Energy Revolution: A Global Outlook

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Headline messages

The global energy revolution

As a contribution to COP24, this report informs the debate on decarbonising the global energy system, evaluating how rapidly nations are transforming their energy systems, and what lessons can be learned from the leading countries across five energy sectors. It was commissioned by power utility Drax Group, and delivered independently by researchers from Imperial College London and E4tech.*

Clean power

- Several countries have lowered the carbon content of their electricity by 100 g/kWh over the last decade. The UK is alone in achieving more than double this pace, prompted by strong carbon pricing.
- China is cleaning up its power sector faster than most of Europe, however several Asian countries are moving towards higher-carbon electricity.
- Germany has added nearly 1 kW of renewable capacity per person over the last decade. Northern Europe leads the way, followed by Japan, the US and China. In absolute terms, China has 2.5 times more renewable capacity than the US.

Fossil fuels

- Two-fifths of the world's electricity comes from coal. The share of coal generation is a key driver for the best and worst performing countries in clean power.
- Coal's share of electricity generation has fallen by one-fifth in the US and one-sixth in China over the last decade. Denmark and the UK are leading the way. Some major Asian nations are back-sliding.
- Many European citizens pay out $100 per person per year in fossil fuel subsidies, substantially more than in the US or China. These subsidies are growing in more countries than they are falling.

Electric vehicles

- In ten countries, more than 1 in 50 new vehicles sold are now electric. China is pushing ahead with nearly 1 in 25 new vehicles being electric and Norway is in a league of its own with 1 in 2 new vehicles now electric, thanks to strong subsidies and wealthy consumers.
- There are now over 4.5 million electric vehicles worldwide. Two thirds of these are battery electric, one third are plug-in hybrids. China and the US together have two-thirds of the world's electric vehicles and half of the 300,000 charging points.

Carbon capture and storage

- Sufficient storage capacity has been identified for global CCS roll-out to meet climate targets, but large-scale CO_2 capture only exists in 6 countries.
- Worldwide, 5 kg of CO_2 can be captured per person per year. The planned pipeline of CCS facilities will double this, but much greater scale-up is needed as this represents only one-thousandth of the global average person's carbon footprint of 5 tonnes per year.

Efficiency

- Global progress on energy intensity is mixed, as some countries improve efficiency, while others increase consumption as their population become wealthier.
- Residential and transport changes over the last decade are mostly linked to the global recession and technological improvements, rather than behavioural shift.
- BRICS countries consume the most energy per $ of output from industry. This is linked to the composition of their industry sectors (i.e. greater manufacturing and mining activity compared to construction and agriculture).

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Introduction

Methodology

First, global decarbonisation scenarios were examined to identify five critical technologies and measures that are consistently relied upon to limit climate change to below 2°C. The measures and reports consulted are detailed in Appendix I.

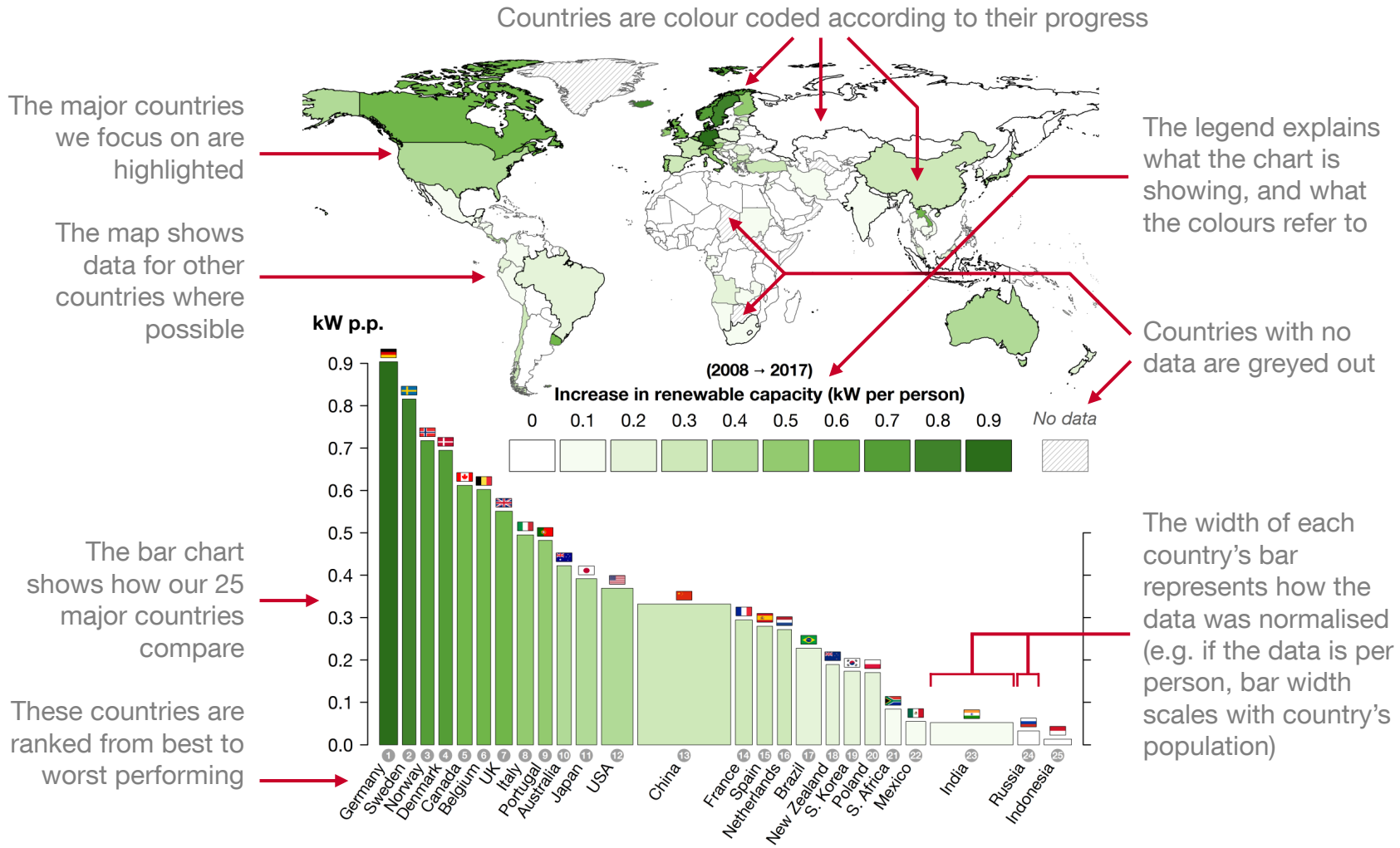
International datasets were then compiled to investigate the progress made by countries towards these key areas. The results presented are based upon data collected from other sources, as opposed to fresh modelling. When the geographic coverage of a dataset was limited, complementary statistics were sourced and methodologies were aligned to form a single dataset.

Progress towards these metrics is typically represented as the pace of change in the last decade, as this is important in understanding how energy systems are transforming in the context of achieving targets. Metrics have been normalised to the human scale (e.g. the share of vehicles, emissions per person), to ensure that actual process is reflected as opposed to the sheer size of a country.

The progress of 25 major countries is highlighted throughout the report. These include all of the G7 and BRICS countries, and together they represent 80% of the global population, 77% of GDP, and 73% of carbon emissions.

Reading the charts

Each metric is presented with a global map and the leader board for the 25 major countries:



How is the UK performing?

Across the five areas we consider, Denmark is leading the way in transforming its energy system, followed closely by the UK in 2nd and Canada 3rd.

The UK's performance is consistent across the 14 metrics we consider, being in the top 5–10 countries across most of them. It is within the top 7 countries for reducing the energy intensity of its economy, and it has the 5th largest fleet of electric vehicles.

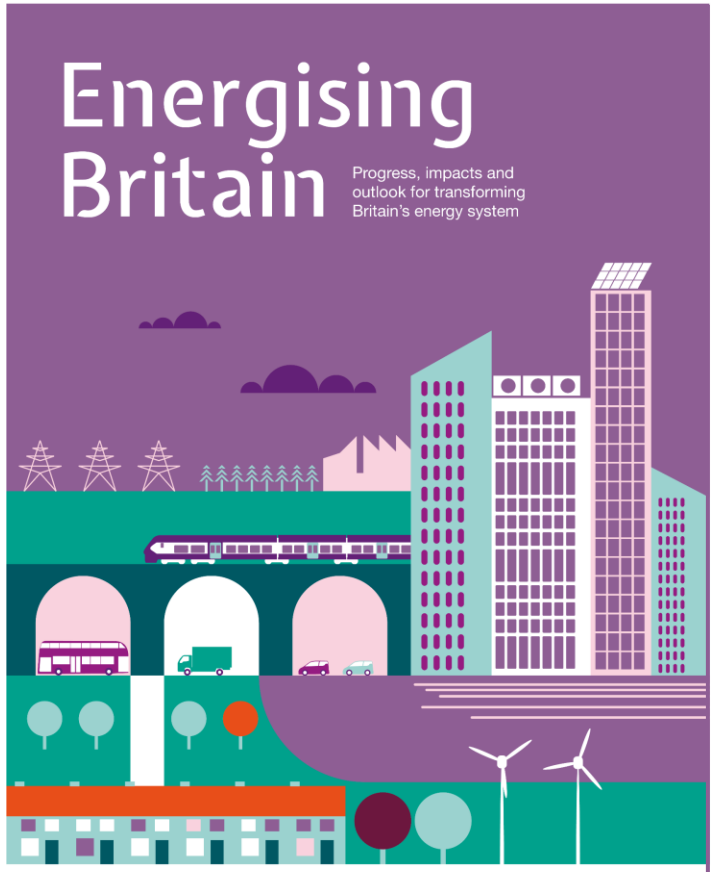
The UK is world-leading in grid decarbonisation, reducing its carbon content by over 250g CO_2/kWh in the last decade. Linked to this, the UK has seen the world's fastest rate of phasing out coal power generation.

The two notable let-downs are the UK's high and growing subsidies for fossil fuels, and the lack of large-scale carbon capture and storage (CCS) capacity. The UK is among the worst performers in supporting the fossil fuel industry through direct budgetary transfers and tax expenditures.

UK government has rebooted its support for CCS with a vision to become a world leader and deploy at scale in the 2030s. After cancelling a £1bn scheme in 2015, new funding of £335m has been announced. In comparison, consistent government support in the US and China has allowed large-scale CCS facilities to already be demonstrated.

The UK has demonstrated conclusively that market instruments can be implemented in a cost-effective manner to transition energy systems in line with climate goals. For example, the carbon floor price is credited with causing the coal phase-out, as well as spurring investment in low carbon technologies. Other market mechanisms, such as Contracts for Difference have greatly expanded renewable generating capacity.

The UK should think more holistically about its policies that directly or indirectly support fossil fuels, as these are working against overall climate targets. This could see the UK modelling itself after Denmark, which has decreased its fossil fuel support by almost 90% over the last decade.



Read more about how Britain's energy systems transition is progressing, the regional inequalities that are emerging, and how these will impact upon households, businesses and the environment

https://www.drax.com/energy-policy/energising-britain-progress-impacts-outlook-transforming-uk-energy-system/

Clean power

Carbon content of electricity

Clean electricity supply is fundamental to virtually all visions of a decarbonised global economy. This requires the rapid transition away from coal, oil and gas towards renewables and nuclear. Clean electricity can then power vehicles, heating and industry as a major route to decarbonising these sectors.

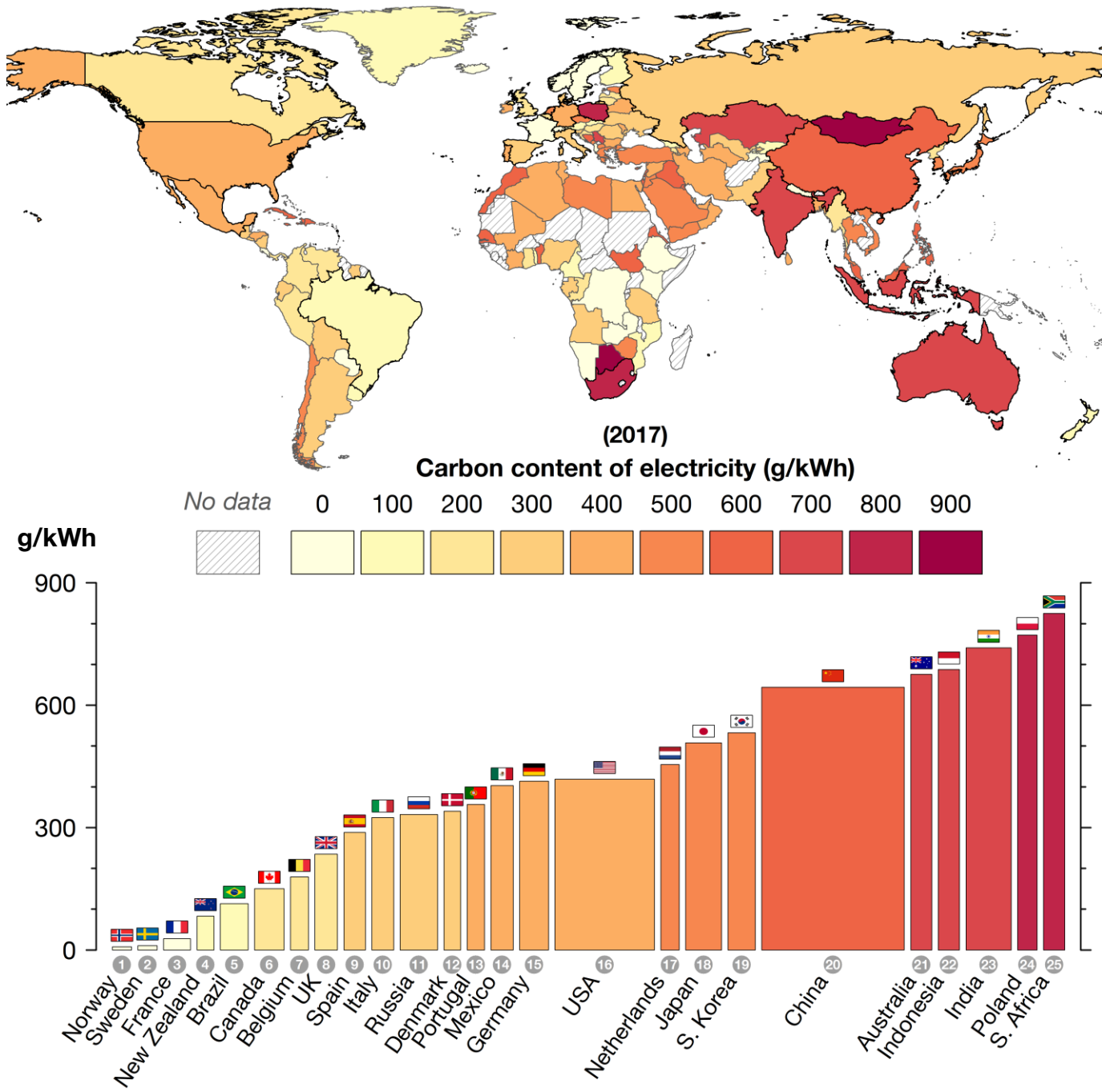
In 2017, the global average carbon intensity of electricity was 450 gCO_2 per kWh consumed. In our league table, 16 out of 25 major countries are below this average, and 3 are below a longer-term target of 50 gCO_2/kWh.

The wide variation in carbon intensity across countries reflects the diversity in their generation mixes:

- Scandinavia, France and New Zealand benefit from abundant hydro resources and/or nuclear power, resulting in almost zero carbon grids.
- Many countries emit around 300–500 g/kWh, using a mix of coal, gas and low-carbon sources.
- China, India, Poland and South Africa rely heavily on coal power, and so their electricity contains up to twice the global average amount of CO_2.

Comparing the two largest economies: China consumes ~6,500 TWh of electricity per year with a carbon intensity of 640 g/kWh, and the US consumes ~4,250 TWh at 420 g/kWh.

If China could reduce its carbon intensity by a third to match the US, global CO_2 emissions would fall by around 4%. If China and America could both match the UK, global emissions would fall by 9%; a testament to the scale and importance of the power sector.



Sources: IEA (2017a), BP (2018), Wilson and Staffell (2018)

Clean power

Carbon content of electricity

The global average carbon intensity of electricity has fallen by only 7% (33 gCO_2/kWh) in the last decade (2008 to 2017).

Countries have on average cleaned up their power systems at twice this rate (67 gCO_2/kWh). However, rising consumption in the higher-carbon countries (India, Indonesia, China) has tempered the global average fall.

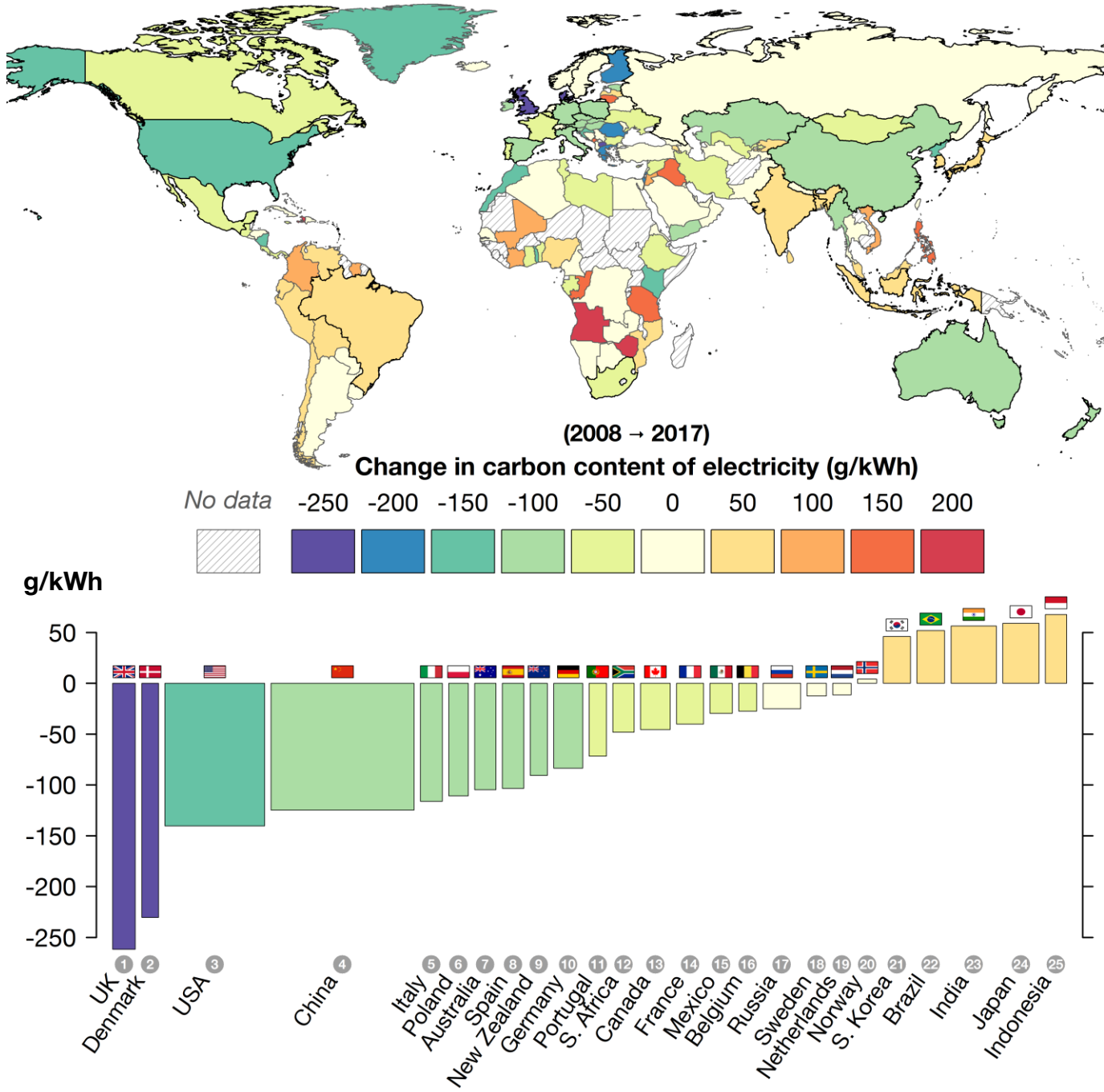
The UK has decarbonised its power sector much faster than any other country in the world. The carbon intensity of the UK's electricity has more than halved in the last decade, due to the rapid phase-out of coal power and growth of renewables.

Despite talk of bringing back coal in America, or China building a new coal power station every week, these two countries have performed better than most in cleaning up their power sectors in the last decade.

Other countries with high-carbon grids, such as Poland, Australia and South Africa are also slowly reducing their carbon intensity.

Several large Asian countries are moving towards higher-carbon grids due to nuclear phase-out (Japan), rapid demand growth (South Korea) and an entrenched coal industry (Indonesia). Brazil also saw a large increase (albeit from a low level) due to the 2017 droughts reducing hydro output.

The UK's lesson is that carbon pricing can be a fast and effective tool for decarbonisation. The decision to increase the UK's CO_2 price by £16 ($21) per tonne made coal power stations uneconomic relative to gas. Stronger carbon pricing added to clean air legislation in pushing older coal plants into early retirement, and the conversion of several coal units to burn biomass.



Sources: IEA (2017a), BP (2018), Wilson and Staffell (2018)

Clean power

Installed renewable capacity

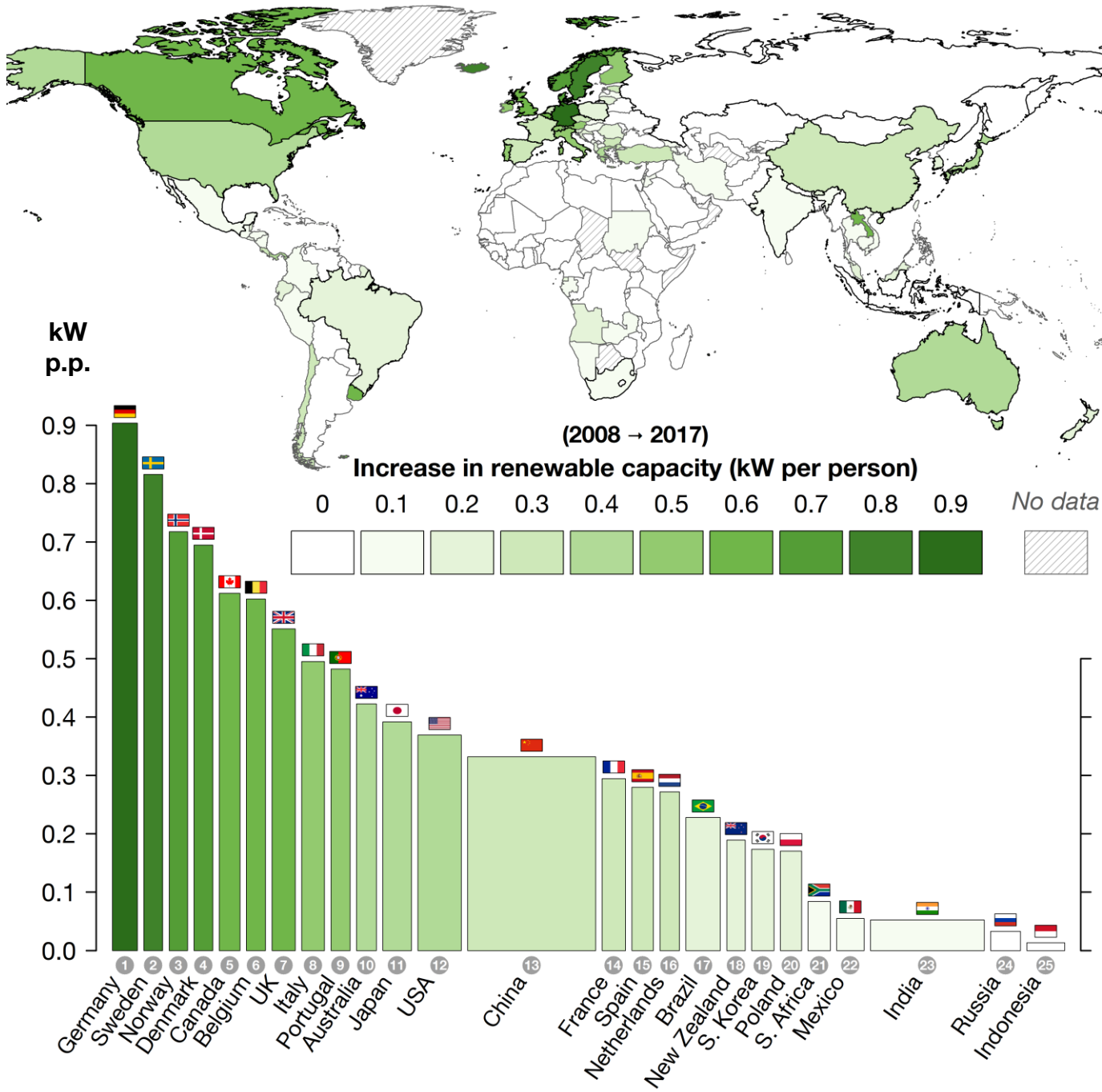
Renewable energy has revolutionised the power sector, forming half of all new generating capacity installed for the last two years running. Global wind and solar capacity are increasing by around 20% and 40% annually, while biomass and hydro are growing at around 8% and 4% respectively.

