TRENDS IN GLOBAL CO_2 EMISSIONS

2014 Report

BACKGROUND STUDIES

PBL Netherlands Environmental Assessment Agency

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Trends in global CO_2 emissions: 2014 Report

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This CO_2 report 2014 is one in a series of annual publications by PBL-JRC. After publishing web reviews in 2007 and 2008, the CO_2 report series started in 2009 and provide up-to-date knowledge on the trend of global CO_2 emissions. CO_2 emission estimates have been made by PBL Netherlands Environmental Assessment Agency and the European Commission's Joint Research Centre (JRC), on the basis of energy consumption data on 2010 to 2013, as published by British Petroleum, except for coal consumption in China over the 2012–2013 period, for which data were used as published by the International Energy Agency (IEA) and by the National Bureau of Statistics of China. The estimations are also based on production data on cement, lime, ammonia and steel, as well as on emissions per country, from 1970 to 2010, from the Emission Database for Global Atmospheric Research (EDGAR) version 4.2 FT 2010, developed jointly by JRC and PBL. The greenhouse gas emissions of from the EDGAR 4.2 FT2010 data set have also been used for the global emissions overviews in the Fifth Assessment Report of IPCC Working Group III on mitigation of climate change, combined with the latest estimates of the IEA on CO_2 emissions from fossil fuel combustion. All reports are available from http://edgar.jrc.ec.europa.eu/whats_new.php?p=3 and http://www.pbl.nl/en/publications/trend%20global%20co2

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Contents

Summary

Global carbon dioxide (CO_2) emissions from fossil fuel combustion and from industrial processes (cement and metal production) increased in 2013 to the new record of 35.3 billion tonnes (Gt) CO_2, which is 0.7 Gt higher than last year's record. This moderate increase of 2% in 2013 compared to 2012 is a continuation of last year's trend and of the slowdown in the annual emissions growth. The actual increase of 2012 compared to 2011 was 0.6 Gt or 1.7% (excluding leap year correction) and both are about half the average annual growth rate of 1.1 Gt or 3.8% since 2003 (excluding the 2008–2009 recession years). Note that the average annual emission increase in the 1995–2002 period (after the large decline in energy consumption in the former Soviet Union countries) was about 1.2% or 0.4 Gt CO_2 per year. With the global economic growth of 3.4% and 3.1%, in 2012 and 2013 respectively, a further decoupling of the global economic and emission trends can be observed. This decoupling is consistent with the increasing service sector share (growing by 1.5% and 1.8% in 2012 and 2013 on average in middle income countries, including China) to the overall gross domestic product, at the expense of more energy-intensive industrial activities.

The global increase in CO_2 emissions largely reflects the increase in fossil energy consumption, driven mainly by emerging economies with a steadily increasing energy use over the past decade. Regionally, annual CO_2 emission trends show large differences both in magnitude and underlying causes, complicating the evaluation of the robustness of observed trends. Comparison of the trends in the energy mix and of the resulting emissions in major emitting regions reveals different approaches adopted by different countries towards a low-carbon economy and society.

The top 3 emitting regions in 2013, together accounting for more than half (55%) of the total global CO_2 emissions, are China (10.3 billion tonnes CO_2 or 29%), the United States (5.3 billion tonnes CO_2 or 15%) and the European Union (EU28) (3.7 billion tonnes CO_2 or 11%). China increased its CO_2 emissions by 4.2% in 2013, compared to 2012, which is much lower than the annual increases of about 10% over the last decade, but higher than the increase of 3.4% in 2012. In 2013, the United States increased its CO_2 emissions for the first time in five years by 2.5%, compared to 2012. The EU28's CO_2 emissions, which started to decrease in 2006, continued to decrease by 1.4% in 2013, and at a larger rate than in 2012. Other OECD countries also mainly show decreases or minor increases below 2%. Russia's emissions decreased by 0.8%. In contrast, CO_2 emissions in emerging economies mainly increased in 2013, compared to 2012 (e.g. in India by 4.4%, in Brazil by 6.2% and in Indonesia by 2.3%).

In 2013, the Chinese per capita CO_2 level of 7.4 tonnes CO_2/cap exceeded the mean EU28 level of 7.3 tonnes CO_2/cap, but remained still under half the US level of 16.6 tonnes CO_2/cap. Evaluating the emitted CO_2 per Gross Domestic Product (corrected for purchasing power parity) (PPP)), China is still scoring high with 650 kg CO_2/1000 USD of GDP, which is more than Russia (530 kg CO_2/1000 USD), almost double that of the United States (330 kg CO_2/1000 USD), and almost triple that of the EU28 (220 kg CO_2/1000 USD). This is due to a relative high energy intensity of the sector contributing to GDP growth in China, even though the intensity continued to decline by 3.1% in 2013, compared to 3.6% in 2012. Although China needs fuel to drive its economic development, it will need a stronger decrease in consumption next year to meet the 12th Five Year Plan target for 2015 of a cumulative 17% reduction in its energy intensity relative to GDP. China started to take measures to achieve a fuel shift, away from coal, by implementing Provincial Environmental Plans with coal consumption targets, an increase in hydropower and structural change. China reported that its CO_2 emissions intensity per unit of GDP declined by 5% in the first half of 2014, which corresponds with an annual CO_2 emission growth of 2% and suggests that the slowdown in the increase in annual emissions is continuing, if not further decreasing.

In the United States, in 2013 and for the first time in five years, per capita CO_2 emissions increased, mainly due to a shift back from gas to coal in power production, of 4 percentage points, together with a 4% increase in gas consumption due to a higher demand for space heating. The United States increased its gas production in 2013 (primarily by unconventional shale gas) and introduced

the Clean Power Plan with targets for the CO_2 content per kWh, favouring the highly energy efficient natural gas combined cycle plants over the aged coal-fired power plants. Not only the shale oil production doubled in 2013 compared to 2012 (now representing a share of 30% of the total oil consumption), but also the conventional oil production increased by almost 1%, impacting both oil price and oil consumption. Overall, natural gas production in the United States increased by 2% in 2013 compared to 2012, resulting mainly from the 13% increase in unconventional shale gas production, currently representing a 40% share of the total gross production. Since the United States remains the world's largest gas producer, increased US gas production influences the gas market and the global fossil fuel market, in particular leading to lower coal prices.

In particular the European Union, in 2013, saw a continuation of its since 2006 decreasing CO_2 emissions by 1.4%, compared to 2012, even though GDP recovered, with a 0.1% increase in 2013 (compared to 0.3% decline in 2012). Main reasons are the decreases in primary energy consumption from coal (2.7%), oil (2.2%) and gas (1.4%) and the emissions from the sectors under the EU Emissions Trading System, which saw a 3% decline. Investments in renewable energy continued in 2013; the electricity demand in the EU28 was met by 8% supply through wind power, and the installed capacity for solar energy slightly increased to a total of 81.5 GW in 2013. Europe remained in the lead with respect to its cumulative installed photovoltaic capacity, which was 59% of the world's total in 2013. In October 2014, the EU28 committed to a new climate and energy policy framework with indicative collective targets for 2030 to reach a 40% reduction in greenhouse gas emissions, a 27% energy efficiency increase and a 27% increase in the share of renewable energy by 2030, compared to 1990 levels. Main greenhouse gas reductions are targeted also through a reformed EU *Emissions Trading System* with a so-called *Market Stability Reserve*.

It is uncertain how global economic and technological trends will continue into the future. Since 1970, energy carriers in primary supply increased globally by 35% per decade. The total primary energy in the United States and the European Union up to 2008 grew and was supplied in increasing amount of fossil fuels. After 2008, this energy supply decreased, as did the fossil fuel share but not that of renewable energy. China continued to increase its energy use, mostly supplied in fossil fuels, specifically coal (and continues to obtain its increasing energy supply in fossil fuel, mainly coal (+35%) over the past decade alone, four times faster than observed in the United States or the European Union). However, in its primary energy supply, China has a larger amount of renewable energy (hydropower) than currently in the United States and EU28, even though renewable energy in the EU28 over the past decade, increased by 87%, which requires further technological investments. Further investment in renewable or nuclear energy will be needed for a less carbon-intensive energy supply and a higher energy efficiency is required to substantially mitigate climate change.

Other analyses are needed to show whether countries' CO_2 trends as estimated in this report are consistent with the total national greenhouse gas emissions and their trends from analyses of the country's pledges. As such, the UNEP's *Emissions Gap Report 2014* presents the latest estimates of the emissions gap by 2020 between the emission levels consistent with the 2 °C limit, and those expected if country pledges/commitments will be met, and underlines the necessary new global climate agreement for curbing greenhouse gas emissions as soon as possible.

However, future emission trends will be determined by the collective emissions from all countries, partly due to developments that are controlled by government policies and those that are more autonomous, such as economic and technological developments that each have inherent uncertainties. Examples of recent changes in government policies aimed at mitigating greenhouse gas emissions are the EU's new climate and energy package, China's actions to control its coal consumption increase, and policy changes in the United States to further increase the country's gas production (primarily from shale gas wells) to continue a shift from coal to gas. The China–United States 'carbon deal' of 12 November 2014 is an example of international negotiations on national emission targets to mitigate climate change. The recent global emissions trend shows national policies collectively do reduce the rate of increase of global CO_2 emissions. The big outstanding question is: when will global CO_2 emissions level-off and start declining in absolute numbers and at what rate?

The CO_2 emissions for the 1990–2013 time series for all countries can be downloaded from the EDGAR website: http://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts1990-2013.
For an interactive infographic on global CO2 emission trends, see http://www.pbl.nl/globalco2 and for a summary of the greenhouse gas emission reduction proposals (pledges) and domestic policies of 19 major countries and regions and the impact on the emissions by 2020 see the interactive Climate Pledge-Act-Review tool: http://infographics.pbl.nl/climate-pledge-act-review-tool/

ONE

Introduction

This report presents the results of a trend assessment of global CO_2 emissions up to 2013 and updates last year's assessment (Olivier et al., 2013). This assessment focuses on the changes in annual CO_2 emissions from 2012 to 2013, and includes not only fossil-fuel combustion on which the BP (2012, 2013, 2014) reports are based, but also incorporates other relevant CO_2 emissions sources including flaring of waste gas during gas and oil production, cement clinker production and other limestone uses, feedstock and other non-energy uses of fuels, and several other small sources. The report clarifies the CO_2 emission sources covered, and describes the methodology and data sources. For the 2010–2013 period, more details are provided in Annex 1, including a discussion of the degree of uncertainty in national and global CO_2 emission estimates.

This assessment excludes CO_2 emissions from deforestation and logging, forest and peat fires, from post-burn decay of remaining above-ground biomass, and from decomposition of organic carbon in drained peat soils. The latter mostly affects developing countries. These sources could add as from 10% to 20% of CO_2 to global emissions according to different authors (Van der Werf et al., 2009; Harris et al., 2012). However, these percentages are highly uncertain and show a large annual variability. Such variability is also one of the reasons why emissions and sinks from land use, land-use change and the forestry sector (LULUCF) are kept separately in reporting under the UN Climate Convention (UNFCCC) and the Kyoto Protocol. For the same reason, the emissions from the LULUCF sector are not included in this assessment. Information on recent emissions from forest and peat fires and post-burn emissions is being assessed by the *Global Carbon Project*, which has published a comprehensive assessment of the global carbon budget including all CO_2 sources and sinks (GCP, 2014; Le Quéré et al.,2014).

Chapter 2 presents a summary of recent CO_2 emission trends, per main country or region, including a comparison between emissions per capita and per unit of Gross Domestic Product (GDP), and of the underlying trend in fossil-fuel production and use, non-fossil energy and other CO_2 sources. Specific attention is given to a comparison of emission data used in the fifth assessment report (AR5) of Working Group III (WG III) of the Inter-governmental Panel on Climate Change (IPCC) (IPCC, 2014a) and in the Global Carbon Project (GCP, 2014) (Section 2.7). This chapter also summarises the main conclusions on trends, mitigation achievements and prospects and the main conclusions of WG III regarding global greenhouse gas emissions (Section 2.1).

Chapter 3 focuses on the energy trends and shifts in the energy mix, with a special focus on fossil fuels, renewable energy and nuclear energy. In addition, the extent to which structural changes have caused the observed slowdown in the increase in global CO_2 emissions is discussed. For more information on energy efficiency improvements and carbon capture and storage (CCS) activities, please see last year's CO_2 report (Olivier et al., 2013).

National CO_2 emissions here have been accounted for in accordance with the official IPCC reporting guidelines, approved and used by countries to report their national greenhouse gas emissions to the UN Climate Convention (UNFCCC) and Kyoto Protocol and based on domestic activities that generate greenhouse gas emissions ('actual' national emissions) (IPCC, 2006). However, due to the use of other data sources and emission factors, the data reported here will differ somewhat from the emissions officially reported by the individual countries to the UNFCCC. Nevertheless, data are generally consistent within the related uncertainty estimated for both data sets (see Annex A1.1).

1.1 Methodology and data sources used

This report assesses the trend in global CO_2 emissions with a focus on the contribution of fossil fuel use. For a comprehensive assessment of the trends in all

Box 1.1 Changes compared to the 2013 CO_2 report

For the sake of comparison and readability, this 2014 report follows the structure of last year's 2013 report. Please note that apart from the numerical changes for the last year reported, the main textual changes can be found in the following sections:

- 2.1 (Slowdown in the increase in global CO_2 emissions);
- 2.2 (Trends in seven largest emitting countries/regions);
- 2.7 (Comparison with other global CO_2 emissions inventories).

In addition:

- 2.5 (on hydraulic fracturing of shale oil and gas) has a short new paragraph on the latest developments;
- 3.2 (on trends in fossil fuel consumption and fuel mix) shows the trend and mix of the total primary energy supply (TPES) for China, United States, European Union (EU28) and the world as a whole.

This study provides CO_2 time series 1990–2013 per country, which are also available on http://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts1990-2013

greenhouse gas emissions up to 2010, also including CO_2 from forest fires and other land-use change and the non-CO_2 greenhouse gases such as methane and nitrous oxide, which contribute about one quarter to the global total CO_2 eq greenhouse gas emissions, we refer to the Fifth Assessment report of IPCC Working Group III 'Mitigating of Climate Change', for which EDGAR 4.2 provided data.

For global CO_2 emissions from 1970 to 2008 we use the EDGAR 4.2 data set (JRC/PBL, 2011) for greenhouse gases, which result from a joint project of the European Commission's Joint Research Centre (JRC) and the PBL Netherlands Environmental Assessment Agency, published in November 2011 because it covers all world countries with a detailed sectoral breakdown and consistent time series. This data set provides greenhouse gas emissions per country and on a 0.1 x 0.1 degree grid for all anthropogenic sources identified by the IPCC (JRC/PBL, 2011) for the 1970–2008 period. Although the data set distinguishes about 25 source categories, emissions are estimated for well over 100 detailed categories as identified in the Revised 1996 IPCC guidelines for compilation of emission inventories (IPCC, 1996). The core EDGAR 4.2 dataset was extended to 2010 using a fast-track approach for CO_2 from fossil fuel combustion based on IEA (2012) fossil fuel-use trends for 2009–2010. This dataset is used for the for the greenhouse gas section in the CO_2 report of IEA (Olivier and Janssens-Maenhout, 2014) and combined with the latest estimates of the IEA for CO_2 emissions from fossil fuel combustion for global greenhouse gas emission overviews in the Fifth Assessment Report of the IPCC Working Group III on Mitigation of Climate Change (IPCC, 2014a). This extended EDGAR 4.2 FT2010 data set is also used for this CO_2 trend assessment.

EDGAR 4.2 includes CO_2 emission factors for cement production per tonne cement produced and taking into account the decreasing share of clinker in cement. In addition to cement production, EDGAR 4.2 includes also other industrial non-combustion processes, such as the production of lime and soda ash (2A) and carbon used in metal production (2C). All sources of CO_2 related to non-energy/feedstock uses of fossil fuels were estimated using the Tier 1 methods and data recommended by the 2006 IPCC's guidelines for national greenhouse gas inventories (IPCC, 2006). Collectively, the other carbonate sources added about 30% to global cement production CO_2 emissions in 2008, which are not estimated in most other CO_2 datasets (see Table 2.3 in Section 2.7). More information on the data sources and methodologies used can be found in Olivier and Maenhout (2014), which is part III of IEA (2014a).

Although not used in this study, the EDGAR 4.2 data set also includes annual CO_2 emissions from forest fires and peat fires as well as fires in other wooded land, grassland and savannahs estimated by Van der Werf et al. (2006). Also not used here, but included in the EDGAR 4.2 data set are the significant, albeit highly uncertain, CO_2 emissions from the decay of organic materials of plants and trees, which remain after forest burning and logging, and from drained peat soils (JRC/PBL, 2011), while net carbon stock changes (resulting in CO_2 emissions or carbon storage) for forests, based on data from the FAO's Forest Resources Assessment (FAO, 2010) are included in the EDGAR 4.2 data set for completeness.

For each country, the trend from 2008 onwards has been estimated by either using the trend in the appropriate activity data or by approximating this trend using related statistics as the estimator. For the fuel combustion emissions (1A) that account for about 90% of total global CO_2 emissions, excluding forest fires, 2008 emissions were divided per country into four main fuel types for use as trend indicators. These fuel types are coal and coal products, oil products, natural gas, and other fuels (e.g., fossil-carbon containing waste oils). For each sector, the 2008–2011 trend was based on IEA CO_2 data (for 2008–2010: IEA, 2012a; for 2010–2011: IEA, 2013b), and the 2011–2013 trend was based on BP data released in June 2014 (BP, 2014), except for coal consumption in China in 2012 and 2013, for which data from the IEA (2014b) was used showing a 2.4% increase in coal consumption in 2012, and the National Bureau of Statistics of China (NBS, 2014b) which reported a 3.7% (actual) increase in 2013 over 2012. A similar approach was used for the other source sectors.

To estimate the trend for the 2011–2013 period, all CO_2 emissions have been aggregated into five main source sectors (corresponding IPCC category codes in brackets):
(1) fossil-fuel combustion (1A), including international ‘bunkers’, (marine and aviation),
(2) fugitive emissions from fuels (1B),
(3) cement production and other carbonate uses (2A),
(4) feedstock and other non-energy uses of fossil fuels (2B+2C+2G+3+4D4),
(5) waste incineration and fuel fires (6C+7A).

More details on the methodology and data sources are presented in Annex 1. Data quality and uncertainty in the data are also discussed in this Annex. The uncertainty in CO_2 emissions from fossil-fuel combustion using international statistics is discussed in detail by Marland et al. (1999) and Andres et al. (2012) and general uncertainty characteristics in global and national emission inventories in Olivier and Peters (2002). Differences with the previous CO_2 report of 2013 by Olivier et al. (2013) are given in Box 1.1.

TWO

Results

2.1 Slowdown in the increase in global CO_2 emissions confirmed and continued

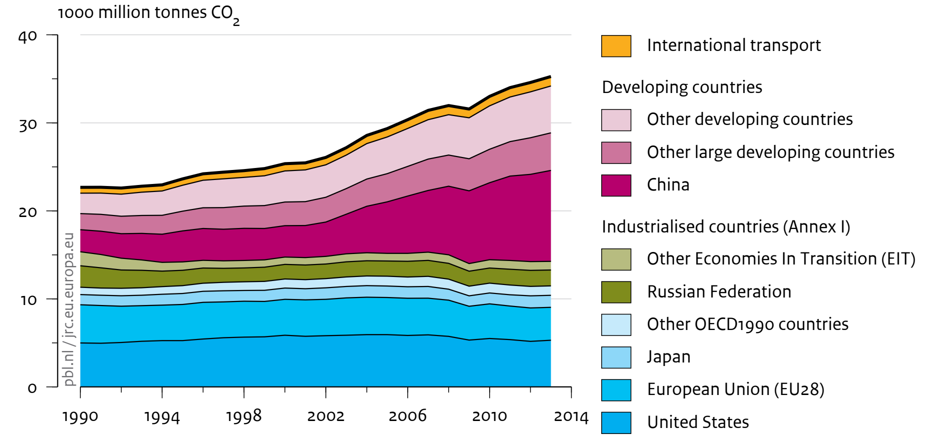
Global CO_2 emissions reached a new high of 35.3 billion tonnes (Gt) CO_2 (Figure 2.1) in 2013, which is an increase of 0.7 Gt or 2.0% compared to the previous year. This moderate increase is similar to the actual increase in 2012 of 0.6 Gt or 1.7% (excluding leap year correction). After an average annual increase of CO_2 emissions of 1.1 Gt or 3.8% per year since 2003 – when excluding the effect of the credit crunch recession years 2008 and 2009 – the annual increases in 2012 and 2013 in global CO_2 emissions are about half of the increases in the preceding decade, albeit higher than the average annual increase in the 1995–2002 period. The average annual increase over the 1995–2002 period (after recession in the former Soviet Union countries) was about 1.2% or 0.4 Gt CO_2 per year. The increase in emissions over the 2012–2013 period is much smaller than expected, given that in 2012 and 2013 the global economy grew by 3.4% and 3.1%, respectively, which is slightly less than the average annual 3.9% growth rate of GDP since 2003 (again excluding the 2008–2009 years) (IMF, 2014). Within the total increase in global emissions in 2013, there are remarkable differences between countries.

Global coal consumption (responsible for about 40% in total CO_2 emissions) grew by 2.7% in 2013, well below the decadal average of 4%. China contributed two-thirds to the net growth and India and the United States both about one-fifth. We note that in BP's release of last year the increase in China's coal consumption in 2012 was estimated to be 6.4%, while the Chinese NBS reported this to be 2.5%. BP (2014) revised this coal consumption estimate with a 5.4% increase in 2012 compared to 2011. The BP (2014) and NBS (2013) estimates for coal consumption growth in 2012 have been replaced with the 2.4% increase that was officially reported in detail by the International Energy Agency (IEA, 2014b) for 2012. For 2013, the (actual) coal consumption increase in China in 2013 was 3.7%, in both the BP report (2014) and that of the National Statistics Bureau of China (NBS, 2014b), which was applied in the 2012 estimate (based on IEA, 2014b). The global consumption of oil products increased by 1.1% in 2013, somewhat below the historical trend of 1.3% annually, with China contributing more than one third and the United States and Brazil about 30% and 15%, respectively. Consumption of natural gas increased globally by 1.1% in 2013, much lower than the historical trend of 4.3%, annually, with China and the United States contributing both about 40% and Brazil about 15% to the net growth (BP, 2014).

The six largest emitting countries/regions (with their share in 2013 between brackets) were: China (29%), the United States (15%), the European Union (EU28) (11%), India (6%), the Russian Federation (5%) and Japan (4%) (Figure 2.2). Remarkable trends were seen in the top 3 emitting countries/regions, which account for 55% of total global CO_2 emissions. In China emissions increased by 4.2%, while in the United States emissions saw a rebound of 2.5% in 2013 after a decrease of 3.8% in 2012. The European Union as a whole also saw a decrease of 1.4% in 2013 compared to 2012. In the aftermath of the Fukushima nuclear accident, Japan's CO_2 emissions that showed a 6.5% increase in 2012, saw a small 0.6% decrease in 2013. Within the European Union, increases were seen in, for example, France and Germany, whereas emissions decreased in Spain (10.8%), Italy (5.5%) and the United Kingdom (2.6%). The increase in China was equivalent to about 60% of the net global CO_2 increase in 2013; for the United States and India this was roughly 15%, whereas the European Union experienced a decrease of 10% in 2013 expressed as a fraction of the net global emission increase in 2013.

China's CO_2 emission increase of 4.2% in 2013 was about 6 percentage points lower than its historical average 10% increase in emissions in the 11 years between 2001 and 2011. This was primarily due to a decline in electricity and

Figure 2.1
Global CO_2 emissions per region from fossil-fuel use and cement production



Source: EDGAR 4.2FT2010 (JRC/PBL 2012); BP 2014; NBS China 2014; USGS 2014; WSA 2014; NOAA 2012

fuel demand from the basic materials industry, possibly due to the slowdown in economic growth when the *stimulus package* was terminated and the production of hydropower rebounded, aided by an increase in the use of renewable energy and by energy efficiency improvements (IEA, 2014d). The somewhat higher annual increase compared to 2012 was due to an uptake of production increase by the heavy industry compared to 2012.

In the United States, CO_2 emissions increased by 2.5% in 2013 following a 3.8% decrease in 2012 (BP, 2014). Main drivers of the increase were a shift from natural gas to coal in power generation that caused a 4.4% increase in coal consumption, together with an increase of 2.2% in total natural gas consumption, in particular in the building sector. The fuel shift in the power sector was caused by relatively higher gas prices compared with coal prices. The increase in natural gas use in 2013 was due to a much larger demand for space heating than in 2012, which was a year that saw a very mild winter (EIA, 2013c).

The European Union's CO_2 emission reduction of 1.4% in 2013 was 1.1% lower than the historical trend, and this was partly due to continued weak economic conditions after 2009, with a 0.3% decrease in total GDP in 2012 (in PPP units; IMF, 2014) followed by an increase of 0.1% in 2013 (Eurostat, 2014d). The companies covered by the EU *Emissions Trading System* (EU ETS), covering more than 40% of the EU's CO_2 emissions, together reported a 3% decrease in CO_2 emissions for 2013 compared to 2012 (EC, 2014b). In 2013, the European Union saw decreases of 2.2%, 1.4% and 2.7% for primary energy consumption of oil, gas and coal, respectively (BP, 2014). These drops were mainly due to a 0.5% decline in average industrial production and a 1.2% reduction in electricity production, combined with an increased use of renewable energy with a share of 11.5% in primary energy consumption in 2013, compared to 10.3% in 2012 (Eurogas, 2014; Eurostat, 2014c).

The moderate 1.7% and 2.0% increases in global CO_2 emissions in 2012 and 2013 seem remarkable in times when global economic growth of 3.1% (2013) was about two-thirds of the average growth levels of the last decade. Within this percentage, however, there are notable differences in the performance of various groups of countries. Economic growth in the 24 first OECD countries[1], with 1.1% in 2013, was lower than half the average over the 2003–2007 period (2.5%), while the 2% economic growth in the group of 14 'Economies In Transition' or EIT[2] countries in 2013 was not even one third of the level of the 2003–2007 trend (7.1%). The developing ('Non-Annex I') countries[3] with emerging economies showed a growth rate of 4.7% in 2013 which is about two-thirds of the average growth over the 2003–2007 period (7.4%) (IMF, 2014; World Bank, 2014). However, note that the not energy-intensive service sector currently contributes about 70% to global GDP (for the various countries it ranges between from 20% to 87%), and, thus, increases in total energy consumption are not always closely related to overall economic growth, since overall energy consumption is dominated by more energy-intensive sectors such as manufacturing industries that have only a small share in total GDP (World Bank, 2014).

