EDITORIAL • OPEN ACCESS

Global energy growth is outpacing decarbonization

To cite this article: R B Jackson et al 2018 Environ. Res. Lett. 13 120401

View the article online for updates and enhancements.

Environmental Research Letters

EDITORIAL

Global energy growth is outpacing decarbonization

OPEN ACCESS

PUBLISHED 5 December 2018

Original content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence.

CrossMark

Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.



R B Jackson^{1,7}, C Le Quéré², R M Andrew³, J G Canadell⁴, J I Korsbakken³, Z Liu^{2,6}, G P Peters³ and B Zheng⁵

Department of Earth System Science, Woods Institute for the Environment, and Precourt Institute for Energy, Stanford University, Stanford, CA 94305–2210, United States of America

Tyndall Centre for Climate Change Research, University of East Anglia, Norwich Research Park, Norwich, NR4 7TJ, United Kingdom

CICERO Center for International Climate Research, PO Box 1129 Blindern, NO-0318 Oslo, Norway

Global Carbon Project, CSIRO Oceans and Atmosphere, Canberra, ACT 2601, Australia

⁵ Laboratoire des Sciences du Climat et de l'Environnement, CEA-CNRS-UVSQ, UMR 8212, Gif-sur-Yvette, France

Deparment of Earth System Science, Tsinghua University, Beijing 100084, People's Republic of China

⁷ Author to whom any correspondence should be addressed.

E-mail: rob.jackson@stanford.edu

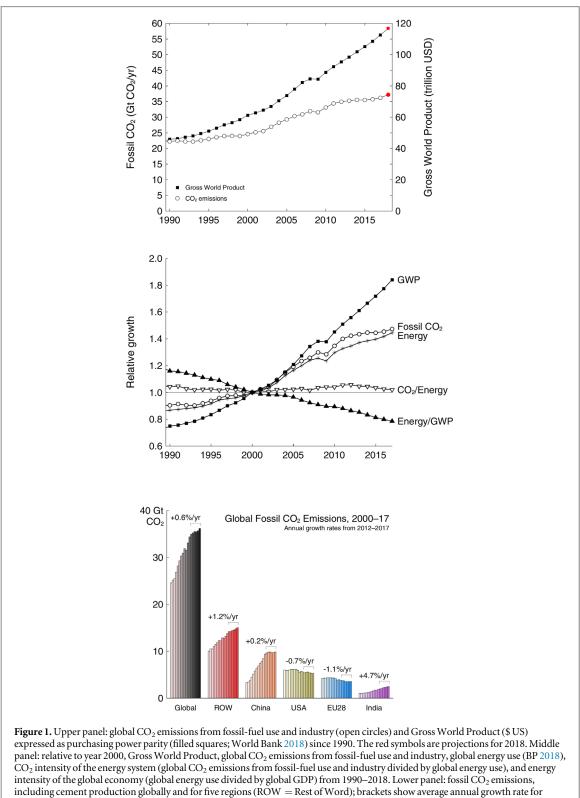
Abstract

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 CO₂ 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), CO₂ 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 \pm 2 Gt CO₂ (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 CO2 emissions. Peak emissions will occur only when total fossil CO2 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).

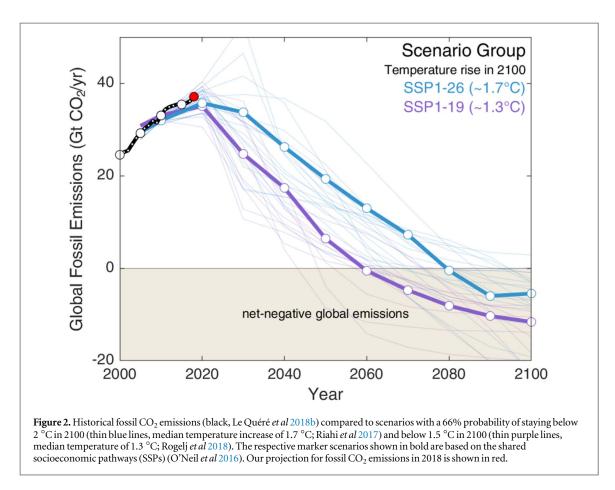
CO₂ emissions are responsible for most of the climate change that has occurred and will occur (e.g. Etminan *et al* 2016, Huntingford and Mercado 2016) and emissions are rising again (Figueres *et al* 2018). Fossil CO₂ emissions increased 1.6% to 36.2 Gt (billion tonnes) in 2017 after three years of 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 \pm 1.8 Gt CO₂ (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.



