PBL Netherlands Environmental Assessment Agency

# TRENDS IN GLOBAL $CO_2$ AND TOTAL GREENHOUSE GAS EMISSIONS

## Summary of the 2017 report

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**28 September 2017**

PBL

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The Hague, 2017
PBL publication number: 2983

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**Acknowledgements**
We thank IEA, USGS, IFA and GCP for providing recent statistics. We thank the members of the EDGAR team at EC-JRC for their support in the data compilation of the $CO_2$ Fast Track 2016 and comments on the draft of this summary.

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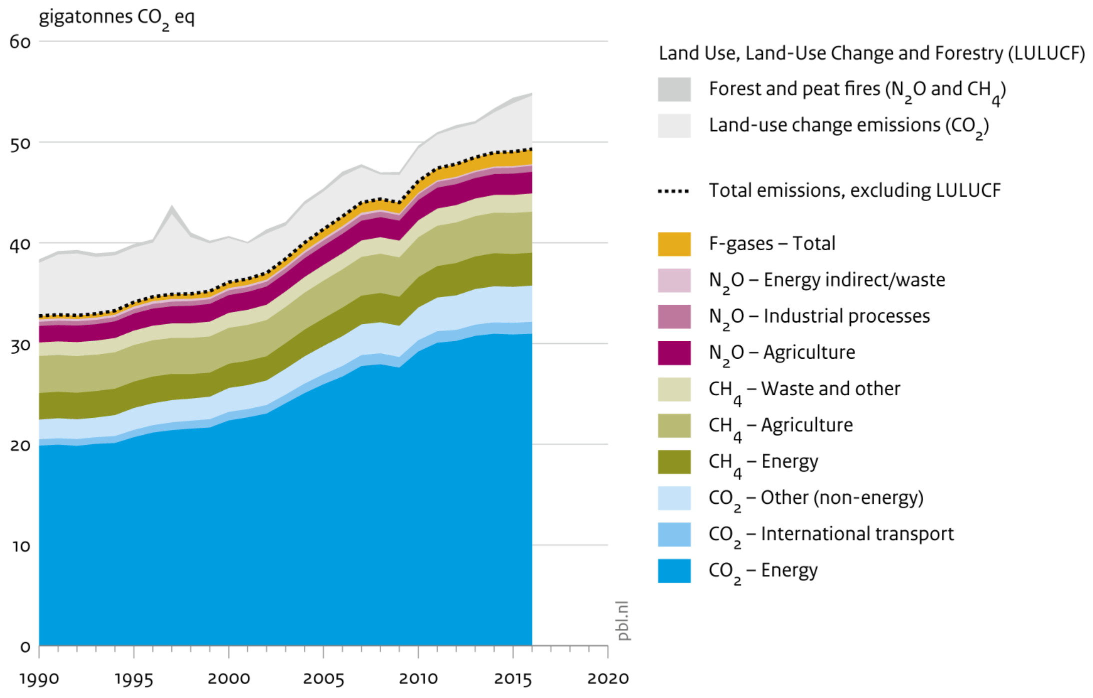
## Trends in global $CO_2$ and total GHG emissions

**In 2016, total global greenhouse gas (GHG) emissions continued to increase slowly by about 0.5% (±1%), to about 49.3 gigatonnes in $CO_2$ equivalent (Gt $CO_2$ eq). Taking into account that 2016 was a leap year, and therefore 0.3% longer, and together with the 0.2% increase in 2015, the 2016 emission increase was the slowest since the early 1990s, except for global recession years. This is mainly the result of lower coal consumption from fuel switches to natural gas and increased renewable power generation; in particular, in wind and solar power. Most of the emissions (about 72%) consist of $CO_2$, but methane ($CH_4$), nitrous oxide ($N_2O$) and fluorinated gases (F-gases) also make up substantial shares (19%, 6% and 3%, respectively). These percentages do not include net emissions from land use, land-use change and forestry (LULUCF), which are usually accounted for separately, because they show large interannual variations and are very uncertain. They mostly consist of net $CO_2$ emissions from changes in land use and land cover, plus small amounts in $CH_4$ and $N_2O$ from forest and peat fires. When including LULUCF emissions — for 2016, estimated at about 4.1 Gt $CO_2$ eq — estimated global total GHG emissions come to 53.4 Gt $CO_2$ eq. The trend in global $CO_2$ emissions excluding those from LULUCF has remained more or less flat, over the last two years (±0.5%), see Figure 1. Non-$CO_2$ greenhouse gases retained an annual growth rate of about 1%. In contrast, $CO_2$ emissions from LULUCF show a highly varying pattern that reflects the periodically occurring strong El Niño years, such as in 1997–1998 and 2015–2016 (Figure 1).**