It is obvious that energy-intensive activities are of the highest relevance for the CO_2 emissions trend and that fossil-fuel combustion accounts for 90% of total CO_2 emissions (excluding deforestation and other land uses). Power generation remains the most important sector in

Box 2.1 Main conclusions on anthropogenic global greenhouse gas emissions from IPCC's Fifth Assessment Report (AR5) (IPCC, 2014a,b)

- The effects of anthropogenic greenhouse gas emissions have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century.
- Cumulative emissions of carbon dioxide largely determine global mean surface warming by the late 21st century and beyond.
- It would be possible, using a wide array of technological measures and changes in behaviour, to limit the increase in global mean temperature to 2 °C above pre-industrial levels.
- Substantial emissions reductions over the next few decades can reduce climate risks in the 21st century and beyond.
- Without additional mitigation efforts beyond those in place today, and even with adaptation, warming by the end of the 21st century will lead to high and very high risk of severe, widespread, and irreversible impacts, globally.
- There are multiple mitigation pathways that are likely to limit the increase in global mean temperature to 2 °C above pre-industrial levels. These pathways would require substantial emissions reductions over the next few decades and near zero emissions of CO_2.
- Many adaptation and mitigation options can help address climate change, but no single option is sufficient by itself. Mitigation options are available in every major sector.

relation to fossil-fuel consumption; therefore, the choice of fossil fuel by the power sector is of the utmost importance. More details on recent energy trends are presented in Chapter 3 and, on sector-specific shares in CO_2 emissions, in Table 3.1. In contrast to the power industry for which a relatively large variety of fuels can be selected (from fossil fuel to nuclear fuel and renewable energy sources), other energy-intensive sectors, such as manufacturing and construction, are less flexible in the short term.

CO_2 emissions from cement clinker production (the largest source of non-combustion-related CO_2 emissions, contributing about 4.8% to the global total or about 10% when including combustion-related emissions for heating the kilns) increased globally by 7.4% in 2013 after a 4.8% increase in 2012, mainly due to a 9.3% increase in the production in China, which accounted for more than half of total global production. The 2013 trend in CO_2 emissions from gas flaring, contributing about 1% to global total emissions, is not yet known, due to the absence of data updates from the NOAA satellite observation systems following changes in sensors.

Last year's report (Olivier et al., 2013) suggested that the small increase in emissions in 2012 of 1.7% (1.4% when including a leap year correction) could be a first sign of a slowdown in the increase in global CO_2 emissions. The 2013 growth rate of 2.0% is a continuation of the slower annual emission growth rate. Moreover, energy consumption data on China in the first half of 2014 also shows a continuation of this 'stagnation' in annual growth. Of course, further mitigation of fossil fuel use will be needed not only to curb the increasing emissions trend over time but also to have an absolute decrease in the global greenhouse gas emissions trend, which the Working Group III report on Mitigation and the Synthesis Report of the Fifth Assessment of IPCC (AR5) (IPCC, 2014a,b) concluded as necessary to substantially mitigate anthropogenic climate change within this century. Technically, these reductions are still feasible according to IPCC WG III (IPCC, 2014b; UNEP, 2014), but need to be widely implemented soon, if governments wish future global greenhouse gas emission levels to be compatible with pathways that could limit global warming in this century to 2 °C (see Box 2.1).

This report assesses the trend in global CO_2 emissions, mainly from fossil fuel use. For a comprehensive assessment of the trends in all greenhouse gas emissions up to 2010, also including CO_2 from forest fires and other land-use change and the non-CO_2 greenhouse gases such as methane and nitrous oxide, which contribute about one quarter to the global total CO_2 eq greenhouse gas emissions, we refer to the Fifth Assessment report of IPCC Working Group III 'Mitigating of Climate Change' (IPCC, 2014a). For an analysis of the more recent trends in all greenhouse gas emissions of all major countries, including CO_2 emissions from forest fires and other land-use change and non-CO_2 greenhouse gases, the pledges by the countries to mitigate national emissions by 2020 and an assessment of the resulting national emissions trend by 2020, we refer to Den Elzen et al. (2013). Further analysis may also show whether the recent national CO_2 trends as estimated in this report fit into the total national greenhouse gas emissions trends expected from analyses of country pledges (see e.g. Den Elzen et al., 2013, 2104; UNEP, 2104).

In line with the Fifth IPCC Assessment Report (AR5) (IPCC, 2014a,b), we recognise that more knowledge and data (in particular the IPCC AR5 database, but also within the *Global Carbon Project* (Le Quéré et al., 2014) are now available on the sources of these emissions. In contrast to the previous IPCC assessment report published seven years ago, presently emerging economies and developing countries in general now have a share of more than 50% in current global greenhouse gas emissions and in their annual increase.

However, future emission trends will be determined by the collective emissions from all countries, partly due to developments that are controlled by government policies and more autonomous developments, such as economic and technological developments which have individually inherent uncertainties. Examples of the last category are:

- the dependence of the use of new technologies on the energy price: the oil price, recently (November 2014) dropping to well below USD 80 per barrel, affects the economic feasibility of new energy sources, such as shale oil production and production of shale gas, which may affect natural gas prices worldwide;
- increased transport and storage capacity of LNG may expand intercontinental trade in LNG and thus influence continental natural gas markets;
- overcapacity and flexibility in power generation may cause rapid changes in the fuel mix used by utilities in case of changes in the relative prices of gas and coal.

Examples of recent changes in government policies aimed at mitigating greenhouse gas emissions are China that starts to control its coal consumption increase with levies since October 2014 (Reuters, 2014) and the United States that further increases its gas production (primarily in an unconventional way) to continue a shift from coal to gas. On 12 November 2014, China and the United States made a joint announcement on climate change and clean energy cooperation, which is referred to as the so-called 'China-US carbon deal'. (White House, 2014a, 2014b; Podesta and Holdren, 2014). First analysis of the targets and actions announced led to various reactions regarding the question of how big this deal actually is (e.g. Ladislaw et al., 2014; Levi, 2014; Olesen, 2014; Rom, 2014; Victor, 2014; Wong, 2014) and whether it may result in a breakthrough at the international negotiations on national emissions targets to mitigate climate change in Paris next year. The European Union recently also committed to a new climate and energy package with collective commitments on energy efficiency, renewable energy and greenhouse gas reductions by 2030, partially through a reformed EU Emissions Trading System with a so-called Market Stability Reserve (EC, 2014b). These examples show both the potential and the uncertainty in reducing the rate of increase and curbing global CO_2 emissions in the near future. The recent global emissions trend shows national policies collectively do reduce the rate of increase in global CO_2 emissions. The big question is that of when and how fast global CO_2 emissions will level off and start decreasing in absolute numbers.

We note that all national emissions inventories are subject to uncertainty. Uncertainties in national CO_2 emissions vary between countries; in this report ranging from 5% to 10% (95% confidence interval), with the largest uncertainties concerning the data on countries with fast changing or emerging economies, such as Russian Federation data on the early 1990s and data on China since the late 1990s, and the most recent statistics, based on Marland et al. (1999), Tu (2011), Andres et al. (2012) and Guan et al. (2012). Moreover, newly published statistics are often subject to subsequent revisions. Therefore, for China and the Russian Federation, we assumed 10% uncertainty, whereas for the European Union, the United States, Japan and India, a 5% uncertainty was assumed. Our preliminary estimate for total global CO_2 emissions in 2013 is believed to have an uncertainty of about 5% and the increase of 2.0% may be accurate to within 0.5%. For more details, see Section A1.4 of Annex 1.

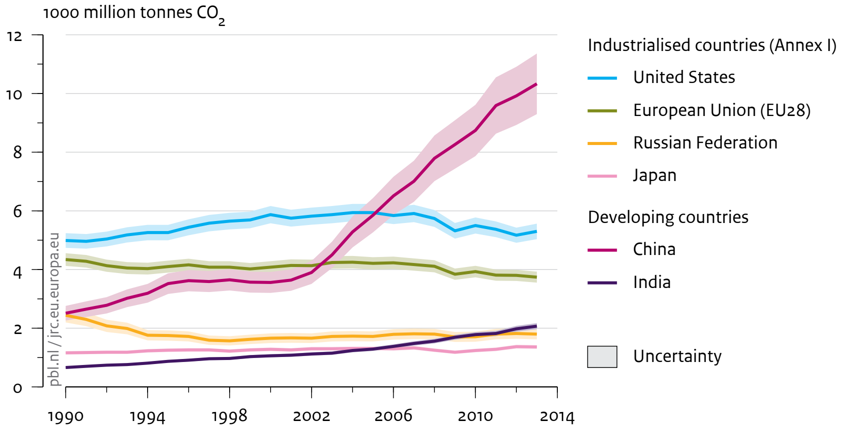
2.2 Different trends in the six largest emitting countries/regions

This section analyses the emissions and changes from the six largest emitting countries/regions in descending order of importance. The largest CO_2 emitting country by far is China, which share of 29% in 2013 was much larger than the second-largest, the United States, with 16% and the European Union with 11% (Figure 2.2).

A comparison between the shares of national GDP (on the basis of Purchasing Power-Parity (PPP) in global GDP expressed in USD showed that the top 3 countries/regions are very close (World Bank, 2014): the share in the world economy of the European Union, the United States and China was 17%, 16% and 15%,respectively. At a distance these three are followed by India (7%), the Russian Federation (3%) and Brazil (3%). However, when looking at their contributions to the global economic growth over the last ten years, which was 47% since 2002, China contributed 31%, India 11%, United States 8%, European Union 6%, Russian Federation 4% and Brazil and Indonesia 3%.

Figure 2.2

CO_2 emissions from fossil-fuel use and cement production in the top 5 emitting countries and the EU



Source: EDGAR 4.2FT2010 (JRC/PBL 2012); BP 2014; NBS 2014; USGS 2014; WSA 2014; NOAA 2012

In 2013, the growth in the world economy was around 3.1%, about four-fifths of that in the last 10 years, apart from the global credit crunch years of 2008 and 2009, but with large differences between the largest countries/ regions. The economy of the United States grew in 2013 by 1.9%, which is similar to their average historical growth rates, whereas the EU economy increased by 0.1% in 2013 versus the annual average of 1.3%. China's annual economic growth in 2013 of 7.6%, and 7.5% in 2012, was only about three-quarters of the ten year annual average, so far the lowest since 2000. In contrast, the economic growth of the Russian Federation of 1.3% in 2013 was only one quarter of the last decade average. The economic growth rates in 2013 of India (5.0%) and Brazil (2.5%) are two-thirds of their annual average over the last 10 years (World Bank, 2014).

Please note that these GDP statistics do not yet reflect the revisions of the definition of the Gross National Product (GDP) as adopted the updated international guidelines for national economic account in the 2008 UN System of National Accounts ('SNA 2008') (UN, 2009). For example the World Bank data used for the EU28 countries, the United States and China do not yet include these revisions, but these countries have in 2014 published their first revisions (United States and European Union) or their plans to do so (IMF, 2014).

For most industrialised countries, the past decade has been characterised mainly by the 2008–2009 recession, which has since been slowly recovering. In 2013, most OECD countries outside Europe, such as the United States, Canada and Australia, saw their historical economic growth rates continued. Japan showed a GDP growth of 1.5%, almost one percent higher than its historical average growth rate of 0.8%.whereas in several western EU countries, economic growth was very small (e.g. Germany, France) or even negative (Italy, Spain and the Netherlands).

2.2.1 China

In 2013, China's CO_2 emissions increased by 4.2% ('actual') to 10.3 billion tonnes. Together with the 3.4% increase in 2012 these are the slowest rates of increase in a decade compared with the annual average increase of 10.1% of the ten preceding years. The increase in 2013 was mainly caused by a relatively small increase of 3.7% in domestic coal consumption, as reported by BP (2014) and NBS (2014b), whereas in the preceding decade, the annual growth rate was mostly around 10%. Coal consumption was responsible for three-quarters of China's CO_2 emissions from fossil-fuel combustion. In contrast, the increase in natural gas consumption was 10.5% in 2013, following annual increases of about 18% on average. The increases of about 3 and 4% were the lowest since 2001, the year after which the increase in Chinese emissions on average accelerated from about 3% to 10%, annually. Even in the two recent credit crunch recession years, China's CO_2 emissions continued to increase by about 6% per year.

This relatively small emissions increase in 2013 was consistent with the relatively small increase of 7% in thermal power generation (predominantly coal-fired power plants), reported by the National Bureau of Statistics of China (NBS, 2014b). The 'small' increase in the kWh's generated by coal-fired power plants, which produce about three-quarters of total electricity, was due to the still relatively 'small' growth rate of total electricity consumption of 7.5% in 2013, compared to the decade

Table 2.1

Growth rates in 2012 and 2013 in selected energy trend indicators in China, compared to average growth rates since 2002

Indicator	Average annual growth rate 2002–2011 (± 1SD*)	Growth rate 2012	Growth rate 2013	Growth rate H1 2014 compared to H1 2013
CO_2 emissions	10.2 ± 3.8%	3.4%	4.2%	2%
GDP	10.6 ± 1.7 %	7.7% [7.5%]	7.7% [7.6%]	7.5%
Cement	12.2 ± 4.7 %	5.3%	9.3%	
Crude steel	16.5 ± 7.5 %	4.7% [3.7%]	7.6% [9.3%]	
Electricity consumption	12.3 ± 3.4 %	5.9%	7.5%	5.3%
Coal consumption	10.5 ± 5.1 %	2.4%	3.7%	

** Standard Deviation*

Sources:

2002–2011, 2012: GDP (constant prices) (World Bank, 2014), cement and crude steel (USGS, 2014), electricity (IEA, 2014b; BP, 2014);

2012 and 2013: NBS (2013, 2014b); between brackets: World Bank (2014) and WSA (2014);

H1 2014 (first half year): GDP (NBS, 2014c), CO_2 emissions (Ministry of Environmental Protection China, 2014, 28 Aug; Xinhua, 2014, 10 Sep), electricity consumption (Xinhua, 2014, 15 July).

before, which showed double digit growth figures, and was the lowest since 1998 (2008) (Table 2.1). The surge in electricity demand was driven by an uptick of industrial demand that consumes 70% of all electricity produced, as indicated by crude steel, chemicals, cement and automobile production. In addition to increasing output, also the electrification (share of electricity in total energy demand) of the industry is steadily increasing over time (Table 2.1 and Davidson, 2014).

In addition, hydropower generation increased by 4.5% following an expansion of installed capacity of 12.5% by the end of 2013. Coal-fired power had a three-quarter share in the increase in electricity production in 2013, whereas the increase in hydropower represented one-eighth of the electricity production increase. Wind power, with a production increase of about 37%, had a 10% share in the expansion, and nuclear power contributed by about 5% due to an increase in production of 13.6% (BP, 2014; REN21, 2014). The increase in wind power has benefited from improved grid interconnection and, possibly, from reduced curtailment (Davidson, 2014).

After years of double digit increases in GDP, China's increase in 2012 and 2013 was only 7.7% [7.5%] and 7.7% [7.6%], respectively (NBS, 2014c; World Bank, 2014). Unlike in developed countries, China's manufacturing industry is the sector with the largest consumption of electricity and fuels. Therefore, the demand for energy in general is largely driven by trends in basic materials production (Houser, 2013).

Restrictions on investments in construction activities (buildings, power plants, infrastructure), and the termination of economic stimulus package to reverse the impact of the global recession years 2008 and 2009, resulted in a substantial slowdown in the growth rate of the demand for materials, halving the growth in this sector. Thus, not only the growth of the Chinese economy but also of other key energy trend indicators, such as production of cement, steel and electricity, decreased significantly in 2012 and 2013, compared to the high annual growth rates over the 2002–2011 period. The growth rate in cement, steel and electricity production was almost half of that observed in most previous years (except for 2007–2008[4]) (see Table 2.1). Nevertheless, China's 2012 and 2013 GDP growth of about 7.5% was only about 3% lower than the decadal average of around 10%.

So, the slowdown of the growth of CO_2 emissions in China as observed in 2012 has continued in 2013. Still, again the question can be asked whether this is accidental or a more structural change in the trend in China's CO_2 emissions, in line with its own target for a maximum level of energy consumption by 2015 and its shift to gas with a natural gas share of 10% by 2020.

The first reports on the development in the first half year of 2014 suggest that the slowdown of the increase continues in 2014 as well. The Ministry of Environmental Protection (2014) reported that the CO_2 emissions intensity per unit of GDP declined by 5% and the energy intensity decreased by 4.2% year on year (Xinhua, 2014, Sep 10). This decline in CO_2 intensity corresponds with an annualised growth of 2% in CO_2 emissions, suggesting that the slowed growth continues, if not further decreases. This is corroborated by (a) Provincial Environmental Plans with coal consumption targets (Shuo and Myllyvirta, 2014), (b) hydropower increased in the first half of 2014 and much more capacity expansion is planned (Kuo, 2014; Bloomberg, 2014), and (c) structural change of the economy towards less energy-intensive activities (Guay, 2014).

In September 2013, the State Council released an 'Airborne Pollution Prevention and Control Action Plan' (Ministry of Environmental Protection China, 2013), in response to the suffering of major Chinese cities of long episodes with high levels of air pollution. The plan contains ten measures to improve air quality by 2017 in the country at large and in specific provinces (Beijing, Tianjin, Hebei) and regions (Yangtze and Pearl river deltas), aimed at specific reductions of the concentration of particulate matter in these areas. These areas will target at a reduction of total coal consumption by 2017 compared to 2012. By 2017, the share of coal in national total energy consumption should be below 65%, down from 68% in 2012 (IEA, 2014b). So apart from caps on provincial coal consumption, 10 of the 31 provinces which account for 38% of total coal consumption in 2012 are targeting at reducing their coal consumption in four years time (Beijing, Tianjin, Hebei, Shandong, Shaanxi, Chongqing, Shanghai, Jiangsu, Zhejiang and Guangdong). Two more (Liaoning and Jilin), accounting for 7% of total coal consumption, aim at reducing growth of coal consumption to below 2% per year (Shuo and Myllyvirta, 2014). Together these 12 provinces – in 2012 accounting for 45% of the national total (NBS, 2014a) – aim at reducing their consumption by 7% or more. In absolute values, this is comparable to the annual CO_2 equivalent greenhouse gas emissions of a country such as the Netherlands. Seventeen more provinces have announced their intention to cap or reduce their coal consumption. Together these 29 provinces cover most of the China's coal consumption.

In 2012 in 10 provinces, accounting for one quarter of total coal use, coal consumption decreased from 2011 to 2012 on average by 5.8%, contributing to the slowdown in 2012 of the annual growth of total national coal consumption to 2.4% per year. Moreover, from 15 October 2014 onwards China levies import tariffs (3%–6%) on coal import. This will reduce the coal import from Australia and Russia, but not from Indonesia (because of free trade agreement) (Reuters, 2014). The discussion in the media has been intensified that China nears 'peak coal consumption' as a result of new clean air policies combined with policies to improvement energy efficiency and to restructure the economy. These analysis vary in their estimates of the time span when that could be happening, anywhere from around 2030 to even before 2020. Citi (2013) explored the consequences and Greenpeace East Asia published April 2014 a short briefing summarising the essentials of the recent change in coal consumption trends in China (Shuo and Myllyvirta, 2014). Many others followed suit, e.g. CarbonTracker (2014), King (2014), Nicola (2014), Pearce (2014), Reuters (2014), Trembath (2014), Tweed (2014) and Vorrath (2014).

Myllyvirta (2014) suggests even that coal consumption may have dropped in the first half of 2014, based on coal production data for that period that dropped by 1.8% and the growth of imports virtually stopped after five years of rapid growth. However, there is considerable uncertainty over the changes in coal stockpiles that could have enabled consumption to grow while production and imports declined.

According to Guay (2014) there is a change from energy-intensive fossil fuel industries such as production of cement, steel and glass and coal-fired power plants to services and other non-energy-intensive economic activities. In fact, the growth in services (excluding real estate) and private consumption has recently outpaced the manufacturing industry.

To meet the carbon intensity target in the 12th Five Year Plan of 17% reduction per unit of GDP in 2015 relative to 2010, China's carbon intensity needs to continue decreasing at a slightly higher rate (4.6%) for the next three years (Houser, 2013). For 2012, the China Greentech Initiative (2013) concluded that China had made 'clear progress in meeting targets related to energy supply' but it 'will need to focus more on its demand-related targets and on improving industrial energy efficiency (where it is currently falling short)'. For 2013, it concluded that 'development and installation of wind power, natural gas, and nuclear energy offer a mixed progress report'. Installed wind power capacity grew by about 25% in 2013, and grid connectivity for wind farms has improved. Only 11% of wind-generated power was not transferred to the grid in 2013, while this was 17% in 2012 and 25% in 2011. Both wind and natural gas power generation capacity seem to be on track based on 12th Five-Year Plan targets. In contrast, nuclear energy has remained relatively stagnant since March 2011' (China Greentech Initiative, 2014).

A more detailed discussion on the uncertainty in Chinese fuel consumption data as reported by different sources is presented in Annex 1, Section A1.4. This discussion, which includes conclusions from recent literature on the accuracy of China's CO_2 emissions (Tu, 2011; Andres et al., 2012; Guan et al., 2012), yields an uncertainty for our estimates of about 5% for most industrialised countries, and in the range of 10% for China and the Russian Federation.

2.2.2 United States

In the United States, in 2013, CO_2 emissions increased by 2.5% to 5.3 billion tonnes, following a 3.7% decrease in 2012. The emissions level in 2012 was the lowest since 1993 and occurred while the economy was growing, whereas, since 2007 CO_2 emissions had been steadily decreasing every year, with the exception of 2010. CO_2 emissions from fossil-fuel combustion, the main source, increased by 2.5% in 2013 compared to 2012, but are still below the 2011 level. When comparing long term trends, we note that while the United States saw a relatively high annual population increase 26% since 1990, its CO2 emissions increased by 6% in this period (for more details see Section 2.3).

The emissions increase in 2013 was mainly due to an increase of 4.4% in the use of **coal** (BP, 2014), mostly in power generation where it regained some share from natural gas since April 2012 due to the low coal prices, which are lower than those of gas and oil (EIA, 2013c).

However, the consumption of **natural gas** also increased, by 2.1% (BP, 2014), primarily due to an increase of 4.8% in the residential sector (EIA, 2014h). The latter is due to a much larger demand for space heating in 2013 than in 2012, when the United States experienced abnormally warm winter temperatures (23% more so-called Heating Degree Days; AGA, 2014). In the first half of 2013 gas consumption by the residential and commercial sectors was 20% above 2012 levels (EIA, 2013e) and also in the industrial sector gas consumption was 3% up from 2012. There was also a lower summer peak load and, therefore, less gas consumed for air conditioning in 2013, due to cooler summer weather compared to 2012 (EIA, 2013c; EIA 2014k).

In contrast, natural gas consumption for electric power production was in the total United States more than 10% lower than in 2012 but still higher than the levels before 2012. Electric power plants are stopped or operated based on their cost of operation, which is determined by the price of the fuel and the plant efficiency (EIA, 2013c). Therefore, trends in gas used for power generation vary significantly by region, depending on plant availability, age and efficiency and the relative cost of fuels to operate them (EIA, 2013b).

The large increase in shale gas production (see Olivier et al., 2013) caused natural gas prices to decline in the first half of 2012 to the lowest level in a decade, leading to a switch to gas-fired power generation and less coal-fired power generation in 2012. Moreover, largely due to these lower gas prices, dry natural gas production showed a much slower growth in 2013 of 0.9% compared to the annual average growth of 4.5% in the preceding years since 2007 when also shale gas production started. Combined with an increase in total demand that was larger than total supply, gas prices saw an upward pressure in 2013 (EIA, 2013e).

However, 50% of power plant capacity additions in 2013 came from natural gas, with more than half located in California. In contrast, about 10% of the capacity addition came from coal, consisting of two plants which were both delayed (EIA, 2014d), and the remaining part of capacity addition was obtained with renewable energy. The increase in 2013 was mainly due to an increase of 4.4% in the use of coal (BP, 2014), mostly in existing power generation.

The US Environmental Protection Agency (US EPA) in September 2014 proposed emission guidelines for the states to address greenhouse gas emissions from existing fossil fuel-fired electric generating units and designed a rule to cut carbon dioxide emissions from existing coal plants by as much as 30% by 2030, compared with 2005 levels (US EPA, 2014b). Currently, coal-fired power plants emit about 30% of total fossil fuel CO_2 emissions in the United States (see Table 3.1), mainly caused by 63% of the operating coal-fired units with over 40 years age (Eilperin and Mufson, 2014). The proposal reflects that different states have a different mix of sources and opportunities and reflects the important role that states have in reducing pollution as partner of the federal government. The EPA plans to finalise the proposal in mid-2015 (US EPA, 2014b). The proposal will mainly affect coal-fired power plants and has generated much debate by industry groups, environmental organisation and politics at state and, most importantly, at national level. Due to the latter, the implementation of this proposed reduction policy is uncertain (Eilperin and Mufson, 2014).

The consumption of **oil products** increased by 1.7% in 2013 (BP, 2014), of which three-thirds was used in the transport sector and the remainder mainly by refineries and the manufacturing and building industries in almost equal shares. According to national statistics, in 2013 total oil consumption in transport increased somewhat by 0.5%, relative to 2012 levels. This is in contrast to most preceding years since 2007, in which annual oil consumption decreased by 2.2% on average, mainly due to the increased energy efficiency of vehicles over time. Biofuel use for transport increased by 7.3% in 2013, increasing their share in transport fuels by 0.3 percentage points to 4.7% (natural gas has a 3% share) (EIA, 2014l). Imports of sugarcane ethanol from Brazil fell by 40% in 2013, which led the United States to become a net exporter of fuel ethanol in 2013 (EIA, 2014i). Conversely, although biodiesel production increased 35% over 2012, this could only partially offset the increased biomass-based diesel consumption 2013, driving up imports to a record level of about half of the domestic consumption (EIA, 2014g).

For a discussion on gas flaring including the role of hydraulic fracturing, we refer to Section 2.4. Recent policy developments on oil and gas production by hydraulic fracturing in the United States are presented in Section 2.5. A discussion on the sources renewable energy is given in Section 3.3. It is worth to mention that, for the United States, the power production of non-hydro renewable energy (biomass, biofuel, solar power, wind power, land fill gas and geothermal sources) has been exceeding that of hydropower since the end of 2013 (EIA, 2014f).

2.2.3 European Union

The European Union, as a whole, after a period of recession saw a slow-moving economic growth in 2013; its GDP in that year increased only by 0.1% compared to 2012 (Eurostat, 2014b) while CO_2 emissions decreased by 1.4%. The economic recession after 2008 influenced the emission trend but only explains less than 50% of the greenhouse gas emission reductions over this period (EEA, 2014b; Eurogas, 2014).

The share of the EU28 in global total CO_2 emissions was 10.6% in 2013 with Germany (2.4%), the United Kingdom (1.3%) and Italy and France (1% each) the largest contributors. Very different trends were noticed in the EU Member States, between 2012 and 2013, with increases in Germany (2.3%), France (1.5%) and Poland (1%) and decreases in Spain (10.8%), Italy (5.5%) and the United Kingdom (2.6%).

For the cement and lime production, between 2012 and 2013 the increase in emissions was 6.8% in the EU28; in particular, emissions increased in France with 6.7%, Germany with 2.7%, Spain with 10.3%, the United Kingdom with 11.7% and in Poland with 9.3%. Only in Italy cement and lime production decreased by 8.6% (USGS, 2014).

Regarding transport sector, CO_2 emissions in the EU28 decreased in rail freight by 0.9% between 2012 and 2013 and the road freight increased only by 0.3% (International Transport Forum, 2014).

In 2013, CO_2 emissions from fossil fuel combustion in EU28 declined by 1.4% compared with 2012, which is more than the 0.4% decrease in 2012 in our present dataset. We note that Eurostat, the statistical office of the European Union, estimates for only CO_2 from fossil fuel combustion a decrease in 2013 of 2.5% compared to a 1.6% decrease in 2012 (Eurostat, 2014b). According to Eurostat, CO_2 emissions decreased in almost all Member States, except Denmark (6.8%), Estonia (4.4%), Portugal (3.6%), Germany (2%), France (0.6%) and Poland (0.3%) (Eurostat, 2014b). The main causes of the decline are decreasing fossil fuel consumption and decreasing CO_2 emissions in industry and power plants that are part of the EU *Emissions Trading System* (ETS) (see below).