The last ten years (2008 to 2017) has seen an extra 1,125 GW of renewable power generating capacity installed worldwide. Of this, 400 GW of wind, 375 GW of solar, 310 GW of hydropower and 55 GW of biomass and waste. Worldwide this amounts to an average of 156 Watts per person, enough to power a small fridge freezer or ten LED lightbulbs for every person on the planet.

Germany and Scandinavia lead the pack, and 8 of the top 10 countries are in Europe. Germany has installed nearly 1 kW of renewable capacity per person over the last decade, due to the widespread rollout of both wind and solar power. This has been facilitated by generous feed-in tariffs whilst costs were coming down. Germany ranks 1st for solar and 3rd for wind capacity installed per person.

China, the US and Japan are comparable, with 0.33–0.4 kW of renewables per person installed over the last decade. In absolute terms, China has installed 2.5x more renewables than any other country, with over 600 GW installed in total, versus 230 GW in 2nd ranked America.

India is rapidly increasing its ambitions for renewables, but as of 2017 had just one-third the global average, with 52 watts installed per person.



Sources: IRENA (2018)

Fossil fuels

Phasing out coal power

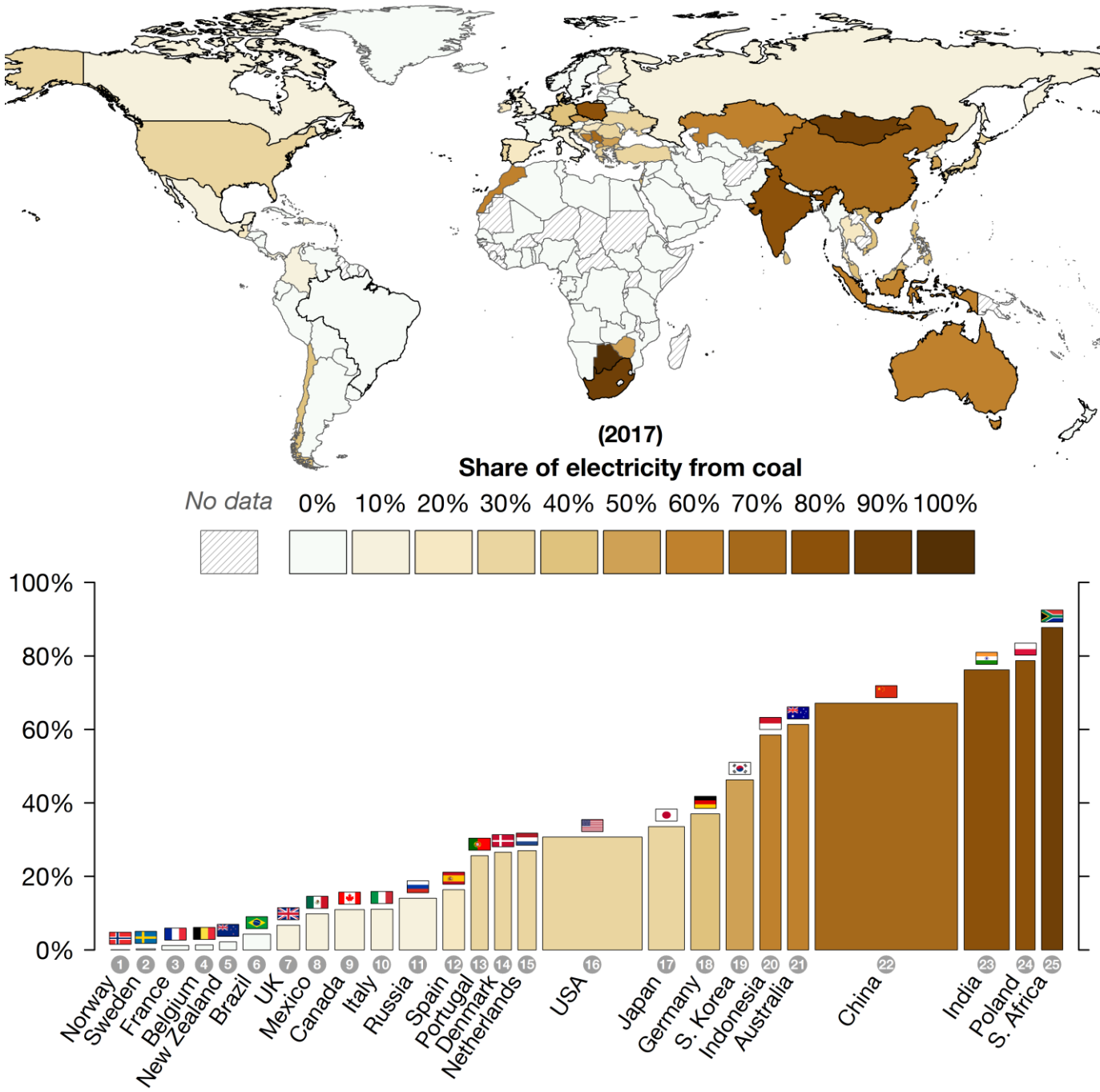
As the most polluting fuel for electricity generation, a shift away from coal power generation is essential. The pathways to limit climate change to below 2°C universally show a worldwide abandonment of unabated coal-fired electricity eliminated between 2040 and 2050. Overall coal power (including with CCS) falls by 90% between now and 2050.

Coal has provided around two-fifths of the world's electricity for the last 30 years. This has barely moved over the last decade as the falling share in most OECD countries is being countered by growing electricity demand in coal-reliant Asian countries.

In 2017, our sample of major countries ranged from using coal for 0% up to almost 90% of their electricity generation. Of the six least-reliant countries, four are in Europe, and all make significant use of hydropower or nuclear for their electricity supply. The UK sits just outside this group in 7th position.

Of the six heaviest coal users, three are in Asia, joined by South Africa, Australia and Poland. All of these countries have significant indigenous coal resources, which presents complex challenges to reducing reliance on coal. Three major elements are fears of job losses in the powerful mining industries, security concerns if coal is replaced with imported fuels, and the risk of raising electricity bills which would impact economic growth and living standards.

In a growing number of regions, new wind and solar plants can now compete with the short-term generation costs of existing coal plants. In the US, coal is further being undercut by low-cost natural gas, while in Europe stronger CO_2 prices are having a similar effect.



Sources: IEA (2017a), BP (2018), Wilson and Staffell (2018)

Fossil fuels

Phasing out coal power

The share of coal in global electricity generation has only fallen by 2% over the last decade (2008 to 2017). The progress being made in some countries is offset by the increasing reliance on coal in parts of Asia, and a shift in the centre of gravity of electricity consumption from Europe and the US (which average 25%) towards Asia (which averages 60%).

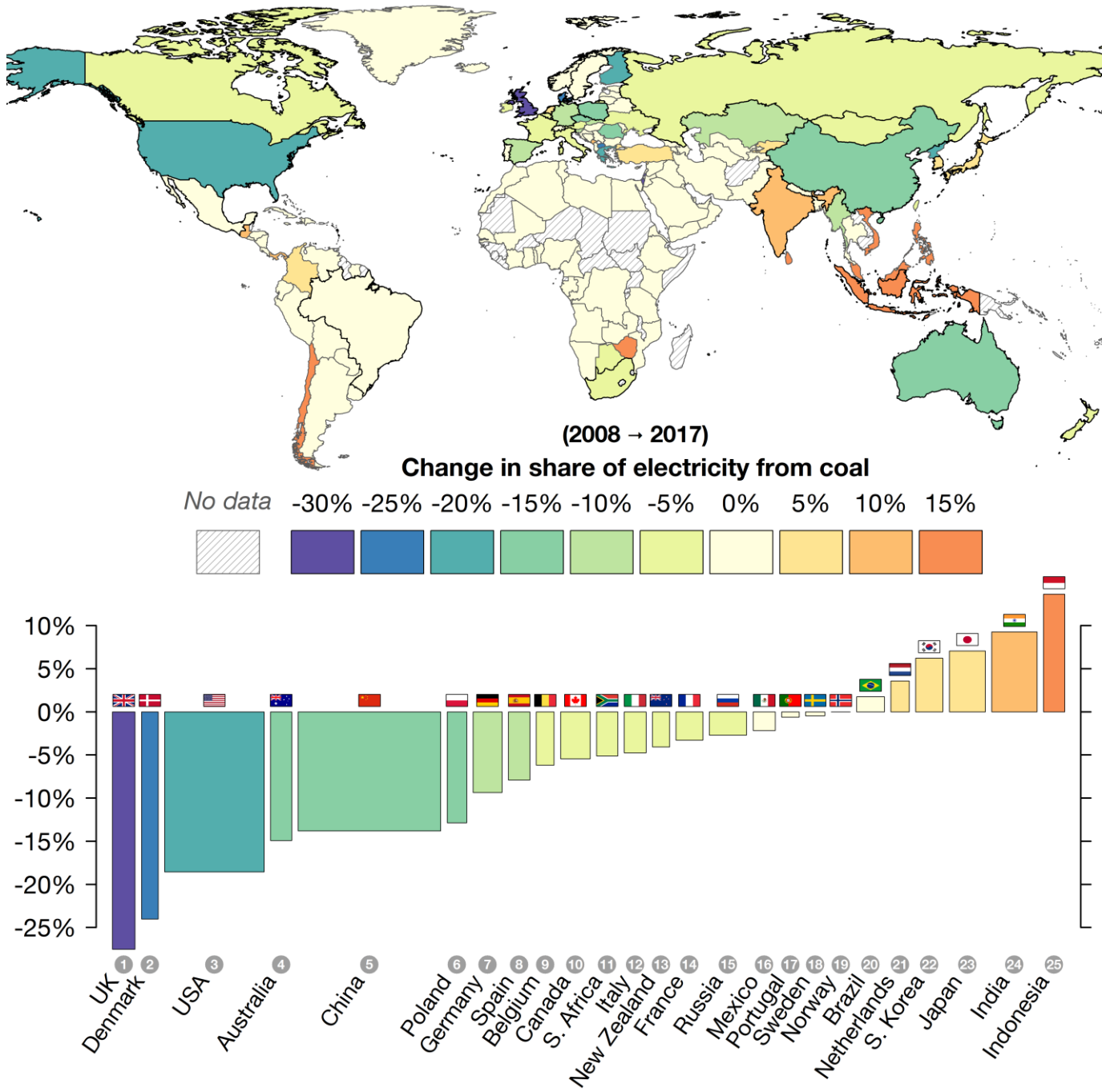
The largest national reductions have happened in the UK and Denmark, who have switched one quarter of their electricity supplies from coal to gas and renewables over the last decade.

Coal reliance has declined slightly across Europe (from 26 to 22% on average). Clean air directives have hastened the closure of older coal plants, although the EU-wide carbon price has done little to disincentivise coal generation until recently.

Coal's share in the US has fallen to 30% primarily because of market forces. The low cost of natural gas since the shale revolution has made coal uncompetitive, and the latest pro-coal policies are not seeing its resurgence.

However, many Asian countries are strengthening their reliance: Indonesia, India, Japan and South Korea have all seen marked increases. Of all the countries in Asia, North Korea is the unlikely climate champion for having halved its coal reliance to 20% over the last decade.

At COP23, Canada and the UK launched the Powering Past Coal Alliance, which has grown to 75 countries, states and companies. Its mission is to see a complete phase-out of unabated coal by 2030 in the OECD and EU, and 2050 worldwide.



Sources: IEA (2017a), BP (2018), Powering Past Coal Alliance (2018)

Fossil fuels

Removing fossil fuel subsidies

Government support for fossil fuels is a perverse feature of many economies, especially in the developed world. We use the OECD's estimates of the level of government support for fossil fuels.

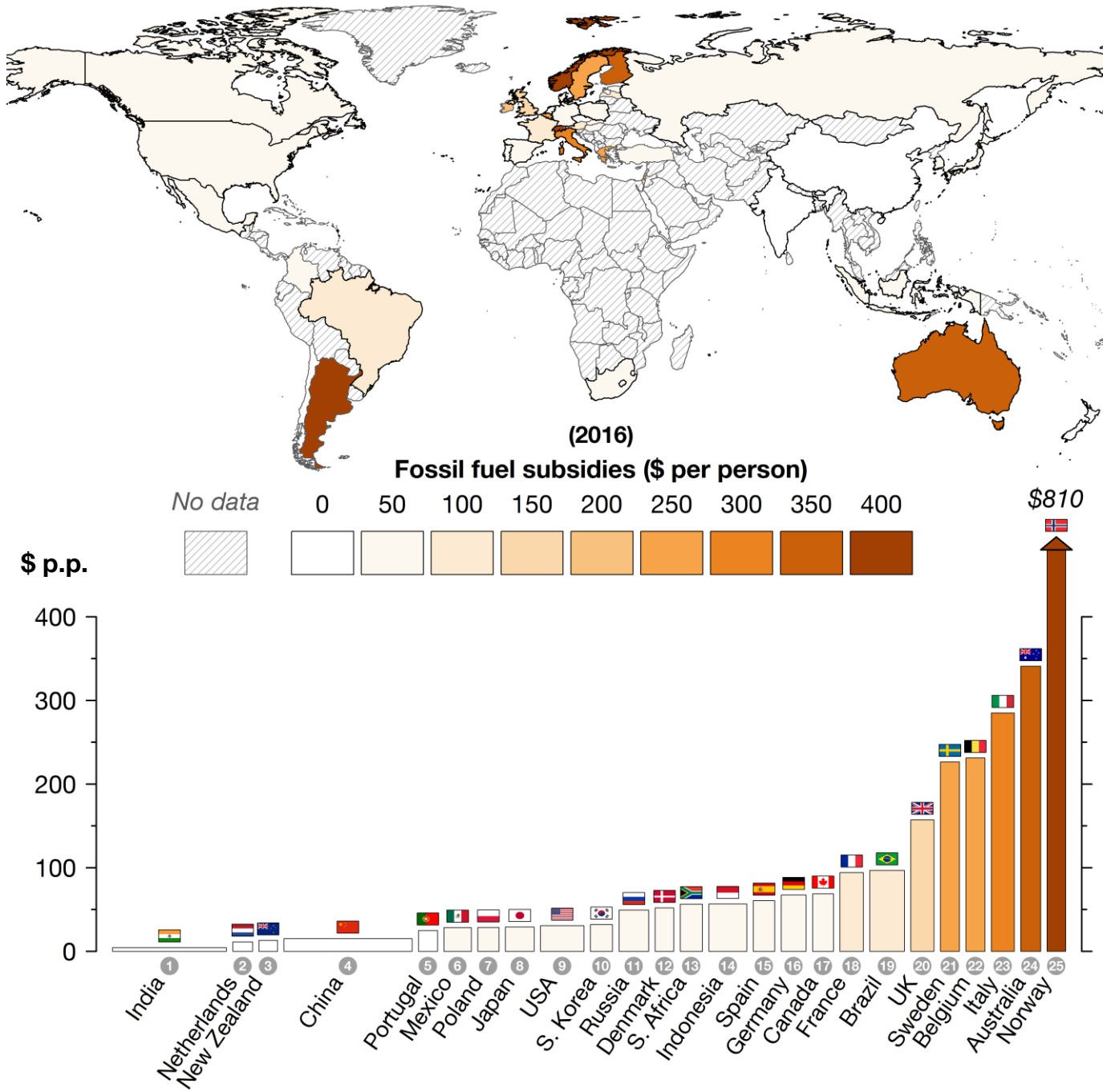
The OECD use a consistent definition of subsidy/support mechanism, which includes direct expenditures by government, forgone tax revenues and other fiscal concessions. This may differ from specific national definitions.

For example, the UK defines a fossil fuel subsidy as any government action that lowers the pre-tax price to consumers below the international market level. The UK government does not believe it has any fossil fuel subsidies.

According to the OECD definition, the UK is the 5th largest* supporter of fossil fuels among our 25 countries, to the tune of $10 billion per year. Fossil fuels are supported by direct budgetary transfers (e.g. seismic survey programme), tax expenditures (e.g. onshore allowances) and VAT relief on household fuel bills.

The inventory is populated with information from published government sources, mainly from their annual budgets. The OECD does not claim that this is an exhaustive list as it is dependent on the data from countries' budget books.

Countries with large fossil fuel endowments tend to have higher fossil fuel subsidies, for example Norway and Australia. Fossil subsidies per person, and as a share of GDP, are highest in developed nations. However, this may, at least partly, be related to greater transparency in their national accounts compared to more developing countries.



Sources: OECD (2018a, 2018b) Note: * 5th largest in absolute terms, 6th largest per capita

Fossil fuels

Removing fossil fuel subsidies

The change in fossil fuel subsidies from 2007 to 2016 varies considerably, with 15 countries having increased their support over that period.

Russia and Norway have seen the largest increases. In 2015, Russia introduced tax reductions for the extraction of oil from isolated hydrocarbon deposits. In the same year, Norway reinstated a subsidy to cover the costs of a state-owned coal mine operator, Store Norske, to avoid bankruptcy.

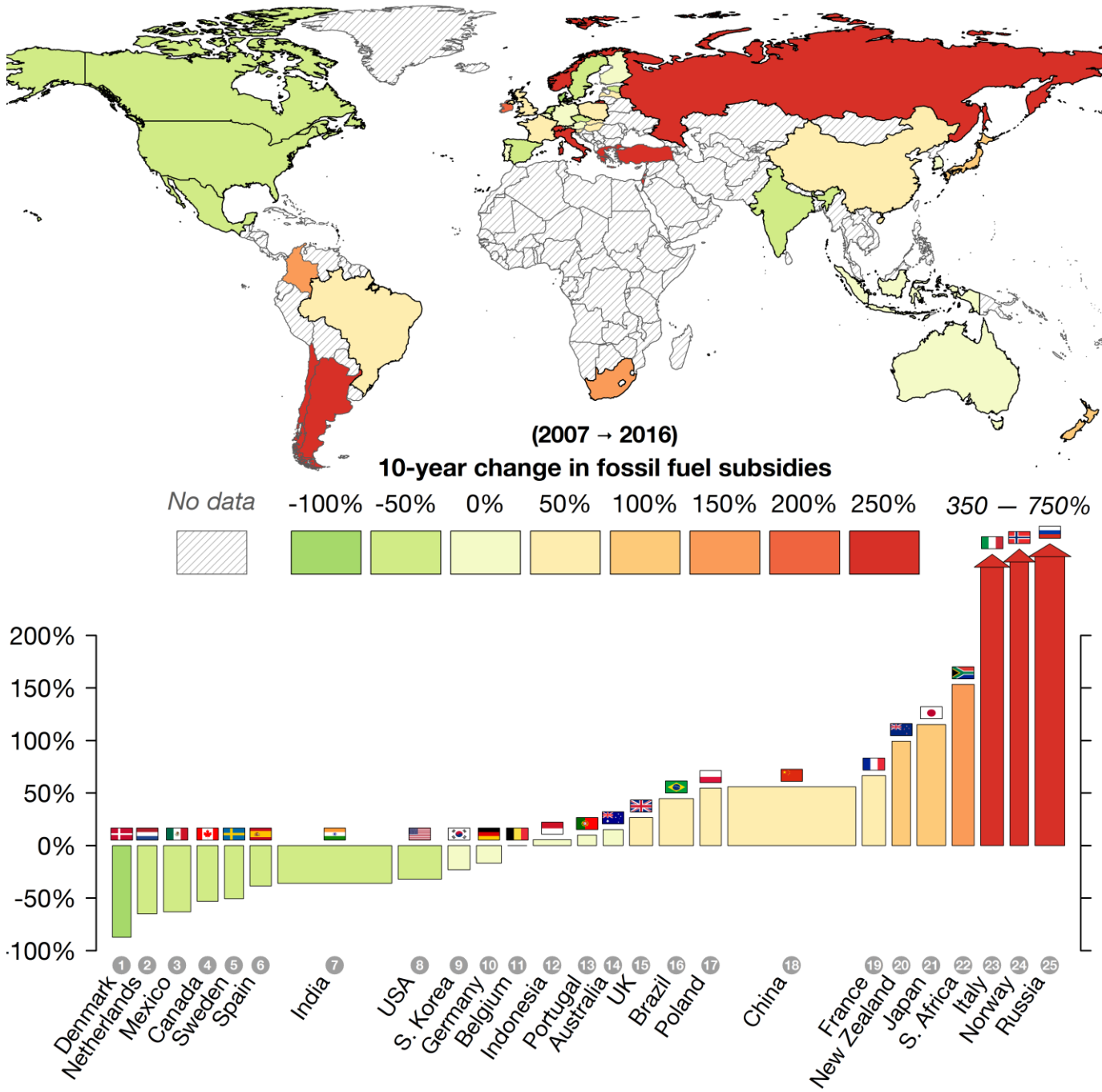
Some countries have decreased their relative fossil fuel support, though for some this is more strongly related to the recent fall in oil price, resulting in lower forgone taxes.

Denmark reduced its fossil fuel support by almost 90% between 2007 and 2016. This is a result of ending the Reduced Energy Duty for CHP Generation, as well as greater renewable energy use backing out fossil fuels and therefore decreasing forgone taxes.

Mexico implemented a special excise tax (IEPS) with an overarching goal to eliminate gasoline and diesel fuel support. This saw fossil fuel subsidies as a proportion of GDP halve in just two years.

China, the US, Germany, Mexico, Peru, New Zealand, the Philippines, Taiwan, Vietnam, Finland and Sweden have conducted peer reviews to identify inefficient fossil fuel subsidies. Indonesia, Italy, Argentina, Canada, and Brunei are understood to be completing their reviews.

A Sustainable Development Goal indicator for fossil fuel support is being developed, and by 2020 all countries will start reporting on it annually.



Sources: OECD (2018a, 2018b)

Electric vehicles

Share of EV sales

The sales of electric vehicles are increasing rapidly, and here we show the latest data (to September 2018) in partnership with EV-volumes.com.

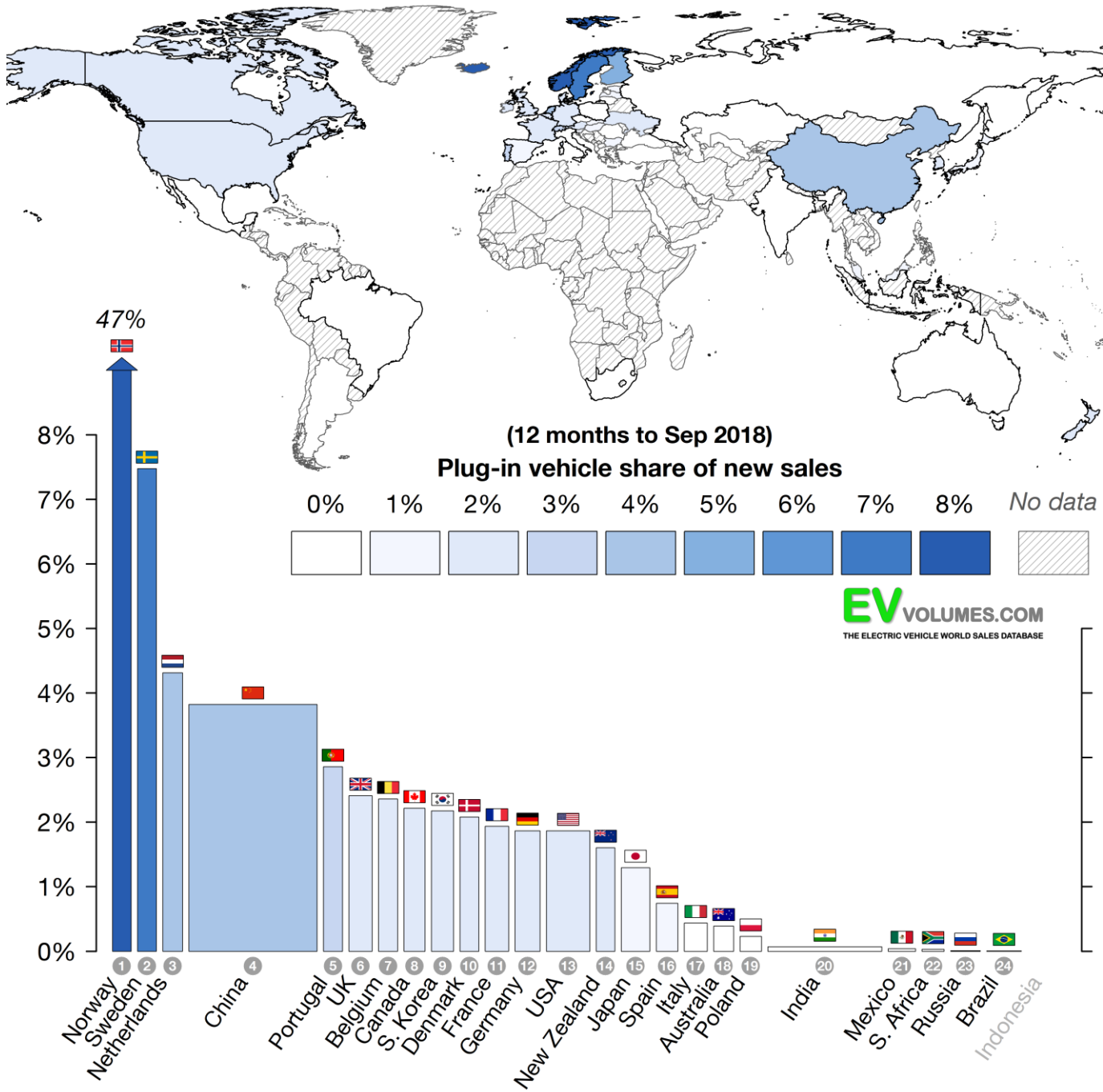
Over 4.5 million vehicles on the roads are electric, of which two-thirds are battery electric (BEV) and one-third plug-in hybrid electric (PHEV) vehicles. New electric vehicle sales in 2017 surpassed 1.2 million units.

