

**F20**

Limiting Global Warming to 1.5 °C:

Renewable  
Target  
Mapping  
for the

**G**

**20**



Reaching the renewable power target of 70% by 2030  
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The Foundations Platform F20 is a network of more than 75 foundations and philanthropic organizations from different parts of the world.

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The Institute for Sustainable Futures (ISF) is an interdisciplinary research and consulting organisation at the University of Technology Sydney. ISF has been setting global benchmarks since 1997 to help governments, organisations, businesses, and communities achieve changes that support sustainable futures.

ISF acknowledges and respects the Aboriginal and Torres Strait Islander custodians of Australia and the Gadigal people, custodians of the land upon which the UTS City Campus now stands. We continue to value the generations of knowledge that Aboriginal and Torres Strait Islander peoples embed within our university, and we pay our respect to their elders past, present, and emerging.

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# FOREWORD

Dear colleagues, dear friends,

How much area would it take to power the whole world with solar energy? It's less than half the size of a matchbox on your computer screen picturing the world map. Placed in the Sahara Desert totalling more than 9 million km<sup>2</sup> the required space for the world's energy demand would be as small as some 400 km in both directions. There was this famous graph in the late 1980ies early 1990ies from different sources which displayed a tiny area in North Africa that could supply the world with 100% electrical power through solar energy. A mind-blowing graph that was also used by the Desertec Foundation in 2009 to illustrate the sheer potential of solar power.

Indeed, the graph puts things into perspective. While it certainly doesn't make any sense to harvest the world's renewable energy only from the sun in the Sahara, the graph tells an important story: World's daily renewable energy potential could cover our energy needs several times. Also, the IPCC Special Report on Renewable Energy back in 2011 confirmed, that the technical potential of renewable energy could supply every continent's energy demand at least by a factor of 10. Much less mining needed, no refineries or pipelines and much smaller environmental and climate impacts.

Keeping global temperature increase below the dangerous benchmark of 1.5°C is possible. Technically as well as economically. And as complex the goal of this journey may sound - we basically 'only' need to do three things:

- Protecting and restoring nature
- Making our food healthier and more sustainable
- Stop burning fossil fuels for thermal and electricity-based energy services and replace it by using renewable sources

The G20 are representing the world's biggest energy generation capacities, 80% of the global GDP and 80% of global greenhouse gas emissions - not to speak about their large global infrastructure initiatives in literally every part of the world. The group of the 20 is also a place where the Global South and the Global North perspectives come together. So, this group will have to lead the way for the transition. With this report we seek to provide some key numbers, milestones and measures for transforming the energy sector of the G20 countries.

Germany and Indonesia are both hosting the G7 and the G20 summit this year. Egypt is heading the UN climate summit (COP27). This provides a huge opportunity for a well-coordinated and inclusive effort to help build a credible and Paris-aligned pathway. So-called Just Energy Transition Partnerships (JET-P) can be an excellent means to accelerate the transition to economies powered by renewable energy, new forms of cooperation and for solidarity among partners.

The German government aims to establish a climate club - an "international climate alliance geared towards close collaboration that have a strong appeal to other countries globally". So far so good, but it bears repetition: as long as we don't set renewable targets and remove the barriers for investments into renewable energy, investments into renewable energy will not happen fast enough.

With hope that this report helps to understand the opportunities and the enormous potential of renewable energy the purpose of this report is to inform political decision making and encourage the G20 to set clear and measurable targets for renewable energy - not only in the remote future but for the next years and up to 2030.

With a big thanks to the authors of this report we hope you enjoy reading it.

With best regards,



**Klaus Milke,**  
F20 Chair



**Stefan Schurig,**  
F20 Secretary General



# EXECUTIVE SUMMARY

## G20 Hamburg Climate and Energy Action Plan for Growth

*Economic growth, sustainable development and prosperity are at the heart of G20 cooperation. They rely on universal access to affordable, reliable, sustainable energy sources and clean technologies. The leaders of G20 members will continually develop their economies and energy systems to better reflect the evolution of the global energy and environmental landscape. To facilitate the implementation of UNFCCC, the Paris Agreement and the 2030 Agenda for Sustainable Development, we will strive to move forward in a coherent and mutually supportive manner that will provide us with significant opportunities for modernising our economies, enhancing competitiveness, stimulating employment and growth and ensuring socio-economic benefits of increased energy access. In addition, and in view of the increasing impacts of climate change, we will strive to increase the resilience of our communities and economies. Our action will be guided by the Sustainable Development Goals (SDGs) and the Paris Agreement's aim to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels; by increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience; and by making finance flows consistent with a pathway towards low greenhouse gas emissions and climate resilient development. Our actions pursuant to the implementation of the Paris Agreement will reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances. (...)*

**Preamble of the G20 Energy Ministers Meeting in Hamburg / Germany 7th July 2017**

## G20 member states are responsible for 80% of global energy related CO<sub>2</sub> emissions

The 20-member countries of the G20 are responsible for about 80% of global energy-related CO<sub>2</sub> emissions. Therefore, the G20 has the greatest responsibility globally to limit the global temperature rise according to the Paris Climate Agreement, which has been ratified by 197 countries –including all G20 members. The political processes currently in place to phase-out the combustion of fossil fuels and increase our renewable energy targets are too slow to remain within the carbon budget left to limit global temperature rise to +1.5°C. The group of the G7 - in fact a subgroup of the G20 - still displays biggest per capita emissions among all G20 countries and therefore need to take the lead in implementing the energy transition towards renewable energy.

According to the International Renewable Energy Agency, 'several high-emitting countries and G20 members have passed or proposed laws concerning net zero emissions or have placed net zero targets in policy documents. Within the G20, Canada, the European Union, France, Germany, Japan, the Republic of Korea and the United Kingdom have passed laws on net zero. Canada and the Republic of Korea have proposed net zero in legislation, while Brazil, China, Italy, Japan, Turkey, and the United States have included net zero ambitions in policy documents. In addition, Australia, India, Russia, Saudi Arabia, and South Africa have communicated net zero targets in declarations/pledges' (IRENA 2022)<sup>2</sup>.

1. IPCC. United Nation Climate Change—Paris Agreement—Status of Ratification. 2021. Report of the Intergovernmental Panel on Climate Change. Cambridge University Press; 2021.
2. IRENA (2022). NDCs and renewable energy targets in 2021: Are we on the right path to a climate-safe future?, International Renewable Energy Agency, Abu Dhabi.

## G20 member countries: Current (renewable) energy policies are insufficient for 'Net-Zero by 2050

Our analysis of the G20 member countries shows significant differences in their energy supply structures. The highest renewable energy share in the primary energy supply is in Brazil, at 47%, and the lowest is in Saudi Arabia, at only 0.02%.

On average, today renewable energy contributes 10% of the primary energy of the G20.

## G20 Energy sector—Trends and Target mapping

In this report we've analysed two potential future developments on energy generation trajectories. The first one displays a trend projection whereas the second offers a target projection - assuming that governments would take the lead on their own commitments and align the energy sector to the global carbon budget.

To develop a renewable energy target for the G20, the trends in energy demand and supply for the past 15 years (2005–2020), based on the IEA World Energy Balances, have been analysed. Based on this analysis, two projections have been calculated:

**1. Trend projection:** The trends of the past 15 years—in terms of both energy demand and supply—will continue for the next 30 years, until 2050. The average growth rates for coal-, gas-, and oil-based electricity, heat generation, and transport fuel supply will continue and renewables will provide the remaining energy to meet the demand. In this projection, fossil fuels have priority over renewable energy—so increased use of fossil fuels might push renewables out of the market. Renewables will only be deployed if the overall energy demand is not met with the projected growth in fossil fuels.

**2. Target projection:** The energy demand develops according to the trend minus a 1.5% efficiency gain. Fossil fuels for electricity and heat generation and to supply the transport demand are phase-out, with average annual decline factors that are based on a global 1.5°C pathway<sup>3</sup>. The entire gap between the demand and—declining—fossil fuels will be supplied with renewables. A detailed breakdown by renewable energy technologies has not been calculated. The rate of fossil fuel decline is higher for industrialized countries than for developing countries.

## The current trend in energy supply would lead to stagnation of renewable energy shares on today's level

Under the *Trend* projection, only the EU27 and three European G20 member countries (France, Germany, and Italy) will triple their renewable energy supply share, but will still fail to decarbonize, with fossil fuels still providing more than half the remaining energy demands. The continuation of the *Trend* in the United Kingdom and the USA will double, leading to fossil fuel supply shares of 76% and 82%, respectively. All other countries will either stabilize their shares of renewable energy to 2019 values or even reduce them. Under the *Target* projection, all countries can significantly increase their renewable energy shares to an accumulated number of 64% of primary energy supply by 2030—across the G20, with significant regional differences. The current share of renewable energies in primary energy demand is around 8% in both Mexico and Australia. While Australia would reach 64% renewable energy under the '*Target*' projection, Mexico would reach only 47% by 2030.

3. Teske S, Niklas S (2021), Fossil Fuel Exit Strategy: An orderly wind down of coal, oil and gas to meet the Paris Agreement, June 2021



## Energy-related CO<sub>2</sub> emissions

The annual reduction achieved up to 2030 will define whether or not the Paris Climate Agreement goals can be achieved and emissions remain within the carbon budget. However, the trend in energy-related carbon emissions in the G20 since 2005 has developed in the wrong direction—not a steady decline, but an increase of around 2.5% per annum. **To achieve the Paris Climate Agreement, the emissions of all the G20 member states must decrease by about 60%, from 32GtCO<sub>2</sub> in 2019 to 13.5 GtCO<sub>2</sub> in 2030.**

Figure 1 shows the development of energy-related carbon emissions between 2005 and 2019 and the possible development under the *Trend* and *Target* projections. The *Trend* trajectory will lead to a doubling of emissions by 2050. By 2030, energy-related CO<sub>2</sub> emissions will increase by about 30% under *Trend*, whereas the calculated emissions under the *Target* projection will decrease to 42% of the 2020 emissions. Under the ‘*Trend*’ projection the cumulative CO<sub>2</sub> emission between 2020 and 2050 will add to about 1,470 GtCO<sub>2</sub>—4.5 times the G20’s carbon budget required to remain under 1.5°C.

## G20: 60% Renewable energy share in primary energy by 2030 required to meet Paris Climate Agreement

To remain within the carbon budget that will limit global warming to +1.5°C, drastic changes in existing energy policies are required to support energy efficiency and the uptake of renewable energies. Establishing legally binding targets for renewable energies has proven an effective and successful policy measure.

However, renewable targets must be accompanied by policies to implement them. Suggestions are made in Chapter 4. Figure 2 shows all the renewable energy shares for primary energy, electricity generation, heat generation, and transport under the *Target* projection for the G20. All sector targets across all member countries must be in the range of 57%–71% by 2030.

**FIGURE 1:** G20—Energy-related CO<sub>2</sub> emissions—historic emissions and ‘Trend’ versus ‘Target’ projections

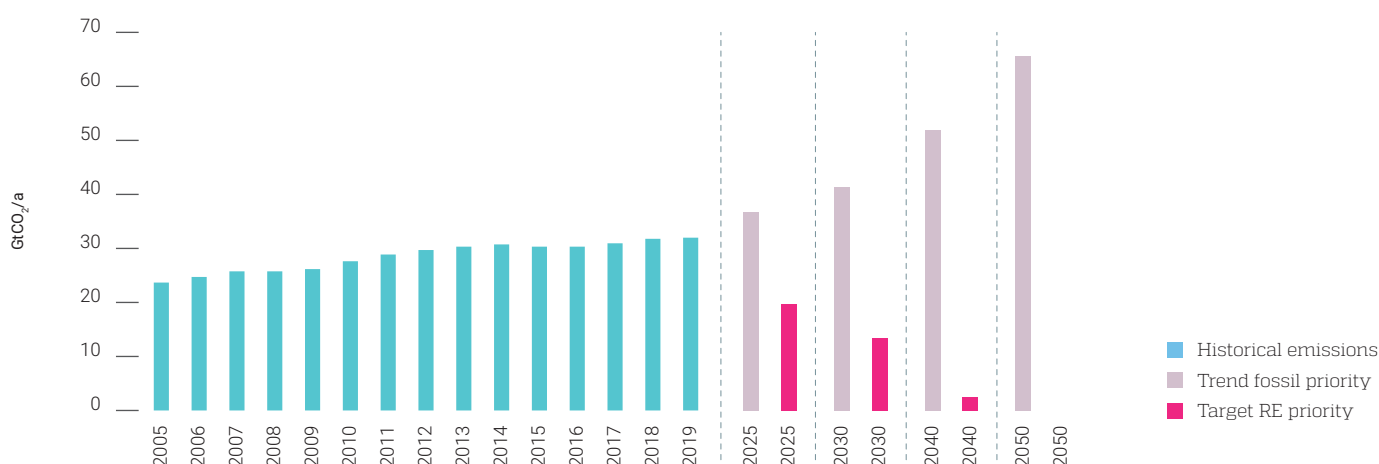
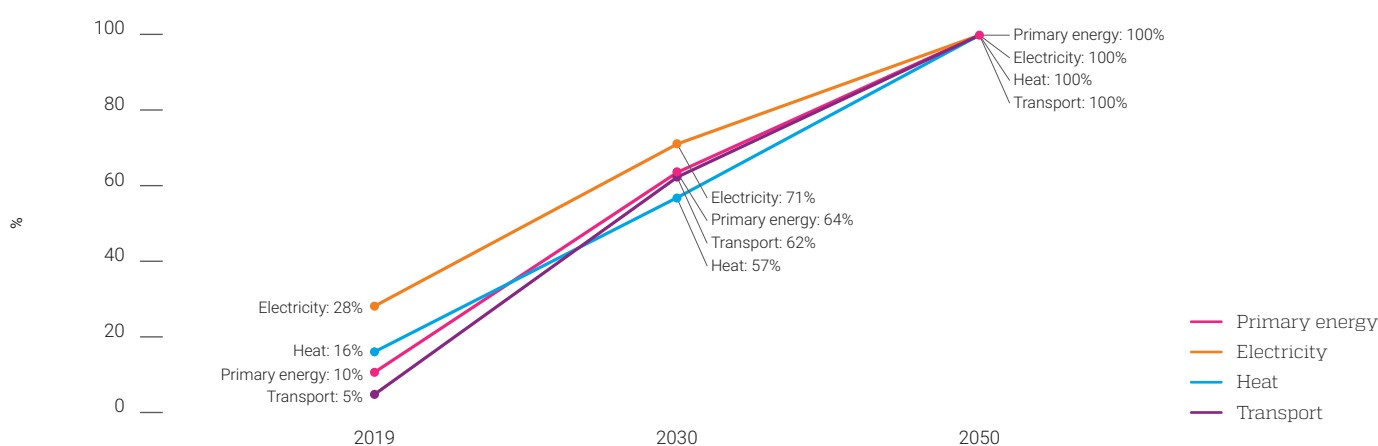


FIGURE 2: G20—Renewable target sketch by sector



## The G20: Renewable energy potential is not the barrier for 100% renewables

The combined renewable energy potential of the G20 countries exceeds their current energy demand by an order of magnitude and enables these countries to completely replace fossil energies with renewable energies.

The available solar and wind potential has been assessed with a GIS mapping analysis (see methodology in chapter 3). The primary purpose of the GIS mapping is to project the renewable energy resources (primarily solar and wind) available in G7 and G20 countries. It also contributes to the regional analysis of geographic and demographic parameters and the available infrastructure that can be leveraged in developing scenarios to deal with energy concepts.

On the territory of the G20, the total theoretical solar potentials under space-constrained conditions - excluding protected areas, urban areas, and infrastructures such as roads - is estimated with 36.8 million km<sup>2</sup> or 924,000 GW (Table 16). Under the conservative assumption that a solar

photovoltaic generator produces 1,100 kWh for each installed kilowatt—which is the average value in Central Europe—the solar potential of the G20 is sufficient to supply the 2019 global electricity demand 37 times over, and 2.7% of the potentially suitable area could deliver the global electricity demand. Therefore, there is no lack of solar potential to satisfy the entire electricity demand of the G20, even under the assumption that the demand will increase significantly over the next 30 years.

The onshore wind potential of the G20 is smaller than the solar potential, but is nonetheless able to generate 18 times the current global electricity demand. Under the assumption that an average wind turbine operates with a capacity factor of 34% (3,000 h/a), the wind potential of the G20 should be able to generate 553,000 TWh.

The combined solar and wind potentials of the G20 are sufficient to generate over 50 times the current global electricity demand. About 2% of the theoretical solar and wind areas could supply the global electricity demand. The potential for onshore wind and roof-top solar would come on top of this.

## G20 Policy recommendations

Our recommendations focus on the targets that G20 nations must set to ensure that the development of renewable energy is accelerated to meet climate change targets. Consequently, this is not a comprehensive set of recommendations:

- 60% Renewable energy share on Primary energy
- 70% Renewable electricity
- 55% Renewable heat
- 60% Renewable powered electric mobility

## Calculated renewable energy targets by member state

Based on the projections documented in Chapter 2, the

estimated renewable energy targets by country and/or region for primary energy are shown in the table below, electricity, heat, and transport.

## Multilateral Partnerships to accelerate a just energy transition

G20 countries are currently considering multilateral energy partnerships aiming to accelerate the decarbonization of economies and removing barriers for investments into renewable energy. So called Just Energy Transition Partnerships (JET-P) can be an excellent means to accelerate the transition to renewable energy powered economies, new forms of cooperation and for solidarity among partners. However, JET-Ps require a clear compass on what a 'just transition' entails and they must indeed ensure the transition from fossil fuel lead economies to renewable energy.

**TABLE 1: Renewable energy target projections—Primary energy for member countries of the G7 and G20**

| Renewable Energy Target Projections - Primary Energy | Unit | 2019         | 2025         | 2030         | 2040         | 2050        |
|------------------------------------------------------|------|--------------|--------------|--------------|--------------|-------------|
| Argentina (G20)                                      | %    | 9.1%         | 32.9%        | 47.3%        | 90.5%        | 100%        |
| Australia (G20)                                      | %    | 7.3%         | 47.3%        | 64.3%        | 93.4%        | 100%        |
| Brazil (G20)                                         | %    | 46.8%        | 64.9%        | 74.9%        | 92.7%        | 100%        |
| Canada (G20) & (G7)                                  | %    | 16.5%        | 44.5%        | 58.3%        | 93.2%        | 100%        |
| China (G20)                                          | %    | 9.6%         | 47.7%        | 66.5%        | 96.9%        | 100%        |
| EU27 (G20) & (G7)                                    | %    | 16.0%        | 41.9%        | 54.6%        | 91.2%        | 100%        |
| France (G20) & (G7)                                  | %    | 10.6%        | 34.1%        | 46.7%        | 93.1%        | 100%        |
| Germany (G20) & (G7)                                 | %    | 15.4%        | 48.8%        | 61.1%        | 90.9%        | 100%        |
| India (G20)                                          | %    | 25.8%        | 38.8%        | 48.9%        | 96.1%        | 100%        |
| Indonesia (G20)                                      | %    | 13.2%        | 44.3%        | 64.2%        | 89.3%        | 100%        |
| Italy (G20) & (G7)                                   | %    | 18.6%        | 36.9%        | 45.9%        | 86.7%        | 100%        |
| Japan (G7 & G20)                                     | %    | 6.4%         | 37.3%        | 51.7%        | 88.0%        | 100%        |
| South Korea (G20)                                    | %    | 2.0%         | 46.9%        | 65.8%        | 94.9%        | 100%        |
| Mexico (G20)                                         | %    | 9.0%         | 31.8%        | 45.7%        | 85.8%        | 100%        |
| Russia (G20)                                         | %    | 2.8%         | 35.6%        | 51.6%        | 94.0%        | 100%        |
| Saudi Arabia (G20)                                   | %    | 0.0%         | 47.4%        | 67.2%        | 94.0%        | 100%        |
| South Africa (G20)                                   | %    | 6.7%         | 34.5%        | 50.6%        | 78.2%        | 100%        |
| Turkey (G20)                                         | %    | 15.3%        | 48.6%        | 65.7%        | 91.8%        | 100%        |
| United Kingdom (G20) & (G7)                          | %    | 12.8%        | 48.0%        | 64.1%        | 89.7%        | 100%        |
| United States of America (G20) & (G7)                | %    | 8.1%         | 36.9%        | 50.9%        | 90.5%        | 100%        |
| <b>G7</b>                                            | %    | <b>9.9%</b>  | <b>48.1%</b> | <b>65.5%</b> | <b>92.2%</b> | <b>100%</b> |
| <b>G20</b>                                           | %    | <b>10.5%</b> | <b>45.9%</b> | <b>63.5%</b> | <b>94.6%</b> | <b>100%</b> |

# INTRODUCTION

Achieving the goals of the Paris Climate Agreement will require the total decarbonization of the global energy system by 2050, with an emissions peak between 2020 and 2025<sup>4</sup>, and a drastic reduction in non-energy-related greenhouse gas (GHG) emissions, including land-use-related emissions<sup>5</sup>.

The role of nature and ecosystem services as climate solutions is gaining increasing attention. As well as their climate mitigation and carbon sequestration potential, ecosystem approaches have co-benefits that contribute to sustainable development goals in terms of livelihoods, productivity, biodiversity conservation, health, and ecosystem services. However, it is important to note that even with ambitious land-use restoration, carbon removal can still only compensate for, at most, 15% of current emissions. The vast majority of emissive activities must cease if we are to achieve an approximately 1.5°C target, and all the available removal strategies are required to achieve net-negative emissions pathways and reduce the atmospheric concentrations of CO<sub>2</sub>. Thus, both decarbonization of the energy system with renewable energies AND biodiversity conservation and the increase of natural carbon sinks are equally important and must go together to achieve the *Paris Climate Agreement* goals.

## We cannot ‘recover’ from climate change—we must limit further emissions

The G20’s slogan for its 2022 meeting in Indonesia is ‘*Recover together—Recover stronger*’. However, unlike global economic crises, which can be overcome and ‘recovered from’, furthering climate change must be avoided in the first place. Ecosystems that have been devastated by climate change, such as coral reefs, cannot be ‘repaired’ and their unique biodiversity will be irretrievably lost.

The 20-member countries of the G20 are responsible for about 80% of global energy-related CO<sub>2</sub> emissions. Therefore, the G20 has the greatest responsibility globally to limit the global temperature rise according to the Paris Climate Agreement, which has been ratified by 197 countries<sup>6</sup>—including all G20 members. The political processes currently in place to phase-out carbon emissions and increase our

renewable energy targets are too slow to remain within the carbon budget left to limit global temperature rise to +1.5C.

Whereas the G20 acknowledges that ‘*The impacts of climate change are becoming increasingly real and are beginning to affect local and global development*’<sup>7</sup>, the discussion of how an energy transition can be implemented with policy instruments and how this will be financed is on-going.

The governments of the G20 member countries have received considerable support for developing pathways to finance the energy transition. The United Nations Climate Change Race to Zero Campaign aims to mobilize cities, regions, businesses, financial institutions, and institutions of higher education to establish ‘net-zero’ decarbonization targets over and above the activities of national governments<sup>8</sup>. These will not only support governments, but will also create more investment security for the financial resources required. To develop, implement, and monitor these supportive net-zero targets, tailor-made energy scenarios for the various actors are required. The finance industry, for example, requires energy and emissions pathways for specific industries, such as the steel and aluminium industries. The International Energy Agency published ‘Net-Zero by 2050—A Roadmap for the Global Energy Sector’<sup>9</sup> to support the setting of net-zero targets. However, more-detailed energy scenarios, with higher resolution and broken down by industry sub-sector, are required for institutional investors. The Institute for Sustainable Futures (ISF) at the University of Technology (UTS; Sydney, Australia) has developed science-based energy and GHG emissions strategies for specific industries on the global level.

3. IPCC. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press; 2021.
4. Rogelj J, Den Elzen M, Höhne N, Fransen T, Fekete H, Winkler H, et al. Paris Agreement climate proposals need a boost to keep warming well below 2 °C. *Nature*. 2016;534: 631-9.
5. IPCC. United Nation Climate Change—Paris Agreement—Status of Ratification. 2021.
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7. G20 website - viewed May 2022, <https://g20.org/>
8. UNFCCC. Race to Zero. United Nations Climate Change. 2021.
9. IEA NZ. Net-Zero by 2050—A Roadmap for the Global Energy Sector. Paris, France; 2021.

## Renewable energy targets provide investment security

If current energy-related CO<sub>2</sub> emission levels are maintained, the remaining carbon budget required to limit global warming to 1.5°C will be exhausted in less than a decade. Unless emissions are urgently and severely limited, the world will overshoot this carbon budget, and therefore exceed 1.5°C warming. To achieve the steep decarbonization of the global economy required, (energy) policies must be adjusted to support transitioning economies, renewable energy technologies must be scaled up, energy efficiency must increase, and consumer behaviour must change.

Establishing renewable energy targets for all member countries of the G20 will increase the investment security for the energy sector and will encourage the global finance industry to provide the required support.

This report contributes to the determination of renewable energy targets for all individual member countries of the G20 and G7, and the organizations as a whole. We have analysed the development of the energy demand and supply since 2005 and calculated two projections. The *Trend* projection shows what the energy sector will look like in 2050 if the trends of the last 15 years continue unchanged. The *Target* projection outlines what must happen to stay within the carbon budget and to replace fossil fuel use with renewable energies. Although these are simplified projections, which cannot replace detailed technical concepts for all G20 countries, they provide a useful pathway for setting renewable energy targets – in line with the remaining carbon budget before surpassing the threshold of 1.5°C average temperature increase.



Wind turbines and solar panels, Ninh Thuan, Vietnam.  
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Establishing renewable energy targets for all member countries of the G20 will increase the investment security for the energy sector and will encourage the global finance industry to provide the required support.



# **G20** **Renewable** **Energy Policy:** Current State of Affairs

# 01

Windturbine.  
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The report starts with an overview of the current state of affairs for renewable energy policy across the G20, focussing on targets. Targets do not equate to action and their achievement requires the implementation of policy, regulation, funding, and programmes. However, robust targets are necessary to provide long-term certainty for investors, industry, and policy-makers.

In this section, the following targets across the G20 and for individual members are reviewed:

| Target                    | Definition                                                                                                                                                          |
|---------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Renewable electricity     | Share of renewable energy in electricity generation.                                                                                                                |
| Renewable energy          | Share of renewable energy in primary or final energy consumption.                                                                                                   |
| Sectoral renewable energy | Share of renewable energy in heating, industry, and transport.                                                                                                      |
| Energy storage            | Targets for the installation of energy storage resources, including battery storage and pumped hydro storage, and committed demand responses.                       |
| Energy efficiency         | Targets for improvements in energy efficiency, which are defined with a variety of metrics, including absolute or relative energy consumption and energy intensity. |

References: IEA (2021a - 1)<sup>10</sup>, IEA (2022 a,b)<sup>11</sup>, IRENA (2021a,b)<sup>12</sup>, IRENA (2022)<sup>13</sup>, country reports as listed under<sup>14</sup>.