The EU's primary energy consumption of oil, gas and coal decreased in 2013 by 2.2%, 1.4% and 2.7%, respectively (BP, 2014). These decreases were mainly driven by a 1.2% reduction in electricity production, increased competition from renewable energy, and a decline by 0.5% of average industrial production in the EU28 compared with 2012 affected the demand from industry (Eurogas, 2014; Eurostat, 2014c).

Emissions from power plants and manufacturing industry installations in the EU28 participating in the EU *Emissions Trading System* decreased by 3% in 2013 (EC, 2014b). Further reductions are expected also in the other sectors under *Effort Sharing Decision* (ESD) policy instrument, which establishes binding annual targets for GHG emissions not covered by EU ETS for all Member States for the 2013–2020 period (Eurostat, 2014c).

Coal consumption decreased by 2.7% for the EU28 primarily by a decline of 6.5% in the United Kingdom (after an increase of 24% in 2012), 31.7% in Spain (after an increase of 23% a year before), 4.5% in Czech Republic and 10.5% in Italy, versus increases in France, Germany, Poland and the Netherlands of 6.7%, 1.5%, 3.3% and 1.7%, respectively (BP, 2014). Almost all coal consumption in these countries was for power generation, except in a few of them, where iron and steel production also had substantial shares. For example, in 2013 Germany contributed to the global iron and steel production by 2.5%, Italy by 1.5%, and Spain and France by 1% each (USGS, 2014; WSA, 2014).

In Europe, there is considerable dynamics around the (expected) decommissioning of old coal-fired power plants, the mothballing of both coal and gas plants and the construction of new plants as older coal-fired power stations are to be replaced by new more efficient coal-fired or natural gas plants, or by wind and solar power (see e.g. Cardecott and McDaniels, 2014). Some of the main changes in the coming years in coal-fired power production are described below.

The German Government has been shifting away from nuclear energy, and over the past decade, has expanded its renewable energy sector, but no specific policy is in place for coal and lignite. Coal mining in Germany is subsidised until 2018; lignite production does not need subsidies and more than 90% is used for electricity and heat generation (Poyry, 2013). In 2011 and 2012, old coal-fired power plants with a total capacity of 1,700 MW were permanently closed down. However, also 2 new coal-fired plants with a total capacity of 2,700 MW started production in 2012, 2 plants with a total capacity of 1,500 MW started production in 2013, and 8 are currently (2014) under construction, which will provide a total additional capacity of 7,000 MW in the coming year (Sourcewatch, 2013a; Bundesnetzagentur, 2014).

In the Netherlands, three new coal-fired power plants with a total capacity of 2,700 MW started production in 2014. These plants will not replace closed down old power plants, but have been built in anticipation of the closure of some old plants, for which complying with the emission standards set in the *Large Combustion Plants Directive* (LCPD, 2011) is expensive. For example, 85% of Poland's power generation is supplied for about 85% by coal-fired plants, of which two thirds are over 30 years old (CCE Bankwatch, 2013). In most EU Member States, these new coal plants are said to be 'CCS ready', i.e. the infrastructure would allow for a carbon capture and storage (CCS) facility next to the power plant.

The United Kingdom has not constructed any new coal-fired power plants over the last decade (DECC, 2012). Moreover, it has already converted three plants to biomass with a total capacity of 5,160 MW, and closed another four coal-fired plants with a total capacity of 14,670 MW (Sourcewatch, 2013b; Reuters, 2012d; Airlie, 2011).

Spain has also decreased the share of coal in its power generation, considerably, and continues to do so by quadrupling the tax rate on coal and not renewing the subsidies for such coal-fired plants. Since 2010, Spain has been delivering more than 20% of its electricity from renewable sources by widespread deployment of wind power and is investing further in wind and solar technologies (Poyry, 2013). Recently, Spain has made a series of large legislative changes to its renewable energy policy, in order to control the country's growing electricity tariff deficit, turning renewable energy into a fully regulated business resulting in a levelling-off of further growth (Economist, 2013b; Ernst and Young, 2012).

The European Council gives strategic orientations with respect to consensus on ETS, non-ETS, interconnections and energy efficiency and agreed in October 2014 on the 2030 Climate and Energy Policy Framework (EC, 2014h), committing mainly to:

- A binding target of at least 40% domestic reduction in GHG emissions by 2030 compared to 1990, delivered by the European Union collectively through reductions in the ETS and non-ETS sectors;
- A binding target of at least 27% in 2030 is set for the share of renewable energy consumed collectively in the European Union and 27% for improving the energy efficiency;
- To ensure the achievement of a minimum target of 10% of existing electricity interconnections by 2020;
- To increase the EU's energy security for electricity and gas.

To achieve the overall 40% target, the sectors covered by the EU emissions trading system (EU ETS) would have to reduce their emissions by 43% compared to 2005. Emissions from sectors outside the EU ETS would need to be cut by 30% below the 2005 level. The new Energy Efficiency Directive entered into force in December 2012 and establishes a common framework of measures for the promotion of energy efficiency within the Union in order to ensure the achievement of the Union's 2020 20 % headline target on energy efficiency and further improvements towards 2030 (EC, 2014c). The European Council agreed to review by 2020 the 2030 targets, which remain so far indicative. The willingness of all 28 EU Member States to go together for 40-27-27 by 2030 sends a clear message for the next UNFCCC round of COP21 in Paris, 2015. The unanimous backing of the Council on the 40% reduction target, including a 43% target compared to 2005 for the ETS sectors also sends a political signal to the market that the EU ETS remains a major greenhouse gas reduction mechanism for the European Union.

During the first two phases, the EU ETS struggled by oversupply and falling carbon prices – up to one order of magnitude. In addition, so-called windfall profit increased due to free allowances (given through grandfathering) to sectors that can include these potential costs in their price setting. In the first phase from 2005-2007 oversupply was a genuine issue because the Member States had allocated too much, while in the second period 2008-2012 the oversupply was due to a larger than expected emissions drop caused the economic recession. During the third EU ETS phase (from 2013 to 2020) auctioning of allowances (for the power generation) was introduced progressively from January 2013 onwards. Some estimates suggest that the current surplus of allowances amount to 1.5 billion – 2 billion tonnes of carbon and might even worsen before the end of Phase 3 in 2020. The surplus prompted the implementation of 'backloading', involving the removal of 900 million allowances from the market in 2014–2016, which will be reintroduced in 2019–2020, when allowance prices are expected to be more resilient (EC, 2014b).

A new instrument, rendering the supply of emission allowances on auction more flexible and making the ETS more resilient to any future large-scale event that may severely disturb the supply–demand balance was considered: a *Market Stability Reserve* of CO_2 (MRS), which will be introduced from 2021 onwards (EC, 2014b).

2.2.4 India

India, where domestic demand makes up three-quarters of the national economy (Damodaran, 2011), has been relatively unaffected by the global financial recession because this recession in fact stimulated the already high share of domestic consumption in total national expenditure. Nevertheless, after an increase of about 10% in 2010, India's GDP growth has slowed in recent years; in 2012 the GDP increased by 4.7% and in 2013 by 5.0% that is comparable to a 4% GDP growth in 2008, which was the lowest in a decade (World Bank, 2014).

India's CO_2 emissions in 2013 continued to increase by 4.4% to about 2.1 billion tonnes, making it the fourth largest CO_2 emitting country, following closely the European Union, and well ahead of the Russian Federation, which is the fifth largest emitting country (Figure 2.2). This high ranking is partly caused by the size of its population and economy; the workforce is expanding in the industry and services sectors, partially because of international outsourcing (World Bank, 2014). Per capita, India's CO_2 emissions were much lower than those of most developed countries and China (Figure 2.4).

The increase in 2013 was mainly caused by a 7.3% increase in coal consumption, which accounted for 59% of India's total fossil-fuel primary energy consumption and 55% of its total primary energy consumption (BP, 2014). This growth rate was lower than in the previous year, but much higher than those of 2010 and 2011. Coal-based power production, accounting for almost 70% of all of India's coal-related CO_2 emissions, grew by about 13% in 2012, the highest annual growth ever. Both the additional capacity and generation level were higher (Saikia and Sarkar, 2013). This coal share of 59% in India is smaller than those of China and South Africa (74% share of coal in their fossil-fuel mix) but similar to that of Poland and Kazakhstan, other countries with large coal resources, and larger than the global average share in 2013 of 34.4%.

In the last five years the amount of imported coal and coke rose more than two times reaching 168 million tonnes in 2013. Over the last four decades, through investment programmes and application of new technologies, the production of coal increased seven times (Coal India, 2014b). In India, further increases are envisaged in coal demand for the next years. As indicated in the Annual Report 2013–2014 (Coal India, 2014a), the demand will increase by 2% over 2014–2015 and by 25% over 2016–2017. The 12th Five-Year Plan (2012–2017) envisions an increasing coal production to 795 million tonnes by 2016–2017, also fuelling new power plants, which are planned to deliver an additional 78 GW.

2.2.5 Russian Federation

Russia alone keeps accounting for a share of 5.1% in global CO_2 in 2013 as in 2012 and keeps representing 56% of the emissions of the EIT countries. After a big drop in emissions of 5.7% in 2009, compared to 2008, due to the global recession, Russia recorded the highest increase of the last 20 years of 5.2% in 2011, compared to 2010. The increase levelled off to only a 1.0% increase in 2012, compared to 2011, and a 0.8% decrease in 2013, compared to 2012.

Russia toughened the environmental legislation and since 1 January 2012 the associated petroleum gas needs to be recovered for 95%, which ramped up in 2013 the environmental expenditure of half of the companies, according to Deloitte (2014). Other companies delay such investments in anticipation of government support measures, expected to take the form of preferential tax treatment. Technical regulations require oil companies to upgrade their facilities by 2016 and switch to the production of modern types of fuel. Oil refineries owned by large state-owned companies are not prepared to produce higher-quality fuel in the necessary volumes. Moreover incentives for geologic exploration, Mineral Extraction Tax differentiation for hard-to-extract reserves and legislation for Russian continental shelf operations are fostered (Skolkovo Moscow School of Management, 2014).

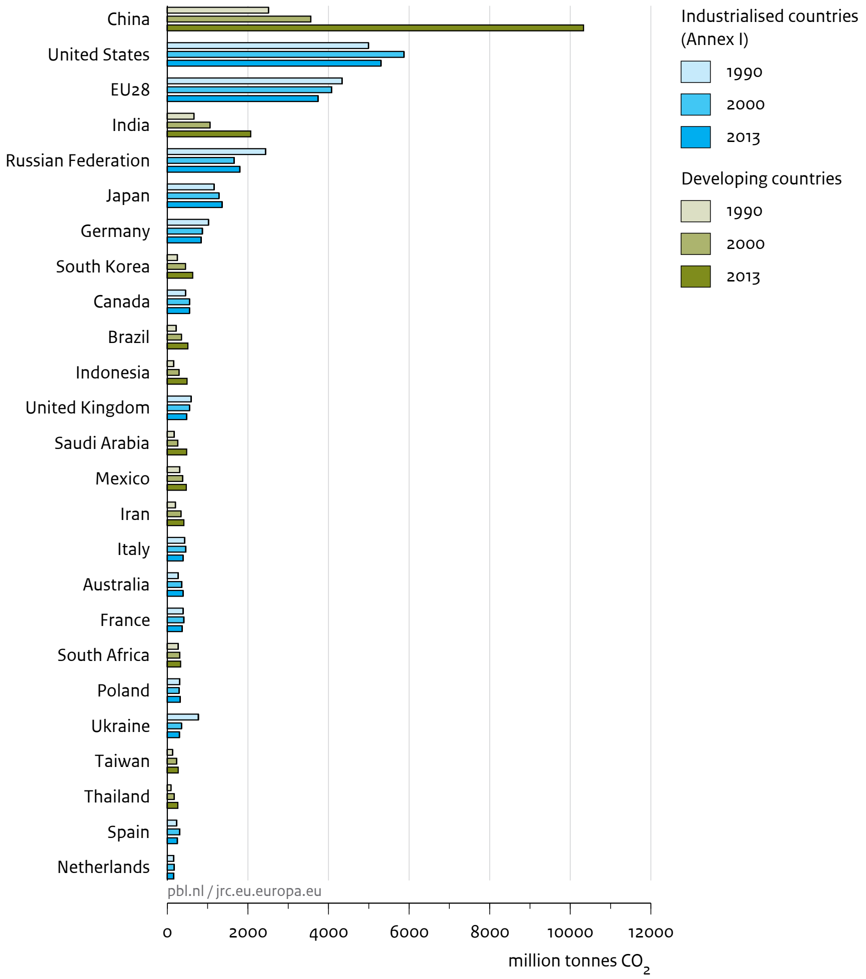
2.2.6 Japan

The share of Japan in global CO_2 emissions decreased slowly, from 5.2% in the 1990s, to 4.5% in following decade, to 3.8% in the 2011–2013 period. However, economic recovery following the recession of 2009 and the closure of nuclear power plants after the Fukushima accident in 2011, led to the highest increases in CO_2 emissions of the past 20 years, with 6.5% in 2012, compared to 2011, which levelled off by 0.6% in 2013, compared to 2012. The increase in 2012 was partly due to a 5.4% increase in the use of coal, with consumption levels back to those of the years 2007 to 2010.

In 2013 Japan became the world's largest importer of liquefied natural gas, and the second-largest coal importer behind China and the third largest net oil importer, because Japan has very limited domestic energy resources and, according to the EIA, can only

Figure 2.3

CO_2 emissions per country from fossil-fuel use and cement production



Source: EDGAR 4.2FT2010 (JRC/PBL 2012); BP 2014; NBS China 2014; USGS 2014; WSA 2014; NOAA 2012

produce 3% of its domestic gas consumption and 0.3% of its domestic oil consumption (EIA, 2014a). By 2013 Japan had a bilateral agreement with New Zealand that allowed it to hold oil stocks on New Zealand's behalf (IEA, 2013a).

2.2.7 Other OECD and eastern European countries

In 'other OECD-1990' countries[5], not included in the group of six largest emitting countries/regions, CO_2 emissions after a decline of 1.3% in 2012 continued to decrease by 0.6% in 2013. Their share in global CO_2 emissions was 4% in 2013, with the largest contributions from Canada (1.6%), Australia (1.1%) and Turkey (0.9%). Over the course of 2013 compared to 2012, emissions dropped in Turkey by 1.1% and in Australia by 2.8%, and increased in Canada by 0.7%.

The eastern European countries, excluding the Russian Federation and the EU's 13 new Member States, recorded a decrease of only 0.9% in 2013, following an increase of 0.6% in 2012 and large increases in CO_2 emissions in 2010 and 2011 of about 8.3% and 4.6%, respectively. This group of countries accounted for a share of 2.8% in global CO_2, with the largest emitting countries being the Ukraine (0.9%) and Kazakhstan (0.7%) with an emission decrease of 2.6% and an increase of 2.3% in 2013, respectively.

2.2.8 Other developing countries

In 2013, emissions from the category of 'other big developing countries'[6] represented 12% of the total in global CO_2 emissions, and the other developing countries[7]

Table 2.2

Trends in CO_2 emissions per region/country, 1990–2013 (unit: billion tonnes of CO2), also available on http://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts1990-2013

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
United States	5.0	5.0	5.0	5.18	5.3	5.3	5.4	5.6	5.7	5.7
EU28	4.3	4.3	4.1	4.1	4.0	4.1	4.2	4.1	4.1	4.0
France	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Germany	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Italy	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Netherlands	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Poland	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Spain	0.2	0.2	0.3	0.2	0.2	0.3	0.2	0.3	0.3	0.3
United Kingdom	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5
Japan	1.2	1.2	1.2	1.2	1.2	1.3	1.3	1.3	1.2	1.3
Other Annex II	0.8	0.8	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0
Australia	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4
Canada	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Russian Federation	2.4	2.3	2.1	2.0	1.8	1.8	1.7	1.6	1.6	1.6
Other Annex I-EIT	1.6	1.5	1.3	1.2	1.0	1.0	0.9	0.9	0.9	0.8
Ukraine	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.4
China	2.5	2.7	2.8	3.0	3.2	3.5	3.6	3.6	3.7	3.6
	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Other Big DC	1.8	1.9	2.0	2.0	2.2	2.2	2.4	2.5	2.5	2.6
India	0.7	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.0
Brazil	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Mexico	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4
Iran	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Saudi Arabia	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3
South Africa	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Other non-Annex I	2.3	2.4	2.5	2.7	2.8	3.0	3.1	3.3	3.3	3.4
Asian Tigers	**0.7**	**0.8**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.2**	**1.2**	**1.3**
South Korea	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.4	0.4
Indonesia	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3
Taiwan	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Thailand	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2
International transport	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8
Total	22.7	22.7	22.6	22.8	23.0	23.6	24.2	24.4	24.6	24.8

Note:

EIT = economies in transition, including all other countries of the former Soviet Union except Russia and including Turkey.

Asian Tigers here are: Indonesia, Singapore, Malaysia, Thailand, South Korea and Taiwan.

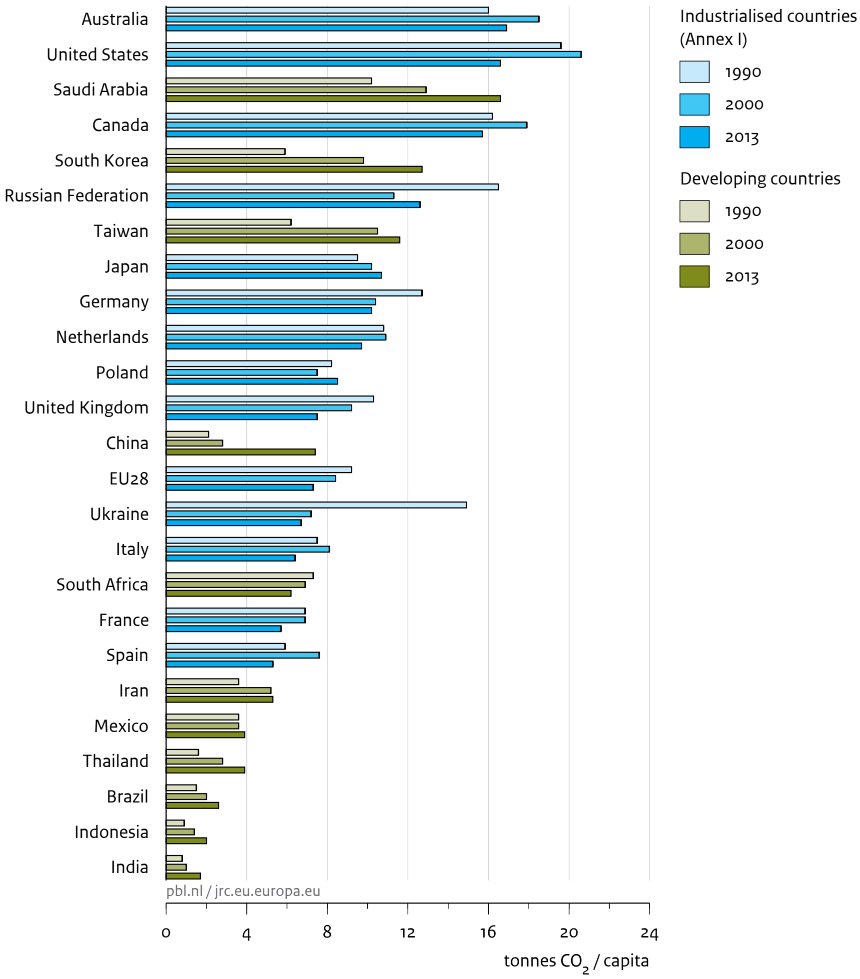
DC= developing countries. Other large developing countries are: Brazil, Mexico, South Africa, Saudi Arabia, India and Iran.

Other non-Annex I countries are remaining developing countries.

(Sub)totals may not match precisely due to independent rounding.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
	5.9	5.8	5.8	5.9	5.94	5.94	5.8	5.9	5.7	5.3	5.5	5.4	5.17	5.30
	4.1	4.1	4.1	4.2	4.3	4.2	4.2	4.2	4.1	3.8	3.9	3.8	3.8	3.7
	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
	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.9	0.8	0.8	0.8	0.8	0.8
	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
	0.2	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	0.3
	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3
	0.6	0.6	0.5	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.3	1.4	1.4
	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.2	1.1	1.1	1.1	1.1	1.1	1.1
	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
	0.6	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.6	0.6	0.6	0.6
	1.7	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.7	1.7	1.80	1.82	1.80
	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9	1.0	0.9	1.0	1.0	1.0	1.0
	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3
	3.6	3.6	3.9	4.5	5.3	5.9	6.5	7.0	7.8	8.3	8.7	9.6	9.9	10.3
	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.7	0.9	0.9	1.0
	2.7	2.7	2.8	2.9	3.1	3.2	3.4	3.6	3.5	3.7	3.8	3.9	4.2	4.3
	1.1	1.1	1.1	1.2	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.82	1.98	2.07
	0.4	0.4	0.4	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5
	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.4	0.5	0.5	0.5	0.5
	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.5	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	0.4	0.4	0.4	0.4	0.4	0.5	0.5
	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
	3.5	3.6	3.7	3.8	4.0	4.2	4.3	4.5	4.6	4.7	4.9	5.1	5.2	5.3
	1.3	**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**
	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
	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5
	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
	0.2	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
	0.8	0.8	0.8	0.8	0.9	1.0	1.0	1.1	1.0	1.0	1.1	1.1	1.1	1.1
	25.4	25.5	26.1	27.2	28.6	29.4	30.4	31.4	31.96	31.57	32.99	34.01	34.58	35.27

Figure 2.4
CO_2 emissions per capita from fossil-fuel use and cement production



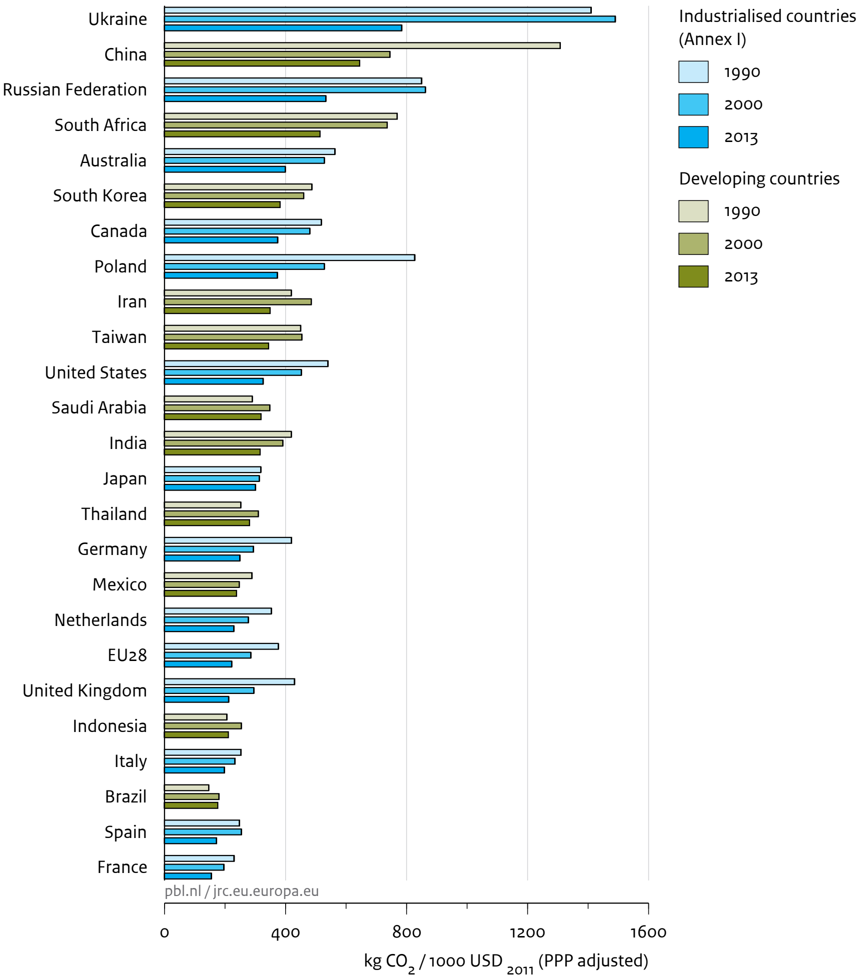
Source: EDGAR 4.2FT2010 (JRC/PBL 2012); UNDP 2014; BP 2014; NBS China 2014; USGS 2014; WSA 2014; NOAA 2012

contribute with 15% to the total. These include South Korea having a share of 1.8%, Brazil 1.5%, Indonesia and Saudi Arabia 1.4% each and Mexico 1.3% in the global total. After the economic recovery in most of these countries following the recession of 2009, large increases in CO_2 emissions were recorded for 2010. However, in the subsequent years, CO_2 emissions increased much less. Total CO_2 emissions in these 'other developing countries' changed by 2.6% in 2011, 3.1% in 2012 and 2.1% in 2013, down from the large jump of 5.3% in 2010, following the economic recovery in these countries after the global recession of 2009. Of the larger of these countries, CO_2 emission levels in Mexico decreased by 0.9% in 2013, but increases were seen in Brazil (6.2%), South Korea (1.3%) and Indonesia (2.3%) and Iran (2%).

2.3 Comparison between emissions in the various countries

Although emissions in China and other countries with emerging economies increased very rapidly in recent years (Table 2.2 and Figure 2.3), in both relative and absolute figures, the picture is different for CO_2 emissions per capita (see Table A1.2 and Figure 2.4) and per unit of GDP (Figure 2.5). Where, since 1990, in the European Union CO_2 emissions decreased from 9.2 to 7.3 tonnes per capita, and in the United States from 19.6 to 16.6 tonnes per capita, they increased in China from 2.1 to 7.4. As such, Chinese citizens, together representing 20% of the world population, on average emitted about the same amount of CO_2 per capita in 2013 as the average European citizen.

