dropped in the field, the use of synthetic nitrogen fertilisers, and indirect N_2O emissions from agriculture, contributed the most to the 4.5% global emission growth since 2014, whereas some global N_2O decreases were seen in the production of chemicals and savannah burning.

Figure 2.6
Global nitrous oxide emissions, per main source



Source: EDGAR v5.0 (EC-JRC/PBL, 2019) FT 2018, incl. savannah fires, based on IEA, BP, SRIC, FAO, UNFCCC, GFED 4.1s
*) Other crop sources are the use of histosols, crop residues left on the field, and N fixing crops

Global N_2O emissions of most sources generally developed rather smoothly from 1990 to 2018 (Figure 2.6). An exception is N_2O from the production of chemicals, such as adipic acid and nitric acid, where N_2O abatement technology has been applied in many chemical plants, resulting in a reduction in their global N_2O emissions of 48% since their emissions peaked in 1979 and after small 'peaks' in 1997 and 2007. From 2004 to 2014, global N_2O emissions increased by 10%, which is 1.2% per year, on average. Sources that contributed most to this increase were fuel combustion (+1.3% per year, on average), synthetic fertilisers (+1.6%), livestock droppings (+0.9%), other crop-related emissions (+0.9%) and indirect N_2O emissions from NO_x emissions from fuel combustion (+1.8%). Countries with the largest absolute increase over these ten years are India, China, Brazil and Mexico, whereas the largest decrease occurred in the European Union followed by Iran and the United States.

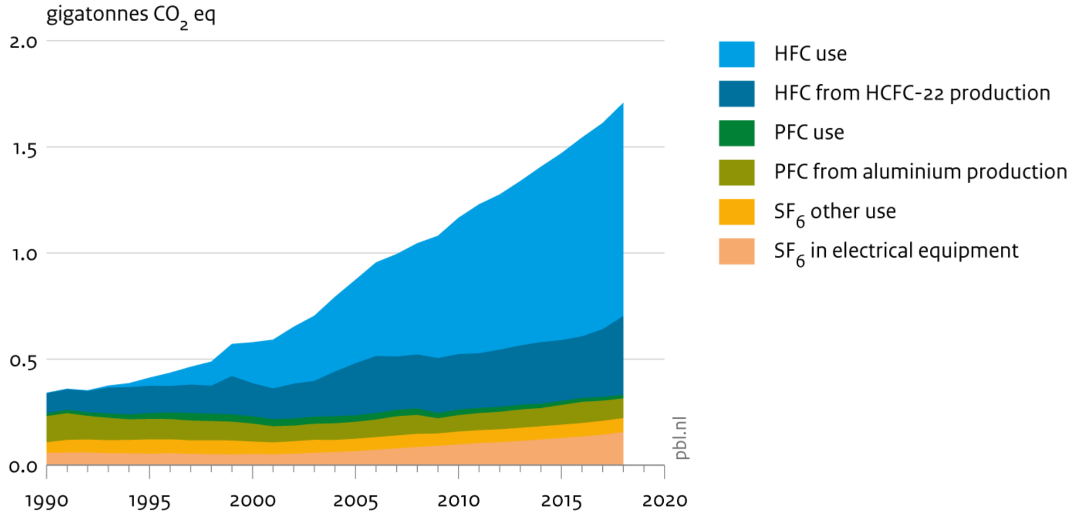
[15] Histosol is a soil consisting primarily of organic materials, such as peat. They often have poor drainage.

Fluorinated-gas emissions

The trend in F-gas emissions is presented in Figure 2.6. Although they make up the smallest category of the non-CO_2 greenhouse gases, the group shows the strongest emission growth with estimated annual global growth rates of 6.5% on average, in the 2004–2014 period, and slowing down somewhat in the years 2015-2017 to 4.5%, 5.0% and 4.4% respectively.

Please note that F-gas emissions in EDGAR v4.2 FT2018 were estimated from 2010 onwards by using the 2010–2017 emission trend of the most emitted F-gases, as reported by industrialised countries (so-called Annex I countries) to the UNFCCC (2019) and by extrapolating the average annual 2007–2010 trend for all other countries. Using these estimation methods, global total F-gas emissions, in 2018, amounted to 1.7 $GtCO_2$ eq, worldwide, almost four times the emissions of 1990, which were estimated at 0.35 $GtCO_2$ eq.

Figure 2.7
Global F-gas emissions, per main source



Source: EDGAR 4.2 (EC-JRC/PBL, 2011) FT 2018 based on AFEAS, UNEP, RAND, UNFCCC

The main reason for this very high growth is the introduction of HFCs in the early 1990s to replace the use of CFCs as these were first phased out by industrialised countries to comply with the Montreal Protocol to protect the stratospheric ozone layer, developing countries would follow later. This accounts for about 1.0 $GtCO_2$ eq of the global increase, and these HFC emissions account now for about 60% of all F-gas emissions (Figure 2.6), and emissions of HFC-134a, HFC-143a and HFC-125 make up most of them (about 90%). In addition, HFC-23 as by-product adds one fifth to total F-gas emissions. We note that these are very heterogeneous source categories, with large differences in growth rates for the different constituents, and often with very large uncertainties in emissions, at country level and per gas of the order of 100% or more.

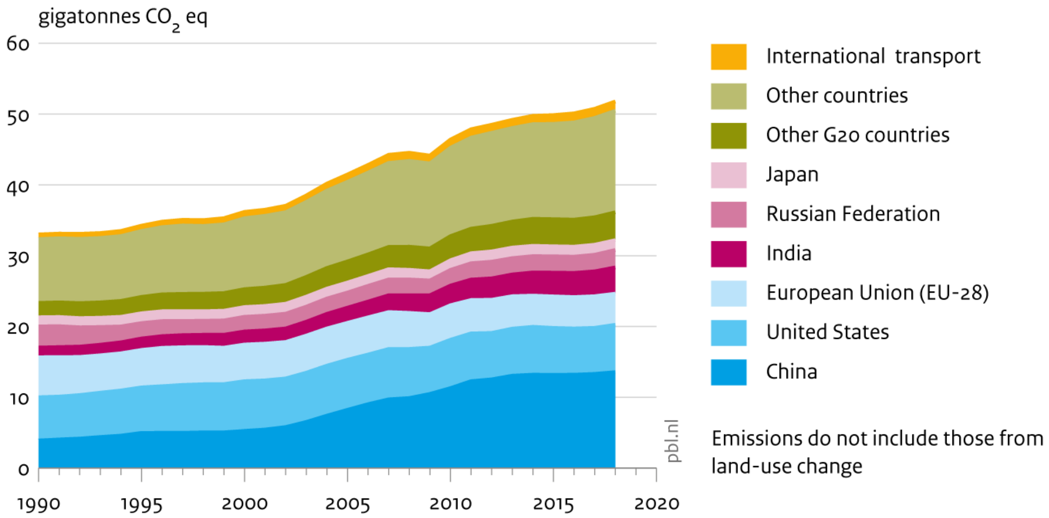
Greenhouse gas emissions in top-5 countries and the European Union

Figure 2.8 illustrates the 1990–2018 trends in total GHG emissions of the five largest emitting countries and the European Union, complemented with those in the other countries and from international transport (i.e. international marine and aviation emissions). These five largest emitters of GHG, together accounting for 62%, globally, are China (26%), the United States (13%), the European Union (more than 8%), India (7%), the Russian Federation (5%) and Japan (almost 3%). These countries also have the highest CO_2 emission levels. Most of these five countries and the EU showed a real increase in GHG emissions in

2018, except the European Union and Japan, where emissions decreased by 1.5% and 1.2%, respectively: China (+1.9%), India (+5.5%), the United States (+2.7%) and Russian Federation (+5.1%) (ranked according to the largest absolute changes). However, the increase in the rest of the world was even more substantial than in the individual, largest emitting countries. This is different from the recent past when China's emission growth eclipsed the increases elsewhere.

Together these five largest emitting countries and the European Union account for 49% of the world population, 65% of global gross domestic product (GDP) and 60% of the global total primary energy supply (TPES), accounted for 67% of total global CO_2 emissions and about 62% of total global GHG emissions. Within the European Union, Germany, Italy, France, the United Kingdom, Spain and the Netherlands showed decreasing emissions whereas the largest increase in 2018 was seen in Poland.

Figure 2.8
Global greenhouse gas emissions, per country and region



Source: EDGAR v5.0 (EC-JRC/PBL, 2019) FT2018, incl. savannah fires FAO, except F-gas: EDGAR v4.2 FT2018

The total group of 20 largest economies (G20[16]), accounting for 77% of 2018 GHG emissions, showed a 1.9% increase. The collective emissions from the rest of the world showed a 2.6% increase in 2018 (3.6% for the eight largest countries and 2.1% for remaining 186 countries). Appendix B provides more detailed tables, with the 1990–2018 GHG emission time series for the top 30 countries/regions, as well as per capita and per USD of GDP.

Following UNFCCC reporting and accounting guidelines (UNFCCC, 2011), GHG emissions from international transport (aviation and shipping) are excluded from the national total in countries' GHG emission reports, but nevertheless constitute about 2.5% of total global GHG emissions in 2018, for which 1.5% increase was estimated. For CO_2 emissions only, their total share is 3.4%: 1.5% for international aviation and 1.9% for international marine transport with estimated increases in 2018 of 1.0% and 2.0%, respectively. However, these growth percentages are rather uncertain, compared to CO_2 emissions trends for country totals (Olivier et al., 2017). According to Statistica (2019), total fuel consumption of global

[16] Group of Twenty: 19 countries and the European Union. The 19 countries are: Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, the Russian Federation, Saudi Arabia, South Africa, Turkey, United Kingdom, and the United States.

aviation (thus including domestic flights) increased by around 5%, in 2018. However, this includes *domestic* aviation, which CO_2 emissions are about 40% of total global aviation CO_2 emissions. For inland shipping this percentage is 20% of total global marine CO_2 emissions.

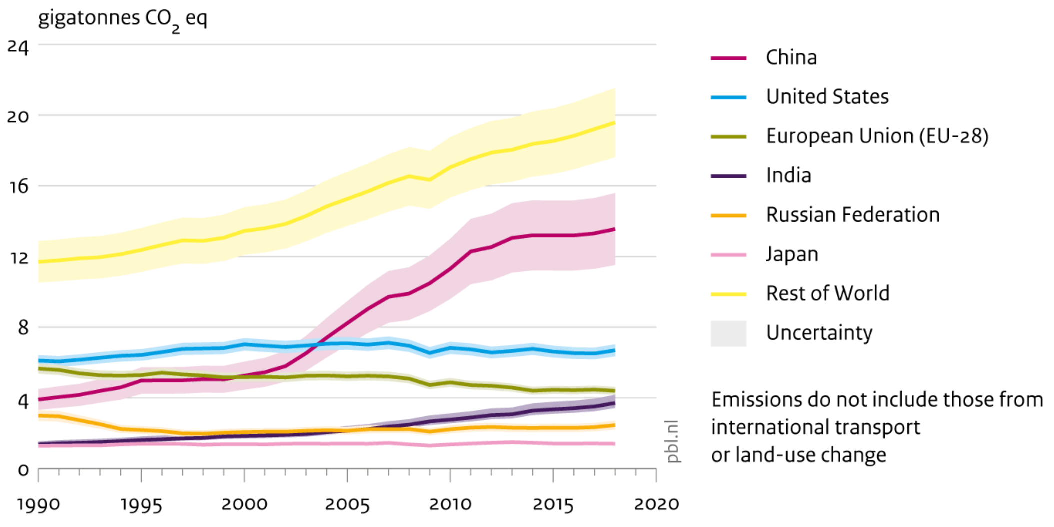
Appendix A provides tables with the 1990–2018 time series of CO_2 emissions for the top 30 countries/regions, as well as per capita and per USD of GDP, whereas Appendix B provides tables with the 1990–2018 time series of total GHG emissions for these countries/regions. as well as for their CH_4, N_2O and F-gas emissions, and GHG emissions per capita and per USD of GDP.

3 Trends in largest emitting countries and the EU-28

In this chapter we discuss the emission trends in the six main emitters, consisting of five large countries, being the United States, China, India, the Russian Federation and Japan, and of the European Union (EU-28) as a region. Between them there are large differences, in the share of the various greenhouse gases, and in the emission intensity of their energy use. Globally, the combined share of CH_4, N_2O and F-gas emissions is presently about 28% in total GHG emissions (19%, 5%, and 3%, respectively), but it varies for the largest countries, from 14% for Japan to 30% for India. China's current share of non-CO_2 GHG emissions is estimated at 17%, that of the United States at 21% and the European Union at 24% and the Russian Federation at 30%.

These shares reflect the relative importance of non-CO_2 GHG emission sources, such as coal, oil and natural gas production (releasing CH_4), agricultural activities, such as livestock farming (CH_4 emissions from ruminants and manure), rice cultivation (wet fields release CH_4 through fermentation processes in the soil), animal manure and fertiliser use on arable land (N_2O), and landfill and wastewater practices (CH_4).

Figure 3.1
Greenhouse gas emissions, per country and region



Source: EDGAR v5.0 FT2018; incl. savannah fires FAO; F-gas: EDGAR v4.2 FT2018

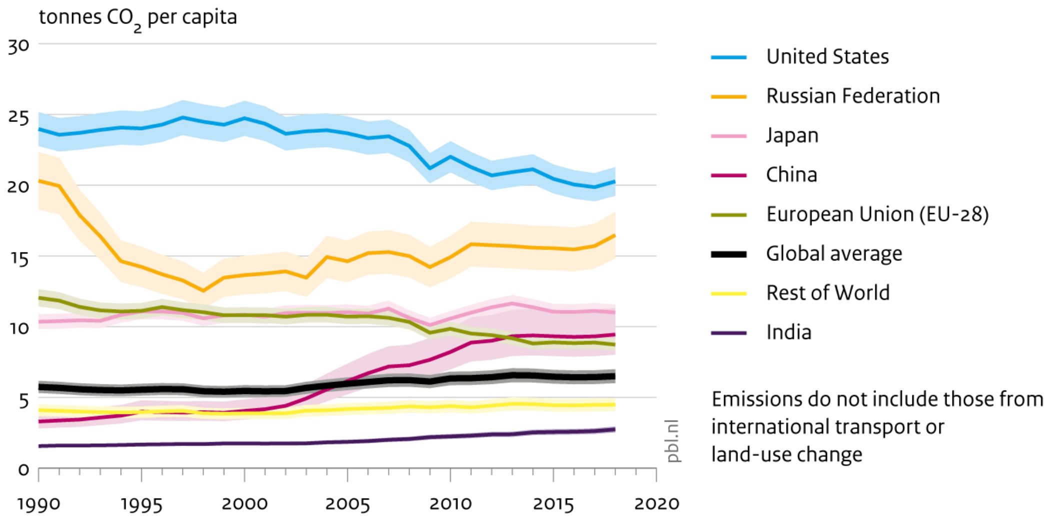
As discussed in Chapter 2, the GHG emission trends of four of the largest countries and regions have continued or resumed to grow in 2018, except for the European Union and Japan that saw decreases of 1.5% and 1.2%, respectively. In absolute values, the largest emitters for CO_2 and total GHG emissions are China, the United States, and the European

Union, followed by India, the Russian Federation, and Japan. For non-CO_2 emissions only, India and the European Union switch rank.

In 2005, after its very rapid rise in CO_2 emissions caused by the fast industrialisation that started in 2002 (the first year that it was a full member of the World Trade Organisation, China surpassed the United States as the world's largest emitting country. Since 2013, China's CO_2 emissions have been more than twice those of the United States. Using our estimates, the same occurred in 2004 and 2016 for total GHG emissions. However, for a proper perspective in comparisons between countries also the size of a country's activities should be accounted for. Therefore, the per capita emissions, and the emissions per USD of GDP, and their trends, are presented below, which allows for better comparison of level and trends between countries because it eliminates either population size or size of the economy of a country from the equation. Apart from that, it also provides reference values to assess in what direction emissions will progress if structural changes occur in population or economy of a country (or in the rest-of-world countries as a group).

Figure 3.2 shows GHG emissions per capita for the five main emitting countries, the European Union, the rest of the world, and for the world average. Except for India, all main emitters have per capita emission levels that are significantly higher than those for the rest of the world and the world average. China, in this measure, has rank 4, rather than rank 1, which it has for absolute emissions. Although CO_2 eq emissions in the United States have been steadily decreasing since 2000, from 24.7 tCO_2 eq/cap to about 20.3 tCO_2 eq/cap by 2018, it still has the highest amount among the top 5 emitting countries, but it is surpassed by three other G20 countries: Saudi Arabia, Australia and Canada (not shown in the graph). The United States, the Russian Federation, and Japan make up the top 3 GHG emitting countries, per capita, among the five main emitting countries and the European Union.

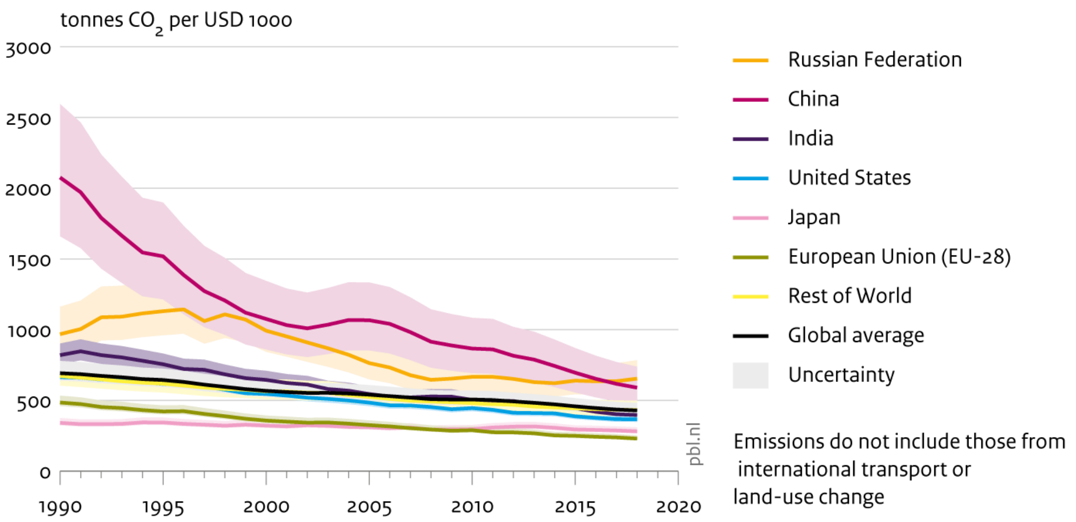
Figure 3.2
Greenhouse gas emissions, per capita, per country and region



Source: UNPD; EDGAR v5.0 (EC-JRC/PBL, 2019) FT2018; incl. savannah fires FAO; F-gas: EDGAR v4.2 FT2018

The emissions per USD of GDP [in 2011 prices and corrected for Purchasing Power Parity (PPP)] presented in Figure 3.3, show yet another image. Contrary to the per capita emissions, the top 5 countries and the European Union are not all above the world average when it comes to emissions per USD of GDP. In the United States, emissions per USD of GDP are virtually equal to the world average, while those in the European Union are the lowest per USD of GDP worldwide, closely follow by Japan. Emissions per USD in China and the Russian Federation are the highest, and significantly higher than the world average. The trend for all countries is downward, including that for the world average, except for the Russian Federation, which emissions per USD remain flat in recent years. Since 2018 the emissions per USD of GDP of China are below those of the Russian Federation.

Figure 3.3
Greenhouse gas emissions, per USD of GDP, per country and region



Source: World Bank, IMF; EDGAR v5.0 (EC-JRC/PBL, 2019) FT2018; incl. savannah fires FAO; F-gas: EDGAR v4.2 FT2018

Appendix A provides for the top 30 countries/regions more details with 1990–2018 time series of CO_2 emissions, totals per country, per capita CO_2 emissions and a similar table with CO_2 emissions per USD of GDP. For the top 30 countries/regions, Appendix B provides more details, with 1990–2018 time series of GHG emissions, on GHG totals, CH_4, N_2O, F-gas and per capita GHG emissions, as well as per USD of GDP, for the top 30 countries/regions.

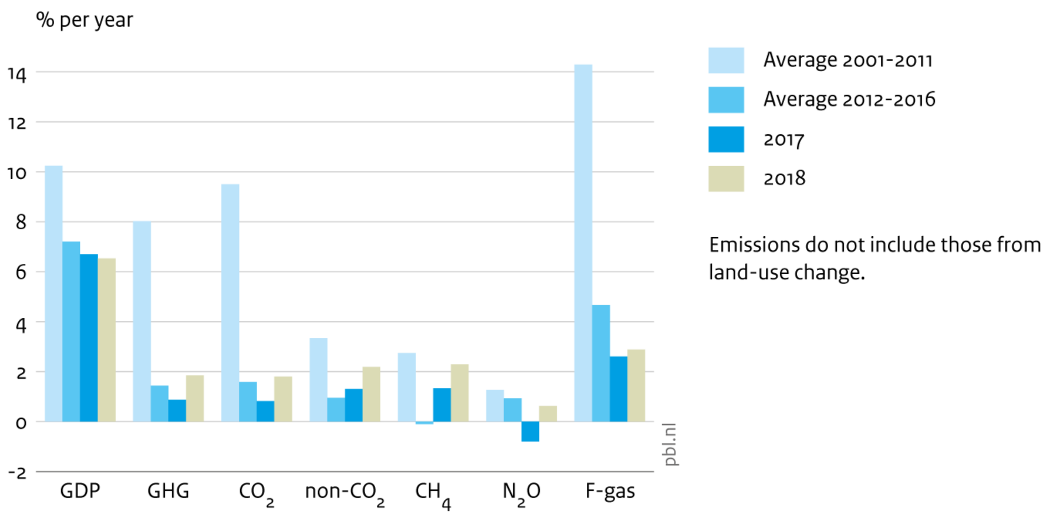
In the remainder of this chapter we analyse the level and trends in emissions for the top-5 emitting countries and the European Union as in Chapter 2 for global total emissions.

3.1 China

In 2018, China contributed about 26% to global greenhouse gas emissions and about 30% to global CO_2 emissions. Total greenhouse gas emissions consisted of 82.5% CO_2 and 17.5% non-CO_2, the latter of which consisted mainly of methane: 11.6% CH_4, 3.0% N_2O and 2.9% F-gas emissions.

Since 2013, China's official annual growth in GDP was around 7%, which is about 3 percentage points lower than in the decade before. However, in contrast to the 8.8% average annual increase in China's greenhouse gas emissions between 2003 and 2012, emissions remained almost level between 2014 and 2017, with annual growth rates of 1.1%, 0.0%, 0.0% and 0.9%, respectively. However, in 2018, emissions increased by 1.9% to a level of 13.6 $GtCO_2$ eq. This was mainly due to a CO_2 and CH_4 emission growth of 1.8% and 2.3%, respectively, in 2018, both of which at one percentage point higher than in 2017. In the 2012–2016 period, the annual growth rate was 1.6% for CO_2 and -0.1% for CH_4 emissions. Since 2010, total greenhouse gas emissions increased by about 20%, driven by a 22% increase in CO_2 emissions (Figure 3.4).

Figure 3.4
Annual changes in GDP and greenhouse gas emissions in China, 2001-2018



Source: GDP: World Bank, IMF; GHG: EDGAR v5.0 (EC-JRC/PBL, 2019) FT2018, except F-gas: EDGAR v4.2 FT2018

CO_2 emissions

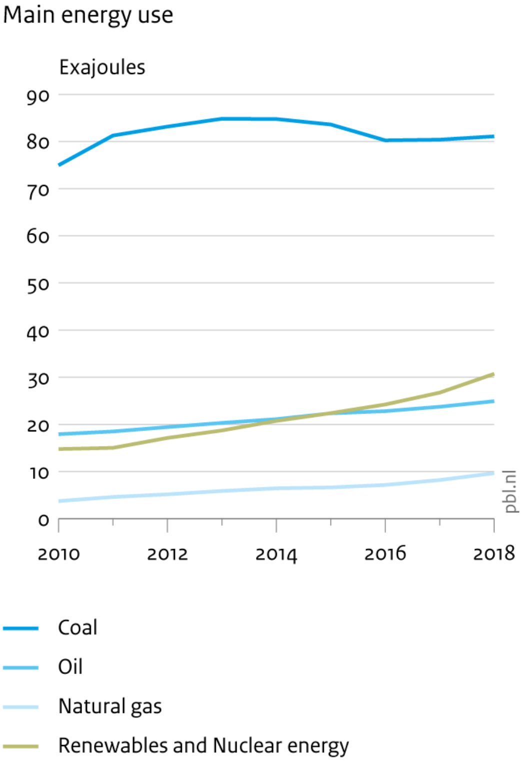
As illustrated in Figure 3.5, although China's coal consumption in 2018 showed almost no increase (+0.9%) and cement production declined by 5.3% (NBSC, 2019), the relatively small increase of 1.8% in total CO_2 emissions, compared to years before 2014, was mainly due to increased consumption of oil (5.0%) and natural gas (17.7%). Almost half of the consumed natural gas was imported, as Liquified Natural Gas (LNG) or by pipeline, and the government added new incentives for expanding domestic production of tight gas and shale gas (EIA, 2019j). IEA data shows that almost 50% of China's CO_2 emissions from fossil fuel combustion are the result of power generation (IEA, 2018). Therefore, this sector is key in curbing China's CO_2 emissions.

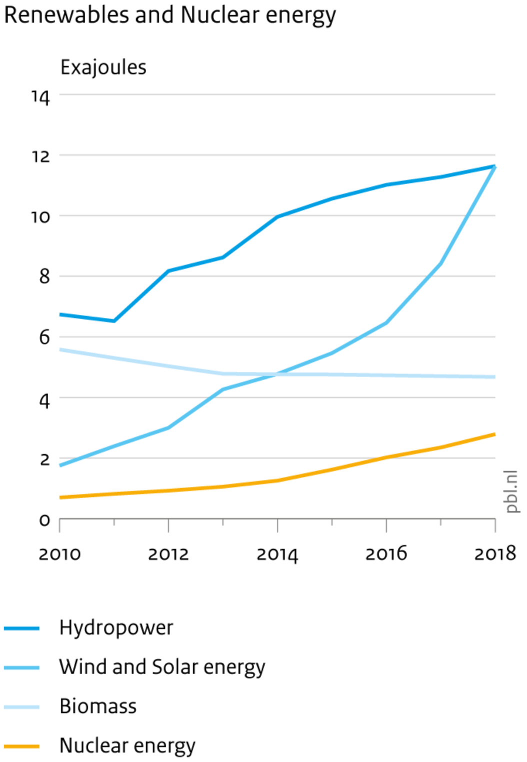
In 2018, power generation, China's largest source of CO_2 emissions, increased by 7.7% to 7.1 GWh. Of the total increase of 0.51 GWh, fossil-fuel-fired power plants (in total about 97% coal) provided well over half of the increase, almost all coal, hydropower provided 7%, other renewable power 28% (mainly wind and solar) and 9% of the increase was in nuclear power (BP, 2019). Total primary energy use increased by 5.3% in 2018, which is much more than the 1.8% in CO_2 emissions (see below).