- International Energy Agency (2021a) Security of Clean Energy Transitions, IEA: Paris. International Energy Agency (2021b) World Energy Outlook 2021, IEA: Paris. International Energy Agency (2021c) Energy Efficiency 2021, IEA: Paris. International Energy Agency (2021d) Renewables 2021, IEA: Paris. International Energy Agency (2021e) France 2021: Energy Policy Review, IEA: Paris. International Energy Agency (2021f) India Energy Outlook 2021, IEA: Paris. International Energy Agency (2021g) Japan 2021: Energy Policy Review, IEA: Paris. International Energy Agency (2021h) Turkey 2021: Energy Policy Review, IEA: Paris. International Energy Agency (2021i), Energy Storage, IEA: Paris. International Energy Agency (2021j) Italy, <https://www.iea.org/countries/italy>. International Energy Agency (2021k) Energy Strategy of Russia to 2030, <https://www.iea.org/policies/1370-energy-strategy-of-russia-to-2030>. International Energy Agency (2021l) World Energy Outlook 2021, IEA: Paris.
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# RENEWABLE ELECTRICITY TARGETS

## Renewable electricity targets

Electricity is the sector in which the growth of renewable energy and higher targets is most advanced amongst the G20 nations. Although half the G20 nations did not set a renewable electricity target for 2020, only three nations have not set a renewable electricity target for 2030. Of these nations, the United Kingdom has set a target of 100% 'clean electricity target by 2035 that includes non-renewable nuclear electricity which contributed 16% in 2020, while Turkey has set a target of 38.8% by 2023 (which is higher than the 2030 targets of many other G20 nations). The United States is the only G20 nation without a 2030 renewable electricity target, but around 30 individual states have set targets amounting to around 20%.

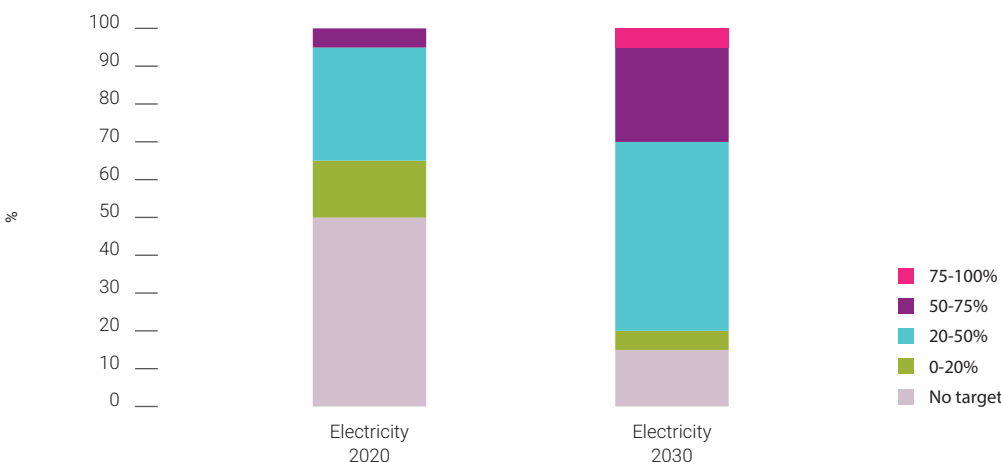
Not only has the number of G20 nations with renewable electricity targets increased, but most nations with existing targets have also increased their ambitions. Only one G20 nation now has a 2030 target of less than 20% (Russia). Most G20 nations have targets of 20–50%.

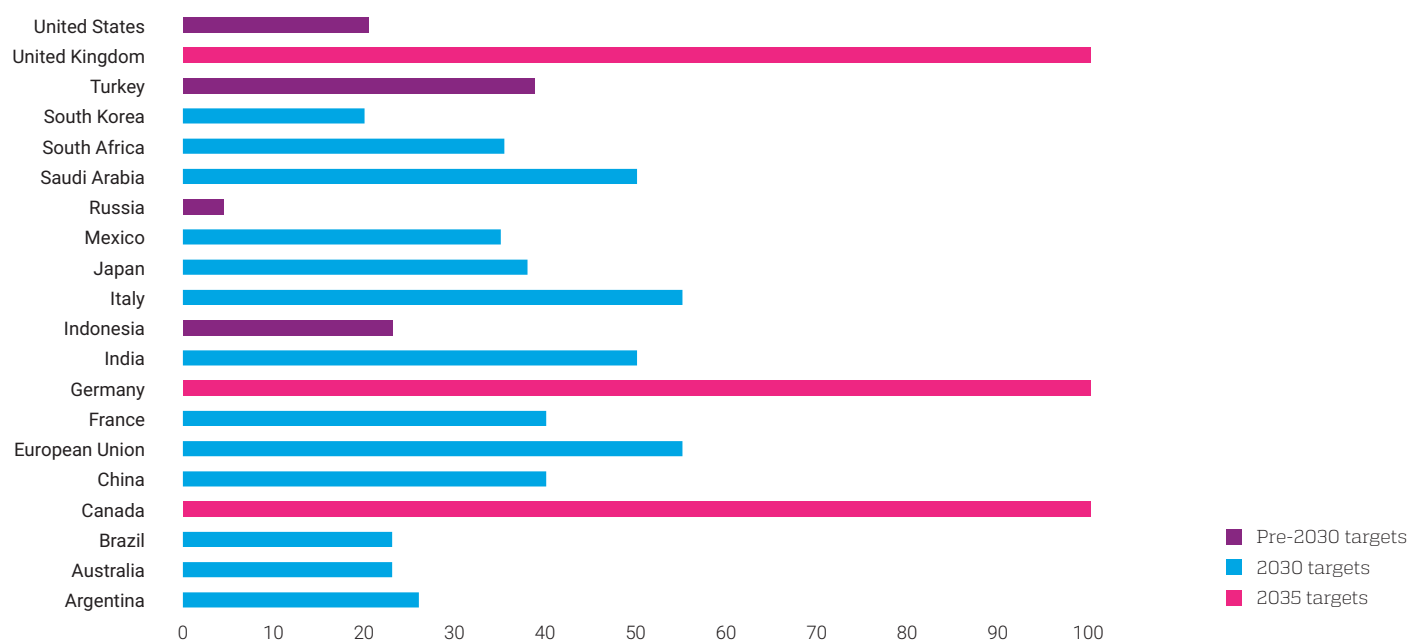
During this analysis, it became clear that some countries do not set clear targets for renewable energy, but mix them with non-renewable energies such as nuclear. This makes a direct comparison difficult and leads to inaccuracies. In the future, it would be desirable to clearly separate renewable and non-renewable energies in the G20 Renewable Energy Target Setting Process.

There are four broad groupings of the renewable electricity targets across the G20 (Figure 3):

- Three G20 nations have established themselves as leaders by announcing 100% renewable electricity targets by 2035 (Canada, Germany, United Kingdom).
- The second grouping of nations has set 50–55% targets by 2030 (EU, India, Italy, Saudi Arabia).
- The third grouping has set targets of 35–40% by 2030 (China, France, Japan, Mexico, South Africa, Turkey).
- The final grouping has existing or 2030 targets of 20–25% (Argentina, Australia, Brazil, Indonesia, South Korea, United States) or lower (Russia).

FIGURE 3: G20 renewable electricity targets, 2020 and 2030



**FIGURE 4: Renewable electricity targets (%), G20 nations**


Notes: The United States target is an estimate of the combination of states with renewable electricity targets. For a comprehensive analysis of renewable electricity policies, see REN21 (2021).

## Renewable electricity to power government operations

The United States is the only G20 nation that has not set a 2030 renewable electricity target—but it is a leader in fuelling government operations with renewable energy. President Biden signed an Executive Order for 100% of electricity consumed by the Federal Government to be sourced from carbon-pollution-free generation processes by 2030, half of which will be matched on a 24/7 basis. The requirement for hour-by-hour matching of supply and demand is an innovative element that supports emerging procurement models. It is estimated that the initiative will support 10 GW of new renewable energy.

Other commitments in the Executive Order included:

- 100% electric vehicles in the government fleet by 2035;
- a 50% reduction in building emissions by 2032 and net zero emissions by 2045;
- net zero emissions in the supply chains used for government procurement by 2050.

Source: White House 2021.

## RENEWABLE ENERGY TARGETS

### Overarching or Inclusive Renewable Energy Targets

Overarching Targets for the use of renewables in energy consumption (whether primary or final) are less common but not necessarily less ambitious than electricity targets as the entire energy supply including heating and transport is included – not only the power sector. There has also been much less progress in setting these inclusive energy consumption targets for 2030 than in setting (only) electricity targets for 2030 – reflecting the slow progress and the greater challenges involved in achieving wider decarbonization of certain parts of the energy system such as the transportation, heating, and industrial sectors. In fact, between 2020 and 2030, the same number of nations have targets and only a handful of those nations have increased their targets beyond 20%.

Looking closer, there has been some churning beneath the overall stability (Figure 5). Five G20 nations have lapsed on their 2020 targets, five G20 nations that did not have 2020 targets have now set 2030 targets, and five nations have set targets for both 2020 and 2030. Only five nations (Australia, Argentina, South Africa, Saudi Arabia, United States) have not set a renewable energy target.

FIGURE 5: Renewable energy targets (%) for G20

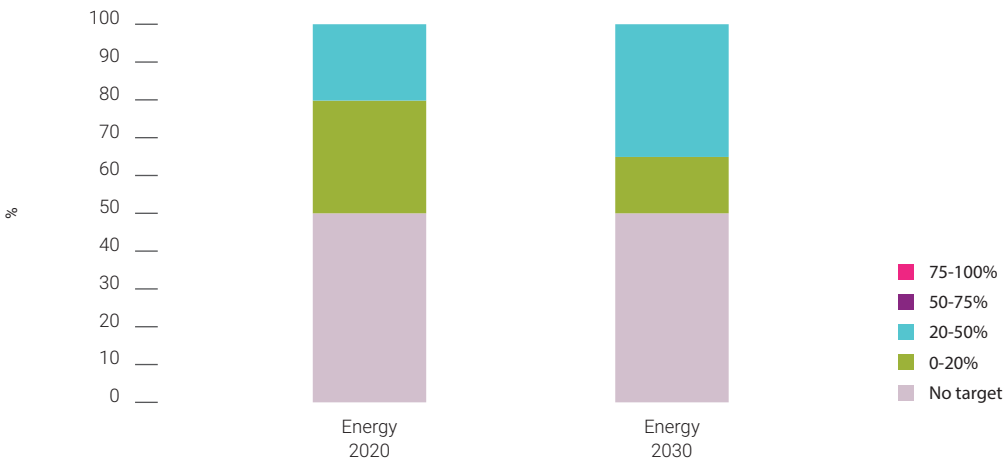
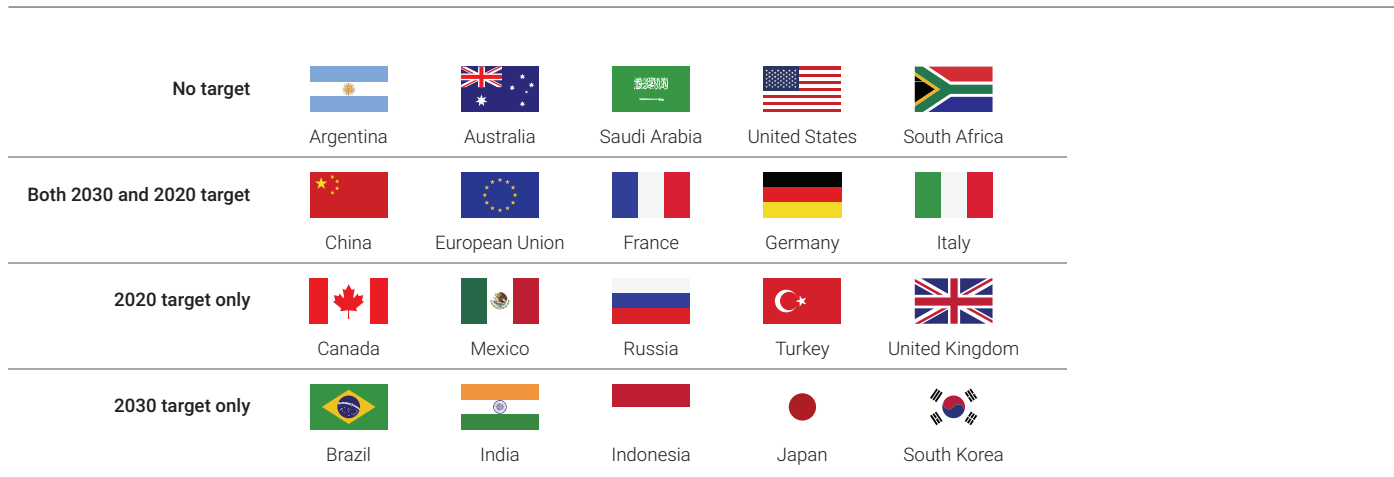


FIGURE 6: G20 renewable energy Targets, Changes between 2020 and 2030

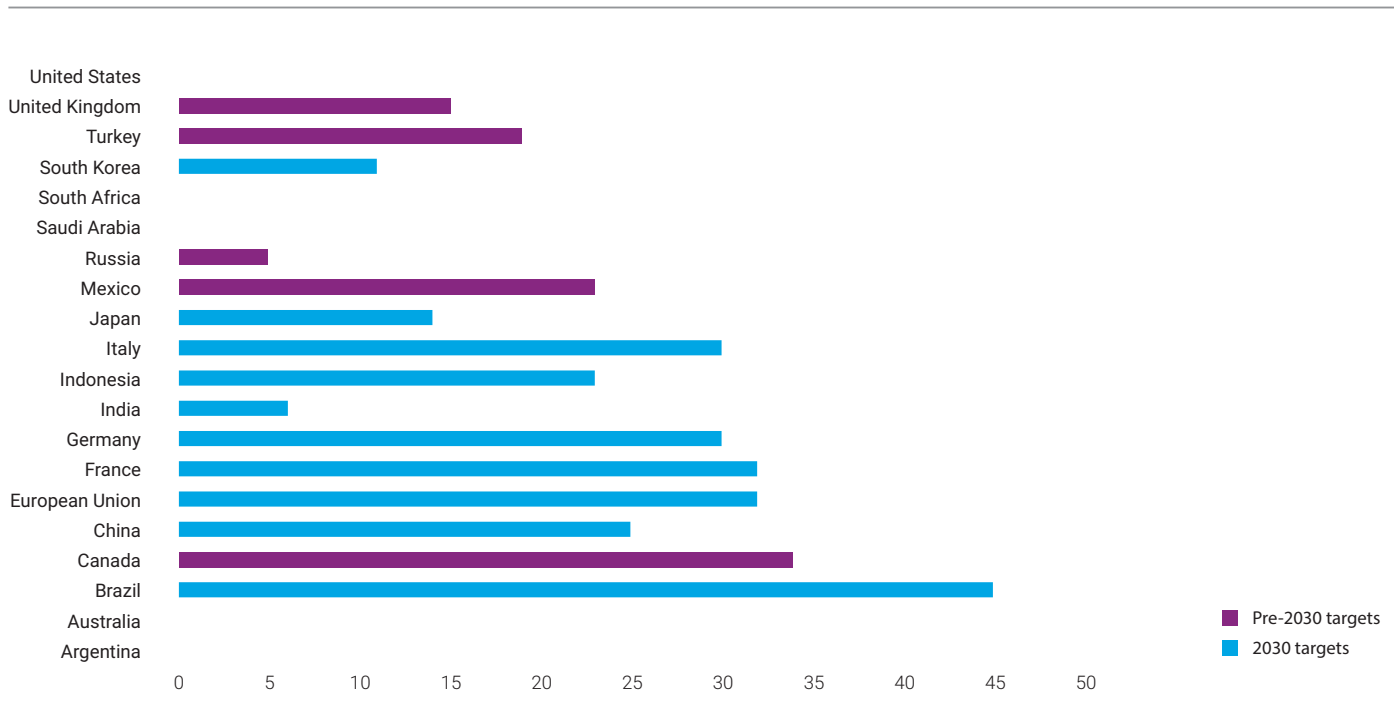


Most of the 2020 and 2030 targets cluster between 20 and 30%, with Brazil the clear leader at 45%.

Only five G20 nations set 2020 renewables targets for their final energy consumption (EU, France, Germany, Italy, UK)

(REN21 (2021)<sup>15</sup>: 32). Targeting the share of renewable energy in primary or final energy consumption is an area in which greater consistency and ambition is required by G20 nations.

FIGURE 7: Overarching renewable energy targets (%), G20 nations



15. REN21 (2021) REN21 (2021) Renewables 2021 Global Status Report, Paris: REN21 Secretariat.

## SECTORAL RENEWABLE ENERGY TARGETS: HEATING/COOLING AND TRANSPORT

### Sectoral renewable energy targets: Heating/cooling and transport

Overarching renewable electricity and energy targets can be supplemented with sectoral renewable targets for heating, transport, and industry. Progress in setting targets for heating, transport, and industry has been extremely uneven.

#### Heat and industry

Renewable heat has not received policy focus commensurate with its importance in the energy transition (IRENA, IEA & REN21 2020).

- Heat is the largest global source of energy use, accounting for almost half the global final energy consumption in 2021, greater than either electricity (20%) or transport (30%). Most of the heating demand is attributable to industrial processes (51%) and buildings (46%).
- Fossil fuels dominate the production of heating energy, and the renewable energy share has remained static, at around one-quarter of the demand, for the past three decades (IEA 2021d: 114). Some of the largest sources of heating demand are within the G20, with China accounting for one-quarter of the global demand and the US, EU, India, and Russia combined accounting for a further 35%.
- The state of play in industry is similar. Renewable energy provides 14.8% of the industrial energy demand, whereas in heavy industries (iron and steel, cement, and concrete), renewables meet less than 1% of the energy demand (REN 2021: 16). The IEA (2021d: 125) projects that only one-fifth of the growth in the industrial energy demand in the next five years will be met by renewable energy. The focus in 'hard-to-abate' industry sectors is decarbonization-directed innovation (e.g., green steel) and the development of renewable hydrogen. Renewable hydrogen targets, action plans, and funding are areas of rapid growth.

Only just under half the G20 nations have some type of renewable heat target—and those targets are highly variable in terms of their format, sectoral coverage, and extent. Moreover, most G20 nations with renewable heat targets have not updated or set targets beyond 2030.



Targets are not everything—some of the strongest global performers in renewable heat growth do not have a target. Nonetheless, progress overall is limited, and “stronger RE targets are required to focus policymakers’ and the private sector’s attention on how to accelerate the decarbonization of the heating system” (REN21 2020).

#### Transport

Transport has the lowest share of renewable energy among the major sources of energy consumption—just 3.3%, comprising biofuels (3.1%) and renewable electricity (0.25%) (REN 2021: 17). Rapid electrification, electricity supply from renewable energy, and a greater market share for biofuels are required to increase the proportion of renewable energy from its very low base.



**TABLE 2:** Renewable heating and cooling targets

| Country        | Renewable Heating Targets                                                                                                                                                                                                                                                                                                                          |
|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Argentina      | No target. Policies for commercial and industrial sectors.                                                                                                                                                                                                                                                                                         |
| Australia      | No target. Solar hot water systems are included in the national the renewable energy target.                                                                                                                                                                                                                                                       |
| Brazil         | No target. One of the leading markets for solar thermal installations.                                                                                                                                                                                                                                                                             |
| Canada         | Regional initiatives. For example, Quebec has set a target for a 50% reduction in emissions in heat for buildings by 2030.                                                                                                                                                                                                                         |
| China          | No target. China leads the world in solar thermal installations.                                                                                                                                                                                                                                                                                   |
| European Union | The EU target for 2020 was 20%, which was achieved with a 22% share by 2019 (IEA 2021: 115). Under the Renewable Energy Directive, a 1.1% per annum increase in the renewable energy share for heating and cooling is a binding target and member states are required to achieve at least 49% renewable energy in energy use by buildings by 2030. |
| France         | 38% by 2030. France has a Heat Fund and a new building code, and the installation of oil-fired boilers was banned from 2021.                                                                                                                                                                                                                       |
| Germany        | Had a target of 15.5% by 2020. A National Emissions Trading Scheme for heat and transport fuels was launched in 2021 and the Building Energy Act limits the installation of oil-fired heating systems and fossil-fuel boilers from 2026.                                                                                                           |
| India          | Solar hot water target of 20 million m <sup>2</sup> by 2022. Investment subsidies are in operation across the residential, commercial, industrial, and public sectors.                                                                                                                                                                             |
| Indonesia      | No target.                                                                                                                                                                                                                                                                                                                                         |
| Italy          | Had a target of 17% by 2020. The replacement of heating and cooling systems has been strong under the 110% Super bonus tax deduction scheme. Incentives are in place for residential, commercial, and industrial sectors.                                                                                                                          |
| Japan          | No target.                                                                                                                                                                                                                                                                                                                                         |
| Mexico         | Had a target of 33% by 2020.                                                                                                                                                                                                                                                                                                                       |
| Russia         | No target.                                                                                                                                                                                                                                                                                                                                         |
| Saudi Arabia   | No target.                                                                                                                                                                                                                                                                                                                                         |
| South Africa   | No target.                                                                                                                                                                                                                                                                                                                                         |
| South Korea    | No target. Subsidies are offered in the residential sector.                                                                                                                                                                                                                                                                                        |
| Turkey         | No target. Turkey is one of the leading nations undertaking solar thermal installations.                                                                                                                                                                                                                                                           |
| United Kingdom | Had a target of 12% by 2020. Key initiatives include the Social Housing Net Zero Fund and banning new gas boilers from 2035.                                                                                                                                                                                                                       |
| United States  | No target. Various incentives, at the state level, across the residential, commercial, industrial, and public sectors.                                                                                                                                                                                                                             |

References: European Commission (2021a), International Energy Agency (2019), International Energy Agency (2020a), International Energy Agency (2021a), International Energy Agency (2021b), (IRENA et. al. 2020).

Note: See IEA 2021d: 117–121 for a summary of recent policy developments at the national level. REN21 (2021) (p23) summarizes the recent trends in global market sales.

16. European Commission (2021a) 'Commission presents renewable energy directive revision', [https://ec.europa.eu/info/news/commission-presents-renewable-energy-directive-revision-2021-jul-14\\_en](https://ec.europa.eu/info/news/commission-presents-renewable-energy-directive-revision-2021-jul-14_en).
17. International Energy Agency (2019) Energy Policies of IEA Countries: United Kingdom, IEA: Paris.
18. International Energy Agency (2020a) Germany 2020: Energy Policy Review, IEA: Paris.
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20. International Energy Agency (2021b) World Energy Outlook 2021, IEA: Paris.
21. (IRENA et. al. 2020) International Renewable Energy Agency, International Energy Agency & REN21 (2020) Renewable energy Policies in a Time of Transition: Heating and Cooling, IRENA, OECD/IEA and REN21.

## ENERGY EFFICIENCY TARGETS

The IEA estimates that the growth in the biofuel demand must quadruple to align with its 2050 Net Zero Emissions scenario. With a few exceptions (Saudi Arabia, Russia), most G20 countries have 'clean' fuel targets, including various mixes of biodiesel, bioethanol, and advanced biofuel targets. The leaders in 'clean' biofuel targets are Indonesia, India, and Brazil (20%–30%). In the USA, the Sustainable Aviation Challenge has set a goal of 11 billion litres of sustainable aviation fuel by 2030 (equivalent to 15% of the jet fuel demand) and changes to its main instrument (Renewable Fuel Standard) are under development (IEA 2021d: 90–91). The EU and its member states, Canada, and Mexico are in the next tier (10%–20%). The remaining nations have biodiesel and/or bioethanol targets of less than 5%.

However, although targets for biofuels are common, targets for the overall share of renewable energy in the transport sector are relatively uncommon at this point. The increasing use of electric vehicles increases the scope for renewable energy, but few nations have created a direct link between the two (REN 21: 75). Within the G20, only the European Union

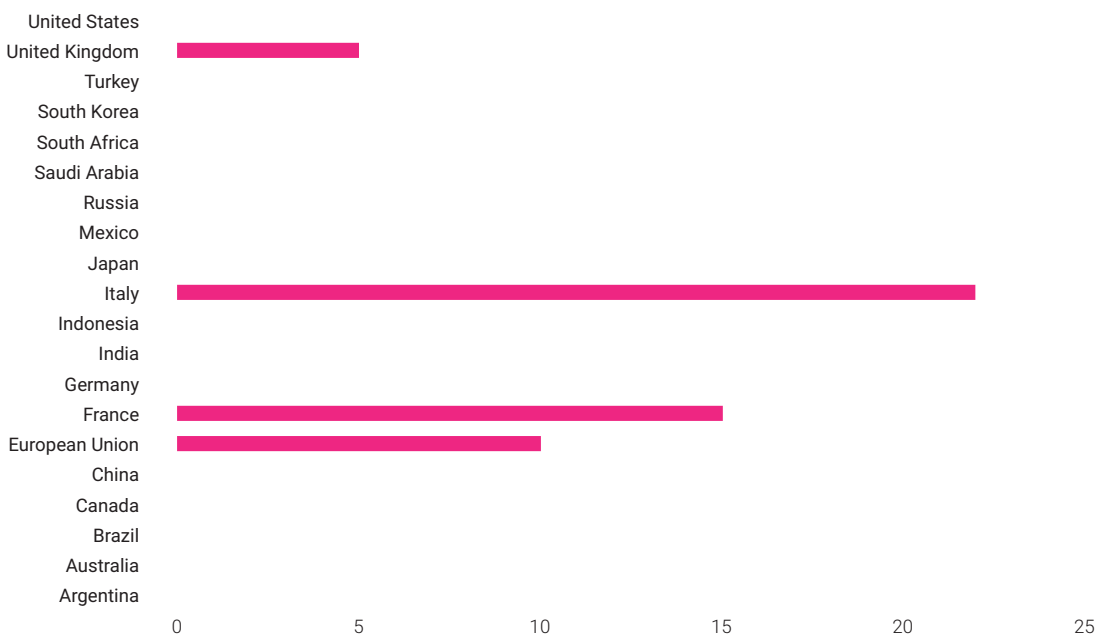
and a handful of its members have set targets for the use of renewable energy in transport. The European Union has increased its renewable energy target for transport from 10% (2009) to 14% by 2030 in Renewable Energy Directive II.

Most G20 nations have policies to increase the uptake of electric vehicles. However, only a handful of nations have commitments or targets to phase out cars with internal combustion engines: the United Kingdom (2030), Canada, and the EU (2035). As REN21 (2021) notes: 'Overall, the transport sector is not on track to meet global climate targets. Many countries still lack a holistic strategy for decarbonising transport'.

### Energy efficiency targets

Increased energy efficiency is an essential adjunct to the growth of renewable energy. Energy efficiency can reduce the cost, risk, and volume of renewable energy deployment required to achieve targets. IEA (2021a) listed the prioritization of energy efficiency as one of seven key principles required to maintain

FIGURE 8: Targets for renewable energy in transport (%), G20 nations



energy security through the ‘clean’ energy transition. Although most G20 nations have an energy efficiency target, most are voluntary, the levels of ambition are very uneven, and few

countries have targets to drive change within individual sectors (transport, buildings, industry). The range of energy efficiency targets is wide, as illustrated in Table 3.