Figure 1
**Global greenhouse gas emissions, per type of gas and source, including LULUCF**




Source: EDGAR v4.3.2 (EC-JRC/PBL 2017); Houghton and Nassikas (2017); GFED 4.1s (2017)

*The data presented here have been calculated using the new EDGAR 4.3.2 data set, which provides emissions per source and country, for the 1970–2012 period (Janssens-Maenhout et al., 2017a,b). The data set was extended for $CO_2$, using international statistics through 2016 (so-called Fast Track 2016), and for other GHGs, using statistics through 2014 (FAO), 2016 (IEA, BP), and other data sources (including CDM projects in developing countries through 2016 (e.g. reductions in $CH_4$,*

*$N_2O$ and HFC-23)). In cases where data through 2016 were lacking, which was often the case for non-$CO_2$ GHGs, we extrapolated data from three recent years. For a more detailed description of the Fast Track methodology for $CO_2$, see Olivier et al. (2016), and, for the methodology used for other GHGs, see the upcoming background report (Olivier et al., 2017). The total in GHGs is expressed in terms of gigatonnes of global annual $CO_2$ equivalent emissions (Gt $CO_2$ eq), calculated using the so-called Global Warming Potentials for 100 years (GWP-100) as listed in the IPCC Fourth Assessment Report (AR4) (IPCC, 2017). The historical GHG emission trends from the EDGAR database are also presented in UNEP's Emissions Gap Report 2017, but using the GWPs of the IPCC Second Assessment Report (UNEP, 2017).*
*For LULUCF emissions, we used data generated in the Global Carbon Project (GCP) through 2015 (Houghton and Nassikas, 2017), which include data on $CO_2$ emissions from forest and peat fires from the GFED4.1s database through 2016 (Van der Werf et al., 2010). Those data are inherently very uncertain and therefore typically not included in representations of emission data. However, for the comprehensive overview of GHG emissions and removals, we included them in Figure 1 to illustrate their share in overall, total global anthropogenic GHG emissions. Further discussions on emission data focus on those derived from the EDGAR database, which excludes LULUCF emissions.*

## Global GHG emissions

Over the past two years, total global greenhouse gas emissions (excluding those from LULUCF, thus also from forest and peat fires) have shown a slowdown in growth, reaching 49.3 gigatonnes $CO_2$ equivalent in 2016, with calculated increases of 1.0%, 0.2% and 0.5%, in 2014, 2015 and 2016, respectively (see Figure 1). Note that 2016 was a leap year and, therefore, about 0.3% longer than a normal year. Since the early 1990s, such slow annual emission increases have only occurred during the economic crisis in 2008–2009, and the major global financial crisis in 1998 that resulted from the Asian financial crisis. Non-$CO_2$ GHG emissions originate from many different sources and are much more uncertain than $CO_2$ emissions (their uncertainty on a global level is of the order of 30% or more, whereas for $CO_2$ this is about ±10% or less). Over the past three years, non-$CO_2$ GHG emissions have continued to grow somewhat faster than $CO_2$ emissions, namely by 1.5% (2014), 1.2% (2015) and 1.0% (2016), whereas $CO_2$ over the same period increased by a respective 0.8%, -0.2% and 0.3%. Note that, due to limited statistical data for 2015 and 2016 for these sources, the annual trends in the emission of $CH_4$, $N_2O$ and F-gases are much more uncertain than those in $CO_2$.

Although varying per country, non-$CO_2$ emissions constitute a significant share in total GHG emissions. Globally, the combined share of $CH_4$, $N_2O$ and F-gas emissions is about 28% in total GHG emissions (19%, 6%, and 3% respectively), but it varies for the largest countries; with 11% for Japan and 31% for India. China's current share is estimated at 20%, that of the United States and the European Union at 23%, and of Russia at 25%. 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), other crops ($N_2O$), and landfill and wastewater practices ($CH_4$). The global share of non-$CO_2$ GHGs is estimated to have declined from 35% in 1970 to 27% in 2013, after which it started to increase, slowly, to about 27.5% in 2016, because of the reduction in the growth in $CO_2$ emissions.