Despite the recent growth in EV sales, in all countries, apart from Norway, EVs make up less than 10% of newly sold vehicles, with many around the 2% mark (i.e. 1 in 50 new cars sold are electric). This is related to the higher initial cost of an electric vehicle compared to a petrol/diesel one. Therefore, EV sales are currently dependent on a series of measures implemented to stimulate their growth.

Norway started offering EV incentives in the 1980s. The current incentive portfolio for electric vehicles includes: no import or purchase taxes, no VAT, no road tax, no road tolls, half price on ferries, free municipal parking and access to bus lanes. This package of support makes the total cost of owning an electric vehicle cheaper than a conventional vehicle in Norway.

In Sweden and the Netherlands grants and tax exemptions have been implemented, respectively, based on a vehicle's CO_2 emissions, therefore heavily favouring electric vehicles.

China has had one of the fastest growth in EV sales and claims over 50% of the passenger plug-in car market. The government has set a target of EV annual sales totalling 2 million by 2020, which is being facilitated by generous subsidies. This is paired with a target for manufacturers to produce at least one EV model by 2019.



Sources: EV-volumes (2018a, 2018b), Ecofys (2018), Reuters (2017), Zhou (2017), CleanTechnica (2017), European Automobile Manufacturers Association (2017), Jones (2018).

Electric vehicles

Number of EV charging points

Governments and private companies are providing charging facilities to stimulate EV uptake. In partnership with EV-volumes.com, we show the number of available chargers per thousand people, as of September 2018.

As with EV sales, Norway leads with approximately 1 charger for every 500 people. This compares to 1 charger for every 5,000 people in the UK, 1 for every 10,000 people in China, Japan and the US, and 1 for every 5 million people in India.

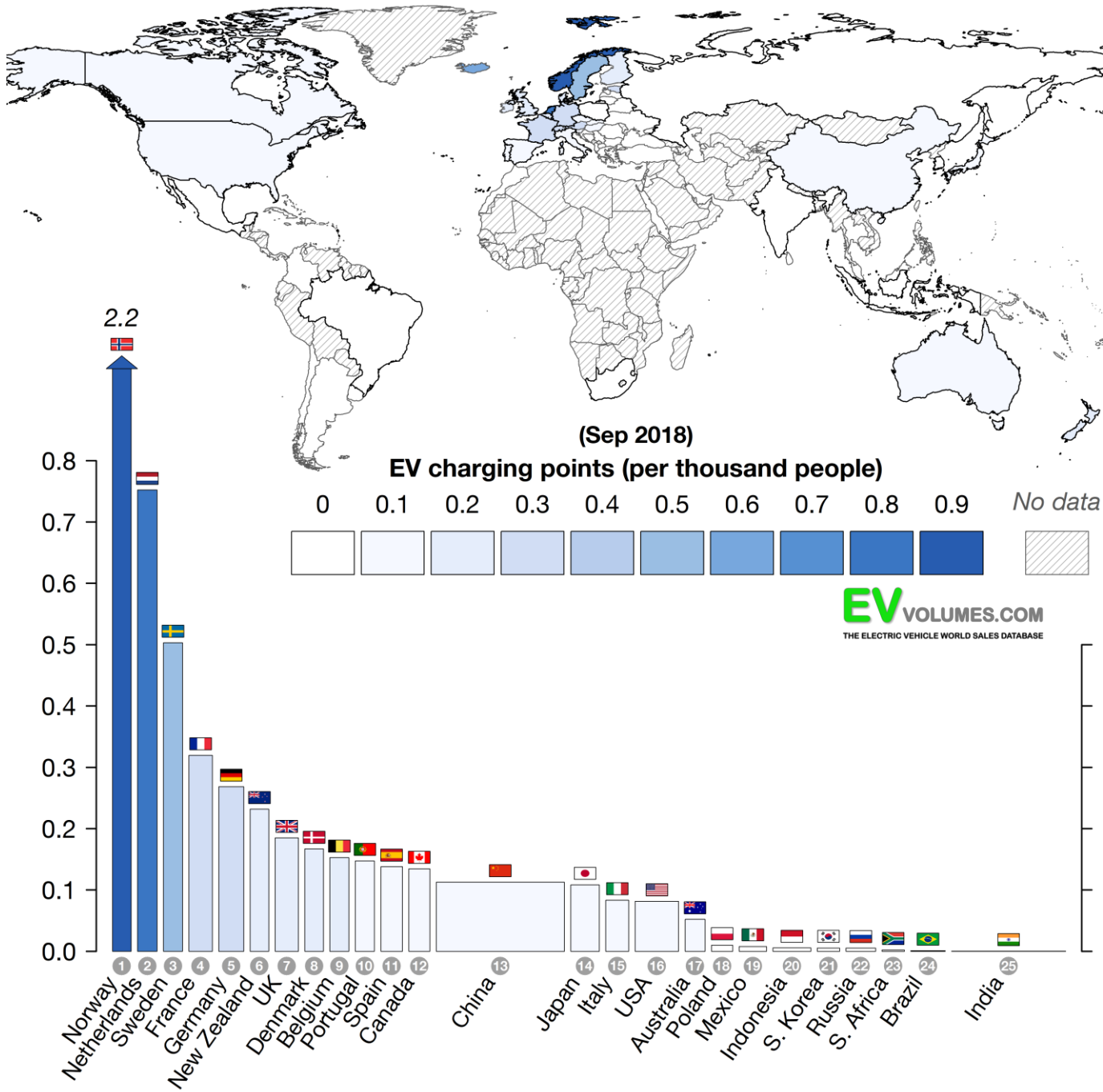
There are some 300,000 charging points worldwide, half of which are in China. Despite its size, the US has only slightly more charging points than Germany or France at present.

Charging network development is heavily driven by policy, with major support in the three countries that lead in terms of per-capita deployment.

Norway is implementing an extensive charging infrastructure network, by installing two fast charging stations for every 50 km of main road.

In the Netherlands, the Dutch Living Lab Smart Charging is a public-private partnership which aims to provide EV charging from wind and solar power in a cost-effective manner. Electric vehicles are also offered free charging in public places.

Sweden has implemented a range of support measures to support the development of a charging network. For example the 'Charge at Home' incentive or the 'Klimatklivet' provide grants for the installation of charging points to various stakeholders. The Swedish government is also investing in charging infrastructure that could help dispel concerns over range capabilities e.g. EV charging road outside Stockholm.



Sources: EV-volumes (2018a), Ecofys (2018), Zhou (2017), CleanTechnica (2017), Siemens (2017)

CCS

Capacity for carbon capture

According to most scenarios, significant CCS deployment is required to remain below 2°C of warming. Despite this, progress has been slow and current capture rates represents around 0.1% of total worldwide emissions. Worldwide, 5 kg of CO_2 can be captured per person per year, versus an average carbon footprint of 5 tonnes CO_2 per annum.

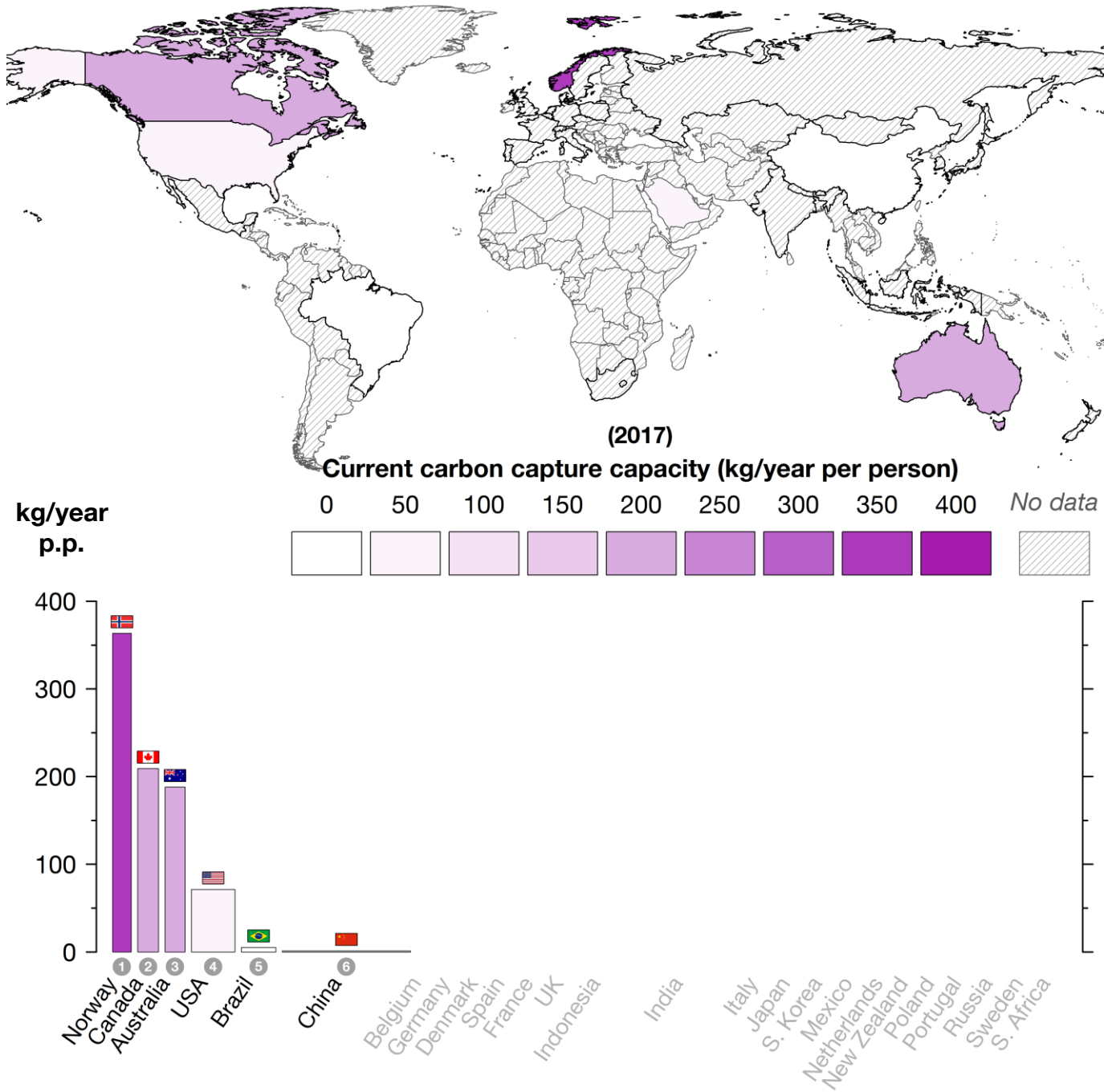
Currently, there are 18 operating capture facilities worldwide, concentrated in 6 countries with a total capacity of 32 $MtCO_2$ p.a. A further 5 facilities are under construction in 3 countries, totalling 7 $MtCO_2$ p.a. The US has the greatest absolute capture capacity, of over 20 $MtCO_2$ p.a.

Norway, Canada and Australia rank highest per capita due to their large fossil fuel industries, relative to population size. Together with the UK and US, these countries are ranked highest for 'CCS readiness' due to their progress in removing barriers to future CCS deployment.

The current deployment of carbon capture facilities is strongly influenced by national political environments. In the US, tax credits have been in place since 2008 for the geological storage of CO_2, and the US Congress approved an increase in these credits in 2018.

In China, the 12th and 13th Five Year Plans had a specific goal to develop CCS, which has resulted in China having the largest number of CCS pilot and demonstration plants, and the most large-scale facilities in planning.

Other policy measures can also indirectly support the deployment of CCS, for example carbon taxes in Norway and Japan, emission performance standards in the UK, and carbon trading schemes such as the EU ETS in Europe and the impending one in China.



Sources: Global CCS Institute (2018a, 2018b, 2018c)

CCS

Potential CO_2 storage capacity

Storage resources are not a barrier to CCS deployment. The IEA estimates that 100 billion tonnes of CO_2 must be stored (cumulative to 2060) to limit temperature rise to 2°C at least cost, in a scenario where one-sixth of emissions reductions come from CCS. The US alone has an estimated storage capacity of over 10 trillion tonnes of CO_2.

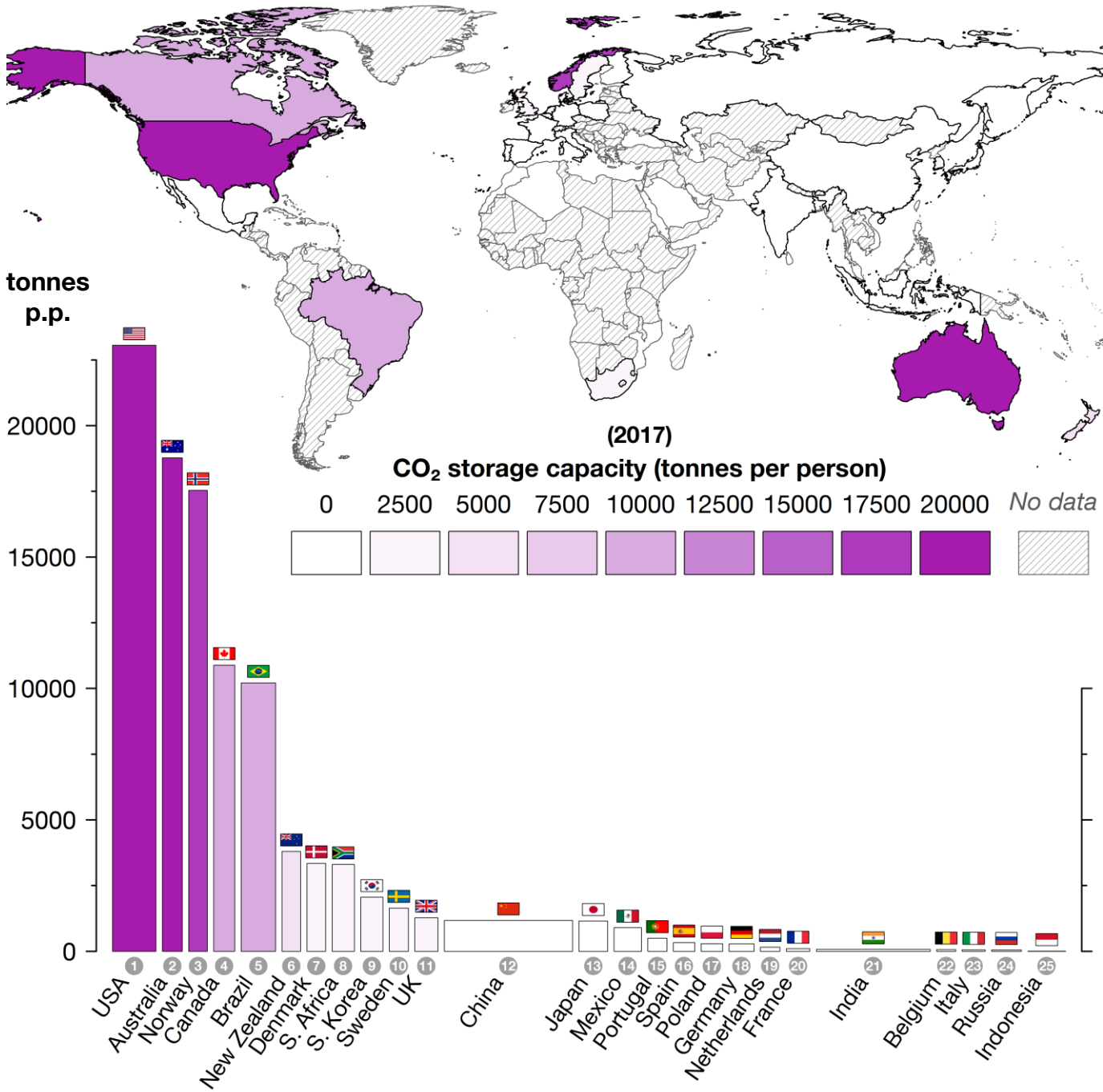
Many countries possess over 1,000 tonnes of CO_2 per person, which is several times an average person's lifetime carbon footprint.

Only 20% of large-scale industrial plants store captured CO_2 in dedicated geological storage. The majority use it instead for Enhanced Oil Recovery. As this increases oil production (which is unlikely to be burnt with CCS), this is not compatible with reducing global carbon emissions.

Expected to be completed in 2019, Australia's Gorgon Project will be the world's largest storage dedicated CO_2 store with injection rates of between 3.4 and 4 million tonnes per year.

Dedicated national programs have advanced storage portfolios in countries:

- In the US, the National Technology Energy Laboratories Regional Carbon Sequestration Partnerships is considered a pioneering model for storage site development. Several storage projects have been established with capacities over 1 million tonnes.
- Norway are continually assessing their storage potential, and currently have two operating sites Snøhvit and Sleipner, with a third in planning.
- The UK has estimated its storage capacity at around 70 billion tonnes. However, it has yet to deploy a site, due to the lack of capture capacity.



Sources: Global CCS Institute (2018d); Consoli and Wildgust (2017), Anthonsen et al. (2013), Höller and Viebahn (2011), Rütters and the CGS Europe partners (2013)

Efficiency

Energy intensity of households

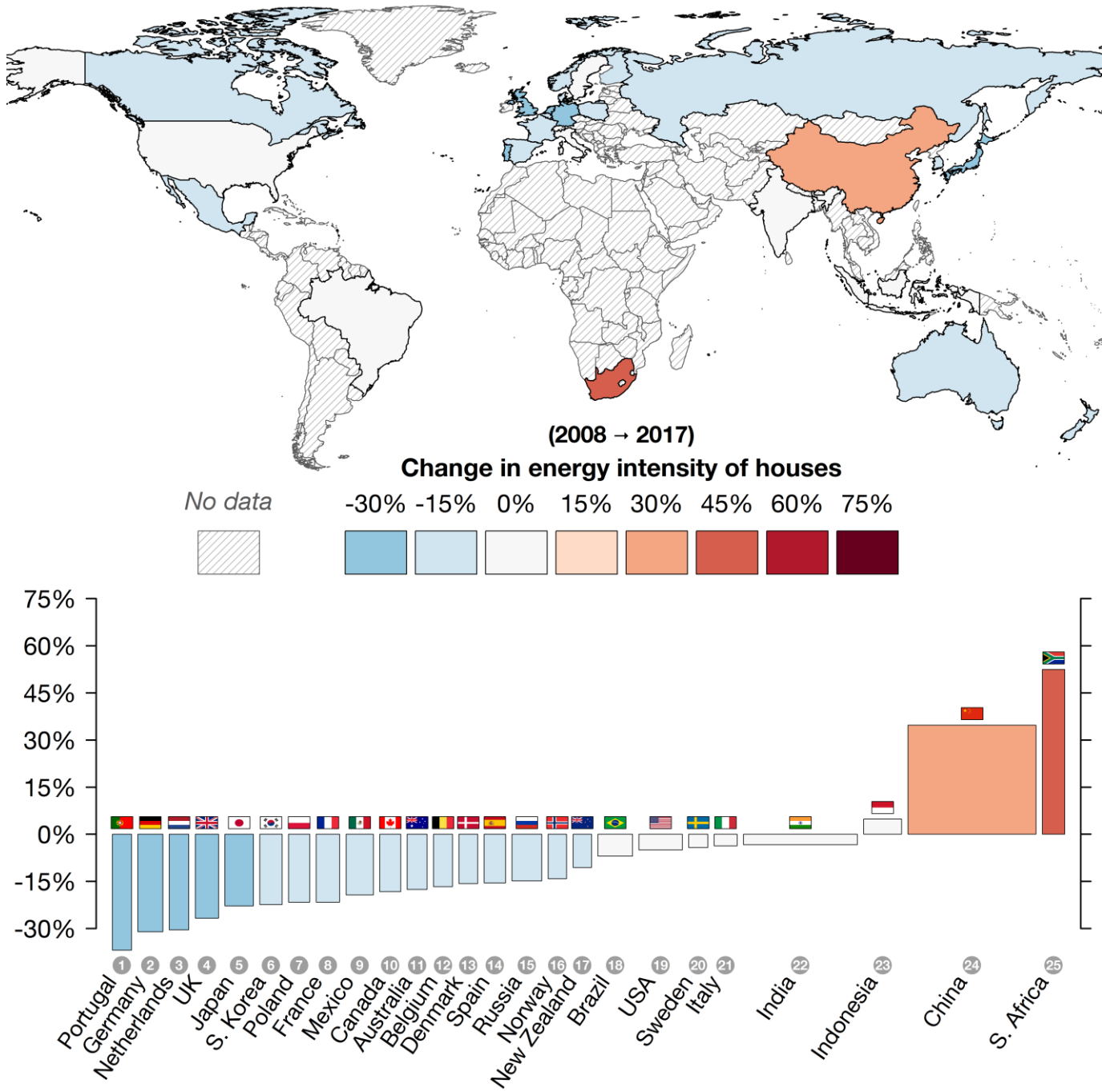
Energy efficiency is widely referred to as ‘the first fuel’ for energy transitions, as improvements can result in significant cost, energy and emission reductions. We evaluate the change in energy intensity from 2008–17.

Most countries have reduced their energy consumption per m^2 of household floor area. This is linked to improvements in housing stock, strict energy performance standards for appliances, milder winters (possibly a symptom of climate change) and residual effects of the global recession.

Rising incomes in South Africa, China and Indonesia have seen appliance usage and thermal comfort increase, pushing up residential energy intensity.

A number of policy instruments have been implemented worldwide to improve residential energy efficiency. Countries with more diverse policies tend to be more successful in reducing home energy consumption:

- Japan: Flat35 Mortgage scheme which secures fixed, low-interest 35 year mortgages for homes that, among other requirements, meet stringent energy efficiency standards.
- Netherlands: Energiesprong, a government-funded innovation programme, refurbishes homes to a net zero energy standard. This concept has spread to France, the UK, Germany and New York state.
- Germany: Rising energy taxes can explain residential efficiency gains. In 2018, 80% of household electricity prices were taxes and fees, compared to 65% in 2008, causing electricity prices to increase by 35% despite a fall in wholesale price.
- UK: Reduced VAT charges of 5% are available when installing energy-saving products, like solar panels, heat pumps and insulation.