Main energy use in China

In 2018, China's total primary energy supply (TPES) consisted of 55% coal, 21% renewable and nuclear energy, 17% oil, and 7% natural gas (IEA, 2019a; BP, 2019). In other words, 79% of China's energy supply was still generated from fossil fuels. In 2018, about 30% of the electricity was generated from renewable and nuclear sources. Their share in TPES of 21% in 2018 was 1.8 percentage points higher than in 2017, and 7.7 percentage points higher than in 2010. In this report, the BP definition of TPES is used, which uses a substitution method for nuclear, hydropower and other non-biomass renewable energy and assumes a 38% conversion efficiency in all these cases. As Figure 3.5 (left side) shows, since 2010, renewable and nuclear energy showed the largest and continuous annual growth, most rapidly in the last two years (with 10% and 15%, respectively). This acceleration was due to the very large growth in wind and solar power the past few years, which shares together now equal that of hydropower. Figure 3.5 (right side) also shows a steady increase in hydropower and nuclear power . However, in 2018, they still covered only 30.7 EJ of China's total energy demand of 146 EJ (IEA, 2019a; BP, 2019).

Figure 3.5
Trends in energy use in China, 2010-2018





Source: IEA, BP

Since 2010 the share of these non-fossil energy sources increased 8 percent points from about 13% to 21%, which is a large change in the energy supply system in only eight years. Together with increasing shares of natural gas and oil products this has reduced the share of coal in energy supply from 67% to 55% over these years and has moderated the increase in total CO_2 emissions from China to 22% since 2010 compared to 31% increase in TPES.

However, with a fossil fuel share of more than two thirds (79%), China's energy use in 2018 still heavily depended on fossil fuels, with 55% of TPES provided by coal, 17% by oil and 7% by natural gas. The remaining 21% share of non-fossil energy consisted of 8% wind and solar energy, another 8% hydropower, 3% biomass fuels and 2% nuclear energy.

A comparison of changes in TPES shares in ***percentages*** conceals that ***absolute*** changes are very different, with power generated from renewable and nuclear energy having increased in 2018 by 225 TWh, while coal-fired power generation increased even more with 287 TWh (BP, 2019). Similarly, of the 2900 TWh increase in power generation between 2010 and 2018f, 58% was generated from fossil fuel and 42% from renewable and nuclear energy. For the increase in electricity production in 2018, 61% was even generated by fossil fuels vs 39% by renewable and nuclear power.

From these recent trends (fossil fuel use still increasing despite increases in renewable and nuclear energy), it can be inferred that China's CO_2 emissions are unlikely to peak within a few years. In fact, a recent analysis by Coalswarm concluded that if the *China Electricity Council's* proposal — to cap China's coal-fired power generation at 1,300 gigawatts (GW) by 2030 — would be approved, this would mean a large expansion of its coal fleet, as China would then increase its coal-fired power capacity by 290 GW, or 29% above current levels (Shearer et al., 2019). Besides estimating China's growth in CO_2 emissions in 2018, Korsbakken et al. (2019) also analyse the data challenges; in particular, when trying to accurately estimate the emission trend related to coal consumption.

Other emissions

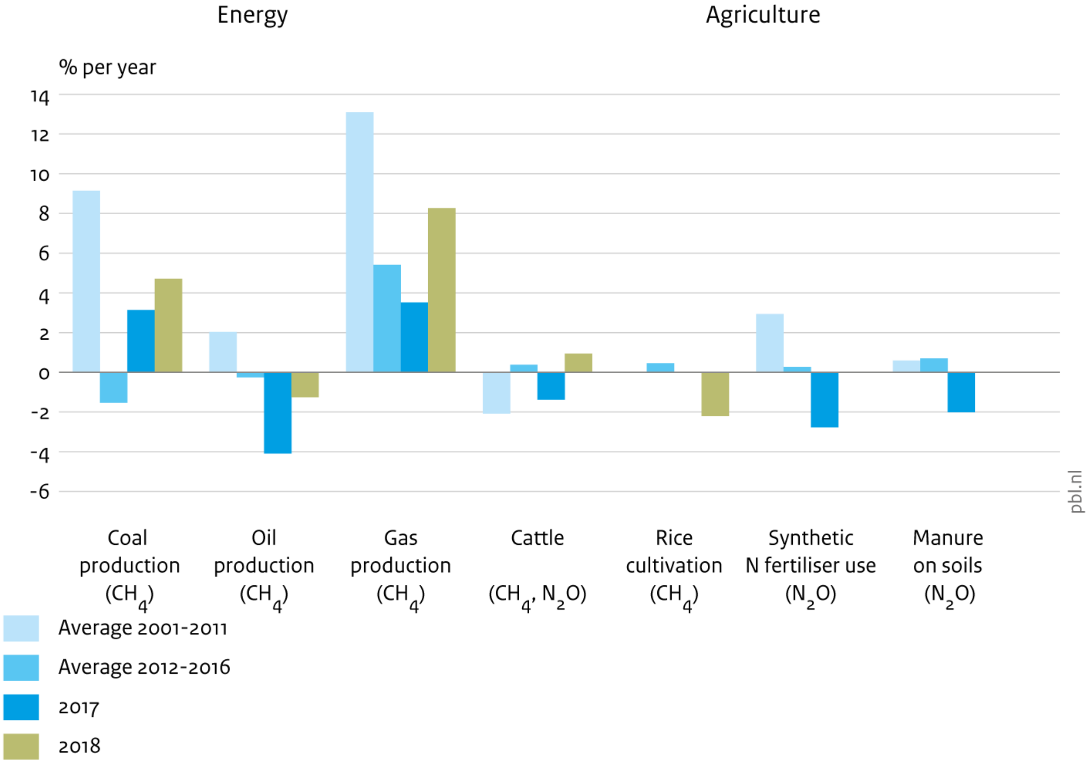
In 2018, CH_4 emissions in China increased by about 2% and N_2O emissions by 0.6%, whereas F-gases were estimated to increase by about 3% (Figure 3.4, right side). The increase in **CH_4 emissions** was mainly due to a 5% increase in emissions from coal production (mainly underground mining), with a share of 30%, which is therefore also the largest source of methane in China (BP, 2019). The second largest methane source in China is that of rice cultivation, with 22%, which decreased by about 2% in 2018 (IRRI, 2019).

Other sources that contributed to the total increase were natural gas production and transmission and domestic waste water, the CH_4 emissions of which increased by about 9% and 0.6%, respectively. Methane emissions from livestock remained almost at the same level, as also indicated by the trend in cattle numbers in Figure 3.6.

The relatively low amount of **N_2O emissions** only increased by 0.6% in 2018 and for F-gas emissions this was about 3%. N_2O emissions from the use of synthetic fertilisers, the largest source of nitrous oxide with a share of almost a quarter, remained level in 2018, as did those from most other sources (see Figure 3.6).

In 2018, **F-gas emissions** in China increased by an estimated 3% (expressed in kg CO_2 eq). This is less than in the years after 2011, when the average annual increase was 4.7% (Figure 3.4). More than half of China's F-gas emissions are estimated to be HFC emissions, mostly HFC-23 as the by-product from the production of HCFC-22, which increased by an estimated 2% in 2018. About a quarter of total F-gas emissions consisted of SF_6, most of which from the use of SF_6-containing switchgear in the power sector, which are estimated to have increased by 6% in 2018. In China, PFC emissions are almost all emitted as a by-product of aluminium production, with an estimated increase of 1.4% in 2018. Due to the

Figure 3.6
Annual changes in main drivers of CH_4 and N_2O emissions in China, 2001-2018



Source: CH_4: IEA, BP, FAO, IRRI; N_2O: IFA, FAO
Note: Between brackets the greenhouse gas(es) are listed for which the activities are drivers.

relatively large increases over time, the 2018 share of F-gas emissions in China's total greenhouse gas emissions more or less equalled that of N_2O emissions.

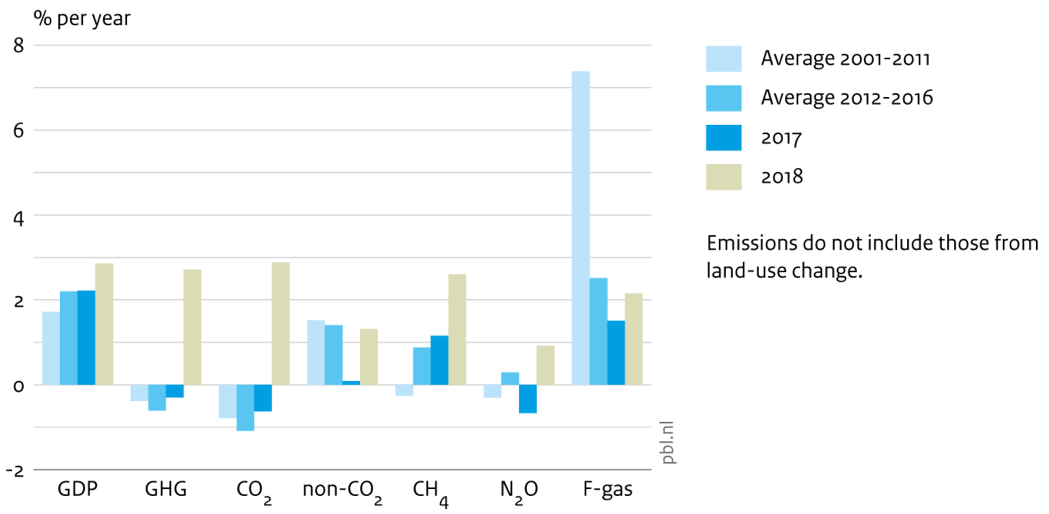
3.2 United States

In 2018, the United States contributed 13% to global greenhouse gas emissions and about 14% to global CO_2 emissions. Total greenhouse gas emissions consisted of 78.4% CO_2 and 21.6% non-CO_2, specifically: 9.7% CH_4, 4.5% N_2O and 7.4% F-gas.

Since 2011, US annual economic growth has been about 2.1% on average. In 2018, the US economy grew by about 2.9%. In contrast, since 2011, its total greenhouse gas emissions have decreased for four years and increased only in 2013 (1.3%) and 2104 (1.8%), and increased in 2018 by 2.7% to about 6.7 $GtCO_2$ eq. This is the largest annual growth in emissions since 1997, when emissions increased by 2.7%. The increase in greenhouse gas emissions in 2018 was also after three years of decreasing emissions; from 2015 to 2017, annual decreases were -2.2%, -1.3% and -0.3%, respectively.

Since 2010, total greenhouse gas emissions in the United States have decreased by about 2.0%, driven by a 5.6% decline in CO_2 emissions (which makes up almost 80% of total US greenhouse gas emissions) (Figure 3.7), whereas non-CO_2 emissions increased by 12.3% over this period. Since they peaked in 2005, US greenhouse gas emissions declined by 6%, from 7.1 to 6.7 $GtCO_2$ eq in 2018. As Figure 3.7 shows, the inter-annual changes in total greenhouse gas emissions were mostly due to similar variations in CO_2 emissions, whereas non-CO_2 emission levels were much smoother and showed a rising trend.

Figure 3.7
Annual changes in GDP and greenhouse gas emissions in the United States, 2001-2018



Source: GDP: World Bank, IMF; GHG: EDGAR v5.0 (EC-JRC/PBL, 2019) FT2018, except F-gas: EDGAR v4.2 FT2018

CO_2 emissions

The 2.9% increase in CO_2 emissions, in 2018, was mainly due to the large increase of 10.5% in natural gas consumption and increase of 2.1% in oil consumption, whereas coal consumption continued to decrease, by 4.3% (BP, 2019) (Figure 3.8). These percentages are very close to those reported by the U.S. Energy Information Administration, considering that their numbers include fuel use in international transport (bunker fuel) (EIA, 2019a, 2019h). Another CO_2 increase estimated by Houser et al. (2019) is very close to our estimate, taking into account that the estimate only concerns emissions from fossil fuel combustion. However, it must be noted that their preliminary US emission estimates for 2018, released on 8 January 2019, differed significantly from this newer estimate released in May.

Power generation contributes one third to total US CO_2 emissions, just behind transportation, the share of which is a few per cent higher. Industry emits almost one fifth of total US CO_2 emissions from fuel combustion, and the buildings sectors (residential and commercial services) are responsible for the remaining 11% (EIA, 2019k). The large increase in CO_2 emissions in 2018 was partly due to changes in the weather compared to 2017, aided by relatively large economic growth; 2018 winter months were much colder (more space heating) and summer months were very warm (more air conditioning). This had its impact on the use of natural gas and electricity.

The jump in **natural gas** use last year was partly caused by a much colder winter compared to that of 2017 that saw a relatively very mild winter. This is illustrated by the number of so-called *Heating Degree Days* (HDDs), which was 11.7% higher in 2018 than in 2017, which had the lowest number of HDDs since 1949 (EIA, 2019h). HDD is used to estimate the demand for space heating in the residential and service sectors, which both mostly use natural gas or electricity. About one third of the houses use electricity as their primary energy source for space heating in the winter months (EIA, 2019b). However, the summer of 2018 was one of the hottest since 1949, as is illustrated by the record number of *Cooling Degree Days* (CDD) since 1949, an increase of 11.1% compared to 2017. This CDD is used to estimate the demand for electricity for air conditioning in the summer months, with record levels in 2018 (EIA, 2019h; 2019b). Both these weather effects caused the increase in electricity demand in 2018. However, retirement of coal-fired power generation, combined with a higher electricity demand in both summer and winter, was the main cause of a 13.2% jump in gas-fired power generation, and thus in total natural gas consumption.

As explained above, the 3.7% increase in **power generation** in 2018 was largely due to the cold winter and the hot summer that drove record levels of residential and commercial electricity consumption, further aided by economic growth. Coal-fired power generation continued to decline in 2018, from its peak in 2005, and the U.S. Energy Information Administration (EIA) expects the retirement of coal-fired power plants to continue (EIA, 019c). In 2018, the retired coal capacity amounted to 17.6 GW, which is the year with the second-highest amount for US coal-fired power plant retirements. The highest was in 2015, when this was 21 GW (Shearer et al., 2019). In 2018, the 3.7% increase in electricity demand and 4.9% decrease in coal-fired power generation was mainly due to a 13.2% increase in natural-gas-fired power generation. This increase was necessary, not only to compensate for the loss of coal-fired power generation, but also to meet the relatively large increase in total electricity demand. Until then, such a large increase could not yet be met through increased wind and solar power, which, in fact, covered only a quarter of the increase in demand (EIA, 2019k; BP, 2019).

The important **transport** sector, with the greatest use of **oil products** (fuel), saw its CO_2 emissions increase by 1.5% in 2018, mainly due to a large increase in diesel consumption, whereas petrol consumption remained constant (EIA, 2019k). The **industrial** sector, also because of economic growth, CO_2 emissions increased by 3.5% in 2018. This increase was mainly due to a 5.7% increase in natural gas consumption, as total petroleum combustion increased by only 1.9%. These are the two main types of fuel used in this sector.

Although gas flaring is a relatively small source, its CO_2 emissions soared by more than 50%, to 21 $MtCO_2$ in 2018, due to large increases in domestic shale oil production (Banji, 2019).

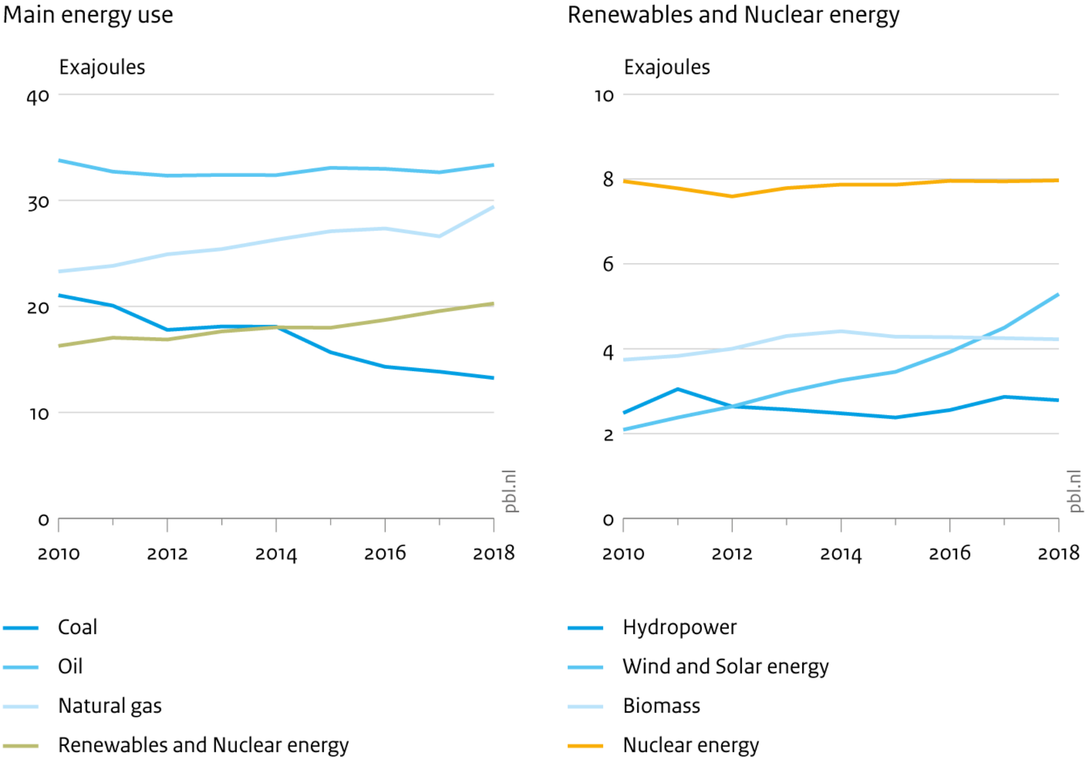
Main energy use in the United States

In 2018, with a share of 79%, the United States' energy use was still largely based on fossil fuels, with 34.8% of total primary energy supply (TPES) provided in the form of oil products, 30.5% in natural gas, 2.1% in renewables plus nuclear energy and 14% in coal (Figure 3.8, left side) (IEA, 2019a; BP, 2019). The 21% share of non-fossil energy consisted of 8.4% nuclear energy, 5.6% wind and solar energy, 4.5% biofuel, and 3.0% hydropower. Incidentally, in 2018, both China and the United States had a 79% share of fossil fuel.

In 2018, about 36% of power generation was supplied from renewable and nuclear sources. In 2018, these sources contributed 21% to the TPES, which is the same percentage as in 2017 but almost 4 percentage points higher than in 2010. As Figure 3.8 clearly shows, since 2010, renewable plus nuclear energy and natural gas have shown continuous annual growth. Figure 3.8 (right side) shows that the growth in renewable and nuclear energy was mainly due to a very large annual growth in wind and solar power, which accelerated to double digits, over the last three years (14% to 18% per year). This figure also shows that the percentages for hydropower and nuclear power have not changed significantly over time, with hydropower varying somewhat depending on annual weather conditions (IEA, 2019a; BP, 2019).

Since 2010, the share of these non-fossil energy sources increased by 4.1 percentage points, from about 17.2% to 21.1%. Together with an increasing natural gas share, from 24.7% to 30.5% (or 5.9 percentage points), this has compensated for the very large decline in the share of coal in energy supply, from 22.3%% to 13.8% over these years (by 8.5 percentage points). This has resulted in a 5.6% absolute decrease in CO_2 emissions from the United States since 2010, and a decrease of almost 12% since 2005. For a long-time perspective,

Figure 3.8
Trends in energy use in the United States, 2010-2018



Source: IEA, BP

CO_2 emissions in 2018 were 3.6% above 1990 levels. From the comparison of percentage changes in shares in the energy supply we can conclude that the United States has strongly reduced the use of coal in power generation, over the past decade, which was compensated for by an increase in renewable power and, even more so, in gas-fired power generation.

Nuclear power generation in the United States will not increase in the near future (EIA, 2019m), so low levels of carbon intensity of electricity generation can only be attained by increasing the share of renewable power. Under a reference case scenario, the EIA expects the amount of coal used in the coming decades to remain at the 2020 level, even with the retirement of one third of the 2018 coal-fired power capacity, as the remaining coal fleet is assumed to be utilised more efficiently. Natural gas surpassed coal in 2016, becoming the most-used fuel in electricity generation, and the EIA scenario projects a further increase in gas-fired power generation (EIA, 2019c).

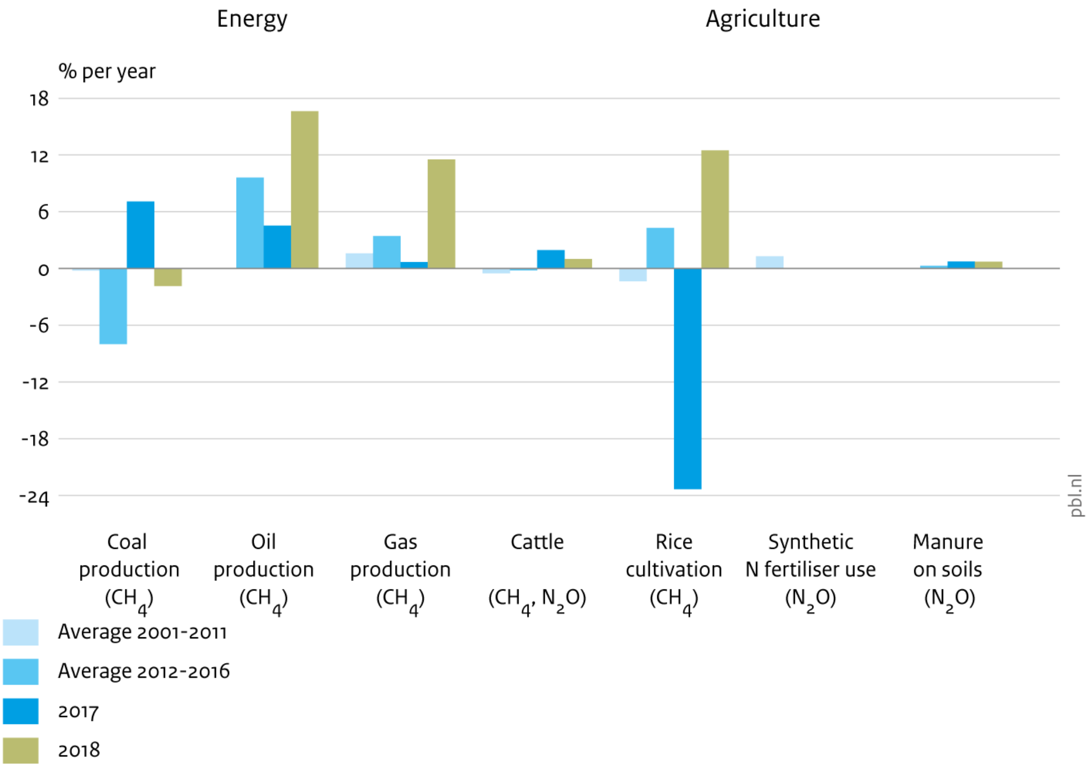
Other emissions

In contrast to CO_2 emissions, those of non-CO_2 greenhouse gases have all increased since 2010, collectively by 12.3%, and by an estimated 1.3% in 2018. CH_4 emissions were still the largest in this group, with a share of 9.7%, but F-gas emissions are close behind, with increases of almost a quarter since 2010, as corroborated by recent inventory reports to the Climate Secretariat (UNFCCC, 2019). The F-gases had a share of around 7% in 2018 and N_2O emissions are contributing about 4.4% to total greenhouse gas emissions.

For 2018, **CH_4 emissions** are projected to have increased by 2.6%, mainly due to a large increase (9%) in methane emissions from natural gas production and its transport and distribution. This source showed by far the largest absolute emission change in 2018.

However, all other methane sources also increased in 2018, with the largest changes seen in oil production (+7%) and agriculture, in livestock (+1%) and rice production (+12%) (in order of largest absolute changes). The largest methane sources in the United States are livestock, predominantly cattle, natural gas production and its transmission, and gas venting, which account for about 60%. Other significant sources are landfills and other forms of agriculture. As illustrated in Figure 3.9, over the past years, CH_4 emissions from coal mining have been decreasing due to downward trends in coal production, which has plummeted in those years. In contrast, the growth in oil production was much larger between 2012 and 2016 than in the decade before, and oil and gas production showed large increases in 2018.

Figure 3.9
Annual changes in main drivers of CH_4 and N_2O emissions in the United States, 2001-2018



Source: CH_4: IEA, BP, FAO, IRRI; N_2O: IFA, FAO
Note: Between brackets the greenhouse gas(es) are listed for which the activities are drivers.

In 2018, **N_2O emissions** increased by an estimated 0.9%, mainly due to changes in the largest sources of N_2O emissions in the United States. These emission mostly related to agricultural activities), such as the use of synthetic fertilisers, the use of manure as fertiliser, N-fixing crops and crop residues left on the field, as well as manure dropped in pastures, ranges and paddocks; and fossil fuel combustion, which together account for almost three quarters of total N_2O emissions. Only one source has shown decreasing N_2O emissions, over time, namely that of industrial processes, with a decrease of 4% in 2018.

In 2018, **F-gas emissions** in the United States increased by an estimated 2.2% (expressed in kg CO_2 eq). This is similar to the years after 2011, when the average annual rate of increase was 2.3% (Figure 3.9). This was lower than in the 2000–2011 period, when F-gas emissions, on average, increased by 7.5%, annually. In that period, over 90% of emissions were estimated to be HFCs, which continued to increase in 2018 by about 2.5%. In contrast, PFC and SF_6 emissions in the United States continued to decrease in 2018, by 6% and 0.3% respectively. Because of the relatively large increases over time, the 2018 share of F-gases in total greenhouse gas emissions was in 2018 about twice that of N_2O.

HFC emissions in the United States mostly consist of HFC-125, HFC-143a and HFC-134a, which account for about nine tenth of HFC emissions when comparing amounts in CO_2 eq. HFC-134a emissions have been decreasing since 2010; in 2018 by 6%. HFC-125 emissions, however, have still been increasing over time; in 2018 by an estimated 7%. The estimated total HFC emission increase was 2.5% in 2018, mainly due to a large increase in HFC-23 by-product emissions from HCFC-22 manufacture.

The annual *rate of increase* in HFC emissions from *HFC use*, however, has gone down since around 2000. Since 2010, the *rate of increase* in these HFC emissions — collectively and expressed in CO_2eq — slowed down further and was near zero in 2017 (UNFCCC, 2019). Most of the remaining F-gas emissions in the United States consist of SF_6, with a share of 7% in total F-gas emissions, most of which is from switchgear in the electricity sector and from a large unknown source of SF_6. In the United States, generally, PFC emissions are mainly emitted from semi-conductor manufacture and as by-product from aluminium production, with an estimated decrease of 6% in 2018.

3.3 European Union

In 2018, the European Union contribute 9% to global greenhouse gas emissions and to global CO_2 emissions. Total greenhouse gas emissions consisted of 76.7% CO_2 and 23.3% non-CO_2, i.e. 13.3% CH_4, 6.1% N_2O and 3.6% F-gases.