Figure 2.5
CO_2 emissions per unit of GDP from fossil-fuel use and cement production

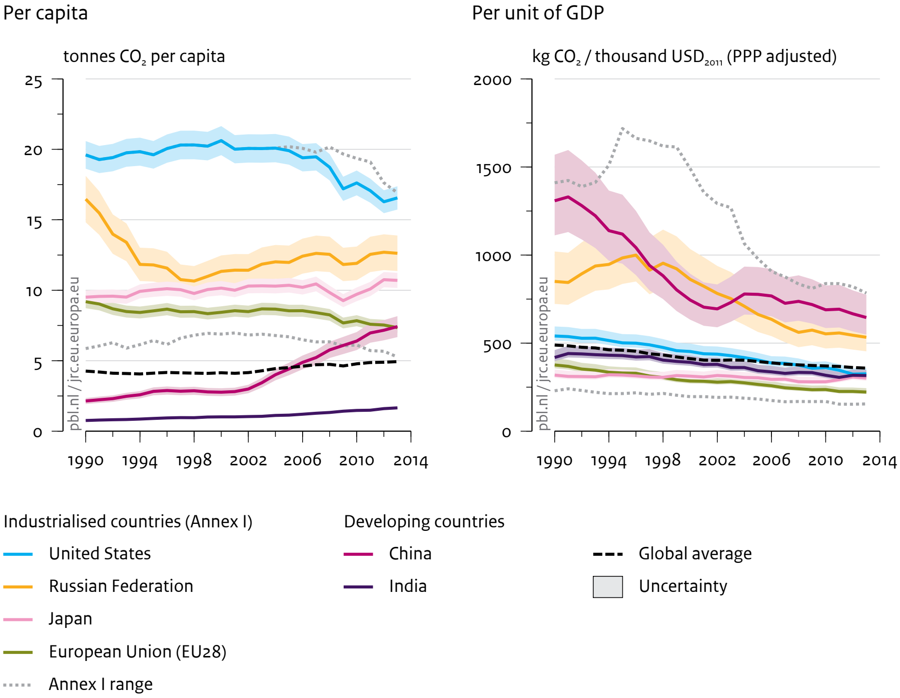


Source: EDGAR 4.2FT2010 (JRC/PBL 2012); World Bank 2014; IMF 2014; BP 2014; NBS China 2014; USGS 2014; WSA 2014; NOAA 2012

The European Union saw a decrease of 1.4% in total CO_2 emissions from fossil fuel and cement production between 2012 and 2013, whereas in the United States after a decrease of 3.8 in the previous year the emissions increased by 2.5% in 2013. China's total CO_2 emissions increased by 4.2%, and for India this was even more, with 4.4%. Japan, with one of the strongest increases in total CO_2 emissions (6.5%) a year before mainly due to the use of fossil fuel instead of nuclear energy in their power generation, has seen a decrease of 0.6% in 2013.

The trends in CO_2 emissions per capita in the top 5 emitting countries and the EU28 are shown in Figure 2.6 (left). These trends reflect a number of factors, including the large economic developments in China, structural changes in national and global economies, the impacts of major economic downturns for example such as those in the Russian Federation in the early 1990s, in the United States in 2008, 2009 and 2011, and in Europe in 2009 (for the whole of the EU28) and 2011 and 2012 (mainly in some EU15 countries). Factors that also contributed to the emission decrease in the United States between 2007 and 2012, were high oil prices with a relatively large impact on retail prices due to low fuel taxes and an increased share of 3% natural gas in total national fossil-fuel consumption (EIA, 2012a,b). However, the CO_2 emissions in 2013 are 2.5% above the 2012 level, mainly because of a small increase in coal consumption in the electric power sector (EIA, 2014b,h). The European Union saw a smaller decrease in emissions during the recession years, among other things, because of high fuel taxes, which dampened the impact of strong international variations in oil prices on retail prices.

Figure 2.6
CO_2 emissions from fossil-fuel use and cement production in the top 5 emitting countries and the EU



Source: EDGAR 4.2FT2010 (JRC/PBL 2012); UNDP 2013 (WPP, Rev. 2013); World Bank 2014; IMF 2014

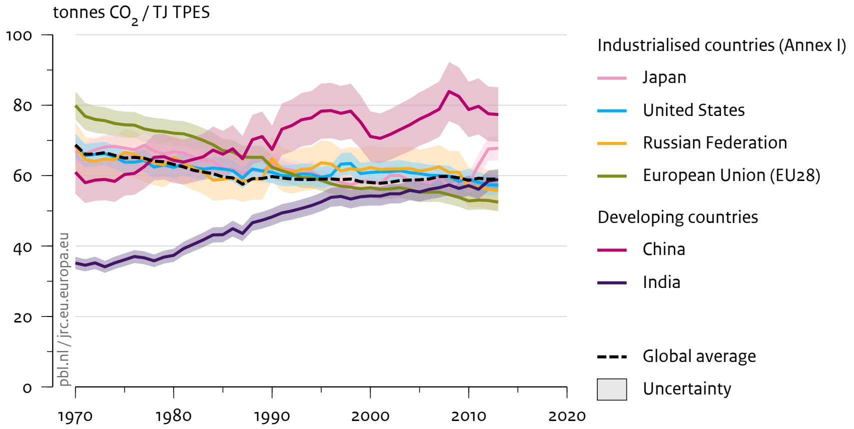
The two dotted lines in Figure 2.6 represent the range of CO_2 emissions per capita (minimum and maximum) for the major industrialised countries (the developed countries listed in Figure 2.2), the lowest levels of CO_2 per capita being those in France (5.7 tonnes CO_2/cap because of the amount of nuclear energy used in that country) and the highest levels were seen in Australia (16.9 tonnes CO_2/cap because of natural resource depletion). The per-capita CO_2 emissions in the United States decreased in 2013 down to 16.6 tonnes CO_2/cap, and increased in Japan to 10.7 tonnes CO_2/cap. When comparing CO_2 trends between countries over a decade or more, trends in population numbers also should be taken into account, as population growth differs considerably, also between developed countries, with the highest growth rate since 1990 seen in Australia (+36.5% between 1990 and 2013), in Canada (+27.2%) and in the United States (+25.8%). The populations of the European Union and Japan, however, increased much less (by 7.7% and 4%, respectively), and the Russian Federation even saw a decline of 3.6%. In comparison, the population of China increased by 19%, India 14% and Brazil 34% since 1990. (see Table A1.2).

Another indicator of the CO_2 intensity of a country is the ratio of emissions and GDP as shown in Figure 2.6b (right). However, this indicator is much more uncertain than population, as is explained in Box 2.2. For the CO_2 intensity related to GDP of a country (CO_2 per USD of GDP) it is recommended to compare levels between countries and longer term trends only. Main reason is that a substantial contribution to a country's economic activities, and thus to its GDP, is made by the service sector, which is not an energy-intensive activity. In contrast, in many countries energy-intensive activities such as power generation and fossil fuel production are only contributing a small fraction to total GDP. Therefore, the correlation between annual changes in CO_2 and GDP for a specific year is rather weak, so this indicator should be used best to analyse longer term trends and country-specific CO_2 intensity levels.

Figure 2.6 (right) shows that over the past decade, most top 5 emitting countries and the EU28 experienced a declining trend in CO_2 in terms of GDP, but the ranking order of countries more or less remains the same: with a lower emission level in the European Union; medium levels in the United States and India; and higher levels in the Russian Federation and China, the last two emitting relatively high amounts of CO_2 per USD of GDP. The trends for the Russian Federation and China were less smooth; partially due to very large and fast changes in their economies. Japan is an exception, with more or less the same level of CO_2 per USD in GDP, even over the last

Figure 2.7

CO_2 emissions per unit of Total Primary Energy Supply (TPES) in the top 5 emitting countries and the EU



Source: IEA 2014; BP 2014

Box 2.2 Uncertainty in Gross Domestic Product (GDP) in USD, in constant Purchasing Power Parity (PPP)

Gross Domestic Product (GDP) is more uncertain than population due to different reasons:

- It is more difficult to have complete and accurate statistics because it tries to capture various inhomogeneous economic activities: from large to small, from product manufacture to services, for temporary and permanent businesses. Sometimes revisions of definitions and estimation methods occur, that may lead to changes of several per cent.
- To produce consistent time series with constant prices instead of current prices in the years, all annual data needs to be corrected for inflation. The definition and estimation method of annual inflation is not unambiguous and therefore also adds to uncertainty in the annual GDP at constant prices.
- To compare between countries, GDP in national currency needs to be converted into one common currency unit, for example the USD. Here the annual average exchange rates to the common currency are a cause of uncertainty, even more so when GDP are compared using Purchasing Power Parity (PPP) conversion factor, to correct for differences in purchase power of currencies between countries (sometimes called 'the hamburger' unit).
- Only officially recorded activities are being accounted for, whereas in practice there are always illegal or unrecorded economic activities that could range from a few per cent to much more than 10 per cent, of which only estimates can be made.

For example, when converting the GDP at PPP prices from constant USD of 2005 to prices of 2011 in this report, the changes in many OECD countries are in the same range as the United States, about 20%, but for some countries the changes are much larger, e.g. of the top-25 countries about 50% for India and Russia and about 100% for Indonesia and Saudi Arabia.

Note that present World Bank and IMF GDP statistics do not yet reflect the revisions of the definition of the Gross National Product (GDP) as adopted the updated international guidelines for national economic account in the 2008 UN System of National Accounts ('SNA 2008') (UN, 2009). These revisions include, amongst others, estimates of illegal economic activities. Countries that have very recently published GDP revisions to include the SNA 2008 guidelines showed increases up to 5%.

two decades. In 2013, the emission intensity of the European Union was about three-quarters of the United States and about one third of China. The higher levels for the Russian Federation and China indicated a larger share of more energy-intensive economic activities, the use of less energy-efficient technologies, a larger share of coal in the energy mix, or a combination of these factors. This is also the case for the Ukraine, which is depicted in Figure 2.6 by the upper dotted line. The 3.4% global economic growth in 2012 and 3.1% in 2013 was about two-thirds of the average growth level since 2003 (4.8% per year), excluding the recession years 2008 and 2009, and was comparable with the average annual growth of 3.4% over the 1995–2002 period (after the large decline in energy consumption in the former Soviet Union countries).

In addition Figure 2.7 shows the CO2 intensity relative to total primary energy supply (TPES). It indicates that so far China's total primary energy supply was over the past two decades increasing in carbon intensity. Since 2010, the carbon intensity of the primary energy supply stabilised, but at levels much higher than in Europe or the United States. The large and increasing energy demand in China was mainly supplied with many new coal power plants. India is also showing a similar increasing carbon intensity, but hopefully does not grow to a similar level as China has today. Europe is giving the example with lowest carbon intensity of the primary energy supply, followed by the Russian Federation and the United States. All three show a slowly but steadily decreasing carbon intensity (with the exception of 2013 for the United States).

2.4 CO_2 emissions from oil and gas production

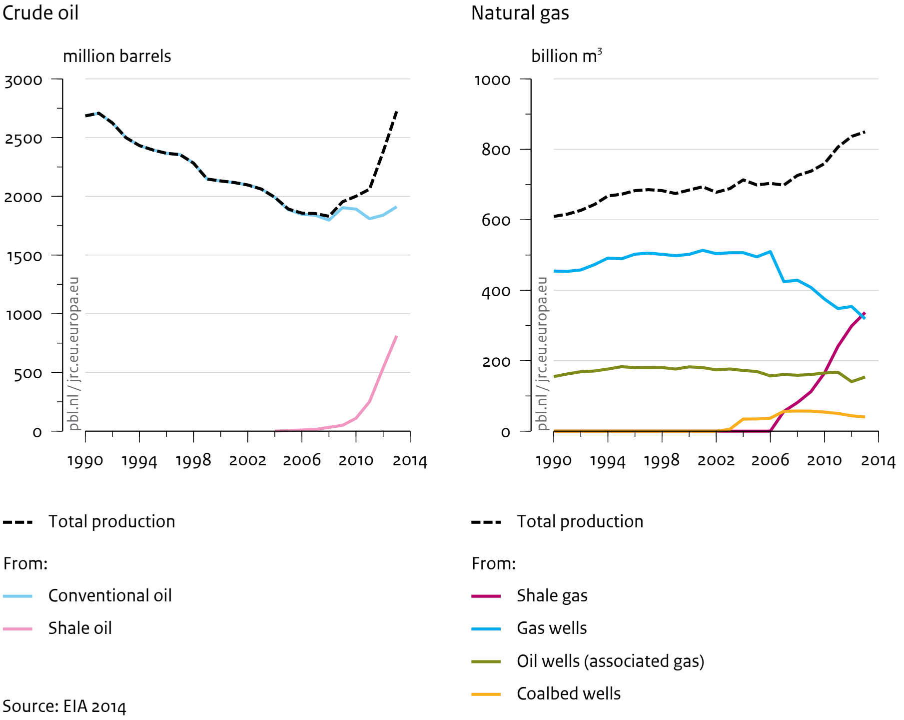
When natural gas is co-produced during conventional or unconventional oil production and cannot be marketed, this waste stream of gas is either vented or flared. Venting or flaring occurs in areas that are remote from market demand and from gas transport infrastructure. Both practices lead to the emissions of greenhouse gases: methane from venting and CO_2 from flaring.

The global CO_2 emissions of about 250 million tonnes from flaring of unused gas during oil production – comparable in magnitude with total CO_2 emissions in a medium-sized country such as Spain – did not significantly change in 2011, after a steady decrease by about a quarter since 2003. These estimates for natural gas flaring were derived from DMSP-OLS and MODIS satellite measurements, analysed by the US National Oceanic and Atmospheric Administration (NOAA) and supported by *the Global Gas Flaring Reduction* Partnership (GGFR), a public–private partnership which is led by the World Bank. The night-time light emitted from gas flares observed by the satellites provides an estimate of the amounts of gas flared, when related to reported flaring volumes available from the GGFR Partnership (Elvidge et al., 2009a). Countries with the largest satellite-observed flaring emissions are the Russian Federation and Nigeria, with shares of global flaring emissions of about one quarter and one tenth, respectively. These two countries also contributed the most to the global emission decrease over the last decade, followed by Iran, Iraq and the United States (NOAA, 2012, pers. comm.; World Bank, 2012).

However, in 2012 NOAA has changed to a new sensor, for which cloud corrections and calibration to the flared gas volume needs to be done. Earlier, satellite information shows that flaring emissions in the United States are on the rise, with a steep increase of 50% in 2011, making the country the fifth largest gas flaring country. The main cause of the jump in emissions was the country's recent massive increase in the use of hydraulic fracturing, or *fracking*, and other advanced drilling techniques for oil production and the ensuing flaring of co-produced gas (Nicholson, 2012, EIA, 2014j), in particular, in North Dakota and Texas. We tentatively assumed that gas flaring in the United States increased in 2012 by 35%, which is lower than the increase in crude oil production in North Dakota in 2012, to account for the expansion of gas processing capacity and gas gathering infrastructure that reduces flaring. Due to lack of information, we assumed that in other countries the flaring level did not change in 2012 over 2011. For 2013 we assumed that for all countries CO_2 emissions did not change compared to 2012. Recently, the governments of these countries announced policy measures aimed at reducing CO_2 emissions from gas flaring. The US Environmental Protection Agency announced that drillers that use fracking to extract natural gas and oil, from January 2015 onwards, will be required to use equipment to capture the emissions, a process known as 'green completion' (US EPA, 2012). Until that time, they may burn off or flare the gas.

The Russian Ministry for Natural Resources and Ecology has announced that oil companies, on average, utilise 76% of the associated gas they produce. A target of 95% utilisation of produced gas was set in 2012, and companies will be fined if they flare more than 5%. The ministry expects that the 95% target will be met by 2014–2015 (Reuters, 2012b; Moscow Times, 2012). Gazprom increased the utilisation efficiency of associated gas production from 59% in 2010 to 70% in 2012 (Gazprom, 2013).

Figure 2.8
Gross oil and natural gas production in the United States by type of source



Source: EIA 2014

In Nigeria, the Associated Gas Re-injection Act 1979 (AGRA) required the oil companies to cease gas flaring by 1 January 1984. However, this cease date has been moved several times (2005) and also some of the oil companies are allowed to continue to flare the gas under special conditions and paying a nominal fine. Furthermore, the draft Petroleum Industry Bill (PIB) has set the cease date to January 2013 with more severe consequences for the companies; if endorsed, it has the potential to change the face of operations and petroleum industry (Practical Law, 2014). The revised PIB is currently discussed in the Nigerian Parliament, and finally it will be resubmitted to the President (Liewerscheidt, 2014). Even if the regulatory authority considers that gas flaring has reduced considerably, about 50% of the total gas produced in Nigeria is still flared and the lack of funds to invest in additional gas gathering facilities is seen by the oil companies as a future challenge (Nigerian Tribune, 2013).

According to the official reporting by industrialised countries to the UN Climate Convention, the fraction of methane in total greenhouse gas emissions from venting and flaring varies largely between countries; for example, in the Russian Federation and the European Union as a whole this is about a quarter, in Canada it is about half, and in the Ukraine this is about 90% (UNFCCC, 2013).

2.5 Gas and oil production by hydraulic fracturing and oil sands exploitation

Globally about 32% of the total estimated technically recoverable natural gas resources (proven and unproven reserves) are in shale formations and 10% of estimated global crude oil resources are in shale or tight formations (EIA, 2013d). The variation across the world's shale formations makes it difficult to estimate the extent to which these shale resources will prove to be economically recoverable. Most of the technically recoverable shale gas has been found in the United States (33 trillion m³), China (32), Argentina (23), Algeria (20), Canada (16), Mexico (15) and the European Union (13) and most of the technically recoverable shale oil in Russia (75 billion bbl), United States (48), China (32), Argentina (27), Libya (26) and European Union (14).

The United States and Canada produce shale gas and shale oil at industrial scale. For a detailed discussion of the development in these countries and the environmental concerns of fracking and oil sands production we refer to last year's report (Olivier et al., 2013). Here we only briefly summarise a few of the latest developments. Exploration activities begun in shale formations in a number of other countries, including Algeria, Argentina, Australia, China, India, Mexico, Poland, Romania, Russia, Saudi Arabia, Turkey, Ukraine and the United Kingdom. However, there is considerable uncertainty in all estimates as illustrated by the large downward adjustments for some oil and gas basins after two years (EIA, 2013d) (Figure 2.8).

2.5.1 United States

In recent years, the United States expanded the production of shale gas by fracking such that they became in 2011 the largest gas producer of the world. By 2011 shale gas had a share of about one third in total gross gas production in the United States. A similar trend was seen for shale oil (tight oil) production, which share was only 1% in 2007 but increased to 11% in 2011 and to 30% of total US oil production in 2013, reversing the slow decrease over time in 2008 into increasing total production with 2013 production at the highest level since 1991 (EIA, 2014c,j).

In 2013 the gross natural gas production is mainly determined by shale gas production (exceeding the conventional gas well production). Moreover the shale gas production keeps increasing at constant rate and the same is expected for the shale oil. From January 2015 onwards, drillers that use fracking to extract natural gas and oil will be required to use equipment to capture the natural gas that currently escapes to the air and either use or sell it, a process known as 'green completion' (US EPA, 2012).

2.5.2 Canada

In Canada, the share of unconventional gas production in 2011 was about 40% of total gas production, twice as high as in 2002: 6% from *shale gas*, 32% tight gas and a few per cent coalbed methane (Environment Canada, 2013).

Commercial production of oil from the Athabasca *oil sands* in the province Alberta began in 1967, when the first surface mine produced synthetic crude oil. The oil contained in Alberta's *oil sands* is about the same amount as Canada's conventional proven oil reserves (BP, 2014). Canada's total crude oil production increased by about 30% since 2002, which was wholly due to oil sands products (crude bitumen and synthetic crude oil. Presently, Canada is the largest supplier of oil imported by the United States, supplying about 150,000 m^3 per day from oil sand sources (Swart and Weaver, 2012). In 2011, the decline in conventional crude oil production (i.e. non-oil sands) in Canada was reversed due to the increased use of hydraulic fracturing. Over time the energy intensity of conventional oil production has increased due to a shift to production of more difficult to obtain oils, such as heavy oil and oil extraction using enhanced oil recovery (EOR) techniques.

The greenhouse gas emissions intensity of bitumen and synthetic crude production from *oil sands* (mining, in-situ bitumen recovery, upgrading) is about three times as high as of conventional light oil production, but similar to that of conventional heavy oil production. However, the main source of greenhouse gas emissions from oil sands operations is CO_2 from fuel combustion whereas in heavy oil production it is gas venting. Increasingly, bitumen instead of synthetic crude oil is shipped to the United States, and thereby more emissions associated to upgrading and refining to occurring outside Canada (Environment Canada, 2013).

2.5.3 Impacts of new extraction techniques on uncontrolled methane emissions

In recent years considerable concern has been expressed in the environmental impact of hydraulic fracking in general (direct local impacts such as aerial footprint, air pollution, noise, night lights, traffic, earthquakes, local water depletion, waste water, possible groundwater contamination by additives in the fracturing fluids and substances in waste water) and also in the impact of greenhouse gas emissions related to shale gas production in comparison with conventional natural gas production. The concern in the impact on greenhouse gas emissions of fracking and shale gas and oil production refers to the higher *energy intensity* of the fracking and production process and to possibly larger emissions of *methane*, the second important greenhouse gas, that has a *global warming potential* ('GWP') which is per kilogramme more than 20 times as large as CO_2, or additional emissions of CO_2 from flaring, when gas is produced that cannot be economically utilised due to lack of infrastructure.

The knowledge on current and future emission levels from flaring (CO_2) and venting (CH_4) related to oil and shale gas hydraulic fracturing, as well as from other oil and gas activities, is highly uncertain (Olivier et al., 2013). According to the IEA, vast resources of shale gas could be produced if done in an socially and environmentally acceptable manner, but it requires 'a continuous drive from governments and industry to improve performance is required if public confidence is to be maintained or earned' (IEA, 2012b).

2.5.4 Recent attention at policy level

In the United States, the US EPA is drafting a report on the potential impacts of hydraulic fracturing on drinking water resources (Cocklin, 2014). US EPA allows the public to follow its study of hydraulic fracturing for oil and gas and its potential impact on drinking water resources via their web page: http://www2.epa.gov/hfstudy, including academic papers and a summary report of a Technical Roundtable held December 9, 2013 (US EPA, 2014a).

In July 2014, the US Government Accountability Office (US GAO) published a report on the US EPA's programme to protect underground sources from the injection of fluids associated with oil and gas production, in which it concluded that it needs improvement since the US EPA is not consistently conducting two key oversight and enforcement activities for oil and natural gas wells (US GAO, 2014). Jackson et al. (2014) published a synthesis paper on a study of the environmental costs and benefits of fracking, including data from government databases. It compared water requirements with conventional energy sources and concluded that groundwater contamination has happened, although not commonly. Most wastewater from fracking is injected deep underground but an increasing amount is recycled for subsequent drilling or sent to advanced water treatment facilities. However, a handful of US States still allow the wastewater to be used, for example to water cattle or spraying onto roads for dust control. Among critical topics for future research are the factors that could cause wastewater injection to generate large earthquakes (Golden, 2014).

In 2014, the European Commission has published an impact assessment and recommendation on oil and gas production with hydraulic fracturing (EC, 2014a,d). It has invited Member States to inform the Commission by the end of 2014 on measures they put in place in response to the recommendation on minimum principles for oil and gas production with hydraulic fracturing. Related documents on environmental aspects on unconventional fossil fuels can be found on the web site of the EC (EC, 2014f). Other European studies and guidelines on fracking can be found on another web page (EC, 2014g). Two other studies published by the Commission are one on the macro-economic effects of shale gas extraction in the European Union (EC,2014e) and another study for DG CLIMA on mitigation of climate impacts of possible future shale gas extraction in the European Union (ICF International, 2014).

2.6 CO_2 from cement and steel production (non-combustion)

Globally, both cement production and steel production are indicators of national construction activity, with cement mainly used in building and road construction, and steel also in the construction of railways, other infrastructure, ships, and machinery.

2.6.1 Cement production

CO_2 emissions are generated by carbonate oxidation in the cement clinker production process, the main constituent of cement and the largest of non-combustion sources of CO_2 from industrial manufacturing, contributing to about 4.8% of the total global emissions in 2013. Fuel combustion emissions of CO_2 related to cement production are of approximately the same level, so, in total, cement production accounts for roughly 9.5% of global CO_2 emissions. The combustion emissions of these activities are not included in this section but included under the industrial energy-related emissions. This section focuses on process emissions (i.e. emissions from carbonate oxidation).

The world's cement production remains heavily dominated by China, with an estimated share of 57.8% in global cement emissions in 2013 from cement production, followed by India with a more than 6.1% share. The cement producers next in row have shares between 2.09% and 1.5% and are: the United States, Turkey, the Russian Federation, Japan, Iran, and Brazil. The EU28 accounted for 5% of the global total production. With a continuing trend in China, global cement production increased by 5.3% in 2013. China increased cement production by 9.3% and was responsible for 58% of the world's cement produced in 2013 and three quarters of the global increase in production (USGS, 2014). According to estimates by USGS (2014), cement production increased in 2013 in most countries among which Indonesia, Iran, the Russian Federation, Turkey and Vietnam by 5% to 10% and decreased in Italy by 12% and in Thailand with 5%. In the EU28 cement production increased by 8% in 2013, compared to a decrease of 4% in 2012. However, emissions are not directly proportional to cement production level, since the fraction of clinker – in this industry the main source of CO_2 emissions – in cement tends to decrease over time. A study by the World Business Council on Sustainable Development (WBCSD, 2009) has shown that the share of blended cement that has been produced in recent years in most countries has considerably increased relative to that of traditional Portland cement.