For **methane** ($CH_4$), the largest amount of non-$CO_2$ greenhouse gas, the predominant source is non-dairy cattle, with over 16% of $CH_4$ emissions in 2016. Dairy cattle adds another 5%, and manure management for cattle another 1% — together making cattle responsible for 23% of methane emissions, worldwide. Coal mining, oil and natural gas production and gas distribution, together, account for 25% of methane emissions, and rice cultivation contributes 10%. Methane emissions from industrial waste water is one of the fastest growing categories, accounting for 3% of $CH_4$ emissions. Since 2000, emissions from both this category and coal and natural gas production have grown by more than 65%. With an estimated 1.2% increase in 2016, waste was the fastest growing source of methane emissions in 2016. In the same year, methane emissions from agriculture increased by 0.4%, while those from energy decreased by 0.3%.

The main sources of **$N_2O$ emissions** consist of the manure in pastures, rangeland and paddocks, and synthetic fertilisers (22% and 18%, respectively, in 2016). Agriculture, in general, including indirect $N_2O$ emissions, accounted for about 75% of $N_2O$ emissions, and this was also the fastest growing category, over the past three years (by a respective 1.7%, 2.1% and 1.3%). In recent years, savannah fires have been responsible for about 5% of $N_2O$ emissions.

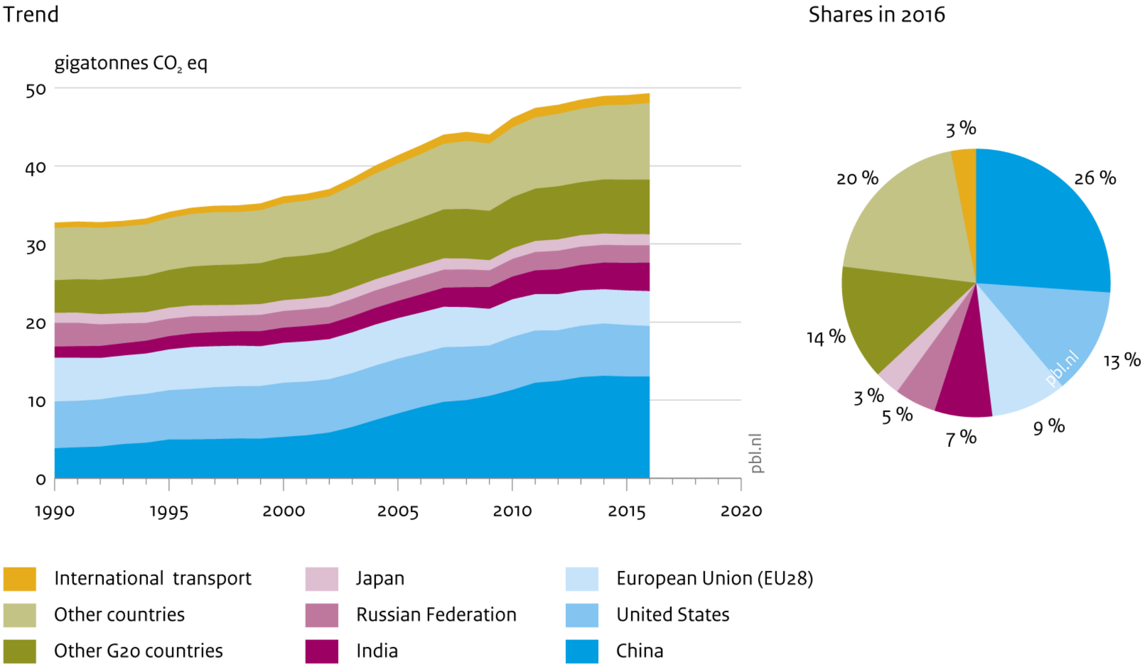
**F-gases** are a very heterogeneous category, with large differences in growth rates and large uncertainties in emissions. The largest sub-categories are HFC-134a from refrigeration and air conditioning (about 19%), HFC-125 and HFC-143a from consumption (17% and 19%), and HFC-23, which is a by-product of the production of HCFC-22 (19%).

Net emissions from **land-use change** are usually accounted for separately, among other things because they are inherently very uncertain and show large interannual variation. Thus, they are less suited for determining trends in anthropogenic global GHG emissions. They constitute net $CO_2$ emissions from changes in land use and land cover (estimated at about 3.9 Gt $CO_2$ in 2016) plus small amounts of $CH_4$ and $N_2O$ emissions from forest and peat fires (about 0.2 Gt $CO_2$ eq). However, estimates of these emissions range widely. For 2016, we used a middle-range estimate of about 4.1 Gt $CO_2$ eq (Houghton and Nassikas, 2017). This adds another 8% to the global total GHG emissions, making it an important component to consider for reducing greenhouse gas emissions.