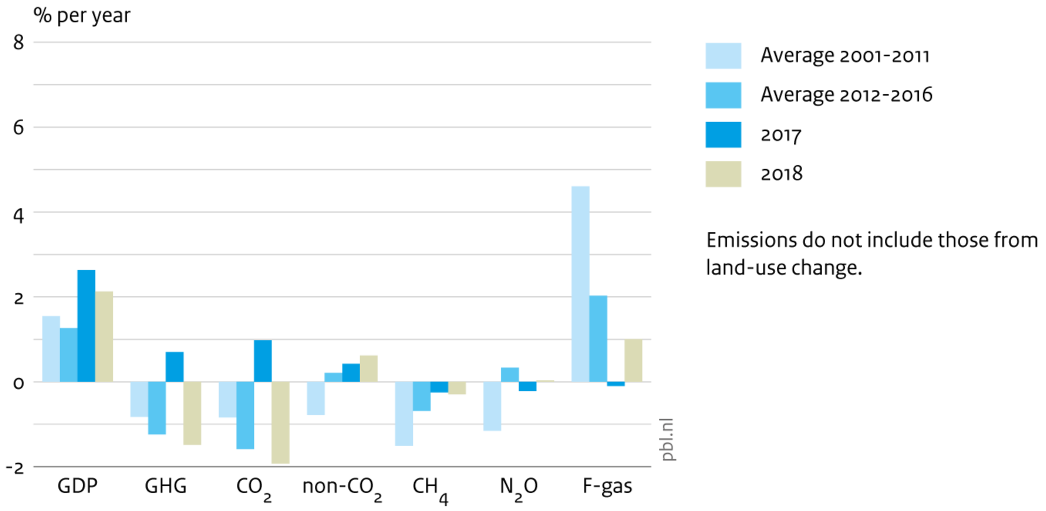
Because of the eurozone's debt crisis in the years from 2008 to 2013, its average annual GDP growth was nil (0.0%). Since 2014, however, growth has been recovering and increasing, annually, by 2.3% on average and by 2.1% in 2018 (World Bank, 2019a). Since the 'peak year' of 2004, when greenhouse gas emissions were at the highest level in recent history, the EU's total greenhouse gas emissions declined by 1.7% per year, on average, from 5.25 $GtCO_2$eq in 2004 to 4.4 $GtCO_2$eq in 2014. After 2014, total greenhouse gas emissions first remained almost at the same level, with two small increases and one small decrease: +1.1% in 2015, -0.4% in 2016 and +0.7% in 2017, but, in 2018, greenhouse gas emissions saw a larger decrease of 1.5% to 4.4 $GtCO_2$eq. Of the 28 EU Member States, 15 showed decreasing emissions in 2018, which Germany contributing the most (-3.5%), followed by the United Kingdom, France and Italy, and 15 Member States showed increasing emissions, with Poland in the lead (+1.6%), followed by Belgium and the Czech Republic. The greenhouse gas emissions decrease in 2018 was driven by a 1.9% decline in CO_2 emissions that, in 2018 had a 77% share in total EU greenhouse gas emissions (Figure 3.10).

Figure 3.10 shows the annual emission changes per type of gas, since 2010, as well as total greenhouse gas and GDP. Since 2010, EU's total greenhouse gas emissions decreased by 9.8%. This trend is mainly set by the trend in CO_2 emissions, which have declined by 12.3% since 2010 and by almost 20% since they peaked in 2004. Also, inter-annual changes in total greenhouse gas emissions have mostly been due to similar variations in CO_2 emissions, whereas the non-CO_2 emission trend is much smoother and shows a small overall rising trend of 1.8% since 2010.

CO_2 emissions

The 1.9% decline in the EU's CO_2 emissions in 2018, to a level of about 3.4 $GtCO_2$, was mainly due to decreases in al main types of fossil fuel consumption in 2018: -5.1% in the consumption of coal, -1.6% in natural gas and -0.6% in oil products (BP, 2019) (Figure

Figure 3.10
Annual changes in GDP and greenhouse gas emissions in the European Union, 2001-2018



Source: GDP: World Bank, IMF; GHG: EDGAR v5.0 (EC-JRC/PBL, 2019) FT2018, except F-gas: EDGAR v4.2 FT2018

3.10). Cement production in the EU is estimated to have increased by 0.4% in 2018 to 0.064 $GtCO_2$. Our estimate of the decrease in CO_2 emissions in 2018 is somewhat smaller than the 2.5% decrease estimated by Eurostat, however their estimation refers to CO_2 from fossil fuel combustion only, which is based on the sum of monthly statistics of coal, peat, oil and natural gas consumption (Eurostat, 2019a).

The EU Member States that were responsible for most of the total **natural gas** decrease of 1.6% — ranked in order of largest absolute changes — were Italy (-3.3%), France (-4.6%) and Germany (-1.6%), followed by Portugal, Austria, the Czech Republic, Hungary and the Netherlands. Countries that saw increases are notably Poland (+2.9%) and Belgium (+2.8%), followed by Finland, Ireland, Latvia and the United Kingdom, also in order of largest absolute changes. The decrease in natural gas consumption was aided by milder winter months in 2018, which were even milder than in 2017. This is illustrated by the number of so-called *Heating Degree Days* (HDD), which is used for estimating the demand for space heating in the residential and service sectors. In 2018, EU-wide number of HDDs was 3.1% lower than in 2017, thus requiring less space heating, which mostly affected the use of natural gas and electricity for that purpose (Eurostat, 2019b). For most individual EU Member States, the number of HDDs in 2018 was lower than in 2017, e.g. for Germany -6.4%, Netherlands -0.7%, Italy -6.6%, Poland -5.0% and France -6.6%. Exceptions were the United Kingdom (+2.5%), Spain and Portugal.

Apart from a milder winter, the **summer of 2018** was again very warm in many parts of the world. Temperatures across much of the world were warmer to much warmer than average, during 2018, and record warm temperatures were measured across much of Europe. A heat wave of unprecedented intensity and duration affected Europe from 18–22 April. France, Germany and Switzerland had their warmest year since national records began. The Netherlands also had its second warmest year on record (the record year set in 2014) (NOAA, 2019).

The 2018 heatwave had a number of effects on power generation: several water-cooled nuclear plants and hard coal plants had to shut down temporarily; hydropower in northern Europe was down due to much less than normal rainfall, and peak demand for air conditioning was much higher than normal. Also, wind power generation was below normal as there was less wind, however fewer clouds meant more solar power (Agora Energiewende and Sandbag, 2019). This illustrates the possible impact on the energy system from continental changes in weather patterns/climate change.

The Member States with the largest contribution to the total EU **hard and brown coal** use in 2018 are Germany and Poland (together more than half of total EU coal consumption), followed by the Czech Republic, Spain, Italy, France and the Netherlands (together, making up a quarter of total EU coal consumption) (BP, 2019). However, the largest reductions in coal consumption contributing to the total EU decline of 5.1% in 2018 were seen in Germany (-7.2%). Spain (-17.3%) and the United Kingdom (-16.6%) (in order of absolute changes) (BP, 2019). This large decrease of 5.1% in coal use, mainly by coal-fired power plants, is the main reason for the 1.8% decline in CO_2 emissions in 2018. The mild winter aided to this trend.

In 2018, more than 80% of coal consumption in the European Union occurred in **power generation** (IEA, 2018). According to the EU *Emission Trading System* (ETS) total CO_2 emissions from the power sector fell by 5% and the amount of coal-fired power generation decreased by 6%. Between 2012 and 2018, most of this decrease in CO_2 emissions was from hard coal power plants and much less from brown coal (lignite) plants, with decreases in CO_2 emissions in 2018 of 9% and 3%, respectively.

About half of the lignite power generation took place in Germany and the other half in Poland, Czech Republic, Bulgaria, Greece, Romania and Slovenia. In Germany, a phase-out of coal-fired power generation is planned, slower for lignite than for hard coal (Agora Energiewende and Sandbag, 2019). In addition, in Germany and Poland, new or extended coal-fired power plants are under construction (Shearer et al., 2019).

Total electricity generation in the European Union remained almost constant in 2018 (only 0.2% lower than in 2017 (BP, 2019). Data from Eurostat (2019c) confirms this.
While coal-fired power generation decreased in 2018, total hydropower increased by 15.7%, as it recovered from the extremely low level in 2017 (by far the lowest since decades). This increase compensated for the 5.7% drop in coal-fired power generation. Moreover, increases in wind and solar power, by 4.6% and 7.3% respectively, notably in Germany, United Kingdom and France, were so large that these renewables also caused a 6.2% drop in gas-fired power generation. In Spain, Italy and France, an increase in hydropower led to a reduction in gas-fired power generation (BP, 2019; Agora Energiewende and Sandbag, 2019).

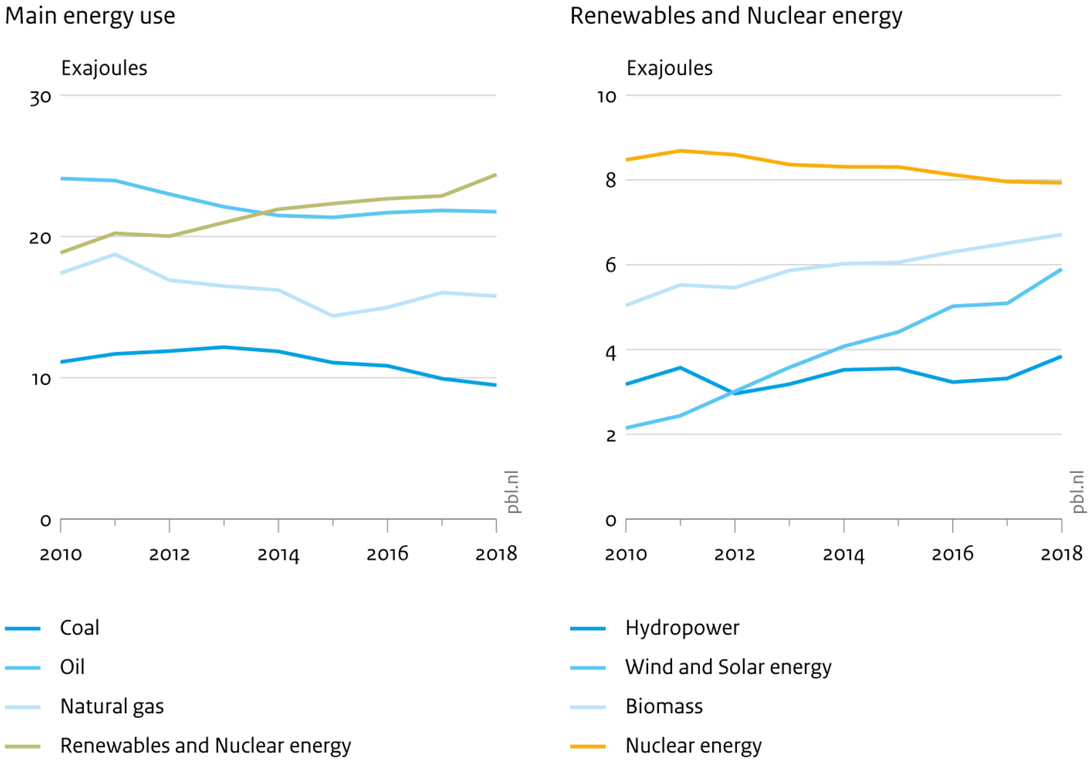
The important **transport** sector, with the greatest use of **oil products** and the EU sector from which most CO_2 is being emitted, saw its CO_2 emissions decrease by 0.6% in 2018. Some 25 years ago, a tax-incentivised shift from petrol to diesel began, which led to a major decline in demand for petrol as well as a large increase in diesel production (and, in some years, led to a shortage) in the EU. However, since 2017 this trend has been slowly reversing; demand for diesel has declined while, for petrol, it continues to improve (FuelsEurope, 2019).

Main energy use in the European Union

In 2018, 30.5% of the European Union’s total primary energy supply (TPES) consisted of oil, 34.2% of renewables plus nuclear, 22.1% of natural gas, and 13.3% of coal (Figure 3.11, left side) (IEA, 2019a; BP, 2019). This means that 66% of the EU’s energy supply was still composed of fossil fuels. In 2018, about 60% of the power was generated from renewable and nuclear sources and, in 2018, these sources contributed 34% to TPES. The latter is 1.8 percentage points higher than in 2017 and 7.8 percentage points higher than in 2010. As Figure 3.11 (left side) clearly shows, since 2010, renewable plus nuclear energy has been showing continuous annual growth. Figure 3.11 (right side) shows that this growth was mainly due to the large annual growth in wind and solar power, with 14% per year, on average. In addition, biomass-fired power generation also increased steadily, by an average 4% per year.

Hydropower did not change significantly, over time, varying only slightly, depending on annual weather conditions (IEA, 2019a; BP, 2019). However, Figure 3.11 (right side) also shows that, since 2011, total nuclear energy in the European Union has been decreasing, over time. This is mainly due to a 45% decrease in Germany, since 2011, which is part of the phase-out of nuclear energy agreed upon in the German Parliament (the so-called *Energiewende*). In 2018, Germany's share in total EU nuclear energy was less than 10%.

Figure 3.11
Trends in energy use in the European Union, 2010-2018



Note: Here we have excluded 'Other energy' in total TPES of the EU.
Source: IEA, BP

Since 2010, the share of these non-fossil energy sources increased by 7.8 percentage points, from about 26.4% to 34.2%, which is a rather large change in the energy supply system in only eight years. In the European Union, this rapid, large growth resulted in reductions in the shares of coal, oil and natural gas, by 2 to 3 percentage points, since 2010. This has contributed to the 12% decrease in the EU's CO_2 emissions, since 2010. For a long-term perspective, CO_2 emissions in 2018 were 22% below the 1990 level. For individual EU Member States, percentages can differ from the overall EU trend. For example, since 2010, the United Kingdom has had a 14 percentage points increase in the share of renewable and nuclear energy, to 26%, which coincided with decreases in the share of coal and natural gas of 11 and 5 percentage points, respectively. The Netherlands, within the same timeframe, saw a 5 percentage points increase in renewable and nuclear energy, to 11%, which coincided with an 8 percentage points decrease in the share of natural gas.

However, with a share of 66% the European Union's energy use, in 2018, was still heavily leaning on fossil fuels, with 30% of TPES being provided in oil products, 22% in natural gas and 13% in coal. The 34% share of non-fossil energy consisted of 11.1% nuclear energy, 9.4% biomass fuels, 8.3% wind and solar energy and 5.4% hydropower. From a comparison between changes in percentages and shares in the energy supply, we can conclude that the EU has reduced its shares of oil, coal and natural gas, over the past decade, which was compensated for by an increase in renewable energy.

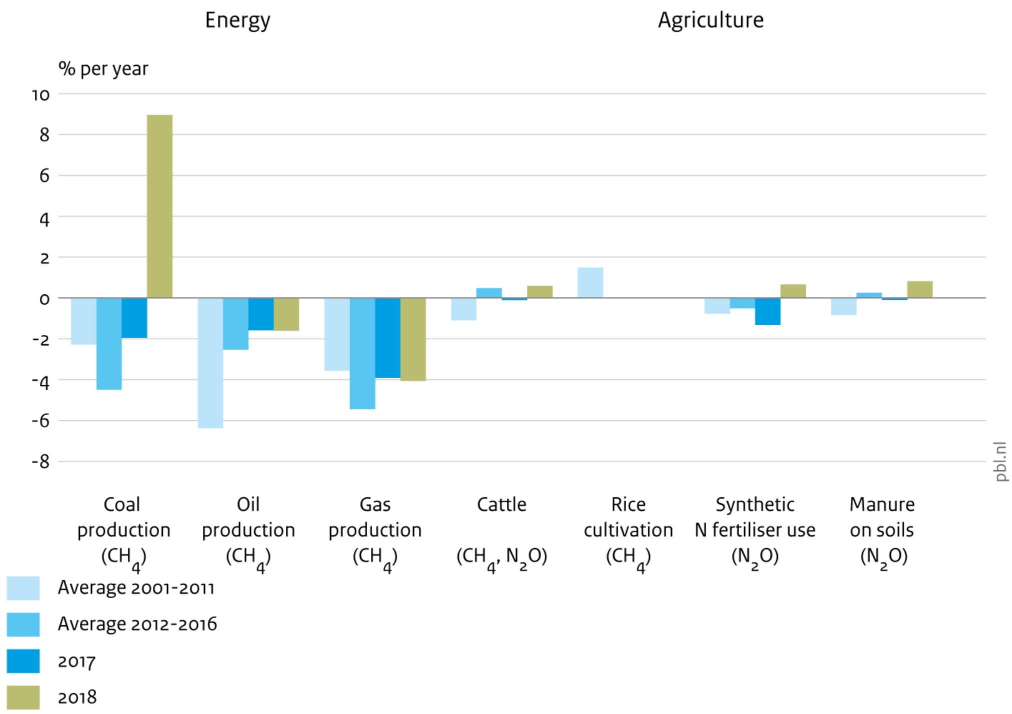
Other emissions

In contrast to CO_2, the emissions of non-CO_2 greenhouse gases have all increased since 2010, collectively by 1.8%. The increase in 2018 was estimated at 0.6%. CH_4 emissions are the largest in this group, with a share of 13.5%, followed by 6.1% for N_2O emissions and about 3.6% for F-gas emissions, in total greenhouse gas emissions in the European Union. EU oil production took place mainly in the United Kingdom.

CH_4 emissions continued to decrease, for the third consecutive year, in 2018 by 0.3%, mainly caused by a large 3% decrease in net methane emissions from landfills, partly compensated by increases in natural gas production and transmission (transport and distribution) (+3%) and enteric fermentation by livestock (+0.8%). These sources showed the largest absolute emission changes in 2018. The largest methane sources in the European Union are livestock, predominantly cattle, and landfill, which accounted for about 60%. Other significant sources are natural gas production and transmission and other agriculture. As illustrated in Figure 3.10, since 2001, CH_4 emissions have slowly decreased, aided by downward trends in fossil fuel production, especially natural gas and oil, and cattle numbers (Figure 3.12).

Figure 3.12

Annual changes in main drivers of CH_4 and N_2O emissions in the European Union, 2001-2018



Source: CH_4: IEA, BP, FAO, IRRI; N_2O: IFA, FAO
Note: Between brackets the greenhouse gas(es) are listed for which the activities are drivers.

In 2018, total **N_2O emissions** in the European Union remained constant, following two years of very small decreases (Figure 3.10). Although emissions from most agricultural sources increased slowly, decreases in N_2O emissions from industrial processes, especially nitric acid production, and from fuel combustion, in particular in road transport and coal-fired power plants, compensated for the increases in other sources.

The largest sources of N_2O emissions in the European Union related to agricultural activities: the use of synthetic nitrogen fertilisers, other agricultural sources such as the use of manure as fertiliser, N-fixing crops and crop residues left on the field, as well as manure dropped in pastures, ranges and paddocks, which, together with their indirect N_2O emissions, account for two thirds of total N_2O emissions. Fossil fuel combustion and industrial processes account for about one quarter. Only one source has been decreasing, over time: industrial processes generating N_2O emissions, which saw their emissions decrease by 3% in 2018, have decreased by more than 60% since 2005.

In 2018, **F-gas emissions** in the European Union increased by an estimated 1.3% (expressed in kg CO_2 eq). This is roughly similar to the years after 2011, when the average annual increase was 0.7% (see Figure 3.10), which was a slowdown compared to the 2000–2011 period when F-gas emissions increased by an average 5% per year. About 90% are estimated to be HFC emissions, which continued to increase in 2018 by about 1.0%, mainly due to a large increase in HFC-23 by-product emissions from HCFC-22 manufacture and increases in HFC-125 and HFC-227ea emissions.

In contrast, PFC and SF_6 emissions in the EU, with respective shares of 4% and 6%, slowly decreased up to 2011 and, since then, have remained more or less constant. In 2018, they are estimated to have increased by about 9% and 1.5% respectively. Most of the SF_6 emissions in the EU are from SF_6-containing switchgear in the electricity sector, and PFC emissions are mainly emitted as a by-product from aluminium production and from their use in semiconductor manufacture.

HFC emissions in the European Union mostly consisted of HFC-134a, HFC-125, HFC-143a and HFC-227ea from the use of these substances, that account for almost nine tenth of HFC emissions, when comparing amounts in units of CO_2 eq. HFC-134a emissions have been decreasing since 2017, in 2018 by 2%, and HFC-143a emissions are also decreasing over time, by an estimated 4% in 2018. However, HFC-125 and HFC-227ea emissions are continuing to increase, in 2018 by about 3% and 5%, respectively.

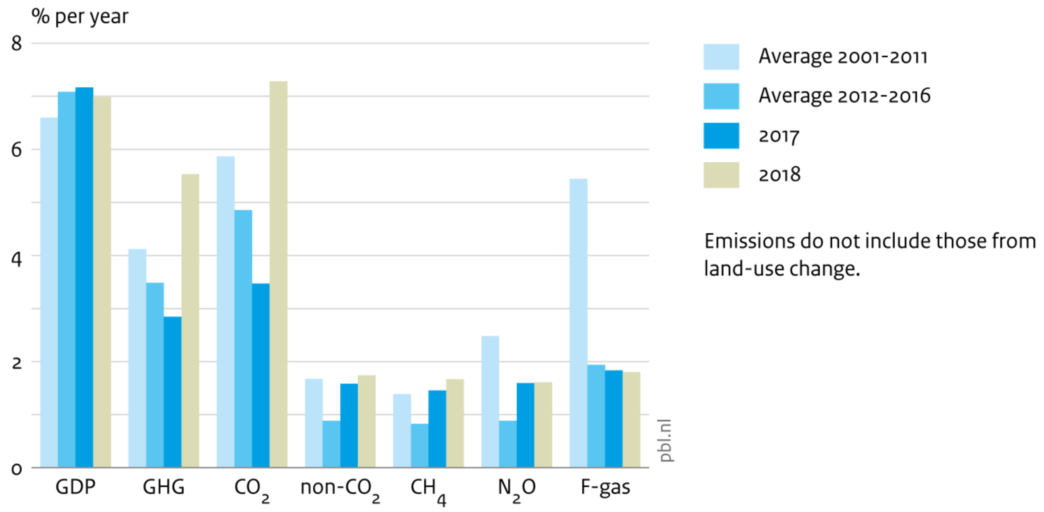
3.4 India

In 2018, India contributed about 7.2% to global greenhouse gas emissions and about 6.9% to global CO_2 emissions. Total greenhouse gas emissions consisted of 70% CO_2 and 30% non-CO_2, mostly methane, with 23.5% CH_4, 5.7% N_2O and 0.9% F-gas emissions.

For more than a decade, India's annual growth in GDP has been around 7% and, in 2018, this trend continued with a 7.0% increase. However, the annual change in greenhouse gas emissions showed a more variable character, as shown in Figure 3.13, mostly between 2% and 4% but varying between 1.5% in 2013 and 6.8% in 2014. After an increase of 2.8% in 2017, India's greenhouse gas emissions increased in 2018 by about 5.5% to 3.7 $GtCO_2$eq. This large growth was mainly due to the very large growth in CO_2 emissions; 7.3% in 2018, up from 3.5% in 2017. Indeed, CO_2 emissions showed a pattern similar to that of total greenhouse gas emissions, whereas non-CO_2 greenhouse gas emissions showed a more constant annual trend for all years, also for the three individual gases, CH_4, N_2O and F-gases

(Figure 3.13). Since 2010, India's total greenhouse gas emissions increased by 34%, consisting of 48% increase in CO_2 emissions and 9% increase in non-CO_2 greenhouse gas emissions.

Figure 3.13
Annual changes in GDP and greenhouse gas emissions in India, 2001-2018



Source: GDP: World Bank, IMF; GHG: EDGAR v5.0 (EC-JRC/PBL, 2019) FT2018, except F-gas: EDGAR v4.2 FT2018

CO_2 emissions

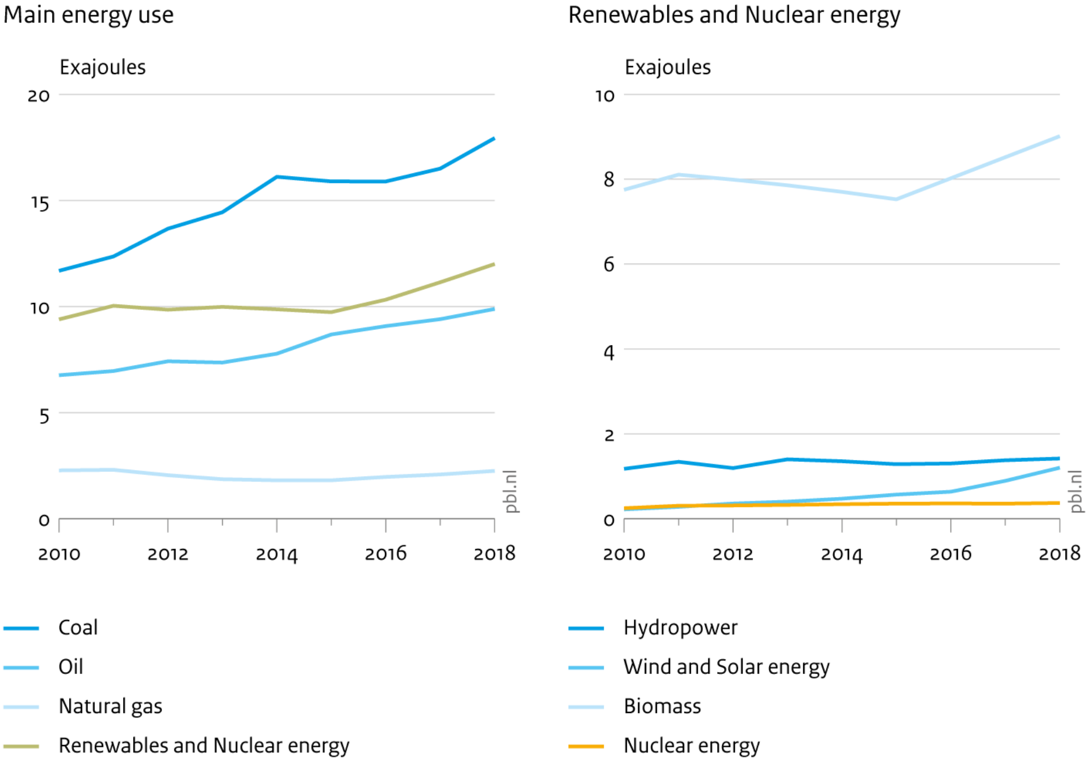
In 2018, the 7.3% increase in CO_2 emissions was mainly due to the large increase of 8.7% in coal consumption, 8.1% in natural gas consumption, and 5.1% in oil consumption (BP, 2019). **Electric power** production, with a 50% share the largest source of CO_2 emissions in India, increased by 6.2% in 2018, to 1.56 GWh. In 2018, coal-fired power plants provided three quarters of the total power, natural gas 5%, renewable energy 16.7% and nuclear power 2.5%. Of the total power increase in 2018, coal power contributed almost two thirds, hydropower 4%, other renewable power 28% (mainly wind and solar energy) and 2% of the increase consisted of nuclear power (BP, 2019).

The second largest CO_2 emitting sector is the **manufacturing industry,** with a share of 25% in 2018, three quarters of which from coal combustion and one quarter from oil combustion. In other words, coal combustion in the energy and industry sectors accounted for about 75% of India's CO_2 emissions. With a share of around 12%, **transport** was the third largest source of CO_2, mostly from oil products (IEA, 2018).

