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Global energy growth is outpacing decarbonization

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Abstract

Recent reports have highlighted the challenge of keeping global average temperatures below 2 °C and —even more so—1.5 °C (IPCC 2018). Fossil-fuel burning and cement production release ~90% of all CO_2 emissions from human activities. After a three-year hiatus with stable global emissions (Jackson *et al* 2016; Le Quéré C *et al* 2018a ; IEA 2018), CO_2 emissions grew by 1.6% in 2017 to 36.2 Gt (billion tonnes), and are expected to grow a further 2.7% in 2018 (range: 1.8%–3.7%) to a record 37.1 ± 2 Gt CO_2 (Le Quéré *et al* 2018b). Additional increases in 2019 remain uncertain but appear likely because of persistent growth in oil and natural gas use and strong growth projected for the global economy. Coal use has slowed markedly in the last few years, potentially peaking, but its future trajectory remains uncertain. Despite positive progress in ~19 countries whose economies have grown over the last decade and their emissions have declined, growth in energy use from fossil-fuel sources is still outpacing the rise of low-carbon sources and activities. A robust global economy, insufficient emission reductions in developed countries, and a need for increased energy use in developing countries where per capita emissions remain far below those of wealthier nations will continue to put upward pressure on CO_2 emissions. Peak emissions will occur only when total fossil CO_2 emissions finally start to decline despite growth in global energy consumption, with fossil energy production replaced by rapidly growing low- or no-carbon technologies.

Climate change is here. Average global temperatures have risen 1 °C above pre-industrial levels and, at current rates of warming, are projected to reach 1.5 °C within two decades (IPCC 2018). The Great Barrier Reef in Australia has lost half of its coral cover in its northern range, reflecting damage from two severe bleaching events since 2014 and cyclones (AIMS 2018). Extreme events, from hurricanes to heat-waves and wildfires, increasingly disrupt societies, including the loss of human lives. Changes in the intensity and frequency of climate extreme events and their impacts on ecosystems and society now have a discernable influence from climate change and its underlying warmer temperatures (Herring *et al* 2018). Weather and climate disasters in the United States cost an estimated \$306 billion in 2017, a hundred billion more than ever before (National Oceanic & Atmospheric Administration (NOAA) 2018).

CO_2 emissions are responsible for most of the climate change that has occurred and will occur (e.g. Etminan *et al* 2016, Huntingford and Mercado 2016) and emissions are rising again (Figueres *et al* 2018). Fossil CO_2 emissions increased 1.6% to 36.2 Gt (billion tonnes) in 2017 after three years of little or no emissions growth (Jackson *et al* 2017, Le Quéré *et al* 2018a, 2018b). Emissions in 2018 are projected to grow even faster, at a rate of 2.7% (range: 1.8%–3.7%) (figure 1), reaching a record 37.1 ± 1.8 Gt CO_2 (Le Quéré *et al* 2018b). These emissions place us on a trajectory for warming that is currently well beyond 1.5 °C (figure 2).

The global growth in emissions in 2018 can be examined more closely through national trends.