**TABLE 3: Energy efficiency targets**

| Country        | Energy Efficiency Targets                                                                                                                                         |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Argentina      | Voluntary target of 8.8% improvement in energy efficiency on business as usual (BAU by 2030).                                                                     |
| Australia      | Voluntary target of 40% reduction in energy intensity by 2030.                                                                                                    |
| Brazil         | 10% reduction by 2030.                                                                                                                                            |
| Canada         | Voluntary target to increase the rate of energy efficiency improvement from 1% to 3% per annum by 2030.                                                           |
| China          | The 14th 5-year plan has a target to improve energy intensity by 13.5% by 2025.                                                                                   |
| European Union | The EU Energy Efficiency Directive has a target for 36% and 39% reductions in primary and final energy consumption (based on 2007 levels), respectively, by 2030. |
| France         | A 20% reduction in final energy consumption by 2030.                                                                                                              |
| Germany        | The National Action Plan on Energy Efficiency has a target of 50% reduction in primary energy consumption by 2050 (based on 2008 levels).                         |
| India          | 33%–35% reduction in energy intensity by 2030.                                                                                                                    |
| Indonesia      | Reduction in the energy/GDP ratio to < 1 by 2025.                                                                                                                 |
| Italy          | 125.1 MTOE (primary) and 103.8 (final) by 2030.                                                                                                                   |
| Japan          | 13% reduction in energy consumption against BAU by 2030—non-binding target to improve energy intensity by 1% per annum.                                           |
| Mexico         | 1.9% improvement in energy intensity by 2030 (based on 2016 levels).                                                                                              |
| Russia         | 56% reduction in energy intensity by 2030.                                                                                                                        |
| Saudi Arabia   | No target.                                                                                                                                                        |
| South Africa   | 29% reduction in energy intensity in the 2016 National Energy Efficiency Strategy.                                                                                |
| South Korea    | Energy intensity targets for industrial and building sectors.                                                                                                     |
| Turkey         | National Energy Efficiency Action Plan target to reduce primary energy consumption by 14% on BAU by 2023.                                                         |
| United Kingdom | 20% improvements in energy efficiency for business and industry by 2030.                                                                                          |
| United States  | Target to double energy productivity by 2030 (based on 2010 levels).                                                                                              |

References: Ashurst (2021)<sup>22</sup>, DMRE-SA (2019)<sup>23</sup>, Federated Republic of Brazil (2020)<sup>24</sup>, European Commission (2021b)<sup>25</sup>, International Energy Agency (2021c)<sup>26</sup>.

22. Ashurst (2021) PLN's New Green(er) RUPTL - Key Highlights, <https://www.ashurst.com/en/news-and-insights/legal-updates/plns-new-greener-ruptl-key-highlights/>.

23. DMRE-SA (2019), Department of Mineral Resources and Energy, South Africa (2019) Integrated Resource Plan 2019.

24. Federated Republic of Brazil (2020) Intended Nationally Determined Contribution Towards Achieving the Objective of the United Nations Framework on Climate Change.

<https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Brazil%20First/BRAZIL%20INDC%20english%20FINAL.pdf>

25. European Commission (2021b) 'Assessment of the final national climate and energy plan of Italy', [https://ec.europa.eu/energy/sites/ener/files/documents/staff\\_working\\_document\\_assessment\\_necp\\_italy.pdf](https://ec.europa.eu/energy/sites/ener/files/documents/staff_working_document_assessment_necp_italy.pdf).

26. International Energy Agency (2021c) Energy Efficiency 2021, IEA: Paris.

27. Bloomberg (2022) G20 Zero-Carbon Policy Scorecard 2022 Executive Summary.

## ENERGY EFFICIENCY TARGETS

The Global Commission for Urgent Action on Energy Efficiency recommends that governments be ‘significantly more ambitious’ in setting short- and long-term targets for energy efficiency and policy implementation (IEA 2021: 13).

### Energy storage targets

As the penetration of renewable electricity increases, one of the key priorities is the establishment of initiatives to integrate renewable energy using a suite of elements, including the transmission infrastructure, energy storage, demand-side flexibility, and the modernization of the electricity system to maintain supply security. The energy transition will only be successful if energy affordability and security are maintained as grids and markets are transformed during the adoption of renewable energy. The IEA (2021) has produced a report on energy security in the context of ‘clean’ energy transitions. The progress of the G20 on energy storage has been modest. Thirteen G20 nations have implemented energy storage initiatives, but six are only at a regional level (Bloomberg 2022 : 5). India and South Africa are incorporating storage into their renewable energy auctions. At present, only one G20 nation (Italy) has an energy storage target.



Carnsore Wind Farm, Ireland.  
© shutterstock.com /4H4 Photography

The energy transition will only be successful if energy affordability and security are maintained as grids and markets are transformed during the adoption of renewable energy.



# G20

## Energy Sector: Trends & Target Mapping

# 02

Solar panels, China.  
© Istockphoto.com/  
shansekala



The diversity of the G20 countries is significant in economic terms, as well as geographically and in terms of their energy demand and supply situations. For a comprehensive analysis of the energy sector of the G20 group, a bottom-up analysis that includes all countries is required.

The total remaining carbon budget to limit global warming to 1.5°C (67% likelihood), assumed for the mapping of renewable energy targets, is 400 GtCO<sub>2</sub> between 2020 and 2050, according to the IPCC AR6<sup>28</sup> report published in 2021. According to the OECD<sup>29</sup>, the G20 was responsible for 80% of the global energy-related carbon emissions in 2021. Therefore, the carbon budget remaining for the G20 member states is assumed to be 320 GtCO<sub>2</sub> (2020–2050).

To develop a renewable energy target for the G20, the trends in energy demand and supply for the past 15 years (2005–2020), based on the IEA World Energy Balances, have been analysed. Based on this analysis, two projections have been calculated:

**1. Trend projection:** The trends of the past 15 years—in terms of both energy demand and supply—would continue for the next 30 years, until 2050. The average growth rates for coal-, gas-, and oil-based electricity, heat generation, and transport fuel supply would continue and renewables would provide the remaining energy to meet the demand. In this projection, fossil fuels have priority over renewable

energy—so increased use of fossil fuels might push renewables out of the market. Renewables would only be deployed if the overall energy demand is not met with the projected growth in fossil fuels.

**2. Target projection:** The energy demand develops according to the trend minus a 1.5% efficiency gain. Fossil fuels for electricity and heat generation and to supply the transport demand are phase-out. The average annual decline factors for oil, gas and coal (Table 4) are based on a global 1.5°C pathway<sup>30</sup>. The entire gap between the demand and—declining—fossil fuels would be supplied with renewables. A detailed breakdown by renewable energy technologies has not been calculated. The rate of fossil fuel decline is higher for industrialized countries than for developing countries. The resulting average for the entire G20 is shown in the table below.

The historical development analysis and the two projections have been undertaken for the overall primary energy, heat, transport, and electricity demands. These demands are provided for the three main sectors: industry, transport, and ‘other sectors’. The category ‘other sectors’ is dominated by buildings, but also includes agriculture, forestry, and fisheries. The structure of this analysis is based on the IEA Advanced World Energy Balances<sup>31</sup>.

**TABLE 4:** Projected average decline rates for fossil fuels necessary to remain within a 1.5°C scenario

| 1.5 °C Scenario<br>Carbon Budget 2020–2050:<br>400 GtCO <sub>2</sub> | Average annual<br>rate of decline:<br>2021–2030 | Average annual<br>rate of decline:<br>2031–2050 | Average annual<br>rate of decline:<br>2021–2030 | Average annual<br>rate of decline:<br>2031–2050 | Average annual<br>rate of decline:<br>2021–2030 | Average annual<br>rate of decline:<br>2031–2050 |
|----------------------------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
|                                                                      | Industrialized Countries                        |                                                 | Developing Countries                            |                                                 | G20 average                                     |                                                 |
| Coal                                                                 | –9.5%/a                                         | –5.0%/a                                         | –5.5%/a                                         | –5.5%/a                                         | –6.8%/a                                         | –8.1%/a                                         |
| Gas                                                                  | –3.5%/a                                         | –9.0%/a                                         | –3.5%/a                                         | –9.0%/a                                         | –3.5%/a                                         | –9.0%/a                                         |
| Oil                                                                  | –8.5%/a                                         | –6.0%/a                                         | –5.5%/a                                         | –6.0%/a                                         | –6.7%/a                                         | –8.0%/a                                         |

28. IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Masson-Delmotte V, Zhai P, Pirani A, Connors SL, Péan C, Berger S, Caud N, Chen Y, Goldfarb L, Gomis MI, Huang M, Leitzell K, Lonnoy E, Matthews JBRs, Maycock TK, Waterfield T, Yelekçi O, Yu R, and Zhou B (eds). Cambridge University Press.

29. OECD 2021: G20 economies are pricing more carbon emissions but stronger globally more coherent policy action is needed to meet climate

goals, says OECD; <https://www.oecd.org/tax/g20-economies-are-pricing-more-carbon-emissions-but-stronger-globally-more-coherent-policy-action-is-needed-to-meet-climate-goals-says-oecd.htm>

30. Teske S, Niklas S (2021). Fossil Fuel Exit Strategy: An orderly wind down of coal, oil and gas to meet the Paris Agreement, June 2021.

31. IEA. IEA World Energy Statistics and Balances. IEA. 2021. Available online: <https://doi.org/https://doi.org/10.1787/enestats-data-en> (accessed on March 2022).



**TABLE 5:** Assumed emission factors by fossil fuel

| Fuel      | Units                  | Emission factor |
|-----------|------------------------|-----------------|
| Lignite   | kT CO <sub>2</sub> /PJ | 101             |
| Hard coal | kT CO <sub>2</sub> /PJ | 93              |
| Oil       | kT CO <sub>2</sub> /PJ | 75              |
| Gas       | kT CO <sub>2</sub> /PJ | 56              |

In a last step, the energy-related CO<sub>2</sub> emissions for the historical and projected primary fossil fuel demands have been calculated with emission factors (Table 5). Both projections are by no means scenarios, but only trajectories calculated on the basis of fixed annual percentages of growth and decline.

This method was chosen to narrow the possible targets for renewable energies without having to calculate complete energy scenarios. The ‘Trend’ and ‘Target’ projections are not as exact as a detailed energy scenario and therefore do not replace detailed energy scenarios.

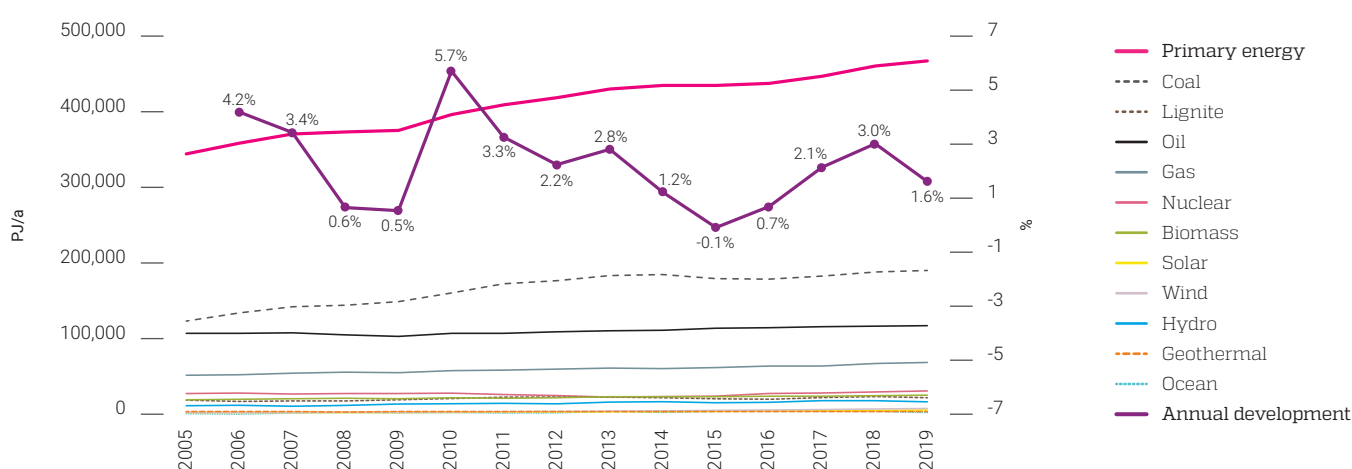
**This will be the next necessary step in the development of detailed individual goals for all G20 countries.**

## G20: Renewable Target Mapping

The combined energy demand and supply development for the G20, the G7, and member countries are described in this section. The primary energy supply, final energy consumption, electricity and heat generation, and the development of transport energy between 2005 and 2019 are documented and the two projections—*Trend* and *Target*—provide an overview of whether countries are on track to decarbonize their energy sectors or whether changes are required.

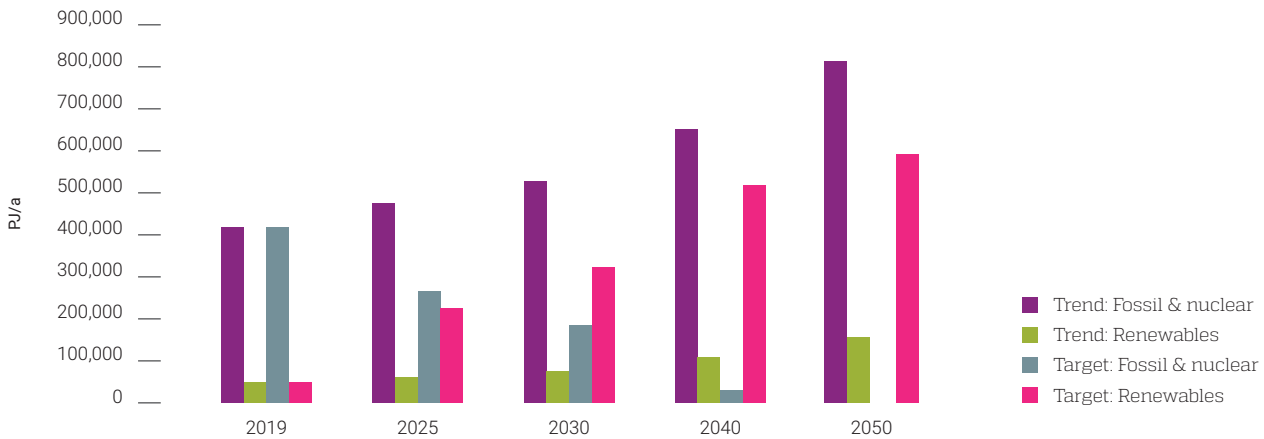
### Primary Energy Supply

Figure 9 shows the development of the primary energy supply in total and by source for the G20 as a whole between 2005 and 2019. All the renewable energies combined showed only minor growth, whereas nuclear remained stable. The main fuel source that supplied the increased energy demand was coal, followed by natural gas and oil. The annual deviation in the combined G20 primary energy demand alternated between -0.1% in 2015 and +5.7% in the year of recovery after the global financial crisis in 2010. On average, the energy demand grew by 2.3% per year in G20 countries.

**FIGURE 9:** G20—Primary energy supply—development in 2005–2019

## G20: RENEWABLE TARGET MAPPING

**FIGURE 10: G20—Primary energy supply—‘Trend’ versus ‘Target’**



A continuation of the primary energy development trend of the past 15 years until 2050 would lead to a doubling of energy demand, with fossil fuels supplying 84% compared with 90% of total primary energy demand in 2019. Under such a trajectory, renewable energies would remain a niche source of supply, even though the overall renewable energy generation would increase from around 50 EJ in 2019 to just over 150 EJ in 2050. Therefore, if current trends are continued into the future, renewable energy would cover only slightly more than the anticipated increase in demand, and the required replacement of fossil fuels will not be achieved. Furthermore, G20 energy imports would increase substantially accordingly.

Under the second trajectory, in which fossil fuels are phased-out by 2050 at the assumed annual decline rates (Table 4), the contributions of coal and oil would decrease by 40% by 2030 and be replaced by renewables. Then 64% of the G20's primary energy would come from renewables, increasing to 96% in 2040 and 100% in 2050. The share of imported energy—across all G20 countries—would fall significantly because of the structure of the regional renewable energy

supply. The majority of imported energy would be derived from renewably-produced hydrogen, ammonia, and synthetic fuels to power industrial processes, heating, aviation, and shipping. However, projections do not replace energy scenarios, which were beyond the scope of this assessment. The 1.5°C energy pathways published by the authors (Teske et al. 2019)<sup>32</sup> predict that renewables will have a 38% share of primary energy in China in 2030 and 47% globally.

### G7: Primary energy supply

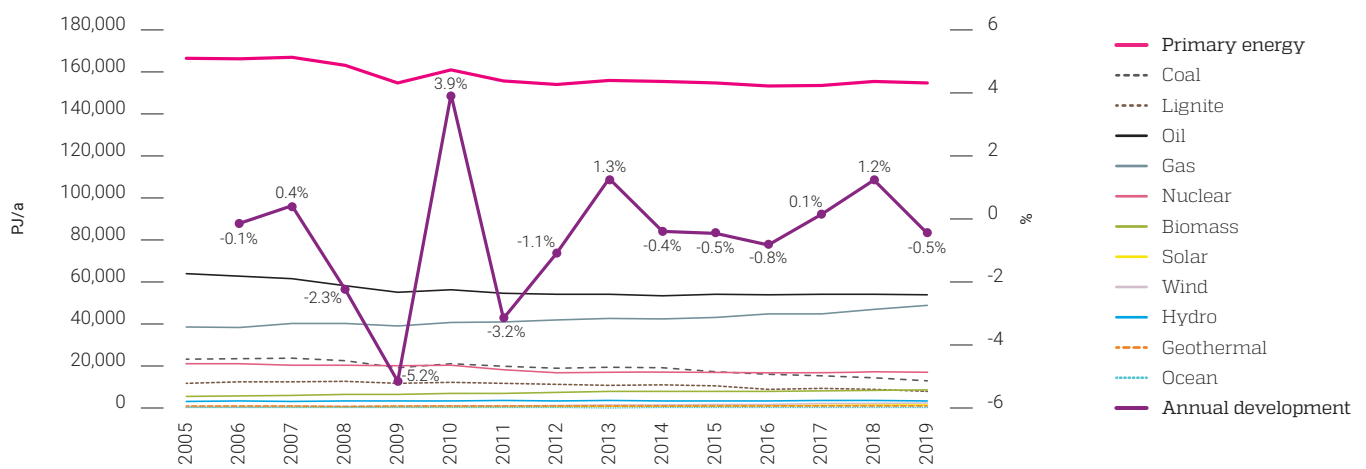
The G7 countries Canada, France, Germany, Italy, Japan, United Kingdom, the United States, and the European Union have no members from developing countries, so the changes over the past 15 years have been minor in terms of the overall primary energy supply. In fact, the total primary energy demand has decreased by 0.5% per year on average since 2005. In terms of fossil fuels, the demands for coal and lignite have also decreased, whereas the demands for gas and renewables—especially solar and wind—have increased accordingly. Under the *Trend* projection, fossil fuels will

32. Teske et al. (2019). Energy Scenario Results. In: Teske S (ed.) Achieving the Paris Climate Agreement Goals. Springer, Cham. [https://doi.org/10.1007/978-3-030-05843-2\\_8](https://doi.org/10.1007/978-3-030-05843-2_8)

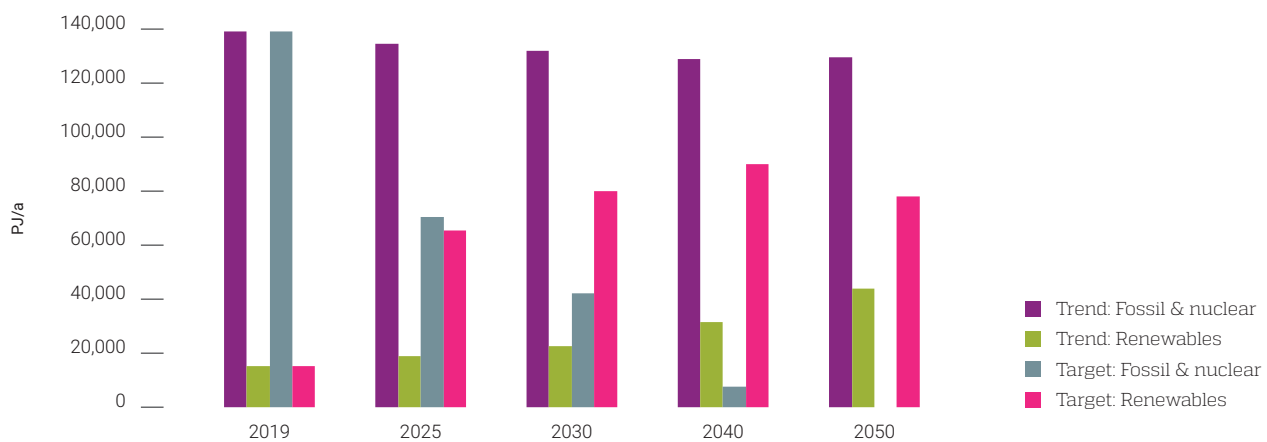
decline slowly and renewable energy will double to a share of 25% by 2050, which is insufficient to meet the climate targets.

Under the *Target* projection, the renewable energy share will jump from 10% in 2019 to 66% in 2030 and to 92% by 2040.

**FIGURE 11: G7—Primary energy supply—development in 2005-2019**



**FIGURE 12: G7—Primary energy supply—‘Trend’ versus ‘Target’**



## G20: RENEWABLE TARGET MAPPING

### Primary energy supplies in G7 and G20 member countries

An analysis of the G20 member countries shows significant differences in their energy supply structures. The highest renewable energy share in the primary energy supply is in Brazil, at 47%, and the lowest is in Saudi Arabia, at only 0.02%. On average, today renewable energy contributes 10% of the primary energy of the G20. Table 6 shows the current renewable energy shares of all G20 member countries and in the two projections until 2050. Under the *Trend* projection, only the EU27 and three European G20 member countries (France, Germany, and Italy) will triple their renewable energy supply share, but will still fail to decarbonize, with fossil fuels still providing more than half the remaining energy demands.

The continuation of the *Trend* in the United Kingdom and the USA will double, leading to fossil fuel supply shares of 76% and 82%, respectively. All other countries will either stabilize their shares of renewable energy to 2019 values or even reduce them. Under the *Target* projection, all countries can significantly increase their renewable energy shares to an accumulated number of 64% of primary energy supply by 2030—across the G20, with significant regional differences. The current share of renewable energies in primary energy demand is around 8% in both Mexico and Australia. While Australia would reach 64% renewable energy under the ‘*Target*’ projection, Mexico would reach only 47% by 2030. The assumed annual rates of decline for oil—minus 8.5% between 2019 and 2030—and gas (–3.5% per annum.) will lead to a

**TABLE 6:** Renewable energy contributions to the primary energy supply in member countries of the G7 and G20

|                                         |      |            | Trend<br>Fossil<br>priority | Target<br>RE<br>priority | Trend<br>Fossil<br>priority | Target<br>RE<br>priority | Trend<br>Fossil<br>priority | Target<br>RE<br>priority | Trend<br>Fossil<br>priority | Target<br>RE<br>priority |
|-----------------------------------------|------|------------|-----------------------------|--------------------------|-----------------------------|--------------------------|-----------------------------|--------------------------|-----------------------------|--------------------------|
| Renewable energy share - Primary energy | Unit | 2019       | 2025                        | 2030                     | 2040                        | 2050                     |                             |                          |                             |                          |
| Argentina (G20)                         | %    | 9%         | 9%                          | 33%                      | 9%                          | 47%                      | 10%                         | 90%                      | 10%                         | 100%                     |
| Australia (G20)                         | %    | 7%         | 8%                          | 47%                      | 8%                          | 64%                      | 8%                          | 93%                      | 8%                          | 100%                     |
| Brazil (G20)                            | %    | 47%        | 47%                         | 65%                      | 47%                         | 75%                      | 46%                         | 93%                      | 45%                         | 100%                     |
| Canada (G20) & (G7)                     | %    | 17%        | 16%                         | 44%                      | 15%                         | 58%                      | 14%                         | 93%                      | 13%                         | 100%                     |
| China (G20)                             | %    | 10%        | 9%                          | 48%                      | 8%                          | 66%                      | 6%                          | 97%                      | 4%                          | 100%                     |
| EU27 (G20) & (G7)                       | %    | 16%        | 21%                         | 42%                      | 26%                         | 55%                      | 36%                         | 91%                      | 48%                         | 100%                     |
| France (G20) & (G7)                     | %    | 11%        | 14%                         | 34%                      | 17%                         | 47%                      | 24%                         | 93%                      | 33%                         | 100%                     |
| Germany (G20) & (G7)                    | %    | 15%        | 22%                         | 49%                      | 28%                         | 61%                      | 42%                         | 91%                      | 57%                         | 100%                     |
| India (G20)                             | %    | 26%        | 24%                         | 38%                      | 22%                         | 49%                      | 19%                         | 96%                      | 17%                         | 100%                     |
| Indonesia (G20)                         | %    | 13%        | 11%                         | 44%                      | 10%                         | 64%                      | 7%                          | 89%                      | 5%                          | 100%                     |
| Italy (G20) & (G7)                      | %    | 19%        | 26%                         | 37%                      | 33%                         | 46%                      | 48%                         | 87%                      | 63%                         | 100%                     |
| Japan (G7 & G20)                        | %    | 6%         | 8%                          | 37%                      | 9%                          | 52%                      | 11%                         | 88%                      | 13%                         | 100%                     |
| South Korea (G20)                       | %    | 2%         | 3%                          | 47%                      | 5%                          | 66%                      | 8%                          | 95%                      | 15%                         | 100%                     |
| Mexico (G20)                            | %    | 9%         | 8%                          | 32%                      | 7%                          | 46%                      | 5%                          | 86%                      | 4%                          | 100%                     |
| Russia (G20)                            | %    | 3%         | 3%                          | 36%                      | 3%                          | 52%                      | 2%                          | 94%                      | 2%                          | 100%                     |
| Saudi Arabia (G20)                      | %    | 0.02%      | 0%                          | 47%                      | 0%                          | 67%                      | 2%                          | 94%                      | 9%                          | 100%                     |
| South Africa (G20)                      | %    | 7%         | 6%                          | 34%                      | 6%                          | 51%                      | 6%                          | 78%                      | 5%                          | 100%                     |
| Turkey (G20)                            | %    | 15%        | 16%                         | 49%                      | 16%                         | 66%                      | 17%                         | 92%                      | 18%                         | 100%                     |
| United Kingdom (G20) & (G7)             | %    | 13%        | 15%                         | 48%                      | 16%                         | 64%                      | 20%                         | 90%                      | 24%                         | 100%                     |
| United States of America (G20) & (G7)   | %    | 8%         | 10%                         | 37%                      | 11%                         | 51%                      | 15%                         | 91%                      | 18%                         | 100%                     |
| <b>G7</b>                               | %    | <b>10%</b> | <b>12%</b>                  | <b>48%</b>               | <b>15%</b>                  | <b>66%</b>               | <b>20%</b>                  | <b>92%</b>               | <b>25%</b>                  | <b>100%</b>              |
| <b>G20</b>                              | %    | <b>10%</b> | <b>12%</b>                  | <b>46%</b>               | <b>13%</b>                  | <b>64%</b>               | <b>14%</b>                  | <b>95%</b>               | <b>16%</b>                  | <b>100%</b>              |

significant jump in the renewable energy supply from < 1% in Saudi Arabia in 2019 to 47% in 2025 and 74% in 2030. This increase might not be possible within the very short time frame, and a detailed energy scenario for Saudi Arabia is required to set renewable energy targets. However, the required decarbonization trajectory required to remain within the carbon budget means that the necessary uptake of renewables is significant.