Sources: IEA (2017a, 2017b), World Energy Council (2017), OECD (2017), GOV.UK (2018), Energiesprong (2018), Clean Energy Wire (2018)

Efficiency

Energy intensity of transport

Transport energy intensity is an interplay between several factors:

- Shifting from petrol to diesel vehicles
- Modal shifts
- Improvements in vehicle fuel efficiencies
- Increased electrification of transport
- Decrease in occupancy rates of vehicles
- Increased size of vehicles e.g. SUVs

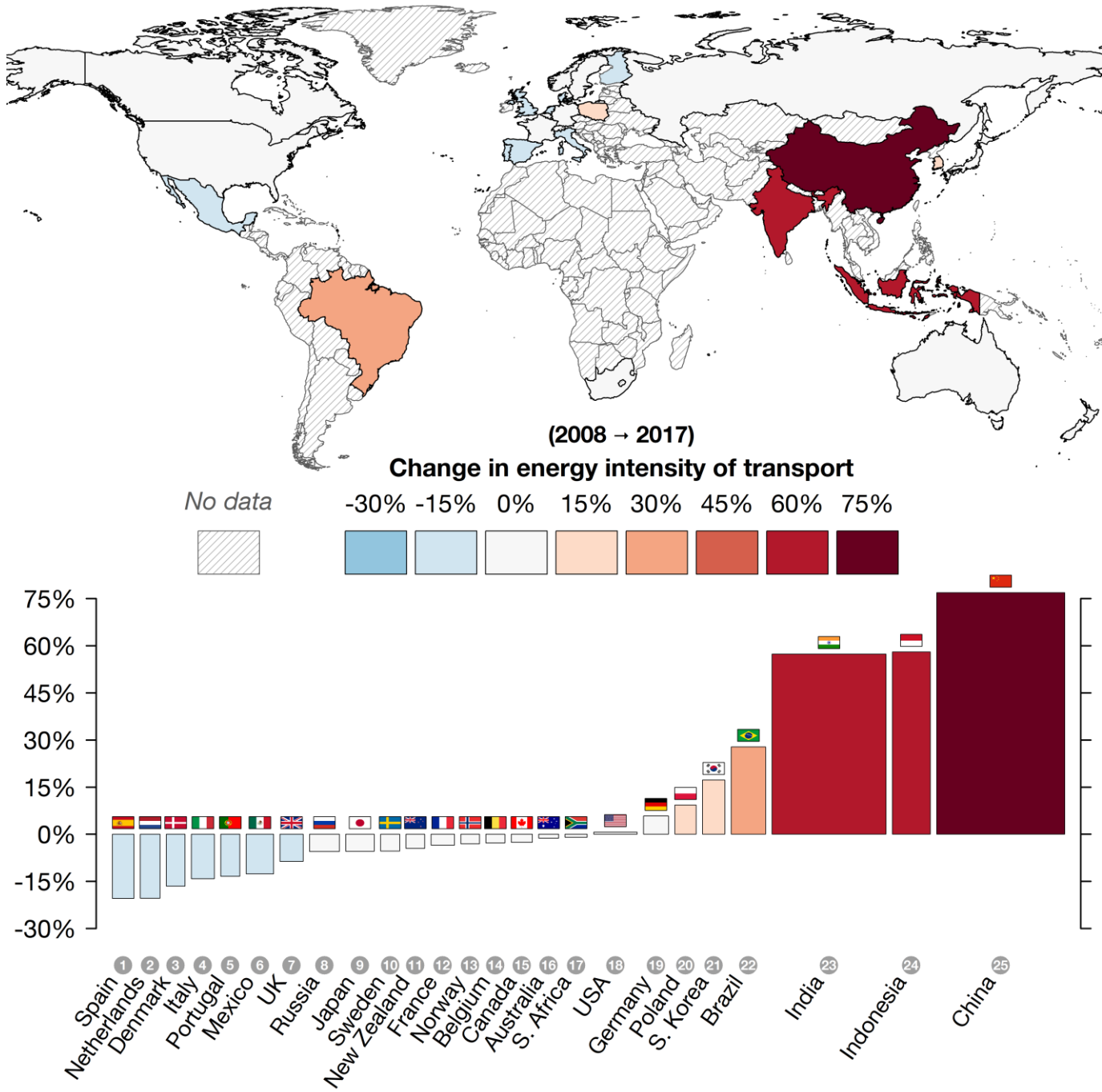
China, India and Indonesia have increased their energy consumption per person in transport by over 50%. Rising incomes are leading to private vehicles displacing public transport and decreasing private vehicle occupancy rates.

In Europe, fuel efficiency standards and the replacement of petrol vehicles with diesel vehicles explain the modest decreases in the energy intensity of transport in the last decade (albeit with negative impacts on air quality).

The varying fuel efficiencies across different markets suggest greater potential efficiency gains for many countries. According to research by the IEA, in the period between 2000 and 2017, 2.2 million barrels of oil per day could have been saved if all vehicles had the best-standard fuel efficiency.

In Spain, a variety of support programs were implemented to improve transport efficiency focusing on encouraging smaller passenger cars, the modal shift, uptake of alternative vehicles, and rail efficiency.

The Netherlands have continued to increase their share of freight transported by rail or on waterways – more efficient modes per tonne kilometre than road.



Sources: IEA (2017a, 2018), World Bank (2018), Odyssee-Mure (2012, 2018)

Efficiency

Energy intensity of industry

We compare industrial efficiency in terms of energy consumed per $ of gross value added (GVA). Improvements vary widely, with more than half our countries consuming more energy per dollar than they did a decade ago.

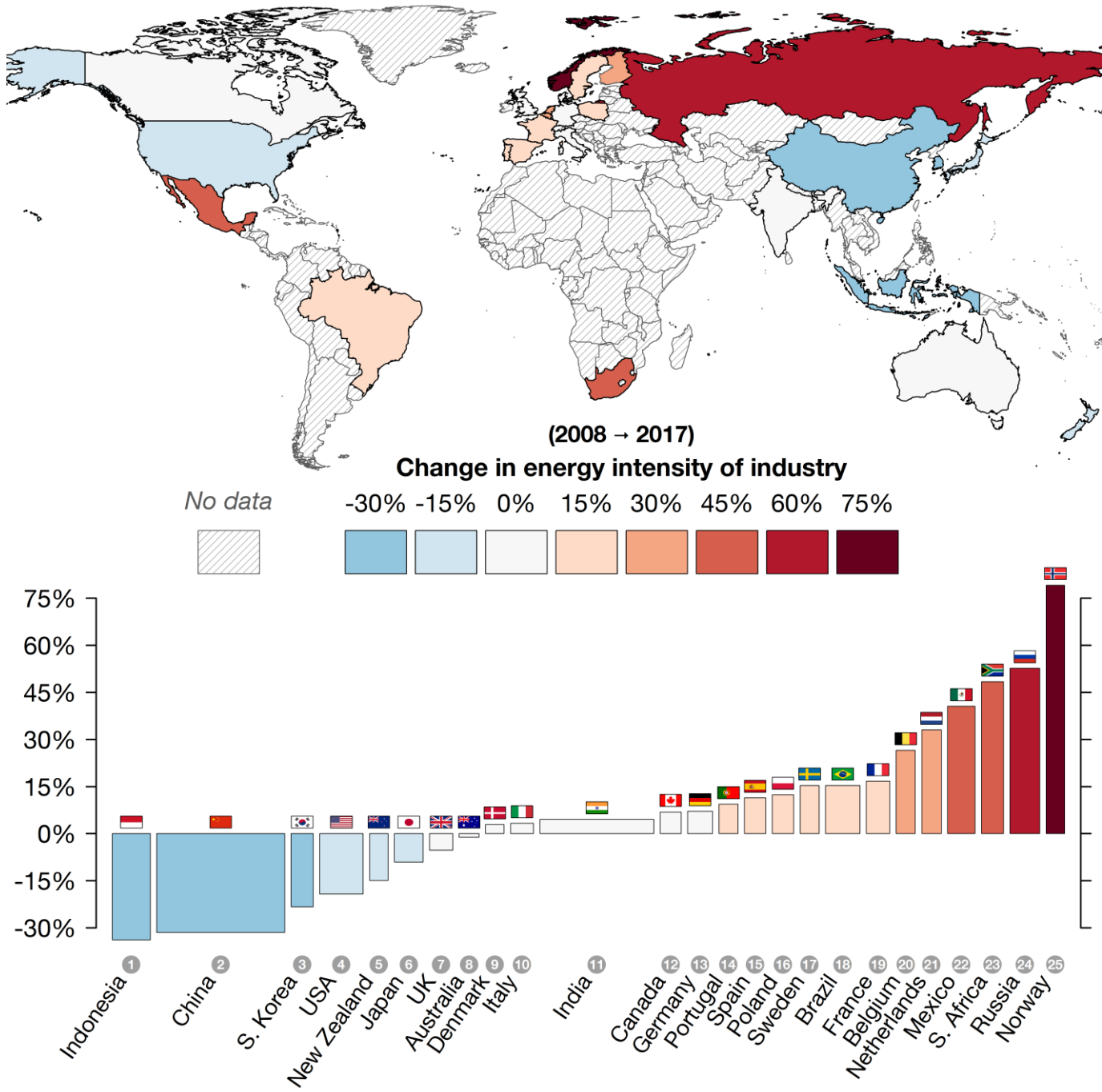
In absolute terms, BRICS countries consume the most energy per GVA – a result of large manufacturing and mining sectors. However, in the last decade, of these countries, only China decreased its energy intensity.

In China's 12th 5-year plan, a provision was included on industry efficiency improvements – the Top 1,000 Programme. The overall aim was for the top 1,000 most energy intensive companies to reduce their energy consumption per unit of GDP produced by 20% over the 5 years. This was achieved with over of 1,200 TWh of energy saved. This programme was subsequently transitioned to include the top 10,000 companies.

Implemented in 2009, Japan set mandatory efficiency targets for steel, cement, pulp and paper and chemicals manufacturing sectors. These sectors consume 60% of the total energy use in industry. Since its implementation, energy intensity in these manufacturing sectors have improved by 1.4% per year.

In 2012, India implemented the Perform, Achieve and Trade (PAT) scheme, whereby energy efficiency targets are set for energy-intensive, industrial consumers. A key feature of the policy is a trading mechanism, where energy saving certificates are produced for consumers who exceed their required energy savings. These certificates can then be traded with other consumers who have not met their targets.

Norway has seen the largest increase, but over 70% of its industry sector is electrified, making it susceptible to large changes in electricity prices.



Sources: IEA (2017a, 2018), UN Stats (2018), Industrial Efficiency Policy Database (2018)

Conclusions

- The average worldwide carbon intensity of electricity production is 440 gCO_2 per kWh. However, there are large variations from close to 0g per kWh in Norway to upwards of 800 g per kWh in South Africa, reflecting the different generation mixes in each country. In the UK, carbon pricing has been an effective tool to decarbonise its grid by over 250 g per kWh in a decade.
- In the last ten years, 1,125 GW of renewable capacity has been installed, which is equivalent 156 W per person. Wind and solar capacities are the fastest growing renewables with rates of 20% and 40% per year, respectively. Countries with the largest uptake in renewables are also those that have provided the greatest subsidies. This has helped these technologies progress down their cost curves, and are now approaching cost parity point, where their uptake would be fully market-driven.
- A few countries have made a significant move away from coal for electricity generation, which has had a significant effect on decarbonising their grids. The Powering Past Coal Alliance has expanded to 28 countries, and seeks the elimination of coal within the next 12 years.
- Government subsidies for fossil fuels are a perverse feature of many economies. Subsidies per capita are highest in developed countries such as Norway and Australia. Over half of the 25 countries investigated have increased their support between 2007 and 2016, hampering the energy transition needed to achieve climate targets. However, more promisingly, 16 countries worldwide are using peer review to identify and assess inefficient fossil fuel subsidies. The effect of these reviews will hopefully be seen in future iterations of the OECD fossil fuel subsidy inventory.
- One two countries have achieved a 5% share (more than 1 in 20) of new cars sold being electric. The higher upfront costs of electric vehicles is a barrier, suggesting that support measures are required to help drive this technology forward. Norway has implemented a wide range of measures that push the total cost of ownership of an electric vehicle well below that of petrol and diesel cars. Almost 1 in 2 new cars sold in Norway today are electric.
- With increasing EV deployment, governments and private companies are providing greater charging facilities. This will not only encourage further uptake in the technology, but will also help dispel fears around lower driving range.
- If CCS is to play a role in decarbonisation, as most scenarios predict, then progress to date must be radically increased. Currently, large-scale CCS deployment is limited to 6 countries, with a total capacity of around 40 $MtCO_2$ per annum, or 0.1% of global emissions. Four-fifths of this is used to support oil production, and may not contribute effectively to decarbonisation.
- Carbon storage resources are not a barrier to meeting climate targets. Clearer political support and greater synergies are required to develop CCS capacity, especially for heavy industry which may be difficult to fully decarbonise otherwise.
- Improvements in residential and transport efficiency have been mixed. Improving living standards in developing countries are pushing up their energy intensities towards those of developed countries. In developed countries, appliance saturation, environmental policies and residual effects of the recession are resulting in apparent efficiency gains.
- Industrial efficiency improvements have also varied and are largely driven by changing composition in national industrial sectors, as opposed to process efficiencies. Only a few countries – e.g. China, India and Japan – have directly targeted industry to implement measures improving efficiency.

Appendix I

Methodology & References

Methodology

Technology and measure selection

Technologies and measures were selected based on a review of influential scenarios; namely the IPCC Special Report on 1.5 degrees, IEA Energy Technology Perspective and World Energy Outlook, and analysis of the IAMC 1.5 degree scenarios database.* This highlighted the following suite of technologies and measures required to achieve climate targets:

- Clean power: low carbon electricity generation, including renewables, biomass and nuclear
- Phase-out of fossil fuels, with a focus on eliminating coal power and fossil fuel subsidies
- Electrification of passenger vehicles
- Carbon Capture and Storage
- Improved energy efficiency across the economy

Country selection

Country selection was based on including all G7 and BRICS countries, as well as the five more populous countries, ensuring that the largest developed and emerging economies were considered. The remaining countries were selected based on their membership to the IEA/OECD and/or their geographical location (i.e. to ensure countries selected were spatially distributed). Lastly, some countries could not be included due to limited data availability.

Data collection

International data was then collected to investigate the progress made by countries towards these key areas. The results presented are based off data collected from other sources, as opposed to internal modelling. When the geographic coverage of a dataset was limited, complementary statistics were sources and methodologies were aligned to form a single dataset.

Progress assessment

Progress towards these metrics is typically represented as the pace of change in the last decade, as this is important in understanding how energy systems are transforming the context of achieving targets. Metrics are also normalised to the human scale (e.g. the share of vehicles, emissions per person), to ensure that actual process is reflected as opposed to the sheer size of a country.

* Huppmann, Rogelj, Kriegler, Krey and Riahi. 2018.
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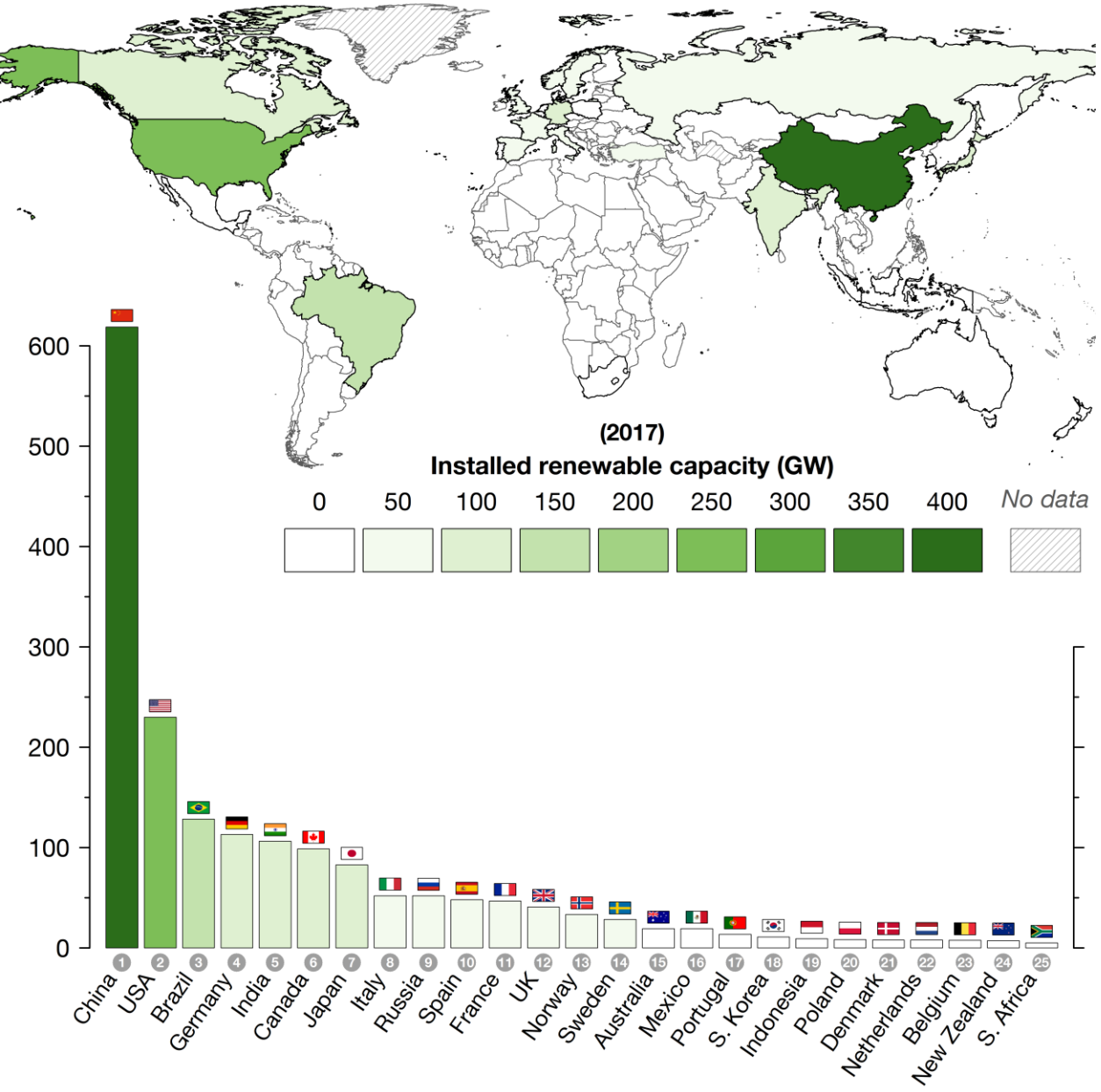
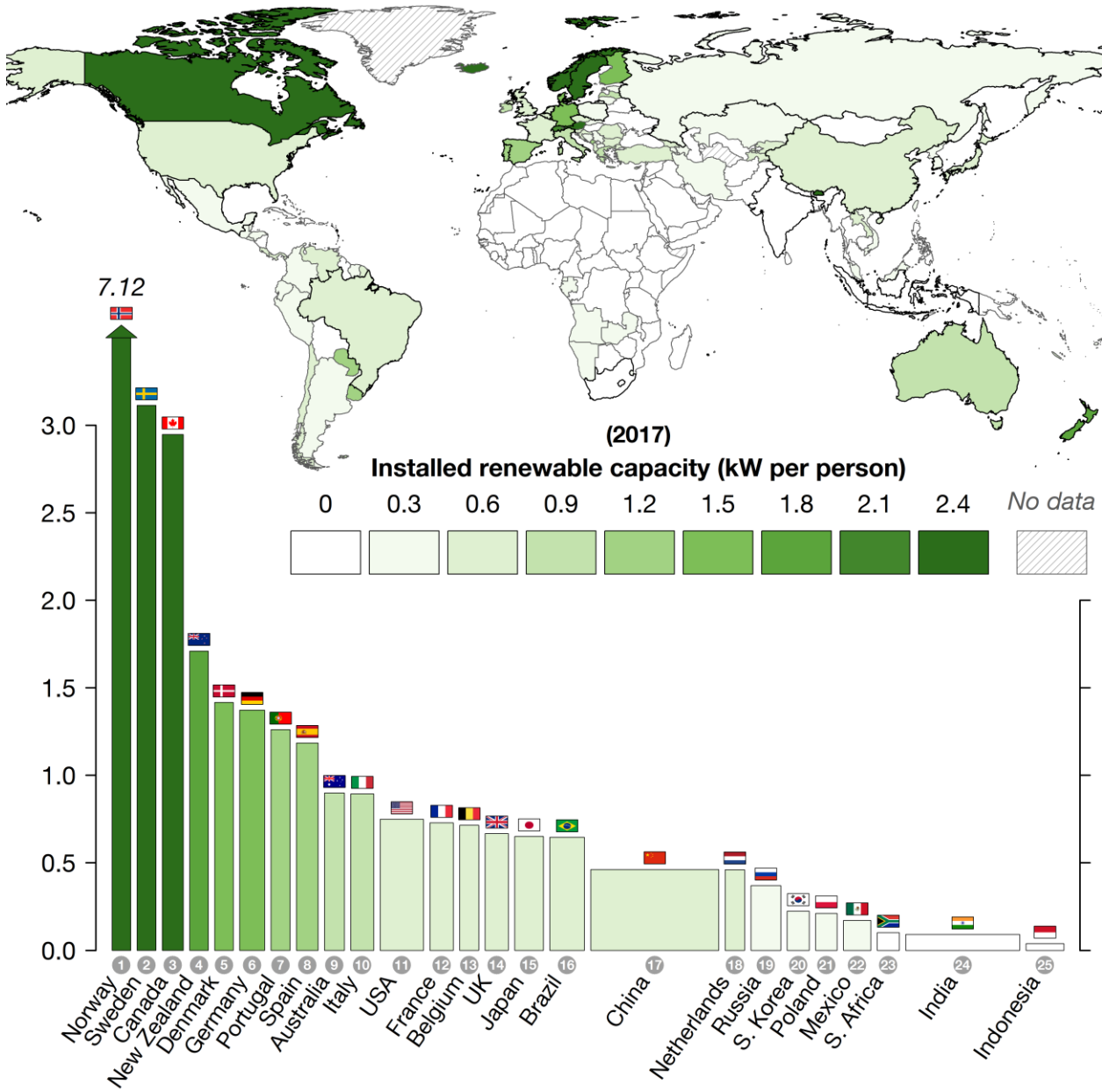
Appendix II

Supplementary Results

Clean power

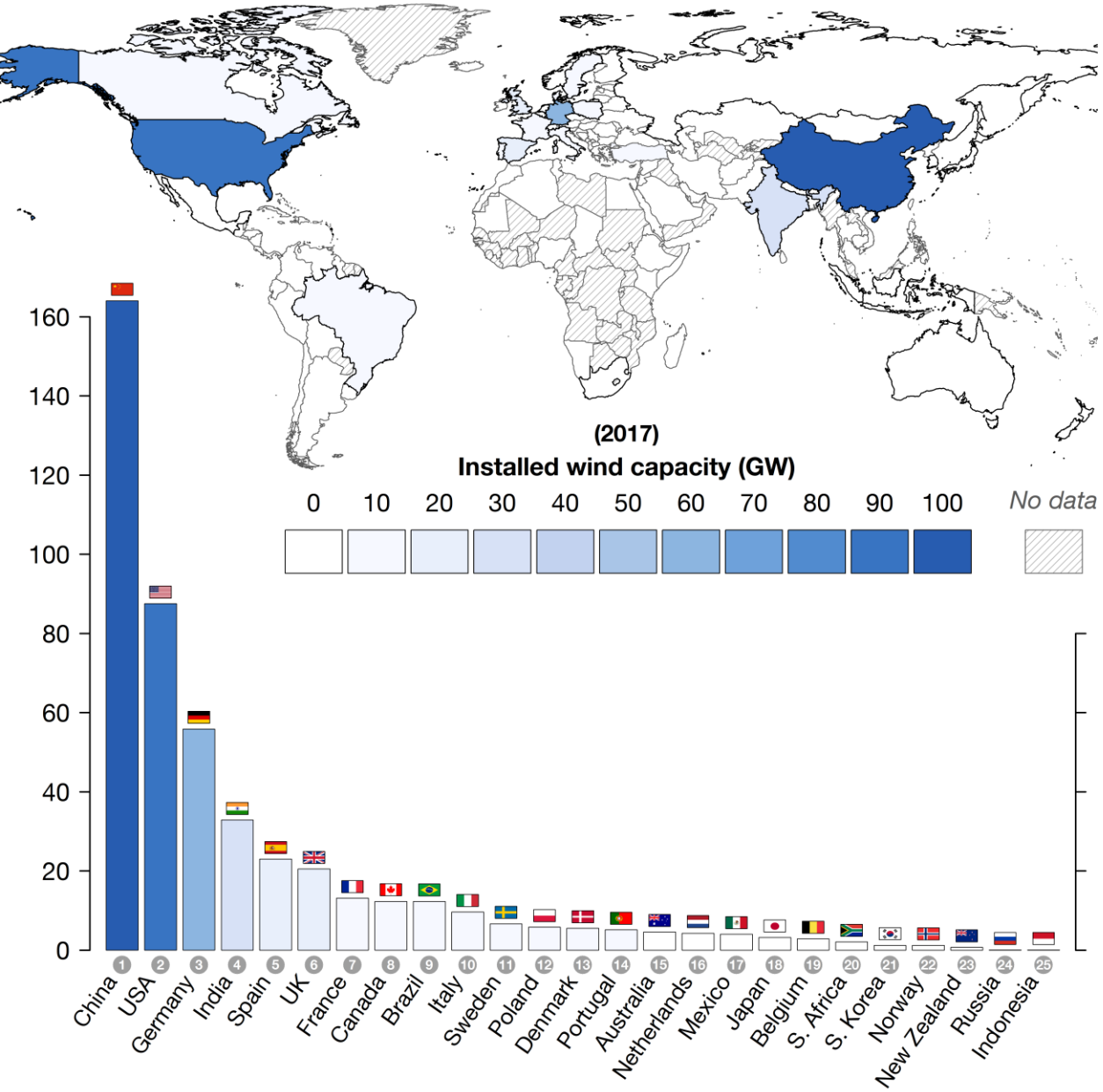
Installed capacity of renewables (end of 2017)