## Trends in $CO_2$ emissions in the largest emitting countries and the European Union

In 2016, the five largest emitting countries and the European Union, which together account for 51% of the world population, 65% of global gross domestic product (GDP) and 67% of the total primary energy supply (TPES[1]), accounted for 68% of total global $CO_2$ emissions and about 63% of total global GHG emissions. Emissions from international transport (aviation and shipping) are excluded from the national total in countries' GHG emission reports, but nevertheless constitute about 3% of total global GHG emissions. See Figure 2 for the trends and the shares per country and region in 2016. $CO_2$ is the dominant component of GHG emissions in all countries. A country's share in global CO2 emissions often very similar to its share in global GHG emission. The exception to this is China, where the share of $CO_2$ emissions in 2016 was 29% versus 26% in GHG, due to the large share of coal in the fossil fuel mix. The group of 20 largest economies (G20) accounted for 81% of global $CO_2$ emissions and 78% of global GHG emissions (Figure 2).

Figure 2
**Global greenhouse gas emissions, per country and region**

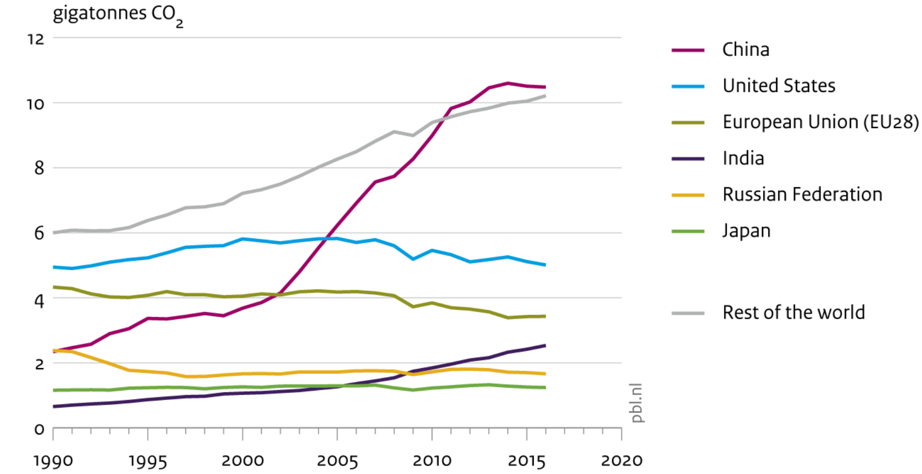



Emissions do not include those from land use, land-use change and forestry and forest and peat fires (LULUCF)

Bron: EDGAR v4.3.2 (EC-JRC/PBL 2017)

The trends in $CO_2$ emissions of the largest emitting countries/regions are shown in Figure 3. Most of them showed a decrease in $CO_2$ emissions in 2016; most notably the United States (-2.0%), the Russian Federation (-2.1%), Brazil (-6.1%), China (-0.3%), and, within the European Union, the United Kingdom (-6.4%). In contrast, the largest absolute increases were seen in India (+4.7%) and Indonesia (+6.4%) and smaller increases in Malaysia, Philippines, Turkey and Ukraine. For many of the largest emitting countries, this is a continuation of the trend of 2015. With an estimated 0.2% increase in $CO_2$ emissions, emissions in the European Union remained more or less the same in 2016. In contrast to most of the main emitters, the emissions from the rest of the world show a rising trend.

Figure 3
**$CO_2$ emissions from fossil-fuel use and cement production, per country and region**

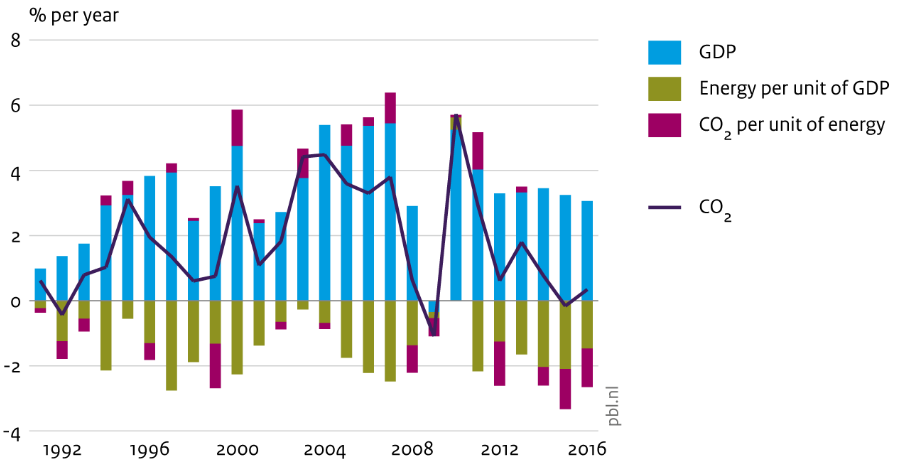



Source: EDGAR v4.3.2 CO2 FT2016 (EC-JRC/PBL 2017)