Main energy use in India

In 2018, 42.6% of India's total primary energy supply (TPES) consisted of coal, 28.5% of renewables plus nuclear energy, 23.5% oil, and 5.4% natural gas (Figure 3.14, left side) (IEA, 2019a; BP, 2019). This means that 71.5% of India's energy supply still consisted of fossil fuels. In 2018, almost 20% of power generation was supplied from renewable and nuclear sources, which contributed 29% to TPES, the same share as in 2017, and 2.7 percentage points less than in 2010. As noted before, this report uses the BP definition of TPES, which uses a substitution method for nuclear, hydropower and other non-biomass renewable energy and assumes 38% conversion efficiency in all these cases.

Figure 3.14
Trends in energy use in India, 2010-2018



Source: IEA, BP

As Figure 3.14 (left side) clearly shows, since 2010, in particular coal and oil showed the largest annual growth, but since 2015, the most rapid growth was in renewable energy (i.e. wind and solar power, and biomass as fuel, according to the right part of the figure). At the same time, the growth in coal use was temporarily suppressed in 2015 and 2016. In power generation, we see that, since 2016, a significant part of the growth was in wind and solar power generation, mitigating the increase in coal used in power generation. India, like China, saw an unprecedented slowdown in coal plant permits, with less than 3 GW in 2018, compared to 39 GW in 2010. Moreover, the pre-construction pipeline shrunk 83%, from 218 GW in 2015 to 36 GW in 2018. Since 2017, investments in renewable energy have been larger than in fossil-fired power generation. These trends are expected to continue (Myllyvirta, 2019; Schearer, 2019).

The *decreasing* share of non-fossil energy sources, since 2010 by 2.7 percentage points from 31.2% to 25.5%, is very different compared with those of China, the United States and the European Union, which show increases in non-fossil energy. The difference is due to the fact that, in India, the increase in renewable and nuclear energy started only in 2016, not yet in 2010, resulting in large annual increases in fossil fuel consumption, not only in the first half of this decade, but also in recent years. Coal and oil consumption increased by roughly 50% in 2018, compared to 2010 levels, while the low consumption of natural gas remained at the 2010 level. As a result, the shares of coal and oil products in total energy supply have increased between 2010 and 2018, from 39% to 43% for coal and from 22% to 23% for oil sproducts, while the share of natural gas decreased from 8% to 5%, over these years (IEA, 2018; BP 2019).

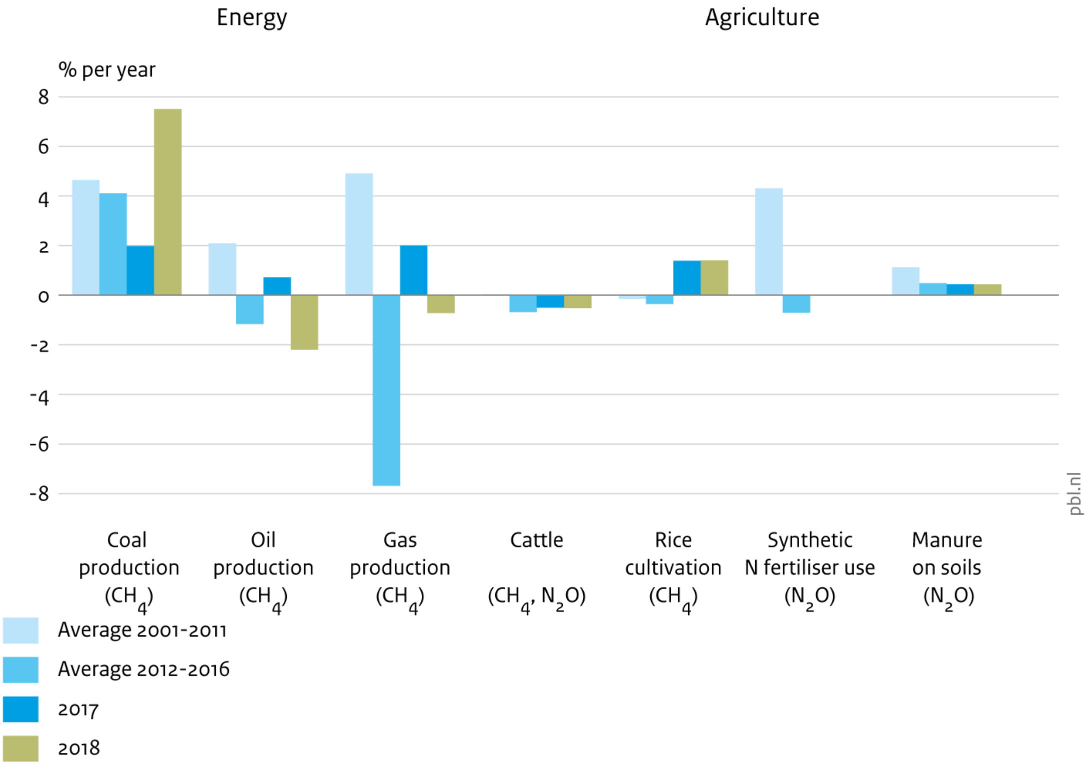
Please note the specific characteristic of India's energy supply (Figure 3.14): the very high shares of biomass used as fuel of from 26% in 2010 to 30% in 2018. For most other large countries, total biomass shares were generally 10% or less. We note that the biomass figures for 2017 and 2018 were estimated based on the trend for 2016, which explains the graph in Figure 3.14 (right side). Another feature is India's large reliance on coal (60% in 2018), which it has in common with China, as both countries have large domestic coal reserves and thus coal production.

However, with a share of more than two thirds (71%), India's energy use is still heavily leaning on fossil fuels, with 43% of its TPES being provided by coal, 23% by oil and 5% by natural gas. The 29% share of non-fossil energy consisted of 21% biomass, 3% hydropower, 3% wind and solar power, and 1% nuclear power.

Other emissions

Since 2010, all of India's non-CO_2 greenhouse gas emissions have been increasing, collectively by 9.4%. In 2018, the increase was estimated at 2.0%. With a share in total greenhouse gas emissions of 23.5%, CH_4 emissions are by far the largest in this group, followed by 5.7% for N_2O and about 0.9% for F-gas. The 30% share of non-CO_2 greenhouse gases in total greenhouse gas emissions is among the highest of the top-6 countries.

Figure 3.15
Annual changes in main drivers of CH_4 and N_2O emissions in India, 2001-2018



Source: CH_4: IEA, BP, FAO, IRRI; N_2O: IFA, FAO
Note: Between brackets the greenhouse gas(es) are listed for which the activities are drivers.

In 2018, **CH_4 emissions** continued to increase in India, by 1.7% to a level of 34.8 $MtCH_4$ (0.9 $GtCO_2eq$), which is also the highest since 2008 when the increase was also 1.7%, following a 1.5% increase in 2017. The increase in 2018 was mainly caused by large increases in net emissions from coal mining (+7%) and from residential biofuel combustion (+6%), together with those from waste water and landfill (+2%), rice cultivation (+1%) and enteric fermentation by livestock (+0.3%) (Figure 3.15). These sources showed the largest absolute emission changes in 2018. The largest methane sources in India were livestock, predominantly cattle, and waste water accounting for about 40% and 18%, respectively. Other significant sources were rice cultivation, coal production, biofuel combustion and landfill. As illustrated in Figure 3.13 in 2017 and 2018, the annual increase in CH_4 emissions was somewhat larger than in other years since 2008, which showed average annual increases of 0.9%.

In 2018, **N_2O emissions** also continued to increase, for the fifth consecutive year, by 1.6%, to reach a level of 0.7 MtN_2O (0.2 $GtCO_2eq$). This increase was the same as in the three preceding years. In 2018, the increase was mainly caused by large increases in fossil fuel combustion, in particular residential biofuel combustion (+6%) together with smaller increases from other agricultural activities, such as the use of manure as fertiliser, N-fixing crops and crop residues left on the field, and waste water (Figure 3.15). The largest sources of N_2O emissions in India related to agricultural activities, such as the use of synthetic nitrogen fertilisers, animal manure in pastures, ranges and paddocks, which, together with their indirect N_2O emissions, account for more than half of India's total N_2O emissions. Fossil fuel combustion accounts for about one fifth.

In 2018, **F-gas emissions** increased by an estimated 1.8% (expressed in kg CO_2eq). This was very similar to other years since 2011, when the average annual increase was 1.9% (Figure 3.13), which was a slowdown compared to the 2000–2011 period when F-gas emissions increased by about 8.0%, annually. About two thirds are estimated to have been HFC emissions, which continued to increase in 2018 by about 1%. In contrast, PFC and SF_6 emissions in India, with respective shares of about 10% and 25%, have been increasing more rapidly, and, in 2018, were estimated to have increased by about 4% and 3%, respectively. Most of SF_6 emissions in India are from SF_6-containing switchgear in the electricity sector. PFC emissions are mainly emitted as a by-product of aluminium production.

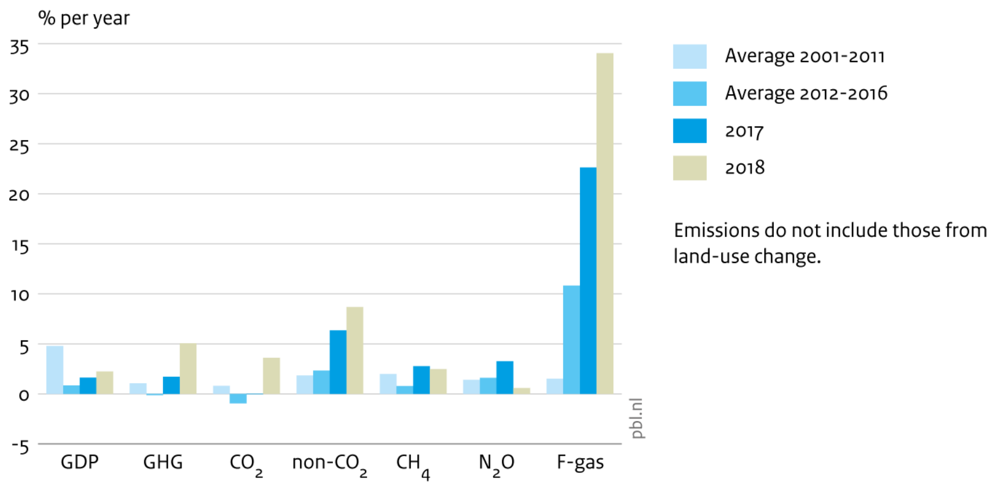
3.5 Russian Federation

In 2018, Russia contributed about 4.8% to global greenhouse gas emissions and about 4.6% to global CO_2 emissions. Total greenhouse gas emissions consisted of 70% CO_2 and 30% non-CO_2 emissions: 19.0% CH_4, 3.4% N_2O and 7.5% F-gas.

Since 2010, Russia's annual GDP growth has been around 1.8%; however, in 2015, it showed a *decrease* of 2.3% and since then GDP increased by 0.3%, 1.6% and 2.3%. In 2014 and 2015, the Russian economy suffered a financial crisis due to a sharp devaluation of the Russian ruble, the fall of the oil price in the second half of 2014 and international economic sanctions imposed on Russia. The annual change in the Russian greenhouse gas emissions also shows a variable character as is shown in Figure 3.16: mostly between -1% and 4%, varying between -1.7% in 2013 and 6.5% in 2010. Note that, in 2013 and 2014, CO_2 and CH_4 emissions decreased, as did total greenhouse gas emissions. After an increase of 1.7% in 2017, Russia's greenhouse gas emissions showed a very large increase in 2018, of about 5.1%, to 2.45 $GtCO_2$ eq. This growth percentage in 2018 was the second largest among the G20 countries (only India had more growth, Section 3.4).

This very high growth percentage, to some extent, was due to the growth in CO_2 emissions of 3.6% in 2018, up from 0% growth in 2017. CO_2 emissions had a 70% share in total greenhouse gas emissions. However, F-gases, in particular a very large increase in 2018 extrapolated from the 2017 trend for one of them, caused the increase in total greenhouse gas emissions in 2018 to be as high as 5.1%. If, however, we assume a much smaller increase in this F-gas source, instead of extrapolating the past trend, the increase in 2018 of total greenhouse gas emissions would be 3.4%. This example illustrates the large uncertainties in F-gas emissions at country level, as discussed in Section 2.1.

Figure 3.16
Annual changes in GDP and greenhouse gas emissions in the Russian Federation, 2001-2018



Source: GDP: World Bank, IMF; GHG: EDGAR v5.0 (EC-JRC/PBL, 2019) FT2018, except F-gas: EDGAR v4.2 FT2018

CO_2 emissions in Russia showed a variable pattern, similar to that of total greenhouse gas emissions, and this was also the case for CH_4 and F-gas emissions. Together, they had a share of about 25%. In contrast, Russia's N_2O emissions showed a more constant trend in all years up to 2018 (Figure 3.16). Since 2010, Russia's total greenhouse gas emissions have been increasing by 11%, which included 3.7% increase in CO_2 emissions, and the increase in non-CO_2 greenhouse gas emissions was 32%.

CO_2 emissions

The 3.6% increase in CO_2 emissions in 2018 was mainly due to large increases of 5.4% in natural gas consumption and 4.9% in coal consumption and a small increase of 0.5% in oil consumption (BP, 2019). The sectors that saw the largest emission increases were public combined heat and power (CHP) generation, private heat generation, specific industries and the residential sector.

Electric **power generation**, with a more than 50% share by far the largest source of CO_2 emissions in Russia, increased by 1.9% in 2018 to 1.1 GWh. Natural-gas-fired power plants provided almost half of the total power in 2018, and 16% coal, 16.7% renewable energy, and 18.4% nuclear power. The large share of natural-gas-fired plants related to 60% of the sector's total CO_2 emissions and, for coal-fired plants, this was more than 30% (IEA, 2018). When looking at the sources used for the total increase in power in 2018, coal- and natural-gas-fired power generation contributed by two thirds, hydropower by almost one quarter (other renewable energy was negligible with 0.6%) and 6% of the increase was met by nuclear power (BP, 2019).

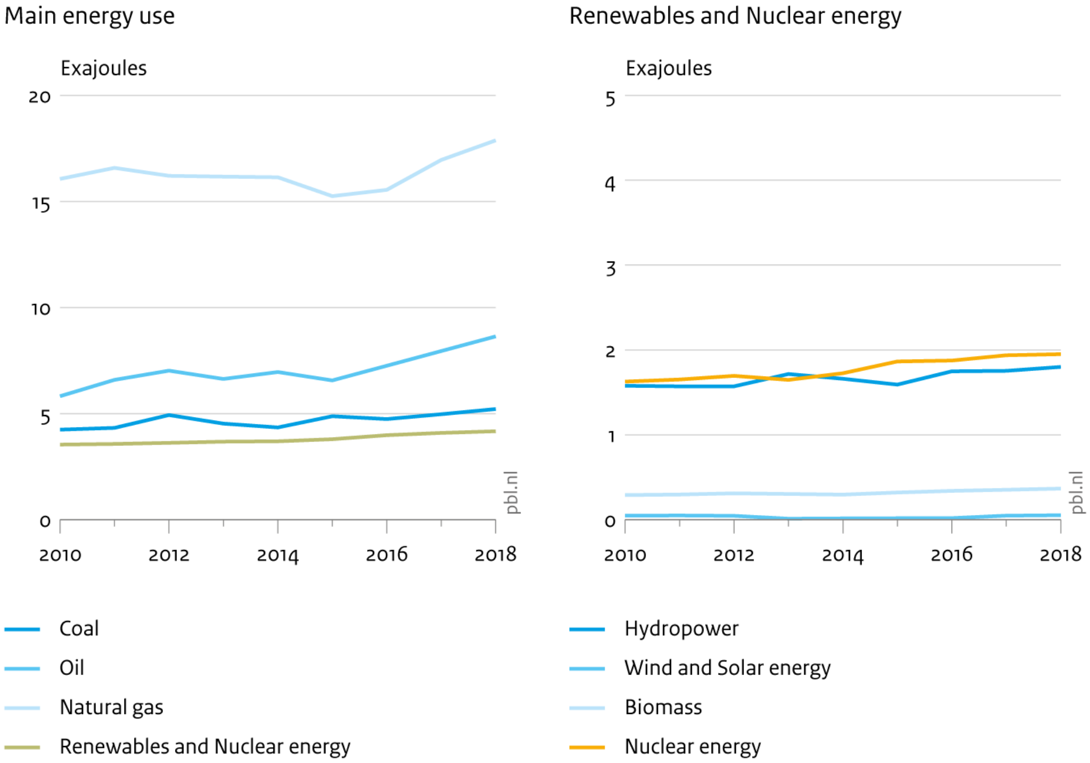
The second largest CO_2 emitting sector is the **transport** sector, with in 2018 a share of 17%, 60% of which from road transport and — because Russia is a large exporter of oil and natural gas — 30% of the sector's CO_2 emissions were from natural gas used in the transport and export of natural gas and oil. Third and fourth are the **manufacturing industry** and the **buildings** sector, each with a share of about 12% in 2018. However, 70% of CO_2 emissions from the residential and service sectors were from natural gas used for heating, whereas for the manufacturing industry, the share of natural gas was 45% with the remainder in about equal shares in coal and oil combustion (IEA, 2018).

Main energy use in the Russian Federation

In 2018, 49.8% of Russia's total primary energy supply (TPES) was from natural gas, 24.1% oil, 14.5% coal, and 11.6% renewables plus nuclear (Figure 3.17, left side) (IEA, 2019a; BP, 2019). This means that 88.4% of Russia's energy supply still was from fossil fuels. In 2018, about 36% of the power was generated using renewable and nuclear sources. These sources contributed 11.6% to TPES in 2018, a share that was about the same as that of 2017 and 0.3 percentage points lower than in 2010. This report uses the BP definition of TPES, which uses a substitution method for nuclear, hydropower and other non-biomass renewable power and assumes 38% conversion efficiency, in all these cases.

As Figure 3.17 (left side) clearly shows, since 2015, in particular natural gas and oil showed the largest annual growth, while coal and renewable and nuclear power increased slowly and had been continuing at the same rate since 2010. The slow increase in non-fossil energy mainly consisted of hydropower and nuclear power, according to Figure 3.17 (right side). Russia is the only country in the six largest greenhouse gas emitting countries where virtually no wind and solar power nor biofuels for road transport were used.

Figure 3.17
Trends in energy use in the Russian Federation, 2010-2018



Source: IEA, BP

In the power sector, over the last two decades, there has been no significant increase in coal-fired power generation, but also no phasing out. In 2018, Russia had 5 GW in coal-fired capacity under development, using lignite from a nearby coal mine at a site 100 km from the Chinese border, aiming for export of electricity to China (Schearer et al., 2019).

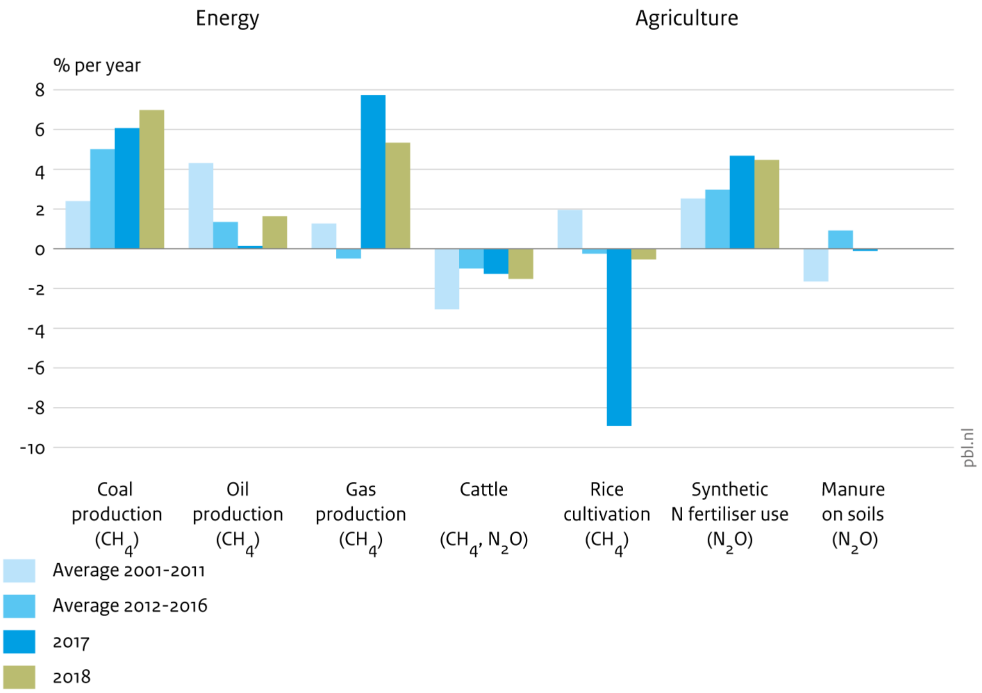
Please note the specific characteristic of Russia's energy supply (Figure 3.17) as having a the very high share of natural gas and oil in TPES, with 50% and 24%, respectively, and a 15% share of coal. The 12% share of non-fossil energy consisted of 5% hydropower, 1% biomass and 5% nuclear power. The share of wind and solar power was negligible.

Other emissions

In contrast to CO_2 emissions that only increased by 3.6% since 2010 and 3.6% in 2018, non-CO_2 greenhouse gas emissions increased much more since 2010, collectively by 32%, and by an estimated 8.7% in 2018 (Figure 3.16). Since 2010, CH_4 and F-gas emissions show the same kind of pattern as CO_2 emissions and, in 2018, they had shares in total greenhouse gas emissions of 21% and 8.3%, respectively. Russia's N_2O emissions showed a more constant annual trend for all years (Figure 3.16 (right side)) and their 2018 share was 3.7%.

In 2018, **CH_4 emissions** continued to increase by 2.5%, to a level of 18.7 $MtCH_4$ (0.45 $GtCO_2$ eq), after several years of similar increases, apart from 2013 and 2014, when methane emissions *decrease*d. The increase in 2018 was mainly caused by large increases in net emissions from natural gas production and transmission (+5%) and coal mining (+7%), and somewhat mitigated by small decreases in emissions from livestock, in particular dairy cattle (-2%) (Figure 3.18). These sources showed the largest absolute emission changes in 2018. The largest methane sources in Russia were natural gas production and transmission, and gas venting, which, together with oil production, accounted for half of Russia's CH_4 emissions. Other significant sources were coal production, landfill and livestock, predominantly cattle, which accounted for a respective 40% and 18%.

Figure 3.18
Annual increases in main drivers of CH_4 and N_2O emissions in the Russian Federation, 2001-2018



Source: CH_4: IEA, BP, FAO, IRRI; N_2O: IFA, FAO
Note: Between brackets the greenhouse gas(es) are listed for which the activities are drivers.

In 2018, **N_2O emissions** also continued to increase for the fourth consecutive year, but slowly, by 0.6%, to reach a level of around 0.3 MtN_2O (less than 0.1 $MtCO_2$eq) (Figure 3.16). The net increase in 2018 was mainly caused by emission increases in industrial processes (+6%), in particular nitric acid production, the use of synthetic fertilisers (4%) and fuel combustion (+4%), in particular in road transport and agricultural machinery (Figure 3.18). The largest Russian sources of N_2O emissions related to industrial processes (almost one third) and agricultural activities; i.e. the use of synthetic nitrogen fertilisers, crops residues, animal manure in pastures, ranges and paddocks, which together with their indirect N_2O emissions accounted for about half of Russia's total N_2O emissions. Fossil fuel combustion, including indirect emissions, accounted for about one tenth.

In 2018, total Russian **F-gas emissions** increased by an estimated 34% (expressed in kg CO_2eq). This appears high but should be compared with our estimate of 23% increase in 2017. We note that, according to Russia's national emissions inventory submitted to the UN Climate Secretariat, the increase in total F-gas emissions in 2017 was 36.8% (UNFCCC, 2019). The large increases in 2017 and 2018 were predominantly due to increases in HFC emissions, which in 2018 accounted for about 85% of total F-gas emissions. About half of these consisted of HFC-23 emissions, mostly HFC-23 as by-product from the production of HCFC-22, unabated emissions of which about doubled in 2017 and 2018. The other HFC emissions, in Russia, were mostly from the use of HFC-125, HFC-143a and HFC-134a (UNFCCC, 2019), which accounted for almost all of the remaining HFC emissions and which increased by 9% to 15% in 2018. These trends caused total HFC emissions to increase by almost 50%.

PFC and SF_6 emissions accounted for about 10% and 5%, respectively. Most of the PFC emissions in Russia were emitted as by-product of aluminium production, which saw an estimated 14% decrease in 2018. Other PFC emissions were from the use of PFCs in semiconductor manufacturing. Total PFC emissions declined by 13% in 2018.
SF_6 emissions, most of which from the use of SF_6-containing switchgear in the electricity sector, were estimated to have increased by 2% in 2018.

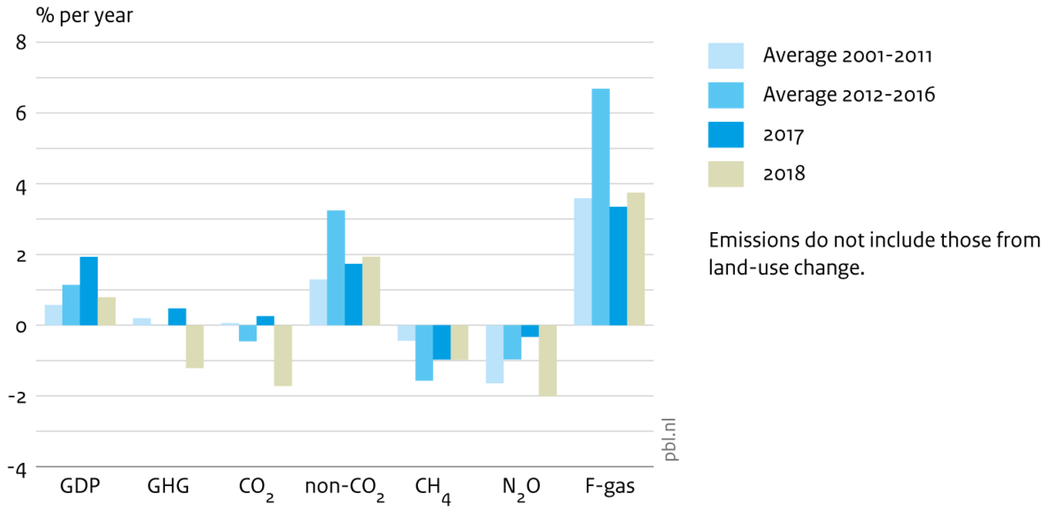
3.6 Japan

Japan contributed about 2.7% to global greenhouse gas emissions and about 3.2% to global CO_2 emissions in 2018. Total greenhouse gas emissions were 85.8% CO_2 and 14.2% non-CO_2 emissions: 3.6% CH_4, 1.3% N_2O and 79.3% F-gas.

In 2018, the annual GDP growth in Japan was 0.8%, which is almost similar to the average annual increase of 1.1% since 2010 but lower than the 1.9% increase in 2017. However, Japan's total greenhouse gas emissions declined in 2018 by 1.7% to a level of 1.4 $GtCO_2$ eq, following a small increase of 0.3% in 2017 and three years with declining emissions before 2017. In 2018, as was the case in 2014 to 2016, declining greenhouse gas emissions were due to decreases in CO_2 emissions but also in CH_4 and N_2O emissions in those four years. Only F-gas emissions continued to increase, since 2004. These varying trends since 2010 are clearly shown in Figure 3.19 for total greenhouse gas, CO_2 and CH_4 emissions. For other emissions, the share is very small, and, for GDP, the annual changes are rather small.