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 CO₂ 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,



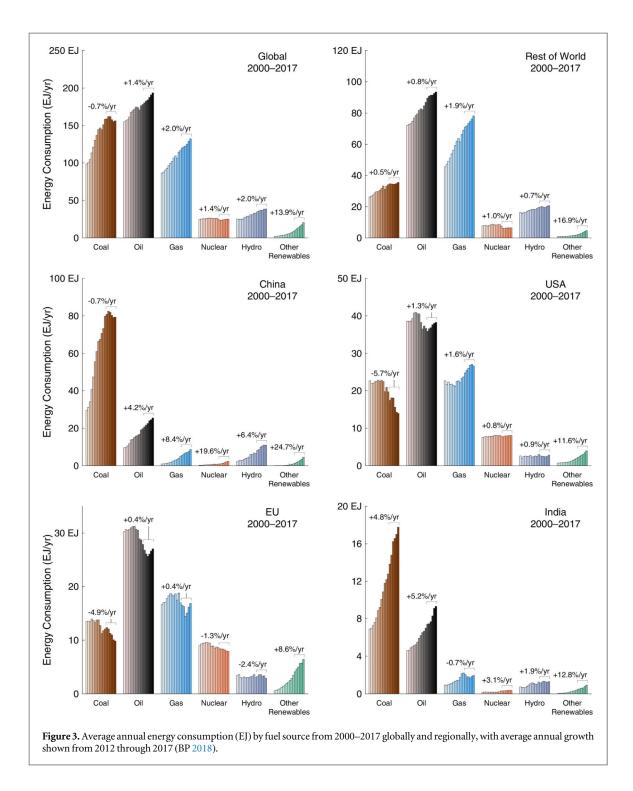
Trinidad and Tobago, United Kingdom, USA, and Uzbekistan. These countries contribute 20% of CO_2 emissions globally.

Different fossil fuels are contributing varying amounts to the observed increases in global and regional CO2 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 CO₂ 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 CO₂ emissions as a result (figure 3). In China natural gas use has grown at a rapid $8.4\% \text{ yr}^{-1}$ 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 $\sim 4\% \text{ yr}^{-1}$ 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 $\sim 5\% \text{ yr}^{-1}$ 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

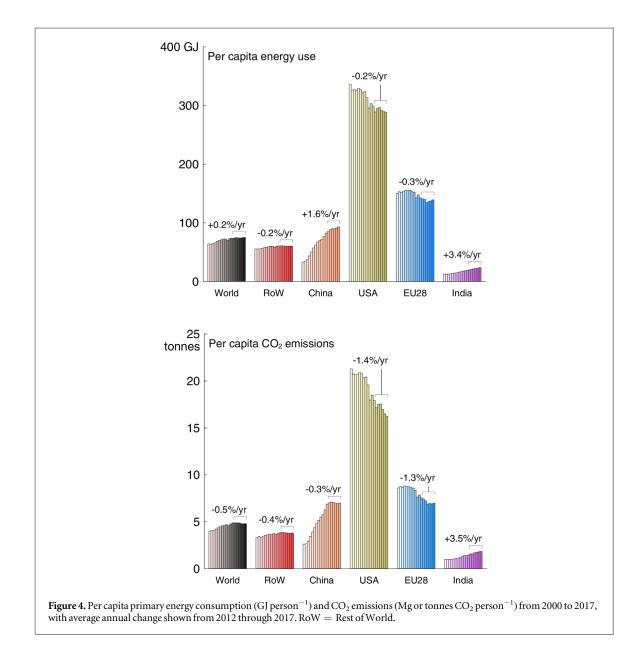


by increased coal use elsewhere, particularly where energy poverty is prevalent (Hubacek *et al* 2017). Increased coal consumption is occurring regionally in the Asia Pacific and Central/South America at rates of ~3% yr⁻¹ over the past decade (BP 2018). Recent coal consumption in India grew at rates 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 CO₂ 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



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 CO₂ emissions in 2018 compared with 2017 is a substantial increase in both energy consumption and CO₂ 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% (\pm 2.4%), 3.6% (\pm 4.5%), and a striking 17.7% (\pm 3.0%), respectively (table 1); cement production in China should also increase $\sim 1.0\%$ 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	0.08 ± 0.45	-0.10 ± 0.08	0
change			
2018 total	40.4 ± 0.92	6.14 ± 0.27	2.81 ± 0.07
Compared	$4.5\pm2.4\%$	$3.6\pm4.5\%$	$17.7\pm3.0\%$
to 2017			

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 CO₂ 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 nonfossil 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 CO₂ 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 CO₂ 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 CO₂ 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 \pm 1.8 Gt CO₂ (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.'

Acknowledgments

The authors acknowledge support from Stanford University, Future Earth, and the Gordon and Betty Moore Foundation (RBJ), the Australian Government's National Environmental Science Programme's Earth Systems and Climate Change Hub (JGC), and the European Commission Horizon 2020 project VERIFY (grant no. 776810) (GPP, RMA, and JIK). We thank the many scientists and funding agencies whose efforts and support contributed to the Global Carbon Budget 2018 released by the Global Carbon Project (globalcarbonproject.org).