## Decomposition of the trends in $CO_2$ emissions

The trend in GHG emissions and, more specifically, $CO_2$ emissions, can be further analysed using a decomposition method called 'Kaya identity', which is useful for separating the effects from 1) changes in gross domestic product (GDP), 2) energy use per unit of GDP, which is an aggregate indicator of the overall energy intensity of an economy, and 3) $CO_2$ emissions per unit of energy (Figure 4). The latter depends on the share of fossil fuels in the total energy mix — with renewable energy sources and nuclear energy making up the remaining share – and also on the shares of coal, oil and natural gas in the fossil fuel mix. With respect to fossil fuel combustion, the combustion of coal emits more $CO_2$ than that of oil products and about twice as much as that of natural gas. Figure 4 shows how these factors change over time, for the global economy.

Figure 4
**Change in global $CO_2$ emissions and their drivers, GDP and energy, based on Kaya decomposition**




Source: EDGAR v4.3.2 CO2 FT2016 (EC-JRC/PBL 2017); World Bank (2017); IEA (2017); BP (2017)

The declining growth in annual $CO_2$ emissions since 2011 has continued over the past years, with 0.6% in 2012, 1.8% in 2013, and 0.8% in 2014, followed by -0.2% in 2015 and 0.3% in 2016 (±0.5%). Over the last five years, global GDP has increased on average by about 3.3% per year, representing a slowdown relative to pre-economic crisis growth rates between 2003 and 2007, during which typical global economic growth was around 5% per year (for the 5-year average). In contrast, the energy intensity of the economy, defined as total primary energy use (TPES[1]) per unit of GDP (shown in green in Figure 4), shows similar negative annual growth levels (i.e. annual energy efficiency improvement of the economy) compared to the pre-crisis period. From this can be deduced that, despite lower GDP growth, the economy as a whole has maintained its annually decreasing energy intensity, but no structural change on this indicator has occurred in recent years.

In 2016, global Total Primary Energy Supply (TPES[1]) increased by 1.3%. However, the emission intensity of energy, represented by $CO_2$ per unit of energy, shown in purple in Figure 4, has decreased over most of the past five years. This can be attributed to the recent trend of coal having been substituted by other fuels (with lower emission factors) and of renewable energy having increased in the energy mix, in particular in China and the United States. This trend is in sharp contrast with developments prior to the economic crisis of 2007–2008. In several years in the early 2000s, global $CO_2$ emissions per unit of energy *increased*, which can be largely attributed to the fast industrialisation of China. Globally, the share of coal in total energy supply peaked in 2011 at 27.6% and declined to 25.3% in 2016, which corresponds with that in China, with a peak

[1] 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 (2017): using a substitution method for nuclear, hydropower and other non-biomass renewable energy and assuming 38% conversion efficiency in all cases.

in 2011 at 66% and a much faster decline to 57.5% in 2016. In the United States, the share of coal in TPES also decreased relatively fast, from 21% in 2011 to 15% in 2016, with 4 percentage points in the last two years. In the European Union, the share also declined in these five years, from 14% to 11%, mainly due to a reduction in coal use in the United Kingdom. In contrast, large increases were seen in India and Indonesia, where coal consumption increased by a respective 4% and 23%. These countries showed a similar pattern in 2015 (BP, 2017).

In 2016, global fossil fuel combustion had a 75% share in total primary energy use. The increase in oil and natural gas consumption of 2% more than offset the 1.4% decrease in coal use. The largest increases in natural gas occurred in the European Union (notably in the United Kingdom and Germany), China and the United States. Oil consumption increased predominantly in China, India, the European Union, with smaller increases in South Korea and the United States. Hydropower and new renewable energy sources, such as wind and solar energy, had an 11% share, for nuclear power this was about 4.5%, and biofuels accounted for the remaining 10% of TPES. Wind and solar together have continued to grow at double-digit growth rates, with a 20% increase in 2016. In absolute figures, the largest increases in wind and solar energy in 2016 occurred in China and the United States.

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