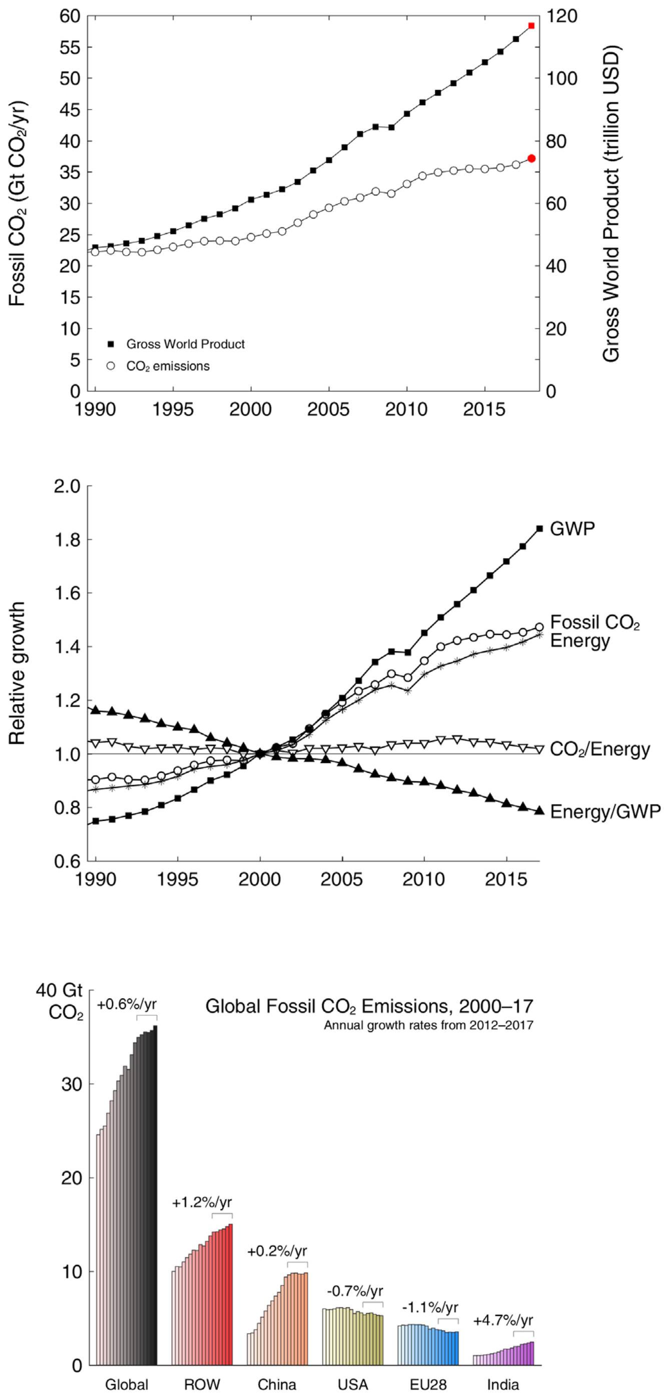

Figure 1. Upper panel: global CO_2 emissions from fossil-fuel use and industry (open circles) and Gross World Product ($ US) expressed as purchasing power parity (filled squares; World Bank 2018) since 1990. The red symbols are projections for 2018. Middle panel: relative to year 2000, Gross World Product, global CO_2 emissions from fossil-fuel use and industry, global energy use (BP 2018), CO_2 intensity of the energy system (global CO_2 emissions from fossil-fuel use and industry divided by global energy use), and energy intensity of the global economy (global energy use divided by global GDP) from 1990–2018. Lower panel: fossil CO_2 emissions, including cement production globally and for five regions (ROW = Rest of Word); brackets show average annual growth rate for 2012–2017.

Changes in emissions (and estimated ranges) for 2018 compared to 2017 for major emitting countries and regions are: China +4.7% (range of 2.0% to +7.4%), the United States +2.5% (range of +0.5% to +4.5%), the European Union −0.7% (range of −2.6% to +1.3%), India +6.3% (range of 4.3% to +8.3%), and the Rest of the World +1.8% (range of 0.5% to +3.0%). Despite the return of rising emissions in 2018, positive developments can be found in at least 19 countries having significantly lower fossil CO_2 emissions over the past decade without decreases in Gross Domestic Product (GDP): Aruba, Barbados, Czech Republic, Denmark, France, Greenland, Iceland, Ireland, Malta, Netherlands, Romania, Slovakia, Slovenia, Sweden, Switzerland,