Consequently, average clinker fractions in global cement production have decreased to between 70% and 80%, compared to nearly 95% for Portland cement with proportional decrease in CO_2 emissions per tonne of cement produced. Both non-combustion and combustion emissions from cement production occur during the clinker production process, not during the mixing of the cement clinker. This has resulted in about 20% decrease in CO_2 emissions per tonne of cement produced, compared to the 1980s. At that time, it was not common practice to blend cement clinker with much other mixing material, such as fly ash from coal-fired power plants or blast furnace slag. According to EDGAR 4.2 data, this yielded an annual decrease of 250 million tonnes in CO_2

Table 2.3

Comparison of six datasets for CO_2 emissions: data sources, methodology, level of detail in countries, fuels and sources, emissions from current datasets (as of 1 December 2014) (global emissions 2005/2010 in million tonnes CO_2)

Source	EDGAR	IEA	CDIAC	EIA	BP	UNFCCC	
Greenhouse gases	CO_2, CH_4, N_2O, F-gases	CO_2	CO_2	CO_2	CO_2	CO_2, CH_4, N_2O, F-gases	a
Update frequency	Annual/ Periodic	Annual	Annual	Annual	Annual	Annual	
Start year	1970	1971	1751	1980	1965	1990	b
Latest year	2008 (2010 for FT2010)	2012	2010 (2012 for 67 + 5 other)	2011	2013	2012	
Countries in dataset	214	137+3 other	224	224	67+5 other	44 (Annex I)	c
Fossil fuel combustion	**28 593** (2005) **31 940** (2010)	**27 494** (2005) **30 482** (2010)	**28 280** (2005) **31 745** (2010)	**27 649** (2005) **30 382** (2010)	**29 480** (2005) **32 876** (2010)		*
Fossil fuel types in energy database distinguished for CO_2 calculation	42 (as IEA)	42 (23 oils, natural gas, 16 coals + 2 non-renewable wastes)	4 (hard coal, brown coal, gas, liquid)	~40 (in CO_2 dataset)	3 (coal, oil, gas)	~40	
Fossil fuel types in CO_2 dataset	- (not in public dataset)	same	3 (solid, gas, liquid)	8	same	7 (solids, gas, liquid, other + petrol, diesel (road)	
Sectors in CO_2 dataset	20	46	-	-	-	20	
Energy data source	IEA energy statistics	IEA statistics *(from IEA questionnaire + UN questionnaire)*	UN energy statistics	open sources	open sources	CRF (national statistics)	
Emission factor source	2006 IPCC	1996 IPCC	U.S.-based	see note	unknown	country-specific	d
Fraction of C oxidised	2006 IPCC	1996 IPCC	U.S.-based for liquid and gas; also others for coal	see note	unknown	country-specific	d
Non-fuel use (feedstock)							
Countries in CO_2 dataset	214	137+3 other included in fuel combustion	included in global only	included in fossil fuel combustion	-	44 (Annex I)	
Activity data type and data source	industrial production statistics (USGS, UN)	non-energy use of fuels (IEA)	non-energy use of fuels (UN)	unknown	-	country-specific (production and/or non-energy use)	d
Carbon content	2006 IPCC	1996 IPCC	U.S.-based	see note	-	country-specific	d
Fraction of C stored	not applicable	1996 IPCC	U.S.-based	see note	-	country-specific	d
International bunkers	**952** **1 067**	**934** **1 111**	**985** **1 067**				*
Countries	global only	137+3 other	224	included above	included above	44	e
Sectors in CO_2 dataset	marine, aviation	marine, aviation	total	included in country totals	included in country totals	marine, aviation (memo items)	
Data source	IEA statistics	IEA statistics	UN energy statistics	-	-	country-specific	
Gas flaring	**454** **422**	**-**	**220** **216**	**227** **227**	**-**		*

Table 2.3 (continued)

Source	EDGAR	IEA	CDIAC	EIA	BP	UNFCCC	
Source of activity data	mainly NOAA/ NCDC for 54 countries (satellite derived)	-	mainly UN	open sources	-	country-specific	f
Sectors in CO_2 dataset	flaring only (venting separately)	-	includes venting	includes venting	-	country-specific (venting separately)	
Industrial processes	**958** **1352**	**-**	**1 173** **1 650**	**-**	**-**		*
Sources	cement, lime, other carbonate use, ethylene, etc.	-	cement	-	-	cement, lime, other carbonate use, ethylene, etc.	
Activity for cement	cement production	-	cement production	-	-	cement clinker production	
Data source	USGS	-	USGS	-	-	country-specific	
Emission factor	2006 IPCC, corrected for clinker fraction		own global value, adopted by 1996 IPCC				g
Forests/ Landuse change	forest fires peat fires, postburn	-	see note	-	-	-	h

Notes:

a UNFCCC: Annex I countries only (non-Annex I countries submit irregularly and in much less detail).

b IEA: For OECD countries starting in 1960.

c IEA and EIA: other countries have been summed in a number of 'other countries' in a region.
UNFCCC: has annual, detailed data for Annex I countries. In addition, UNFCCC has also emissions from non-Annex I countries but much less frequent, detailed and documented. Here we only specify the dataset of the Annex I countries.

d EIA: Emission factors for petroleum, coal, and natural gas consumption and natural gas flaring are from EIA, Documentation for Emissions of Greenhouse Gases in the United States 2006 (October 2008), Tables 6.1 and 6.2. Storage fraction for non-fuel use of petroleum products are from the same report.
EDGAR uses a sector specific approach for industrial processes and therefore uses industrial production as activity data, rather than amounts of non-fuel use of fossil fuels, which are often not fully distinguished in energy statistics.

e EDGAR reports only global marine and aviation bunker emissions since most of the emissions from these bunker fuel sales occur outside the country of sale.

f EDGAR data rely mainly on independent observations of the amount flared vs. CDIAC and EIA estimate it from the amount of gas produced minus the amount of gas marketed and assumes the remainder is all flared, but does include gas vented.

g EDGAR corrects for the decreasing fraction of clinker in the cement produced since emissions are actually related to clinker production not cement production.

h EDGAR estimates all actual emissions from forest and peat fires and postburn and peat soil decomposition due to drainage, but does not include net carbon storage. CDIAC CO_2 emissions are part of the Global Carbon Project's dataset, that includes that net carbon storage from land use and land use change).

** Global total emissions (in million tonnes CO_2): top: 2005; bottom: 2010 (Unit: million tonnes CO_2). Fossil fuel combustion values include non-fuel use of fossil fuels (e.g. as chemical feedstock) and international bunkers. Industrial processes values refer to cement production only (not e.g. lime and other limestone use).*

Home pages of the datasets:

EDGAR: http://edgar.jrc.ec.europa.eu/

IEA: http://www.iea.org/statistics/topics/co2emissions/

CDIAC: http://cdiac.ornl.gov/trends/emis/meth_reg.html

EIA: http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=90&pid=44&aid=8

BP: http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy/statistical-review-downloads.html

UNFCCC: http://unfccc.int/ghg_data/items/3800.php emissions, compared to the reference case of Portland cement production. Moreover, a similar amount has been reduced in fuel combustion for cement production and related CO_2 emissions.

2.6.2 Iron and steel production

When looking at steel production, with related non-combustion CO_2 emissions from blast furnaces used to produce pig iron and from conversion losses in coke manufacturing, China accounted for 49% of global crude steel production in 2013, followed by Japan (7%), the United States (5%), India (5%), the Russian Federation and South Korea (each 4%). The EU28 accounted for 10% of the global total. According to WSA (2014), global crude steel production rose 3% in 2013, compared to 1.4% in 2012. The 9.3% increase in China in 2013 corresponds with an increase of 66 million tonne, which is about the same as the overall global total increase in production in 2013. Production plummeted in Italy (12%), Canada (8%), Poland (5%) and South Korea (4%) and production strongly increased in the United Kingdom (24%), Austria (8%), Taiwan (7%), Iran (6%) and India and Malaysia (each by 5%). In the EU28 steel production decreased by 1% in 2013 compared to a decrease of 4% in 2012.

In steel production, most CO_2 is generated in iron and steel making processes that use coke ovens, blast furnaces and basic oxygen steel furnaces. However, the share of electric arc furnaces and direct reduction in secondary and primary steel making, which generate much less CO_2 per tonne of crude steel produced, is increasing over time (WSA, 2014).

2.6.3 Other industrial sources

Lime and ammonia production are other industrial sources of CO_2 emissions. In 2013, lime production increased globally by 1% and ammonia production remained the same (USGS, 2014).

2.7 Comparison with other global greenhouse gas inventories

In the Fifth Assessment report of IPCC Working Group III (IPCC,2014a) the reported greenhouse gas emissions (e.g. Figure SPM.1) combines CO_2 emissions related to fossil fuel use from IEA (2012c) and other CO_2 emissions sources and non-CO_2 emissions from EDGAR 4.2 FT2010 (JRC/PBL, 2012). Figures TS.2 and TS.4 from the Technical Summary of the Working Group III report provide insights on the growing uncertainty of the emissions and the range of per capita emissions, using definitions as given in Annex II of the WG III report (IPCC, 2014a).

Table 2.3 summarises the differences between six global CO_2 datasets in coverage, sources, methodology and key global CO_2 totals per source for 2005 and 2010 from the currently available datasets (as of 1 December 2014). The level of detail for the fuel use calculations differs substantially, however at global level the differences are often relatively small. It should be noted that differences for individual countries can be much larger (Marland et al., 2009; Olivier and Peters, 2012; and Table A1.1).

As shown in Table 2.3 at global level the differences between CDIAC and EDGAR fossil-fuel related CO_2 emissions are very small. However, at global level the differences between IEA and EDGAR CO_2 emissions are around 4%, which can be explained largely by the difference in overall emission factors used (differences due to different default values for the emission factors and carbon oxidation factors in the 1996 and 2006 IPCC Guidelines for Greenhouse gas Inventories (IPCC, 1996, 2006). The latter changes results in 2%, 1% and 0.5% higher CO_2 emissions from respectively coal, oil and gas combustion, and increases overall fossil fuel emissions by about 1.3%. In addition, for recent years the latest IEA statistics for these years will show more updated values for fuel consumption than for years further in the past. For a more detailed analysis of the differences between EDGAR, IEA, CDIAC and EIA datasets see Andres et al. (2012) and between EDGAR/IEA and CDIAC/UN see Marland et al. (1999).

For flaring EDGAR reports values about twice as high as CDIAC and EIA (Table 2.3), which is remarkable since the CDIAC and EIA data also include venting. This difference can be explained by the different estimation method for the activity data, which is mainly based on reported energy statistics for CDIAC and EIA but mainly on satellite data for EDGAR.

For cement production the emission factors used in EDGAR include a correction for the fraction of clinker in the cement produced. As this fraction has be decreased significantly in most countries in the last decades, thereby proportionally decreasing the emission factor expressed in per tonne of cement produced, the EDGAR emissions are about 20% lower than the unadjusted values in the CDIAC dataset (Table 2.3).

Notes

1 The 24 OECD countries of 1990 are: Australia, Austria, Belgium, Canada, Switzerland, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Ireland, Iceland, Italy, Japan, Luxembourg, The Netherlands, Norway, New Zealand, Portugal, Sweden, Turkey, the United States.

2 The EIT countries are: Bulgaria, Belarus, Czech Republic, Estonia, Croatia, Hungary, Lithuania, Latvia, Poland, Romania, Russian Federation, Slovakia, Slovenia and Ukraine.

3 The developing countries (further for clarity referred to as Non-Annex I countries) are the remaining countries, not under the 24 original OECD members, and not the 14 countries with economies in transition. They are not listed in the annex to the Kyoto Protocol and as such did not have emissions targets for the 2008–2012 period. The use in this report of Annex I/Non-Annex I grouping of countries refers to the UNFCCC definition of country groupings (IPCC, 2014a) and does not imply any recommendation whatsoever with respect to future political commitments.

4 In 2007–2008 physical growth rates plummeted also in China due to the global economic recession caused by the credit crunch in OECD countries.

5 The category 'other OECD-1990 countries' include Australia, Canada, Iceland, New Zealand, Norway, Switzerland and Turkey. These are seven of the 24 countries that were members of the OECD in its composition of 1990, which furthermore consisted of the EU15 countries, the United States and Japan. In the 1990s other 5 countries, Mexico, Korea, Hungary, Estonia, and Czech Republic joined and since 2010 another 3 countries, Slovenia, Israel and Chile.

6 Other big developing countries include Brazil, India, Iran, Mexico, Saudi-Arabia, South-Africa.

7 Other developing countries include all non-Annex I countries except China and except the other big developing countries.

What controls CO_2 emissions from energy supply and consumption

3.1 Introduction

CO_2 emissions originate for 90% from fossil-fuel combustion and therefore are determined by the following three main factors:
- Energy demand or the level of energy-intensive activity; in particular, related to power generation, basic materials industry and road transport;
- changes in energy efficiency;
- shifts in fuel mix, such as from carbon-intensive coal to low-carbon gas, or from fossil fuels to nuclear or renewable energy.

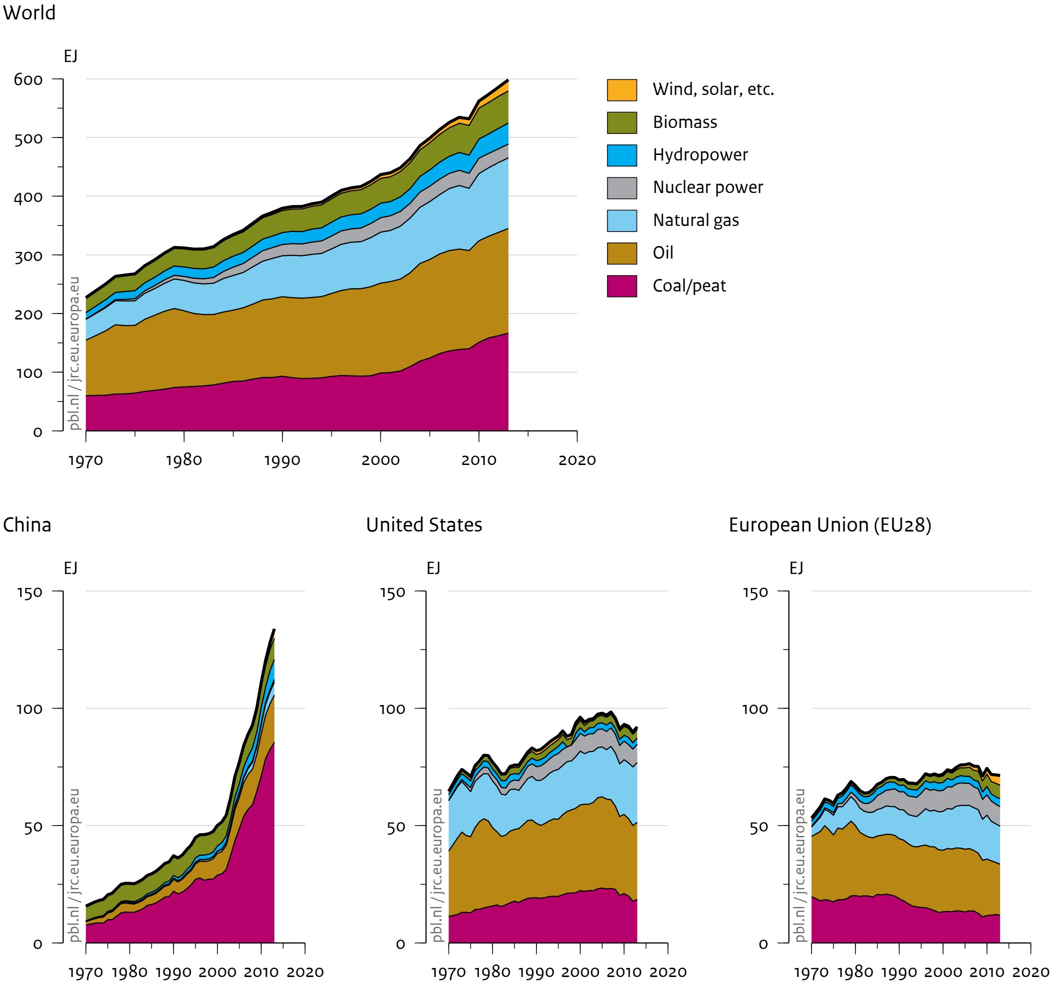
Important drivers of specific fossil-fuel consumption are the fuel price, in general, and relative price differences between coal, oil products and natural gas. Of course, energy policies also are aimed to manage fossil-fuel use. In addition, energy consumption is affected by certain preconditions, such as weather: warm or cold winters affect the demand for space heating and in some countries hot summers affect the demand for air conditioning. Moreover, the topography, orography and climate of a country affect activities such as distances travelled and the potential for renewable energy such as hydropower and wind, solar and tidal energy.

Analysis for a group of IEA countries showed that improved energy efficiency has been the main reason for decoupling total energy consumption from economic growth (IEA, 2008). The IEA has published many studies showing and analysing historical improvements in various economic sectors (e.g. IEA 2004; 2007; 2008). It was concluded that changes caused by the oil price shocks in the 1970s and the resulting energy policies had a larger impact on the increase in energy demand and reduction in CO_2 emissions than the energy efficiency and climate policies implemented in the 1990s. For more detailed information on trends in energy efficiency improvement and on carbon capture and storage (CCS) we refer to last year's report (Olivier et al., 2013).

Section 3.2 presents general trends in the fuel mix, Section 3.3 shows more detailed trends in renewable energy, and Section 3.4 looks more specifically at changes in nuclear energy.

For CO_2 emissions it is important to note that natural gas (~15 kg C/GJ) per unit of energy contains roughly half the amount of carbon (C) compared to coal (~26 kg C/GJ), with the amount of carbon in oil products somewhere in between (~20 kg C/GJ). Thus, the combustion of coal produces about 75% more CO_2 than that of natural gas. In addition, since natural-gas-fired combined cycle power plants operate at a higher temperature, they can achieve up to almost 15% higher energy efficiency than coal-fired power plants. Therefore, recent trends in the fossil-fuel mix with shifts from coal to gas, or vice versa, in the United States, China and Europe, are very relevant for the overall trend in CO_2 emissions. IEA data for 2012 shows that coal combustion globally is responsible for 43% of CO_2 emissions from fossil-fuel combustion, with 28% emitted from coal-fired power plants, the remaining 15% emitted mainly from other industrial combustion (in cement, iron and steel, chemical industries in particular) but also from some smaller scale combustion in the residential sector. Industry, in particular iron and steel manufacturing, is the second largest source. The use of coal is country-specific: the share of coal in the energy mix of the top 25 countries varies from 33% in the United States to 43% in India, 47% in China and 49% in Poland (Table 3.1). Swart and Weaver (2012) also point to the large tonnage of coal available and its high carbon content in comparison to other fossil-fuel resources. The full consumption of the known reserves of global coal resources would cause 5 times more CO_2 eq emissions, than the full consumption of all global shale gas and oil resources. Full consumption of all shale gas and oil reserves, in turn, would cause 10 times more CO_2 eq emissions, than the full consumption of the total conventional global gas and oil resources.

Figure 3.1
Total primary energy supply by type



Source: IEA 2014; BP 2014

Note: Using substitution method for nuclear, hydro and other non-biomass renewables as in BP (2014) (i.e. assuming 38% conversion efficiency)

3.2 Trends in global fossil-fuel consumption and fuel mix

The historical trend in global energy mix shown in Figure 3.1 shows a steady increase in the share of natural gas consumption in the total primary energy mix, between 1970 and the early 2000s. The stagnation of the natural gas share since 2002 has not been due to an absolute decrease in gas consumption, but trend breaks in the relative growth rate of natural gas and oil shares were due to the much higher growth rate of coal consumption since 2002. This strong increase in coal consumption mainly was caused by the fast developing economy of China, which shows a quite different primary energy supply mix than that of the United States and European Union, as shown in Figure 3.1. The situation of related CO_2 emissions in 2012 reported by IEA is given in Table 3.1.

Fossil fuel combustion accounts for about 92% of total global CO_2 emissions, excluding those from forest fires and the use of wood fuel (EDGAR 4.2; JRC/PBL, 2011). As the global economy continued to grow (3.1%) in 2013 compared to 2012, CO_2 from global fuel combustion saw an actual growth of 1.9%, which represents half the average annual CO_2 growth over the last decade (BP, 2014; NBS, 2014b). The CO_2 emission trends in OECD and non-OECD countries are diverging, with a stabilisation of 0.0% in OECD countries after five decreases over the past seven years, versus a 2.8% increase in non-OECD countries.

Global fossil oil consumption increased by about 1.1% in 2013 compared to 2012 (BP, 2014). China's oil consumption increased by 3.5%, which is below half of the 10-year average growth, and accounted for more than half of the

Table 3.1

CO_2 emissions from fossil fuel combustion in the top 4 in 2012 by main sector and fuel type (billion tonnes CO_2) (source: IEA, 2014b)

China	Total	Coal	Oil	Natural gas	Other
Total sectors	**8.2**	**6.8**	**1.2**	**0.3**	**0.0**
Main activity power generation *	**4.0**	3.97	0.01	0.05	
Autoproducers/other energy industry	**0.4**	0.25	0.08	0.04	0.02
Manufacturing industry **	**2.5**	2.23	0.24	0.08	
Road transport	**0.6**		0.54	0.03	
Other transport ***	**0.1**		0.13	0.00	
Residential sector	**0.3**	0.19	0.07	0.06	
Other buildings ****	**0.2**	0.13	0.10	0.02	0.00
United States	**Total**	**Coal**	**Oil**	**Natural gas**	**Other**
Total sectors	**5.1**	**1.6**	**2.1**	**1.4**	**0.0**
Main activity power generation *	**2.0**	1.49	0.02	0.49	0.02
Autoproducers/other energy industry	**0.4**	0.03	0.12	0.20	0.01
Manufacturing industry **	**0.5**	0.09	0.14	0.26	0.01
Road transport	**1.4**		1.41	0.00	
Other transport ***	**0.3**		0.22	0.04	
Residential sector	**0.3**		0.08	0.23	
Other buildings ****	**0.2**	0.00	0.08	0.16	0.00
European Union (EU28)	**Total**	**Coal**	**Oil**	**Natural gas**	**Other**
Total sectors	**3.5**	**1.1**	**1.4**	**0.9**	**0.06**
Main activity power generation *	**1.2**	0.89	0.05	0.21	0.03
Autoproducers/other energy industry	**0.3**	0.08	0.12	0.09	0.02
Manufacturing industry **	**0.5**	0.12	0.17	0.21	0.02
Road transport	**0.8**		0.81	0.00	
Other transport ***	**0.0**		0.04	0.00	
Residential sector	**0.4**	0.04	0.11	0.25	
Other buildings ****	**0.2**	0.01	0.10	0.12	0.00
India	**Total**	**Coal**	**Oil**	**Natural gas**	**Other**
Total sectors	**2.0**	**1.4**	**0.5**	**0.1**	**0.0**
Main activity power generation *	**0.9**	0.86	0.01	0.03	
Autoproducers/other energy industry	**0.2**	0.12	0.07	0.02	0.00
Manufacturing industry **	**0.5**	0.34	0.10	0.04	
Road transport	**0.2**		0.20	0.00	
Other transport ***	**0.0**		0.02	0.00	
Residential sector	**0.1**	0.01	0.06	0.01	
Other buildings ****	**0.1**	0.03	0.04	0.00	0.00

** Includes main activity heat production*

*** Includes emissions from non-energy and feedstock uses of fuels*

**** Includes international marine and aviation bunkers*

***** Service sector; includes agriculture and forestry* increase in oil trade in 2013, with oil import increasing by 5.9%. End 2013, China also became the world's largest oil importer (EIA, 2014b) in reply to the steady economic growth with rapidly rising petroleum demand. At global scale, fossil oil has always been taking the lion's share of the world total primary energy supply, but is recently losing ground. Whereas in 2000 its share accounted 36%, it is nowadays 31% and the share of coal increased from 23% to 29%.

Coal consumption increased globally by 2.8% in 2013,compared to 2012, using BP (2014) except for data for China in 2012 and 2013 for which we used IEA (2014b) and NBS (2014) (see Annex A.1.1. for details). China, with a share of 49% in global coal consumption, continued the increase over 2013 of 3.7%, confirming the slowed down increase in coal consumption in 2012 of 2.4% following the large increases in coal consumption in 2010 and 2011 (9.5% in both years). China, the world's largest coal importer, levies import tariffs of 3% to 6% from October 2014, to start reducing imports from Australia and Russia (Reuters, 2014). The coal import volume is determined, to a large extent, by the domestic and international coal price difference. In addition, domestic use of coal produced in China mainly in the western and northern inland provinces faces a transportation bottleneck towards the southern coast with highest coal demand, mainly by lacking southbound rail lines (Tu, 2011, 2012). The accuracy of China's coal consumption data is commonly estimated by at about 5% to 15%, with higher uncertainties expected regarding the data on the last 15 years. Annex A1.4 provides more details in a discussion on uncertainty. Coal consumption in India keeps increasing at a high pace, with 7.3%. Consumption in OECD countries increased collectively by 1.1%, with large decreases in Europe, i.e. in Spain (31.7%), Romania (19.0%), Italy (10.5%) and the United Kingdom (6.5%), as well as in Australia (4.9%) and Turkey (7.7%).

Natural gas consumption increased globally by 1.1% in 2013 compared to 2012 (BP, 2014). Among countries with more than a 2% share in the world's natural gas consumption, the largest increases took place in China (10.5%), Germany (6.7%), Mexico (3.9%) Saudi Arabia (3.7%), Canada (3.2%) and the United States (2.1%). In the European Union, after the largest decline on record (10%) in 2011, due to warm weather, a weak economy, high gas prices and increases in renewable electricity production, gas consumption in the European Union did not take off again, but continued to decrease by 1.2% in 2012, mainly caused by declines in Italy (6.5%) and in the European countries close to Russia, more in particular Lithuania (18.5%), Hungary (16.4%), Romania (7.7%), Finland (6.9%) and Bulgaria (3.4%).

The United States, over the past five years, saw a significant fuel shift of 4 percentage points from coal to gas. The exploration of shale gas increased such that the United States no longer depends as much on fossil-fuel imports. The large decrease in CO_2 emissions in 2013 was mainly caused by the drop in coal consumption, in particular in the power sector. This also shows that in countries with sufficient reserves in power generation capacity, changes in the fuel mix can occur relatively fast. In 2010 the United States has overtaken the Russian Federation to become the world's largest gas producer, which is since 2013 produced for the largest part from shale gas wells (IEA, 2014j) (see also Figure 2.8). As a consequence, the United States since 2008 has relatively low natural gas prices compared to Europe and Japan, and larger reserves of fossil fuel.

3.3 Trends in renewable energy sources

Together, renewable energy sources meet almost one-fifth of global final energy consumption, including traditional biofuels, such as fuel wood (REN21, 2014). More than 56% of the electricity generating capacity added globally in 2013 consisted of renewable energy. At the end of 2013, the total in global power capacity generated from renewable energy had exceeded 1,560 GW, up 8% from 2012, supplying an estimated 22.1% of global electricity (16.4% in hydropower, 2.9% in wind power and 1.8% in biomass power). Today, at least 144 countries, two thirds of which are developing countries, have renewable energy targets in place, up from 138 countries one year before, and the rise of developing world support contrasts with slackening of policy support in some European countries and the United States. In China, new renewable capacity surpassed for the first time new fossil fuel and nuclear energy capacity in 2013. High levels of penetration of different forms of renewable energy meet e.g. 33.2% of electricity demand in Denmark and 20.9% in Spain from wind power, and 7.8% in Italy from PV in 2013 (REN21, 2014).

3.3.1 Hydropower

Hydropower output was 3,782 TWh in 2013, an increase by 2.7% compared to 2012 (down from 4.8 % in 2012) (BP, 2014). The top 5 hydropower producers in 2013 were China (24.1% share), Canada (10.4%), Brazil (10.2%), the United States (7.2%) and the Russian Federation (4.8%). Of the 43% increase in the hydropower output since 2002, China accounted for more than half and Brazil for almost 9% (BP, 2014). In terms of newly installed capacity in 2013 (40 GW), China led with 29 GW, followed by Turkey (2.9 GW), Brazil (2 GW), Vietnam (1.3 GW), India (0.8 GW) and the Russian Federation (0.7 GW), increasing the total global capacity to about 1,000 GW (REN21, 2014).

3.3.2 Wind power

Total global wind power capacity was 318 GW at the end of 2013, an increase of more than 12.5% compared to 2012, lower than the average of about 21% over the last 10 years (GWEC, 2014). Wind power output was 628.2 TWh in 2013, an increase of 20.3% compared to 2012 (BP, 2014). In 2013, most new wind power capacity was installed in Asia (51.6%), Europe (34%) and North America (8.7%). However, Europe still had the largest total wind power capacity in the world, with 38.2% of the total in 2013. China, the world's largest wind power market, added 16,088 MW in new wind capacity in 2013, resulting in a total of 91.4 GW installed by the end of 2013. Wind power represented 2.6% of the total electricity generated in China last year. India added 1,729 MW of new capacity to reach a total of 20.2 GW. During 2013, 11,159 MW of additional wind power was installed in the European Union, resulting in a total capacity of 117.3 GW. Germany installed 3,238 MW of additional capacity, the United Kingdom 1,883 MW, followed by Poland (894 MW), Sweden (724 MW), Romania (695 MW), Denmark (657 MW) and France (631 MW). The total wind power capacity installed in the European Union by the end of 2013, on average, produced 236.5 TWh of electricity, now meeting 8% of EU electricity demand, up from 7% in 2012, 6.3% in 2011 and 4.8% in 2009. After its strongest year ever in 2012 (28% increase), the United States added 1,084 MW wind capacity in 2013, a 1.8% increase from 2012, bringing its total wind capacity to 61.1 GW, equivalent to 5.23% of total US installed generation capacity (GWEC, 2014).