## Final energy consumption

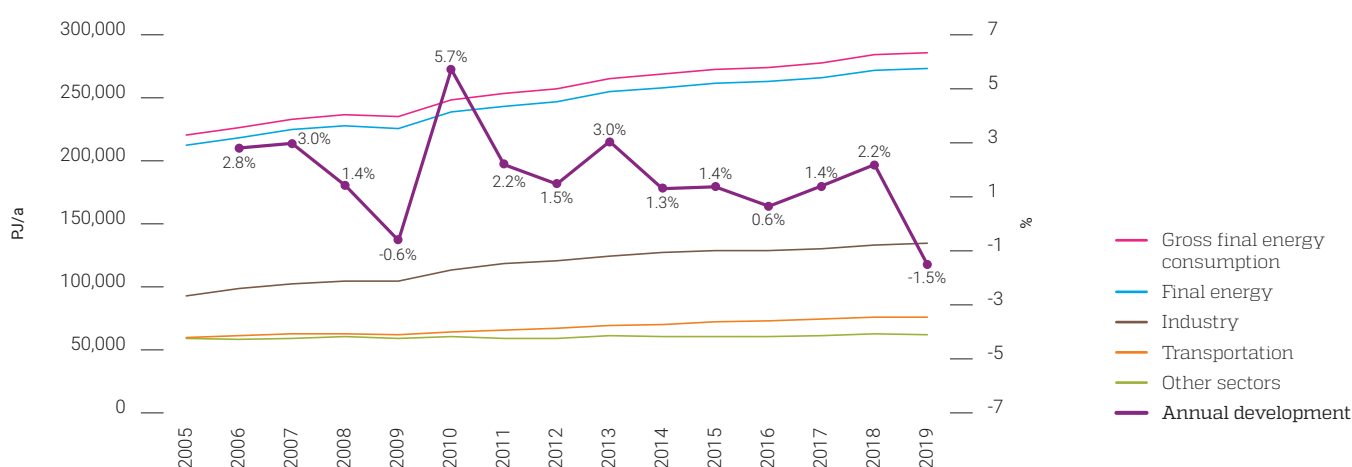
The statistical office of the European Union, Eurostat, defines ‘final energy consumption’ as the ‘total energy consumed by end users, such as households, industry and agriculture. It is the energy which reaches the final consumer’s door and excludes that which is used by the energy sector itself<sup>33</sup>. The IEA Advanced World Energy Balance distinguishes between three sectors: *industry*, *transport*, and *other sectors*. *Other sectors* are dominated by

the energy demand of buildings—electricity and heating—but also includes agriculture, forestry, and fisheries.

The overall final energy consumption follows the same pattern as the primary energy demand. Figure 13 shows the sectoral breakdown of the final energy consumption into industry, other sectors (buildings), and transport. The industry sector is responsible for the majority of the increase in the energy demand in the G20 group. The energy demand for transport also increased, whereas that of the residential sector has remained stable over the past 15 years, with an increase in developing countries and a reduction in industrialized countries.

A continuation of the energy growth trend of 1.9% per year will increase the final energy consumption from 285 EJ in 2019 to 491 EJ in 2050, whereas annual efficiency gains of 1.5% will stabilize the energy demand, with only a minor increase (an additional 35 EJ) over the next 30 years.

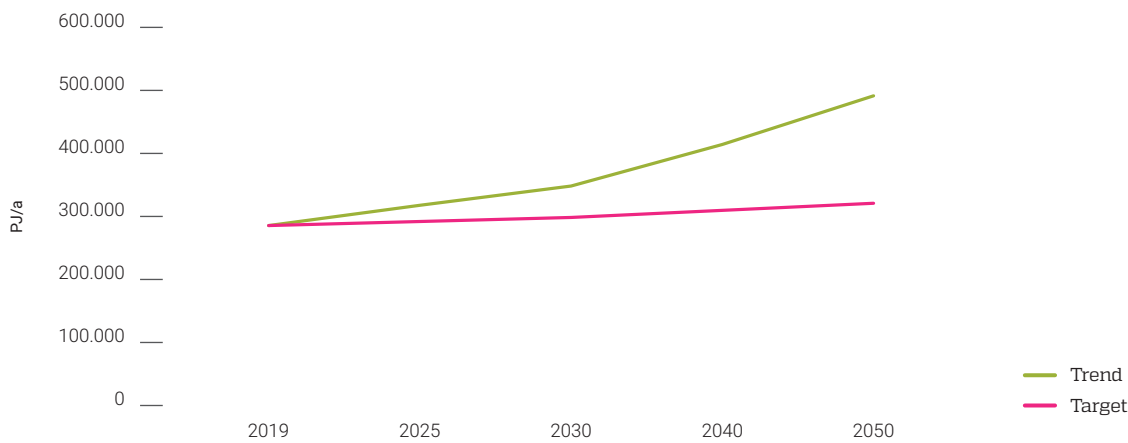
**FIGURE 13: G20—Final energy consumption—development in 2005-2019**



33. Eurostat website—glossary accessed in May 2022; [https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Final\\_energy\\_consumption](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Final_energy_consumption)

# FINAL ENERGY CONSUMPTION

FIGURE 14: G20—Final energy consumption—“Trend” versus “Target”



## G7—Final energy consumption

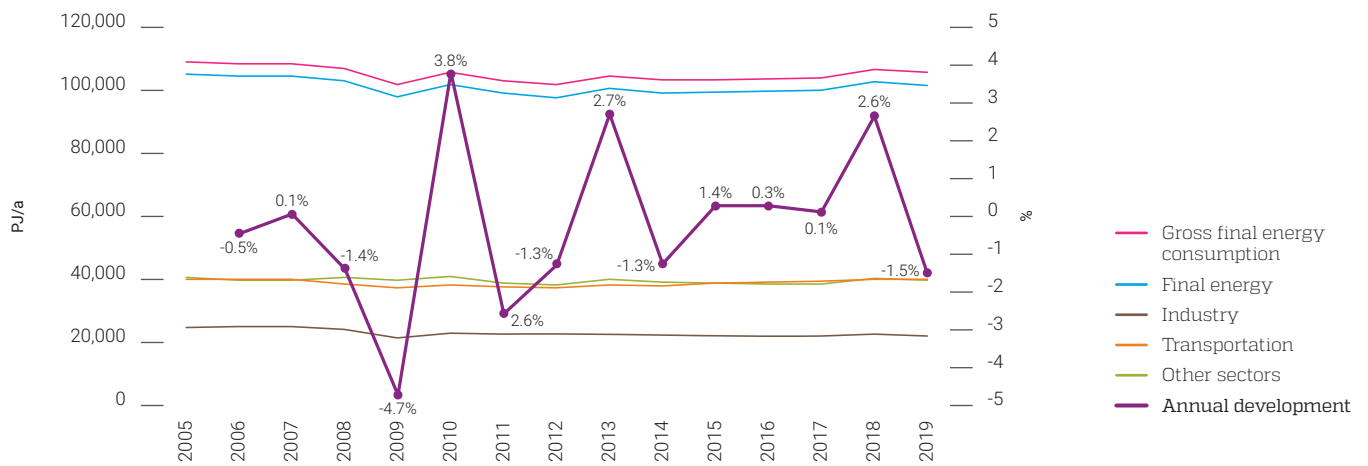
The final energy consumption of the G7 mirrors the development of primary energy over the past 15 years; the energy demands of all sectors stabilized, and any deviation depended, to a large extent, on the annual economic development. The Global Financial Crisis in 2009 led to an overall reduction of 4.7% in 2009, but the energy demand

jumped back to almost the pre-crisis level in the following year (2010). The *Trend* projection continues the very minor decline in the overall energy demand, leading to very little change until the end of the projection period in 2050.

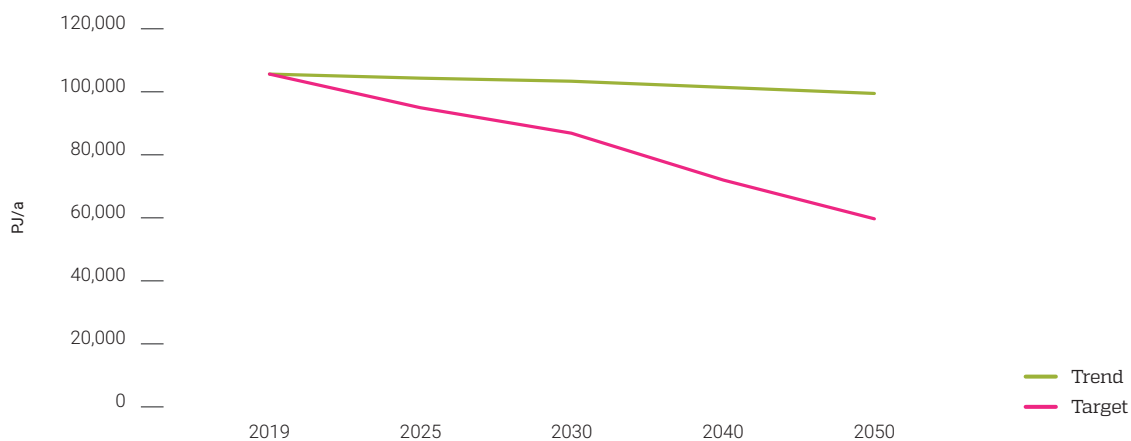
The *Target* projection leads to a decline in the final energy consumption of around 40%—with efficiency gains in all three main sectors: industry, buildings, and transport.



**FIGURE 15: G7—Final energy consumption—development in 2005–2019**



**FIGURE 16: G7—Final energy consumption—‘Trend’ versus ‘Target’**



# FINAL ENERGY CONSUMPTION

## Final energy consumption in G7 and G20 member countries

The final energy statistics include the demand sector but exclude losses, and therefore allow policy makers to set sector-specific energy demand targets for industry, transport, and buildings. A combination of efficiency targets and renewable energy targets is recommended to achieve the cost-efficient decarbonization of the energy sector. Table 7 shows the final energy consumption, in petajoule per year, for the three main sectors for 2019 and 2030 under the *Trend* and *Target* projections for all G20 member countries and the European Union. Breakdowns by electricity, heating, and transport fuels are further specified in Table 8 to Table 10.

## Electricity demand

Only a limited projection of the electricity demand is possible because the calculation of a detailed scenario is required to determine an exact value. In this simplified projection, development to the year 2050 is calculated for the *Trend* projection from the average annual electricity demand development (as a percentage) of the past 15 years. The *Target* projection subtracts 1.5% annually from the *Trend* value to represent the average efficiency gain. Furthermore, it is assumed that by 2030, 33% of the heating supply will be satisfied by electricity, whereas the electrification rate of the transport sector will increase to 70%.

Figure 18 shows the development of electricity generation under the *Trend* projection and the *Target* projection without

**TABLE 7:** Final energy consumption sector in member countries of the G7 and G20

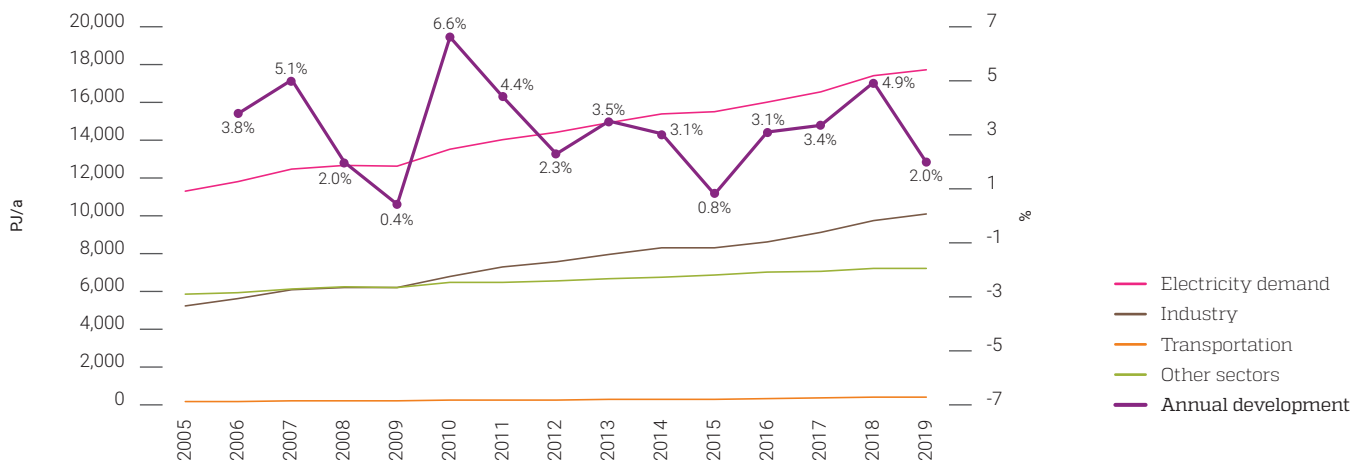
| Final energy by sector                | Unit | 2019           |               |               | Trend          |                | Target        |               | Trend         |               | Target |  |
|---------------------------------------|------|----------------|---------------|---------------|----------------|----------------|---------------|---------------|---------------|---------------|--------|--|
|                                       |      | Industry       | Other sectors | Transport     | No             | 1.5%           | No            | 1.5%          | No            | 1.5%          |        |  |
|                                       |      |                |               |               | efficiency     | efficiency     | efficiency    | efficiency    | efficiency    | efficiency    |        |  |
|                                       |      |                |               |               | 2030           |                | 2030          |               | 2030          |               |        |  |
|                                       |      |                |               |               | Industry       | Other Sectors  | Transport     |               |               |               |        |  |
| Argentina (G20)                       | PJ/a | 560            | 902           | 754           | 660            | 564            | 1,063         | 908           | 888           | 759           |        |  |
| Australia (G20)                       | PJ/a | 927            | 881           | 1,417         | 1,028          | 873            | 977           | 830           | 1,572         | 1,335         |        |  |
| Brazil (G20)                          | PJ/a | 3,098          | 2,237         | 3,610         | 3,903          | 3,351          | 2,819         | 2,420         | 4,548         | 3,905         |        |  |
| Canada (G20) & (G7)                   | PJ/a | 1,969          | 2,970         | 2,847         | 2,106          | 1,784          | 3,177         | 2,690         | 3,045         | 2,579         |        |  |
| China (G20)                           | PJ/a | 42,934         | 23,919        | 13,660        | 63,201         | 54,907         | 35,210        | 30,590        | 20,109        | 17,470        |        |  |
| EU27 (G20) & (G7)                     | PJ/a | 10,044         | 16,539        | 12,120        | 9,542          | 7,995          | 15,714        | 13,165        | 11,515        | 9,647         |        |  |
| France (G20) & (G7)                   | PJ/a | 1,151          | 2,677         | 1,893         | 1,061          | 887            | 2,468         | 2,062         | 1,745         | 1,458         |        |  |
| Germany (G20) & (G7)                  | PJ/a | 2,333          | 3,653         | 2,378         | 2,278          | 1,913          | 3,567         | 2,996         | 2,322         | 1,951         |        |  |
| India (G20)                           | PJ/a | 10,156         | 9,665         | 4,397         | 16,076         | 14,039         | 15,297        | 13,359        | 6,960         | 6,078         |        |  |
| Indonesia (G20)                       | PJ/a | 2,448          | 1,651         | 2,274         | 3,583          | 3,106          | 2,417         | 2,095         | 3,329         | 2,886         |        |  |
| Italy (G20) & (G7)                    | PJ/a | 1,048          | 2,086         | 1,501         | 909            | 755            | 1,810         | 1,503         | 1,302         | 1,082         |        |  |
| Japan (G7 & G20)                      | PJ/a | 3,408          | 3,989         | 2,903         | 2,893          | 2,397          | 3,385         | 2,805         | 2,463         | 2,042         |        |  |
| South Korea (G20)                     | PJ/a | 1,976          | 1,901         | 1,535         | 2,260          | 1,925          | 2,175         | 1,852         | 1,755         | 1,495         |        |  |
| Mexico (G20)                          | PJ/a | 1,409          | 1,166         | 2,095         | 1,534          | 1,301          | 1,270         | 1,077         | 2,281         | 1,935         |        |  |
| Russia (G20)                          | PJ/a | 6,108          | 8,114         | 4,151         | 6,894          | 5,865          | 9,158         | 7,791         | 4,685         | 3,986         |        |  |
| Saudi Arabia (G20)                    | PJ/a | 1,588          | 976           | 1,908         | 2,346          | 2,039          | 1,442         | 1,253         | 2,819         | 2,450         |        |  |
| South Africa (G20)                    | PJ/a | 1,001          | 903           | 804           | 1,094          | 929            | 986           | 837           | 879           | 746           |        |  |
| Turkey (G20)                          | PJ/a | 1,295          | 1,681         | 1,174         | 1,859          | 1,612          | 2,414         | 2,094         | 1,686         | 1,462         |        |  |
| United Kingdom (G20) & (G7)           | PJ/a | 893            | 2,417         | 1,722         | 807            | 673            | 2,186         | 1,823         | 1,558         | 1,299         |        |  |
| United States of America (G20) & (G7) | PJ/a | 11,221         | 21,989        | 26,682        | 11,431         | 9,638          | 22,401        | 18,888        | 27,182        | 22,919        |        |  |
| <b>G7</b>                             | PJ/a | <b>22,022</b>  | <b>39,781</b> | <b>39,926</b> | <b>21,544</b>  | <b>18,099</b>  | <b>38,918</b> | <b>32,694</b> | <b>39,060</b> | <b>32,813</b> |        |  |
| <b>G20</b>                            | PJ/a | <b>134,771</b> | <b>62,207</b> | <b>75,964</b> | <b>164,176</b> | <b>140,560</b> | <b>75,780</b> | <b>64,879</b> | <b>92,539</b> | <b>79,227</b> |        |  |

electrification, and the additional electricity demand for electrification in the heating and transport sectors. The electricity demand is expected to increase significantly with the growing decarbonization of the energy sector due to the high electrification rate.

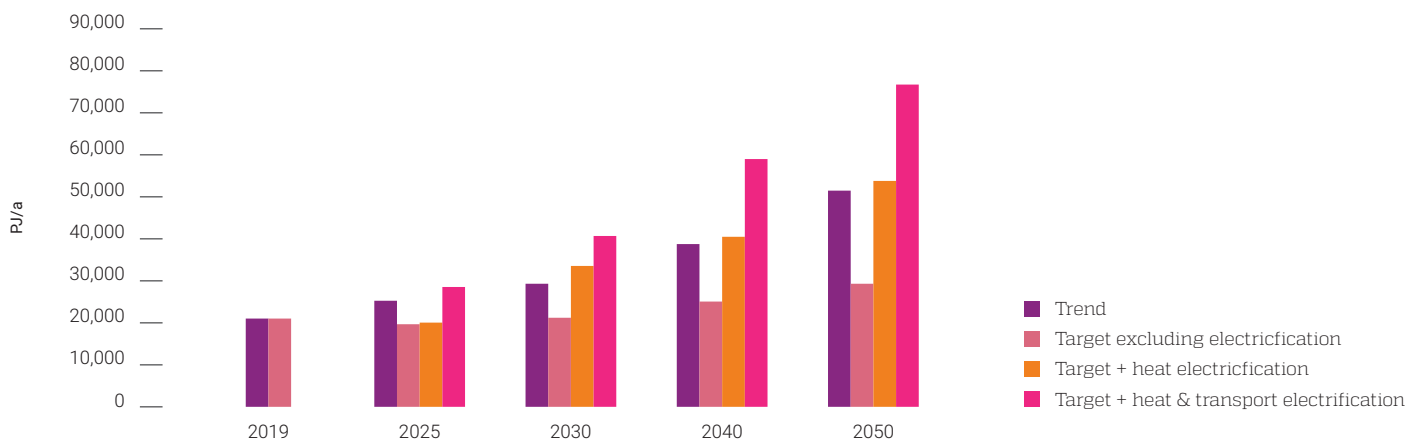
### G7—Electricity demand

G7 member states have been industrial countries for decades, and the development of their economies has stabilized, with smaller growth rates than in developing

**FIGURE 17: G20—Electricity demand by sector—development in 2005-2019**



**FIGURE 18: G20—Electricity demand—‘Trend’ versus ‘Target’**



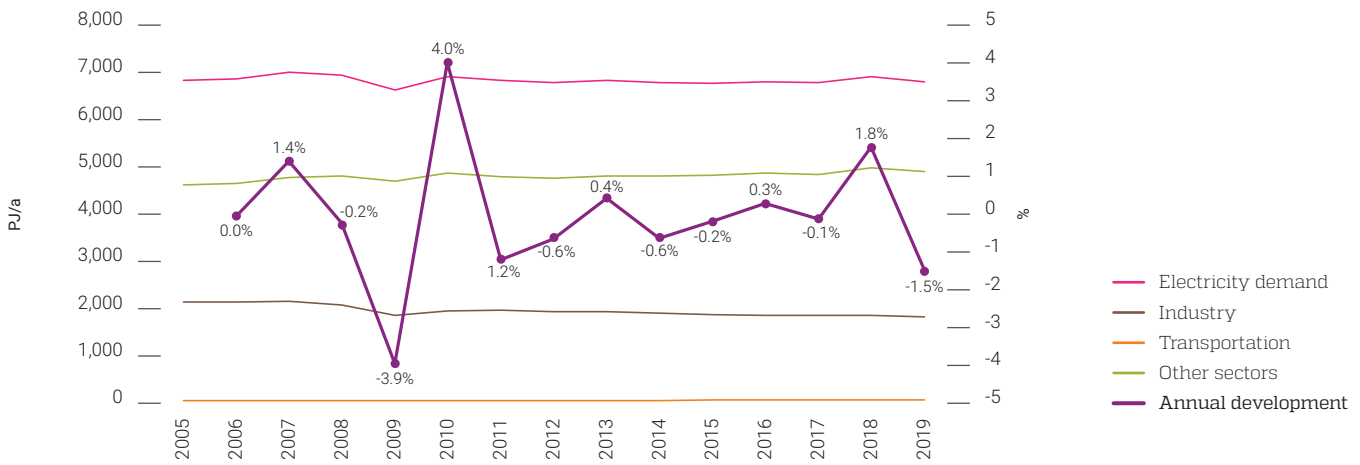
## ELECTRICITY DEMAND

countries, such as India and Indonesia. Therefore, the 2019 electricity demand did not increase at all relative to the 2005 demand (Figure 19). Fluctuations are within the range of economic cycles and are also influenced by weather patterns, such a cold winter or a hot summer, which require more electricity for climatization that a mild winter or cool

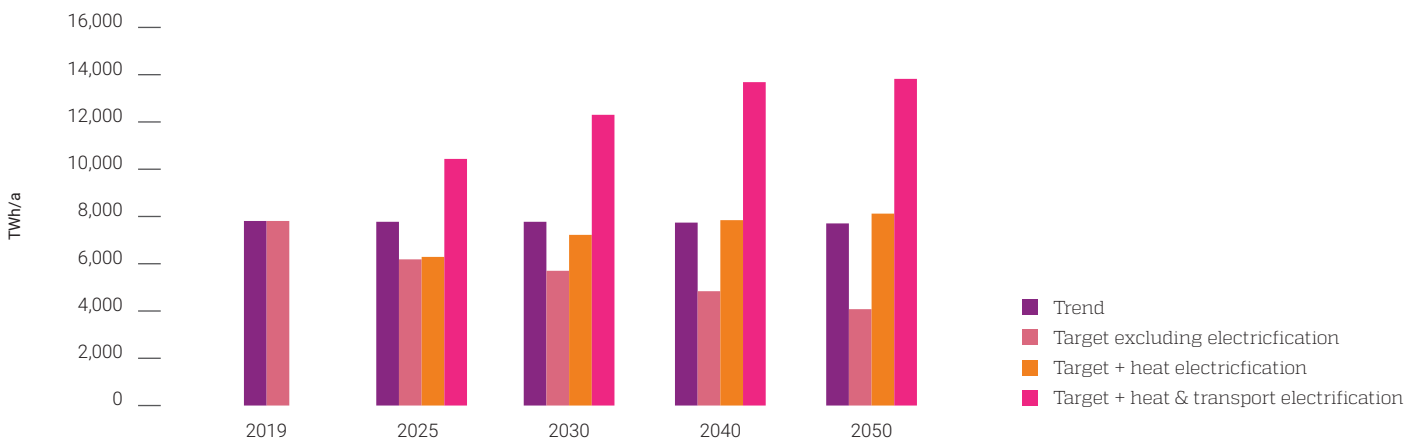
summer. However, future electricity demand is expected to increase under the *Target* projection with higher electrification rates for the heating and transport sectors.

Figure 20 shows the increase in the electricity demand from just under 8,000 TWh per year in 2019 to 13,800 TWh in 2050 under the assumption of full electrification.

**FIGURE 19: G7—Electricity demand by sector—development in 2005-2019**



**FIGURE 20: G7—Electricity demand—“Trend” versus “Target”**

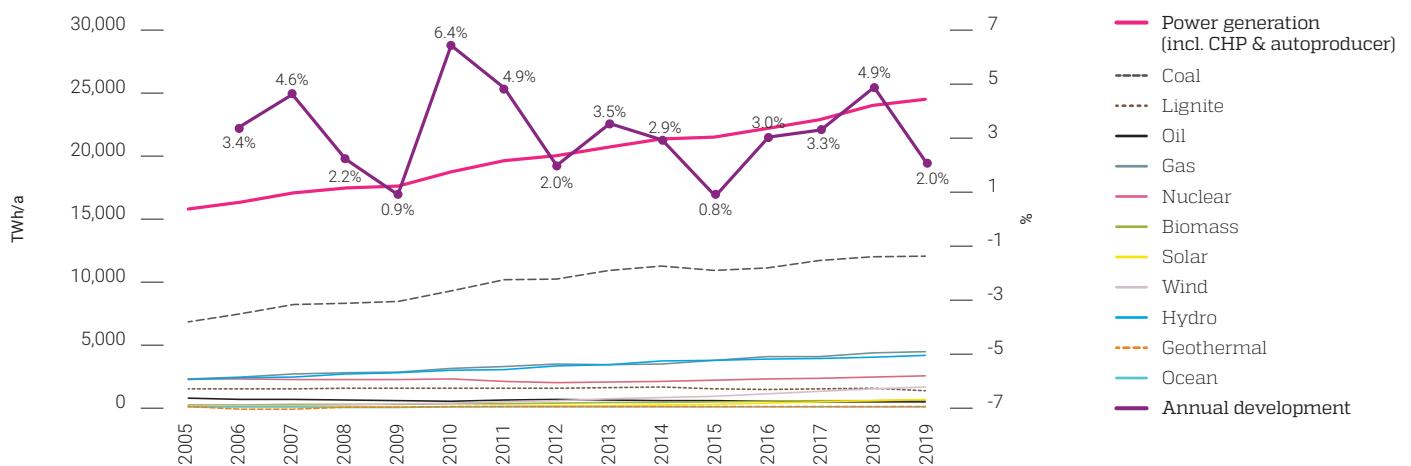


## Electricity generation

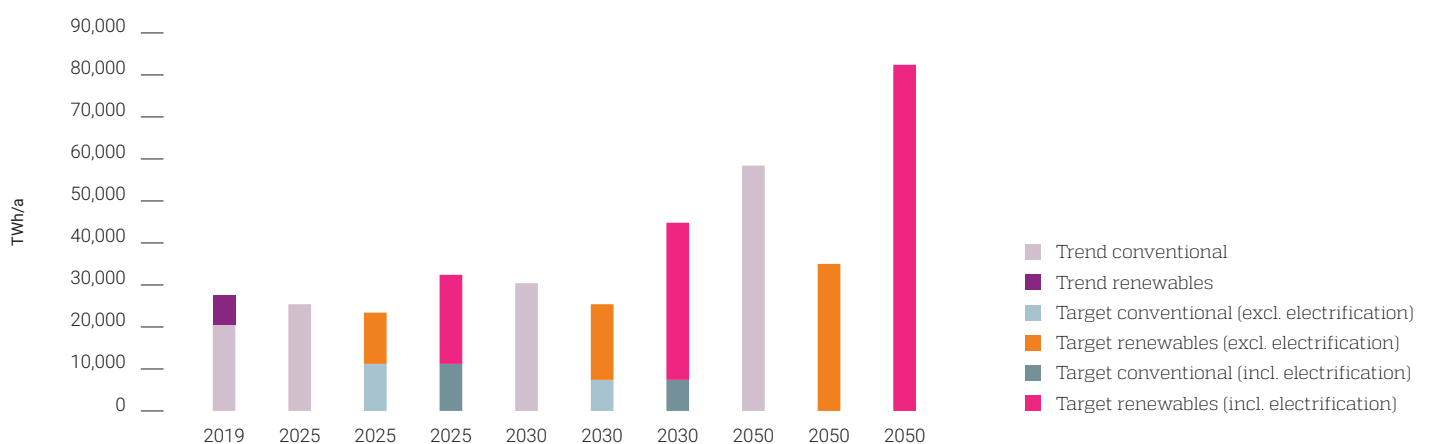
The projected electricity generation mix is based on the electricity demand projections. Figure 21 shows that the majority of the increased electricity demand was supplied by additional coal power plants across the G20 countries in

the years leading up to 2019. This is attributable to the sharp increase in coal power plants in China alone—whereas European and America G20 members have started to reduce their coal-based electricity generation. Gas power plants and wind power increased, as well as solar photovoltaic, but from a significantly lower base.