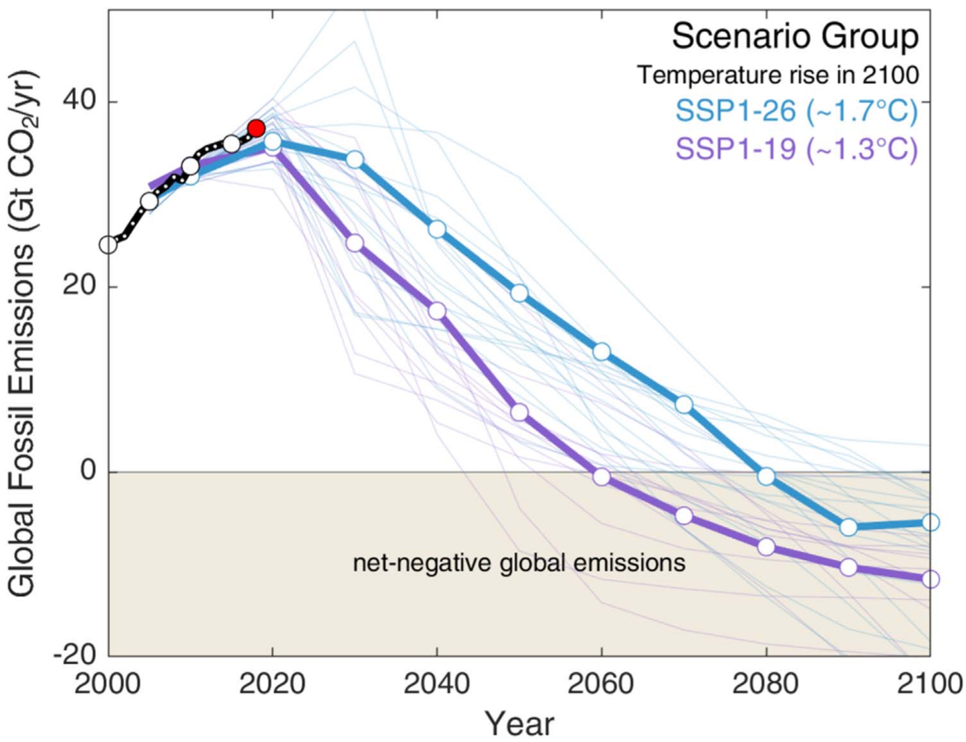

Figure 2. Historical fossil CO_2 emissions (black, Le Quéré *et al* 2018b) compared to scenarios with a 66% probability of staying below 2 °C in 2100 (thin blue lines, median temperature increase of 1.7 °C; Riahi *et al* 2017) and below 1.5 °C in 2100 (thin purple lines, median temperature of 1.3 °C; Rogelj *et al* 2018). The respective marker scenarios shown in bold are based on the shared socioeconomic pathways (SSPs) (O'Neil *et al* 2016). Our projection for fossil CO_2 emissions in 2018 is shown in red.

Trinidad and Tobago, United Kingdom, USA, and Uzbekistan. These countries contribute 20% of CO_2 emissions globally.

Different fossil fuels are contributing varying amounts to the observed increases in global and regional CO_2 emissions. Natural gas use has grown the fastest of any fossil-fuel at a rate of 2.0% yr^{-1} since 2012 (figure 3). Although natural gas is the cleanest of the fossil fuels, it is still a major source of the global increase in CO_2 emissions. In countries such as the United States, some of this growth has come at the expense of coal as a fuel for electricity generation, reducing CO_2 emissions as a result (figure 3). In China natural gas use has grown at a rapid 8.4% yr^{-1} since 2012, both to supply new energy and to reduce air pollution from coal use. Natural gas use has grown in essentially every region of the world—and in many countries—over the past five years as energy consumption has increased.

Oil use has also grown steadily for many decades and, despite rapid increases in electric vehicles around the world, continues to increase in transportation. Oil consumption has grown 1.4% yr^{-1} globally since 2012 (figure 3), with increases of 4% to 5% yr^{-1} in China and India (figure 3) contributing most to the global increase. More surprising has been increased oil use in the United States (1.3% yr^{-1}) and European Union (0.4% yr^{-1}), where oil use was believed to have peaked some years ago (figure 3). Despite improved fuel efficiency, these increases are driven by more vehicles and, in some countries, distance driven per vehicle. Vehicle numbers have grown ~4% yr^{-1} globally since 2012 (OICA 2017). Electric vehicle numbers doubled to 4 million between 2016–2018 but still represent only a tiny fraction of the billion or more of the global light-duty fleet. Finally, air traffic is also using more fuel. Fuel consumption by commercial aircraft grew 27% over the last decade (Statista 2018). Passenger numbers and distance traveled both increased ~5% yr^{-1} over the same period, more than offsetting increases in aviation fuel efficiency (ICAO 2017).

Global coal consumption has declined slowly but steadily since 2013, potentially signaling the advent of peak coal use (figure 3). Global energy consumption from coal decreased from 162 billion GJ in 2013 to 156 billion GJ in 2017, a drop of 0.9% per year on average (BP 2018). Based on price and policy competition with natural gas and renewables, coal consumption in both Canada and the United States has dropped a substantial ~40% since 2005; in 2018 alone, ~15 MW of coal-fired capacity in the US will close, a potential record. In the UK where the industrial revolution was born, coal use has declined rapidly in recent decades and could be phased out by 2025. In the E.U., wind, solar and other non-hydro renewables have grown so quickly that—at average rates of change over the past five years (figure 3)—they are on pace to supply more primary energy than coal by 2021.