In 2018, Japan's share of CO_2 in total greenhouse gas emissions was 86%, which was the highest among the top-6 emitting countries. Consequently, Japan's non-CO_2 greenhouse gas emissions had a relatively small share of 14%. This was mainly due to the very small share of CH_4 emissions of 4%, as Japan has almost no domestic fossil fuel production. The share of N_2O emissions was just over 1% and the F-gas share was estimated at 9%, the largest among the top-6 emitting countries, and also larger than the shares of CH_4 and N_2O emissions together.

Figure 3.19
Annual changes in GDP and greenhouse gas emissions in Japan, 2001-2018



Source: GDP: World Bank, IMF; GHG: EDGAR v5.0 (EC-JRC/PBL, 2019) FT2018, except F-gas: EDGAR v4.2 FT2018

Figure 3.19 (left side) shows the emission trends per gas, since 2010, as well as total greenhouse gas and GDP. Since 2010, Japan's total greenhouse gas emissions increased by 3.0%. This trend was mainly set by that in CO_2 emissions, which have been increasing by 3.7% since 2010 and by the non-CO_2 emissions with an increase of 23% due to F-gas emissions increasing by more than 50% since 2010, as shown in Figure 3.19 (right side). Since 2010, Japan's CH_4 and N_2O emissions have declined by 14% an 10%, respectively, but these are much smaller amounts than for F-gas emissions. Also, inter-annual changes in total greenhouse gas emissions were mostly due to similar variations in CO_2 emissions, whereas the non-CO_2 emission trend was much smoother and showed a small overall rise of 32%, since 2010.

CO_2 emissions

In 2018, the 1.7% decrease in CO_2 emissions to 1.2 GtCO_2 was due to decreases of 2.1% in coal consumption, 1.1% in natural gas consumption and 2.9% in oil consumption (BP, 2019). Electric power production, with a 50% share in 2019 the largest source of CO_2 emissions in Japan, was virtually at the same level, with an increase of 0.1% in 2018, at 1.05 GWh. Natural-gas-fired and coal-fired power plants provided a respective 37% and 33% to total power in 2018, with a 6% share of oil, 19.8% of renewable energy (of which 7.7% in hydropower) and 4.7% nuclear power. In 2017, gas and coal power contributed 3.5 percentage points more, renewable power 1.5 percentage points less and nuclear power 2 percentage points less (BP, 2019).

The second largest CO_2 emitting sector was the manufacturing industry with a share of about 15%, of which more than half was from coal combustion and more than one quarter from oil combustion. In other words, coal combustion in the energy and industry sectors accounted for about 95% of Japan's CO_2 emissions. With a share of about 16.2%, road transport was the third largest source of CO_2 (IEA, 2018).

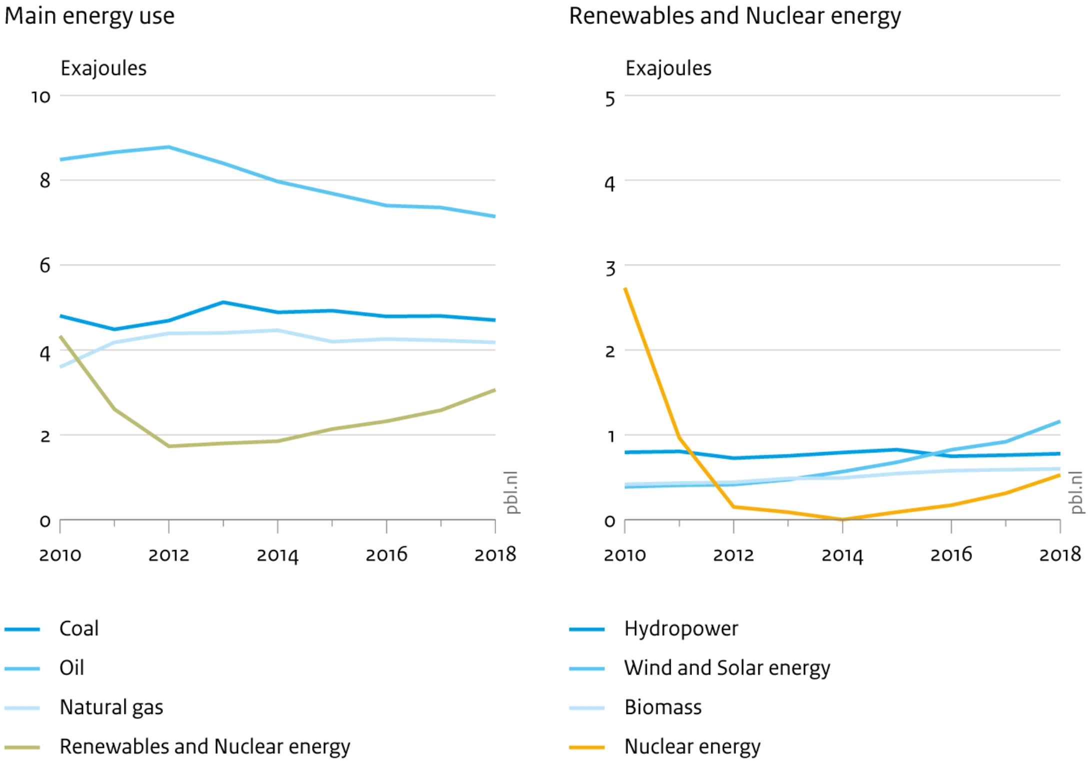
Main energy use in Japan

In 2018, 37.4% of Japan's total primary energy supply (TPES) consisted of oil, 24.6% of coal, 21.9% of natural gas, and 16.0% of renewables plus nuclear (Figure 3.20, left side) (IEA, 2019a; BP, 2019). In 2018, about 24% of power generation was supplied by renewable and nuclear sources, which sources contributed 16% to TPES in 2018, a share that was 2.4

percentage points higher than in 2017 and 4.4 percentage points higher than in 2010. This report uses the BP definition of TPES, which uses a substitution method for nuclear, hydropower and other non-biomass renewable power and assumes 38% conversion efficiency, in all these cases. In 2018, the 86% in other fossil energy supply was composed of 37% oil products, 25% coal and 22% natural gas.

As shown in Figure 3.20 (left side), in 2010, these shares were different, because this was before the tsunami and Fukushima nuclear accident in 2011. In 2018, the share of natural gas was almost 5 percentage points higher, and for coal this was 2 percentage points higher, whereas de share of oil products declined by almost 3 percentage points (IEA, 2019a; BP, 2019). All natural gas consumption was imported as Liquified Natural Gas (LNG) (EIA, 2019l).

Figure 3.20
Trends in energy use in Japan, 2010-2018



Source: IEA, BP

As Figure 3.20 (right side) clearly shows, renewable energy showed a relatively large and continuous annual growth since 2010, with percentages for the last five years of between 12% and 26%. Figure 3.20 also shows that hydropower remained almost constant. However, since 2014, nuclear power has slowly been restarted and is increasing steadily again, after the Fukushima nuclear accident in 2011, when nuclear plants suspended operations for inspections. As nuclear power increases, a further decline in natural-gas-fired power plants is likely (IEA, 2019b; BP, 2019; EIA, 2019l).

With a share of 84%, Japan's 2018 energy use still relied heavily on fossil fuels. The 16% share of non-fossil energy was composed of 6% wind and solar power, another 4% hydropower, 3% biofuels and 3% nuclear power. As nuclear power will get further back online and renewable power will continue to grow, the share of fossil fuels in the energy supply is expected to decline. However, the pace of nuclear restarts has been slow, with an average reactor requiring nearly four years to come back online (EIA, 2019l).

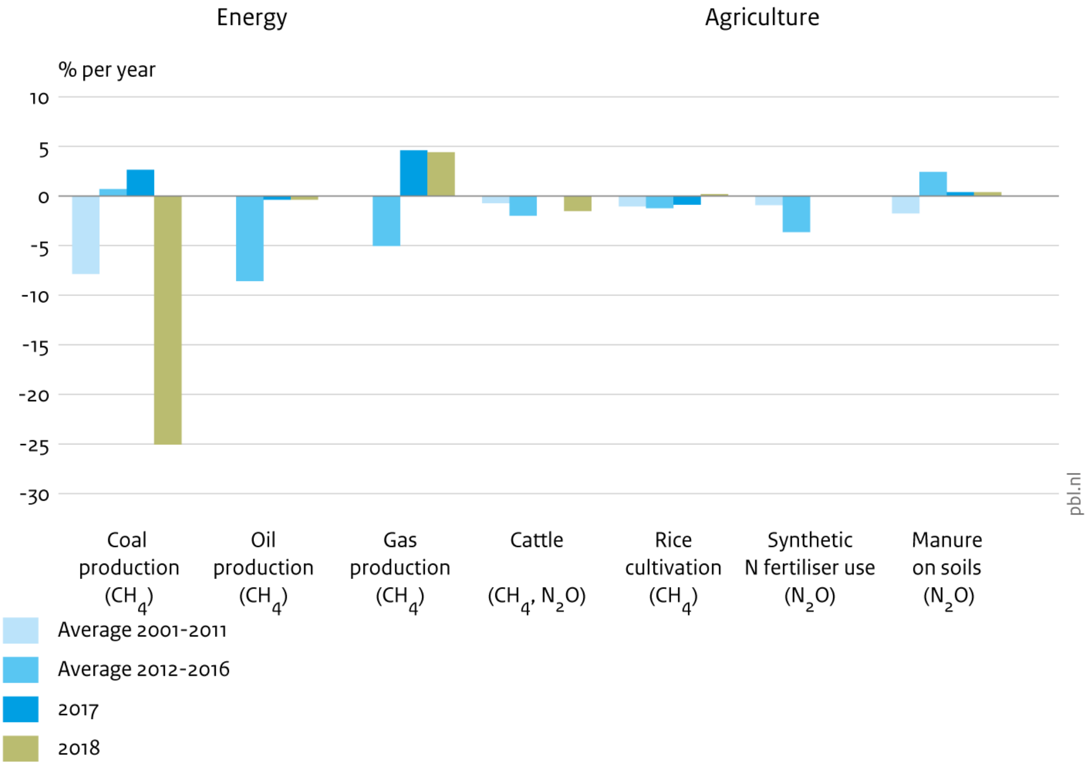
However, Japan also has 8.7 GW in coal-fired capacity under construction and 4.4 GW under development. Plans to expand coal capacity grew after 2011, when it became clear that several nuclear plants were to remain closed. Since 2017, financial institutions have been moving away from coal, but the government is aiming for coal providing a quarter of total electricity generation by 2030 (Shearer et al., 2019).

Other emissions

In contrast to CO_2 emissions, which decreased by 1.7% since 2010 and increased by 0.4% in 2018, Japan's emissions of non-CO_2 greenhouse gases have increased much more since 2010, collectively by 23%, and by an estimated 1.9% in 2018 (Figure 3.19). Since 2010, F-gas emissions have increased by more than 50%, in 2018 by about 4% and the 2018 share was around 9.3%. Together, these emissions are larger than CH_4 and N_2O emissions, which decreased in 2018 by 1% and 2%, respectively. In 2018, they had shares in total greenhouse gas emissions of 3.6% and 1.3%, respectively. Japan's N_2O emissions showed a more constant annual trend, for all years (Figure 3.19, right side) and the 2018 share was 1.3%.

In 2018, **CH_4 emissions** continued to decrease for the fifth consecutive year, by 1.0% to a level of 2.0 MtCH_4 (50 MtCO_2 eq). Compared to 1990, emissions have decreased by 35%. The decrease in 2018 was mainly caused by large decreases in net emissions from enteric fermentation by livestock (-34%), in particular non-dairy cattle, and landfill (-20%), and partly counter-balanced by increases in emissions from poultry manure (+11 %) (Figure 3.21). These sources showed the largest absolute emission changes in 2018. The largest

Figure 3.21
Annual increases in main drivers of CH_4 and N_2O emissions in Japan, 2001-2018



Source: CH_4: IEA, BP, FAO, IRRI; N_2O: IFA, FAO
Note: Between brackets the greenhouse gas(es) are listed for which the activities are drivers.

methane sources in Japan were enteric fermentation by livestock and rice cultivation, which both accounted for one third of Japan's CH_4 emissions. Other significant sources were other agriculture, such as animal manure in particular from poultry and dairy cattle, and waste water, which both accounted for about 10%.

In 2018, **N_2O emissions** also continued to decrease in Japan, for the fifth consecutive year, by 2.0% to a level of 60 kt N_2O (20 $MtCO_2eq$). This is the same decrease as in the four previous years. Compared to 1990, N_2O emissions have declined by 37%. The decrease in 2018 was mainly caused by large decreases in emissions from industrial processes (-22%), (in particular from caprolactam production), and from fossil fuel combustion (-1%), in particular from power generation and road transport. The largest source of N_2O emissions in Japan related to fuel combustion with a share of more than one third and a 50% share when including indirect N_2O emissions from that source. Most of the other large sources related to agricultural activities; the use of synthetic nitrogen fertilisers, animal manure in stables, which together with their indirect N_2O emissions account for about 30% of Japan's total N_2O emissions. Waste water accounted for about 10%.

In 2018, total **F-gas emissions** in Japan increased by an estimated 3.7% (expressed in kg CO_2eq). This is somewhat smaller than the 4.5% average increase in the previous four years. This increase in 2018 was predominantly due to a 4% increase in HFC emissions, which accounted for more than 90% of total F-gas emissions in 2018. Most of the HFC emissions in Japan were due to the use of HFC-143a, HFC-125 and HFC-134a accounted for 95% HFC emissions, the emissions of the first two gases increased by 5% in 2018, whereas HFC-134a emissions decreased by 1%. These trends have led to a 4% increase in total HFC emissions.

PFC and SF_6 emissions from the use of these gases in Japan account for about 5% and 2.5%, respectively. PFC and SF_6 emissions are from the use of PFCs and SF_6, such as in manufacturing of semiconductors, flat panel displays and PV cells. Total PFC emissions remained constant in 2018. SF_6 emissions, most of which most from the use of SF_6-containing switchgear in the electricity sector, are estimated to have decreased by 0.5% in 2018.

Appendices

A. CO_2 emissions per country, per capita, and per USD of GDP

We note that, for CO_2 emissions, the estimated uncertainty is generally between 2% to 5%, with exceptions of up to 10% or 15%. For CO_2 emissions per USD of GDP, the uncertainty is estimated to be larger, generally at about 10%, but for some countries, such as the Russian Federation and China, this is about 20%, due to the uncertainty estimate in the GDP data.

Table A.1 CO_2 emissions per country and group, 1990–2018[17] (unit: $GtCO_2$)

CO_2 emissions per country/group, 1990-2018 (unit: Gt CO_2)																														
Country/group	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Country/group**
China	**2.43**	**2.57**	**2.71**	**2.93**	**3.11**	**3.42**	**3.40**	**3.46**	**3.55**	**3.48**	**3.71**	**3.89**	**4.19**	**4.86**	**5.60**	**6.31**	**7.01**	**7.68**	**7.85**	**8.41**	**9.17**	**10.1**	**10.3**	**10.8**	**10.9**	**10.9**	**10.9**	**11.0**	**11.2**	**China**
United States	**5.06**	**5.02**	**5.10**	**5.22**	**5.31**	**5.36**	**5.51**	**5.68**	**5.69**	**5.71**	**5.92**	**5.86**	**5.78**	**5.85**	**5.94**	**5.95**	**5.84**	**5.92**	**5.73**	**5.31**	**5.56**	**5.43**	**5.24**	**5.32**	**5.39**	**5.23**	**5.13**	**5.10**	**5.25**	**United States**
European Union	**4.35**	**4.29**	**4.14**	**4.06**	**4.04**	**4.09**	**4.20**	**4.10**	**4.09**	**4.03**	**4.05**	**4.11**	**4.09**	**4.19**	**4.19**	**4.17**	**4.19**	**4.14**	**4.05**	**3.72**	**3.85**	**3.69**	**3.65**	**3.56**	**3.38**	**3.42**	**3.41**	**3.44**	**3.37**	**European Union**
France	0.39	0.41	0.40	0.38	0.37	0.38	0.40	0.39	0.41	0.40	0.40	0.41	0.40	0.41	0.41	0.41	0.40	0.39	0.38	0.37	0.38	0.35	0.35	0.35	0.32	0.32	0.32	0.33	0.32	*France*
Germany	1.02	1.00	0.94	0.93	0.92	0.92	0.95	0.91	0.91	0.87	0.87	0.89	0.87	0.87	0.86	0.84	0.85	0.82	0.83	0.77	0.82	0.79	0.80	0.82	0.78	0.79	0.79	0.78	0.75	*Germany*
Italy	0.43	0.43	0.43	0.42	0.41	0.44	0.43	0.44	0.45	0.46	0.46	0.46	0.47	0.49	0.50	0.50	0.49	0.48	0.47	0.42	0.43	0.42	0.40	0.36	0.34	0.35	0.35	0.35	0.34	*Italy*
Netherlands	0.16	0.17	0.17	0.17	0.17	0.18	0.19	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.19	0.18	0.18	0.18	0.18	0.17	0.19	0.17	0.17	0.17	0.16	0.17	0.17	0.17	0.16	*Netherlands*
Poland	0.37	0.37	0.36	0.36	0.35	0.36	0.37	0.36	0.33	0.32	0.31	0.31	0.30	0.31	0.32	0.32	0.33	0.33	0.32	0.31	0.33	0.33	0.32	0.31	0.30	0.30	0.32	0.33	0.33	*Poland*
Spain	0.23	0.24	0.25	0.24	0.25	0.26	0.25	0.27	0.28	0.30	0.32	0.32	0.33	0.34	0.36	0.37	0.36	0.38	0.34	0.31	0.29	0.29	0.29	0.26	0.26	0.27	0.27	0.28	0.28	*Spain*
United Kingdom	0.58	0.59	0.58	0.56	0.56	0.55	0.57	0.54	0.55	0.54	0.55	0.56	0.55	0.56	0.56	0.56	0.56	0.55	0.53	0.48	0.50	0.46	0.48	0.47	0.43	0.41	0.39	0.38	0.37	*United Kingdom*
India	**0.59**	**0.64**	**0.66**	**0.69**	**0.74**	**0.79**	**0.83**	**0.87**	**0.88**	**0.95**	**0.99**	**1.00**	**1.04**	**1.07**	**1.16**	**1.21**	**1.29**	**1.40**	**1.49**	**1.66**	**1.75**	**1.85**	**1.99**	**2.02**	**2.22**	**2.29**	**2.34**	**2.42**	**2.59**	**India**
Russian Federation	**2.36**	**2.32**	**2.14**	**1.94**	**1.72**	**1.67**	**1.63**	**1.53**	**1.52**	**1.57**	**1.60**	**1.60**	**1.59**	**1.63**	**1.64**	**1.62**	**1.68**	**1.67**	**1.68**	**1.56**	**1.66**	**1.75**	**1.76**	**1.71**	**1.69**	**1.69**	**1.67**	**1.67**	**1.73**	**Russian Federation**
Japan	**1.15**	**1.15**	**1.16**	**1.15**	**1.21**	**1.22**	**1.23**	**1.23**	**1.19**	**1.23**	**1.24**	**1.23**	**1.27**	**1.27**	**1.27**	**1.28**	**1.26**	**1.30**	**1.21**	**1.15**	**1.20**	**1.25**	**1.29**	**1.31**	**1.27**	**1.23**	**1.22**	**1.22**	**1.20**	**Japan**
Other OECD G20	**1.44**	**1.48**	**1.53**	**1.57**	**1.65**	**1.70**	**1.78**	**1.86**	**1.85**	**1.89**	**2.02**	**2.01**	**2.03**	**2.09**	**2.14**	**2.18**	**2.23**	**2.32**	**2.32**	**2.28**	**2.36**	**2.43**	**2.47**	**2.45**	**2.45**	**2.48**	**2.53**	**2.59**	**2.60**	Other OECD G20
Australia	0.28	0.28	0.28	0.29	0.29	0.30	0.31	0.32	0.34	0.35	0.35	0.36	0.37	0.37	0.39	0.39	0.40	0.41	0.41	0.42	0.41	0.41	0.41	0.40	0.39	0.40	0.41	0.41	0.41	*Australia*
Canada	0.45	0.45	0.46	0.46	0.48	0.49	0.50	0.52	0.52	0.54	0.56	0.55	0.55	0.57	0.57	0.58	0.57	0.61	0.58	0.55	0.57	0.58	0.58	0.59	0.60	0.59	0.59	0.60	0.59	*Canada*
Mexico	0.29	0.31	0.31	0.32	0.35	0.33	0.34	0.36	0.38	0.37	0.40	0.39	0.40	0.42	0.43	0.45	0.47	0.47	0.47	0.46	0.48	0.49	0.50	0.49	0.48	0.49	0.49	0.50	0.49	*Mexico*
South Korea	0.27	0.30	0.31	0.35	0.37	0.40	0.43	0.45	0.39	0.42	0.48	0.50	0.49	0.50	0.52	0.52	0.52	0.53	0.54	0.55	0.60	0.63	0.63	0.63	0.62	0.64	0.65	0.67	0.69	*South Korea*
Turkey	0.15	0.15	0.16	0.16	0.16	0.18	0.19	0.20	0.21	0.20	0.23	0.21	0.22	0.23	0.24	0.25	0.27	0.30	0.30	0.30	0.31	0.33	0.35	0.33	0.35	0.37	0.39	0.41	0.41	*Turkey*
Other G20 countries	**0.99**	**1.01**	**1.03**	**1.07**	**1.13**	**1.19**	**1.26**	**1.33**	**1.36**	**1.38**	**1.42**	**1.45**	**1.48**	**1.56**	**1.64**	**1.68**	**1.74**	**1.82**	**1.91**	**1.88**	**2.00**	**2.04**	**2.14**	**2.20**	**2.32**	**2.32**	**2.29**	**2.31**	**2.32**	**Other G20 countries**
Argentina	0.11	0.12	0.12	0.12	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.14	0.13	0.15	0.16	0.17	0.18	0.18	0.20	0.19	0.19	0.20	0.20	0.20	0.21	0.21	0.21	0.21	0.21	*Argentina*
Brazil	0.23	0.24	0.24	0.25	0.26	0.28	0.30	0.32	0.33	0.34	0.36	0.37	0.36	0.36	0.38	0.38	0.38	0.40	0.42	0.39	0.45	0.47	0.50	0.53	0.56	0.53	0.49	0.50	0.49	*Brazil*
Indonesia	0.16	0.18	0.18	0.20	0.21	0.24	0.25	0.28	0.28	0.30	0.29	0.32	0.32	0.35	0.36	0.36	0.38	0.40	0.39	0.41	0.42	0.43	0.44	0.44	0.48	0.49	0.50	0.52	0.54	*Indonesia*
Saudi Arabia	0.17	0.18	0.19	0.20	0.22	0.22	0.23	0.23	0.25	0.25	0.26	0.27	0.29	0.30	0.32	0.34	0.36	0.38	0.41	0.44	0.48	0.50	0.53	0.55	0.58	0.61	0.61	0.61	0.60	*Saudi Arabia*
South Africa	0.31	0.30	0.30	0.30	0.31	0.32	0.33	0.35	0.36	0.34	0.35	0.36	0.37	0.39	0.42	0.43	0.44	0.46	0.49	0.45	0.46	0.45	0.46	0.47	0.48	0.48	0.48	0.47	0.48	*South Africa*
Total Group of Twenty (G20)	**18.4**	**18.5**	**18.5**	**18.7**	**18.9**	**19.4**	**19.8**	**20.1**	**20.1**	**20.2**	**21.0**	**21.2**	**21.5**	**22.5**	**23.6**	**24.4**	**25.2**	**26.3**	**26.2**	**26.0**	**27.6**	**28.5**	**28.8**	**29.3**	**29.6**	**29.5**	**29.5**	**29.7**	**30.3**	**Total Group of Twenty (G20)**
Other large emitting countries	**1.76**	**1.79**	**1.75**	**1.67**	**1.61**	**1.64**	**1.64**	**1.65**	**1.63**	**1.69**	**1.74**	**1.81**	**1.87**	**1.99**	**2.08**	**2.18**	**2.26**	**2.36**	**2.45**	**2.35**	**2.48**	**2.54**	**2.59**	**2.65**	**2.65**	**2.63**	**2.70**	**2.73**	**2.86**	**Other large emitting countries**
Egypt	0.09	0.09	0.10	0.10	0.09	0.10	0.11	0.11	0.12	0.13	0.13	0.14	0.14	0.15	0.16	0.18	0.19	0.20	0.20	0.21	0.21	0.22	0.23	0.23	0.23	0.24	0.25	0.25	0.25	*Egypt*
Iran	0.20	0.23	0.24	0.24	0.27	0.28	0.29	0.30	0.30	0.33	0.35	0.37	0.38	0.40	0.43	0.47	0.50	0.54	0.55	0.57	0.57	0.58	0.59	0.61	0.63	0.62	0.64	0.67	0.71	*Iran*
Kazakhstan	0.25	0.26	0.27	0.23	0.20	0.18	0.16	0.13	0.14	0.13	0.13	0.12	0.13	0.15	0.16	0.17	0.19	0.21	0.24	0.22	0.24	0.25	0.26	0.28	0.27	0.26	0.26	0.27	0.31	*Kazakhstan*
Malaysia	0.06	0.07	0.07	0.08	0.09	0.09	0.10	0.11	0.11	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.21	0.22	0.20	0.22	0.22	0.22	0.24	0.25	0.25	0.24	0.24	0.25	*Malaysia*
Nigeria	0.07	0.08	0.09	0.09	0.08	0.09	0.10	0.10	0.09	0.09	0.10	0.11	0.10	0.11	0.10	0.10	0.09	0.08	0.09	0.08	0.09	0.10	0.10	0.10	0.09	0.10	0.10	0.10	0.11	*Nigeria*
Taiwan	0.12	0.13	0.14	0.15	0.16	0.17	0.18	0.19	0.20	0.21	0.23	0.23	0.24	0.25	0.26	0.27	0.28	0.28	0.27	0.25	0.27	0.27	0.26	0.26	0.27	0.26	0.27	0.28	0.28	*Taiwan*
Thailand	0.09	0.10	0.11	0.13	0.14	0.16	0.18	0.19	0.16	0.17	0.17	0.18	0.19	0.20	0.22	0.23	0.23	0.24	0.24	0.23	0.25	0.24	0.26	0.27	0.27	0.27	0.27	0.27	0.28	*Thailand*
Ukraine	0.78	0.74	0.65	0.57	0.47	0.46	0.39	0.38	0.36	0.36	0.36	0.36	0.36	0.38	0.36	0.35	0.36	0.36	0.35	0.29	0.31	0.33	0.32	0.31	0.26	0.21	0.22	0.19	0.20	*Ukraine*
United Arab Emirates	0.06	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.10	0.10	0.11	0.11	0.12	0.13	0.14	0.16	0.17	0.17	0.18	0.19	0.20	0.20	0.20	0.21	0.21	0.21	*United Arab Emirates*
Viet Nam	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.08	0.09	0.10	0.10	0.11	0.12	0.14	0.15	0.15	0.15	0.16	0.17	0.20	0.23	0.23	0.26	*Viet Nam*
Zambia	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	-00.0	*Zambia*
Remaining countries (186)	1.87	1.83	1.78	1.80	1.81	1.86	1.91	1.99	1.99	1.99	2.05	2.11	2.14	2.19	2.27	2.35	2.41	2.46	2.57	2.57	2.69	2.73	2.85	2.89	2.94	2.98	3.03	3.08	3.16	**Remaining countries (186)**
International transport	0.63	0.64	0.68	0.67	0.69	0.72	0.74	0.77	0.79	0.83	0.85	0.82	0.86	0.87	0.95	0.99	1.05	1.10	1.10	1.05	1.12	1.14	1.09	1.10	1.13	1.19	1.23	1.24	1.26	**International transport**
Total	**22.6**	**22.8**	**22.7**	**22.8**	**23.0**	**23.7**	**24.1**	**24.5**	**24.6**	**24.7**	**25.6**	**25.9**	**26.3**	**27.6**	**28.9**	**29.9**	**31.0**	**32.2**	**32.4**	**32.0**	**33.8**	**34.9**	**35.4**	**36.0**	**36.3**	**36.3**	**36.4**	**36.8**	**37.5**	**Total**

[17] Available for all countries on http://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts1990-2018. Totals and sub-totals may differ due to independent rounding. The number of digits does not indicate the accuracy of the figures, See uncertainty information in the Appendix.