ORCID iDs

R B Jackson (b) https://orcid.org/0000-0001-8846-7147

R M Andrew () https://orcid.org/0000-0001-8590-6431

Z Liu [®] https://orcid.org/0000-0002-8968-7050 G P Peters [®] https://orcid.org/0000-0001-7889-8568 B Zheng [®] https://orcid.org/0000-0001-8344-3445

References

- AIMS 2018 Long-Term Reef Monitoring Program—Annual Summary Report on Coral Reef Condition 2017/18 Australian Institute of Marine Science
- BP 2018 *Statistical Review of World Energy June 2018* 67th edition BP Casillas C E and Kammen D M 2010 The energy-poverty-climate
- nexus Science 330 1181–2 EIA 2018 Short-Term Energy Outlook, Energy Information Administration (https://eia.gov/outlooks/steo) (Accessed: 10 October 2018)
- Etminan M, Myhre G, Highwood E J and Shine K P 2016 Radiative forcing of carbon dioxide, methane, and nitrous oxide: a significant revision of the methane radiative forcing *Geophys*. *Res. Lett.* **43** 12,614–23
- Figueres C *et al* 2018 Carbon dioxide emissions rise again *Nature* accepted
- González-Eguino M 2015 Energy poverty: an overview *Renew*. Sustain. Energy Rev. 47 377–85
- Guan D *et al* 2018 Structural decline in China's CO₂ emissions through transitions in industry and energy systems *Nat. Geosci.* 11 551–5

Herring S C, Christidis N, Hoell A, Kossin J P, Schreck C J III and Stott P A 2018 Explaining extreme events of 2016 from a climate perspective *Bull. Am. Meteorl. Soc.* **99** S1–157

Hubacek K, Baiocchi G, Feng K and Patwardhan A 2017 Poverty eradication in a carbon constrained world *Nat. Commun.* 8912

Huntingford C and Mercado L M 2016 High chance that current atmospheric greenhouse concentrations commit to warmings greater than 1.5 °C over land *Sci. Rep.* **6** 30294

ICAO 2017 The World of Air Transport in 2017 (International Civil Aviation Organization) (https://icao.int/annual-report-2017/Pages/the-world-of-air-transport-in-2017.aspx)

- IEA 2018 CO₂ Emissions from Fossil Fuel Combustion 2018 (International Energy Agency) (https://webstore.iea.org/ co2-emissions-from-fuel-combustion-2018) IMF 2018 World Economic Outlook Update (Washington, DC:
- IMF 2018 World Economic Outlook Update (Washington, DC: International Monetary Fund)
- IPCC 2018 Global Warming of 1.5°C. Special Report Intergovernmental Panel on Climate Change
- Jackson R B, Canadell J G, Le Quéré C, Andrew R M, Korsbakken J I, Peters G P and Nakicenovic N 2016 Reaching peak emissions *Nat. Clim. Change* 67–10
- Jackson R B, Le Quéré C, Andrew R M, Canadell J G, Peters G P, Roy J and Wu L 2017 Warning signs for stabilizing global CO₂ emissions *Environ. Res. Lett.* **12** 110202
- Le Quéré C *et al* 2018a Global Carbon Budget 2017 *Earth Syst. Sci.* Data 10 405–48
- Le Quéré C et al 2018b Global Carbon Budget 2018 Earth Syst. Sci. Data accepted (https://doi.org/10.5194/essd-2018-120)
- Liu Z *et al* 2015 Reduced carbon emission estimates from fossil fuel combustion and cement production in China *Nature* 524 335–8 National Oceanic & Atmospheric Administration (NOAA) 2018 (https://ncdc.noaa.gov/billions)
- OICA 2017 Motorization Rate 2015, International Organization of Motor Vehicle Manufacturers (http://oica.net/category/ vehicles-in-use)
- O'Neil B C et al 2016 The scenario model intercomparison project (scenarioMIP) for CMIP6 Geosci. Model Dev. 9 3461–82

- Peters G P, Andrew R M, Canadell J G, Fuss S, Jackson R B, Ivar Korsbakken J, Le Quéré C and Nakicenovic N 2017 Key indicators to track current progress and future ambition of the paris agreement *Nat. Clim. Change* **7** 118–22
- Riahi K *et al* 2017 The shared socioeconomic pathways and their energy, land use, and greenhouse gas emissions implications: an overview *Glob. Environ. Change* **42** 153–68
- Rogelj J, Luderer G, Pietzcker R C, Kriegler E, Schaeffer M, Krey V and Riahi K 2015 Energy system transformations for limiting end-of-century warming to below 1.5 °C *Nat. Clim. Change* 5 519–27
- Rogelj J *et al* 2018 Scenarios towards limiting global mean temperature increase below 1.5 °C *Nat. Clim. Change* 8 325–32
- Seneviratne S I, Donat M G, Pitman A J, Knutti R and Wilby R L 2016 Allowable CO₂ emissions based on regional and impactrelated climate targets *Nature* **529** 477–83
- Statista 2018 Total fuel consumption of commercial airlines worldwide between 2005 and 2018 (https://statista.com/ statistics/655057/fuel-consumption-of-airlines-worldwide)
- US DOT 2018 Average Fuel Efficiency of US Light Duty Vehicles; Bureau of Transportation Statistics (https://bts.gov/ content/average-fuel-efficiency-us-light-duty-vehicles)
- World Bank 2018 Global Economic Prospects, June 2018: The Turning of the Tide ? (Washington, DC: World Bank) (https://doi. org/10.1596/978-1-4648-1257-6)