Steep decreases in coal use in places such as Canada, the US, and EU could eventually be outpaced

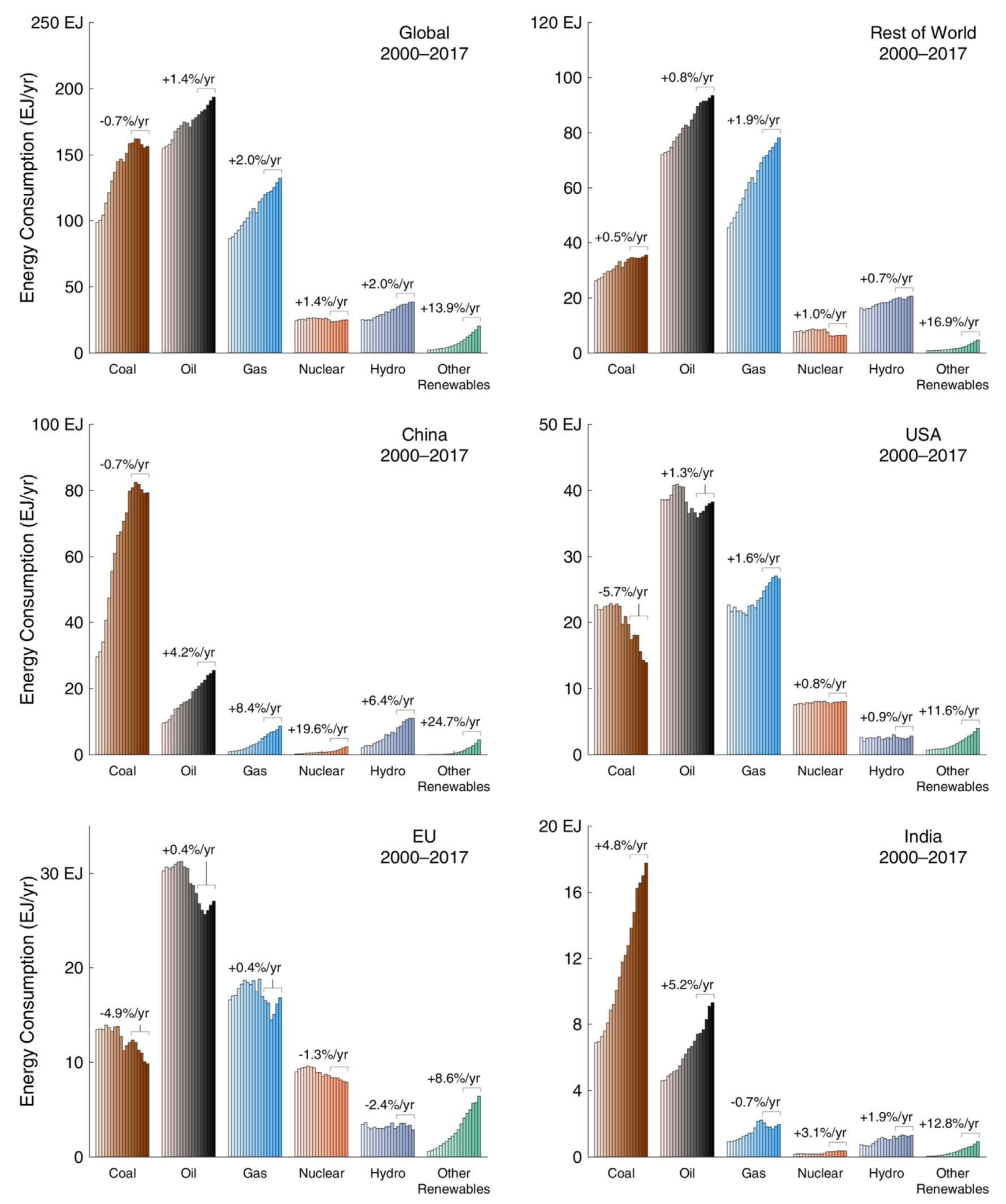

Figure 3. Average annual energy consumption (EJ) by fuel source from 2000–2017 globally and regionally, with average annual growth shown from 2012 through 2017 (BP 2018).

by increased coal use elsewhere, particularly where energy poverty is prevalent (Hubacek *et al* 2017). Increased coal consumption is occurring regionally in the Asia Pacific and Central/South America at rates of $\sim$3% yr^{-1} over the past decade (BP 2018). Recent coal consumption in India grew at rates of 4.8% per year and now surpasses that of both the EU and the United States (figure 3). Sustained growth at this rate would double India's coal consumption in less than two decades and generate more than a billion tonnes of additional CO_2 emissions yearly.