**FIGURE 21: G20—Electricity generation—development in 2005-2019**



**FIGURE 22: G20—Electricity generation—“Trend” versus “Target”**



# ELECTRICITY GENERATION

## G7—Electricity generation

Power generation in the G7 has been characterized by the strong growth of solar photovoltaic and onshore wind—especially over the past 5 years. Coal- and gas-fired power generation plateaued during that time, but with a steady

increase, especially in gas power plants until around 2010. Under the *Target* projection, power generation with renewables will grow rapidly to replace the mainly coal-based power generation, leading to renewable electricity shares of 71% in 2030 and 98% by 2040.

FIGURE 23: G7—Electricity generation—development in 2005–2019

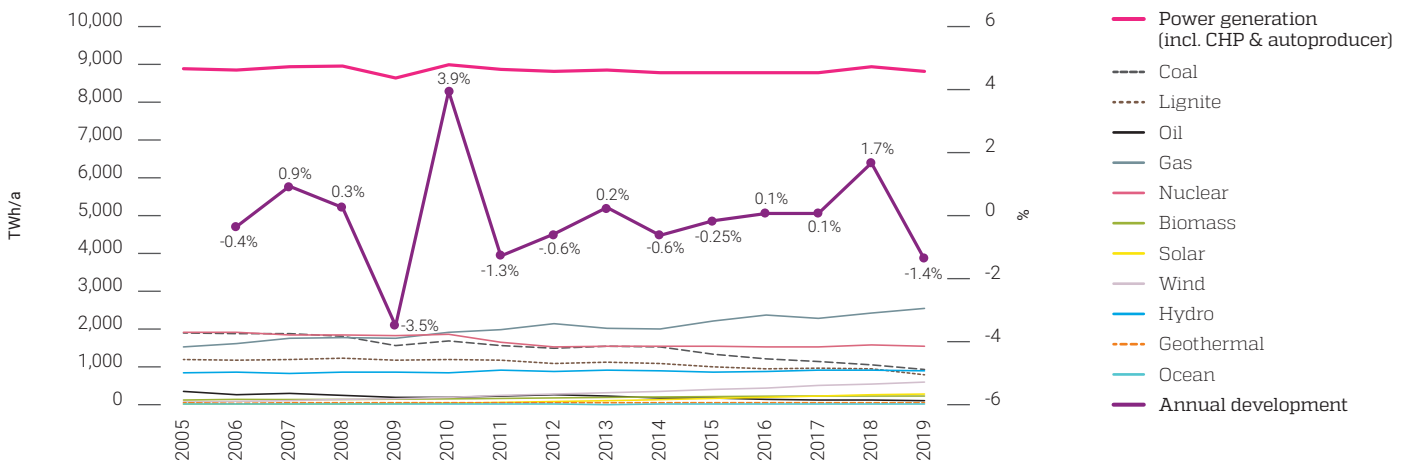
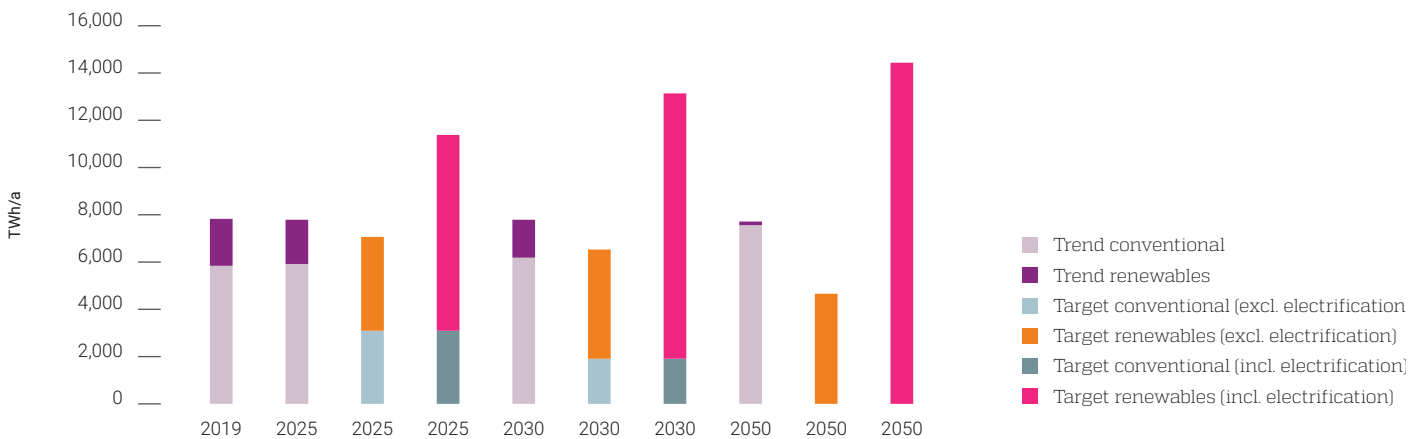


FIGURE 24: G7—Electricity generation—‘Trend’ versus ‘Target’





## Electricity generation in G7 and G20 member countries

The power generation mix across all member countries of the G7 and G20 varies significantly. The average renewable electricity generation share is 28% in the G20 and 22% in the G7, with the highest shares in Brazil and Canada (65% and 60%, respectively), which derive almost entirely from large hydropower plants, whereas Saudi Arabia has only 0.5% renewable power, derived entirely from solar photovoltaics (although the latter is growing rapidly in the country).

Under the *Trend* projection, the renewables share of the power generation mix in the G20 would reach zero under the assumption that the growth of fossil-fuel-based power generation will have priority over renewables-based power

generation. A similar situation would occur in the G7, where the renewables share under the *Trend* projection will decrease to 2% by 2050.

Although the calculated reduction to zero renewable power generation—which would require the closure of all hydro power plants—under the *Trend* projection (e.g., for Brazil) by 2050 is highly unlikely, it shows how significant the growth of gas- and coal-fired power generation has been in past years. If the growth of coal- and gas-fired power generation is maintained, it will outpace the trend in the electricity demand in six countries by 2030 and nine countries by 2050, and will therefore force renewables out of the market because fossil-fuel-based power generation will be prioritized. This indicates that renewables-based power generation is not on the required trajectory in most countries.

**TABLE 8:** Renewable electricity generation shares in member countries of the G7 and G20

| Renewable Energy Share - Electricity  | Unit | 2019       | Trend              | Target         | Trend              | Target         | Trend              | Target         | Trend              | Target         |
|---------------------------------------|------|------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|
|                                       |      |            | Fossil<br>priority | RE<br>priority | Fossil<br>priority | RE<br>priority | Fossil<br>priority | RE<br>priority | Fossil<br>priority | RE<br>priority |
|                                       |      |            | 2025               |                | 2030               |                | 2040               |                | 2050               |                |
| Argentina (G20)                       | %    | 20%        | 26%                | 49%            | 21%                | 60%            | 10%                | 96%            | 2%                 | 100%           |
| Australia (G20)                       | %    | 17%        | 13%                | 56%            | 4%                 | 71%            | 0%                 | 98%            | 0%                 | 100%           |
| Brazil (G20)                          | %    | 65%        | 76%                | 89%            | 64%                | 92%            | 30%                | 99%            | 0%                 | 100%           |
| Canada (G20) & (G7)                   | %    | 60%        | 65%                | 75%            | 64%                | 81%            | 60%                | 99%            | 71%                | 100%           |
| China (G20)                           | %    | 23%        | 30%                | 66%            | 29%                | 81%            | 26%                | 99%            | 31%                | 100%           |
| EU27 (G20) & (G7)                     | %    | 30%        | 39%                | 53%            | 42%                | 62%            | 47%                | 98%            | 69%                | 100%           |
| France (G20) & (G7)                   | %    | 23%        | 11%                | 30%            | 11%                | 43%            | 10%                | 99%            | 72%                | 100%           |
| Germany (G20) & (G7)                  | %    | 38%        | 40%                | 57%            | 41%                | 67%            | 42%                | 97%            | 41%                | 100%           |
| India (G20)                           | %    | 15%        | 15%                | 39%            | 0%                 | 47%            | 0%                 | 59%            | 0%                 | 100%           |
| Indonesia (G20)                       | %    | 15%        | 7%                 | 48%            | 0%                 | 64%            | 0%                 | 94%            | 0%                 | 100%           |
| Italy (G20) & (G7)                    | %    | 32%        | 50%                | 56%            | 52%                | 62%            | 56%                | 95%            | 58%                | 100%           |
| Japan (G7 & G20)                      | %    | 16%        | 4%                 | 41%            | 0%                 | 52%            | 0%                 | 95%            | 0%                 | 100%           |
| South Korea (G20)                     | %    | 4%         | 0%                 | 47%            | 0%                 | 65%            | 0%                 | 98%            | 0%                 | 100%           |
| Mexico (G20)                          | %    | 14%        | 5%                 | 39%            | 0%                 | 54%            | 0%                 | 93%            | 0%                 | 100%           |
| Russia (G20)                          | %    | 18%        | 14%                | 40%            | 12%                | 53%            | 8%                 | 96%            | 31%                | 100%           |
| Saudi Arabia (G20)                    | %    | 0%         | 8%                 | 40%            | 22%                | 62%            | 40%                | 95%            | 55%                | 100%           |
| South Africa (G20)                    | %    | 5%         | 3%                 | 29%            | 3%                 | 44%            | 3%                 | 73%            | 11%                | 100%           |
| Turkey (G20)                          | %    | 44%        | 37%                | 74%            | 27%                | 85%            | 2%                 | 99%            | 0%                 | 100%           |
| United Kingdom (G20) & (G7)           | %    | 38%        | 31%                | 60%            | 29%                | 71%            | 21%                | 98%            | 32%                | 100%           |
| United States of America (G20) & (G7) | %    | 18%        | 0%                 | 33%            | 0%                 | 47%            | 0%                 | 96%            | 0%                 | 100%           |
| <b>G7</b>                             | %    | <b>22%</b> | <b>24%</b>         | <b>56%</b>     | <b>20%</b>         | <b>71%</b>     | <b>9%</b>          | <b>98%</b>     | <b>2%</b>          | <b>100%</b>    |
| <b>G20</b>                            | %    | <b>28%</b> | <b>0%</b>          | <b>52%</b>     | <b>0%</b>          | <b>71%</b>     | <b>0%</b>          | <b>98%</b>     | <b>0%</b>          | <b>100%</b>    |

## SPACE HEAT AND PROCESS HEAT

Under the *Target* projection, all G7 and G20 member countries can achieve a renewable energy share of 70% on average, ranging significantly from 46% in the UK to 81% in China. The high share for China indicates the importance of coal-based power generation in that country and what its phase-out will mean for China, even though China is rapidly expanding its solar photovoltaic capacity with additional 52GW in 2021<sup>34</sup>.

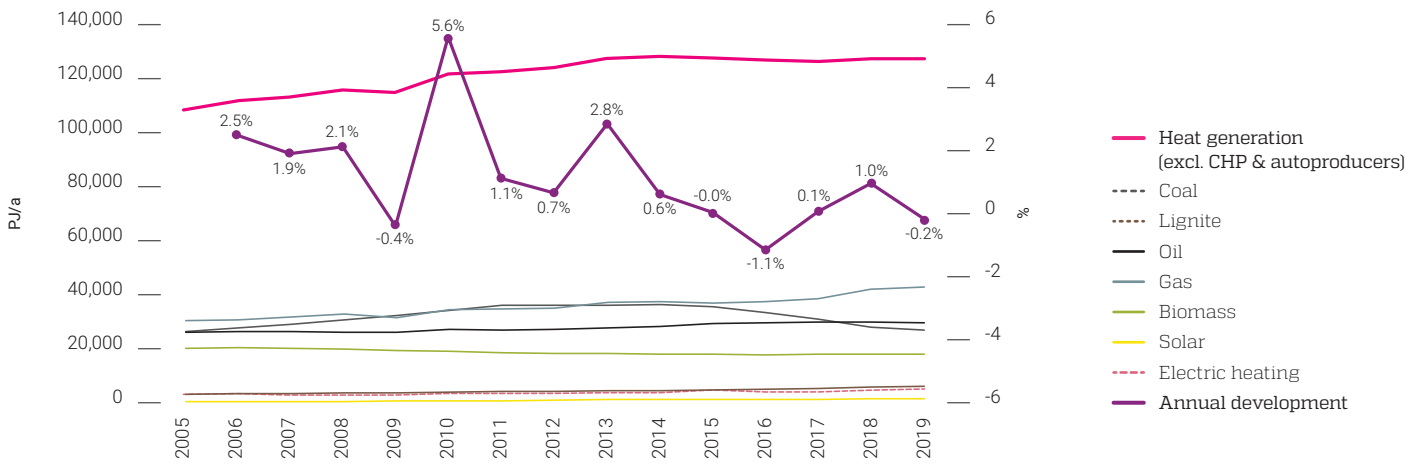
### Space heat and process heat

The heat demand has increased by 1.3% annual, on average, across all G20 member states, whereas renewable heat generation has remained stable since 2005. Therefore, the share of renewable heat generation declined from 19% to 16%

between 2005 and 2019. In the present analysis, biomass, solar heating, and electric heating are counted as renewables. In the past 15 years, the generation of biomass-based heating decreased by 12%, while the generation of solar and electric heating increased accordingly. Space heating is dominated by gas, whereas process heating is dominated by coal.

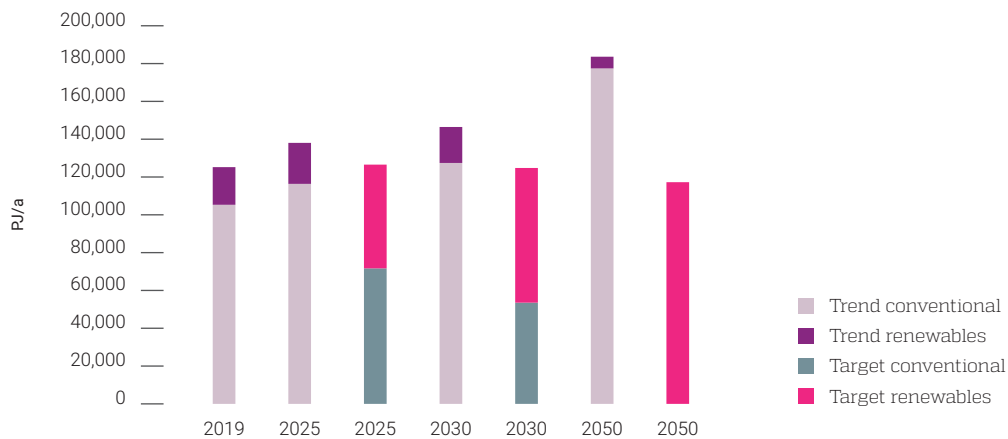
Under the *Trend* projection, renewable heat generation would decline further, to only 3% by 2050, whereas demand would continue to increase. The *Target* projection entails a renewable heating share of 57% by 2030 for the G20 and a slightly lower demand than in 2019. Fossil would be phased-out by 93% by 2040, with coal declining more rapidly than gas.

FIGURE 25: G20—Heat supply—development in 2005-2019



34. PV-Magazine, 01/2022, Chinese PV Industry Brief: China added 53 GW of new PV capacity in 2021; <https://www.pv-magazine.com/2022/01/21/chinese-pv-industry-brief-china-added-53-gw-of-new-pv-capacity-in-2021/>

**FIGURE 26: G20—Heat supply—‘Trend’ versus ‘Target’**



### G7—Space and process heat

The space heat demand has decreased over the past decade, reflecting the improved building standards introduced in G7 member countries. However, process heat demand has not decreased accordingly, so the overall heat demand in the region decreased only slightly between 2004 and 2019, by -0.4% per annum on average.

Space heating is clearly dominated by natural gas, whereas process heat generation still relies on both coal and gas.

Renewable energy—mainly biomass—increased by 1% on average in the past decade, whereas electric heating was stable. The *Target* projection leads to a rapid increase in renewable heat, including electric heating, from 12% in 2019 to 41% in 2030 and 91% by 2040.

## SPACE HEAT AND PROCESS HEAT

FIGURE 27: G7—Heat supply—development in 2005-2019

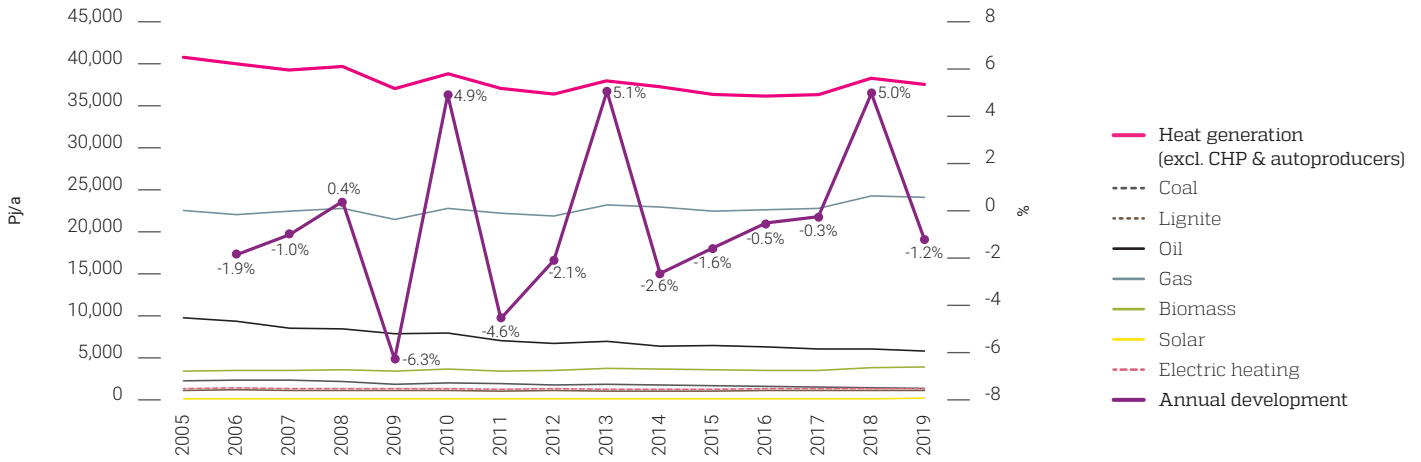
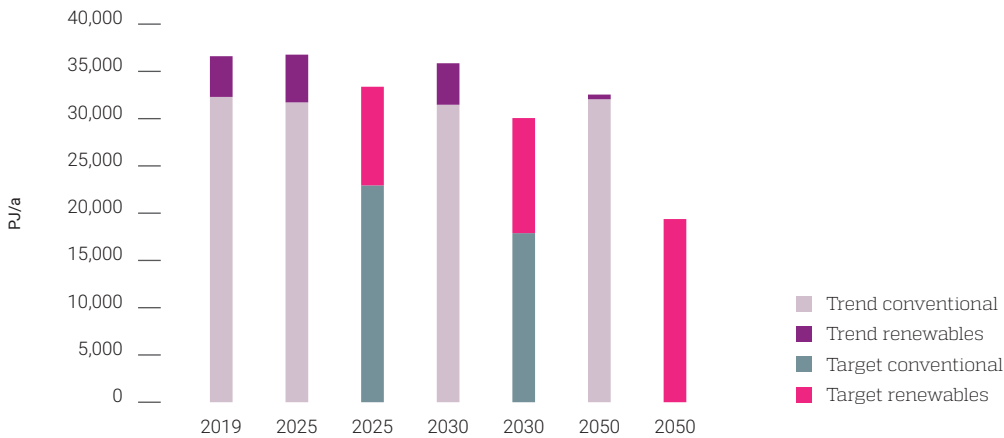


FIGURE 28: G7—Heat supply—‘Trend’ versus ‘Target’



## Heat generation in G7 and G20 member countries

The share of renewable heating varies from literally 0% in Saudi Arabia to 46% in India and 52% in Brazil. Biomass is by far the main source for renewable heating in all G7 and G20 member countries, whereas solar thermal heating technologies still occupy a small market niche. With the continuation of the fossil fuel-based heating trend, the renewable energy demand will decline to zero in eight countries. Australia and the EU27 are the only members in which renewable heating would increase by 2050 under the *Trend* projection—although by only 6% and 7%, respectively.

Under the *Target* projection, renewable heating shares would increase to 63% in the G20 and 41% in the G7 by 2030. It is important to note that biomass use is not always sustainable, and that the reason for the higher renewable heating shares

in developing countries is related to the high utilization of traditional biomass, which often negatively affects the environment and human health (due to indoor air pollution).

## Transport

The transport sector is dominated by oil, whereas natural gas contributes only 2% in the G20 and 3% in the G7. In 2019, biofuels contributed around 4.5% to the transport energy supply—in both the G20 and G7—and electricity only 2% (G20) and 0.7% (G7). If the trends of the past decades persist, biofuels would hold a share of around 4%–5%. The use of electricity in the transport sector would decline in the G20 under the assumption that the growth of oil would be prioritized over the growth of electricity. However, electricity use for transport would increase in the G7, an indication of successful policies that support electric mobility, although

**TABLE 9:** Renewable heating generation shares in member countries of the G7 and G20

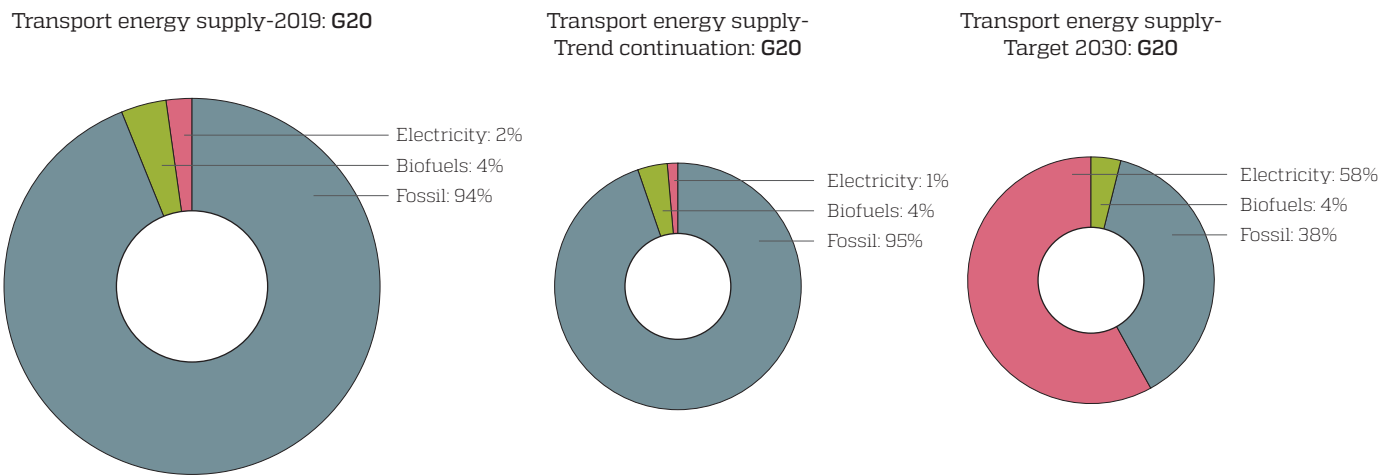
| Renewable Energy Share - Heating, incl. process heat | Unit | 2019       | Trend           | Target      | Trend           | Target      | Trend           | Target      | Trend           | Target      |
|------------------------------------------------------|------|------------|-----------------|-------------|-----------------|-------------|-----------------|-------------|-----------------|-------------|
|                                                      |      |            | Fossil priority | RE priority | Fossil priority | RE priority | Fossil priority | RE priority | Fossil priority | RE priority |
|                                                      |      |            | 2025            |             | 2030            |             | 2040            |             | 2050            |             |
| Argentina (G20)                                      | %    | 4%         | 6%              | 26%         | 4%              | 38%         | 6%              | 89%         | 6%              | 100%        |
| Australia (G20)                                      | %    | 17%        | 24%             | 46%         | 25%             | 58%         | 24%             | 93%         | 23%             | 100%        |
| Brazil (G20)                                         | %    | 52%        | 52%             | 66%         | 52%             | 73%         | 50%             | 91%         | 47%             | 100%        |
| Canada (G20) & (G7)                                  | %    | 14%        | 12%             | 34%         | 9%              | 44%         | 3%              | 92%         | 3%              | 100%        |
| China (G20)                                          | %    | 11%        | 1%              | 40%         | 0%              | 55%         | 0%              | 86%         | 0%              | 100%        |
| EU27 (G20) & (G7)                                    | %    | 18%        | 23%             | 39%         | 24%             | 48%         | 25%             | 91%         | 25%             | 100%        |
| France (G20) & (G7)                                  | %    | 17%        | 20%             | 32%         | 19%             | 37%         | 17%             | 86%         | 12%             | 100%        |
| Germany (G20) & (G7)                                 | %    | 14%        | 18%             | 38%         | 18%             | 49%         | 17%             | 92%         | 14%             | 100%        |
| India (G20)                                          | %    | 46%        | 42%             | 68%         | 36%             | 79%         | 24%             | 97%         | 9%              | 100%        |
| Indonesia (G20)                                      | %    | 34%        | 15%             | 56%         | 0%              | 62%         | 0%              | 85%         | 0%              | 100%        |
| Italy (G20) & (G7)                                   | %    | 15%        | 18%             | 28%         | 17%             | 34%         | 13%             | 89%         | 6%              | 100%        |
| Japan (G7 & G20)                                     | %    | 5%         | 5%              | 30%         | 1%              | 41%         | 0%              | 84%         | 0%              | 100%        |
| South Korea (G20)                                    | %    | 3%         | 0%              | 35%         | 0%              | 49%         | 0%              | 92%         | 0%              | 100%        |
| Mexico (G20)                                         | %    | 22%        | 12%             | 39%         | 0%              | 49%         | 0%              | 84%         | 0%              | 100%        |
| Russia (G20)                                         | %    | 1%         | 0%              | 44%         | 0%              | 61%         | 0%              | 96%         | 0%              | 100%        |
| Saudi Arabia (G20)                                   | %    | 0%         | 0%              | 39%         | 0%              | 57%         | 18%             | 94%         | 19%             | 100%        |
| South Africa (G20)                                   | %    | 18%        | 16%             | 44%         | 12%             | 58%         | 3%              | 95%         | 0%              | 100%        |
| Turkey (G20)                                         | %    | 9%         | 8%              | 50%         | 0%              | 64%         | 15%             | 96%         | 15%             | 100%        |
| United Kingdom (G20) & (G7)                          | %    | 8%         | 13%             | 23%         | 14%             | 31%         | 18%             | 89%         | 21%             | 100%        |
| United States of America (G20) & (G7)                | %    | 12%        | 13%             | 32%         | 9%              | 42%         | 3%              | 92%         | 0%              | 100%        |
| <b>G7</b>                                            | %    | <b>12%</b> | <b>14%</b>      | <b>31%</b>  | <b>12%</b>      | <b>41%</b>  | <b>8%</b>       | <b>91%</b>  | <b>1%</b>       | <b>100%</b> |
| <b>G20</b>                                           | %    | <b>16%</b> | <b>16%</b>      | <b>43%</b>  | <b>13%</b>      | <b>57%</b>  | <b>7%</b>       | <b>93%</b>  | <b>3%</b>       | <b>100%</b> |

## TRANSPORT

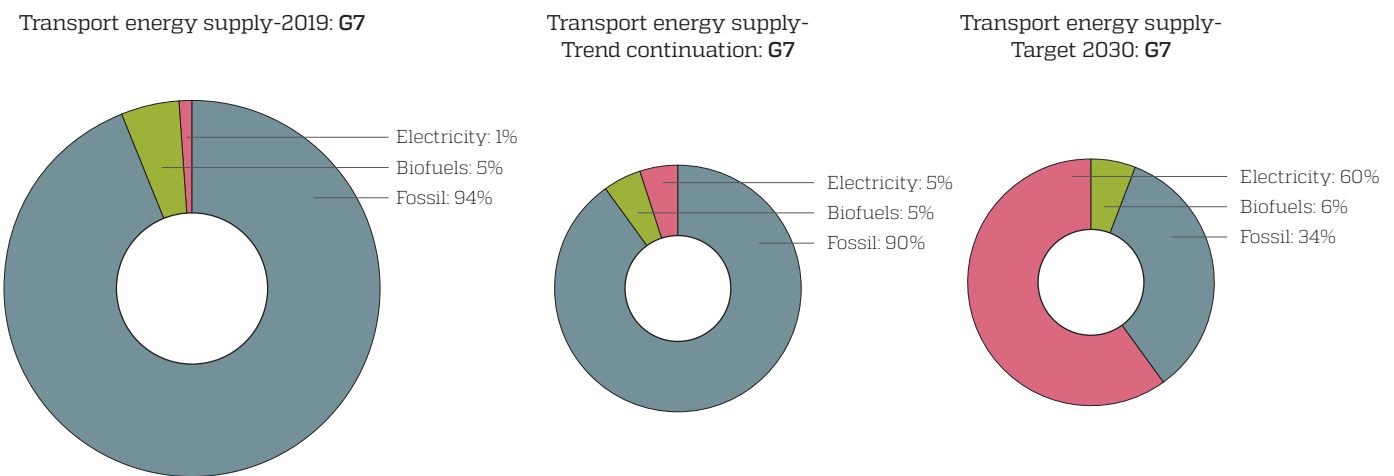
this would not occur rapidly enough to phase-out oil by 2050. Under the G20 *Target* projection (Figure 29), renewable electricity would grow to 62% by 2030, due to the assumed

decline in oil by 6.5% per year (on average) across the G20. By 2030, electricity would supply 60% of the G7 transport energy demand, whereas biofuels would remain at 6%.