3.3.3 Solar energy

Total global *solar photovoltaic* (PV) capacity increased in 2013 by 39% to about 138.9 GW, and could produce, on average, 160 terawatt hours (TWh) of electricity every year (EPIA, 2014). According to BP (2014), PV power output was 124.8 TWh in 2013, an increase of 32.6% compared to 2012. The global total PV installed in 2013 was 38.4 GW, up from 30 GW in 2012 and was dominated by growth in Asia (56%), led by China with 11.8 GW and Japan with 6.9 GW. By comparison, the United States and Germany installed 4.8 and 3.3 GW, respectively, and United Kingdom, Italy, Romania and Greece each exceeded the 1 GW mark. Regarding cumulative installed capacity, Europe is the world's leading region, with 81.5 GW, which represents 59% of the world's cumulative PV capacity in 2013, followed by Asia Pacific countries (40.6 GW) and North America (13.7 GW). In Europe, PV covers 3% of the electricity demand and 6% of the peak[1] electricity demand (EPIA, 2014).

Total global *solar heat* (SH) capacity increased in 2013 by 21% to about 330 GWth (276.6 TWh); including 325.9 GWth of water collectors and about 3.6 GWth of air collectors. China was again the leading country with approximately 36.6 GWth newly installed capacity bringing the country total to about 217 GWth. In 2012 Europe's total operating capacity was 30.2 GWth but the growth continued to slowdown, Germany remained the largest installer in 2013 by adding 0.7 MWth for a total of 12.3 GWth. The solar water heating collectors global capacity shares of the top 10 countries in 2012 were: China 64%, the United States 5.8%, Germany 4.2%, Turkey 3.9%, Brazil 2.1%, Australia 1.8%, India 1.6%, Austria 1.2%, Japan 1.1% and Israel 1% (REN21, 2014). According to Mauthner and Weiss (2013), by the end of 2011, in China, the cumulative installed capacity, per type, was 93% in evacuated tubes and 7% in flat plate collectors, while in Europe 87% was in flat plate collectors, 8% in evacuated tubes and 5% in unglazed water collectors.
By comparison, the United State had 89% in unglazed water collectors and 11% in flat plate collectors in cumulative installed capacity.

Concentrated Solar Power (CSP) is a large-scale promising technology, albeit with high initial capital costs.
The modest growth over the years has been driven by government support schemes. After its record in 2012, when the total global CSP capacity increased by more than 60% to about 2.5 GW, the growth continued in 2013 by an addition of 0.9 GW, up 36%, to about 3.4 GW total global capacity (REN21, 2014), most of which being concentrated in Spain and the United States (Jager-Waldau, 2013). In 2013, Spain increased the operating capacity by 18% to a total of 2.3GW and the United Stated added 375 MW to end the year with almost 0.9 GW. Newly installed capacity also included 100 MW in the United Arab Emirates, 50 MW in India and 10 MW in China. Other countries with existing CSP are Algeria (25 MW), Morocco (20MW), Egypt (20 MW), Australia (13 MW) and Thailand (5 MW).

3.3.4 Competitiveness of wind power and solar power

The competitiveness of wind and solar power is improving considering the price evolution of these technologies. From 2008 to 2012, the wind turbine prices have decreased by 29% and prices of PV modules have decreased by 80% (Clean Technica, 2013). In 2013, even if the global investments in PV declined by 22% relative to the previous year the new capacity installations increased by about 32%. Moreover, recent cost estimates show that global levelised costs (USD/MWh) fell about 15% between 2009 and early 2014 (REN21, 2014). This explains that while in monetary value terms the capacity installed decreased, in capacity terms it actually increased due to reducing prices per unit installed.

3.3.5 Biofuels for transport

Global biofuel production has been growing steadily from 16 billion litres in 2000, 100 billion litres in 2011 to 113 billion litres in 2013 (IEA, 2014d). Consumption of biofuel in road transport has increased by 2% globally in 2013. The two leading countries are the United States with a share of 45.6% and Brazil with a share of 21.2% in global biofuel consumption. In 2013, the EU28 as a whole had a share of 20.8% in global total with Germany and France the largest contributors. In the United States, the biofuel consumption in road transport has been growing rapidly in recent years (4% in 2012 and 9% in 2013) as the share of ethanol in petrol approached the 'blend wall', the practical limit of the fraction of ethanol in petrol that can be used in most modern regular petrol-fuelled car engines; however, continuing further this growth requires moving towards higher ethanol blends (Oil & Gas Journal, 2014). In the European Union, after an increase of 6% in 2012, biofuel consumption decreased by 10% in 2013, driven by large decreases in 2012–2013 in Germany (10%), Italy (9%) and Spain (58%), although significant increases have been seen in the United Kingdom (13%), Sweden (18%) and Denmark (41%) (see Table 3.2).

Current fuel ethanol and biodiesel use represents about 3% of global road transport fuels and could be expected to have reduced CO_2 emissions with a similar percentage if all biofuel had been produced sustainably. In practice, however, net reduction in total emissions in the biofuel production and consumption chain is between 35% and 80% (Eickhout et al., 2008; Edwards et al., 2008). These estimates also exclude indirect emissions, such as those from additional deforestation (Ros et al., 2010). An example of the latter is biodiesel produced from palm oil from plantations on deforested and partly drained peat soils. Thus, the effective reduction will be between 1% and 2%, excluding possible indirect effects. Large uncertainty in terms of GHG emission reductions compared to the fossil fuels is driven by both the complexity of the biofuel pathways and the diversity of the feedstock, nevertheless, in the near future the advanced biofuels (lignocellulosic, algae) are expected to deliver more environmental benefits (Carlsson and Vellei, 2013).

Recently, emission reductions in the transport sector through tax incentives and blending mandates act as a driver for biofuel development. If successfully implemented, global demand will be driven by blending mandates in the European Union, the United States, China and Brazil. In 2013, biofuels mandates were in place in the EU28, 13 countries in North and South America, 12 in Asia and the Pacific and 10 in Africa (Biofuels digest, 2014; GFRA, 2014), but only the United States and the European Union have policies targeting so-called advanced biofuels (IEA, 2014d).

3.4 Trends in nuclear energy

In 2013, nuclear electricity generation of 2359 billion kWh (produced by 435 operable – not all 100% in operation – civil nuclear power reactors) contributed to 11% of the world's total electricity (WNA, 2014). After two consecutive drops of 4% and 7% from 2011 respectively 2012 compared to 2010 and 2011, the nuclear power generation seems to remain stable and is expected to grow with 71 reactors under construction, of which 49 in China, South Korea and India (WNA, 2013).

Of these 2359 billion kWh, 883.2 billion was generated by the 131 power plants in the 14 nuclear energy countries of the European Union. The highest share of nuclear generated electricity is found in western Europe with France (73%), Belgium and Slovakia (52% each) and Hungary (51%). The nuclear energy share in the United States and Russia is respectively 19.4% and 17.5%. South Korea, Japan, India and China show current shares of 28%, 1.7%, 3.5% and 2.1%.

The EU base load electricity generation depends on nuclear power for more than one quarter of its total, but very different energy policies pertain across Europe. The EU's nuclear power generating capacity is 903 GW electric, with almost one third of this in France and Germany but with German's Energiewende policy a phasing out of nuclear power by 2023 will cause a decrease of 122 GW electric (GWe) in the near term.

In 2014 the European Commission accepted an incentive system for low-carbon electricity, including nuclear energy, in the United Kingdom. The UK plans for four EPR nuclear reactors at Sizewell in Suffolk and Hinkley Point in Somerset, retained by EDF and two Chinese companies. In France the new nuclear reactor (1750 MWe) at Flamanville on the Normandy coast is under completion in 2014 and expected to come on the grid in 2016. EDF plans to replace its 58 reactors with EPR units from 2020, at the rate of about one 1650 MWe unit per year. Finland is constructing its fifth nuclear reactor, which is delayed and now expected to come on grid in 2018. Two more are planned and in February 2014 a new intergovernmental agreement with Russia was signed to enable Rosatom to supply a reactor unit.

Table 3.2
Biofuel consumption in road transport (bioethanol and biodiesel) per country, 2005–2013 (in TJ)

Country	2005	2006	2007	2008	2009	2010	2011	2012	2013
Annex I	**487,501**	**728,411**	**975,009**	**1,288,904**	**1,484,925**	**1,656,191**	**1,764,992**	**1,852,966**	**1,915,310**
United States	347,566	482,340	604,448	822,734	931,441	1,019,686	1,085,568	1,130,257	1,236,879
Canada	7,531	5,789	27,051	29,339	32,893	48,285	68,520	73,796	77,748
Turkey	0	815	519	638	278	259	659	3,030	15,565
Australia	777	2,176	4,644	6,952	9,822	12,050	14,323	13,554	13,212
Norway	0	221	1,251	3,412	3,964	4,861	4,811	5,527	5,089
Japan	392	393	522	522	1,109	1,891	3,193	3,193	3,193
Switzerland	251	283	432	432	315	373	368	432	380
Belarus	0	0	0	294	368	478	331	221	221
New Zealand	0	0	40	126	126	155	252	242	173
Monaco	0	10	10	30	30	20	20	20	20
Iceland	0	0	0	10	10	10	6	6	6
EU28, of which:	**130,984**	**236,385**	**336,091**	**424,414**	**504,569**	**568,122**	**586,941**	**622,689**	**562,825**
Germany	80,736	145,342	164,214	132,600	121,924	131,816	125,225	129,228	115,941
France	16,732	30,460	60,574	95,076	103,260	101,336	101,231	113,420	111,721
Italy	7,400	8,251	7,474	30,517	47,918	59,427	58,656	57,273	52,073
UK	3,609	8,380	14,968	33,854	41,698	49,129	45,581	38,943	44,111
Spain	10,819	7,155	16,114	25,935	44,909	60,105	72,074	89,072	37,385
Poland	2,228	4,091	4,441	18,482	27,737	37,123	39,088	34,439	31,702
Sweden	5,650	7,850	11,912	14,392	15,098	15,923	18,222	22,660	26,761
Austria	2,342	11,822	14,735	17,825	22,407	21,852	21,955	21,679	22,609
Belgium	37	481	4,211	4,794	12,771	15,944	14,794	15,027	14,255
Denmark	0	160	240	289	439	1,197	5,633	9,663	13,585
Netherlands	446	2,800	15,156	13,413	16,942	10,180	13,488	14,017	13,341
Finland	0	28	55	3,173	6,521	7,070	9,598	11,752	12,532
Czech Republic	111	757	1,258	4,603	8,155	9,682	12,565	11,525	11,747
Portugal	0	2,997	5,660	5,771	9,434	13,689	12,875	12,020	11,469
Romania	0	0	1,693	2,061	1,690	4,753	7,761	9,126	9,126
Hungary	107	456	1,200	6,892	7,079	7,317	6,934	6,531	6,062
Greece	0	1,932	3,562	2,886	3,266	5,355	4,444	5,355	5,917
Slovakia	439	1,864	2,625	3,104	3,547	4,090	4,089	3,807	4,147
Ireland	37	101	942	2,307	3,228	3,918	4,089	3,541	4,138
Bulgaria	0	331	147	147	221	846	699	3,496	3,496
Lithuania	137	803	2,212	2,557	2,145	1,864	1,874	2,520	2,520
Slovenia	0	185	580	1,029	1,261	1,905	1,452	2,132	2,417
Luxembourg	40	40	1,897	1,897	1,783	1,743	1,908	2,037	2,342
Croatia	0	0	110	147	328	110	164	1,526	1,526
Latvia	110	100	74	74	181	1,121	1,720	894	894
Cyprus	0	0	37	589	626	626	662	662	662
Malta	0	0	0	0	0	0	0	184	184
Estonia	0	0	0	0	0	0	161	161	161

Table 3.2 (continued)

Country	2005	2006	2007	2008	2009	2010	2011	2012	2013
Non Annex I	**339,292**	**378,065**	**513,234**	**706,872**	**795,260**	**856,421**	**799,145**	**795,965**	**641,779**
Brazil	330,433	323,732	451,698	613,262	675,078	706,062	621,661	575,591	53,897
China	0	42,200	39,056	49,188	50,712	48,488	49,560	49,560	52,038
Thailand	1,420	2,680	5,906	20,042	26,542	27,399	29,553	38,808	48,172
Argentina	662	662	662	662	1,987	22,130	33,654	38,758	26,188
Indonesia	0	368	1,489	1,536	4,018	7,286	11,629	21,933	16,266
South Korea	459	1,681	3,324	6,266	9,209	12,571	11,845	12,762	15,565
Peru	0	0	0	0	2,907	3,701	4,793	12,569	13,339
Philippines	54	90	1,295	2,222	7,903	7,047	7,754	10,008	13,050
India	4,261	4,476	4,958	5,494	6,110	6,780	7,504	8,767	8,767
Malaysia	0	258	1,288	1,766	184	184	994	4,821	4,821
Paraguay (PRY)	482	509	429	858	1,635	2,144	2,278	3,296	3,296
Taiwan	0	0	196	1,215	2,091	4,051	3,004	3,028	3,028
Serbia	0	0	980	1,961	2,941	2,941	2,941	2,941	2,941
Trinidad and Tobago	0	0	0	0	0	0	2,605	2,605	2,605
Jamaica	0	0	0	130	1,302	1,302	2,605	2,605	2,605
Nigeria	0	0	391	651	0	0	1,302	1,302	1,302
Colombia	27	268	295	415	532	800	1,038	1,074	1,074
Hong Kong	0	0	0	0	0	196	196	1,067	1,067
Uruguay	59	78	118	98	248	522	874	1,014	1,014
Vietnam	0	0	0	0	0	130	651	651	651
Mexico	0	0	196	196	200	587	587	587	587
Costa Rica	0	0	65	65	651	651	521	521	521
Cuba	1,302	912	521	391	391	391	391	391	391
Pakistan	0	0	0	0	0	260	260	260	260
14 Other countries	132	150	366	416	544	796	947	1,043	1,043
Global total	**826,793**	**1,106,476**	**1,488,243**	**1,995,776**	**2,280,185**	**2,512,612**	**2,564,137**	**2,648,930**	**2,823,890**

Notes: The Table has been updated using data from IEA (2014b) until 2012 and supplemented with EIA (2013a) for four OECD countries and 19 non-OECD countries and with USDA (2013, 2014) data for the last one or two years except for Israel, Japan, Mexico and some others for which the data were extrapolated for 2012 and 2013. The other 14 countries with reported biofuel consumption, for 2013 estimated between 200 TJ and 20 TJ, are in decreasing order: Israel, South Africa, Ecuador, Ethiopia, Malawi, Singapore, Fiji, Guatemala, Honduras, Rwanda and Tanzania. For more details on the data sources see Annex 1.2.
(Sub)totals may not match precisely due to independent rounding.

Annex 1: Methodology and data sources over the 2010–2013 period

A1.1 Methodology and data sources

Trends for the 1970–2010 period were based on EDGAR 4.2 Fast Track 2010 (FT2010) (Olivier and Janssens-Maenhout, 2014). The recent trends were estimated by PBL using trends in most recent data on fossil-fuel consumption, for 2010–2011 from the International Energy Agency (IEA, 2013b) and for 2011–2013 from the BP Review of World Energy 2013 (BP, 2014), except for coal consumption data in China for the 2012–2013 period, for which data were used as published respectively by the International Energy Agency (IEA) and the National Bureau of Statistics of China. For cement production, preliminary data for 2010–2013 were used from the US Geological Survey (USGS, 2014) except for China in 2012 and 2013 for which we used data of National Bureau of Statistics of China (NBS, 2014b). For other sources of CO_2, a similar method was used.

In the previous report we modified the coal consumption in China in 2012 in BP (2013) that represented a 6.4% increase over 2011 into a lower value to reflect 2.5% growth over 2011 reported by NBS (2013). This was done because the much higher BP number was inconsistent with the annual growth in 2012 reported for coal fired power generation and expansion of infrastructure as indicated by the cement and steel production (Olivier et al., 2013).

In this year's report BP revised the coal consumption in China in 2012 in a lower value equivalent to 5.4% increase over 2011 (no revision was made for earlier years), which is 1 percentage point less than in BP (2013) but still much higher than the preliminary estimate of 2.5% made by NBS (2013). Since the latest IEA energy statistics (IEA, 2014b) includes detailed coal statistics for China based on data reported by China, we adopted the growth of 2.4% in 2012 as best estimate for coal consumption in 2012 for this report, instead of the much higher growth of 5.4% in the BP dataset published this year. In this year's BP report (BP, 2014), coal consumption in China in 2013 increased 3.7% over 2012, which is the same as estimated by National Bureau of Statistics of China (NBS, 2014b). However, as we modified the 2012 coal consumption figure, we also had to adjust the 2013 value to maintain the 3.7% increase in 2013 reported by both BP and NBS.

For the trend estimate on 2010–2013, the following procedure was used. Sources were disaggregated into five main sectors as follows (with the defining IPCC source category codes from IPCC (1996) in brackets):
(1) fuel combustion (1A+international marine and aviation bunkers);
(2) fugitive emissions from fuels (1B);
(3) cement production and other carbonate uses (2A);
(4) non-energy/feedstock uses of fuels (2B+2C+2D+2G+3+4D4);
(5) other sources: waste incineration, underground coal fires and oil and gas fires (1992, in Kuwait) (6C+7A).

For these main source sectors the following data was used to estimate 2010–2013 emissions:
(1) Fuel combustion (IPCC category 1A + international bunkers):
   - For energy, for 2010–2011, the most recent detailed CO_2 estimates compiled by the International Energy Agency (IEA) for fuel combustion by major fossil fuel type (coal, oil, gas, other) for these years (IEA, 2013a) were used to calculate the trend per country and for international air and water transport.
   - For energy, for 2011–2013, the BP Review of World Energy was used to calculate the trend in fuel consumption per main fossil fuel type: coal, oil and natural gas (BP, 2014). For coal consumption in China in 2012 and 2013 we used data from the IEA (2014b), that showed a 2.4% increase for coal consumption in 2012, and the National Bureau of Statistics of China (NBS, 2014b) that reported a 3.7% (actual) increase in 2013 over 2012, respectively.

- For oil consumption, the BP figures were corrected for biofuel (fuel ethanol and biodiesel) which are included in the BP oil consumption data. See Section A1.2 for more details on the biofuel dataset.
- 'Other fuels', which are mainly fossil waste combusted for energetic purposes, were assumed to be oil products and the trend was assumed to follow oil consumption per country.
- For the trend in international transport, which uses only oil as a fuel, we applied the trend in oil consumption per country according to BP for the sum of 10 and 12 countries which contributed most to global total marine and aviation fuel sales in 2008 according to IEA statistics (covering about three-quarters and half of the total bunker fuel consumption, respectively).

(2) Fugitive emissions from fuels (IPCC category 1B):
- Fugitive emissions from solid fuel (1B1), which for CO_2 refers mainly to coke production: trends per country for 2010–2013 are assumed to be similar to the trend in crude steel production for 2010–2012 from USGS (2014) and for 2012–2013 from the Word Steel Association (WSA, 2014).
- Fugitive emissions from oil and gas (1B2), which refers to leakage, flaring and venting: trends per country for 2008–2010 in the FT2010 dataset were estimated using the same method and data sets as used for EDGAR 4.2 for the years up to 2008, since the NOAA data set that was used provides flaring data from satellite observation for the most important 58 countries up to 2010 (NOAA/NCDC, 2011; Elvidge et al., 2009a,b), which are prepared for the World Bank's Global Gas Flaring Reduction Partnership (GGFR, 2012). Combined with other data, the satellite data give robust information on the annual change in emissions. For 2011 the updated NOAA data set was used (NOAA, 2012, pers. comm.). For 2012 and 2013 we assumed constant emissions since no updated NOAA data are available, except for the United States in 2012 where we tentatively assumed a 35% increase (see Section 2.4).

(3) Cement production and other carbonate uses (2A):
- cement production (2A1)
- other carbonate uses, such as lime production and limestone use
- soda ash production and use.

CO_2 emissions from cement production, which amount to more than 90% of 2A category, were calculated using cement production data for 2010–2013 (2012 and 2013 preliminary data) published by the US Geological Survey (USGS, 2014), except for China in 2012 and 2013 where use was made of the National Bureau of Statistics of China (NBS,2014b). In addition, we extrapolated the trend in the emission factor due to trends in the fraction of clinker in the cement produced based on data reported by WBCSD (2009). Thus for 2010–2013 the same methodology was used as in EDGAR 4.2 FT 2000. For all other sources in the minerals production category (2A), we used the trend in lime production data for 2010–2013 (USGS, 2014) as proxy to estimate the trend in the other 2A emissions. All 2013 data are preliminary estimates.

(4) Non-energy/feedstock uses of fuels (2B+2C+2D+2G+3+4D4):
- ammonia production (2B1): net emissions, i.e. accounting for temporary storage in domestic urea production (for urea application see below);
- other chemicals production, such as ethylene, carbon black, carbides (2B other);
- blast furnace (2C1): net losses in blast furnaces in the steel industry, i.e. subtracting the carbon stored in the blast furnace gas produced from the gross emissions related to the carbon inputs (e.g., coke and coal) in the blast furnace as a reducing agent, since the CO_2 emissions from blast furnace gas combustion are accounted for in the fuel combustion sector (1A);
- another source in metal production is anode consumption (e.g., in electric arc furnaces for secondary steel production, primary aluminium and magnesium production) (2C);
- consumption of lubricants and paraffin waxes (2G), and indirect CO_2 emissions related to NMVOC emissions from solvent use (3);
- urea applied as fertiliser (4D4), in which the carbon stored is emitted as CO_2 (including emissions from limestone/dolomite used for liming of soils).

For the feedstock use for chemicals production (2B), ammonia production from USGS (2014) was used (2013 data are preliminary estimates). Since CO_2 emissions from blast furnaces are by far the largest subcategory within the metal production category 2C, for the trend in crude steel production was used to estimate the recent trend in the total emissions (USGS and WSA, see above under (1)). For the very small emissions in categories 2G and 3, the 2005–2008 trend was extrapolated to 2013. For simplicity, it was assumed that the small soil liming (4D4) emissions follow the gross ammonia production trend.

(5) Other sources (6C+7A):
- waste incineration (fossil part) (6C);
- fossil fuel fires (7A).

The 2005–2008 trend was extrapolated to 2013 for the relatively very small emissions of waste incineration (6C) and underground coal fires (mainly in China and India) and oil and gas fires (1992, in Kuwait) (7A).

CO_2 emissions from underground coal fires in China and elsewhere have been included in EDGAR 4.2 FT2010, although the magnitude of these sources is very uncertain. Van Dijk et al. (2009) concluded that CO_2 emissions from coal fires in China are at around 30 million tonne CO_2 per year. This is equivalent to about 0.3% of China's CO_2 emissions in 2013.

A1.2 Data set on biofuel use in road transport

This data set is restricted to bioethanol (also known as 'fuel ethanol' or 'biogasoline'), biodiesel and 'other liquid biofuels' used in road transport as substitute for fossil oil products (petrol, diesel or LPG) (see Table 3.2). Palm oil and solid biomass used in stationary combustion such as power generation was not considered, as it is not relevant for this study.
Biofuel consumption data for road transport for 2000–2013 were compiled from the following data sources:

- OECD countries: For 2000–2012 we used for 29 OECD countries IEA statistics for Total Final Consumption (TFC) of bioethanol ('biogasoline'), biodiesel and other liquid biofuels from IEA(2014b). For 2013 we used per biofuel type the trend 2012–2013 of Total Primary Energy Supply (TPES) to estimate the consumption in 2013 (IEA, 2014b). For 2013 only TPES values are known in these IEA (2014a) statistics. In most countries this is equal to road consumption or TFC.
  Of the five OECD countries that reported no biofuel consumption in IEA (2014b), four of them were supplemented by biofuel consumption reported by EIA (2013a) for 2000–2011: Iceland, Israel, Japan and Mexico. (Chili does not use biofuels according to IEA and EIA). Consumption in 2012 and 2013 was estimated by extrapolation.
- Non-OECD countries: For 2000–2012 we used for 24 non-OECD countries IEA (2014b) for biogasoline and biodiesel consumption in road transport 24 countries (plus 'other liquid biofuels' for Brazil and Bulgaria). For 2013 we used the trend 2012–2013 in USDA country reports (USDA, 2013, 2014) for the largest consuming countries: Argentina, Brazil, China, India, Indonesia, Malaysia, Peru, Philippines and Thailand.

This was supplemented with 19 more non-OECD countries with small amounts of biofuel consumption data reported by EIA (2013a) for 2000–2011. Consumption in 2012 and 2013 was estimated by extrapolation.
We used this dataset of all transport biofuel types (bioethanol, biodiesel, other liquid biofuels) as value to correct the oil consumption numbers of BP (2014), which include liquid biofuel consumption.

Although data for 2005 onwards are presented in Table 3.2, only 2010–2013 data are used in the CO_2 estimation method for fossil fuel combustion used in this study. For years up to 2010, the EDGAR 4.2 FT2010 data are used, which were calculated with fuel statistics from the IEA, in which fossil fuel data are separated from biofuel data (no mixing with reported oil consumption data as BP does).

A1.3 Other sources of CO_2 emissions: forest and peat fires and post-burn decay

The trend estimates of CO_2 emissions do not include CO_2 emissions from forest fires related to deforestation/logging and peat fires and subsequent post-burn emissions from decay of remaining above ground biomass and from drained peat soils. Although they are also significant but highly uncertain, CO_2 emissions from the decay of organic materials of plants and trees that remain after forest burning and logging are also not included. Annual CO_2 emissions from peat fires in Indonesia estimated by Van der Werf et al. (2008) indicate that emissions from peat fires vary most around 0.1 to 0.2 billion tonnes per year, except for peak years due to an El Niňo. For the very exceptional 1997 El Niňo, they estimated peat fire emissions at 2.5 billion tonnes CO_2. Joosten (2009) estimated global CO_2 emissions from drained peatlands in 2008 to amount 1.3 billion tonnes CO_2, of which 0.5 billion tonnes from Indonesia.

A1.4 Data quality and uncertainties

For industrialised countries, total CO_2 emissions per country, according to EDGAR 4.2, for the 1990–2008 period, are generally within 3% of officially reported emissions, except for a few economies in transition (EIT) (see examples provided in Table A1.1). Also, most industrialised countries (Annex I) estimate the uncertainty in their reported CO_2 emissions (excluding land use, IPCC sector 5) in the range of 2% to 5% (95% confidence interval, equivalent to 2 standard deviations).

The uncertainty in EDGAR's total national CO_2 emissions from fossil fuel use and other, non-combustion sources is estimated at about 5% for OECD-1990 countries and

Table A1.1

Differences between EDGAR national total CO_2 emissions and official NIR/CRF submissions (excluding LULUCF emissions, IPCC sector 5) (in % of NIR/CRF data) (reported uncertainty estimate cf. IPCC definition: 95% confidence interval, CI)

Country	1990	1995	2000	2005	2008	2010	2011	Average	Reported uncertainty (95% CI)	Note on uncertainty
United States	-2%	-3%	-2%	-3%	-3%	-4%	-4%	-2%	4%	for minimum: -2%
Canada	-2%	-2%	-3%	-2%	-1%	-1%	1%	-2%	2.4%	for energy sector
EU28	-2%	-1%	-1%	-1%	-0.3%	0.5%	1%	-1%	2%	for EU15
Russian Federation	-2%	11%	13%	13%	12%	7%	6%	10%	4%	
Ukraine	7%	25%	19%	6%	5%	4%	5%	13%	3.7%	
Japan	2%	2%	2%	2%	3%	4%	0%	2%	1%	
Australia	-3%	-1%	3%	7%	9%	6%	8%	3%	4 to 5%	
Total	**-1.4%**	**0.5%**	**0.9%**	**0.3%**	**0.5%**	**-0.1%**	**-0.1%**	0.3%		

Source: EDGAR 4.2FT2010: JRC/PBL (2012); NIR/CRF data: UNFCCC (2013).

around 10% for most EIT countries, such as Russia and the Ukraine. For developing countries, the EDGAR uncertainty estimates of national CO_2 emissions vary between 5% for countries with a well-developed statistical systems, such as India, and around 10% or more for countries with less-developed statistical systems. This is based on the uncertainty in the fuel data discussed in the 2006 IPCC Guidelines for greenhouse gas emission inventories (IPCC, 2006) and in the variation in the carbon content per fuel type, compared with IPCC default values (Olivier et al., 2010). Moreover, energy statistics for fast changing economies, such as China since the late 1990s, and for the countries of the former Soviet Union in the early 1990s, are less accurate than those for the mature industrialised countries within the OECD (Marland et al., 1999; Olivier and Peters (2002). For China, we assume an uncertainty of 10%, based on considerations discussed below.