In countries such as India where energy use and CO_2 emissions are growing quickly, per capita statistics highlight inequities in global resource use (figure 4). Energy use in the US is ten-fold higher per capita than in India, where hundreds of millions of people still lack access to reliable electricity. It is five-times higher in the E.U. than in India and, surprisingly, has increased for the last five years, reversing a decade-long trend of declining energy use and CO_2 emissions (figure 4).

Increased CO_2 emissions in 2018 are not attributable solely to relatively poorer nations where energy poverty remains a major concern (e.g. Casillas and Kammen 2010, González-Eguino 2015). The US Energy Information Administration projects US CO_2

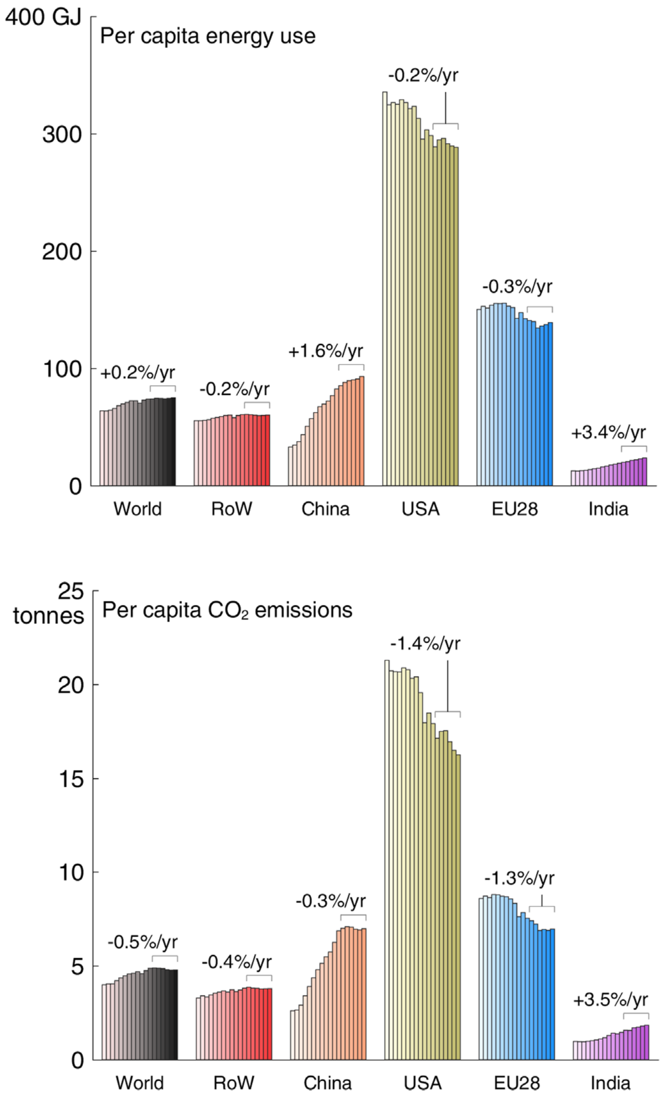

Figure 4. Per capita primary energy consumption (GJ person^{-1}) and CO_2 emissions (Mg or tonnes CO_2 person^{-1}) from 2000 to 2017, with average annual change shown from 2012 through 2017. RoW = Rest of World.

emissions to grow 2.5% in 2018, but expects them to decline 1.3% in 2019 (EIA 2018). A cold winter in the eastern half of the country increased heating demand compared to 2017, and a warm summer increased cooling demand. Oil use in the United States has also increased steadily for the last five years at an average rate of 1.3% per year (figure 3; 2012–2017 average). Low oil prices have spurred both gasoline use and sales of light trucks in the United States; light trucks, which use a third more gasoline per mile on average than passenger cars (US DOT 2018), increased from half of new vehicles sales five years ago to two thirds today.