**FIGURE 29: G20—Transport energy supply in 2019—‘Trend’ versus ‘Target’**



**FIGURE 30: G7—Transport energy supply in 2019—‘Trend’ versus ‘Target’**





## Transport energy supply in G7 and G20 member countries

It is assumed that the electricity and biofuels used in the transport sector are defined as *renewables*. Therefore, the decarbonization of the electricity sector is a prerequisite for achieving large CO<sub>2</sub> reductions in the transport sector.

Under the *Trend* projection, only seven countries would increase their share of renewables, and the largest increase would be in Brazil because its share of biofuels was already significant in 2019, at 20%. All other countries would remain entirely dependent on oil for the transport sector. The *Target* projection would lead to very high electrification rates of between 47% in Mexico and 70% in Australia and South Korea—with 62% on average across all member states by 2030.

**TABLE 10:** Shares of electricity and biofuels in the transport energy supply in member countries of the G7 and G20

| Electricity + Biofuels (= Renewables) for transport | Unit | 2019      | Trend           | Target      | Trend           | Target      | Trend           | Target      | Trend           | Target      |
|-----------------------------------------------------|------|-----------|-----------------|-------------|-----------------|-------------|-----------------|-------------|-----------------|-------------|
|                                                     |      |           | Fossil priority | RE priority | Fossil priority | RE priority | Fossil priority | RE priority | Fossil priority | RE priority |
|                                                     |      | 2025      | 2030            |             | 2040            |             | 2050            |             |                 |             |
| Argentina (G20)                                     | %    | 8%        | 6%              | 37%         | 0%              | 53%         | 4%              | 85%         | 7%              | 100%        |
| Australia (G20)                                     | %    | 1%        | 0%              | 50%         | 0%              | 70%         | 0%              | 88%         | 1%              | 100%        |
| Brazil (G20)                                        | %    | 20%       | 22%             | 51%         | 19%             | 66%         | 28%             | 88%         | 35%             | 100%        |
| Canada (G20) & (G7)                                 | %    | 4%        | 3%              | 49%         | 1%              | 68%         | 5%              | 87%         | 8%              | 100%        |
| China (G20)                                         | %    | 2%        | 0%              | 44%         | 0%              | 63%         | 0%              | 89%         | 0%              | 100%        |
| EU27 (G20) & (G7)                                   | %    | 6%        | 5%              | 48%         | 9%              | 67%         | 14%             | 84%         | 19%             | 100%        |
| France (G20) & (G7)                                 | %    | 7%        | 5%              | 48%         | 5%              | 67%         | 0%              | 83%         | 0%              | 100%        |
| Germany (G20) & (G7)                                | %    | 5%        | 4%              | 48%         | 5%              | 67%         | 7%              | 85%         | 9%              | 100%        |
| India (G20)                                         | %    | 1%        | 0%              | 45%         | 0%              | 65%         | 0%              | 90%         | 0%              | 100%        |
| Indonesia (G20)                                     | %    | 7%        | 0%              | 39%         | 0%              | 56%         | 0%              | 83%         | 0%              | 100%        |
| Italy (G20) & (G7)                                  | %    | 4%        | 4%              | 44%         | 8%              | 62%         | 0%              | 80%         | 0%              | 100%        |
| Japan (G7 & G20)                                    | %    | 1%        | 2%              | 42%         | 9%              | 61%         | 8%              | 78%         | 6%              | 100%        |
| South Korea (G20)                                   | %    | 2%        | 0%              | 51%         | 0%              | 71%         | 0%              | 89%         | 0%              | 100%        |
| Mexico (G20)                                        | %    | 0%        | 0%              | 30%         | 0%              | 47%         | 0%              | 77%         | 0%              | 100%        |
| Russia (G20)                                        | %    | 1%        | 6%              | 45%         | 0%              | 62%         | 0%              | 90%         | 0%              | 100%        |
| Saudi Arabia (G20)                                  | %    | 0%        | 0%              | 42%         | 0%              | 62%         | 0%              | 88%         | 0%              | 100%        |
| South Africa (G20)                                  | %    | 0%        | 0%              | 31%         | 0%              | 48%         | 0%              | 78%         | 0%              | 100%        |
| Turkey (G20)                                        | %    | 1%        | 0%              | 41%         | 0%              | 61%         | 0%              | 87%         | 0%              | 100%        |
| United Kingdom (G20) & (G7)                         | %    | 4%        | 3%              | 46%         | 8%              | 65%         | 13%             | 81%         | 18%             | 100%        |
| United States of America (G20) & (G7)               | %    | 6%        | 7%              | 49%         | 11%             | 68%         | 15%             | 86%         | 18%             | 100%        |
| <b>G7</b>                                           | %    | <b>5%</b> | <b>6%</b>       | <b>48%</b>  | <b>10%</b>      | <b>66%</b>  | <b>14%</b>      | <b>85%</b>  | <b>18%</b>      | <b>100%</b> |
| <b>G20</b>                                          | %    | <b>5%</b> | <b>8%</b>       | <b>44%</b>  | <b>5%</b>       | <b>62%</b>  | <b>9%</b>       | <b>86%</b>  | <b>13%</b>      | <b>100%</b> |

## ENERGY-RELATED CO<sub>2</sub> EMISSIONS

### Energy-related CO<sub>2</sub> emissions

The global carbon budget identifies the total amount of energy-related CO<sub>2</sub> that can be emitted while limiting global warming to a maximum 1.5°C, with no or a low overshoot. The International Panel on Climate Change (IPCC) is the United Nations body that assesses the science related to climate change. In August 2021, the IPCC published a new report that identified the global carbon budget required to restrict climate warming in 2020–2050 to 1.5°C, with 67% likelihood, as 400 GtCO<sub>2</sub> (IPCC AR6, 2021)<sup>35</sup>.

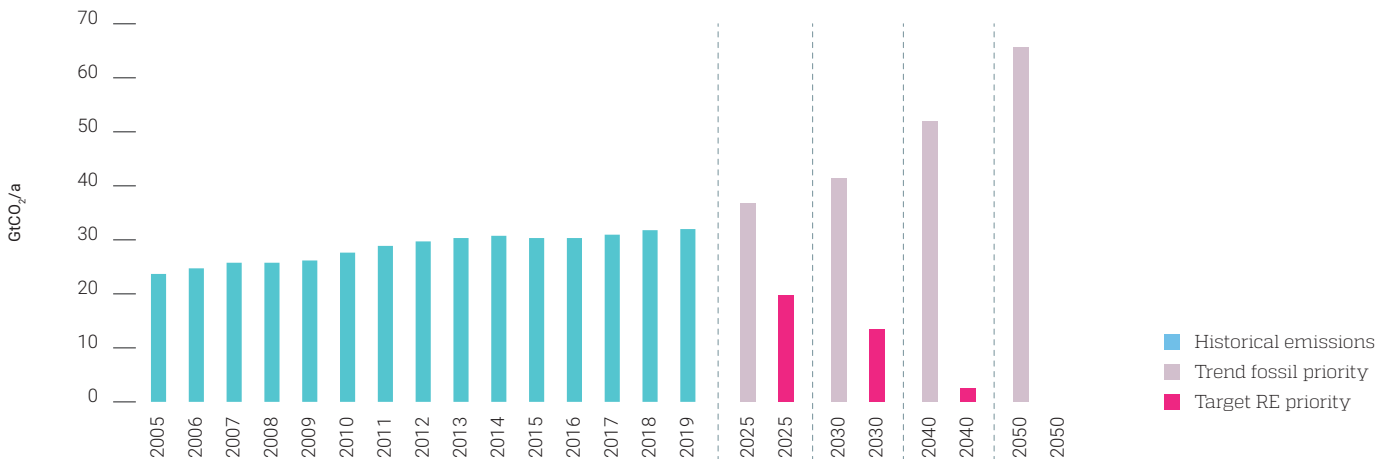
Together, all G20 member states are responsible for 80% of current energy-related CO<sub>2</sub> emissions, and their carbon budget between 2020 and 2050, when full decarbonization must be reached, is therefore 320 GtCO<sub>2</sub>.

The annual reduction achieved up to 2030 will define whether or not this goal can be achieved and emissions remain within the carbon budget. However, the trend in

energy-related carbon emissions in the G20 since 2005 has developed in the wrong direction—not a steady decline, but an increase of around 2.5% per annum. To achieve the Paris Climate Agreement, the emissions of all the G20 member states must decrease by about 60%, from 32 GtCO<sub>2</sub> in 2019 to 13.5 GtCO<sub>2</sub> in 2030.

Figure 31 shows the development of energy-related carbon emissions between 2005 and 2019 and the possible development under the *Trend* and *Target* projections. The *Trend* trajectory will lead to a doubling of emissions by 2050. By 2030, energy-related CO<sub>2</sub> emissions will increase by about 30% under *Trend*, whereas the calculated emissions under the *Target* projection will decrease to 42% of the 2020 emissions. Under the ‘*Trend*’ projection the cumulative CO<sub>2</sub> emission between 2020 and 2050 would add to about 1,470 GtCO<sub>2</sub>—4.5 times the G20’s carbon budget required to remain under 1.5°C.

FIGURE 31: G20—Energy-related CO<sub>2</sub> emissions—historic emissions and ‘Trend’ versus ‘Target’ projections



35. IPCC, 2021: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Masson-Delmotte V, Zhai P, Pirani A., Connors SL, Péan C, Berger S, Caud N, Chen Y, Goldfarb L, Gomis MI, Huang M, Leitzell K, Lonnoy E, Matthew JBRs, Maycock TK, Waterfield T, Yelekçi O, Yu R, and Zhou B (eds). Cambridge University Press.

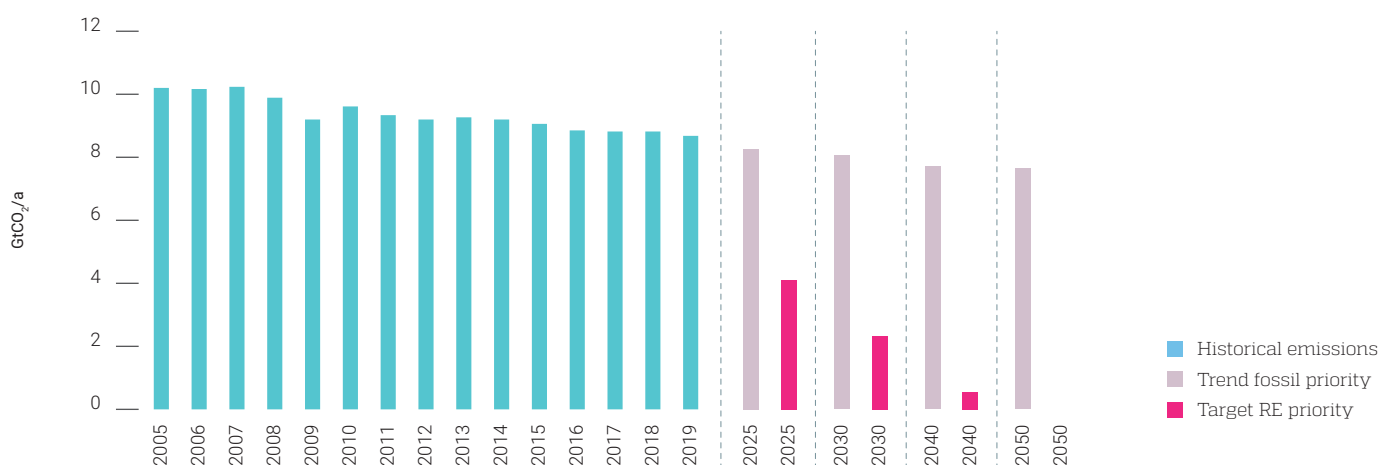
## G7—Energy-related CO<sub>2</sub> emissions

Energy-related CO<sub>2</sub> emissions in the G7 declined by 1% annually between 2005 and 2019, far too slow to meet the climate target. Under the *Trend* projection, the CO<sub>2</sub> emissions will continue to decrease slowly, mainly due to the reductions in oil and coal, whereas gas emission will increase steadily.

Under the *Target* projection, CO<sub>2</sub> emissions will decline by 5.6% per year, leading to total energy-related carbon

emissions of 3.3 Gt by 2030 for the G7 countries. The total carbon budget under the *Trend* projection would sum to 247 Gt between 2020 and 2050—more than half the remaining global budget required to achieve the 1.5°C Paris target. Under the *Target* projection, the total G7 carbon budget would sum to 82 GtCO<sub>2</sub>—one third of that in the *Trend* projection. This is a clear indication that the current policy measures for an energy transition to decarbonize the energy sector are highly inadequate in the G7 and require urgent changes.

**FIGURE 32: G7—Energy-related CO<sub>2</sub> emissions—historic emissions and ‘Trend’ versus ‘Target’ projections**



## ENERGY-RELATED CO<sub>2</sub> EMISSIONS

### Energy-related CO<sub>2</sub> emissions of G7 and G20 member countries

In 2019, China was responsible of one third of all energy-related emissions—a continuation of this trend will increase this share to 39% in 2030 and 63% in 2050. If China alone increases its annual carbon emissions according to the trend in the past 15 years, the global carbon budget of 400 GtCO<sub>2</sub>

will be exhausted by 2042—even if all other countries throughout the world achieve zero emissions by 2025.

In terms of the global carbon budget, targets for the reduction of specific emissions—in emissions per capita or per dollar GDP—are an inadequate metric because only the total resulting CO<sub>2</sub> emissions are relevant to climate targets.

**TABLE 11:** Annual energy-related CO<sub>2</sub> emissions of member countries of the G7 and G20

|                                                 |                      |             | Trend<br>Fossil<br>priority | Target<br>RE<br>priority | Trend<br>Fossil<br>priority | Target<br>RE<br>priority | Trend<br>Fossil<br>priority | Target<br>RE<br>priority | Trend<br>Fossil<br>priority | Target<br>RE<br>priority |
|-------------------------------------------------|----------------------|-------------|-----------------------------|--------------------------|-----------------------------|--------------------------|-----------------------------|--------------------------|-----------------------------|--------------------------|
| Annual energy-related CO <sub>2</sub> emissions | Unit                 | 2019        | 2025                        |                          | 2030                        |                          | 2040                        |                          | 2050                        |                          |
| Argentina (G20)                                 | GtCO <sub>2</sub> /a | 0.2         | 0.2                         | 0.1                      | 0.2                         | 0.1                      | 0.2                         | 0.0                      | 0.3                         | 0.0                      |
| Australia (G20)                                 | GtCO <sub>2</sub> /a | 0.4         | 0.4                         | 0.2                      | 0.5                         | 0.1                      | 0.6                         | 0.0                      | 0.7                         | 0.0                      |
| Brazil (G20)                                    | GtCO <sub>2</sub> /a | 0.5         | 0.5                         | 0.3                      | 0.6                         | 0.2                      | 0.7                         | 0.1                      | 0.9                         | 0.0                      |
| Canada (G20) & (G7)                             | GtCO <sub>2</sub> /a | 0.6         | 0.7                         | 0.4                      | 0.7                         | 0.3                      | 0.8                         | 0.1                      | 1.0                         | 0.0                      |
| China (G20)                                     | GtCO <sub>2</sub> /a | 10.1        | 13.0                        | 6.9                      | 16.3                        | 5.0                      | 25.2                        | 0.6                      | 41.5                        | 0.0                      |
| EU27 (G20) & (G7)                               | GtCO <sub>2</sub> /a | 2.8         | 2.6                         | 1.6                      | 2.5                         | 1.0                      | 2.1                         | 0.2                      | 1.9                         | 0.0                      |
| France (G20) & (G7)                             | GtCO <sub>2</sub> /a | 0.3         | 0.3                         | 0.2                      | 0.3                         | 0.1                      | 0.2                         | 0.0                      | 0.2                         | 0.0                      |
| Germany (G20) & (G7)                            | GtCO <sub>2</sub> /a | 0.7         | 0.7                         | 0.4                      | 0.6                         | 0.2                      | 0.6                         | 0.0                      | 0.5                         | 0.0                      |
| India (G20)                                     | GtCO <sub>2</sub> /a | 2.2         | 2.9                         | 2.2                      | 3.6                         | 2.3                      | 5.5                         | 0.2                      | 8.5                         | 0.0                      |
| Indonesia (G20)                                 | GtCO <sub>2</sub> /a | 1.5         | 1.8                         | 1.0                      | 2.0                         | 0.7                      | 2.7                         | 0.3                      | 3.6                         | 0.0                      |
| Italy (G20) & (G7)                              | GtCO <sub>2</sub> /a | 0.3         | 0.3                         | 0.2                      | 0.3                         | 0.1                      | 0.2                         | 0.0                      | 0.2                         | 0.0                      |
| Japan (G7 & G20)                                | GtCO <sub>2</sub> /a | 1.1         | 1.1                         | 0.6                      | 1.1                         | 0.4                      | 1.1                         | 0.1                      | 1.2                         | 0.0                      |
| South Korea (G20)                               | GtCO <sub>2</sub> /a | 0.7         | 0.8                         | 0.4                      | 1.0                         | 0.2                      | 1.2                         | 0.0                      | 1.6                         | 0.0                      |
| Mexico (G20)                                    | GtCO <sub>2</sub> /a | 0.4         | 0.5                         | 0.3                      | 0.5                         | 0.2                      | 0.6                         | 0.1                      | 0.7                         | 0.0                      |
| Russia (G20)                                    | GtCO <sub>2</sub> /a | 1.8         | 2.0                         | 1.1                      | 2.1                         | 0.8                      | 2.4                         | 0.1                      | 2.7                         | 0.0                      |
| Saudi Arabia (G20)                              | GtCO <sub>2</sub> /a | 0.6         | 0.7                         | 0.3                      | 0.8                         | 0.2                      | 1.2                         | 0.1                      | 1.6                         | 0.0                      |
| South Africa (G20)                              | GtCO <sub>2</sub> /a | 0.5         | 0.5                         | 0.3                      | 0.5                         | 0.2                      | 0.6                         | 0.1                      | 0.6                         | 0.0                      |
| Turkey (G20)                                    | GtCO <sub>2</sub> /a | 0.4         | 0.5                         | 0.3                      | 0.6                         | 0.2                      | 0.9                         | 0.1                      | 1.3                         | 0.0                      |
| United Kingdom (G20) & (G7)                     | GtCO <sub>2</sub> /a | 0.4         | 0.3                         | 0.2                      | 0.3                         | 0.1                      | 0.2                         | 0.0                      | 0.2                         | 0.0                      |
| United States of America (G20) & (G7)           | GtCO <sub>2</sub> /a | 5.2         | 5.1                         | 3.0                      | 5.0                         | 2.0                      | 5.1                         | 0.4                      | 5.4                         | 0.0                      |
| <b>G7</b>                                       | GtCO <sub>2</sub> /a | <b>8.7</b>  | <b>8.3</b>                  | <b>4.1</b>               | <b>8.1</b>                  | <b>2.3</b>               | <b>7.7</b>                  | <b>0.6</b>               | <b>7.6</b>                  | <b>0.0</b>               |
| <b>G20</b>                                      | GtCO <sub>2</sub> /a | <b>32.0</b> | <b>36.7</b>                 | <b>19.7</b>              | <b>41.3</b>                 | <b>13.5</b>              | <b>51.9</b>                 | <b>2.4</b>               | <b>65.7</b>                 | <b>0.0</b>               |

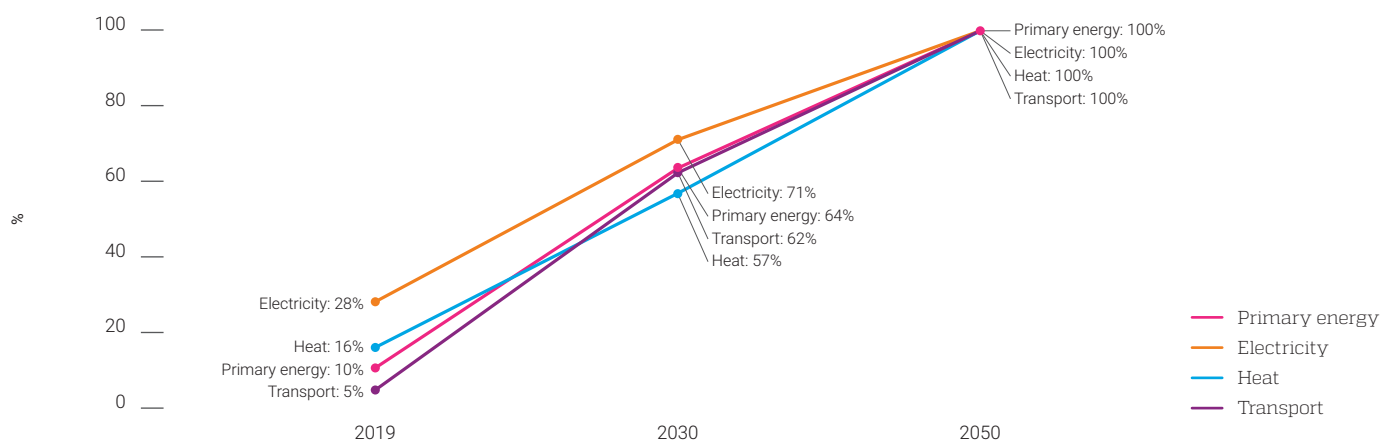
## Summary—Projected renewable energy targets

To remain within the carbon budget that will limit global warming to +1.5°C, drastic changes in existing energy policies are required to support energy efficiency and the uptake of renewable energies. Establishing legally binding targets for renewable energies has proven an effective and successful policy measure. Targets of renewable shares in percentage per annum are therefore well suited, as they

always represent a combination of energy efficiency and (renewable) energy generation.

However, renewable targets must be accompanied by policies to implement them. Suggestions are made in Chapter 4. Figure 33 shows all the renewable energy shares for primary energy, electricity generation, heat generation, and transport under the *Target* projection for the G20. All sector targets across all member countries must be in the range of 57%–71% by 2030.

**FIGURE 33:** G20—Renewable target sketch by sector

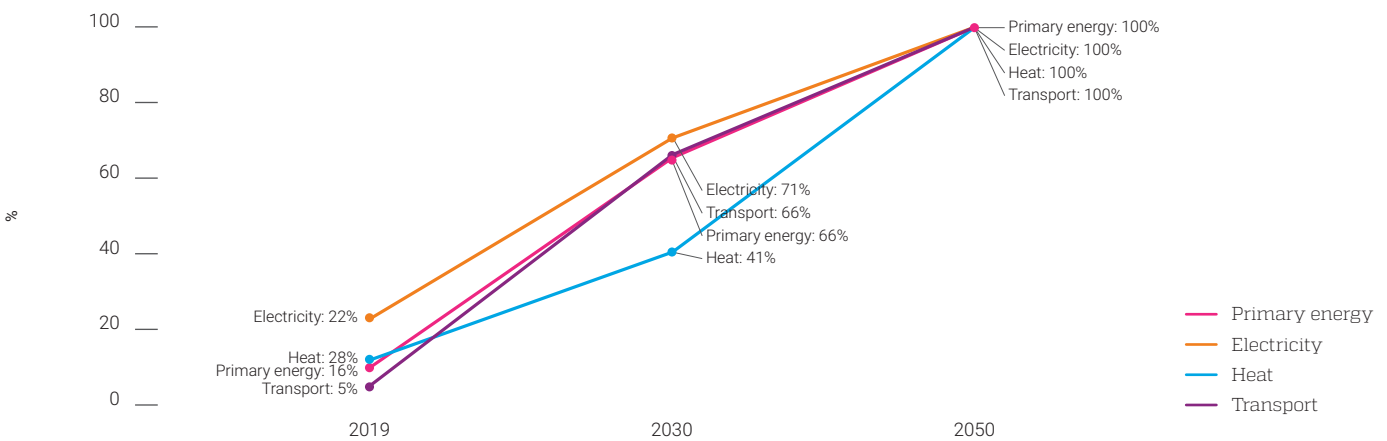


## SUMMARY—PROJECTED RENEWABLE ENERGY TARGETS

Figure 34 shows the projected renewable energy targets for the G7 members. The shares are slightly lower than for the G20 due to the assumed fossil fuel decline factors (Table 4), which are lower for gas than for oil and coal for the first decade (until 2030). Therefore, higher shares of coal and oil

will lead to a requirement for more substitution energy for renewables in response to their faster phase-out than gas-dominated systems, which will increase the annual decline after 2030 to the same levels as oil and coal. Therefore, the targets for 2040 are similar for all countries.