Table A.2 CO_2 emissions per capita, per country and group, 1990–2018[18] (unit: tonnes of CO_2 per person)

CO_2 emissions per capita, per country/group, 1990-2018 (unit: tonnes of CO_2 per person)

Country/group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Country/group
China	2.1	2.1	2.2	2.4	2.5	2.7	2.7	2.7	2.8	2.7	2.9	3.0	3.2	3.7	4.2	4.7	5.2	5.7	5.8	6.2	6.7	7.3	7.4	7.7	7.7	7.7	7.7	7.7	7.8	**China**
United States	20.1	19.7	19.9	20.1	20.2	20.2	20.5	20.9	20.7	20.5	21.0	20.6	20.1	20.2	20.3	20.2	19.6	19.7	18.9	17.4	18.0	17.4	16.7	16.8	16.9	16.3	15.9	15.7	16.0	**United States**
European Union	9.3	9.1	8.8	8.6	8.5	8.6	8.8	8.6	8.6	8.5	8.5	8.6	8.5	8.7	8.7	8.6	8.6	8.5	8.2	7.6	7.8	7.4	7.3	7.1	6.8	6.8	6.8	6.9	6.7	**European Union**
France	6.8	7.2	7.0	6.6	6.5	6.6	6.8	6.7	7.0	6.9	6.8	6.9	6.7	6.7	6.7	6.7	6.5	6.3	6.2	5.9	6.0	5.5	5.5	5.5	4.9	5.0	5.0	5.1	5.0	*France*
Germany	12.9	12.5	11.8	11.6	11.4	11.3	11.6	11.2	11.1	10.7	10.7	10.9	10.7	10.7	10.5	10.3	10.5	10.1	10.3	9.5	10.1	9.8	9.9	10.1	9.6	9.6	9.6	9.5	9.0	*Germany*
Italy	7.6	7.5	7.5	7.4	7.2	7.7	7.6	7.7	7.9	8.0	8.1	8.1	8.2	8.4	8.6	8.5	8.4	8.3	8.0	7.1	7.2	7.0	6.6	6.0	5.7	5.9	5.8	5.8	5.6	*Italy*
Netherlands	10.8	11.1	10.9	11.1	11.1	11.5	12.1	11.5	11.5	11.1	11.1	11.3	11.3	11.4	11.4	11.1	10.8	10.8	10.8	10.5	11.1	10.4	10.1	10.0	9.6	10.0	10.0	9.7	9.5	*Netherlands*
Poland	9.8	9.7	9.4	9.4	9.2	9.3	9.6	9.4	8.7	8.4	8.1	8.0	7.9	8.2	8.3	8.3	8.6	8.6	8.5	8.1	8.6	8.5	8.3	8.2	7.9	8.0	8.3	8.6	8.8	*Poland*
Spain	6.0	6.1	6.3	6.0	6.2	6.5	6.2	6.7	6.9	7.4	7.7	7.6	8.0	8.0	8.3	8.5	8.1	8.3	7.5	6.6	6.2	6.2	6.1	5.6	5.6	5.9	5.7	6.1	6.0	*Spain*
United Kingdom	10.2	10.3	10.1	9.8	9.6	9.5	9.8	9.3	9.3	9.2	9.3	9.5	9.2	9.4	9.4	9.3	9.2	8.9	8.6	7.7	7.9	7.2	7.5	7.2	6.6	6.3	5.9	5.7	5.5	*United Kingdom*
India	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.8	1.8	1.9	**India**
Russian Federation	16.0	15.7	14.4	13.1	11.6	11.3	11.0	10.3	10.3	10.7	10.9	11.0	10.9	11.3	11.4	11.3	11.7	11.7	11.7	10.9	11.6	12.2	12.2	11.8	11.7	11.7	11.5	11.5	11.8	**Russian Federation**
Japan	9.2	9.2	9.3	9.2	9.6	9.7	9.7	9.7	9.3	9.6	9.7	9.6	9.9	9.9	9.9	10.0	9.8	10.1	9.4	8.9	9.3	9.7	10.0	10.2	9.9	9.6	9.5	9.6	9.5	**Japan**
Other OECD G20	6.4	6.5	6.6	6.7	6.9	7.0	7.2	7.5	7.3	7.4	7.8	7.7	7.7	7.8	7.9	7.9	8.0	8.2	8.1	7.9	8.1	8.2	8.2	8.1	8.0	8.0	8.0	8.1	8.1	Other OECD G20
Australia	16.4	16.3	16.3	16.3	16.4	16.8	17.2	17.5	18.4	18.5	18.6	18.8	19.0	19.0	19.5	19.4	19.4	19.5	19.3	19.2	18.6	18.2	17.9	17.4	16.7	16.8	17.1	16.7	16.6	*Australia*
Canada	16.5	16.1	16.3	16.1	16.5	16.8	17.1	17.5	17.5	17.7	18.2	17.7	17.8	18.2	17.8	18.0	17.6	18.4	17.5	16.3	16.6	16.7	16.5	16.8	16.7	16.4	16.2	16.2	16.0	*Canada*
Mexico	3.5	3.6	3.6	3.6	3.8	3.6	3.7	3.8	4.0	3.8	4.0	3.9	4.0	4.1	4.1	4.2	4.3	4.3	4.3	4.1	4.2	4.2	4.3	4.1	4.0	4.0	4.0	4.0	3.9	*Mexico*
South Korea	6.3	6.8	7.2	7.8	8.3	8.9	9.4	9.8	8.3	9.0	10.2	10.4	10.3	10.3	10.7	10.6	10.7	10.9	11.1	11.2	12.1	12.6	12.6	12.4	12.3	12.6	12.7	13.1	13.5	*South Korea*
Turkey	2.8	2.8	2.8	2.9	2.8	3.0	3.3	3.4	3.4	3.3	3.6	3.2	3.3	3.5	3.5	3.6	4.0	4.3	4.3	4.2	4.3	4.5	4.6	4.4	4.6	4.7	4.9	5.1	5.0	*Turkey*
Other G20 countries	2.4	2.4	2.4	2.4	2.5	2.6	2.7	2.8	2.9	2.9	2.9	2.9	3.0	3.1	3.2	3.2	3.3	3.4	3.5	3.4	3.6	3.6	3.7	3.8	4.0	3.9	3.8	3.8	3.8	**Other G20 countries**
Argentina	3.5	3.5	3.6	3.5	3.8	3.7	4.0	4.1	4.1	4.2	4.1	3.8	3.5	3.8	4.2	4.3	4.5	4.6	4.9	4.6	4.7	4.8	4.9	4.8	4.9	4.9	4.9	4.8	4.7	*Argentina*
Brazil	1.5	1.6	1.6	1.6	1.6	1.7	1.8	1.9	2.0	2.0	2.1	2.1	2.0	2.0	2.1	2.1	2.0	2.1	2.2	2.0	2.3	2.4	2.5	2.7	2.8	2.6	2.4	2.4	2.4	*Brazil*
Indonesia	0.9	1.0	1.0	1.1	1.1	1.2	1.3	1.4	1.4	1.4	1.4	1.5	1.5	1.6	1.6	1.6	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.9	1.9	1.9	2.0	2.0	*Indonesia*
Saudi Arabia	10.7	10.6	11.0	11.3	11.9	11.6	12.0	11.9	12.4	12.4	12.8	12.9	13.4	13.6	13.9	14.3	14.7	15.1	16.0	16.4	17.4	17.7	18.3	18.2	18.9	19.2	18.7	18.4	17.8	*Saudi Arabia*
South Africa	8.5	8.1	7.7	7.6	7.6	7.8	7.9	8.1	8.1	7.6	7.7	7.8	8.0	8.4	8.9	9.1	9.0	9.3	9.8	9.0	9.1	8.6	8.7	8.8	8.9	8.6	8.6	8.3	8.3	*South Africa*
Total Group of Twenty (G20)	5.0	4.9	4.9	4.9	4.9	5.0	5.0	5.0	5.0	4.9	5.1	5.1	5.1	5.3	5.5	5.6	5.8	6.0	5.9	5.8	6.1	6.2	6.3	6.3	6.3	6.3	6.2	6.2	6.3	**Total Group of Twenty (G20)**
Other large emitting countries	3.9	3.9	3.8	3.5	3.4	3.4	3.3	3.3	3.2	3.3	3.3	3.4	3.5	3.7	3.8	3.9	4.0	4.1	4.2	4.0	4.1	4.1	4.1	4.2	4.1	4.0	4.1	4.1	4.2	**Other large emitting countries**
Egypt	1.6	1.6	1.7	1.6	1.5	1.6	1.7	1.7	1.8	1.9	1.8	2.0	2.0	2.0	2.1	2.3	2.4	2.6	2.5	2.6	2.6	2.6	2.7	2.6	2.6	2.6	2.6	2.6	2.6	*Egypt*
Iran	3.6	3.9	4.1	4.0	4.5	4.5	4.7	4.8	4.7	5.1	5.4	5.5	5.7	5.9	6.3	6.7	7.1	7.5	7.6	7.8	7.7	7.8	7.8	8.0	8.2	7.9	8.0	8.4	8.7	*Iran*
Kazakhstan	15.5	16.0	16.3	14.1	12.7	11.3	10.0	8.8	9.0	8.4	8.5	8.2	8.9	9.9	10.7	11.2	12.5	13.1	15.4	13.6	14.6	15.3	15.8	16.4	15.4	14.7	14.8	15.1	16.9	*Kazakhstan*
Malaysia	3.2	3.7	3.8	4.1	4.3	4.5	5.0	5.2	5.1	5.4	5.8	5.9	6.2	6.4	6.8	7.1	7.3	7.8	8.1	7.2	7.7	7.6	7.6	8.0	8.4	8.3	8.0	7.8	8.1	*Malaysia*
Nigeria	0.8	0.8	0.9	0.8	0.8	0.8	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.6	0.6	0.6	0.5	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.6	0.6	*Nigeria*
Taiwan	6.1	6.5	6.8	7.2	7.6	7.9	8.3	8.9	9.3	9.7	10.5	10.6	10.9	11.3	11.6	11.9	12.1	12.2	11.7	11.0	11.7	11.7	11.3	11.3	11.3	11.2	11.5	11.9	11.9	*Taiwan*
Thailand	1.6	1.8	2.0	2.2	2.4	2.7	3.0	3.1	2.7	2.8	2.7	2.8	3.0	3.1	3.4	3.5	3.5	3.6	3.6	3.5	3.7	3.6	3.9	4.0	3.9	4.0	3.9	4.0	4.0	*Thailand*
Ukraine	15.2	14.4	12.6	11.0	9.2	9.1	7.8	7.6	7.3	7.3	7.3	7.4	7.5	8.0	7.7	7.6	7.6	7.8	7.5	6.3	6.7	7.1	7.0	6.8	5.9	4.8	5.0	4.4	4.4	*Ukraine*
United Arab Emirates	31.1	33.4	30.5	30.3	31.6	32.1	31.9	31.6	30.8	30.1	28.2	30.6	29.7	29.3	28.3	26.7	24.0	22.2	23.2	20.9	20.1	19.7	20.3	21.3	21.5	21.8	22.3	21.8	22.1	*United Arab Emirates*
Viet Nam	0.3	0.3	0.3	0.3	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.8	0.9	0.9	1.1	1.2	1.2	1.3	1.4	1.6	1.8	1.7	1.7	1.8	1.9	2.2	2.4	2.4	2.7	*Viet Nam*
Zambia	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	*Zambia*
Remaining countries (186)	1.6	1.5	1.5	1.4	1.4	1.4	1.4	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.5	1.5	1.5	1.5	1.5	1.5	**Remaining countries (186)**
International transport	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**International transport**
Total	4.3	4.2	4.2	4.1	4.1	4.1	4.2	4.2	4.1	4.1	4.2	4.2	4.2	4.4	4.5	4.6	4.7	4.8	4.8	4.7	4.9	5.0	5.0	5.0	5.0	5.0	4.9	4.9	5.0	**Total**

[18] Available for all countries on http://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts1990-2018. Totals and sub-totals may differ due to independent rounding. The number of digits does not indicate the accuracy of the figures, See uncertainty information in the Appendix.

Table A.3 CO_2 emissions per USD of GDP, per country and group, 1990–2018[19] (unit: kg CO_2 per 1,000 USD of GDP [PPP, 2011 prices])

CO_2 emissions per USD of GDP, per country/group, 1990-2018 (unit: kg CO_2 per 1,000 USD of GDP (PPP, 2011 prices))																														
Country/group	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Country/group**
China	**1,290**	**1,250**	**1,160**	**1,110**	**1,050**	**1,040**	**950**	**880**	**850**	**770**	**760**	**740**	**730**	**770**	**810**	**820**	**810**	**780**	**730**	**710**	**700**	**710**	**670**	**650**	**610**	**570**	**540**	**510**	**490**	**China**
United States	**550**	**550**	**540**	**530**	**520**	**510**	**510**	**500**	**480**	**460**	**460**	**450**	**440**	**430**	**420**	**410**	**390**	**390**	**370**	**360**	**360**	**350**	**330**	**330**	**330**	**310**	**300**	**290**	**290**	**United States**
European Union	**370**	**360**	**350**	**340**	**330**	**330**	**330**	**310**	**300**	**290**	**280**	**280**	**270**	**270**	**270**	**260**	**250**	**240**	**230**	**230**	**230**	**220**	**210**	**210**	**190**	**190**	**190**	**180**	**180**	**European Union**
France	230	240	230	220	210	210	210	200	210	200	190	190	180	180	180	180	170	160	160	160	160	140	140	140	130	130	130	130	120	*France*
Germany	410	380	350	350	340	330	340	320	310	300	290	290	280	290	280	270	260	250	250	240	250	230	230	240	220	220	210	210	200	*Germany*
Italy	240	240	240	230	230	230	230	230	230	230	220	220	220	230	230	230	220	210	210	200	200	190	190	180	170	170	170	160	160	*Italy*
Netherlands	330	340	330	330	320	330	340	310	300	270	260	260	260	270	270	250	240	230	230	230	240	220	220	220	210	210	210	200	190	*Netherlands*
Poland	950	1,010	960	930	870	820	800	730	650	600	550	540	520	520	500	480	470	440	420	390	400	370	360	350	330	320	320	310	300	*Poland*
Spain	250	250	260	250	250	260	240	250	250	260	260	250	260	250	260	260	240	240	220	200	190	200	200	180	180	180	170	180	170	*Spain*
United Kingdom	380	390	380	360	340	330	330	310	300	290	280	280	270	260	260	250	240	230	230	210	220	200	210	190	170	160	150	140	140	*United Kingdom*
India	**360**	**380**	**370**	**370**	**370**	**370**	**360**	**360**	**350**	**350**	**340**	**330**	**330**	**320**	**320**	**310**	**300**	**310**	**320**	**330**	**320**	**320**	**330**	**310**	**320**	**300**	**290**	**280**	**280**	**India**
Russian Federation	**760**	**790**	**850**	**850**	**860**	**870**	**880**	**810**	**860**	**830**	**770**	**730**	**690**	**670**	**620**	**580**	**550**	**510**	**490**	**490**	**500**	**500**	**490**	**470**	**460**	**470**	**460**	**450**	**460**	**Russian Federation**
Japan	**300**	**300**	**290**	**290**	**300**	**300**	**290**	**290**	**280**	**290**	**290**	**280**	**290**	**290**	**280**	**280**	**270**	**280**	**260**	**260**	**260**	**270**	**280**	**280**	**270**	**260**	**250**	**250**	**240**	**Japan**
Other OECD G20	**400**	**400**	**400**	**400**	**400**	**400**	**400**	**400**	**380**	**380**	**380**	**380**	**370**	**370**	**360**	**350**	**350**	**350**	**340**	**350**	**340**	**330**	**330**	**310**	**300**	**300**	**300**	**290**	**290**	Other OECD G20
Australia	570	570	580	560	550	550	550	540	550	530	520	520	510	500	500	490	490	480	470	470	450	440	420	400	390	380	380	370	360	*Australia*
Canada	520	530	540	520	520	520	520	520	500	490	480	470	460	470	450	440	430	440	420	410	410	400	400	400	390	380	380	370	360	*Canada*
Mexico	250	260	250	260	260	260	260	260	260	250	250	250	250	260	260	260	260	260	260	260	260	260	250	250	230	230	220	220	210	*Mexico*
South Korea	540	540	540	550	550	540	540	530	480	470	500	490	450	440	440	420	400	390	390	390	400	400	400	380	370	370	360	360	360	*South Korea*
Turkey	240	250	240	230	240	250	250	240	240	250	260	250	250	250	230	220	230	240	240	250	240	230	230	200	210	200	210	200	200	*Turkey*
Other G20 countries	**260**	**250**	**250**	**250**	**250**	**250**	**260**	**260**	**280**	**280**	**280**	**280**	**280**	**290**	**280**	**280**	**270**	**270**	**270**	**270**	**270**	**260**	**260**	**260**	**270**	**260**	**260**	**260**	**250**	**Other G20 countries**
Argentina	300	290	270	250	260	270	270	260	260	270	270	270	280	290	290	270	270	260	260	270	250	240	250	240	260	260	260	250	260	*Argentina*
Brazil	150	150	150	150	150	160	170	170	170	180	180	180	180	170	170	170	160	160	160	150	160	160	160	170	180	170	170	170	160	*Brazil*
Indonesia	190	200	190	200	200	200	200	210	240	250	240	250	240	250	240	230	230	230	210	210	200	200	190	180	190	180	180	180	180	*Indonesia*
Saudi Arabia	250	220	230	240	260	260	270	270	280	300	300	310	340	320	310	310	320	330	340	370	380	360	370	370	380	380	370	380	360	*Saudi Arabia*
South Africa	860	840	840	840	830	850	840	860	870	810	790	790	790	820	850	820	790	780	800	760	760	700	710	710	720	700	700	680	680	*South Africa*
Total Group of Twenty (G20)	**470**	**470**	**460**	**460**	**450**	**450**	**440**	**430**	**420**	**410**	**400**	**400**	**390**	**400**	**400**	**390**	**390**	**380**	**370**	**370**	**380**	**370**	**370**	**360**	**350**	**340**	**330**	**320**	**310**	**Total Group of Twenty (G20)**
Other large emitting countries	**530**	**520**	**500**	**470**	**450**	**450**	**430**	**420**	**410**	**410**	**400**	**410**	**400**	**390**	**390**	**380**	**380**	**370**	**380**	**360**	**360**	**350**	**350**	**350**	**340**	**330**	**320**	**320**	**320**	**Other large emitting countries**
Egypt	270	280	280	270	250	250	260	260	260	260	240	260	260	260	270	290	290	290	270	270	260	260	270	260	260	250	250	240	230	*Egypt*
Iran	320	310	330	320	370	370	370	380	370	410	400	420	410	400	410	430	440	430	440	450	430	420	460	480	480	480	430	440	480	*Iran*
Kazakhstan	1,190	1,380	1,480	1,390	1,420	1,370	1,190	1,010	1,040	940	850	730	730	740	740	710	720	700	810	710	720	710	710	720	650	630	630	630	680	*Kazakhstan*
Malaysia	300	330	320	320	310	310	320	320	340	350	350	360	370	370	380	380	380	390	390	360	370	350	330	340	340	320	310	290	290	*Malaysia*
Nigeria	230	250	260	260	250	270	310	290	260	250	270	270	210	220	190	180	150	130	130	110	110	110	110	100	90	90	100	100	100	*Nigeria*
Taiwan	310	310	310	310	320	310	310	320	320	320	330	340	340	350	350	330	340	330	330	320	320	300	290	290	270	270	270	280	270	*Taiwan*
Thailand	250	250	260	270	280	290	310	320	310	310	300	300	300	290	300	300	290	280	280	280	270	270	270	270	260	260	250	240	240	*Thailand*
Ukraine	1,440	1,490	1,440	1,470	1,580	1,770	1,680	1,670	1,620	1,620	1,520	1,390	1,320	1,280	1,090	1,030	960	910	860	830	860	860	840	810	750	670	680	580	560	*Ukraine*
United Arab Emirates	280	310	290	300	310	310	310	300	300	310	270	310	310	300	290	290	280	290	330	350	360	350	350	350	340	330	330	330	330	*United Arab Emirates*
Viet Nam	200	190	190	200	220	230	240	250	270	260	270	280	310	310	340	350	330	340	360	380	400	370	350	350	360	390	410	390	410	*Viet Nam*
Zambia	160	160	170	140	130	130	100	120	110	90	90	80	80	90	80	80	70	50	50	50	50	50	70	70	80	80	70	70	70	*Zambia*
Remaining countries (186)	330	320	310	310	300	300	290	290	280	280	270	270	270	270	260	250	250	240	230	230	230	230	230	220	220	210	210	210	210	**Remaining countries (186)**
International transport																														**International transport**
Total	**470**	**470**	**460**	**460**	**450**	**450**	**440**	**430**	**420**	**410**	**400**	**400**	**390**	**400**	**390**	**390**	**380**	**380**	**370**	**370**	**370**	**370**	**360**	**350**	**340**	**330**	**320**	**320**	**310**	**Total**

[19] Available for all countries on http://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts1990-2018. Totals and sub-totals may differ due to independent rounding. The number of digits does not indicate the accuracy of the figures, See uncertainty information in the Appendix.

B. Greenhouse gas emissions: total, CH_4, N_2O, F-gases, total per capita and per USD of GDP

We note that the estimated uncertainty range in non-CO_2 emissions, both in the national CRF data and as calculated using EDGAR data, is much larger than that for CO_2 emission estimates, for which uncertainties are generally between 3% to 5%, with exceptions of up to 10% or 15%.

The uncertainty of total country emissions per non-CO_2 gas in the EDGAR data sets is generally in the same range as that of official national total emissions, such as 30% to 50% for CH_4 and about 50% for N_2O (or 100% including indirect emissions). However, uncertainties for specific F-gas emissions in EDGAR (on the use of these gases) are in the range of 100% or more (Olivier et al., 2017). However, since CO_2 is the dominant GHG, the uncertainty about total GHG emissions is small, both globally and at country level, compared to those about the individual other greenhouse gases. For global GHG emissions, the uncertainty is estimated at 10%, mainly because the uncertainty about global CO_2 emissions is around 10%, when including large-scale biomass fires and post-burn decay and adding uncertainty about erosion and redeposition.

For most countries, the uncertainty in total GHG emissions is also around 10%, for the same reason as for global GHG emissions. However, there may be a few exceptions where this is up to 15%, in particular in cases where fossil-fuel-related CO_2 emissions have a much smaller share than three-quarters in total national GHG emissions (excluding emissions from land-use change).

All tables in the Appendices are also available as spreadsheets on the PBL website. They can be downloaded from the report page of this report.