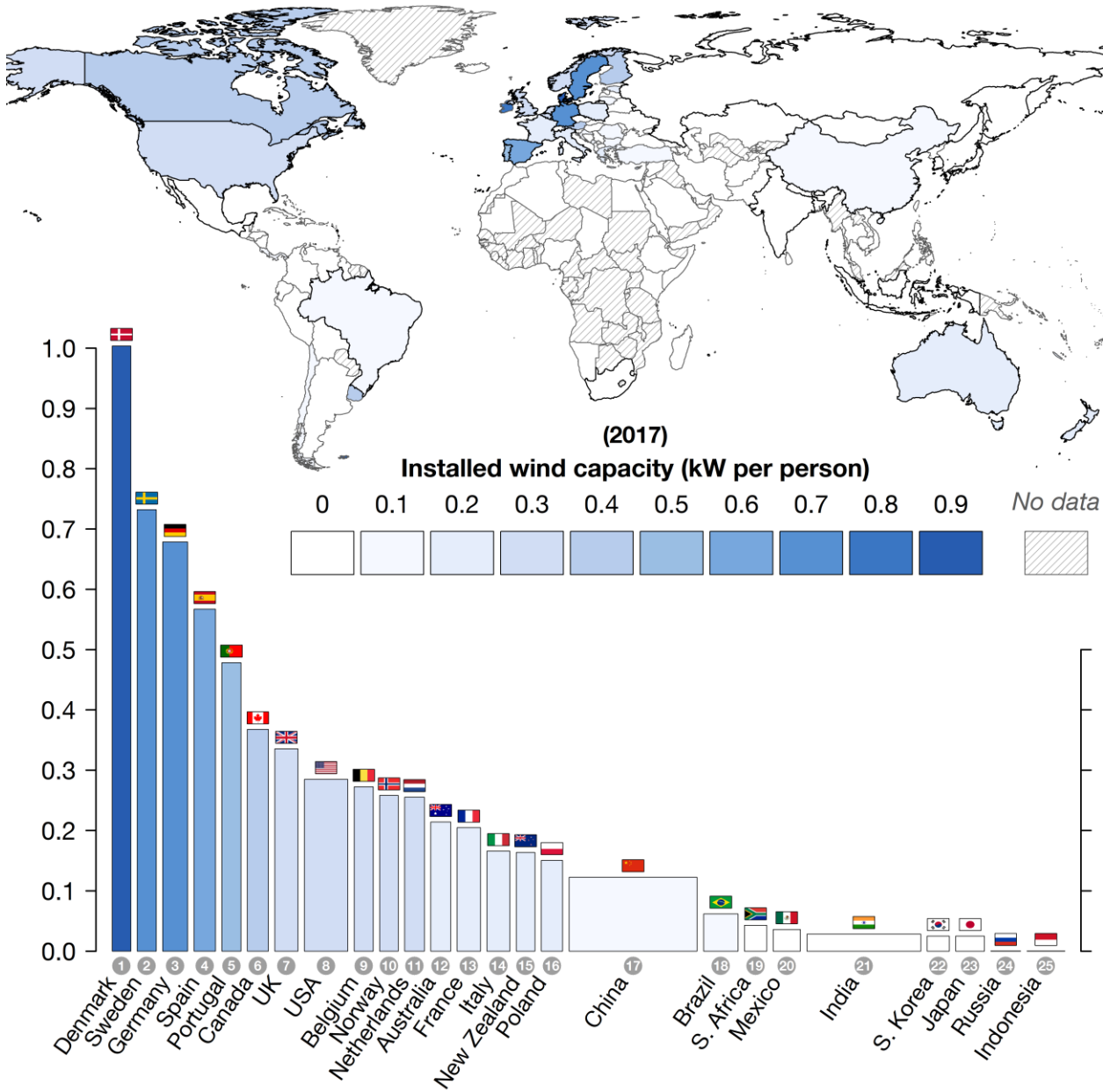




Clean power

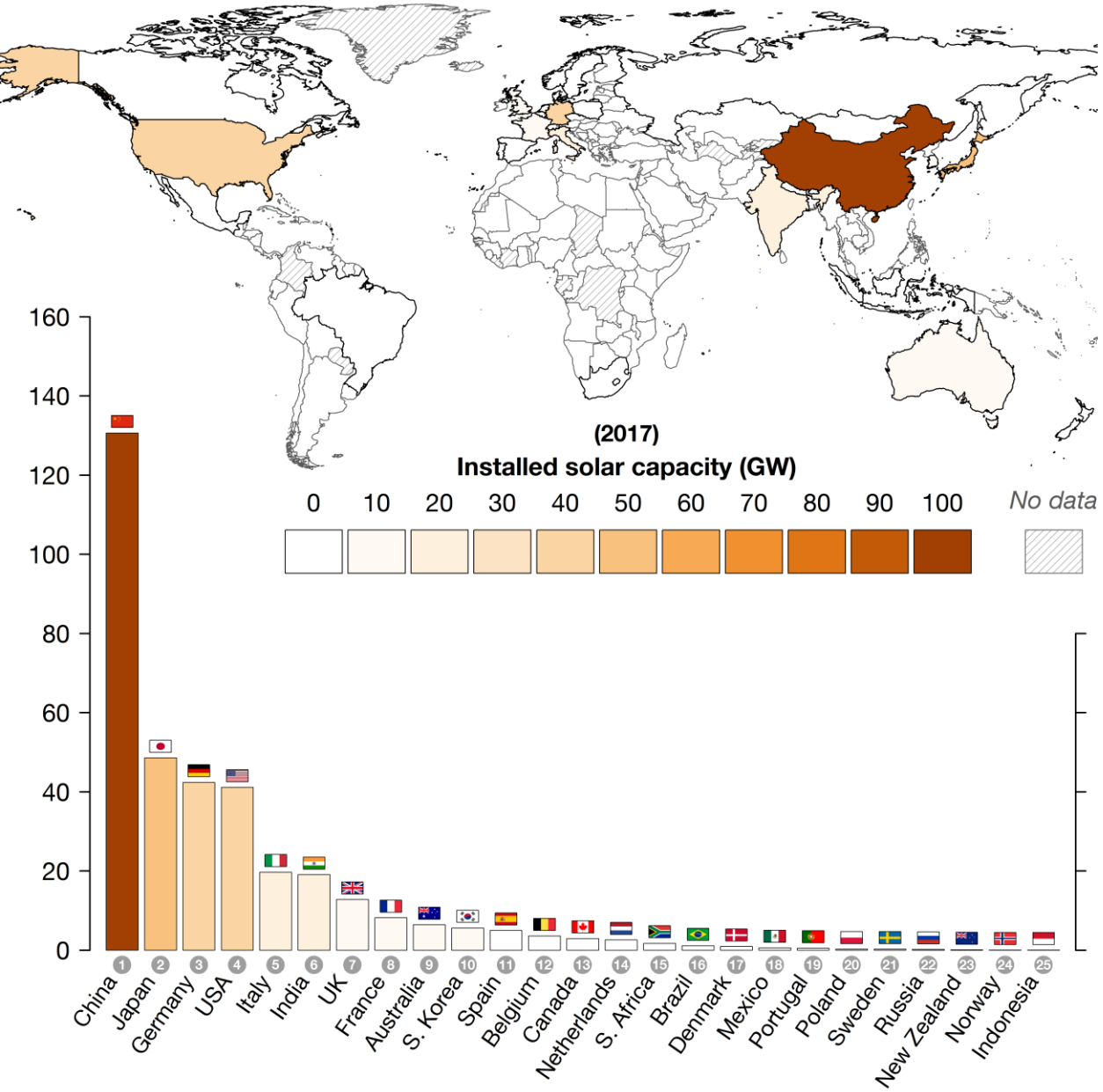
Installed capacity of wind power (end of 2017)

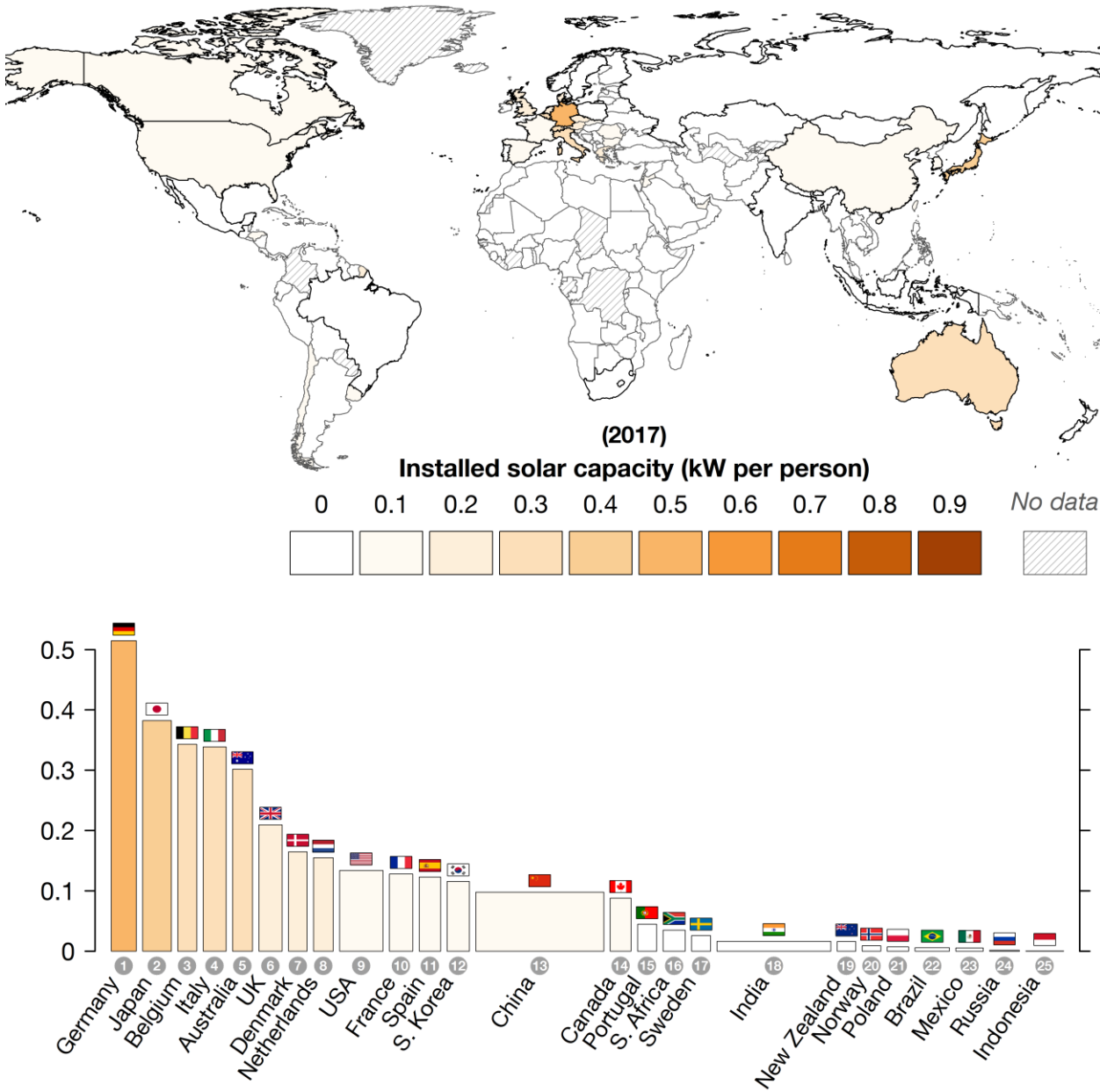




Clean power

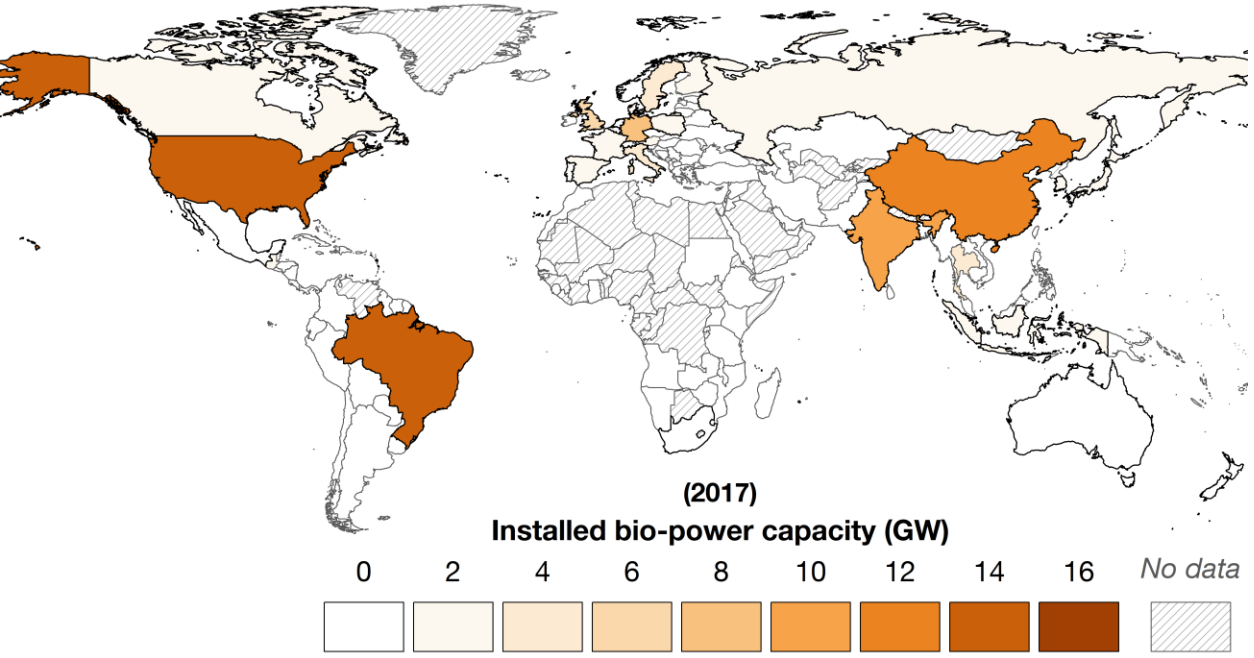
Installed capacity of solar power (end of 2017)

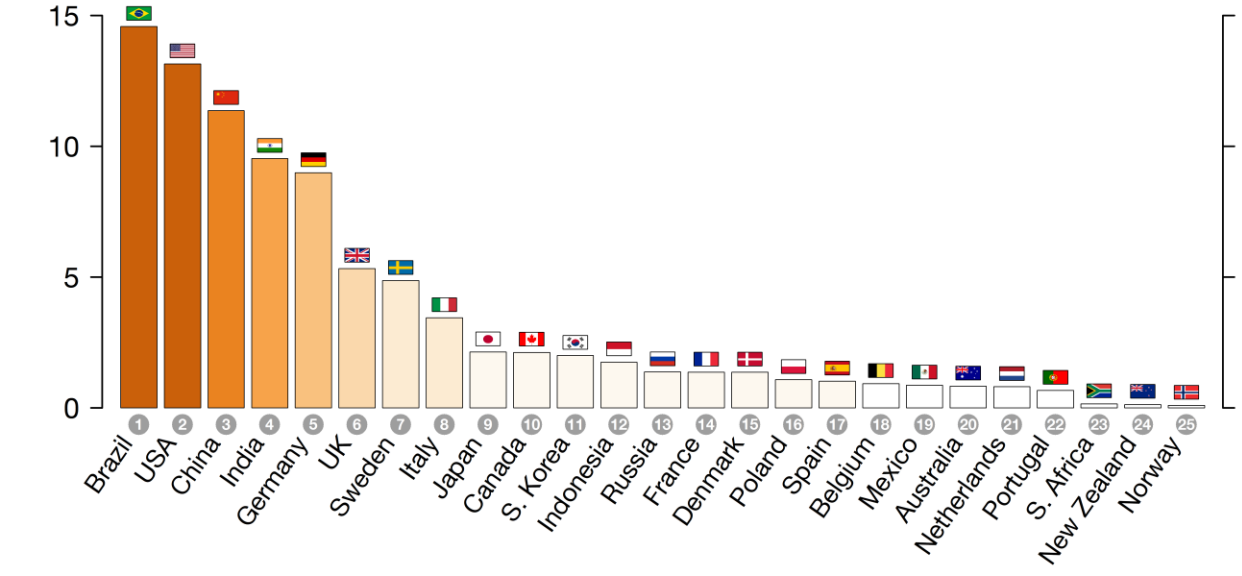


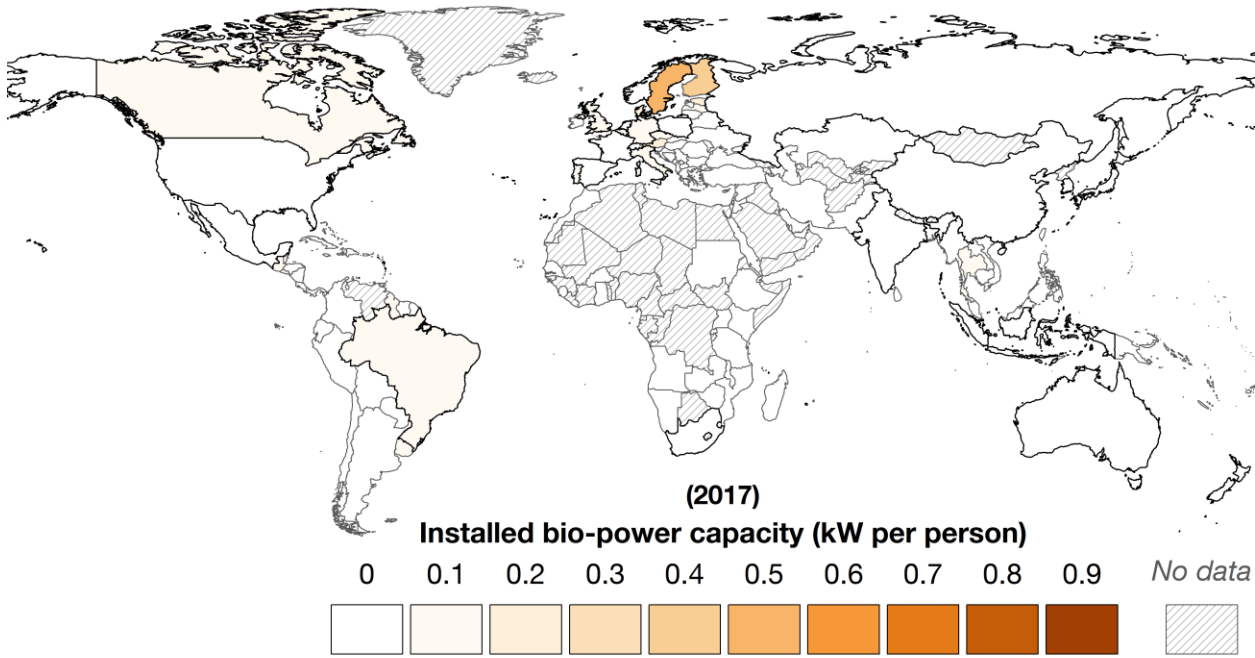


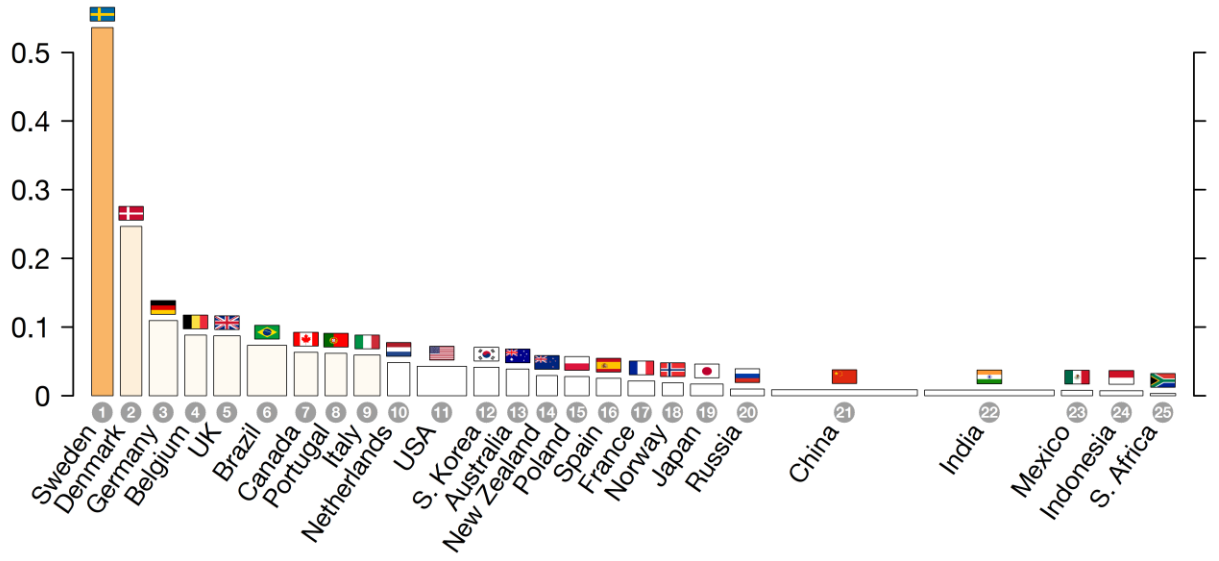
Clean power

Installed capacity of biomass power (end of 2017)