**FIGURE 34:** G7—Renewable target sketch by sector



## Indonesia—Case study

In this section we present key results of the Indonesia National General Energy Plan (Rencana Umum Energi Nasional / RUEN), published in June 2020 and compare it with the Indonesian results of the *Renewable Energy Target Mapping* (RET-M). The RET-M methodology (see previous chapter) applied standard decline rates for fossil fuels for industrialized and developing countries as documented in Table 4.

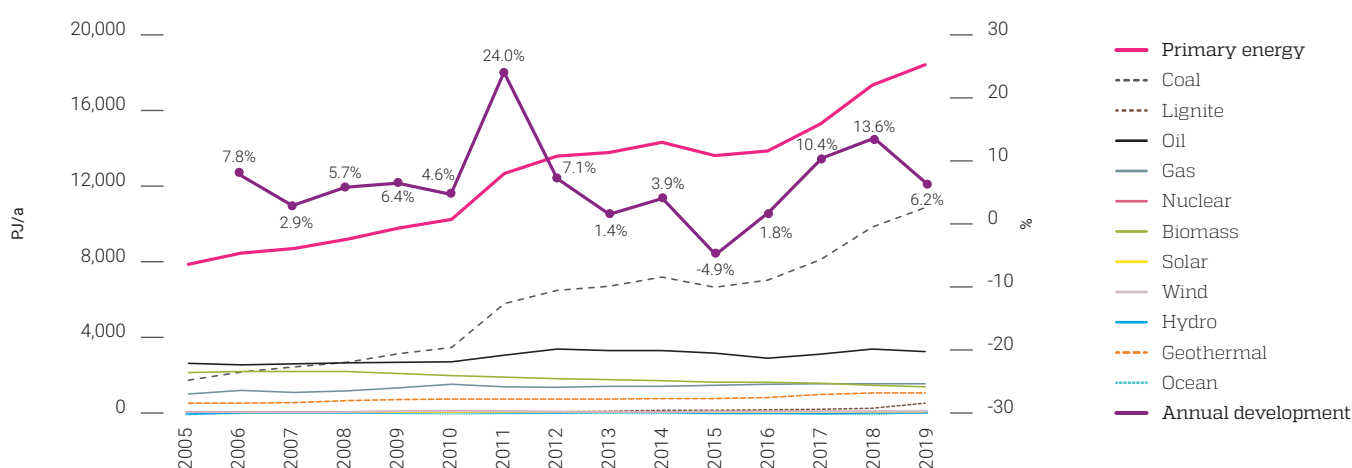
For Indonesia it is assumed that the use of coal and oil will decline by 3% per year between 2021 and 2050, while gas declines by 3.5% until 2030 and 9% annual from 2031 to 2050. In line with the global carbon budget of 400 GtCO<sub>2</sub> between 2020 and 2050, all energy related CO<sub>2</sub> emissions - for all countries - need to be zero by 2050.

## Primary energy: Coal on the rise, renewables stagnant

In Indonesia, coal plays a major role for the domestic energy supply especially for electricity generation - as well as an export commodity. Indonesia's energy demand increased by 17% per on average between 2005 and 2019 with significant variations between plus 6.6% in 2011 and minus 5.2% in 2013. Between 2017 and 2019 the annual increase was around 4%. Additional energy demand was supplied almost exclusively by coal, while renewables played a minor role to provide the additional energy (Figure 35). Thus, coal as a major energy source is on the rise since 2005 in Indonesia while the share of renewables stagnated.

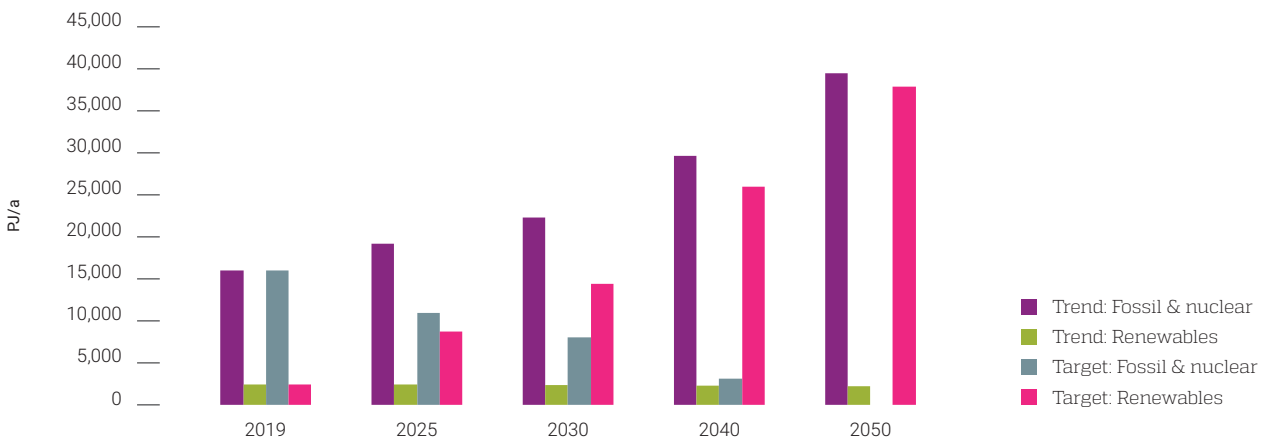
In case of a continuation of the development since 2005, the 'Trend' projection would lead to a primary energy consumption of 31,200 PJ/a in 2050, while the 'Target' projection - which includes an annual efficiency gain of 1.5% - would lead to 28,400 PJ/a (Figure 36).

**FIGURE 35:** Indonesia—Primary energy supply—development in 2005–2019





## INDONESIA—CASE STUDY

**FIGURE 36:** Indonesia—Primary energy supply—‘Trend’ versus ‘Target’

In a next step, we compare those projections with Indonesia's RUEN (IESR 2020)<sup>36</sup>.

In the *existing RUEN*, the final energy needed by 2025 reaches 10 Exajoule (248.4 MTOE), the industrial sector becomes the most energy-intensive sector with a share of 47.6% (including its raw material requirement) followed by transportation sector at 30.3%, household at 15%, commercial sector at 4.9%, and other sectors at 2.2%. To supply this final energy demand, Indonesia will need 16,750 PJ/a (400 MTOE) primary energy in 2025. This discrepancy between energy demand and supply is a result of energy transformation, where oil refineries have 73-80% efficiency, coal-fired power plants have 30-36% efficiency (ultra-supercritical efficiency is higher at 40-42% efficiency), diesel power plants have 33% efficiency, and geothermal power plants have 33% efficiency. On average, the efficiency used in RUEN to convert primary energy to final energy is at 62%. Further, by 2050, the country's final energy requirement is projected to reach 26,850 PJ/a (641.5 MTOE) and the primary energy supply 42,370 PJ/a (1,012.2 MTOE) (IESR 2020).

Under the *'Realization Scenario'*, Indonesia's primary energy demand would increase slower than under the *'RUEN'* scenario; by 2025 the demand would reach 10,800 PJ/a (259 MTOE) increasing to 27,000 PJ/a (646 MTOE), about 65% of the projected RUEN demand saving 16,750 PJ/a (400 MTOE) in 2050.

In comparison, the *'RUEN'* scenario will lead to 42 Exajoule (EJ/a) primary energy demand almost identical to the *'Trend'* projection which calculates with an average annual growth of the energy demand of 2.1% leading to 41.6 Exajoule (EJ/a). Confirming the assumption of a continuation of historical energy demand increase at around 2.0% per year on average over the past two decades.

The *'Realization Scenario'* analyses the actual development in Indonesia and compares with the *'RUEN'* scenario. According to this analysis the primary energy demand by 2050 is likely to be 27 Exajoule (EJ/a) which in line with is the demand of the *'Target'* projection of 28 Exajoule (EJ/a).

**The primary energy demand of the *'IESR Realization Scenario'* is in line with the *'Target'* projection in this report.**

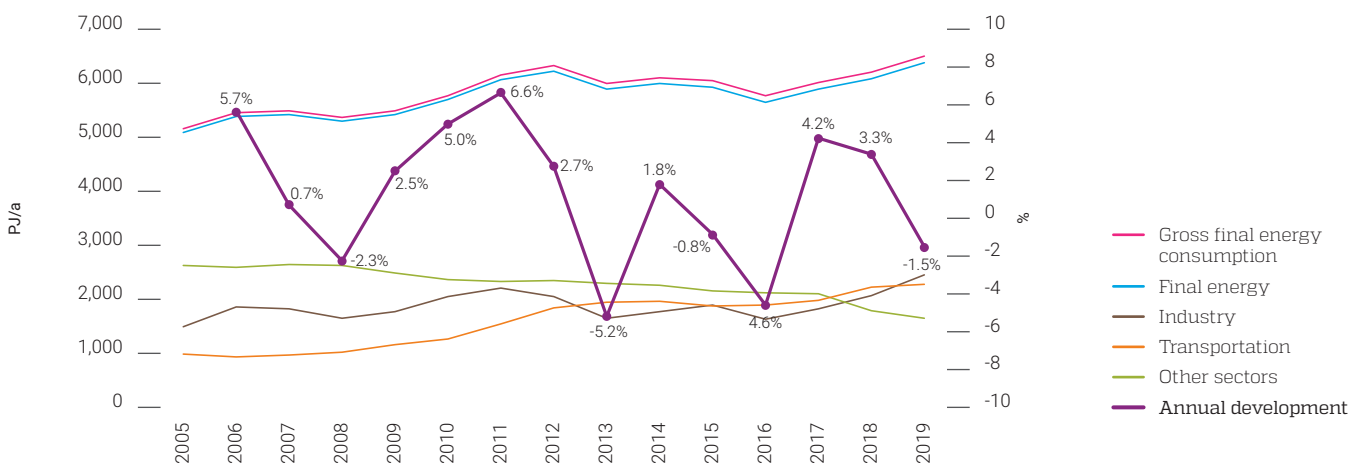
36. IESR (2020); National Energy General Plan (RUEN); Existing plan, current policies implication and energy transition scenario. Jakarta; Institute for Essential Services Reform (IESR), June 2020.

## Indonesia: Final energy consumption

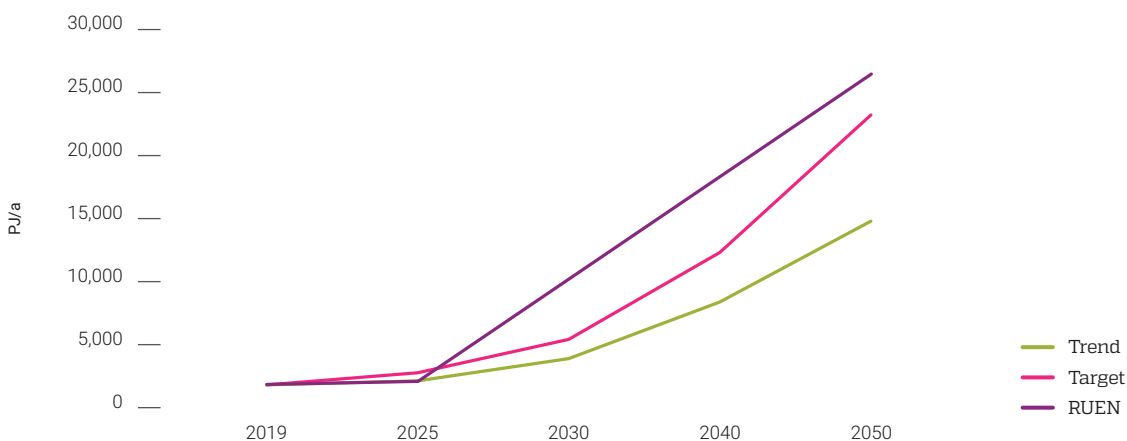
Over the past two decades, Indonesia had periods of significant growth and decline of the final energy consumption which was closely related to the GDP development. The demand of the industry and transport sector grew constantly, while the final energy consumption

of 'Other Sectors' - mainly buildings - actually declined between 2005 and 2019. The reason for this decline is a significantly higher electrification rate and as a result a decrease of fuel demand especially for traditional biomass for cooking. In 2019, Indonesia's final energy consumption shares of the industry and transport sector was within the same order of magnitude of around 37%.

**FIGURE 37: Indonesia—Final energy consumption—development in 2005-2019**



**FIGURE 38: Indonesia—Final energy consumption—'Trend' versus 'Target'**



## INDONESIA—CASE STUDY

The comparison of the 'Trend' and 'Target' projections with the 'RUEN Scenario' shows that the final energy consumption is expected to grow faster than the 'Trend' projection which is based on the average annual energy consumption increase of 2.1% until 2025 and a linear increase from 2031 to 2050 of 6% per year. The 'Target' projection assumes an annual increase of 4.5% between 2020 and 2050.

**The final energy consumption of the 'RUEN' scenario in 2050 is within the same range as the 'Trend' projection.**

### Indonesia: Sectoral energy demand

The final energy consumption of the industry sector under the 'RUEN' scenario is projected to increase by a factor of 3.7 between 2020 and 2050 from 2,084 PJ/a (49.77 MTOE) to 7,714 PJ/a (184.25 MTOE), which is in between the results of the 'Trend' and the 'Target' projection with 9,100 PJ/a respectively 6,530 PJ/a.

Similarly, the 'RUEN' final energy consumption for the transport sector is estimated to increase by a factor of 2.8 between 2020 and 2050, from 2,370 PJ/a (56.6 MTOE) to 6,728 PJ/a (160.7 MTOE) – lower than in the 'Trend' projection (10,000 PJ/a / 239 MTOE) but higher than under the 'Target' projection (6,000 PJ/a / 143 MTOE).

### Indonesia: Primary energy supply

In terms of the energy supply mix, the renewable energy target under the 'RUEN' scenario is projected with 23% by 2025 and 31% by 2050. However, the 'IESR Realization Scenario' shows that those targets will be missed and that renewable energy will only increase to 15% maximum by 2025 and the further increase by 2050 will like be missed by 8% leading to a renewable energy share of only 23%.

In comparison, the renewable energy share under the 'Trend' projection would be 11% in 2025, decreasing to 10% in 2030 and only 5% in 2050, which confirms that Indonesia is not on track for an increased renewable energy share by 2025, 2030 and beyond.

The 'IESR Energy Transition Scenario' describes a more ambitious scenario for renewable energy deployment in Indonesia. However, under this scenario, the fossil share by 2025 will still account for the largest portion. The share of renewables can only surpass the fossil share between 2040 to 2042 under the assumption that the construction of new

coal power plants in Indonesia will be stopped from 2029 onwards and – in an advanced case – a phase-out of combined cycle fossil fuel power plants older than 20 years. In that case the renewable energy share would increase to 66% respectively 69% by 2050.

In comparison, under the 'Target' projection, renewable energy sources would supply 64% of Indonesia's primary energy demand by 2030 and 100% by 2050. The quantitative results of the 'IESR Energy Transition Scenario' for the year 2050 are in line with renewable energy shares calculated with the 'Target' projection for the year 2030. Thus, the remaining fossil fuel use of 10 Exajoule (240 MTOE) projected under the IESR Energy Transition Scenario in 2050 would lead to energy-related CO<sub>2</sub> in the order of Indonesia's current emissions. According to the carbon budget of 400 GtCO<sub>2</sub> between 2020 and 2050 identified by the IPCC, the energy-related carbon emissions should globally be phased-out entirely.

The 'IESR Energy Transition Scenario' confirms the possibility to increase the renewable energy supply in Indonesia from currently around 2.5 Exajoule (60 MTOE) to 15 Exajoule (358 MTOE), but projects a longer transition period to achieve this target. In a next step, an analysis is needed to explore possibilities to accelerate the renewable energy growth in Indonesia and how a complete decarbonization of the energy sector can be achieved by 2050.

### Indonesia: Electricity sector

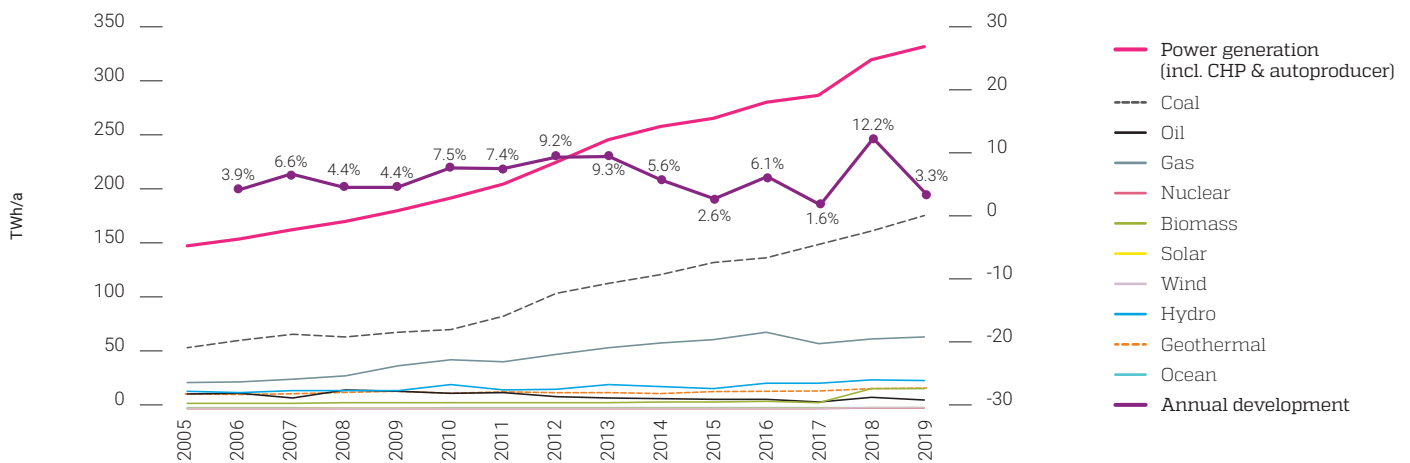
The electricity sector is currently in the focus of the Indonesian government and the energy policy debate. Over the past two decades, the electricity demand grew significantly from 147 Terawatt hours (TWh/a) in 2005 to 331 TWh/a in 2019 (Figure 39). Coal plays a central role in the power generation mix, while renewables remained at a share of only 12% to 15% since 2005.

The 'Trend' projection would lead to a slightly lower electricity demand of 1,150 TWh/a by 2050 compared to 1,475 TWh/a under the 'RUEN' scenario (Figure 40). The electricity demand under the 'Trend' projection would lead to an electricity demand of 1,000 TWh/a by 2050 under the assumption that the transport and industry process heat sector would not be electrified. Including a high electrification rate of 75% of process heat and 97% of land transport, the electricity demand would increase significantly to around 3,000 TWh/a, twice as high as under the 'RUEN' scenario.

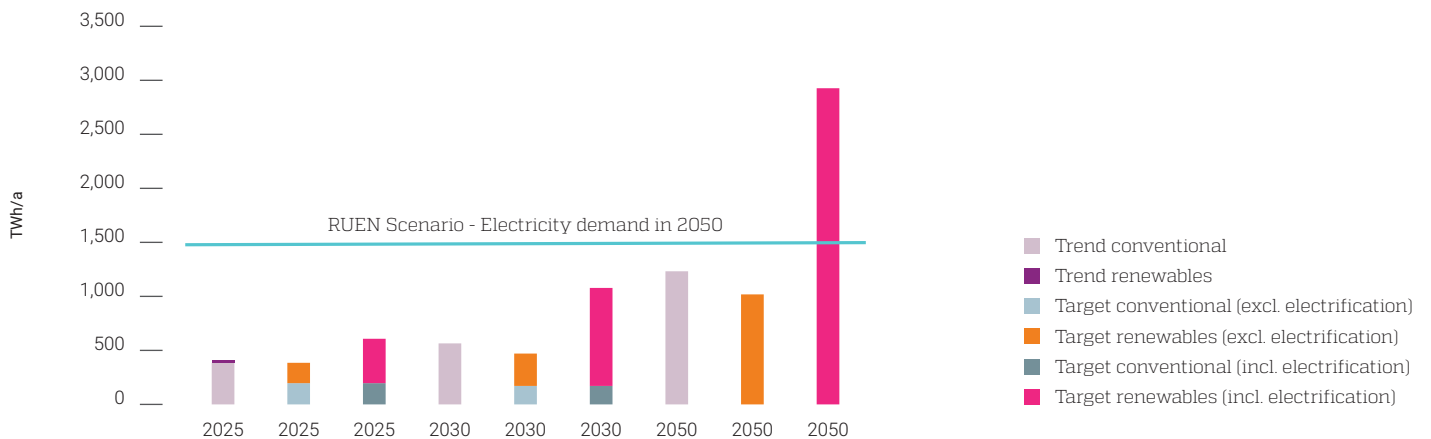
The renewable electricity generation share under the ‘Trend’ projection would continue to decrease if the trend of the past decades would continue, while the renewable generation share under the ‘Target’ project would increase to 64% in 2030 and 100% by 2050.

The ‘IESR Energy Transition Scenario’ shows Indonesia’s possibility to increase the renewable electricity generation share to over 60%. The ‘Target’ projection echoes the IESR scenario, but suggests a shorter time frame to achieve this target.

**FIGURE 39: Indonesia—Power supply—development in 2005–2019**



**FIGURE 40: Indonesia—Power supply—‘Trend’ versus ‘Target’**



# G20

## Solar and Wind Potential

# 03

Wind turbines and solar panels.  
© shutterstock.com  
/west cowboy

The primary purpose of the GIS mapping is to project the renewable energy resources (focused on solar and wind) available in G7 and G20 countries. It also contributes to the regional analysis of geographic and demographic parameters and the available infrastructure that can be leveraged in developing scenarios to deal with energy concepts.

## The [R]ESPACE methodology

Mapping was performed with the software ESRI ArcGIS10.6.1, which allows the spatial analysis and mapping of the results. It has been used to allocate solar and wind resources and for

the demand projections for seven modelling regions. Population density, access to electricity infrastructure, and economic development projections are the key input parameters in the region-specific analysis of G20's future energy situation.

Open-source data and maps from various sources have been collected and processed to visualize each country and its regions and districts. Further demographic data related to population and poverty, as well as transmission networks and power plants, are also plotted on the maps. The main data sources and assumptions made for this mapping are summarized in Table 12.

**TABLE 12:** [R]E 24/7—GIS-mapping—data sources

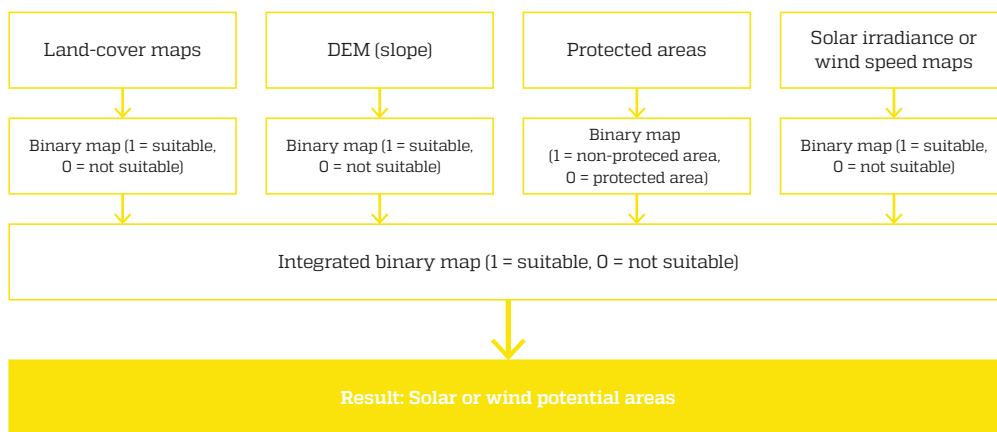
| Data                                              | Assumptions                                                                                                                                                            | Source                                                                                                                                    |
|---------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| Land cover                                        | Land cover classes that are suitable for solar energy and wind energy production were identified from different land-cover maps—see Table 13 for detailed information. | Canada, Japan: Copernicus Global Land Cover—2019<br>USA: National Land Cover Database—2019<br>EU27, UK: Copernicus Corine Land Cover—2018 |
| Digital Elevation Model (DEM)                     | For both wind and solar analyses, any land with a slope of > 30% was eliminated from all scenarios.                                                                    | EU27, UK, Japan: Multi-Error-Removed Improved-Terrain DEM<br>Canada, USA: GMTED2010                                                       |
| Protected areas                                   | All protected areas designated under national parks, wildlife reserves, hunting reserves, conservation areas, and buffer zones were eliminated from all scenarios.     | The World Database on Protected Areas (WDPA)                                                                                              |
| Solar irradiance (direct normal irradiation: DNI) | The average yearly direct normal insolation/irradiation (DNI) values range from 1 to 5 MWh/m <sup>2</sup> per year.                                                    | Global Solar Atlas                                                                                                                        |
| Wind speed at 100 m                               | Wind speeds ≥ 5 m/s were considered at a height of 100 m.                                                                                                              | Global Wind Atlas                                                                                                                         |

## THE [R]ESPACE METHODOLOGY

The mapping procedure is summarised in Figure 41. The areas of land available for potential solar and wind power generation were calculated and visualised by country with ArcGIS. Land-cover maps, topographic surface data/slopes (Digital Elevation Model: DEM), protected area maps, solar irradiation (direct normal irradiation: DNI) and wind speed data were obtained from the websites described above as raster data, which were all converted into binary maps (0 = area not suitable for a

potential solar or wind utilization; 1 = potential area suitable for solar or wind utilization) based on all the assumptions defined in Table 12, and then combined into one binary map by overlaying all the raster data. This map integrates all the above criteria into one map with value 1 (included in potential area) or value 0 (not included in potential area). This input was fed into the calculations for the [R]E 24/7 model, as described below.