The biggest change in CO_2 emissions in 2018 compared with 2017 is a substantial increase in both energy consumption and CO_2 emissions in China (table 1), in stark contrast to relatively stable emissions since 2012 (figure 1, and Liu *et al* 2015, Guan *et al* 2018). We project China's fossil-fuel energy use of coal, oil, and natural gas in 2018 to increase by 4.5% (±2.4%), 3.6% (±4.5%), and a striking 17.7% (±3.0%), respectively (table 1); cement production in China should also increase ~1.0% in 2018. As a result, we also project CO_2 emissions in China to grow by +4.7% (range of 2.0% to +7.4%) in 2018 compared to 2017. The explosive growth of natural gas arises primarily from China's policy for climate change mitigation and air pollution control. The increase in China's energy consumption more broadly in 2018 is driven largely by growth in heavy manufacturing, with additional contributions from household use and the service sector. Iron, steel, aluminum and cement production, for example, all increased compared to 2017: +1.2% for iron production, +6.1% for steel, +4.2% for aluminum, and +1% for cement; thermal power generation increased 6.9% in the first three quarters of 2018, as well. Our estimated uncertainty range of China's 2018 emissions growth is large (i.e. 2.0%–7.4%). This range reflects uncertainties in the evolution of China's economic growth and energy consumption in the last three months of 2018, as well as inherent uncertainties in preliminary monthly statistics. Near-term emission trends will depend on many factors, including the

Table 1. Estimated primary energy use from fossil fuels for China in 2018. We project China's energy consumption in 2018 based on data from the first nine months of the year from the National Bureau of Statistics of China (NBSC) and China's General Administration of Customs (CGAC). Energy consumption is equal to total energy production, coupled with imported fuels, exported fuels, and stock changes. NBS reported the first nine months of production and stock changes for coal, oil and gas in 2018. CGAC reported trade data, including imports and exports, for the same period. We then estimated CO_2 emissions associated with the apparent consumption of coal, oil, natural gas use and cement production process using emission factors from Liu *et al* (2015), including specific fuel heating values and fuel combustion. Our estimates assume no substantive changes in fuel mix and quality between years 2017–2018.

	Coal (10^8 metric tonnes)	Oil (10^8 metric tonnes CO_2)	Natural gas (10^{11} m^3)
Production	37.0 ± 0.53	1.88 ± 0.01	1.57 ± 0.02
Import	3.03 ± 0.36	5.18 ± 0.24	1.27 ± 0.07
Export	0.04 ± 0.01	0.82 ± 0.09	0.03 ± 0.00
Inventory change	0.08 ± 0.45	−0.10 ± 0.08	0
2018 total	40.4 ± 0.92	6.14 ± 0.27	2.81 ± 0.07
Compared to 2017	4.5 ± 2.4%	3.6 ± 4.5%	17.7 ± 3.0%

extent to which the Chinese government continues stimulating its economy and China's international balance of trade.

Whether CO_2 emissions will continue to rise in 2019 and beyond is unclear. As noted above, one positive sign is the number of countries where emissions are declining in the presence of economic growth, led by the E.U. and the United States. Such emission reductions are important but need to accelerate (figures 3 and 4). Emission reductions in the EU have slowed in recent years (Le Quéré *et al* 2018b; BP 2018). Increased CO_2 emissions for the United States in 2018 arise both from weather this year (see above), a factor that is transient, and from sustained increases in oil use; continued reductions in the United States may also be at risk with changing political conditions and a potential withdrawal from the Paris Accord. China and India are experiencing a rapid expansion of non-fossil energy sources, but it is occurring with rapid growth in fossil energy sources in India, in particular. In the rest of the world, emissions are likely to continue to grow as developing countries strive for much needed economic growth and increasing energy use.

In summary, peak CO_2 emissions remain elusive, declining global emissions even more so (Rogelj *et al* 2015, Jackson *et al* 2016, Seneviratne *et al* 2016, Peters *et al* 2017). Short of a global economic downturn, global CO_2 emissions in 2019 are likely to rise further. Projections in 2019 for growth in GDP are similar to the 2018 range of ~3.1%–3.9% (World Bank 2018, IMF 2018). We do not know whether CO_2 emissions in 2019 will grow as fast as the 2.7% rate we forecast for 2018. However, projected economic growth of 6%–8% for India and China and 2.5% in the United States (World Bank 2018) would almost certainly increase emissions over this year's value of 37.1 ± 1.8 Gt CO_2 (Le Quéré *et al* 2018b). A quarter century after the United Nations Framework Convention on Climate Change, we remain far from its signature goal to 'stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.'

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