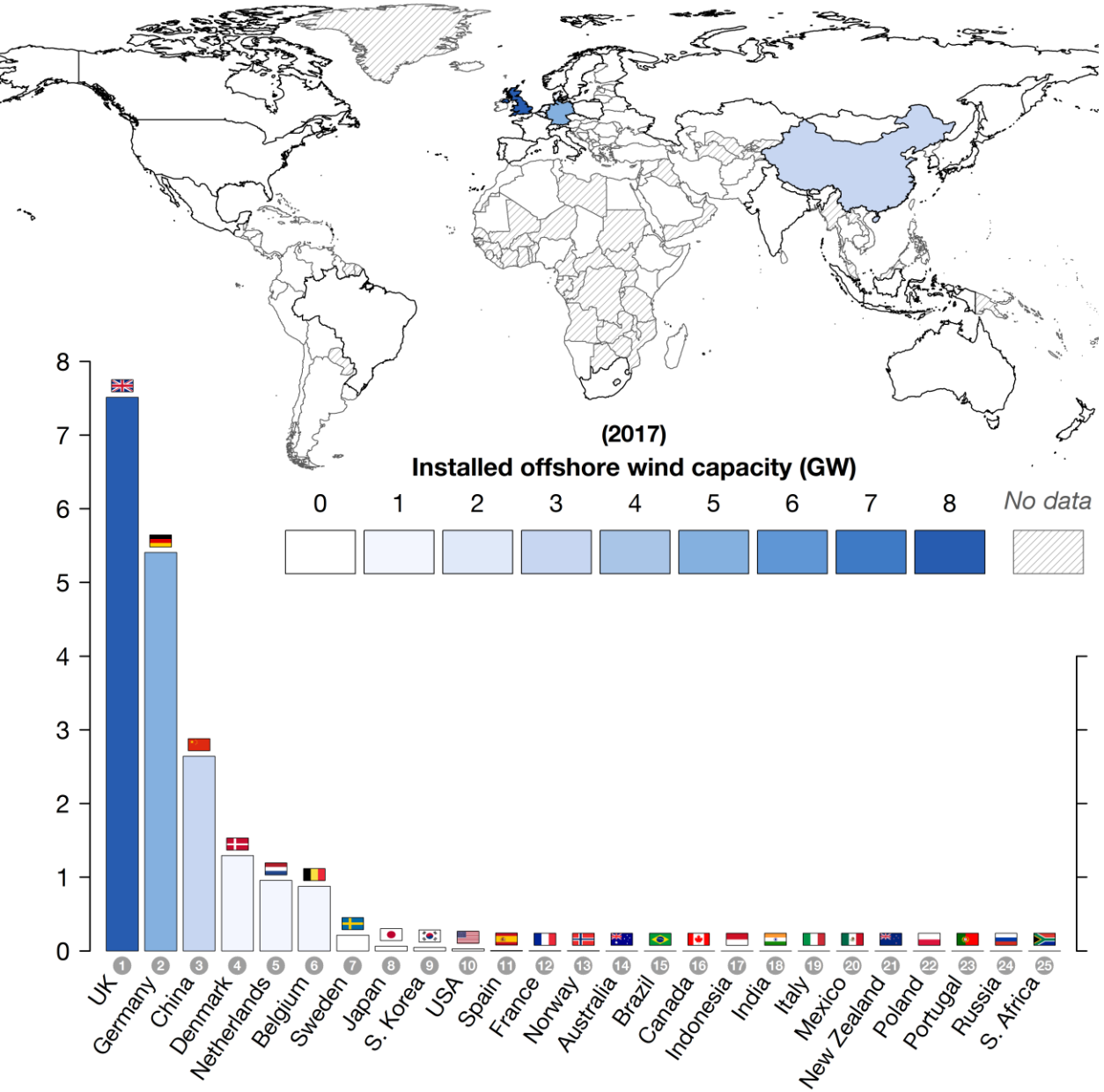


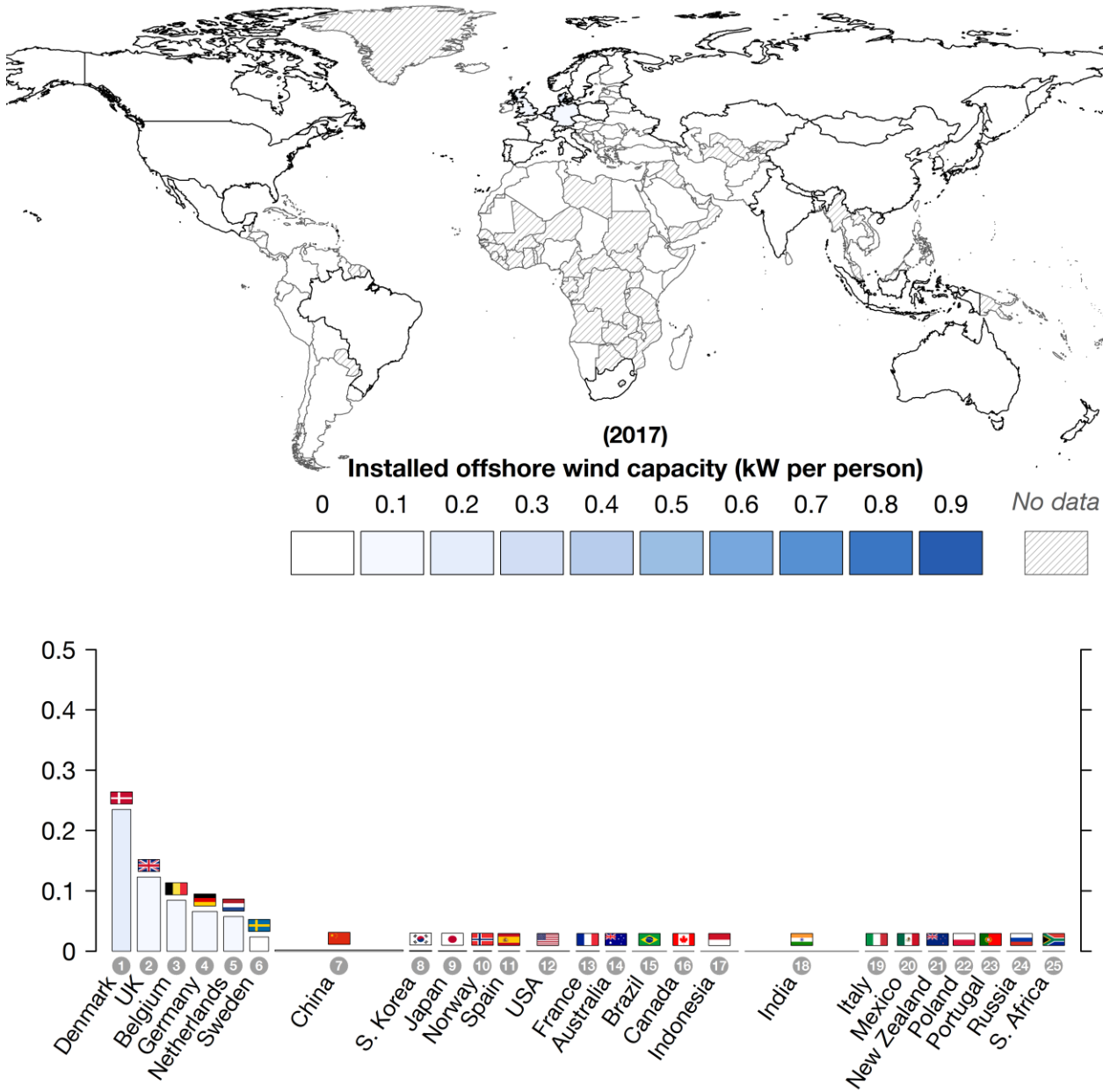




Clean power

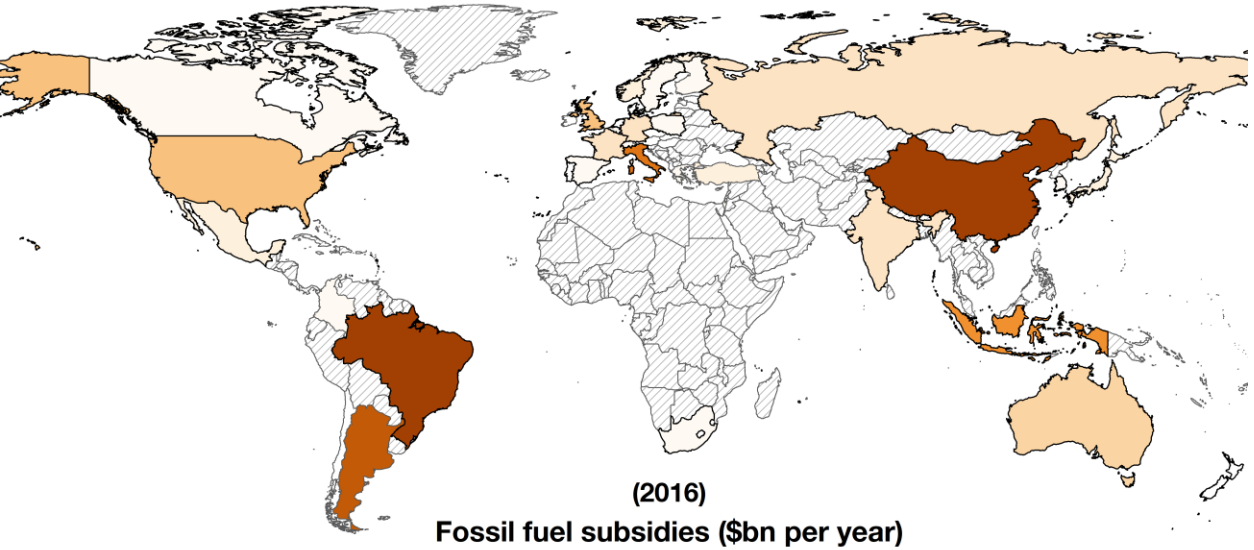
Installed capacity of offshore wind (end of 2017)





Fossil fuels

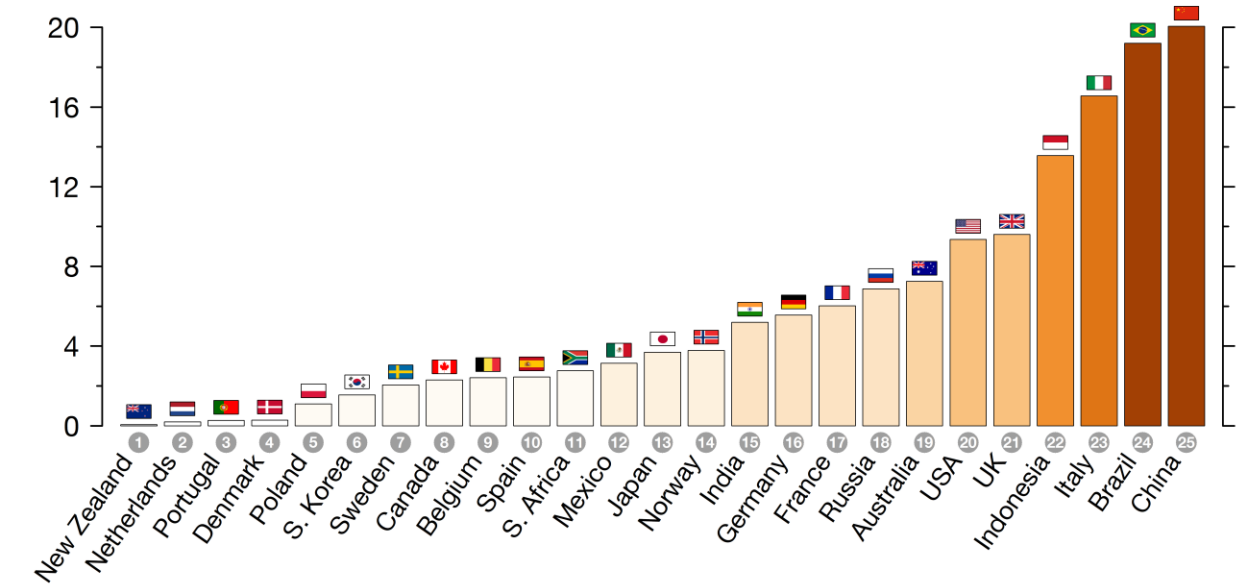
Fossil fuel subsidies in 2016

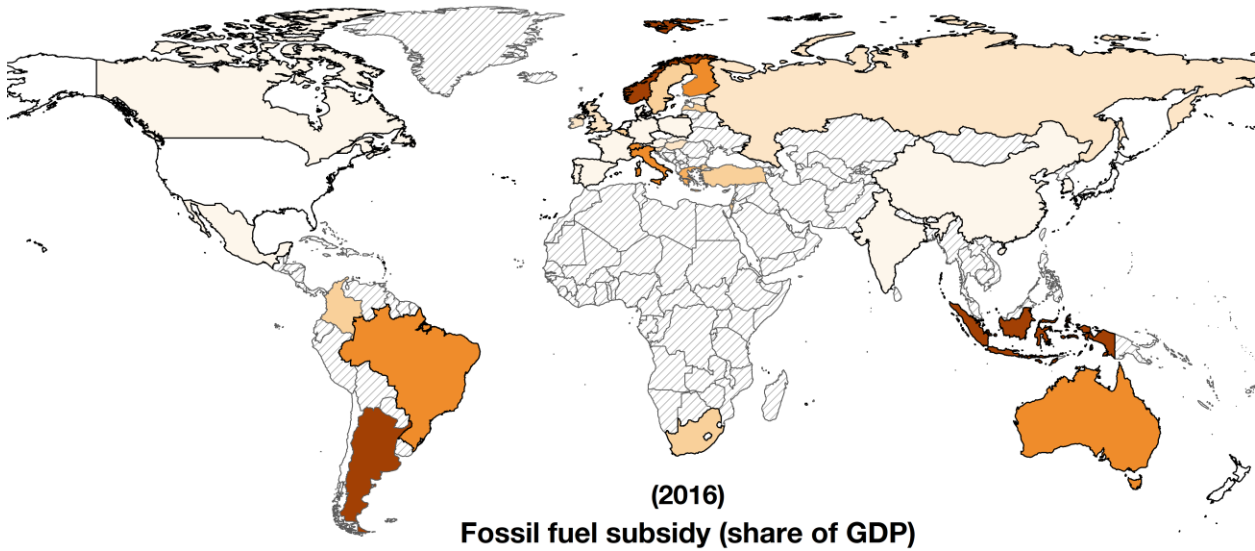


(2016)

Fossil fuel subsidies ($bn per year)

No data 0 2 4 6 8 10 12 14 16 18 20

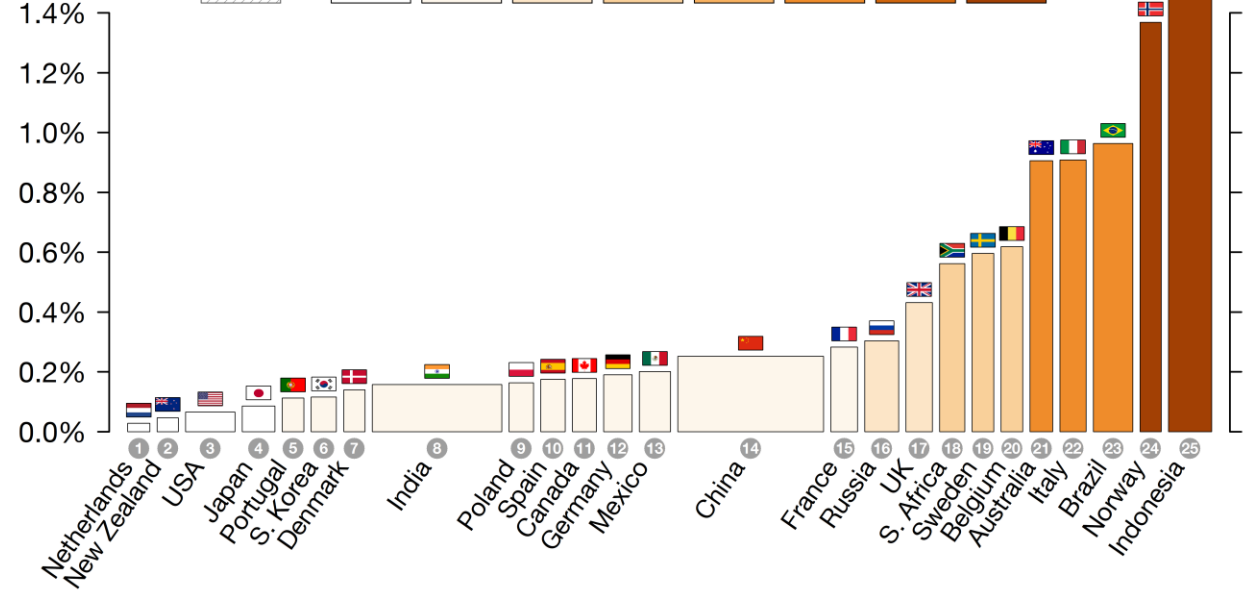




(2016)

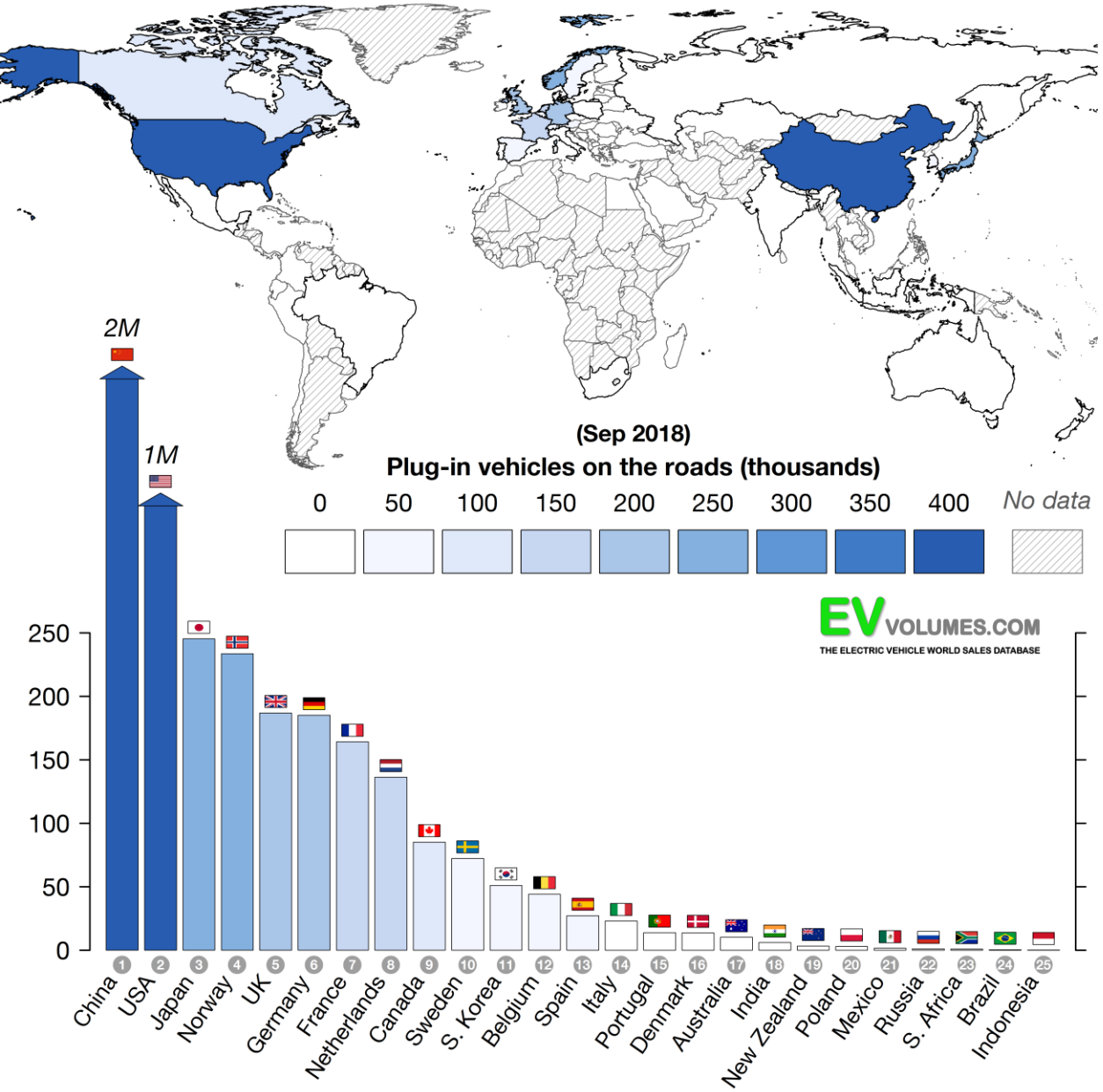
Fossil fuel subsidy (share of GDP)

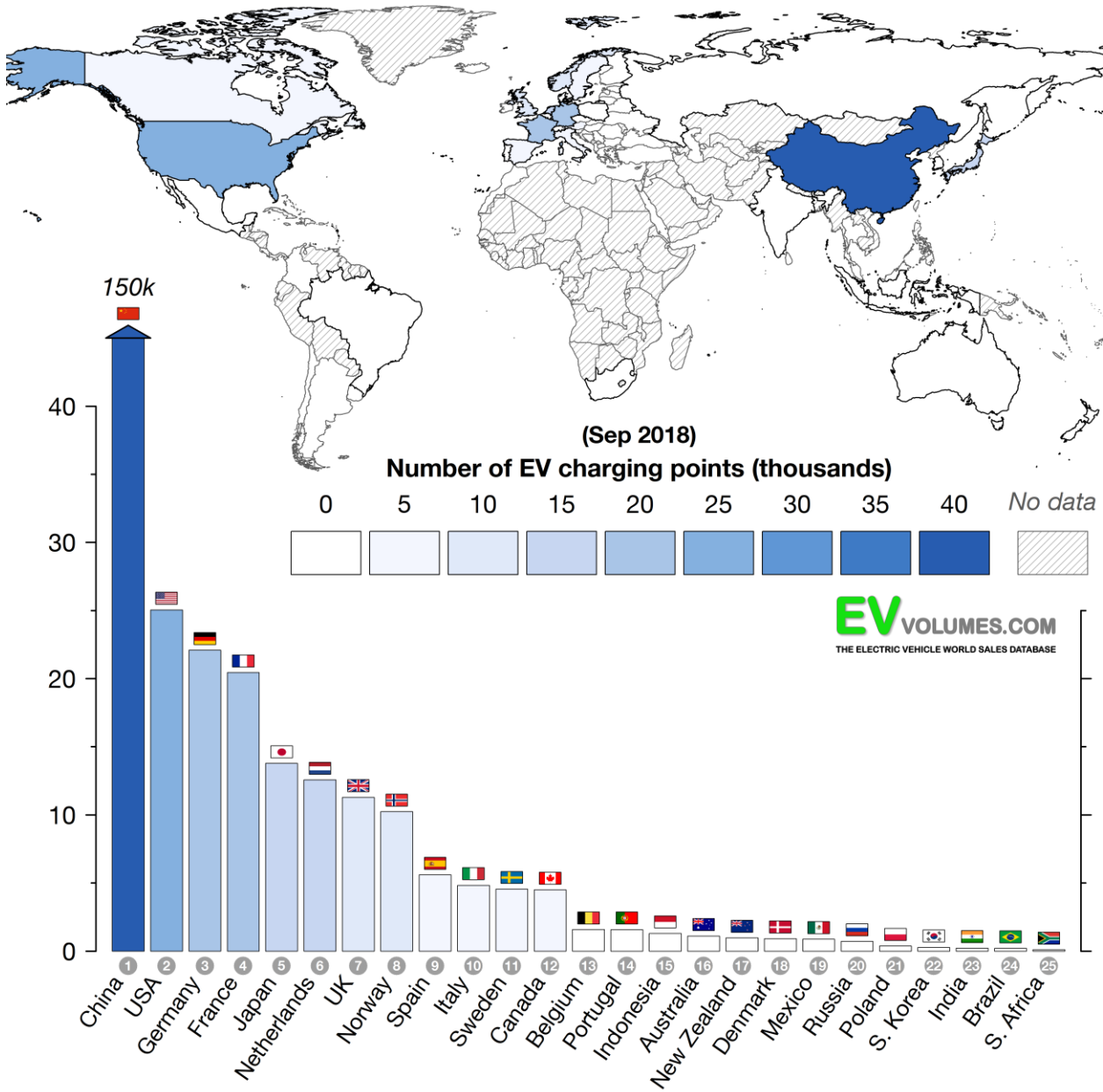
No data 0.0% 0.2% 0.4% 0.6% 0.8% 1.0% 1.2% 1.4%