Table B.1 Total greenhouse gas emissions per country and group, 1990–2018[20] (unit: $GtCO_2$ eq)

Total greenhouse gas emissions per country/group, 1990-2018 (unit: Gt CO_2 eq)																														
Country/group	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Country/group**
China	**3.9**	**4.0**	**4.2**	**4.4**	**4.6**	**5.0**	**5.0**	**5.0**	**5.1**	**5.1**	**5.3**	**5.5**	**5.8**	**6.5**	**7.4**	**8.2**	**9.0**	**9.7**	**9.9**	**10.5**	**11.3**	**12.3**	**12.5**	**13.1**	**13.2**	**13.2**	**13.2**	**13.3**	**13.6**	**China**
United States	**6.1**	**6.1**	**6.2**	**6.3**	**6.4**	**6.4**	**6.6**	**6.8**	**6.8**	**6.8**	**7.0**	**7.0**	**6.9**	**7.0**	**7.1**	**7.1**	**7.0**	**7.1**	**7.0**	**6.5**	**6.8**	**6.7**	**6.6**	**6.7**	**6.8**	**6.6**	**6.5**	**6.5**	**6.7**	**United States**
European Union	**5.7**	**5.6**	**5.4**	**5.3**	**5.3**	**5.3**	**5.4**	**5.3**	**5.3**	**5.2**	**5.2**	**5.2**	**5.2**	**5.2**	**5.3**	**5.2**	**5.3**	**5.2**	**5.1**	**4.7**	**4.9**	**4.7**	**4.7**	**4.6**	**4.4**	**4.5**	**4.4**	**4.5**	**4.4**	**European Union**
France	0.5	0.6	0.6	0.5	0.5	0.5	0.6	0.5	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	*France*
Germany	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	*Germany*
Italy	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	*Italy*
Netherlands	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	*Netherlands*
Poland	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	*Poland*
Spain	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.4	0.3	0.4	0.4	*Spain*
United Kingdom	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.7	0.7	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5	*United Kingdom*
India	**1.4**	**1.4**	**1.5**	**1.5**	**1.6**	**1.6**	**1.7**	**1.7**	**1.7**	**1.8**	**1.9**	**1.9**	**1.9**	**2.0**	**2.1**	**2.1**	**2.2**	**2.4**	**2.5**	**2.7**	**2.8**	**2.9**	**3.0**	**3.1**	**3.3**	**3.4**	**3.4**	**3.5**	**3.7**	**India**
Russian Federation	**3.0**	**3.0**	**2.7**	**2.5**	**2.2**	**2.2**	**2.1**	**2.0**	**2.0**	**2.0**	**2.1**	**2.1**	**2.1**	**2.1**	**2.2**	**2.1**	**2.2**	**2.2**	**2.2**	**2.1**	**2.2**	**2.3**	**2.4**	**2.3**	**2.3**	**2.3**	**2.3**	**2.3**	**2.5**	**Russian Federation**
Japan	**1.3**	**1.3**	**1.3**	**1.3**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.4**	**1.5**	**1.4**	**1.3**	**1.4**	**1.4**	**1.5**	**1.5**	**1.5**	**1.4**	**1.4**	**1.4**	**1.4**	**Japan**
Other OECD G20	**2.1**	**2.2**	**2.2**	**2.3**	**2.4**	**2.5**	**2.6**	**2.7**	**2.7**	**2.7**	**2.9**	**2.9**	**2.9**	**2.9**	**3.0**	**3.0**	**3.1**	**3.2**	**3.2**	**3.2**	**3.3**	**3.5**	**3.5**	**3.4**	**3.5**	**3.6**	**3.6**	**3.7**	**3.8**	Other OECD G20
Australia	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	*Australia*
Canada	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.7	0.8	0.8	0.8	0.8	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	*Canada*
Mexico	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	*Mexico*
South Korea	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	*South Korea*
Turkey	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.7	*Turkey*
Other G20 countries	**2.0**	**2.1**	**2.1**	**2.2**	**2.3**	**2.3**	**2.4**	**2.4**	**2.5**	**2.5**	**2.5**	**2.6**	**2.7**	**2.8**	**2.9**	**3.0**	**3.1**	**3.2**	**3.3**	**3.2**	**3.4**	**3.5**	**3.6**	**3.7**	**3.8**	**3.8**	**3.8**	**3.9**	**3.9**	**Other G20 countries**
Argentina	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	*Argentina*
Brazil	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.0	1.1	1.2	1.2	1.2	1.3	1.3	1.2	1.3	1.3	*Brazil*
Indonesia	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	*Indonesia*
Saudi Arabia	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	*Saudi Arabia*
South Africa	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	*South Africa*
Total Group of Twenty (G20)	**25.5**	**25.6**	**25.5**	**25.7**	**26.0**	**26.6**	**27.1**	**27.3**	**27.3**	**27.5**	**28.2**	**28.4**	**28.8**	**29.9**	**31.3**	**32.2**	**33.3**	**34.5**	**34.5**	**34.2**	**36.0**	**37.3**	**37.7**	**38.3**	**38.7**	**38.7**	**38.7**	**39.2**	**39.9**	**Total Group of Twenty (G20)**
Other large emitting countries	**2.8**	**2.9**	**2.8**	**2.7**	**2.7**	**2.7**	**2.7**	**2.7**	**2.6**	**2.6**	**2.7**	**2.7**	**2.8**	**3.0**	**3.1**	**3.2**	**3.3**	**3.4**	**3.5**	**3.4**	**3.6**	**3.6**	**3.7**	**3.8**	**3.8**	**3.7**	**3.8**	**3.9**	**4.0**	**Other large emitting countries**
Egypt	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	*Egypt*
Iran	0.4	0.4	0.4	0.4	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	*Iran*
Kazakhstan	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	*Kazakhstan*
Malaysia	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	*Malaysia*
Nigeria	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	*Nigeria*
Taiwan	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	*Taiwan*
Thailand	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	*Thailand*
Ukraine	1.0	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	*Ukraine*
United Arab Emirates	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	*United Arab Emirates*
Viet Nam	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	*Viet Nam*
Zambia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	*Zambia*
Remaining countries (186)	4.1	4.0	4.0	4.1	4.1	4.2	4.3	4.4	4.4	4.4	4.5	4.5	4.6	4.7	4.9	5.0	5.1	5.2	5.4	5.4	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.6	**Remaining countries (186)**
International transport	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.1	1.2	1.2	1.1	1.2	1.2	1.2	1.3	1.3	1.3	**International transport**
Total	**33.0**	**33.1**	**33.1**	**33.2**	**33.5**	**34.3**	**34.8**	**35.1**	**35.0**	**35.3**	**36.2**	**36.5**	**37.1**	**38.5**	**40.2**	**41.5**	**42.8**	**44.3**	**44.6**	**44.1**	**46.4**	**47.9**	**48.5**	**49.2**	**49.8**	**49.9**	**50.1**	**50.8**	**51.8**	**Total**

[20] Totals and sub-totals may differ due to independent rounding. The number of digits does not indicate the accuracy of the figures, See uncertainty information in the Appendix. Calculated using the Global Warming Potentials (GWPs) for 100 year from the IPCC's Fourth Assessment Report (AR4).

Table B.2 CH_4 emissions per country and group, 1990–2018[21] (unit: $MtCO_2$ eq)

CH_4 emissions per country/group, 1990-2018 (unit: Mt CO_2 eq)																														
Country/group	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Country/group**
China	**1,180**	**1,170**	**1,160**	**1,140**	**1,150**	**1,200**	**1,200**	**1,160**	**1,140**	**1,140**	**1,140**	**1,140**	**1,140**	**1,170**	**1,250**	**1,310**	**1,360**	**1,380**	**1,390**	**1,420**	**1,470**	**1,530**	**1,530**	**1,560**	**1,570**	**1,560**	**1,520**	**1,540**	**1,580**	**China**
United States	**660**	**660**	**660**	**660**	**660**	**650**	**650**	**640**	**630**	**620**	**620**	**600**	**590**	**580**	**570**	**570**	**580**	**580**	**600**	**580**	**580**	**600**	**600**	**600**	**630**	**630**	**630**	**630**	**650**	**United States**
European Union	**870**	**860**	**830**	**820**	**800**	**790**	**800**	**800**	**770**	**750**	**730**	**700**	**680**	**670**	**680**	**650**	**660**	**660**	**640**	**600**	**620**	**620**	**610**	**600**	**600**	**600**	**600**	**600**	**600**	**European Union**
France	80	80	80	80	80	80	80	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	60	*France*
Germany	140	140	130	130	120	120	110	110	100	100	100	90	90	90	100	90	90	90	90	70	90	90	80	80	80	80	80	80	80	*Germany*
Italy	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	40	40	40	40	40	40	40	40	*Italy*
Netherlands	40	40	30	30	30	30	30	40	30	30	30	30	30	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	*Netherlands*
Poland	120	110	100	100	100	90	90	90	90	80	80	70	70	70	70	70	70	70	70	60	70	60	70	60	60	60	60	60	60	*Poland*
Spain	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	50	40	40	40	40	40	40	40	40	40	*Spain*
United Kingdom	160	170	170	170	170	170	180	180	170	160	150	150	140	140	130	130	130	130	120	100	100	110	100	100	100	110	110	110	110	*United Kingdom*
India	**630**	**640**	**650**	**660**	**660**	**670**	**680**	**680**	**690**	**690**	**700**	**700**	**700**	**710**	**720**	**740**	**750**	**770**	**780**	**790**	**800**	**810**	**810**	**820**	**830**	**830**	**840**	**860**	**870**	**India**
Russian Federation	**500**	**490**	**450**	**420**	**390**	**380**	**360**	**350**	**330**	**340**	**340**	**350**	**370**	**380**	**400**	**380**	**410**	**420**	**410**	**380**	**410**	**430**	**430**	**430**	**420**	**430**	**440**	**460**	**470**	**Russian Federation**
Japan	**80**	**80**	**80**	**80**	**80**	**70**	**70**	**70**	**60**	**60**	**60**	**60**	**60**	**50**	**50**	**50**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**60**	**50**	**50**	**50**	**50**	**50**	**Japan**
Other OECD G20	**490**	**490**	**500**	**510**	**510**	**510**	**530**	**540**	**550**	**560**	**590**	**590**	**580**	**560**	**580**	**580**	**600**	**600**	**590**	**600**	**600**	**650**	**650**	**630**	**660**	**650**	**640**	**670**	**670**	Other OECD G20
Australia	170	170	170	170	160	170	170	170	180	200	220	220	220	190	210	200	220	220	200	210	200	250	250	210	230	220	210	230	220	*Australia*
Canada	110	110	120	120	130	120	130	130	120	120	130	120	120	120	120	120	120	120	120	120	120	120	120	130	140	130	130	130	130	*Canada*
Mexico	130	130	130	140	140	140	140	150	150	150	150	150	150	150	150	160	160	160	170	170	170	170	160	170	170	170	170	170	170	*Mexico*
South Korea	40	40	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	40	40	40	40	30	30	30	30	30	*South Korea*
Turkey	50	50	50	50	50	50	50	60	60	60	60	60	60	60	60	60	60	70	70	70	80	80	90	90	90	100	100	100	110	*Turkey*
Other G20 countries	**800**	**810**	**830**	**850**	**870**	**860**	**870**	**860**	**850**	**850**	**850**	**870**	**890**	**930**	**960**	**980**	**990**	**1,000**	**1,020**	**1,030**	**1,060**	**1,080**	**1,120**	**1,130**	**1,150**	**1,160**	**1,170**	**1,200**	**1,220**	**Other G20 countries**
Argentina	140	130	130	140	140	130	140	120	120	120	120	120	130	130	140	140	140	140	130	130	120	120	120	120	130	120	130	130	130	*Argentina*
Brazil	320	340	350	360	370	380	370	380	380	380	380	400	420	440	460	470	470	470	470	480	500	500	500	510	510	520	530	540	540	*Brazil*
Indonesia	210	220	230	240	220	220	230	230	220	220	210	210	220	220	230	230	240	250	260	270	280	300	330	330	340	340	340	350	370	*Indonesia*
Saudi Arabia	60	60	60	50	70	60	60	60	60	60	60	60	60	70	70	70	70	70	80	70	80	80	80	90	90	90	90	90	100	*Saudi Arabia*
South Africa	60	60	60	60	60	70	70	70	70	70	70	70	70	70	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	*South Africa*
Total Group of Twenty (G20)	**5,210**	**5,200**	**5,150**	**5,120**	**5,120**	**5,130**	**5,140**	**5,110**	**5,030**	**5,020**	**5,020**	**4,990**	**5,010**	**5,060**	**5,220**	**5,270**	**5,410**	**5,470**	**5,500**	**5,460**	**5,600**	**5,770**	**5,820**	**5,820**	**5,920**	**5,930**	**5,900**	**6,000**	**6,100**	**Total Group of Twenty (G20)**
Other large emitting countries	**880**	**890**	**910**	**900**	**890**	**880**	**890**	**840**	**770**	**750**	**750**	**750**	**740**	**790**	**800**	**820**	**830**	**840**	**840**	**840**	**860**	**880**	**910**	**910**	**910**	**900**	**910**	**940**	**950**	**Other large emitting countries**
Egypt	40	50	50	50	50	50	50	50	50	50	50	50	50	60	60	60	70	70	70	70	70	70	70	70	70	60	60	70	70	*Egypt*
Iran	140	150	150	130	150	140	140	130	120	110	120	110	110	130	130	140	150	150	150	150	160	160	150	160	160	160	180	180	190	*Iran*
Kazakhstan	80	80	80	70	60	50	50	50	40	40	40	40	40	40	50	50	50	50	60	60	60	60	90	90	90	90	90	90	90	*Kazakhstan*
Malaysia	30	30	30	40	40	40	40	40	40	40	40	40	40	40	50	50	50	50	50	50	50	50	50	50	60	60	60	60	60	*Malaysia*
Nigeria	240	250	250	260	250	260	280	250	210	190	200	200	170	190	190	190	180	180	170	170	180	180	190	180	180	180	190	180	180	*Nigeria*
Taiwan	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	*Taiwan*
Thailand	100	100	100	100	100	100	100	100	90	100	90	100	90	100	100	100	100	110	110	110	120	120	120	120	110	100	100	110	110	*Thailand*
Ukraine	120	110	120	110	100	100	90	80	80	80	80	70	80	80	70	70	70	70	70	70	70	70	70	70	70	60	60	60	60	*Ukraine*
United Arab Emirates	20	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	40	40	40	40	40	40	40	40	*United Arab Emirates*
Viet Nam	70	70	70	80	80	80	80	80	80	90	90	90	90	90	100	100	100	110	110	110	110	110	110	110	110	110	110	110	110	*Viet Nam*
Zambia	10	10	10	10	10	10	10	10	10	10	10	10	10	10	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	*Zambia*
Remaining countries (186)	1,740	1,730	1,780	1,800	1,830	1,860	1,880	1,870	1,870	1,890	1,900	1,910	1,930	2,000	2,040	2,100	2,140	2,180	2,260	2,260	2,330	2,370	2,420	2,460	2,490	2,520	2,570	2,620	2,670	**Remaining countries (186)**
International transport	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	**International transport**
Total	**7,840**	**7,830**	**7,850**	**7,830**	**7,850**	**7,870**	**7,920**	**7,830**	**7,680**	**7,660**	**7,680**	**7,660**	**7,680**	**7,860**	**8,070**	**8,210**	**8,400**	**8,500**	**8,610**	**8,580**	**8,810**	**9,030**	**9,160**	**9,210**	**9,330**	**9,360**	**9,400**	**9,560**	**9,730**	**Total**

[21] Totals and sub-totals may differ due to independent rounding. The number of digits does not indicate the accuracy of the figures, See uncertainty information in the Appendix. Calculated using the Global Warming Potentials (GWPs) for 100 year from the IPCC's Fourth Assessment Report (AR4).

Table B.3 N_2O emissions, per country and group, 1990–2018[22] (unit: $MtCO_2$ eq)

N_2O emissions per country/group, 1990-2018 (unit: Mt CO_2 eq)																														
Country/group	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Country/group**
China	**280**	**290**	**290**	**290**	**310**	**340**	**350**	**330**	**340**	**340**	**340**	**340**	**350**	**350**	**370**	**390**	**410**	**410**	**400**	**380**	**380**	**390**	**390**	**400**	**400**	**410**	**410**	**400**	**410**	**China**
United States	**280**	**280**	**290**	**290**	**300**	**300**	**310**	**310**	**310**	**300**	**310**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**290**	**290**	**290**	**300**	**290**	**300**	**300**	**290**	**300**	**300**	**300**	**United States**
European Union	**380**	**360**	**350**	**340**	**350**	**340**	**350**	**350**	**320**	**300**	**300**	**300**	**300**	**290**	**300**	**290**	**290**	**290**	**270**	**270**	**270**	**260**	**270**	**270**	**270**	**270**	**270**	**270**	**270**	**European Union**
France	62	62	60	60	61	62	65	64	52	48	48	47	46	45	45	43	42	42	41	40	41	39	40	40	40	40	38	38	38	*France*
Germany	67	66	66	63	66	64	66	63	47	44	44	43	42	42	43	42	40	41	40	39	39	39	39	39	40	39	39	38	38	*Germany*
Italy	26	26	26	25	25	26	26	26	26	26	27	26	26	25	25	24	19	19	18	17	17	17	17	17	17	17	17	17	17	*Italy*
Netherlands	14	14	14	15	15	14	14	14	14	14	14	13	13	14	15	15	17	16	10	10	10	9	12	12	12	13	12	12	12	*Netherlands*
Poland	26	24	24	25	25	25	25	26	25	24	25	25	25	26	26	26	26	27	26	26	27	26	27	26	26	26	28	27	27	*Poland*
Spain	22	22	20	21	21	22	23	23	24	24	25	25	25	25	25	24	24	24	22	22	22	22	22	22	22	22	22	21	22	*Spain*
United Kingdom	55	54	49	45	46	44	45	44	44	33	32	30	29	29	29	28	27	27	26	26	26	25	25	26	26	26	26	27	27	*United Kingdom*
India	**130**	**130**	**130**	**130**	**140**	**140**	**140**	**150**	**150**	**150**	**150**	**150**	**150**	**150**	**160**	**160**	**170**	**180**	**180**	**190**	**190**	**200**	**190**	**190**	**200**	**200**	**200**	**210**	**210**	**India**
Russian Federation	**110**	**110**	**100**	**90**	**80**	**80**	**70**	**70**	**60**	**60**	**60**	**70**	**70**	**70**	**60**	**60**	**60**	**70**	**70**	**70**	**70**	**70**	**70**	**70**	**70**	**80**	**80**	**80**	**80**	**Russian Federation**
Japan	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**Japan**
Other OECD G20	**170**	**170**	**180**	**180**	**190**	**210**	**210**	**210**	**220**	**230**	**250**	**250**	**240**	**210**	**240**	**220**	**240**	**240**	**230**	**240**	**230**	**290**	**310**	**270**	**280**	**270**	**260**	**290**	**290**	Other OECD G20
Australia	70	70	70	70	70	70	70	70	70	90	100	100	90	60	80	60	80	70	60	60	50	110	110	60	80	70	60	80	70	*Australia*
Canada	40	40	40	40	40	40	40	40	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	40	30	30	30	30	30	*Canada*
Mexico	30	30	40	40	50	60	60	70	70	70	80	80	80	80	90	90	90	100	100	110	110	110	110	110	110	110	110	110	110	*Mexico*
South Korea	10	10	10	10	10	10	10	20	20	20	20	20	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	*South Korea*
Turkey	20	20	20	30	20	30	30	20	30	30	30	20	30	30	30	30	30	30	30	30	30	30	40	40	40	40	50	50	50	*Turkey*
Other G20 countries	**210**	**220**	**230**	**230**	**240**	**240**	**240**	**240**	**250**	**250**	**250**	**260**	**270**	**290**	**290**	**300**	**300**	**310**	**310**	**300**	**330**	**320**	**330**	**320**	**330**	**330**	**340**	**350**	**360**	**Other G20 countries**
Argentina	35	35	35	35	35	36	36	36	38	39	41	45	44	48	46	48	50	53	52	46	50	50	49	50	51	50	52	53	53	*Argentina*
Brazil	102	105	110	114	121	125	119	122	127	126	128	134	143	152	157	160	158	167	163	161	180	179	180	177	181	182	184	196	204	*Brazil*
Indonesia	52	53	54	54	55	56	57	57	57	56	56	56	58	58	59	59	60	61	63	66	66	67	69	67	70	70	71	72	72	*Indonesia*
Saudi Arabia	5	5	6	6	6	6	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7	8	8	8	9	9	9	9	10	*Saudi Arabia*
South Africa	20	20	21	21	21	22	23	24	24	23	21	22	23	22	23	23	22	22	22	21	22	21	22	22	22	21	20	21	21	*South Africa*
Total Group of Twenty (G20)	**1,590**	**1,590**	**1,600**	**1,600**	**1,630**	**1,680**	**1,710**	**1,690**	**1,670**	**1,670**	**1,680**	**1,680**	**1,700**	**1,690**	**1,740**	**1,750**	**1,790**	**1,810**	**1,760**	**1,760**	**1,790**	**1,850**	**1,870**	**1,840**	**1,860**	**1,880**	**1,880**	**1,920**	**1,930**	**Total Group of Twenty (G20)**
Other large emitting countries	**160**	**160**	**170**	**160**	**160**	**160**	**160**	**160**	**160**	**150**	**150**	**160**	**160**	**160**	**180**	**180**	**180**	**190**	**180**	**180**	**190**	**190**	**200**	**190**	**190**	**190**	**200**	**200**	**200**	**Other large emitting countries**
Egypt	10	10	12	12	12	13	14	14	15	14	15	15	15	15	16	17	17	17	18	18	19	20	19	19	19	19	19	19	20	*Egypt*
Iran	20	21	23	22	23	23	23	24	24	24	24	25	24	25	37	34	34	39	30	27	28	27	27	27	24	25	25	25	25	*Iran*
Kazakhstan	19	19	22	21	20	17	16	15	13	13	12	13	17	14	15	16	17	15	16	15	17	16	16	15	16	17	16	17	17	*Kazakhstan*
Malaysia	7	7	7	8	8	8	8	9	9	9	9	9	9	9	10	10	10	10	10	11	11	11	12	12	12	12	12	12	12	*Malaysia*
Nigeria	19	20	20	21	21	22	22	23	24	24	25	25	26	26	26	29	28	28	29	29	31	32	32	33	33	33	34	35	35	*Nigeria*
Taiwan	5	5	5	5	5	5	6	5	5	5	6	6	6	6	6	6	6	6	6	5	5	5	5	5	5	5	5	5	5	*Taiwan*
Thailand	15	15	16	17	17	16	16	16	15	15	14	15	15	16	16	16	16	19	18	19	19	20	21	21	21	20	20	21	21	*Thailand*
Ukraine	42	41	38	35	31	28	26	25	21	21	20	20	21	21	20	21	21	22	23	20	22	26	26	25	23	22	24	24	25	*Ukraine*
United Arab Emirates	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	*United Arab Emirates*
Viet Nam	9	9	10	10	11	11	12	12	13	14	14	14	15	16	17	17	17	18	17	18	19	19	19	18	18	20	20	20	21	*Viet Nam*
Zambia	13	13	13	14	13	13	13	13	14	13	13	14	13	14	14	15	13	13	14	13	16	16	17	17	17	17	17	17	19	*Zambia*
Remaining countries (186)	430	430	430	430	440	450	450	460	470	470	480	490	490	500	510	530	530	550	560	560	590	620	600	610	610	620	630	640	650	**Remaining countries (186)**
International transport	19	20	21	21	21	22	23	23	24	25	26	25	26	26	29	30	32	33	33	32	34	35	32	32	33	35	36	37	38	**International transport**
Total	**2,200**	**2,190**	**2,210**	**2,220**	**2,260**	**2,310**	**2,340**	**2,330**	**2,320**	**2,320**	**2,340**	**2,350**	**2,370**	**2,380**	**2,460**	**2,490**	**2,530**	**2,580**	**2,540**	**2,520**	**2,600**	**2,700**	**2,700**	**2,680**	**2,700**	**2,720**	**2,740**	**2,800**	**2,820**	**Total**

22 Totals and sub-totals may differ due to independent rounding. The number of digits does not indicate the accuracy of the figures, See uncertainty information in the Appendix. Calculated using the Global Warming Potentials (GWPs) for 100 year from the IPCC's Fourth Assessment Report (AR4).

Table B.4 F-gas emissions, per country and group, 1990–2018[23] (unit: $MtCO_2$ eq)

F-gas emissions per country/group, 1990-2018 (unit: Mt CO_2 eq)																														
Country/group	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Country/group**
China	**15**	**13**	**15**	**22**	**32**	**24**	**28**	**39**	**30**	**83**	**68**	**85**	**115**	**139**	**185**	**225**	**258**	**243**	**257**	**266**	**281**	**294**	**308**	**323**	**337**	**353**	**370**	**379**	**390**	**China**
United States	**102**	**103**	**102**	**102**	**108**	**118**	**131**	**140**	**161**	**180**	**192**	**195**	**216**	**226**	**246**	**267**	**290**	**312**	**331**	**357**	**399**	**420**	**427**	**439**	**455**	**466**	**475**	**482**	**493**	**United States**
European Union	**60**	**63**	**59**	**63**	**65**	**64**	**71**	**73**	**81**	**82**	**87**	**81**	**86**	**91**	**95**	**102**	**110**	**118**	**127**	**131**	**140**	**143**	**147**	**150**	**154**	**156**	**159**	**158**	**160**	**European Union**
France	10.8	11.6	13.4	16.7	13.6	9.0	9.9	10.7	12.5	13.3	14.8	15.3	16.2	16.7	17.4	17.2	18.7	20.4	22.1	23.1	25.0	25.3	25.8	26.1	26.1	26.4	27.5	27.0	26.9	*France*
Germany	13.7	14.5	12.8	12.7	13.8	15.1	16.7	17.7	18.2	17.8	20.5	18.5	19.4	20.0	21.8	23.8	26.4	27.9	30.2	29.2	30.0	30.9	31.6	32.1	32.9	33.7	34.1	34.1	34.1	*Germany*
Italy	4.7	4.5	4.1	4.3	5.0	5.3	7.9	7.8	9.1	10.4	10.0	11.4	11.7	11.4	11.5	11.8	13.2	14.3	15.3	16.5	17.8	19.0	19.7	20.4	21.1	21.7	22.1	22.5	22.9	*Italy*
Netherlands	7.5	7.6	7.5	8.2	8.6	8.1	8.9	8.6	9.5	8.8	9.1	4.8	3.6	4.3	3.9	4.2	4.6	4.9	5.2	5.4	5.7	5.7	5.7	5.0	4.5	4.8	4.9	4.9	4.9	*Netherlands*
Poland	0.6	0.6	0.6	0.7	0.8	0.9	1.0	1.1	1.3	1.4	1.5	1.7	1.9	2.1	2.5	2.9	3.2	3.5	3.7	3.3	2.9	3.0	3.1	3.2	3.5	3.7	3.1	3.2	3.2	*Poland*
Spain	7.3	7.4	7.6	7.5	7.5	7.7	8.1	8.0	8.8	7.2	8.8	7.8	8.1	9.0	9.7	10.4	11.4	12.3	13.2	13.5	14.1	14.3	14.3	14.8	15.0	12.3	12.7	12.3	12.4	*Spain*
United Kingdom	6.2	6.9	6.8	5.8	8.8	9.2	9.1	8.9	9.9	10.3	9.6	9.8	10.8	11.2	10.8	11.7	12.6	14.0	14.8	15.3	16.4	15.1	15.1	15.3	15.6	15.4	14.7	13.7	12.9	*United Kingdom*
India	**10**	**11**	**10**	**10**	**9**	**9**	**9**	**10**	**13**	**13**	**16**	**16**	**16**	**20**	**24**	**18**	**18**	**26**	**24**	**26**	**28**	**28**	**29**	**30**	**30**	**31**	**31**	**32**	**32**	**India**
Russian Federation	**29**	**39**	**40**	**44**	**42**	**45**	**45**	**48**	**51**	**54**	**58**	**59**	**56**	**57**	**65**	**69**	**70**	**75**	**76**	**67**	**73**	**68**	**86**	**99**	**106**	**106**	**112**	**138**	**184**	**Russian Federation**
Japan	**33**	**39**	**43**	**55**	**54**	**77**	**70**	**69**	**67**	**64**	**59**	**59**	**55**	**58**	**58**	**62**	**67**	**71**	**74**	**78**	**83**	**88**	**96**	**105**	**111**	**116**	**121**	**125**	**130**	**Japan**
Other OECD G20	**33**	**34**	**32**	**33**	**32**	**33**	**41**	**43**	**43**	**52**	**50**	**46**	**54**	**53**	**54**	**61**	**65**	**66**	**69**	**69**	**74**	**79**	**86**	**95**	**111**	**135**	**160**	**178**	**194**	Other OECD G20
Australia	5.6	5.2	4.7	4.2	3.5	3.4	3.3	3.5	3.9	4.3	4.7	5.0	5.5	6.1	6.7	7.3	8.2	8.8	9.5	10.0	10.3	10.9	10.7	11.4	12.5	13.7	14.0	14.1	14.3	*Australia*
Canada	14.2	15.2	14.4	15.4	15.2	15.2	16.3	16.7	17.9	19.1	19.9	20.2	21.2	22.6	23.4	24.9	26.6	27.8	28.8	30.2	33.4	36.5	39.9	42.7	44.5	50.9	54.2	58.2	62.9	*Canada*
Mexico	3.4	3.5	2.5	3.3	2.9	2.8	5.8	6.0	5.2	6.7	5.6	4.6	6.0	5.9	6.0	9.2	12.4	11.2	11.4	12.1	12.9	13.4	14.0	14.5	15.1	15.7	16.2	16.8	17.3	*Mexico*
South Korea	6.7	7.3	7.7	8.0	8.5	9.3	12.9	14.3	14.1	20.0	17.2	13.0	17.6	14.9	13.3	13.7	11.9	11.9	12.3	10.0	9.4	8.6	8.2	8.1	8.0	8.0	7.9	7.8	8.1	*South Korea*
Turkey	2.6	2.6	2.7	2.6	2.4	2.3	2.2	2.2	2.1	2.2	2.7	2.9	3.4	3.9	4.7	5.5	5.9	6.5	7.1	7.1	7.9	9.2	13.4	18.5	30.9	46.8	67.9	80.7	91.2	*Turkey*
Other G20 countries	**18**	**18**	**16**	**15**	**14**	**13**	**12**	**12**	**12**	**10**	**10**	**10**	**11**	**13**	**15**	**16**	**17**	**19**	**19**	**19**	**20**	**21**	**21**	**22**	**23**	**23**	**24**	**24**	**25**	**Other G20 countries**
Argentina	2.7	2.6	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.7	0.9	0.7	0.6	1.1	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	*Argentina*
Brazil	9.6	9.8	10.1	9.8	9.4	9.0	7.4	7.4	7.5	5.9	5.6	5.3	6.3	7.7	8.5	9.6	10.4	11.1	11.5	11.4	11.8	12.1	12.3	12.6	12.8	13.1	13.3	13.6	13.8	*Brazil*
Indonesia	1.8	1.8	1.9	1.8	1.7	1.5	1.4	1.3	1.0	1.0	1.0	1.0	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.4	1.5	1.5	1.6	*Indonesia*
Saudi Arabia	2.3	2.3	2.1	1.8	1.4	1.2	1.2	1.2	1.2	1.3	1.3	1.4	1.6	1.8	1.9	2.1	2.2	2.4	2.5	2.7	2.8	2.9	3.1	3.2	3.4	3.5	3.6	3.8	3.9	*Saudi Arabia*
South Africa	1.5	1.3	1.2	1.2	1.1	1.1	1.5	1.7	1.7	1.8	1.8	1.8	2.0	2.3	2.5	2.6	2.8	2.9	3.0	3.2	3.3	3.4	3.6	3.7	3.8	3.9	4.0	4.2	4.3	*South Africa*
Total Group of Twenty (G20)	**299**	**320**	**318**	**344**	**358**	**385**	**406**	**433**	**457**	**537**	**540**	**550**	**609**	**657**	**741**	**819**	**896**	**931**	**977**	**1013**	**1097**	**1141**	**1201**	**1262**	**1326**	**1384**	**1452**	**1516**	**1608**	**Total Group of Twenty (G20)**
Other large emitting countries	**10**	**11**	**11**	**10**	**9**	**9**	**10**	**10**	**10**	**12**	**14**	**14**	**16**	**17**	**18**	**18**	**20**	**21**	**21**	**20**	**21**	**21**	**21**	**22**	**22**	**22**	**22**	**23**	**24**	**Other large emitting countries**
Egypt	2.2	2.3	2.3	2.2	2.2	2.0	2.6	2.2	2.4	2.6	2.7	2.8	2.9	2.9	3.1	3.4	3.6	3.8	3.9	4.0	4.2	4.3	4.4	4.6	4.7	4.8	5.0	5.1	5.2	*Egypt*
Iran	2.5	3.0	2.8	2.5	2.2	2.0	1.8	1.7	1.8	2.0	1.8	1.9	2.2	2.3	2.2	2.4	2.5	2.6	2.7	2.9	3.0	3.1	3.2	3.4	3.5	3.6	3.7	3.9	4.0	*Iran*
Kazakhstan	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*Kazakhstan*
Malaysia	0.6	0.7	0.7	0.7	0.7	0.7	0.6	0.5	0.5	0.5	0.5	0.7	0.8	1.0	1.0	1.1	1.2	1.3	1.4	1.2	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	*Malaysia*
Nigeria	0.2	0.2	0.1	0.1	0.1	-	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.7	*Nigeria*
Taiwan	2.0	2.1	2.1	2.0	1.9	2.1	2.6	3.8	3.7	5.0	6.9	6.4	7.6	8.3	8.4	7.3	8.4	8.7	9.0	7.1	7.6	7.2	6.9	6.5	6.2	5.9	5.6	5.6	5.7	*Taiwan*
Thailand	1.4	1.4	1.3	1.2	1.0	0.9	0.8	0.7	0.5	0.5	0.4	0.5	0.7	0.8	0.9	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.8	*Thailand*
Ukraine	0.3	0.4	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.0	1.2	1.3	1.5	1.6	1.9	2.2	2.5	*Ukraine*
United Arab Emirates	0.9	1.0	0.9	0.8	0.7	0.6	0.7	0.7	0.7	0.8	0.9	0.9	0.9	0.9	1.0	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.8	1.8	1.9	2.0	*United Arab Emirates*
Viet Nam	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*Viet Nam*
Zambia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*Zambia*
Remaining countries (186)	32	29	24	21	19	19	20	21	21	22	25	27	27	30	34	37	41	44	47	48	48	67	53	56	59	64	70	73	76	**Remaining countries (186)**
International transport	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**International transport**
Total	**341**	**360**	**353**	**375**	**386**	**412**	**436**	**463**	**488**	**571**	**579**	**591**	**652**	**704**	**793**	**874**	**956**	**995**	**1046**	**1081**	**1166**	**1229**	**1276**	**1339**	**1406**	**1470**	**1544**	**1612**	**1,708**	**Total**