CO_2 emission trends over recent years, estimated using energy data published annually by BP, appear to be reasonably accurate for estimating global CO_2 trends. For example, based on older BP energy data, the increase in 2005 in global CO_2 emissions from fuel combustion was estimated at 3.3%, globally. With more detailed statistics by the International Energy Agency (IEA) for 2005, which became available two years later, the increase is estimated at 3.2%. At country level, differences can be larger, particularly for small countries and countries with a large share in international marine fuel consumption (bunkers) and with a large share in non-combustion fuel use.

The uncertainty in CO_2 emissions from fossil-fuel combustion using international statistics is discussed in detail in Marland et al. (1999) and Andres et al. (2012), and general uncertainty characteristics in global and national emission inventories are discussed in Olivier and Peters (2002). Andres et al. (2012) evaluate several studies on the uncertainty of CO_2 emissions from fossil-fuel use and cement production and conclude that they range from between about 3% and 5% for the United States, to between 15% and 20% for China, based on a comparison of CO_2 estimates based on national coal statistics and on the sum of provincial coal statistics (Gregg et al., 2008), to estimates of 50% or more for countries with poorly maintained statistical infrastructure (Marland et al., 1999).

In recent years, the uncertainty in the CO_2 estimates for China was the subject of several studies. The uncertainty estimate by Gregg et al. (2008) was based on revisions of energy data for the transition period of the late 1990s, which may not be fully applicable to more recent energy statistics, since the revisions made by the National Bureau of Statistics of China in 2006 and 2010 (Tu, 2011). Interestingly, a recent study by Guan et al. (2012), continuing the comparison made by Gregg et al. (2008), points out the large difference between total provincial coal consumption statistics and national total statistics, whereas Tu (2011) attributes the discrepancy for a large part to the unreported coal production by small private coal mines in Shanxi in Inner Mongolia that continued producing although officially they had to shut down, together with staffing shortage at the National Bureau of Statistics of China. Tu claims that, therefore, China's coal statistics have been seriously underreported since 1998. He also mentions that in 2006 the NBS of China made statistical revisions for the 1999–2004, which were particularly large in the years between 1999 and 2001, and once more in 2010, with smaller revisions for the 1998–2007 period (see Figure 5.2 in Tu (2011)).

The question remains whether these revisions capture all discrepancies. Guan et al. (2012) conclude that this is not the case, stating a 1.4 billion tonnes CO_2 gap for 2010, between estimates based on national coal statistics and on provincial data. Guan et al. (2012) also compare with other reported estimates for China's CO_2 emissions over the 2007–2010 period, including EDGAR 4.1 data. They show that for 2008, EDGAR CO_2 emissions are one of the highest being compared and are actually almost equal to the higher estimate by Guan, based on the provincial coal statistics and for 2007 the EDGAR estimate is also closer to the higher 'provincial' CO_2 estimate than to the estimated 'national total'. Thus, it could be tentatively concluded that the uncertainty range of the EDGAR 4.2 data for China may be not symmetrical, but may have a larger uncertainty to the low end than to the high end of the range. From these recent studies on the accuracy of the data on China's CO_2 emissions, and taking into account the uncertainty in the default coal emission factors, of the order of 5% or more based on reporting by Annex I countries (Olivier et al., 2010), we conclude that the uncertainty in the EDGAR 4.2 estimate for China is about 10%, possibly with an asymmetrical range. This conclusion was also based on subsequent revisions of CO_2 emission estimates made by the IEA.

BP (2013) reported a 6.4% increase in coal consumption in China for 2012, whereas the National Bureau of Statistics of China reported a 2.5% increase (NBS, 2013). Both values were corrected in 2014. Three years ago there was a similar large discrepancy between these data sources: BP (2011) reported a 10.1% increase in coal consumption in China for 2010 (in energy units), whereas the NBS reported an increase of 5.9% in coal consumption per tonne. In the next BP (2012) the 2010 increase was revised to 6.1%, very similar to the preliminary increase reported by the NBSC. These subsequent changes could be indicative of the order of magnitude of the uncertainties in the statistics.

The coal consumption data for China were in the BP (2013) release updated for the last four years with annual increases very similar to NBS reported values.
In particular, whereas BP estimated last year the increase in China's coal consumption in 2011 to be 10.1%, which was reported by NBS is 5.9%. However, BP has now revised their estimate for 2011 in this year's report to 6.4%. Global consumption of natural gas and oil products increased by 2.2% and 0.9% (leap year corrected), respectively, somewhat below historical trends of 2.7% and 1.2% per year (BP, 2013).

In conclusion, we estimate the uncertainty in our estimates of total national annual CO_2 emissions at 5% for the United States, European Union, other OECD countries and India, and at 10% for the Russian Federation, China and developing countries with less-developed statistical systems. These uncertainties are primarily based on an uncertainty assessment of the emissions from fossil-fuel combustion, since these comprise the majority of total national emissions. The more uncertain CO_2 emissions from gas flaring and from non-combustion sources in industrial manufacturing do not substantially influence the uncertainty regarding total national emissions. The uncertainty in the emission trends, however, may be smaller than the uncertainty in annual emissions, as illustrated in the trend uncertainty assessments included in the national emission reports submitted to the UNFCCC (2012), which applied the methods described in the IPCC good practice guidance (IPCC, 2006).

A1.5 Results

Table 2.1 in Chapter 2 shows the trends in CO_2 emissions per region/country for 1990–2013 as presented in Figure 2.1 and Table A1.2 shows the change in per capita CO_2 emissions for 1990–2013 and of population for a numbers of countries. The emissions are excluding LULUCF emissions ('IPCC sector 5'). These tables and the figures used in Figures 2.1 to 2.7 can also be found as spreadsheet on the PBL website: http://www.clo.nl/nl0533 and on the EDGAR website at JRC: http://edgar.jrc.ec.europa.eu

Table A1.2

CO_2 emissions in 2013 (million tonnes CO_2) and CO_2/capita emissions, 1990–2013 (tonnes CO_2 per person)

Country	Emissions 2013	Per capita emissions 1990	2000	2010	2012	2013	Change '90–'13		Change in CO_2 '90 -'13 in %	Change in population 1990–2013 in %
Annex I*										
United States	5,300	19.6	20.6	17.6	16.3	16.6	-3.1	-16%	6%	26%
European Union	3,740	9.2	8.4	7.8	7.5	7.3	-1.8	-20%	-14%	8%
Germany	840	12.7	10.4	9.9	10.0	10.2	-2.5	-20%	-17%	3%
United Kingdom	480	10.3	9.2	8.2	7.8	7.5	-2.8	-27%	-19%	10%
Italy	390	7.5	8.1	6.9	6.8	6.4	-1.1	-15%	-8%	7%
France	370	6.9	6.9	6.2	5.7	5.7	-1.2	-17%	-6%	13%
Poland	320	8.2	7.5	8.7	8.4	8.5	0.3	4%	4%	0%
Spain	250	5.9	7.6	6.1	5.9	5.3	-0.6	-10%	8%	21%
Netherlands	160	10.8	10.9	10.7	9.8	9.7	-1.2	-11%	0%	13%
Russian Federation	1,800	16.5	11.3	11.9	12.7	12.6	-3.8	-23%	-26%	-4%
Japan	1,360	9.5	10.2	9.7	10.8	10.7	1.2	13%	17%	4%
Canada	550	16.2	17.9	16.2	15.7	15.7	-0.5	-3%	23%	27%
Australia	390	16.0	18.5	19.4	17.6	16.9	0.9	5%	44%	37%
Ukraine	300	14.9	7.2	6.6	6.8	6.7	-8.2	-55%	-61%	-12%
Non-Annex I										
China	10,330	2.1	2.8	6.4	7.2	7.4	5.3	246%	312%	19%
India	2,070	0.8	1.0	1.5	1.6	1.7	0.9	118%	214%	44%
South Korea	630	5.9	9.8	12.2	12.6	12.7	6.8	116%	148%	15%
Indonesia	510	1.5	2.0	2.2	2.4	2.6	1.1	75%	134%	34%
Saudi Arabia	490	0.9	1.4	1.9	1.9	2.0	1.1	120%	208%	40%
Brazil	480	10.2	12.9	15.6	16.9	16.6	6.4	63%	189%	78%
Mexico	470	3.6	3.6	3.9	4.0	3.9	0.3	7%	53%	42%
Iran	410	3.6	5.2	5.2	5.2	5.3	1.6	45%	99%	37%
South Africa	330	7.3	6.9	6.4	6.3	6.2	-1.1	-15%	23%	43%
Taiwan	270	6.2	10.5	11.9	11.5	11.6	5.5	88%	117%	15%
Thailand	260	1.6	2.8	3.6	4.0	3.9	2.3	144%	189%	18%

Source of population data: UNPD, 2013 (WPP Rev. 2012)

* *Annex I countries: industrialised countries with annual reporting obligations under the UN Framework Convention on Climate Change (UNFCCC) and emission targets under the Kyoto Protocol. The United States signed but not ratified the protocol and Canada has withdrawn from the protocol, and thus their emission targets in the protocol have no legal status.*

List of abbreviations and definitions

Annex I Countries	Group of industrialised ('developed') countries defined in the UNFCCC, most of which have specific emission targets under the Kyoto Protocol for the period 2008-12 ('Annex B' of the protocol). They include the 24 original OECD member countries in 1990, the European Union, and 14 countries with economies in transition (EIT).
AR5	Fifth Assessment Report of IPCC
BDEW	BDEW German Association of Energy and Water Industries (Bundesverband der Energie- und Wasserwirtschaft)
BP	BP p.l.c. (energy company; formerly British Petroleum Company plc)
DMSP-OLS	Defense Meteorological Satellite Program - Operational Linescan System
CCS	Carbon Capture and Storage
EC	European Commission
EDGAR	Emission Database for Global Atmospheric Research
EIA	U.S. Energy Information Administration
EIT	Economies in Transition, group of countries defined under the UNFCCC: the former centrally-planned economies of Russia and Eastern Europe
EPA	U.S. Environmental Protection Agency
EPIA	European Photovoltaic Industry Association
ESD	Effort Sharing Directive
ETS	Emissions Trading System
EU28	European Union with 28 Member States
GCP	Global Carbon Project
GDP	Gross domestic product
GGFR	World Bank's Global Gas Flaring Reduction Partnership
GHG	Greenhouse Gas
GAO	U.S. Government Accountability Office
GW	Gigawatt (1 billion W = 10^9 W) (unit of power)
GWth	Gigawatt thermal (unit of power input, as opposed to GWe, which refers to electricity output)
GWEC	Global Wind Energy Council
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IES	Institute for Environment and Sustainability of the Joint Research Centre JRC
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre of the European Commission
LPG	Liquefied petroleum gas
LNG	Liquefied Natural Gas
LULUCF	Land use, land-use change and forestry
MODIS	Moderate Resolution Imaging Spectroradiometer (satellite instrument for remote sensing)
MRS	Market Stability Reserve
NBS	National Bureau of Statistics of China

NMVOC	Non-methane volatile organic compounds
NOAA	U.S. National Oceanic and Atmospheric Administration
NOAA/NCDC	U.S. National Oceanic and Atmospheric Administration/National Climatic Data Center
OECD	Organisation for Economic Co-operation and Development
PBL	PBL Netherlands Environmental Assessment Agency
ppm	parts per million (dry air mole fraction of a compound relative to the number of all molecules in air, including the compound itself, after water vapour has been removed)
PPP	Purchasing Power Parity
PV	Photovoltaic
SNA	2008 UN System of National Accounts
TJ	Terajoule = 10^9 J)
TWh	Terawatt hour (1000 billion W hour = 10^{12} Wh = 3.6 Petajoule, PJ)
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
UNEP	United Nations Environment Programme
UNPD	United Nations Population Division
USD	U.S. Dollar
USGS	United States Geological Survey
WBCSD	World Business Council on Sustainable Development
WSA	Word Steel Association
WPP	World Population Prospects of UNPD

References

AGA (2014) Heating Degree Day Data. A.G. Association. Internet: http://www.aga.org/Kc/analyses-and-statistics/statistics/weeklystats/HeatingDegreeData/Pages/blank.aspx.

Airlie, C. (2011) RWE's Coal-Power Plant in Tilbury to Become Britain's Largest Wood Burner. Bloomberg. Internet: http://www.bloomberg.com/news/2011-04-08/rwe-s-coal-power-plant-in-tilburyto-become-britain-s-largest-wood-burner.html.

Andres, R.J., Boden, T.A., Bréon, F.M., Ciais, P., Davis, S., Erickson, D., Gregg, J.S., Jacobson, A., Marland, G., Miller, J., Oda, T., Olivier, J.G.J., Raupach, M.R., Rayner, P. and Treanton, K. (2012) A synthesis of carbon dioxide emissions from fossil-fuel combustion. *Biogeosciences* 9, 1845-1871, doi:10.5194/bg-9-1845-2012. Internet: http://www.biogeosciences.net/9/1845/2012/bg-9-1845-2012.pdf

Biofuelsdigest (2014) Biofuels Mandates Around the World: 2014. J. Lane. Internet: http://www.biofuelsdigest.com/bdigest/2013/12/31/biofuels-mandates-around-the-world-2014/.

Bloomberg (2014) Shipping Rates Drop as China Hydro Power Cuts Coal Need. Internet: http://www.bloomberg.com/news/2014-07-31/shipping-rates-suffer-as-china-hydro-curbs-coal-imports-freight.html.

BP (2011-2014) BP Statistical Review of World Energy 2011-2014. Internet: http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy.html.

Bundesnetzagentur (2014) List of Power Plants. Internet: http://www.bundesnetzagentur.de/cln_1421/EN/Areas/Energy/Companies/SpecialTopics/PowerPlantList/PubliPowerPlantList_node.html.

Caldecott, B. and McDaniels, J. (2014) Stranded generation assets: Implications for European capacity mechanisms, energy markets and climate policy. Working Paper, January 2014. Smith School of Enterprise and the Environment, University of Oxford, Oxford, UK. Internet: http://www.smithschool.ox.ac.uk/research-programmes/stranded-assets/Stranded%20Generation%20Assets%20-%20Working%20Paper%20-%20Final%20Version.pdf

CarbonTracker (2014) The Great Coal Cap: China's energy policies and the financial implications for thermal coal. Internet: http://www.carbontracker.org/report/the-great-coal-cap-chinas-energy-policies-and-the-financial-implications-for-thermal-coal/.

Carlsson and Vellei (eds.) (2013) 2013 Technology Map of the European Strategic Energy Technology Plan (SET-Plan). Report nr. EUR 26345 European Commission Joint Research Centre Institute for Energy and Transport. Internet: http://ec.europa.eu/jrc/sites/default/files/jrc13_tmap_08ap14_ns-print.pdf.

CCE Bankwatch (2013) Poland energy policy to 2030. Internet: http://bankwatch.org/our-work/projects/coal-fired-power-plants-poland.

China Greentech Initiative (2013) The China Greentech Report 2013. China at a Crossroads. June 2013. A.S. Beebe, C. Eakin, R.S. Hancock, R. Harvey, C. Rhodes (eds.). Internet: www.china-greentech.com.

China Greentech Initiative (2014) The China Greentech Report 2014. Greener, Smarter, More Productive. August 2014. R.S. Hancock, C. Rhodes, C. Eakin (eds.). Internet: www.china-greentech.com.

Citi Research Commodities (2013) The Unimaginable: Peak Coal in China. Effects of possible peaking of coal demand in China could ripple across global coal trade, producers and carbon emissions. Internet: https://archive.org/stream/801597-citi-the-unimaginable-peak-coal-in-china/801597-citi-the-unimaginable-peak-coal-in-china_djvu.txt.

Clean Technica (2013) Solar PV Module Prices Have Fallen 80% Since 2008, Wind Turbines 29%. Internet: http://cleantechnica.com/2013/05/06/solar-pv-module-prices-have-fallen-80-since-2008-wind-turbines-29/.

Coal India (2014a) Annual Report 2013-2014, Government of India, Ministry of Coal. Internet: http://www.coal.nic.in/annrep1314.pdf.

Coal India (2014b) Coal production and import in India, Government of India, Ministry of Coal. Internet: http://www.coal.nic.in/cpddoc,htm.

Cocklin, J. (2014) EPA Expects to Publish Long-Awaited Draft Fracking Report in March. Natural Gas Intelligence. Internet: http://www.naturalgasintel.com/articles/print/100123-epa-expects-to-publish-long-awaited-draft-fracking-report-in-march.

Damodaran H. (2011). How India's growth story differs from China's. *The Hindu Business Line*, 4 June, 2011.

Davidson, M. (2014) China's electricity sector at a glance: 2013. Internet: http://theenergycollective.com/michael-davidson/335271/china-s-electricity-sector-glance-2013.

DECC (2012) Power stations in the United Kingdom. UK Department of Energy and Climate Change. Internet: http://www.decc.gov.uk/media/viewfile.ashx?filetype=4&filepath=Statistics/source/electricity/dukes5_11.xls&minwidth=true.

Deloitte (2014) 2014 Russian Oil & Gas Outlook survey. Internet: http://www.deloitte.com/assets/Dcom-Azerbaijan/Local%20Assets/Documents/2014%20Russian%20Oil%20&%20Gas%20Outlook%20survey%20.pdf.

Den Elzen M.G.J. (2014) The Climate Pledge-Act-Review tool. PBL Netherlands Environmental Assessment Agenvy, The Hague/Bilthoven. Internet: http://infographics.pbl.nl/climate-pledge-act-review-tool/.

Den Elzen, M.G.J., Hof, A.F. and Roelfsema, M. (2013) Analysing the greenhouse gas emission reductions of the mitigation action plans by non-Annex I countries by 2020. *Energy Policy* 56, 633-643, doi:10.1016/j.enpol.2013.01.035.

EC (2014a) Commission Recommendation of 22 January 2014 on minimum principles for the exploration and production of hydrocarbons (such as shale gas) using high-volume hydraulic fracturing (2014/70/EU). *Official Journal of the European Union*, L 39/78, 8.2.2014. Internet: http://ec.europa.eu/environment/integration/energy/unconventional_en.htm.

EC (2014b) Emissions trading: 2013 data show lower emissions but surplus of allowances persists. Internet: http://europa.eu/rapid/press-release_IP-14-561_en.htm.

EC (2014c) Energy Efficiency Directive. Internet: http://ec.europa.eu/energy/efficiency/eed/eed_en.htm.

EC(2014d) Impact Assessment. Exploration and production of hydrocarbons (such as shale gas) using high volume hydraulic fracturing in the EU. European Commission, Brussels, 22.1.2014. Commission staff working document no. SWD(2014) 21 final. [document in 4 parts]. Internet: http://ec.europa.eu/environment/integration/energy/unconventional_en.htm.

EC (2014e) Macro-economic effects of shale gas extraction in the EU. March 2014. European Commission, DG ENV, Brussels. No.: ENV.F.1/SER/2012/0046r. Internet: http://ec.europa.eu/environment/integration/energy/pdf/Macroec%20Impacts%20of%20Shale%20Gas%20Report.pdf.

EC (2014f) Environmental Aspects on Unconventional Fossil Fuels. European Commission, Brussels. Internet: http://ec.europa.eu/environment/integration/energy/unconventional_en.htm

EC (2014g) European studies and guidelines on fracking. European Commission, Brussels. Internet: http://ec.europa.eu/environment/integration/energy/studies_en.htm

EC (2014h) 2030 framework for climate and energy policies. European Commission, Brussels. Internet: http://ec.europa.eu/clima/policies/2030/index_en.htm

Economist (2013) Renewable energy in Spain. The cost del sol. Sustainable energy meets unsustainable costs. Internet: http://www.economist.com/news/business/21582018-sustainable-energy-meets-unsustainable-costs-cost-del-sol.

Edwards R, Larivé J-F, Mahieu V and P, Rouveirolles. (2008) Well-to-Wheels analysis of future automotive fuels and powertrains in the European context. European Commission Joint Rsearch Centre/CONCAWE/EUCAR. Internet: http://ies.jrc.ec.europa.eu/uploads/media/WTT_Report_010307.pd, Ispra, Italy.

EEA (2014a) Distance of non-ETS emissions from ESD targets. European Environment Agency, Copenhagen. Internet: http://www.eea.europa.eu/data-and-maps/daviz/ghg-distance-of-non-ETS#tab-googlechartid_chart_11.

EEA (2014b) EU policies deliver greenhouse gas emission reductions. European Environment Agency, Copenhagen. Internet: http://www.eea.europa.eu/articles/eu-policies-deliver-greenhouse-gas.

EIA (2012a) Monthly Energy Review May 2012, Table 9.4 Motor Gasoline Retail Prices, U.S. City Average. Release Date: May 29, 2012. Internet: http://205.254.135.7/totalenergy/data/monthly/#prices

EIA (2012b) Monthly Energy Review May 2012. Table 1.3 Primary Energy Consumption by Source. Release Date: 29 May 2012.

EIA (2012c) Over one-third of natural gas produced in North Dakota is flared or otherwise not marketed. U.S. Energy Information Administration. Internet: http://205.254.135.7/todayinenergy/detail.cfm?id=4030.

EIA (2013a) International Energy Statistics: Fuel Ethanol and Biodiesel Consumption, 1980-2011. U.S. Energy Information Administration. Internet: http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=79&pid=79&aid=2.

EIA (2013b) Natural gas generation lower than last year because of differences in relative fuel prices. U.S. Energy Information Administration. Internet: http://www.eia.gov/todayinenergy/detail.cfm?id=13111.

EIA (2013c) Natural gas use for power generation falls as industrial sector's use continues to rise. U.S. Energy Information Administration. Internet: http://www.eia.gov/todayinenergy/detail.cfm?id=14031.

EIA (2013d) Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States. U.S. Energy Information Administration. Internet: http://www.eia.gov/analysis/studies/worldshalegas/.

EIA (2013e) U.S. natural gas spot prices increased during first-half 2013. U.S. Energy Information Administration.

Internet: http://www.eia.gov/todayinenergy/detail.cfm?id=12191.
EIA (2014a) Analysis Briefs: Japan. Report, U.S. Energy Information Administration. Internet: http://www.eia.gov/countries/analysisbriefs/Japan/japan.pdf.
EIA (2014b) China is now the world's largest net importer of petroleum and other liquid fuels. U.S. Energy Information Administration. Internet: http://www.eia.gov/todayinenergy/detail.cfm?id=15531.
EIA (2014c) Crude Oil Production. U.S. Energy Information Administration. Internet: http://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm.
EIA (2014d) Half of power plant capacity additions in 2013 came from natural gas. U.S. Energy Information Administration. Internet: http://www.eia.gov/todayinenergy/detail.cfm?id=15751.
EIA (2014e) Monthly Energy Review, May 2014. U.S. Energy Information Administration. DOE/EIA-0035(2014/05). Internet: www.eia.gov/mer.
EIA (2014f) Nonhydro renewables now routinely surpass hydropower generation. U.S. Energy Information Administration. Internet: http://www.eia.gov/todayinenergy/detail.cfm?id=17351.
EIA (2014g) U.S. biomass-based diesel imports increase to record levels in 2013. U.S. Energy Information Administration. Internet: http://www.eia.gov/todayinenergy/detail.cfm?id=16111.
EIA (2014h) U.S. energy-related CO2 emissions in 2013 expected to be 2% higher than in 2012. U.S. Energy Information Administration. Internet: http://www.eia.gov/todayinenergy/detail.cfm?id=14571.
EIA (2014i) U.S. ethanol imports from Brazil down in 2013. U.S. Energy Information Administration. Internet: http://www.eia.gov/todayinenergy/detail.cfm?id=16131.
EIA (2014j) U.S. Natural Gas Gross Withdrawals and Production. U.S. Energy Information Administration. Internet: http://www.eia.gov/dnav/ng/ng_prod_sum_dcu_nus_a.htm.
EIA (2014k) Weather-driven energy intensity increase led to higher energy-related emissions in 2013. U.S. Energy Information Administration. Internet: http://www.eia.gov/todayinenergy/detail.cfm?id=18491.
EIA (2014l). August 2014 Monthly Energy Review. Table 2.5 Transportation Sector Energy Consumption. U.S. Energy Information Administration, Version August 27, 2014. Internet: http://www.eia.gov/totalenergy/data/monthly/
Eickhout B, Van den Born G.J., Notenboom J., Van Oorschot M., Ros J.P.M., Van Vuuren, D.P. and Westhoek, H.J. (2008) Local and global consequences of the EU renewable directive for biofuels. Testing the sustainability criteria. Report nr. 500143001 PBL Netherlands Environmental Assessment Agency, The Hague/Bilthoven. Internet: http://www.pbl.nl/en/publications/2008/LocalandglobalconsequencesoftheEUrenewabledirectiveforbiofuels.
Eilperin J. and Mufson, S. (2014) Everything you need to know about the EPA's proposed rule on coal plants. *Washington Post*, June 2, 2014. Internet: http://www.washingtonpost.com/national/health-science/epa-will-propose-a-rule-to-cut-emissions-from-existing-coal-plants-by-up-to-30-percent/2014/06/02/f37f0a10-e81d-11e3-afc6-a1dd9407abcf_story.html.
Elvidge, C.D., Baugh K.E., Tuttle B.T., Ziskin D., Ghosh T., Zhizhin M. and Pack, D. (2009a) Improving Satellite Data Estimation of Gas Flaring Volumes. Year Two Final Report to the GGFR. Internet: http://s3.amazonaws.com/zanran_storage/www.ngdc.noaa.gov/ContentPages/15507168.pdf.
Elvidge, C.D., Ziskin, D., Baugh, K.E., Tuttle, B.T., Ghosh, T., Pack, D.W., Erwin, E.H. and Zhizhin, M. (2009b) A Fifteen Year Record of Global Natural Gas Flaring Derived from Satellite Data. *Energies* 2, 595-622, doi:10.3390/en20300595.
Environment Canada (2013) National Inventory Report 1990-2011: Greenhouse gas sources and sinks in Canada. Internet: http://www.ec.gc.ca/ges-ghg/ or http://unfccc.int/files/national_reports/annex_i_ghg_inventories/national_inventories_submissions/application/zip/can-2013-nir-15apr.zip.
EPIA (2014) Global Market Output for Photovoltaics 2014-2018. Report European Photovoltaic Industry Association. Internet: http://www.epia.org/fileadmin/user_upload/Publications/EPIA_Global_Market_Outlook_for_Photovoltaics_2014-2018_-_Medium_Res.pdf.
Ernst and Young (2012) Renewable energy country attractiveness indices. November 2012. CAI, 35, November 2012._DE0372. Internet: http://www.ey.com/Publication/vwLUAssets/CAI_issue-35_Nov-2012/$FILE/CAI_issue-35_Nov-2012_DE0372.pdf.
Eurogas (2014) Drop in 2013 EU gas demand emphasizes need for swift change. Press Release. Internet: http://www.eurogas.org/uploads/media/Eurogas_Press_Release_-_Drop_in_2013_EU_gas_demand_emphasises_need_for_swift_change.pdf
Eurostat (2014a) Electricity production and supply statistics. Internet (retrieved August 2014). Internet: http://epp.eurostat.ec.europa.eu/statistics_explained/extensions/EurostatPDFGenerator/getfile.php?file=139.191.171.42_1407328437_56.pdf.
Eurostat (2014b) In 2013, CO_2 emissions in the EU28 estimated to have decreased by 2.5% compared with 2012. Early estimates of CO_2 emissions from energy use. Internet: http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/8-07052014-AP/EN/8-07052014-AP-EN.PDF
Eurostat (2014c) Greenhouse gas emissions in non-ETS sectors. Internet: http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/en/t2020_35_esmsip.htm.