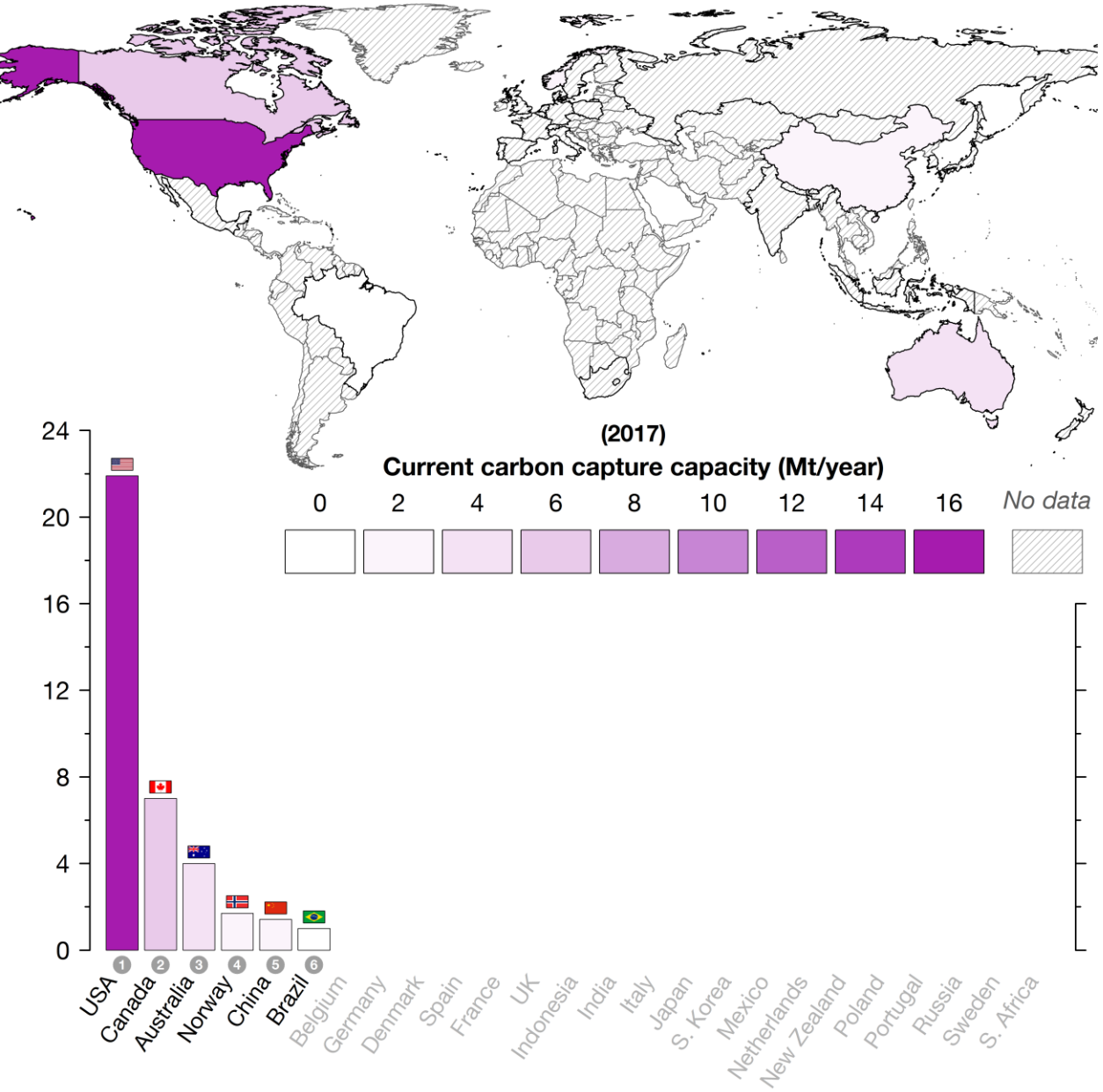
Electric vehicles

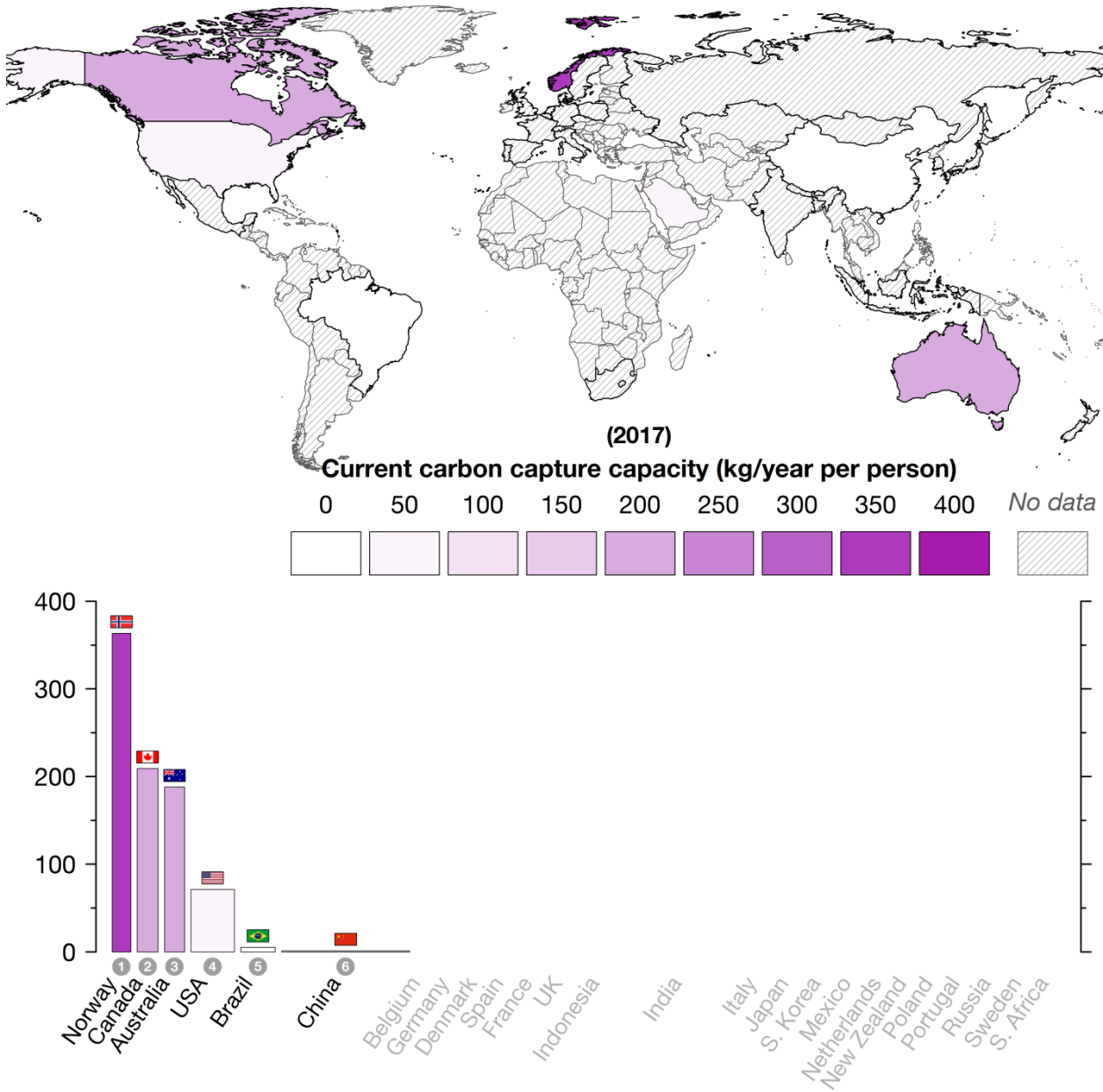
Plug-in vehicles and chargers (September 2018)



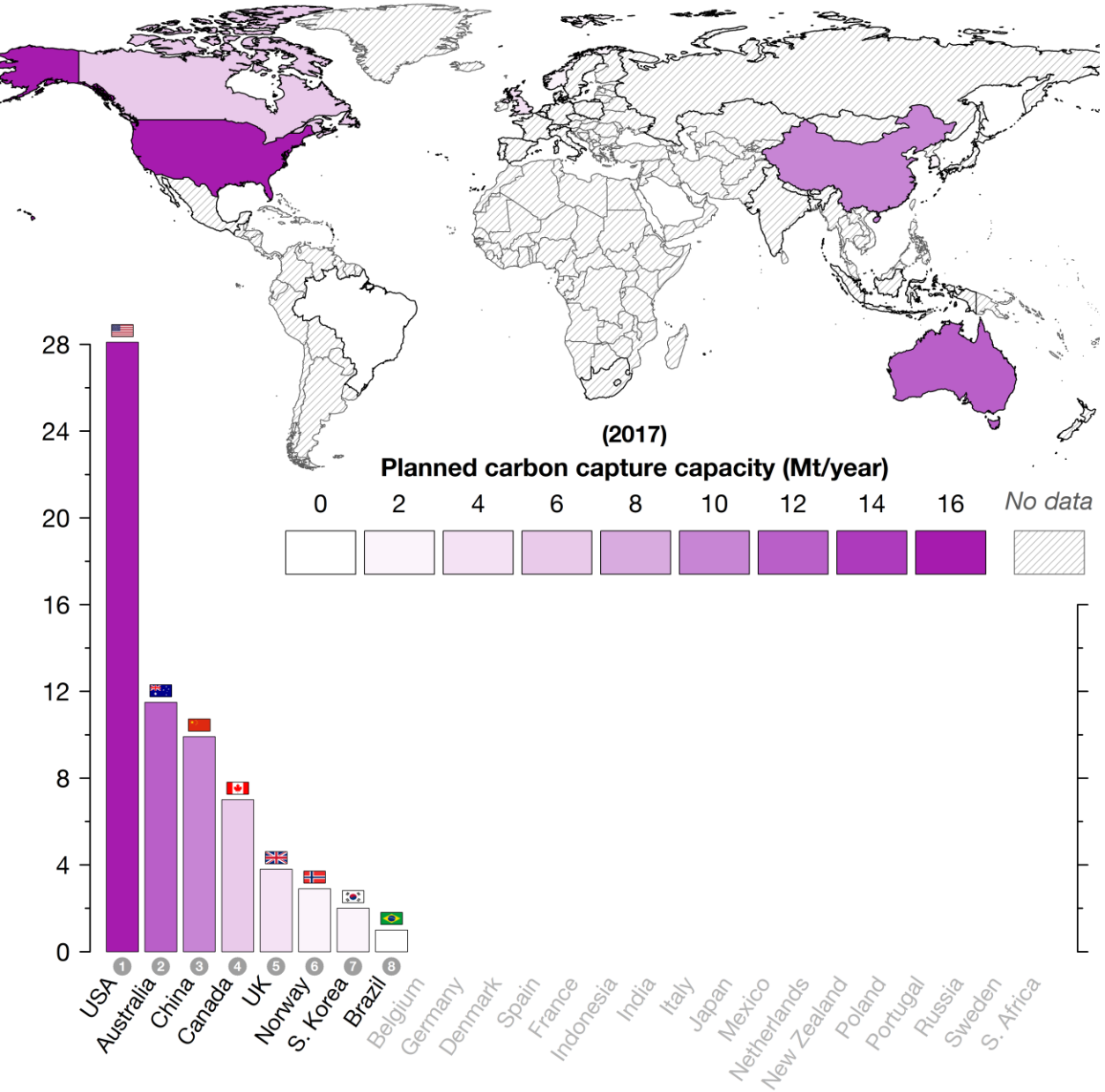


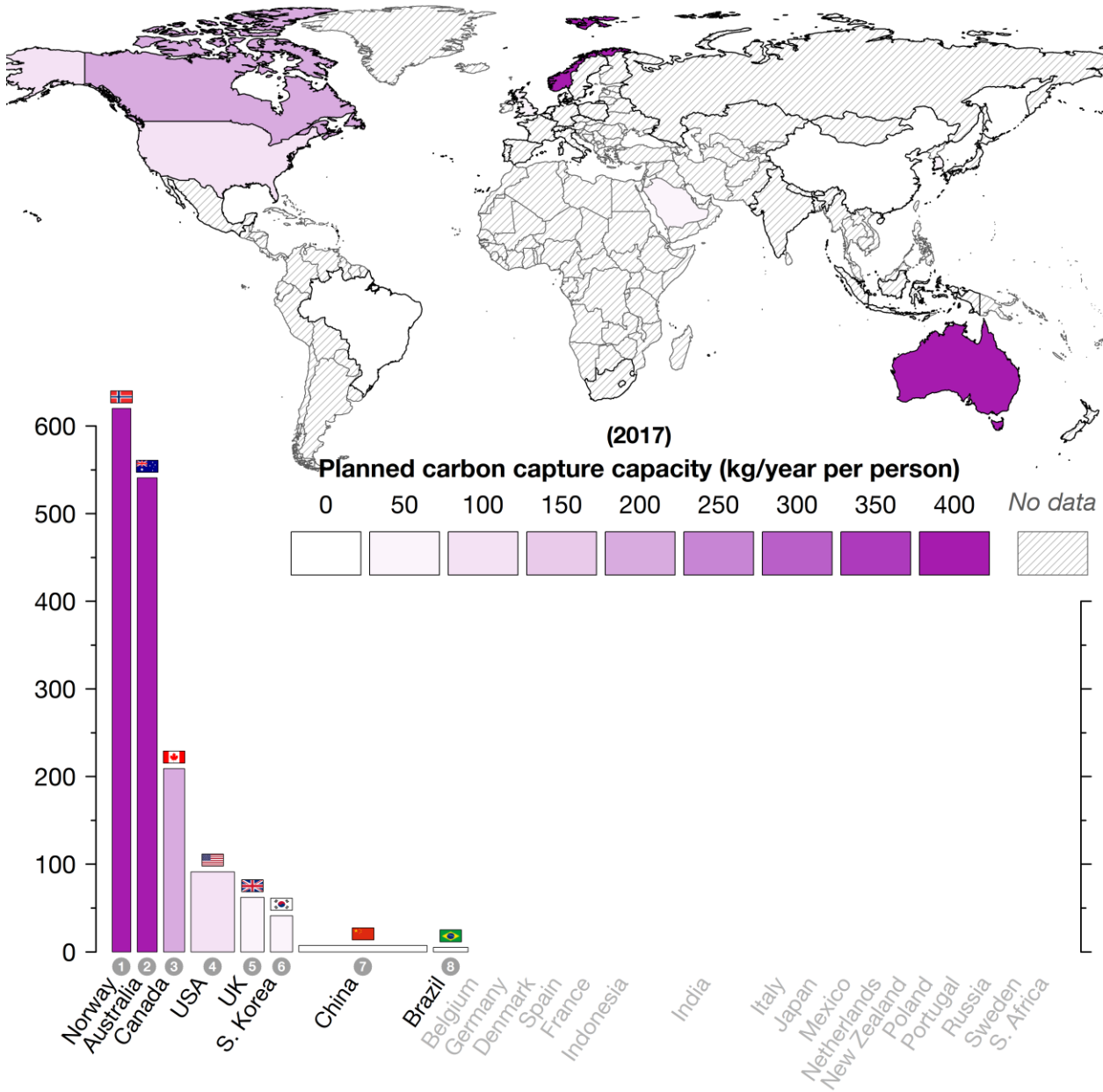
CCS Large-scale capacity operating & under construction (2018)



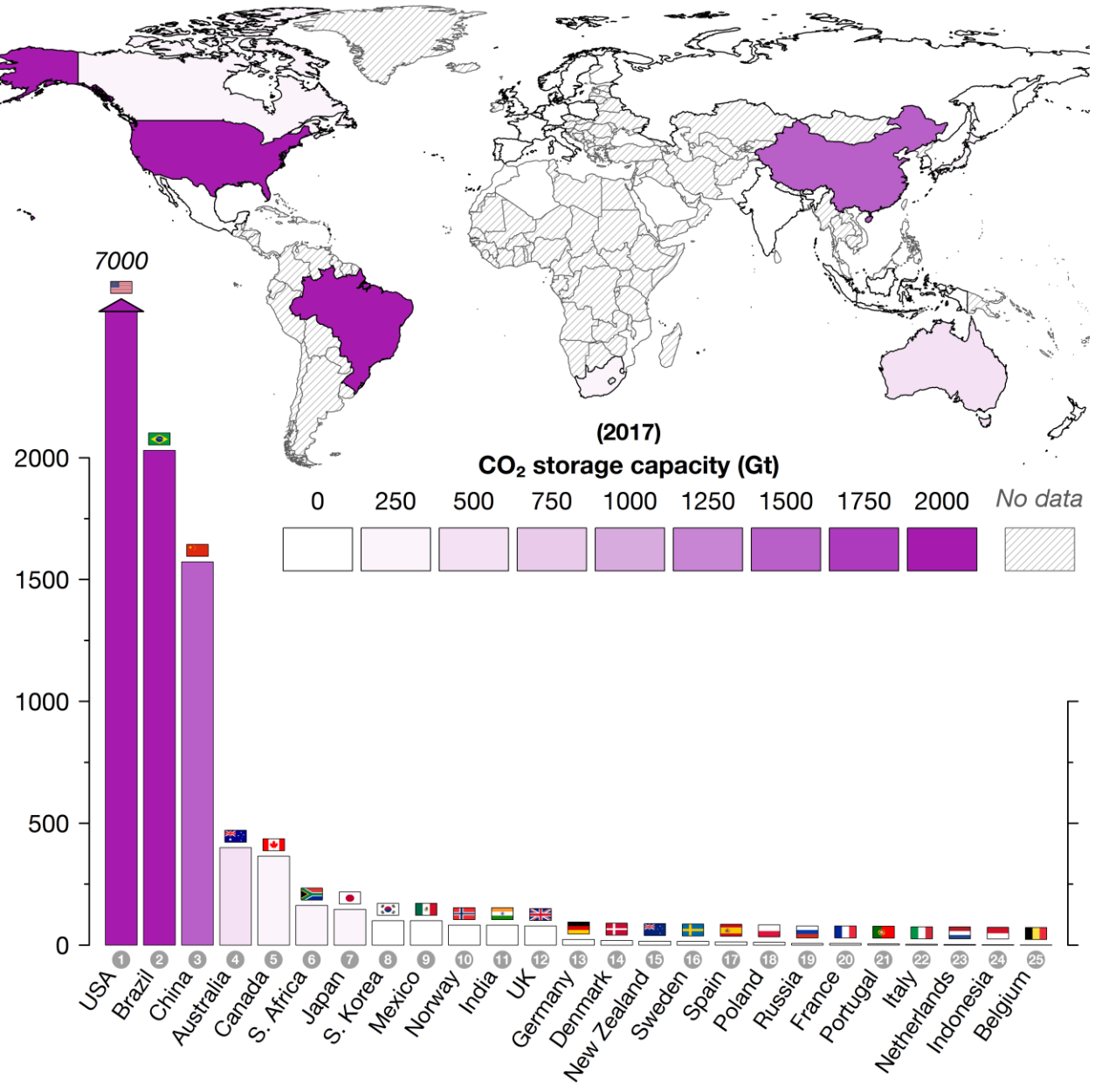


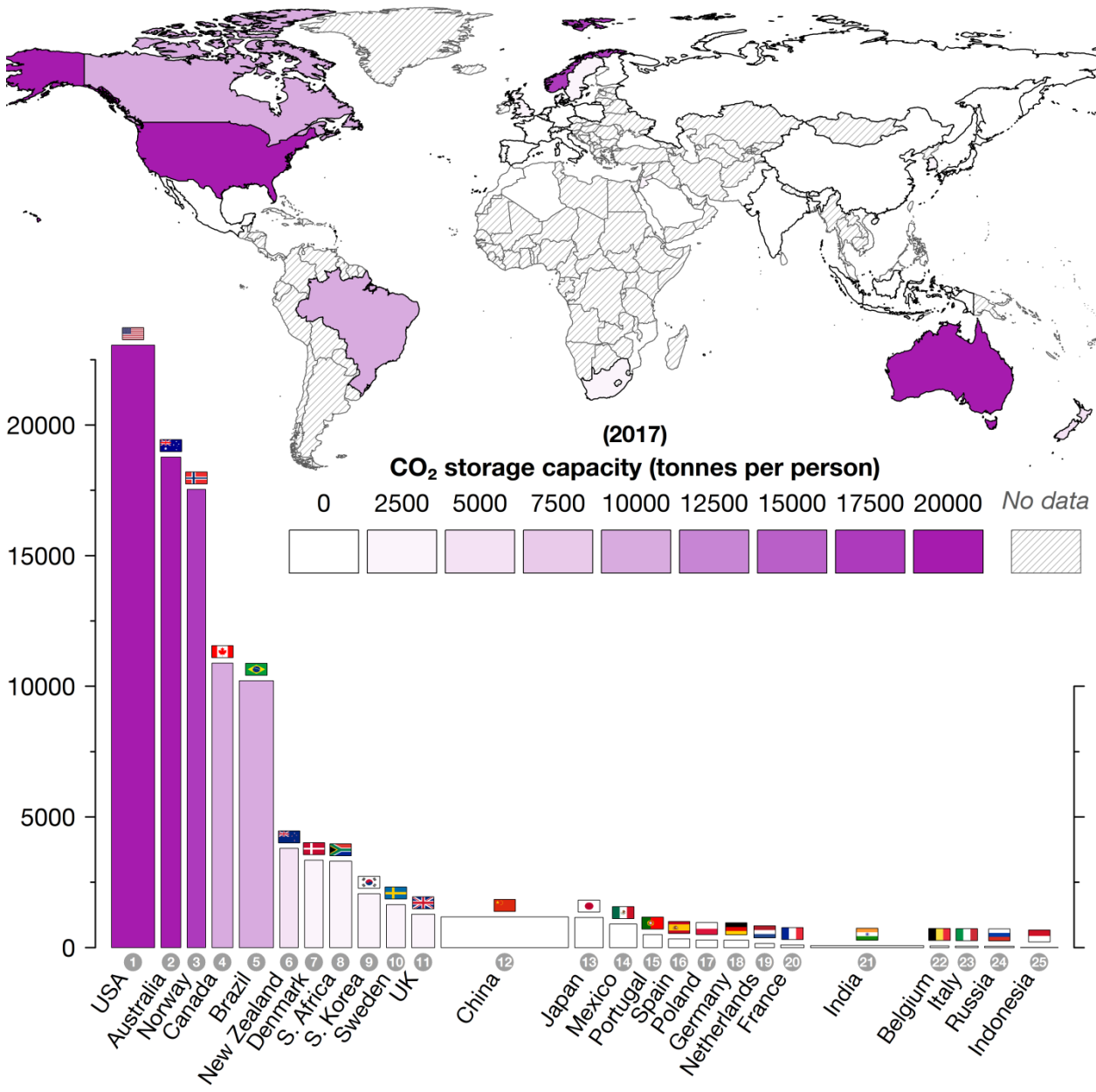
CCS Large-scale capacity operating, under constr. & planned (2018)





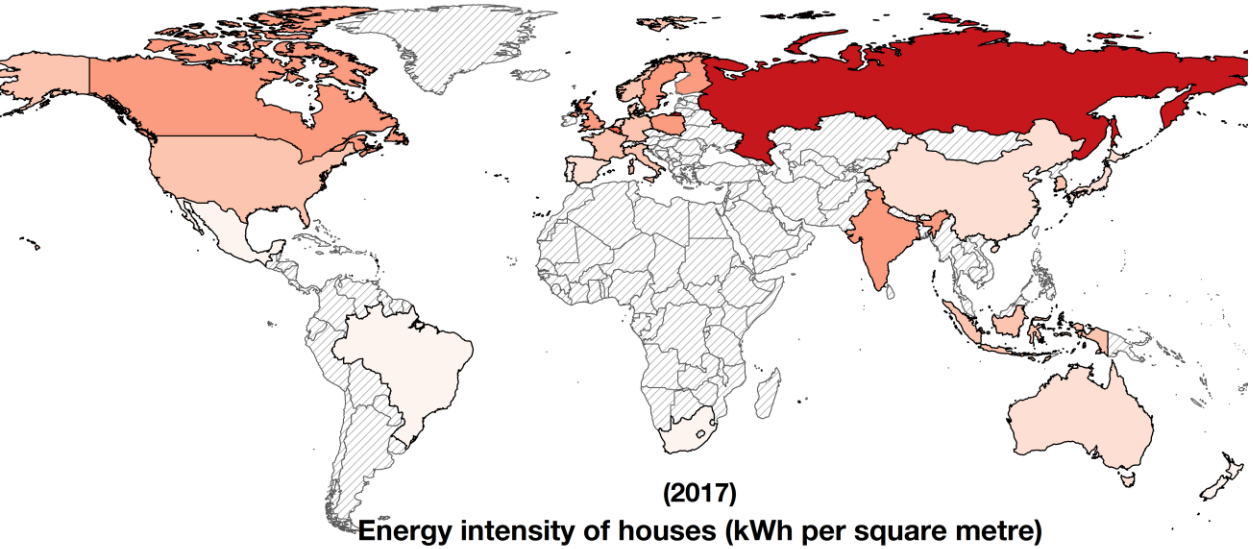
CCS Potential capacity for carbon storage