[23] Totals and sub-totals may differ due to independent rounding. The number of digits does not indicate the accuracy of the figures, See uncertainty information in the Appendix. Calculated using the Global Warming Potentials (GWPs) for 100 year from the IPCC's Fourth Assessment Report (AR4).

Table B.5 Greenhouse gas emissions per capita, per country and group, 1990–2018[24] (unit: tonnes of CO_2 eq per person)

Total greenhouse gas emissions per capita, per country/group, 1990-2018 (unit: kg CO_2 eq per person)																														
Country/group	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**Country/group**
China	**3.3**	**3.4**	**3.4**	**3.6**	**3.7**	**4.0**	**4.0**	**3.9**	**4.0**	**3.9**	**4.1**	**4.2**	**4.4**	**4.9**	**5.6**	**6.2**	**6.7**	**7.2**	**7.3**	**7.7**	**8.2**	**8.9**	**9.0**	**9.3**	**9.4**	**9.3**	**9.3**	**9.3**	**9.4**	**China *1**
United States	**24.2**	**23.8**	**23.9**	**24.2**	**24.3**	**24.2**	**24.6**	**24.9**	**24.7**	**24.5**	**25.0**	**24.4**	**23.9**	**24.0**	**24.2**	**24.0**	**23.6**	**23.7**	**22.9**	**21.4**	**22.1**	**21.6**	**20.9**	**21.0**	**21.3**	**20.6**	**20.2**	**20.0**	**20.5**	**United States *1**
European Union	**12.1**	**11.9**	**11.4**	**11.2**	**11.1**	**11.1**	**11.4**	**11.2**	**11.0**	**10.8**	**10.8**	**10.8**	**10.7**	**10.9**	**10.9**	**10.7**	**10.7**	**10.6**	**10.3**	**9.6**	**9.9**	**9.5**	**9.4**	**9.2**	**8.8**	**8.9**	**8.8**	**8.9**	**8.7**	**European Union *1**
France	9.6	9.9	9.7	9.3	9.1	9.2	9.4	9.2	9.4	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.6	8.5	8.3	8.0	8.2	7.6	7.6	7.6	7.0	7.1	7.0	7.1	7.0	*France *1*
Germany	15.7	15.3	14.4	14.1	13.9	13.8	14.1	13.6	13.2	12.7	12.7	12.8	12.6	12.6	12.5	12.2	12.4	12.1	12.2	11.3	12.1	11.7	11.8	12.0	11.4	11.5	11.4	11.3	10.8	*Germany *1*
Italy	9.1	9.0	8.9	8.8	8.7	9.1	9.1	9.2	9.5	9.6	9.7	9.6	9.7	10.0	10.0	10.0	9.8	9.6	9.3	8.4	8.6	8.3	8.0	7.4	7.0	7.2	7.1	7.1	6.9	*Italy **
Netherlands	14.7	14.9	14.7	14.8	14.7	15.0	15.7	15.3	15.0	14.5	14.3	14.2	13.9	14.0	14.0	13.8	13.6	13.6	13.2	12.8	13.4	12.6	12.6	12.4	11.9	12.3	12.3	11.9	11.7	*Netherlands*
Poland	13.5	13.3	12.8	12.7	12.4	12.4	12.8	12.5	11.5	11.3	10.8	10.6	10.4	10.7	10.7	10.8	11.1	11.1	10.9	10.5	11.0	11.0	10.8	10.7	10.4	10.5	10.8	11.0	11.2	*Poland*
Spain	7.6	7.8	8.0	7.6	7.9	8.2	8.0	8.5	8.7	9.2	9.6	9.4	9.8	9.8	10.1	10.2	9.9	10.1	9.2	8.3	7.9	7.9	7.8	7.2	7.3	7.6	7.4	7.7	7.6	*Spain*
United Kingdom	14.1	14.4	14.0	13.7	13.6	13.4	13.8	13.4	13.2	12.7	12.6	12.7	12.3	12.4	12.2	12.0	12.0	11.7	11.2	10.0	10.2	9.5	9.7	9.4	8.8	8.5	8.1	7.9	7.7	*United Kingdom *1*
India	**1.6**	**1.6**	**1.6**	**1.6**	**1.6**	**1.7**	**1.7**	**1.7**	**1.7**	**1.8**	**1.8**	**1.7**	**1.7**	**1.8**	**1.8**	**1.9**	**1.9**	**2.0**	**2.1**	**2.2**	**2.2**	**2.3**	**2.4**	**2.4**	**2.5**	**2.6**	**2.6**	**2.6**	**2.7**	**India *1**
Russian Federation	**20.3**	**20.0**	**18.4**	**16.9**	**15.1**	**14.7**	**14.3**	**13.5**	**13.4**	**13.8**	**14.1**	**14.3**	**14.3**	**14.7**	**15.0**	**14.9**	**15.5**	**15.6**	**15.6**	**14.6**	**15.5**	**16.1**	**16.3**	**16.0**	**15.9**	**15.9**	**15.8**	**16.1**	**16.9**	**Russian Federation *1**
Japan	**10.4**	**10.4**	**10.5**	**10.4**	**10.8**	**11.1**	**11.1**	**11.0**	**10.6**	**10.8**	**10.9**	**10.7**	**11.0**	**11.0**	**11.0**	**11.0**	**10.9**	**11.3**	**10.6**	**10.1**	**10.6**	**11.0**	**11.4**	**11.6**	**11.4**	**11.1**	**11.0**	**11.1**	**11.0**	**Japan *1**
Other OECD G20	**9.5**	**9.5**	**9.6**	**9.8**	**10.0**	**10.1**	**10.4**	**10.7**	**10.5**	**10.7**	**11.2**	**11.0**	**11.0**	**10.9**	**11.1**	**11.0**	**11.3**	**11.5**	**11.2**	**11.0**	**11.2**	**11.7**	**11.7**	**11.3**	**11.4**	**11.4**	**11.4**	**11.7**	**11.7**	Other OECD G20
Australia	30.7	30.5	30.2	30.0	29.8	30.3	30.2	30.7	32.2	34.1	35.3	35.6	35.5	32.1	34.5	32.9	34.2	33.6	31.9	32.0	30.7	34.9	34.1	29.8	30.2	29.8	28.7	29.8	29.0	*Australia *1*
Canada	22.3	21.9	22.2	22.2	22.8	22.8	23.4	23.7	23.3	23.5	24.1	23.3	23.3	23.8	23.4	23.6	23.1	24.0	22.9	21.6	21.9	22.1	22.0	22.5	22.8	22.4	22.1	22.3	22.3	*Canada *1*
Mexico	5.5	5.6	5.5	5.7	5.9	5.8	5.9	6.2	6.4	6.1	6.3	6.3	6.3	6.5	6.5	6.6	6.8	6.8	6.8	6.7	6.7	6.7	6.7	6.6	6.4	6.4	6.4	6.4	6.3	*Mexico *1*
South Korea	7.5	8.0	8.4	9.0	9.5	10.2	10.8	11.2	9.7	10.5	11.7	11.8	11.6	11.5	11.9	11.8	11.9	12.1	12.2	12.3	13.2	13.7	13.7	13.5	13.4	13.7	13.8	14.2	14.6	*South Korea *1*
Turkey	4.1	4.1	4.2	4.2	4.1	4.3	4.6	4.7	4.8	4.7	5.0	4.6	4.7	4.8	4.8	4.9	5.4	5.7	5.7	5.7	5.8	6.1	6.5	6.4	6.8	7.0	7.5	7.9	8.0	*Turkey *1*
Other G20 countries	**4.9**	**4.9**	**4.9**	**4.9**	**5.0**	**5.1**	**5.2**	**5.2**	**5.2**	**5.2**	**5.2**	**5.2**	**5.3**	**5.5**	**5.6**	**5.7**	**5.8**	**5.9**	**6.0**	**5.9**	**6.1**	**6.1**	**6.3**	**6.3**	**6.5**	**6.5**	**6.4**	**6.4**	**6.4**	**Other G20 countries**
Argentina	8.9	8.6	8.6	8.6	9.0	8.5	8.9	8.6	8.4	8.5	8.5	8.3	8.1	8.7	9.0	9.0	9.3	9.4	9.6	8.9	8.9	8.9	9.0	8.9	9.1	9.0	9.0	9.0	8.9	*Argentina *1*
Brazil	4.5	4.5	4.6	4.7	4.8	4.9	4.9	5.0	5.0	5.0	5.0	5.1	5.2	5.3	5.5	5.5	5.4	5.5	5.6	5.4	5.8	5.9	6.0	6.1	6.2	6.1	5.9	6.0	6.0	*Brazil *1*
Indonesia	2.4	2.4	2.5	2.6	2.6	2.6	2.7	2.8	2.7	2.7	2.7	2.7	2.8	2.9	2.9	2.9	3.0	3.1	3.0	3.1	3.2	3.2	3.4	3.4	3.5	3.5	3.5	3.6	3.7	*Indonesia *1*
Saudi Arabia	15.0	14.7	14.7	14.4	15.9	15.3	15.7	15.6	15.9	15.6	16.0	16.1	16.4	16.9	17.2	17.7	18.1	18.4	19.3	19.5	20.6	20.9	21.6	21.4	22.0	22.4	21.9	21.6	21.0	*Saudi Arabia *1*
South Africa	10.8	10.3	9.9	9.8	9.7	9.9	10.1	10.4	10.3	9.8	9.8	9.9	10.1	10.5	11.1	11.2	11.1	11.4	11.9	11.1	11.1	10.6	10.8	10.8	10.9	10.6	10.5	10.2	10.1	*South Africa *1*
Total Group of Twenty (G20)	**6.9**	**6.8**	**6.7**	**6.7**	**6.7**	**6.8**	**6.8**	**6.8**	**6.7**	**6.7**	**6.8**	**6.8**	**6.8**	**7.0**	**7.3**	**7.4**	**7.6**	**7.8**	**7.7**	**7.6**	**8.0**	**8.2**	**8.2**	**8.2**	**8.3**	**8.2**	**8.1**	**8.2**	**8.3**	**G20 *3**
Other large emitting countries	**6.3**	**6.3**	**6.1**	**5.8**	**5.6**	**5.5**	**5.5**	**5.3**	**5.1**	**5.1**	**5.1**	**5.2**	**5.2**	**5.4**	**5.6**	**5.7**	**5.8**	**5.9**	**6.0**	**5.7**	**5.9**	**5.9**	**5.9**	**6.0**	**5.9**	**5.7**	**5.8**	**5.8**	**5.9**	**Other big countries**
Egypt	2.6	2.7	2.7	2.7	2.6	2.7	2.8	2.8	2.8	2.9	2.8	3.0	3.0	3.0	3.2	3.4	3.6	3.7	3.7	3.7	3.6	3.7	3.8	3.6	3.6	3.5	3.5	3.5	3.5	*Egypt*
Iran	6.6	6.9	7.1	6.7	7.4	7.2	7.3	7.3	7.0	7.3	7.5	7.6	7.8	8.3	8.8	9.3	9.7	10.2	10.1	10.3	10.3	10.3	10.2	10.4	10.6	10.4	10.6	11.0	11.3	*Iran*
Kazakhstan	21.5	21.8	22.6	19.9	17.8	15.8	14.2	12.6	12.6	11.9	11.9	11.7	12.9	13.6	14.8	15.4	17.0	17.5	19.9	18.0	19.2	19.7	21.9	22.3	21.5	20.7	20.6	21.2	22.9	*Kazakhstan*
Malaysia	5.3	5.9	5.9	6.6	6.6	6.9	7.4	7.6	7.5	7.7	8.0	8.0	8.4	8.6	9.1	9.4	9.6	10.0	10.4	9.4	9.8	9.7	9.7	10.3	10.6	10.5	10.3	10.2	10.5	*Malaysia*
Nigeria	3.5	3.6	3.6	3.6	3.4	3.4	3.7	3.3	2.8	2.6	2.6	2.6	2.3	2.5	2.4	2.3	2.1	2.0	2.0	1.8	1.9	1.9	1.9	1.8	1.8	1.7	1.7	1.7	1.7	*Nigeria*
Taiwan	6.9	7.3	7.7	8.1	8.4	8.8	9.2	9.8	10.2	10.6	11.5	11.6	12.0	12.4	12.7	12.9	13.2	13.3	12.8	12.0	12.7	12.6	12.2	12.2	12.2	12.2	12.4	12.8	12.8	*Taiwan*
Thailand	3.6	3.9	4.0	4.2	4.4	4.6	4.9	4.9	4.4	4.5	4.5	4.6	4.7	4.9	5.2	5.3	5.3	5.5	5.6	5.5	5.8	5.7	6.0	6.1	5.9	5.8	5.6	5.9	5.8	*Thailand*
Ukraine	18.4	17.4	15.6	13.9	11.8	11.6	10.1	9.7	9.3	9.3	9.3	9.4	9.5	10.1	9.7	9.6	9.6	9.8	9.6	8.2	8.7	9.2	9.1	8.9	7.9	6.6	6.9	6.2	6.3	*Ukraine*
United Arab Emirates	44.3	47.6	44.3	44.0	45.1	45.0	44.6	43.0	41.1	39.7	37.4	39.7	38.1	37.7	36.0	33.9	30.6	27.9	28.2	25.4	24.4	24.1	24.7	25.9	26.0	26.7	27.1	26.6	27.0	*United Arab Emirates*
Viet Nam	1.5	1.5	1.5	1.5	1.6	1.7	1.8	1.8	1.9	1.9	2.0	2.0	2.2	2.2	2.5	2.6	2.6	2.8	2.9	3.1	3.2	3.2	3.2	3.2	3.3	3.6	3.8	3.8	4.1	*Viet Nam*
Zambia	3.7	3.7	3.6	3.5	3.3	3.2	3.0	3.0	3.1	2.9	2.7	2.8	2.6	2.7	2.8	2.8	2.5	2.5	2.4	2.3	2.7	2.6	2.8	2.8	2.7	2.7	2.6	2.5	2.6	*Zambia*
Remaining countries (186)	3.5	3.4	3.3	3.3	3.2	3.2	3.2	3.2	3.1	3.1	3.1	3.1	3.0	3.1	3.1	3.1	3.1	3.1	3.2	3.1	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	**Remaining countries (186) *4**
International transport	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**International transport *5**
Total	**6.2**	**6.2**	**6.1**	**6.0**	**6.0**	**6.0**	**6.0**	**6.0**	**5.9**	**5.9**	**5.9**	**5.9**	**5.9**	**6.1**	**6.3**	**6.4**	**6.5**	**6.6**	**6.6**	**6.5**	**6.7**	**6.9**	**6.9**	**6.9**	**6.9**	**6.8**	**6.8**	**6.8**	**6.8**	**Total**

[24] The number of digits does not indicate the accuracy of the figures, See uncertainty information in the Appendix. Calculated using the Global Warming Potentials (GWPs) for 100 year from the IPCC's Fourth Assessment Report (AR4).

Table B.6 Greenhouse gas emissions per USD of GDP, per country and group, 1990–2018[25] (unit: kg CO_2 per 1,000 USD of GDP [PPP])

Total greenhouse gas emissions per USD of GDP, per country/group, 1990-2018 (unit: kg CO_2 eq per 1,000 USD of GDP (PPP, 2011 prices))																														
Country/group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Country/group
China	2,080	1,970	1,790	1,660	1,550	1,520	1,390	1,270	1,210	1,120	1,080	1,030	1,010	1,040	1,070	1,070	1,040	980	910	890	870	860	820	790	740	700	650	620	590	**China**
United States	660	660	650	640	630	620	610	600	580	550	550	530	520	510	500	480	470	460	450	440	450	430	410	410	410	390	380	370	370	**United States**
European Union	490	470	450	450	430	420	420	400	390	370	360	350	340	340	340	330	320	300	290	290	290	280	270	270	250	250	240	240	230	**European Union**
France	320	330	310	310	290	290	290	280	280	260	250	250	250	240	240	230	220	220	210	210	210	200	200	200	180	180	180	180	170	*France*
Germany	500	460	430	430	420	410	410	390	370	350	340	340	330	340	330	320	310	300	290	290	290	280	280	280	260	260	260	250	240	*Germany*
Italy	290	290	280	280	270	280	270	270	270	270	260	260	260	270	270	270	260	250	250	240	240	230	230	220	210	210	200	200	190	*Italy*
Netherlands	460	450	440	440	430	430	440	410	390	360	340	330	330	330	330	310	300	290	280	280	290	270	270	270	260	260	260	240	230	*Netherlands*
Poland	1,310	1,390	1,310	1,250	1,170	1,090	1,060	980	860	800	740	720	690	680	650	630	610	570	540	500	510	480	470	450	430	410	410	400	390	*Poland*
Spain	320	320	330	320	320	330	310	320	320	320	320	310	310	310	310	310	290	290	270	250	250	250	250	240	230	230	220	230	220	*Spain*
United Kingdom	530	540	530	510	490	470	470	440	420	390	380	370	350	350	340	320	320	300	290	280	280	260	270	250	230	220	210	200	190	*United Kingdom*
India	820	850	820	800	780	760	720	720	680	660	640	620	610	580	570	550	530	520	530	530	500	500	500	470	470	450	420	400	400	**India**
Russian Federation	970	1,000	1,090	1,090	1,120	1,130	1,140	1,060	1,110	1,070	990	950	910	870	820	760	730	680	650	650	670	670	650	630	620	640	640	640	650	**Russian Federation**
Japan	340	330	330	330	340	340	330	330	320	330	320	320	320	320	310	310	300	310	290	300	300	310	310	320	310	290	290	290	280	**Japan**
Other OECD G20	590	590	590	580	580	580	580	570	550	550	550	550	530	520	510	490	490	480	470	480	470	470	470	440	430	430	420	420	420	Other OECD G20
Australia	1,070	1,080	1,070	1,040	1,000	990	960	950	960	980	990	990	960	850	890	830	860	830	770	780	740	840	800	690	690	680	640	660	640	*Australia*
Canada	710	720	730	720	720	700	720	700	670	650	640	610	600	610	590	580	560	580	550	540	540	530	530	530	530	530	520	510	510	*Canada*
Mexico	400	400	390	400	410	430	420	420	410	390	390	390	400	410	400	410	410	410	410	430	420	410	400	390	370	370	360	360	350	*Mexico*
South Korea	650	630	630	640	630	620	610	610	560	550	570	550	510	490	490	470	450	430	430	430	440	440	430	420	400	400	390	390	390	*South Korea*
Turkey	360	360	360	340	350	350	350	340	340	350	360	360	350	340	320	300	310	320	320	340	320	310	320	290	300	300	320	320	320	*Turkey*
Other G20 countries	530	510	510	500	500	490	490	480	500	510	500	500	510	510	500	490	480	470	460	460	450	430	440	430	440	430	430	430	420	**Other G20 countries**
Argentina	780	700	660	620	620	610	610	550	530	560	570	590	650	640	620	580	550	520	510	520	470	450	460	450	480	470	480	470	480	*Argentina*
Brazil	430	440	450	450	440	440	440	440	450	450	440	450	450	460	450	440	430	410	400	390	400	390	390	390	400	410	420	420	420	*Brazil*
Indonesia	510	500	500	490	450	440	420	420	480	490	460	460	450	450	440	420	420	410	390	390	380	370	360	350	350	340	330	320	320	*Indonesia*
Saudi Arabia	350	310	310	310	350	350	350	350	360	370	370	390	420	400	390	390	400	410	410	440	450	430	440	430	440	440	440	440	430	*Saudi Arabia*
South Africa	1,090	1,080	1,090	1,080	1,070	1,080	1,080	1,090	1,110	1,040	1,010	1,000	1,000	1,030	1,050	1,020	970	960	980	940	930	870	880	870	880	850	850	830	830	*South Africa*
Total Group of Twenty (G20)	660	650	640	630	620	620	600	590	570	550	540	530	530	530	530	520	510	500	490	490	490	490	480	470	460	450	430	420	410	**Total Group of Twenty (G20)**
Other large emitting countries	840	830	800	770	750	730	700	670	650	640	610	610	590	590	570	570	550	540	540	520	510	500	510	500	480	470	460	450	460	**Other large emitting countries**
Egypt	440	450	460	450	420	430	430	420	400	400	370	390	390	390	400	420	420	410	390	380	360	370	380	360	350	340	340	330	320	*Egypt*
Iran	580	550	560	530	610	590	570	580	550	580	570	580	560	550	570	590	590	580	580	590	570	560	610	630	620	620	570	570	620	*Iran*
Kazakhstan	1,650	1,880	2,040	1,970	2,000	1,910	1,680	1,450	1,460	1,320	1,200	1,040	1,050	1,020	1,020	980	980	940	1,050	940	950	920	990	970	910	880	880	880	930	*Kazakhstan*
Malaysia	500	520	500	510	490	470	470	460	510	500	490	500	510	500	500	510	500	500	500	470	470	450	430	440	430	410	390	370	370	*Malaysia*
Nigeria	1,050	1,090	1,080	1,120	1,090	1,150	1,210	1,070	930	860	850	830	650	660	590	560	490	450	420	370	370	370	360	340	310	300	320	320	310	*Nigeria*
Taiwan	350	350	350	350	350	350	340	350	350	350	360	380	380	380	380	360	370	360	360	350	340	330	320	310	300	290	300	300	290	*Taiwan*
Thailand	550	540	520	510	500	490	500	520	520	510	490	490	470	460	460	460	440	440	440	430	430	420	410	410	400	380	360	360	340	*Thailand*
Ukraine	1,750	1,800	1,790	1,850	2,030	2,250	2,180	2,150	2,070	2,060	1,920	1,760	1,680	1,620	1,370	1,310	1,220	1,150	1,090	1,090	1,110	1,110	1,090	1,060	1,000	920	940	820	810	*Ukraine*
United Arab Emirates	390	450	430	440	450	440	430	410	410	400	360	400	390	380	370	370	350	360	410	430	440	430	430	430	410	410	400	400	400	*United Arab Emirates*
Viet Nam	1,010	970	920	890	890	860	830	800	800	790	760	740	760	740	770	760	730	720	710	730	730	690	650	630	630	650	650	610	620	*Viet Nam*
Zambia	1,590	1,610	1,630	1,520	1,620	1,570	1,420	1,420	1,510	1,370	1,280	1,300	1,180	1,170	1,140	1,110	950	880	830	750	810	760	790	760	730	730	700	670	690	*Zambia*
Remaining countries (186)	720	710	690	690	680	670	650	640	620	610	590	590	580	590	560	540	520	500	500	490	490	480	470	460	450	440	440	440	430	**Remaining countries (186)**
International transport																														**International transport**
Total	690	690	670	660	650	640	630	610	600	580	570	560	550	550	550	540	530	520	510	510	510	500	490	480	470	460	450	440	430	**Total**

[25] Calculated using the Global Warming Potentials (GWPs) for 100 year from the IPCC's Fourth Assessment Report (AR4). GDP in USD for Purchasing Power Parity (PPP) and in prices of 2011.

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