Eurostat (2014d) Newsrelease Euroindicators, Euro area GDP up by 0.3%, EU28 up by 0.4%. Internet: http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/2-14022014-AP/EN/2-14022014-AP-EN.PDF.

FAO (2010) Global Forest Resources Assessment 2010. Report Food and Agriculture Organization of the United Nations, Rome. Internet.

Gazprom (2013) Gazprom boosting efficiency of associated petroleum gas utilization. Internet: http://www.gazprom.com/press/news/2013/march/article158616/.

GCP (2014) The Global Carbon Project. Global Carbon Project (GCB). Internet: http://www.globalcarbonproject.org/.

GFRA (2014) Global Biofuel Mandates. Global Renewable Fuels Alliance. Internet: http://globalrfa.org/biofuels-map.

GGFR (2012) Global Gas Flaring Reduction public-private partnership. Global Gas Flaring Reduction. Internet: http://go.worldbank.org/Q7E8SP9J90.

Golden, M. (2014) Stanford-led study assesses the environmental costs and benefits of fracking. Internet: http://news.stanford.edu/news/2014/september/fracking-costs-benefits-091214.html.

Gregg, J.S., Andres, R.J. and Marland, G. (2008) China: Emissions pattern of the world leader in CO_2 emissions from fossil fuel consumption and cement production. *Geophysical Research Letters*, 35, doi:10.1029/2007gl032887.

Guan, D., Liu, Z., Geng, Y., Lindner, S. and Hubacek, K. (2012) The gigatonne gap in China's carbon dioxide inventories. *Nature Climate Change*, doi:10.1038/nclimate1560.

Guay, J. (2014) Chinese coal consumption just fell for first time this century. Huffington Post, 18 August 2014. Internet: http://www.huffingtonpost.com/justin-guay/chinese-coal-consumption_b_5687972.html

GWEC (2014) Global Wind Report – Annual Market update 2013. Global Wind Energy Council. Internet: http://www.gwec.net/wp-content/uploads/2014/04/GWEC-Global-Wind-Report_9-April-2014.pdf.

Harris, N.L., Brown, S., Hagen, S.C., Saatchi, S.S., Petrova, S., Salas, W., Hansen, M.C., Potapov, P.V. and Lotsch, A. (2012) Baseline map of carbon emissions from deforestation in tropical regions. *Science,* 336, 1573-6, doi:10.1126/science.1217962.

Houser, T. (2013) China's 2012 Energy Report Card. Rhodium group report, February 27, 2013. Internet: http://rhg.com/notes/chinas-2012-energy-report-card

ICF International (2014) Mitigation of climate impacts of possible future shale gas extraction in the EU: available technologies, best practices and options for policy makers. Internet: http://ec.europa.eu/clima/policies/eccp/docs/mitigation_shale_gas_en.pdf.

IEA (2004) Oil Crises and Climate Challenges: 30 Years of Energy Use in IEA Countries. IEA, Paris. ISBN 92-64-01882-4.

IEA (2007) Energy Use in the New Millennium. Trends in IEA Countries. International Energy Agency, Paris.

IEA (2008) Worldwide Trends in Energy Use and Efficiency. Key Insights from IEA Indicator Analysis. International Energy Agency, Paris.

IEA (2012a) CO_2 emissions from fuel combustion, 2012 Edition. International Energy Agency, Paris.

IEA (2012b) Golden rules for a golden age of gas. WEO Special Report on unconventional gas. International Energy Agency, Paris. Internet: http://www.iea.org/publications/freepublications/publication/WEO2012_GoldenRulesReport.pdf.

IEA (2012c) Energy Statistics of OECD Countries and Non-OECD Countries, 2012 Edition. International Energy Agency, Paris.

IEA (2013a) CO2 emissions from fuel combustion, 2013 Edition. International Energy Agency, Paris.

IEA (2013b) Energy Statistics of OECD Countries and Non-OECD Countries, 2013 Edition. International Energy Agency, Paris.

IEA (2013c) Oil & Gas Security: Emergency Response of IEA Countries: Japan. International Energy Agency, Paris. Internet: http://www.iea.org/publications/freepublications/publication/2013_OSS_Japan.pdf.

IEA (2014a) CO2 emissions from fuel combustion, 2014 Edition, International Energy Agency, Paris. Internet: http://www.oecd-ilibrary.org/energy/co2-emissions-from-fuel-combustion-2014_co2_fuel-2014-en

IEA (2014b) Energy Statistics of OECD Countries and Non-OECD Countries. International Energy Agency, Paris.

IEA (2014c) Natural Gas Information 2014. ISBN 978-92-64-21706-5. International Energy Agency, Paris. Internet: http://www.iea.org/W/bookshop/644-Natural_Gas_Information_2014.

IEA (2014d) Tracking Clean Energy Progress 2014. International Energy Agency, Paris. Internet: http://www.iea.org/publications/freepublications/publication/Tracking_clean_energy_progress_2014.pdf

IMF (2014) World Economic Outlook Database. International Monetary Fund, October 2014. Internet: http://www.imf.org/external/pubs/ft/weo/2014/02/weodata/index.aspx.

International Transport Forum (ITF) (2014) Key Transport Statistics – 2013. Internet: http://www.internationaltransportforum.org/Pub/pdf/14KeyStat2013.pdf.

IPCC (1996) Revised 1996 IPCC Guidelines for National Greenhouse Gas Emission Inventories. Three volumes: Reference manual, Reporting Guidelines and Workbook. Intergovernmental Panel on Climate

Change. Internet, Hadley Centre, Meteorological Office, Bracknell, United Kingdom.
IPCC (2006) IPCC Guidelines for National Greenhouse Gas Inventories. Prepared by the National Greenhouse Gas Inventories Programme (NGGIP). Intergovernmental Panel on Climate Change. Internet: http://www.ipcc.ch/pdf/special-reports/srccs/srccs_wholereport.pdf., Japan.
IPCC (2014a) Climate Change 2014: Mitigation of Climate Change. Intergovernmental Panel on Climate Change. Internet: http://www.ipcc.ch/report/ar5/wg3/.
IPCC (2014b) Climate Change 2014: Synthesis Report. Intergovernmental Panel on Climate Change. Internet: http://www.ipcc.ch/report/ar5/syr/.
Jackson, R.B., Vengosh, A., Carey, J.W., Davies, R.J., Darrah, T.H., O'Sullivan, F. and Pétron, G. (2014) The Environmental Costs and Benefits of Fracking. *Annual Review of Environment and Resources*, 39, 327-362, doi:10.1146/annurev-environ-031113-144051.
Jager-Waldau, A. (2013) PV Status Report 2013. Report nr. EUR 26118 EN. European Commission, Joint Research Centre (JRC), Institute for Energy and Transport, Renewable Energy Unit. Internet: http://iet.jrc.ec.europa.eu/remea/sites/remea/files/pv_status_report_2013.pdf.
Joosten H. (2009) The Global Peatland CO2 Picture. Peatland status and drainage related emissions in all countries of the world. Wetlands International, Ede.
JRC/PBL (2011, 2012) Emission Database for Global Atmospheric Research (EDGAR), release version 4.2 of 11 November 2011 and version 4.2 FT 2010 released in 2012. European Commission, Joint Research Centre (JRC) and PBL Netherlands Environmental Assessment Agency, Ispra/The Hague. Internet: http://edgar.jrc.ec.europa.eu.
King, E. (2014) China coal demand to peak by 2020 – Standard & Poor. Responding to Climate Change (RTCC). Internet: http://www.rtcc.org/2014/07/22/china-coal-demand-to-peak-by-2020-standard-poor/.
Kuo, L. (2014) China's addiction to hydropower in two dam maps. Internet: http://qz.com/196716/chinas-addiction-to-hydropower-in-two-dam-maps/.
Ladislaw, S.O., Book, K. and Zindler, E. (2014) How big a deal is the U.S.-China climate announcement? W.D. Center for Strategic and International Studies (CCIS). Internet: http://csis.org/publication/uschina-joint-announcement-climate-change-how-big-deal.
LCPD (2001) Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants. Internet: http://europa.eu/legislation_summaries/environment/air_pollution/l28028_en.htm.
Le Quéré, C., Moriarty, R., Andrew, R.M., Peters, G.P., Ciais, P., Friedlingstein, P., Jones, S.D., Sitch, S., Tans, P., Arneth, A., Boden, T.A., Bopp, L., Bozec, Y., Canadell, J.G., Chevallier, F., Cosca, C.E., Harris, I., Hoppema, M., Houghton, R.A., House, J.I., Jain, A., Johannessen, T., Kato, E., Keeling, R.F., Kitidis, V., Klein Goldewijk, K., Koven, C., Landa, C.S., Landschützer, P., Lenton, A., Lima, I.D., Marland, G., Mathis, J.T., Metzl, N., Nojiri, Y., Olsen, A., Ono, T., Peters, W., Pfeil, B., Poulter, B., Raupach, M.R., Regnier, P., Rödenbeck, C., Saito, S., Salisbury, J.E., Schuster, U., Schwinger, J., Séférian, R., Segschneider, J., Steinhoff, T., Stocker, B.D., Sutton, A.J., Takahashi, T., Tilbrook, B., van der Werf, G.R., Viovy, N., Wang, Y.P., Wanninkhof, R., Wiltshire, A. and Zeng, N. (2014) Global carbon budget 2014. *Earth System Science Data Discussions* 7, 521-610, doi:10.5194/essdd-7-521-2014.
Levi, M. (2014) What the Big U.S.-China climate announcement means. Council for Foreign Relations (CFR). Internet: http://blogs.cfr.org/levi/2014/11/12/what-the-big-u-s-china-climate-announcement-means/.
Liewerscheidt, M. (2014) Nigeria: any chance of the progress on the Petroleum Industry Bill? Internet: http://africanarguments.org/2014/06/19/nigeria-any-chance-of-progress-on-the-petroleum-industry-bill-by-malte-liewerscheidt/
Marland, G., Brenkert, A. and Olivier, J. (1999) CO_2 from fossil fuel burning: a comparison of ORNL and EDGAR estimates of national emissions. *Environmental Science & Policy* 2, 265-273, doi:10.1016/s1462-9011(99)00018-0.
Mauther M. and Weiss M. (2013) Solar Heat Worldwide. Markets and Contribution to the Energy Supply. Internet: http://www.iea-shc.org/data/sites/1/publications/Solar-Heat-Worldwide-2013.pdf.
Ministry of Environmental Protection China (2013) The State Council Issues Action Plan on Prevention and Control of Air Pollution Introducing Ten Measures to Improve Air Quality. Internet: http://english.mep.gov.cn/News_service/infocus/201309/t20130924_260707.htm.
Ministry of Environmental Protection China (2014) China's carbon emission down by 5%. Internet: http://english.mep.gov.cn/News_service/media_news/201408/t20140828_288374.htm.
Moscow Times (2012) Oil Companies' Fines for Gas Flaring to Hit $500M in 2012, Moscow Times. Internet: http://www.themoscowtimes.com/business/article/oil-companies-fines-for-gas-flaring-to-hit-500m-in-2012/461221.html.
Myllyvirta, L. (2014) China's coal use might just have dropped first time this century - what's going on? Greenpeace East Asia, blogpost.
NBS (2013) Statistical Communiqué of the People's Republic of China on the 2012 National Economic and Social Development. National Bureau of Statistics

of China. Internet: http://www.stats.gov.cn/english/PressRelease/201402/t20140224_515103.html.
NBS (2014a) Annual data by province. National Bureau of Statistics of China. Internet: http://data.stats.gov.cn/english/easyquery.htm?cn=E0103.
NBS (2014b) Statistical Communiqué of the People's Republic of China on the 2013 National Economic and Social Development. National Bureau of Statistics of China. Internet: http://www.stats.gov.cn/english/PressRelease/201402/t20140224_515103.html.
NBS (2014c) Preliminary Accounting Results of GDP for the First Half of 2014 (2014, 17 July). National Bureau of Statistics of China. Internet: http://www.stats.gov.cn/english/PressRelease/201407/t20140717_582998.html.
NCDC (2011) Climate of 2011. National Climatic Data Center. Internet: http://www.ncdc.noaa.gov/sotc/global/2011/13.
Nicholson, B. (2012) Survey of Flaring Regs for Arkansas, Colorado, Louisiana, North Dakota, Pennsylvania, Texas and Wyoming. Hydraulic fracking. Internet: http://fulbrightfrackingblog.blogspot.nl/2012/05/survey-of-flaring-regs-for-arkansas.html.
Nicola, S. (2014) China Coal Peak Imminent Makes Coal Risky Investment: Study. Internet: http://www.bloomberg.com/news/2014-09-21/china-coal-peak-imminent-makes-coal-risky-investment-study.html.
Nigerian Tribune (2013) Oil sector reform: Challenges of curbing gas flaring, Nigerian Tribune. Internet: http://tribune.com.ng/news2013/en/business-package/2012-10-29-11-35-35/energy/item/13503-oil-sector-reform-challenges-of-curbing-gas-flaring.html.
NOAA (2012) Global Gas Flaring Estimates through 2011.
Oil & Gas Journal (2014) EPA acknowledges blend wall as it proposes 2014 biofuel quotas. N. Snow. Internet: http://www.ogj.com/articles/2013/11/epa-acknowledges-blend-wall-as-it-proposes-2014-biofuel-quotas.html.
Olesen, A. (2014) Why is Beijing downplaying the supposedly huge climate deal? *Foreign Policy*. Internet: http://www.foreignpolicy.com/articles/2014/11/12/china_us_climate_deal_enthusiasm_gap.
Olivier, J.G.J. and Janssens-Maenhout, G. (2014) CO_2 Emissions from Fuel Combustion (Part III). In: "*CO2 emissions from fuel combustion, 2014 Edition*", pp. III.1-III.51. ISBN 978-92-64-21711-9. International Energy Agency, Paris. Internet: http://www.iea.org/W/bookshop/648-CO2_Emissions_from_Fuel_Combustion.
Olivier, J.G.J., Janssens-Maenhout, G., Muntean, M. and Peters, J.A.H.W. (2013) Trends in global CO_2 emissions: 2013 Report. PBL Netherlands Environmental Assessment Agency, The Hague; European Commission, Joint Research Centre (JRC), Institute for Environment and Sustainability (IES). Internet: http://www.pbl.nl/sites/default/files/cms/publicaties/pbl-2013-trends-in-global-co2-emissions-2013-report-1148.pdf.
Olivier J.G.J., Van Aardenne J.A., Monni S., Döring U.M., Peters J.A.H.W. and Janssens-Maenhout, G. (2010) Application of the IPCC uncertainty methods to EDGAR 4.1 global greenhouse gas inventories. In: *'3rd International Workshop on Uncertainty in Greenhouse Gas Inventories, 22–24 September, 2010'. Proceedings*. Lviv Polytechnic National University, Lviv, Ukraine.
Olivier, J.G.J. and Peters, J.A.H.W. (2002) *Uncertainties in global, regional and national emission inventories*. In: Van Ham, J., A.P.M. Baede, R. Guicherit and J.F.G.M. Williams-Jacobse (eds.): 'Non-CO_2 greenhouse gases: scientific understanding, control options and policy aspects. Proceedings of the Third International Symposium, Maastricht, Netherlands, 21-23 January 2002', pp. 525-540. Millpress Science Publishers, Rotterdam.
Pearce, F. (2014) Peak Coal: Why the Industry's Dominance May Soon Be Over. Environment360. Internet: http://e360.yale.edu/feature/peak_coal_why_the_industrys_dominance_may_soon_be_over/2777/.
Podesta J. and Holdren, J. (2014) The U.S. and China Just Announced Important New Actions to Reduce Carbon Pollution. The White House Blog, Washington DC. Internet: http://www.whitehouse.gov/blog/2014/11/12/us-and-china-just-announced-important-new-actions-reduce-carbon-pollution.
Pöyry (2013) Pöyry report to DECC: Outlook for new coal-fired power stations in Germany, the Netherlands and Spain. P.M. Consulting. Internet: https://www.gov.uk/government/publications/poyry-report-to-decc-outlook-for-new-coal-fired-power-stations-in-germany-the-netherlands-and-spain.
Practical Law (2014) Oil and gas regulation in Nigeria. Internet: http://uk.practicallaw.com/5-523-4794
REN21 (2014) Renewables 2014 Global Status Report. Renewable Energy Policy Network for the 21st Century. Internet: http://www.ren21.net/Portals/0/documents/Resources/GSR/2014/GSR2014_full%20report_low%20res.pdf.
Reuters (2012a) Russia oil firms face heavy fines for gas flaring. Internet: http://www.reuters.com/article/2012/06/16/russia-oil-flaring-idUSL5E8HG33G20120616.
Reuters (2012b) UPDATE 1-RWE to close UK coal, oil power plants in March 2013. 18 September 2012. Internet: http://www.reuters.com/article/2012/09/18/britain-rwe-closures-idUSL5E8KIB2120120918.
Reuters (2014) China nears 'peak coal' as carbon and clean growth policies bite. Internet: http://www.reuters.com/article/2014/11/28/china-coal-idUSL3N0TF38420141128
Romm, J. (2014) China to cap coal use by 2020 to meet game-changing climate, Air Pollution Targets. Climate Progress, blog. Internet: http://thinkprogress.org/

climate/2014/11/19/3593567/china-climate-target-peak-coal-2020/.
Ros, J.P.M., Overmars, K.P., Stehfest, E., Prins, A.G., Notenboom, J. and Van Oorschot, M. (2010) Identifying the indirect effects of bio-energy production. Report nr. 500143003 PBL Netherlands Environmental Assessment Agency. Internet: http://www.pbl.nl/en/publications/2010/Identifying-the-indirect-effects-of-bio-energy-production, The Hague/Bilthoven.
Saikia, K. and Sarkar, B.C. (2013) Coal Exploration Modelling using Geostatistics in Jharia Coalfield, India, *Int. Journal of Coal Geology*, 112, 36-52.
Shuo L. and L. Myllyvirta (2014) The end of China's coal boom – 6 facts you should know. Greenpeace East Asia. Internet: http://www.greenpeace.org/international/Global/international/briefings/climate/2014/The-End-of-Chinas-Coal-Boom.pdf.
Skolkovo Moscow School of Management (2014) Gas Pricing in Russia: Searching for a balance of interests. E. Centre. Internet: http://energy.skolkovo.ru/upload/medialibrary/07c/SEneC_DomesticGasMarket_ENG.pdf.
Sourcewatch (2013a) ALEC 40: Turning Back the Clock on Prosperity and Progress: United Kingdom and Coal. Internet: http://www.sourcewatch.org/index.php/United_Kingdom_and_coal
Sourcewatch (2013b) Coal power plants proposals in Germany. Internet: http://www.sourcewatch.org/index.php?title=Coal_power_plant_proposals_in_Germany.
Swart, N.C. and Weaver, A.J. (2012) The Alberta oil sands and climate. *Nature Climate Change* 2, 134-136, doi:10.1038/nclimate1421.
Trembath, A. (2014) Is coal really "peaking" in China? Better technologies needed for emissions to start falling. T.B. Institute. Internet: http://thebreakthrough.org/index.php/voices/energetics/is-coal-really-peaking-in-china.
Tu, K.J. (2011) Industrial organisation of the Chinese coal industry. Freeman Spogli Institute for International Studies, Working Paper 103, July 2011. Internet: http://pesd.stanford.edu/publications/23284.
Tu, K.J. (2012) Understanding China's Rising Coal Imports. Carnegie. Internet: http://carnegieendowment.org/2012/02/16/understanding-china-s-rising-coal-imports.
Tweed, K. (2014) Are We Close to Peak Coal in China? Some predict that China will start dismantling coal by 2030. Others aren't so sure. GreenTechMedia. Internet: http://www.greentechmedia.com/articles/read/are-we-headed-towards-peak-coal-in-china.
UN (2009) System of National Accounts 2008 ("SNA 2008"). United Nations, New York, 2009. Doc no. ST/ESA/STAT/SER.F/2/Rev.5. ISBN 978-92-1-161522-7. Internet: http://unstats.un.org/unsd/nationalaccount/docs/SNA2008.pdf.
UNDP (2013) World Population Prospects (WPP), The 2012 Revision Report United Nations, Department of Economic and Social Affairs, Population Division. Internet.
UNEP (2014) The Emissions Gap Report 2014. U.N. Environment Programme, Nairobi. Internet: http://www.unep.org/publications/ebooks/emissionsgapreport2014/.
UNFCCC (2012) National submissions of National Inventory Reports (NIR) with inventory data in CRF files. United Nations Framework Convention on Climate Change. Internet: http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/6598.php.
UNFCCC (2013) NIR submissions of the greenhouse gas inventories for Annex I countries. United Nations Framework Convention on Climate Change. Internet: http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/7383.php
USDA (2003, 2014) Biofuel Annuals. GAIN Reports for Argentina, Brazil (Sugar Annual), China, India, Indonesia, Malaysia, Peru, Philippines and Thailand. US Department of Agriculture (USDA).
US EPA (2012) EPA Issues Final Air Rules for the Oil and Natural Gas Industry. Internet: http://www.epa.gov/airquality/oilandgas/actions.html.
US EPA (2014a) Summary of the Technical Roundtable on EPA's Study of the Potential Impacts of Hydraulic Fracturing on Drinking Water Resources, Summary of December 9, 2013, Technical Roundtable. US EPA, Washington DC. Internet: http://www2.epa.gov/hfstudy/summary-technical-roundtable-epas-study-potential-impacts-hydraulic-fracturing-drinking.
US EPA (2014b) Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units. Internet: http://www2.epa.gov/carbon-pollution-standards/clean-power-plan-proposed-rule
US GOA (2014) EPA Program to Protect Underground Sources from Injection of Fluids Associated with Oil and Gas Production Needs Improvement. U.S. Government Accountability Office, Washington DC. Internet: http://www.gao.gov/products/GAO-14-555.
USGS (2014) Cement Statistics and Information, and other commodities. US Geological Survey. Internet: http://minerals.usgs.gov/minerals/pubs/commodity/cement/mcs-2014-cemen.pdf.
Van der Werf, G.R., Randerson, J.T., Giglio, L., Collatz, G.J., Kasibhatla, P.S. and Arellano, A.F. (2006) Interannual variability in global biomass burning emissions from 1997 to 2004. *Atmospheric Chemistry and Physics* 6, 3423-3441, doi:10.5194/acp-6-3423-2006.

Van der Werf, G.R., Dempewolf, J., Trigg, S.N., Randerson, J.T., Kasibhatla, P.S., Giglio, L., Murdiyarso, D., Peters, W., Morton, D.C., Collatz, G.J., Dolman, A.J. and DeFries, R.S. (2008) Climate regulation of fire emissions and deforestation in equatorial Asia. *Proc Natl Acad Sci U S A* 105, 20350-5, doi:10.1073/pnas.0803375105.

Van der Werf, G.R., Morton, D.C., DeFries, R.S., Olivier, J.G.J., Kasibhatla, P.S., Jackson, R.B., Collatz, G.J. and Randerson, J.T. (2009) CO_2 emissions from forest loss. *Nature Geoscience* 2, 737-738, doi:10.1038/ngeo671.

Van Dijk PM, Kuenzer C Zhang J, Wolf KHAA and Wang J. (2009). Fossil Fuel Deposit Fires. Occurrence Inventory, design and assessment of Instrumental Options. WAB report 500102021. PBL Netherlands Environmental Assessment Agency, The Hague.

Victor, D.G. (2014) The US-China climate deal is a model for world diplomacy: too small to fail. Internet: http://www.theguardian.com/commentisfree/2014/nov/13/us-china-climate-deal-diplomacy-paris.

Vorrath, S. (2014) Peak Coal? China coal demand could halve by 2020. RenewEconomy. Internet: http://reneweconomy.com.au/2014/peak-coal-china-coal-demand-could-halve-by-2020-93003.

WBCSD (2009) Cement Industry Energy and CO_2 Performance: 'Getting the Numbers Right'. World Business Council for Sustainable Development. Internet: http://www.wbcsd.org/Pages/EDocument/EDocumentDetails.aspx?ID=11095

White House (2014a) Fact Sheet: U.S.-China Joint Announcement on Climate Change and Clean Energy Cooperation. The White House, Washington DC. Internet: http://www.whitehouse.gov/the-press-office/2014/11/11/fact-sheet-us-china-joint-announcement-climate-change-and-clean-energy-c.

White House (2014b) U.S.-China Joint Announcement on Climate Change. Beijing China. Internet: http://www.whitehouse.gov/the-press-office/2014/11/11/us-china-joint-announcement-climate-change.

WNA (2013) Asia's Nuclear Energy Growth. W.N. Association. Internet: http://www.world-nuclear.org/info/Country-Profiles/Others/Asia-s-Nuclear-Energy-Growth/.

WNA (2014) World Nuclear Power Reactors & Uranium Requirements. W.N. Association. Internet: http://www.world-nuclear.org/info/Facts-and-Figures/World-Nuclear-Power-Reactors-and-Uranium-Requirements/.

Wong, E. (2014) China's climate change plan raises questions. Internet: http://www.nytimes.com/2014/11/13/world/asia/climate-change-china-xi-jinping-obama-apec.html.

World Bank (2012) Estimated Flared Volumes from Satellite Data, 2007-2011, Published at the website of the Global Gas Flaring Reduction (GGFR) partnership. Internet: http://go.worldbank.org/G2OAW2DKZ0.

World Bank (2014) Data from database: World Development Indicators. Last Updated: 11/06/2014. Internet: http://databank.worldbank.org/data/views/variableselection/selectvariables.aspx?source=world-development-indicators#.

WNA (2013) Asia's Nuclear Energy Growth. W.N. Association. Internet: http://www.world-nuclear.org/info/Country-Profiles/Others/Asia-s-Nuclear-Energy-Growth/

WSA (2014) World Steel in Figures 2014. World Steel Association. Internet: http://www.worldsteel.org/dms/internetDocumentList/bookshop/World-Steel-in-Figures-2014/document/World%20Steel%20in%20Figures%202014%20Final.pdf.

Xinhua (10 Sep) (2014) China sees big drop in carbon emissions: Premier. Internet: http://news.xinhuanet.com/english/china/2014-09/10/c_133633628.htm.

Xinhua (15 July) (2014) China's power data point to positive signs, pressure. Internet: http://news.xinhuanet.com/english/china/2014-07/15/c_133484853.htm.

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