Efficiency

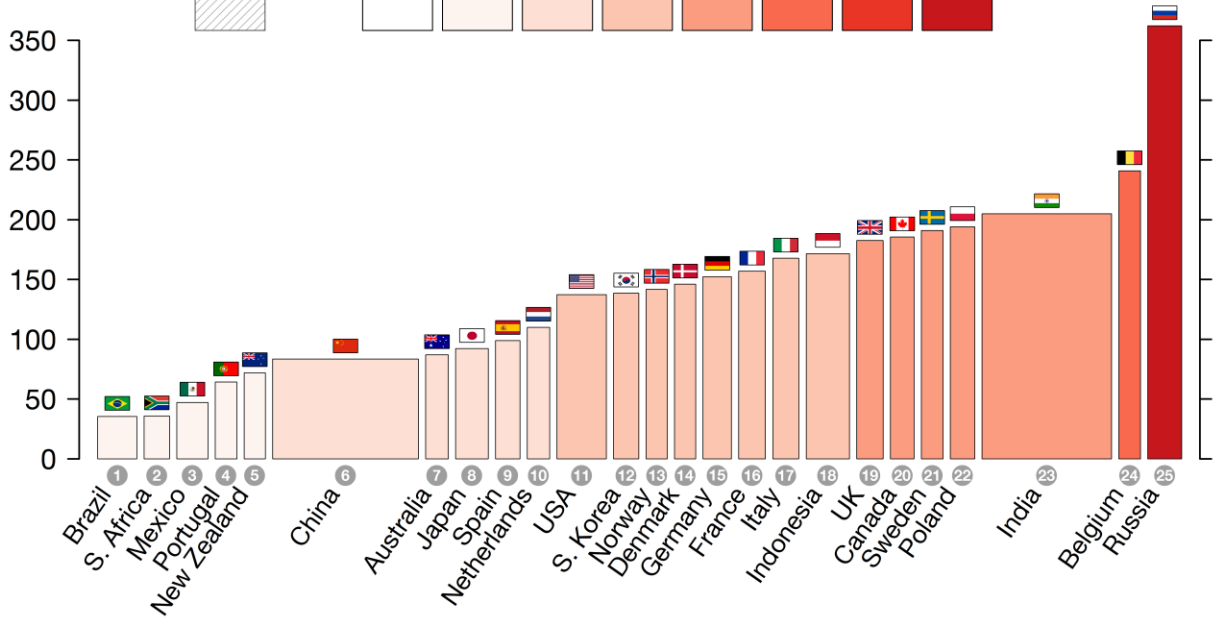
Energy intensity of households

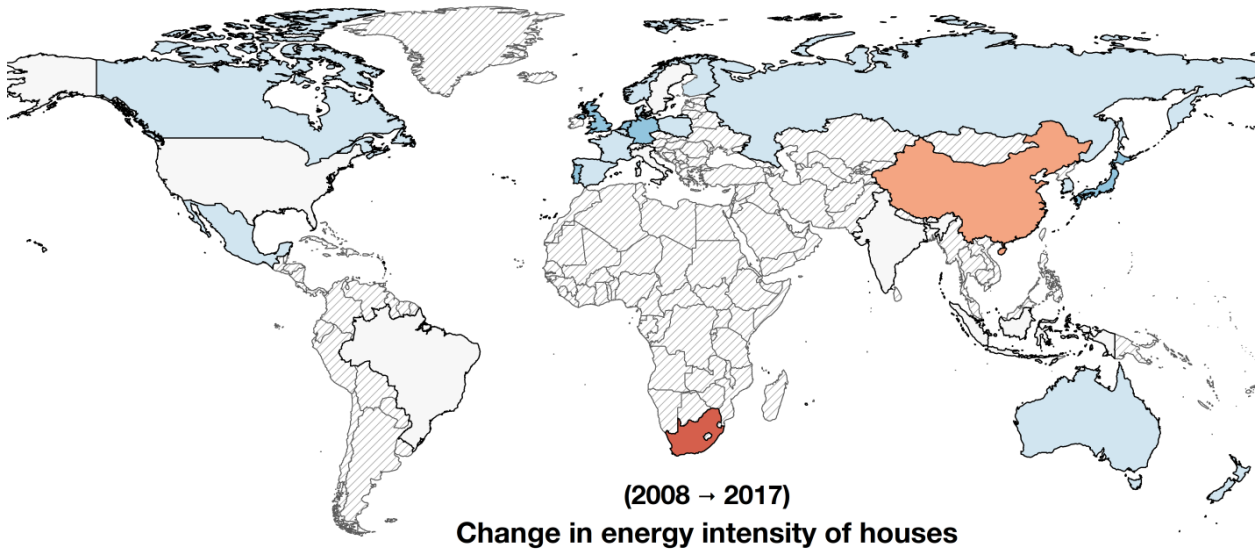


(2017)

Energy intensity of houses (kWh per square metre)

No data 0 50 100 150 200 250 300 350

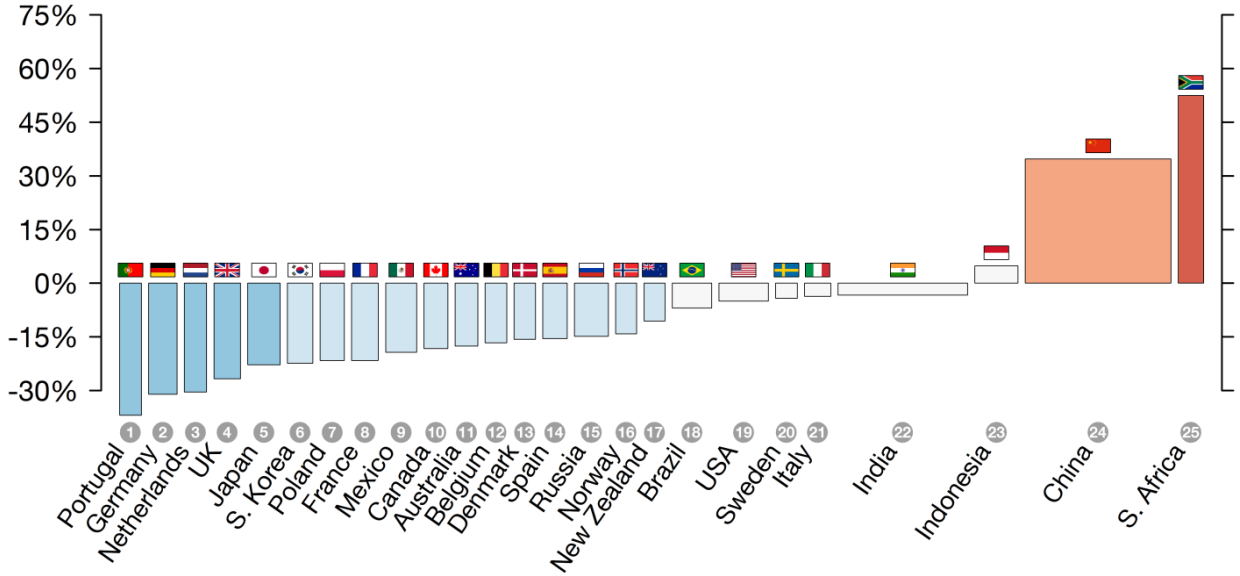




(2008 → 2017)

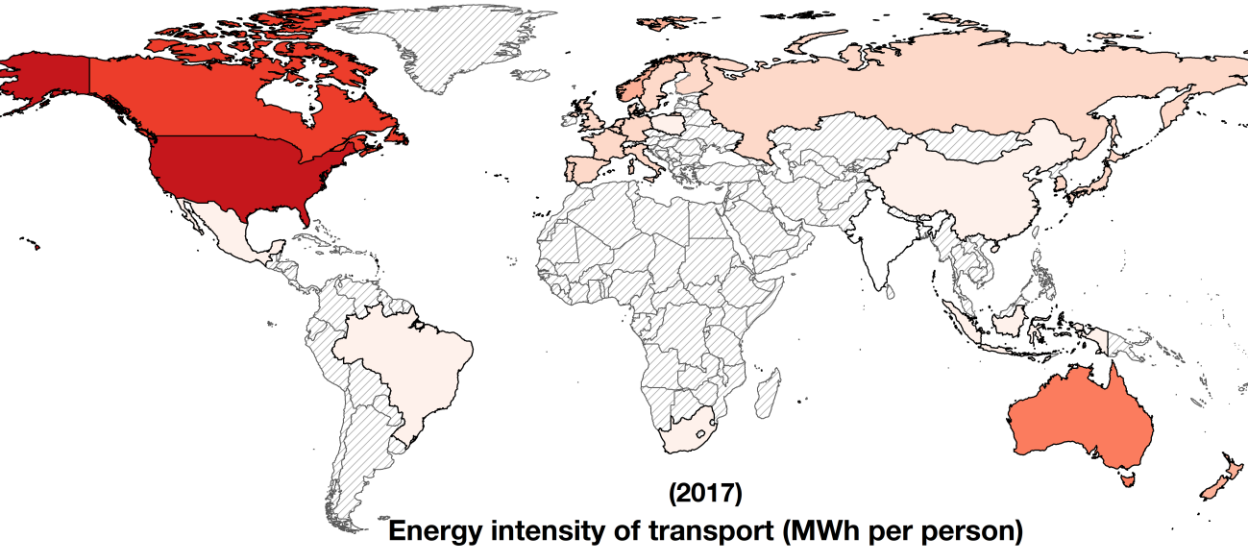
Change in energy intensity of houses

No data -30% -15% 0% 15% 30% 45% 60% 75%



Efficiency

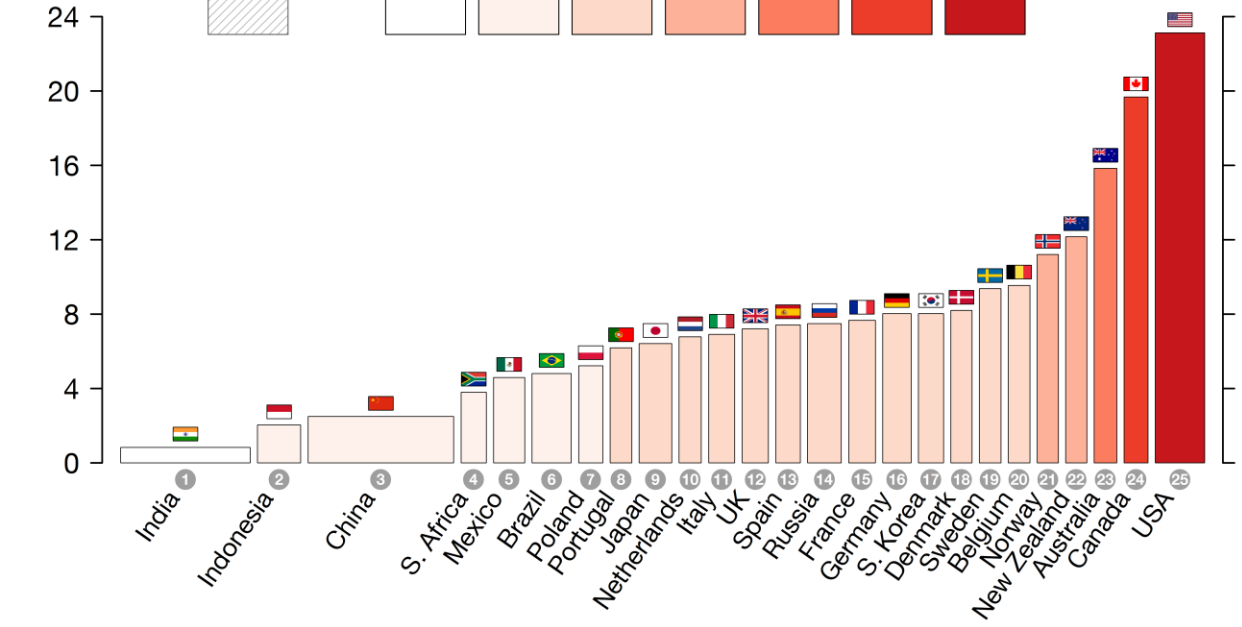
Energy intensity of transport

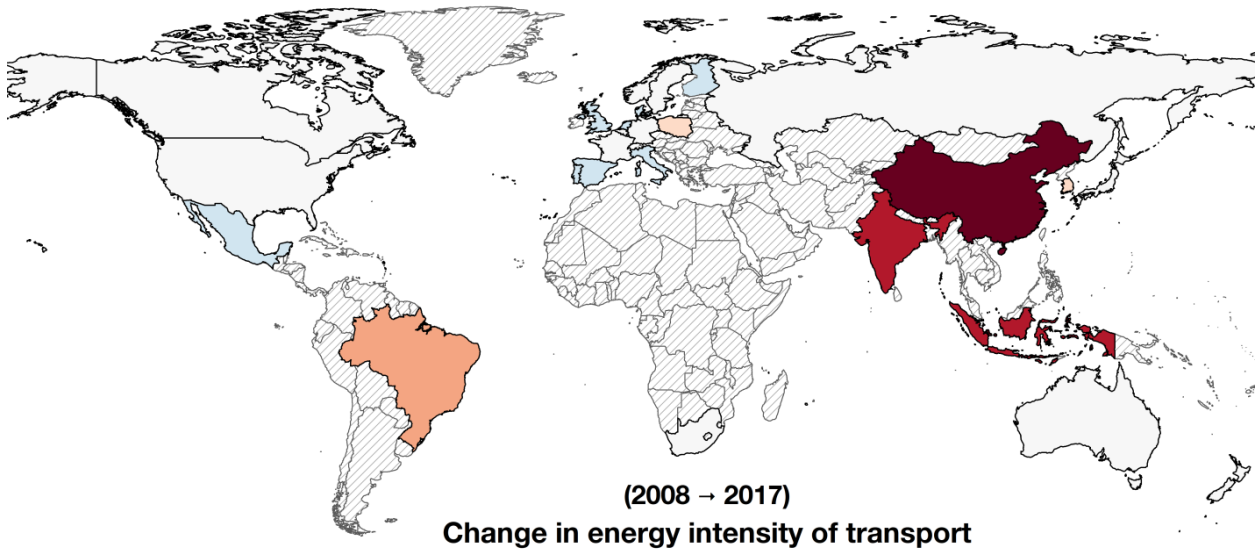


(2017)

Energy intensity of transport (MWh per person)

No data 0 4 8 12 16 20 24

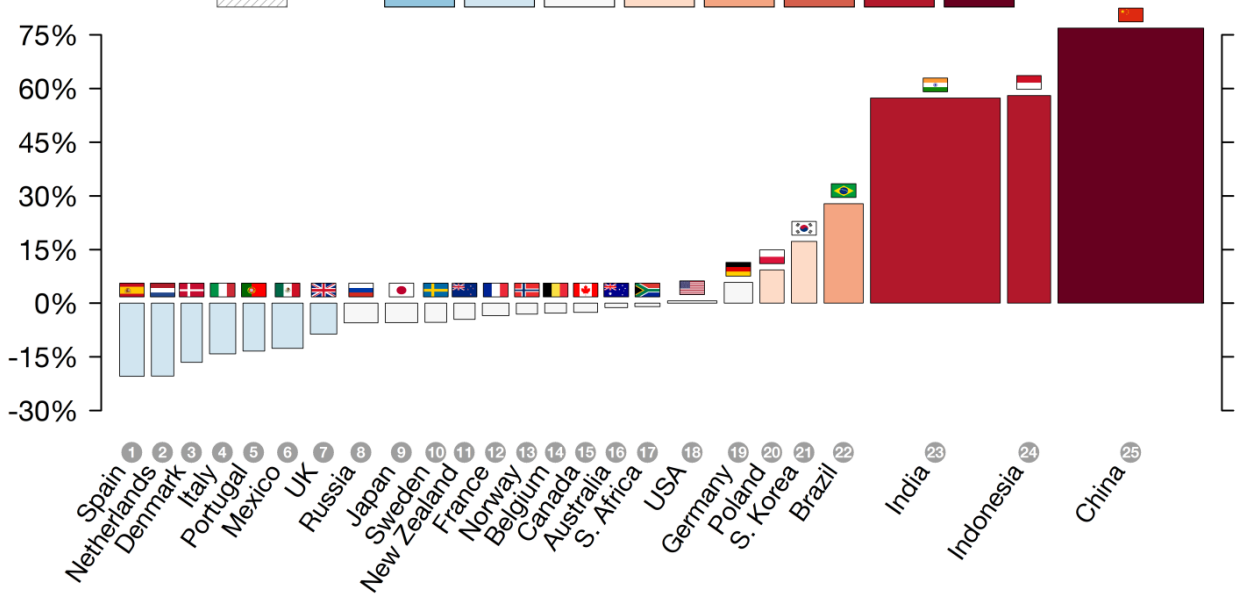




(2008 → 2017)

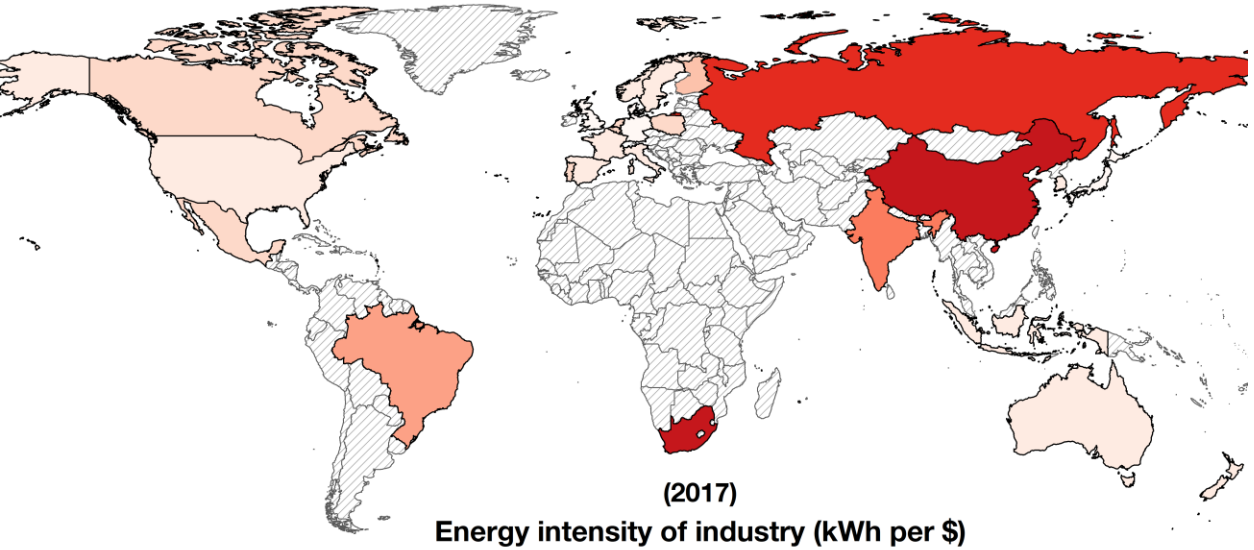
Change in energy intensity of transport

No data -30% -15% 0% 15% 30% 45% 60% 75%



Efficiency

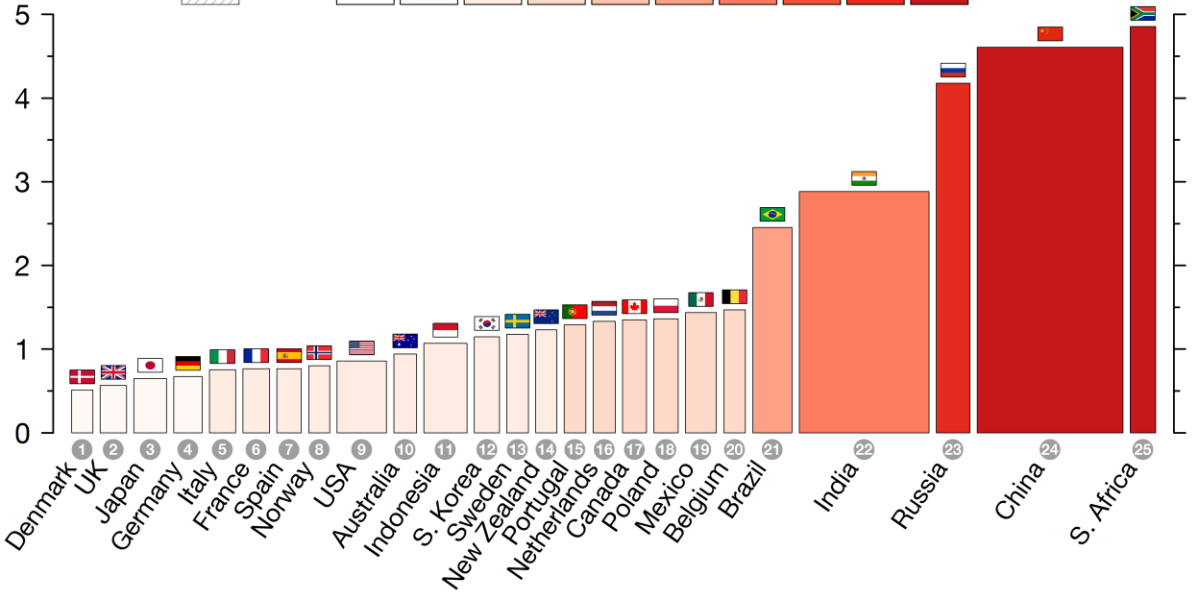
Energy intensity of industry

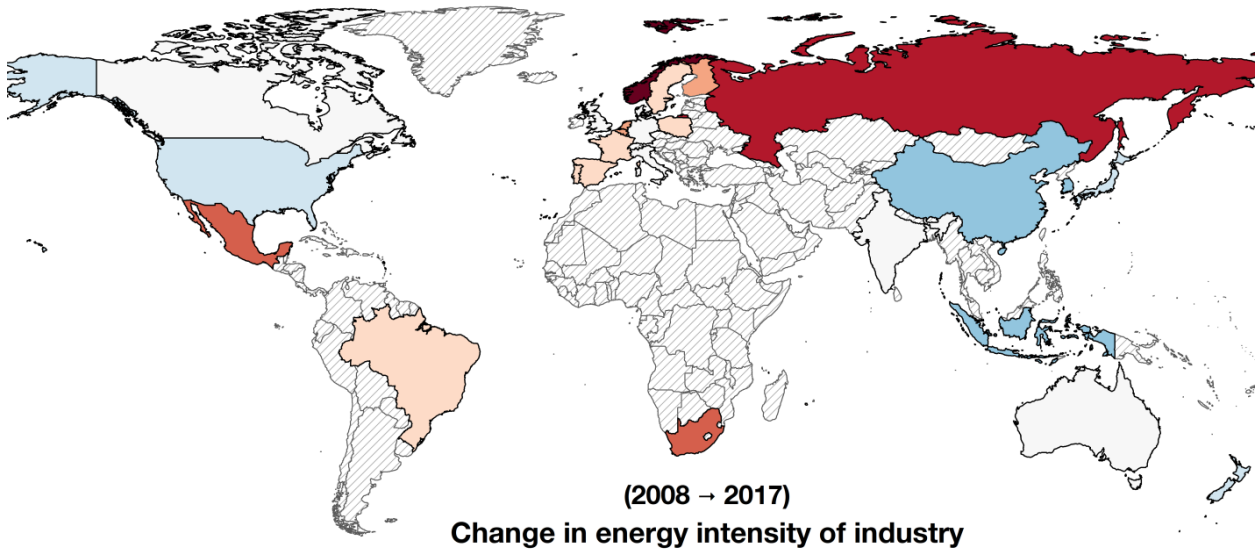


(2017)

Energy intensity of industry (kWh per $)

No data 0 0.5 1 1.5 2 2.5 3 3.5 4 4.5

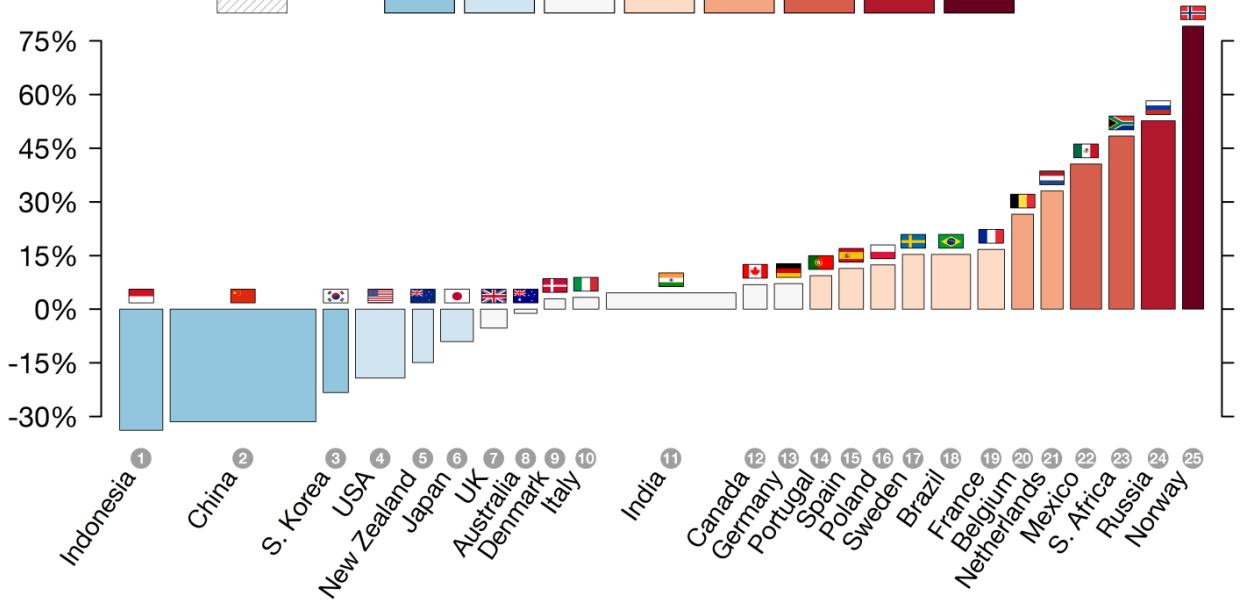




(2008 → 2017)

Change in energy intensity of industry

No data -30% -15% 0% 15% 30% 45% 60% 75%



Please refer to this report as:

I. Staffell, M. Jansen, A. Chase, E. Cotton and C. Lewis (2018). *Energy Revolution: Global Outlook.* Drax: Selby.