**FIGURE 41:** Analysis of solar potential and wind potential





**TABLE 13:** Land cover classes considered for solar- and wind-energy-generating areas

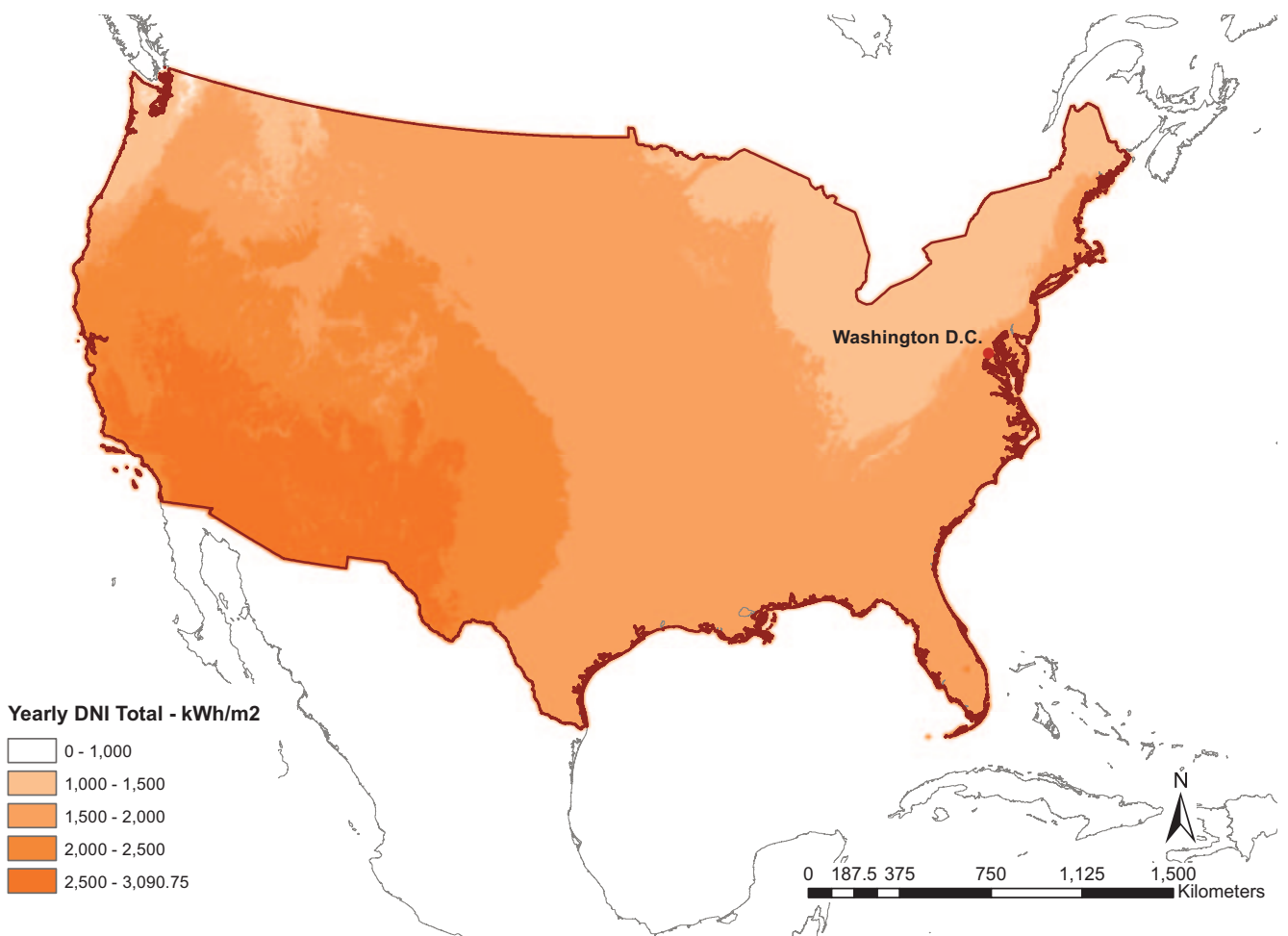
| Data                                      | Solar energy                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Wind energy                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Copernicus Global Land Cover 2019 (World) | <ul style="list-style-type: none"> <li>• Open forest, evergreen needle leaf (121)</li> <li>• Open forest, deciduous needle leaf (123)</li> <li>• Open forest, evergreen broad leaf (122)</li> <li>• Open forest, deciduous broad leaf (124)</li> <li>• Open forest, mixed (125)</li> <li>• Open forest, unknown (126)</li> <li>• Shrubs (20)</li> <li>• Herbaceous vegetation (30)</li> <li>• Bare/sparse vegetation (60)</li> <li>• Cultivated and managed vegetation/ agriculture (cropland) (40)</li> <li>• Urban/built up (50)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | <ul style="list-style-type: none"> <li>• Open forest, evergreen needle leaf (121)</li> <li>• Open forest, deciduous needle leaf (123)</li> <li>• Open forest, evergreen broad leaf (122)</li> <li>• Open forest, deciduous broad leaf (124)</li> <li>• Open forest, mixed (125)</li> <li>• Open forest, unknown (126)</li> <li>• Shrubs (20)</li> <li>• Herbaceous vegetation (30)</li> <li>• Bare/sparse vegetation (60)</li> <li>• Cultivated and managed vegetation/ agriculture (cropland) (40)</li> <li>• (Open sea) (200)</li> </ul>                                                                                                                                                                                                                                         |
| Corine Land Cover 2018 (Europe)           | <ul style="list-style-type: none"> <li>• Discontinuous urban fabric (1.1.2)</li> <li>• Industrial or commercial units and public facilities (1.2.1)</li> <li>• Dump sites (1.3.2)</li> <li>• Non-irrigated arable land (2.1.1)</li> <li>• Permanently irrigated arable land (2.1.2)</li> <li>• Rice fields (2.1.3)</li> <li>• Vineyards (2.2.1)</li> <li>• Fruit tree and berry plantations (2.2.2)</li> <li>• Olive groves (2.2.3)</li> <li>• Pastures, meadows, and other permanent grasslands under agricultural use (2.3.1)</li> <li>• Annual crops associated with permanent crops (2.4.1)</li> <li>• Complex cultivation patterns (2.4.2)</li> <li>• Land principally occupied by agriculture, with significant areas of natural vegetation (2.4.3)</li> <li>• Agro-forestry areas (2.4.4)</li> <li>• Natural grassland (3.2.1)</li> <li>• Sclerophyllous vegetation (3.2.3)</li> <li>• Transitional woodland/shrub (3.2.4)</li> <li>• Bare rock (3.3.2)</li> <li>• Sparsely vegetated areas (3.3.3)</li> </ul> | <ul style="list-style-type: none"> <li>• Dump sites (1.3.2)</li> <li>• Non-irrigated arable land (2.1.1)</li> <li>• Permanently irrigated arable land (2.1.2)</li> <li>• Rice fields (2.1.3)</li> <li>• Pastures, meadows, and other permanent grasslands under agricultural use (2.3.1)</li> <li>• Annual crops associated with permanent crops (2.4.1)</li> <li>• Complex cultivation patterns (2.4.2)</li> <li>• Land principally occupied by agriculture, with significant areas of natural vegetation (2.4.3)</li> <li>• Agro-forestry areas (2.4.4)</li> <li>• Natural grassland (3.2.1)</li> <li>• Sclerophyllous vegetation (3.2.3)</li> <li>• Transitional woodland/shrub (3.2.4)</li> <li>• Sparsely vegetated areas (3.3.3)</li> <li>• Sea and ocean (5.2.3)</li> </ul> |
| National Land Cover Database 2019 (USA)   | <ul style="list-style-type: none"> <li>• Developed, open space (21)</li> <li>• Developed, low intensity (22)</li> <li>• Developed, medium intensity (23)</li> <li>• Developed, high intensity (24)</li> <li>• Barren land (rock/sand/clay) (31)</li> <li>• Dwarf scrub (51)</li> <li>• Shrub/scrub (52)</li> <li>• Grassland/herbaceous (71)</li> <li>• Sedge/herbaceous (72)</li> <li>• Pasture/hay (81)</li> <li>• Cultivated crops (82)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <ul style="list-style-type: none"> <li>• Developed, open space (21)</li> <li>• Dwarf scrub (51)</li> <li>• Shrub/scrub (52)</li> <li>• Grassland/herbaceous (71)</li> <li>• Sedge/herbaceous (72)</li> <li>• Pasture/hay (81)</li> <li>• Cultivated crops (82)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

## EXAMPLE: SOLAR AND WIND POTENTIAL FOR THE USA

### Example: Solar and wind potential for the USA

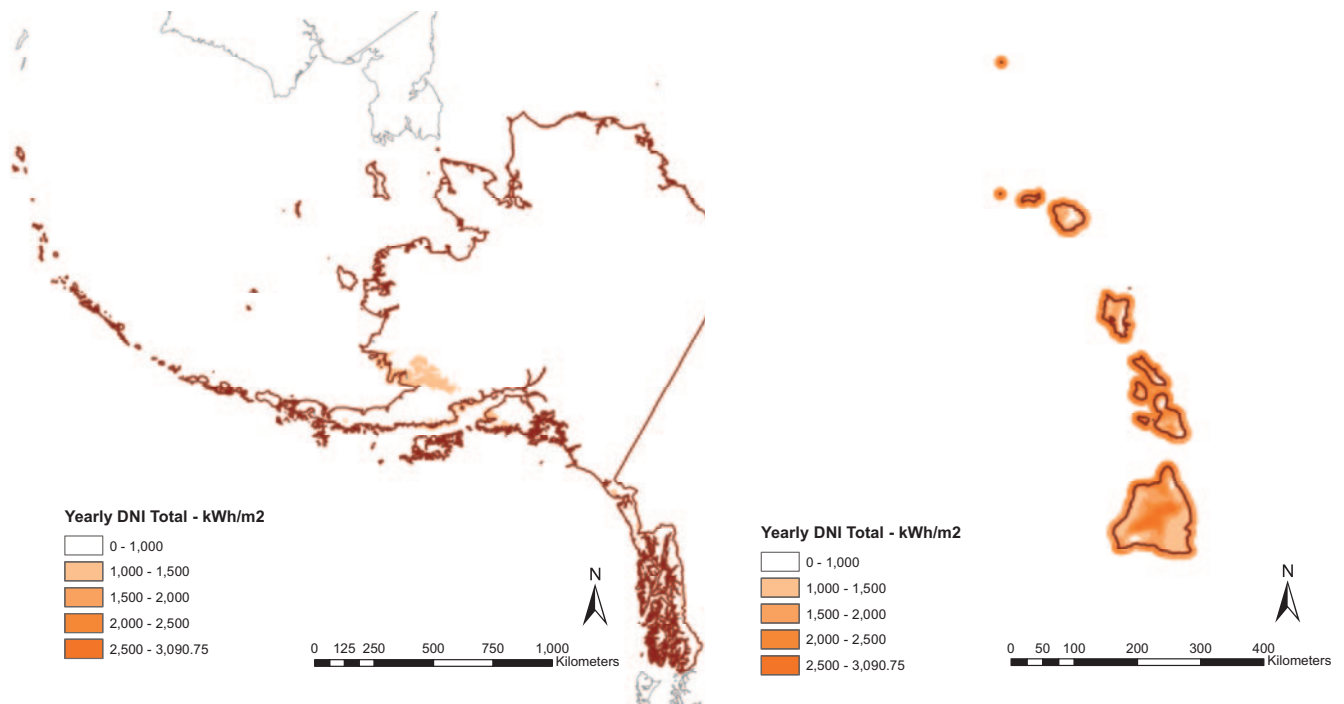
All G20 member states have been analysed in terms of their solar and wind potential. However, because the volume of maps is large, only one example—the USA—of the whole set of maps is described here in detail.

FIGURE 42: Yearly DNI total—continental USA



Source: Global Solar Atlas.

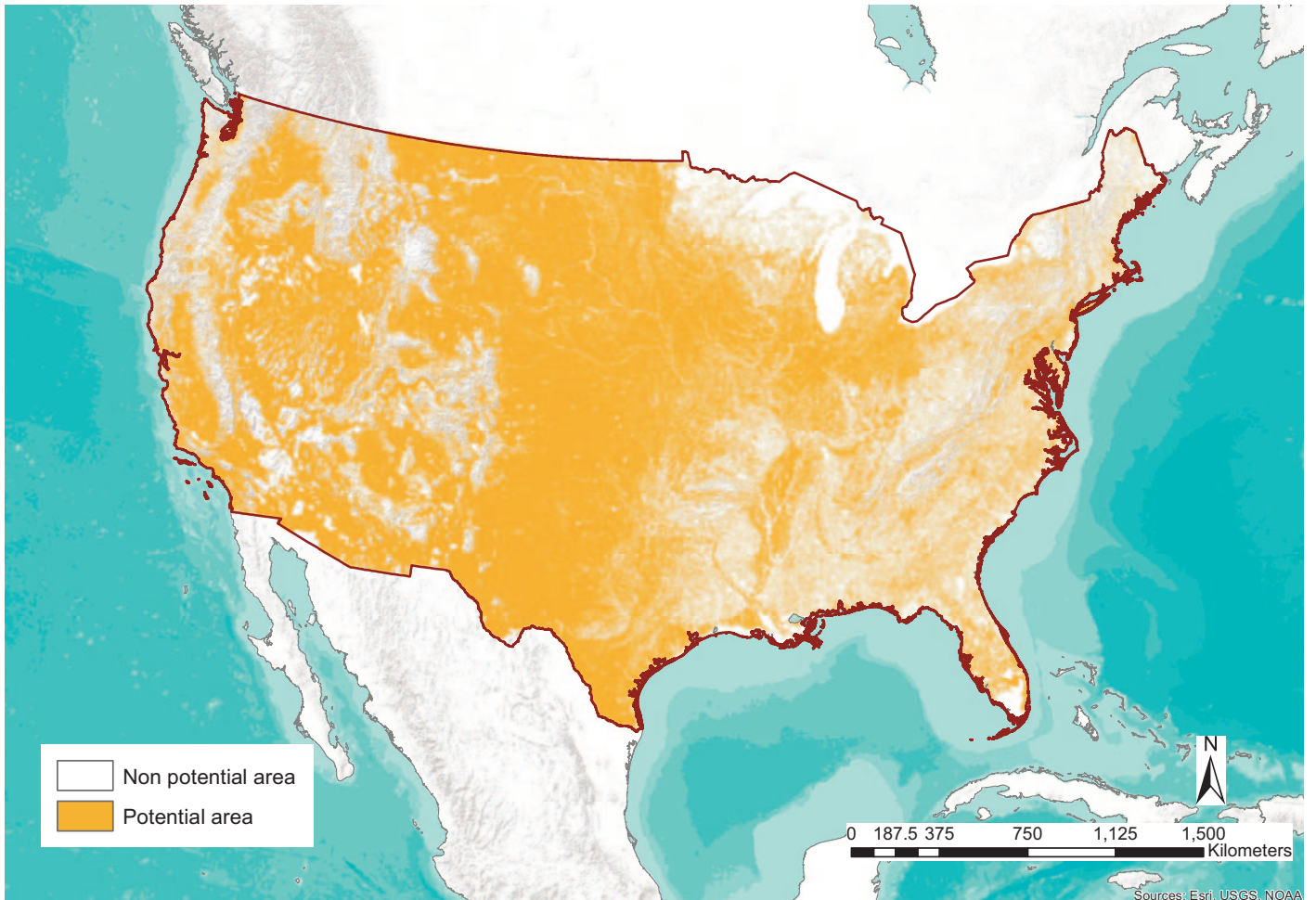
**FIGURE 43:** Yearly DNI total—USA, Alaska, & Hawaii



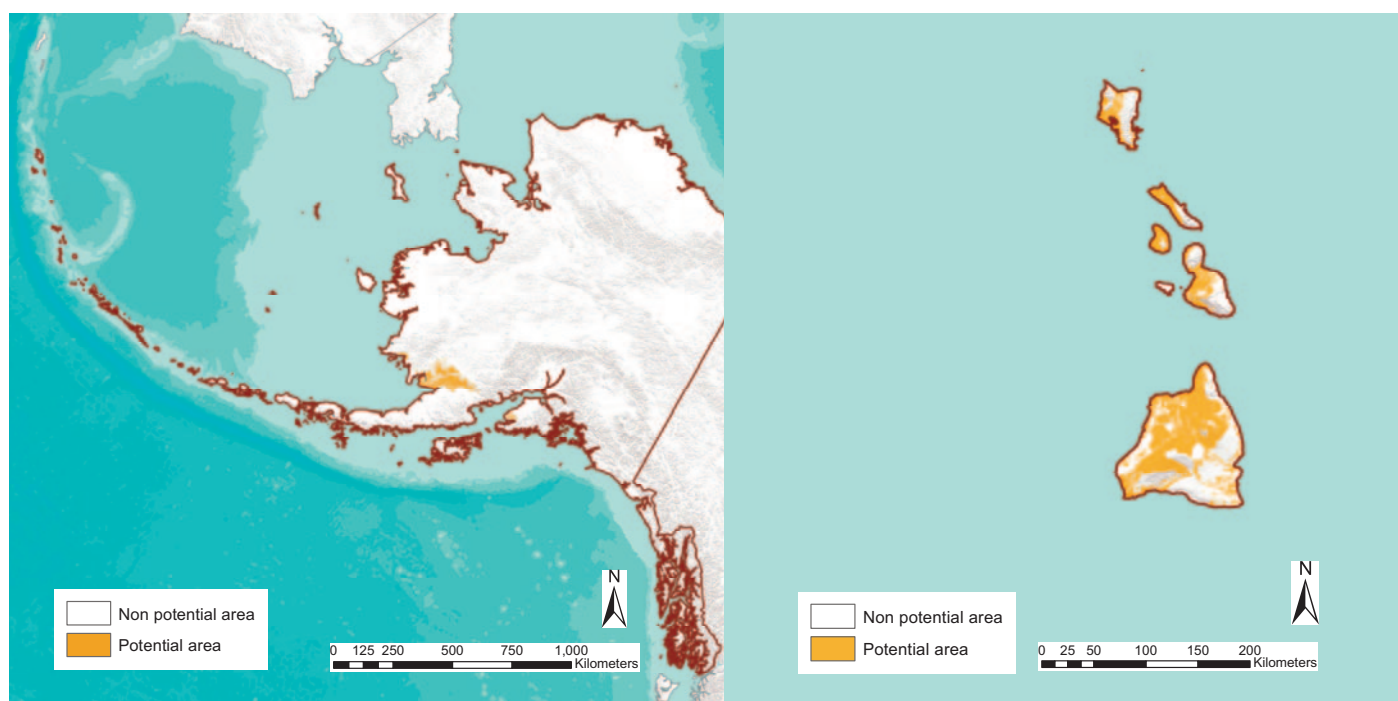
Source: Global Solar Atlas.

## EXAMPLE: SOLAR AND WIND POTENTIAL FOR THE USA

FIGURE 44: Areas of solar potential—continental USA



Source: Global Solar Atlas.

**FIGURE 45: Areas of solar potential—Alaska & Hawaii**


Source: Global Solar Atlas.

Based on the GIS mapping analysis, 4.4 million km<sup>2</sup> have land cover that is classified under the [R]ESPACE methodology as theoretically suitable for utility-scale solar installations, which translates to a total solar potential of 107,000 TW. According to the US Energy Information Administration (EIA)<sup>37</sup>, the

United States has a total utility-scale electricity-generating capacity of 1,143 GW and a small-scale solar-photovoltaic-electricity-generating capacity of about 32.9 GW. Therefore, less than 2% of the total theoretical solar potential is required to provide a sufficient electricity supply.

**TABLE 14: USA solar potential**

| Fuel | Area of solar potential (km <sup>2</sup> ) | Solar potential (GW) |
|------|--------------------------------------------|----------------------|
| USA  | 4,287,785                                  | 107,194              |

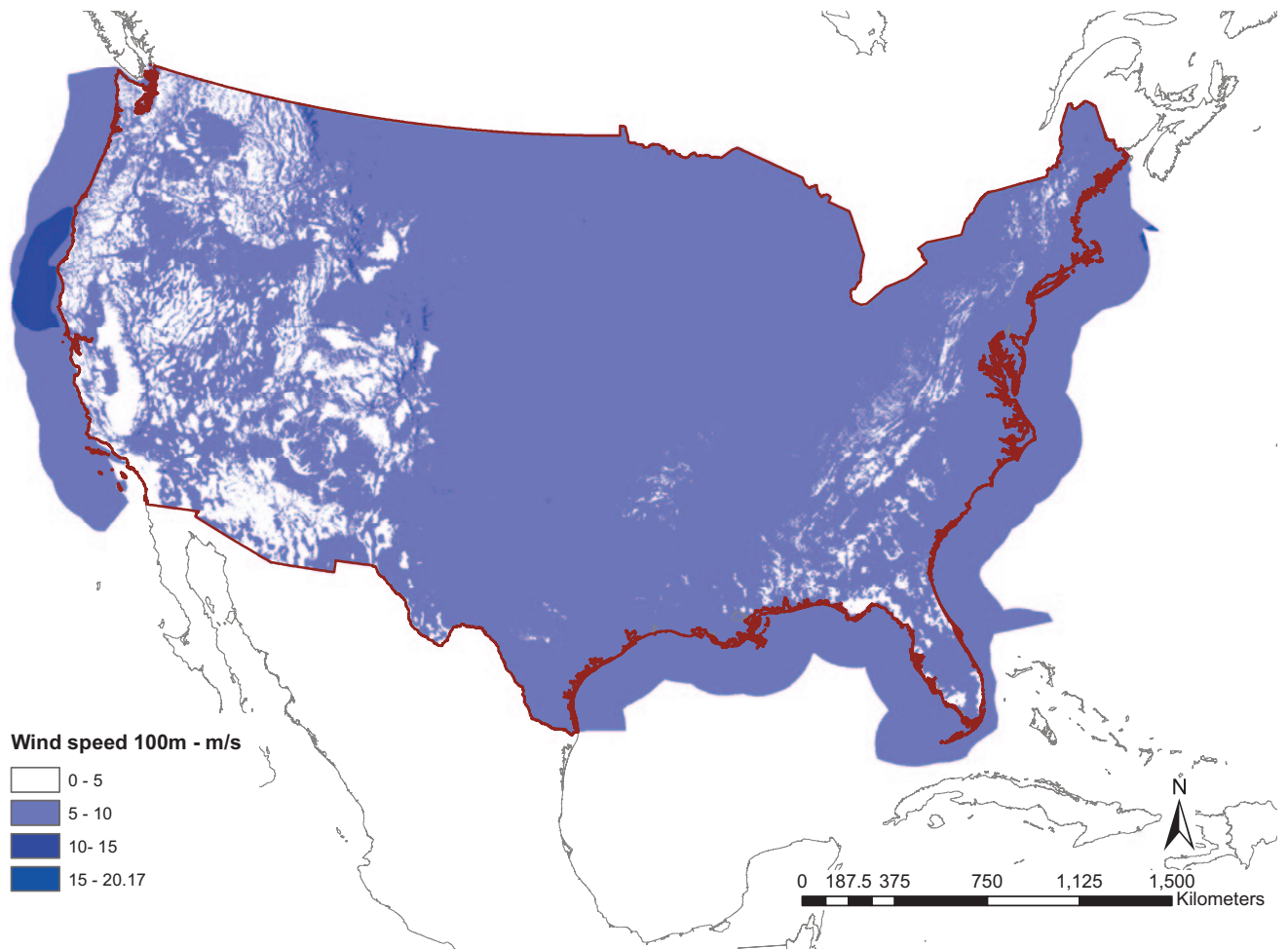
Note: No DNI data are available for any area above the 60<sup>th</sup> median east and west.

Note: GW = potential area (km<sup>2</sup>) × 25 × 0.001.

37. US Energy Information Administration (EIA – website May 2022; <https://www.eia.gov/energyexplained/electricity/electricity-in-the-us-generation-capacity-and-sales.php#:~:text=At%20the%20end%20of%202021,solar%20photovoltaic%20electricity%20generating%20capacity>).

## EXAMPLE: SOLAR AND WIND POTENTIAL FOR THE USA

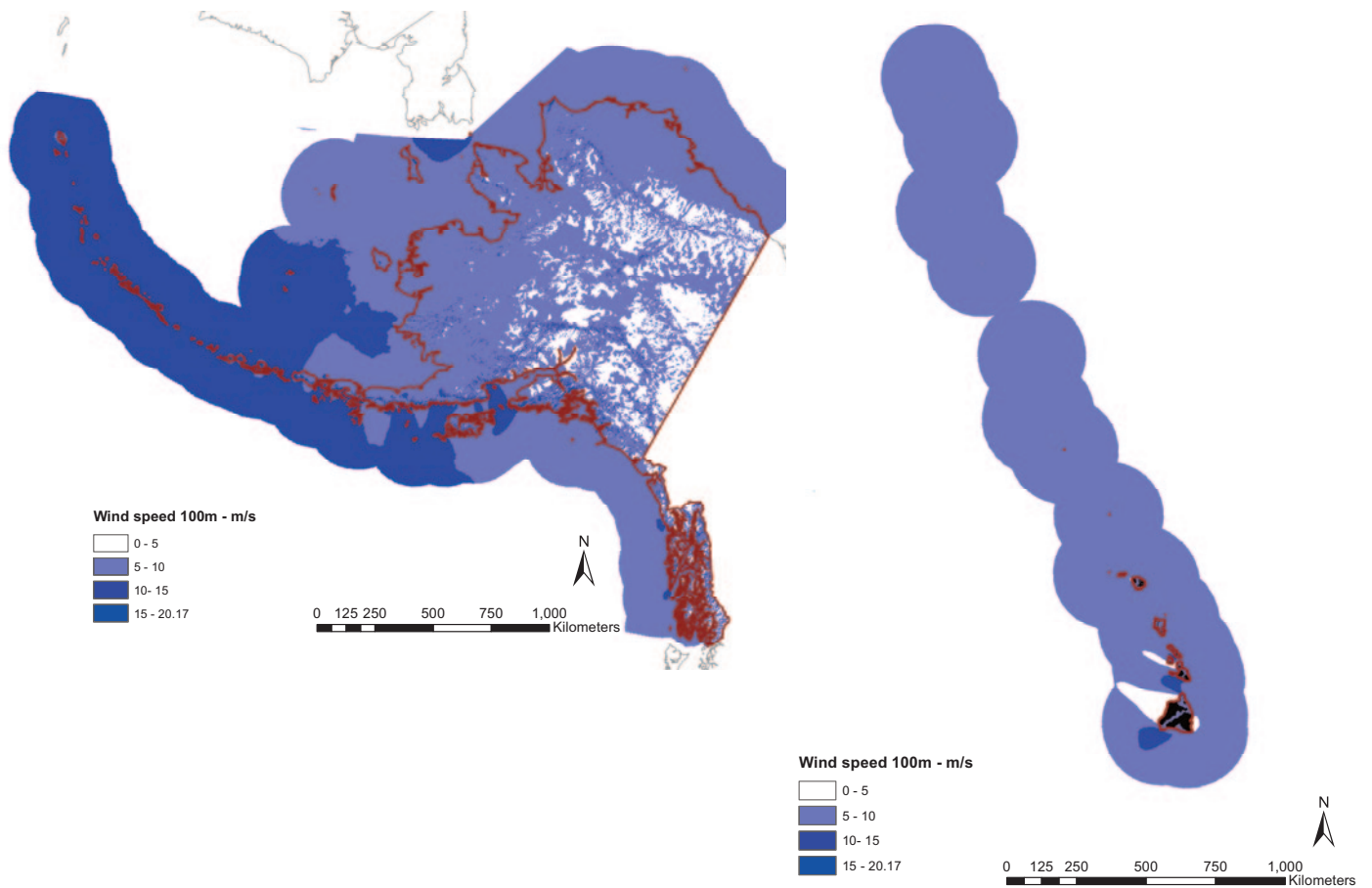
FIGURE 46: Wind speed 100 m (m/s)—continental USA



Source: Wind Solar Atlas.



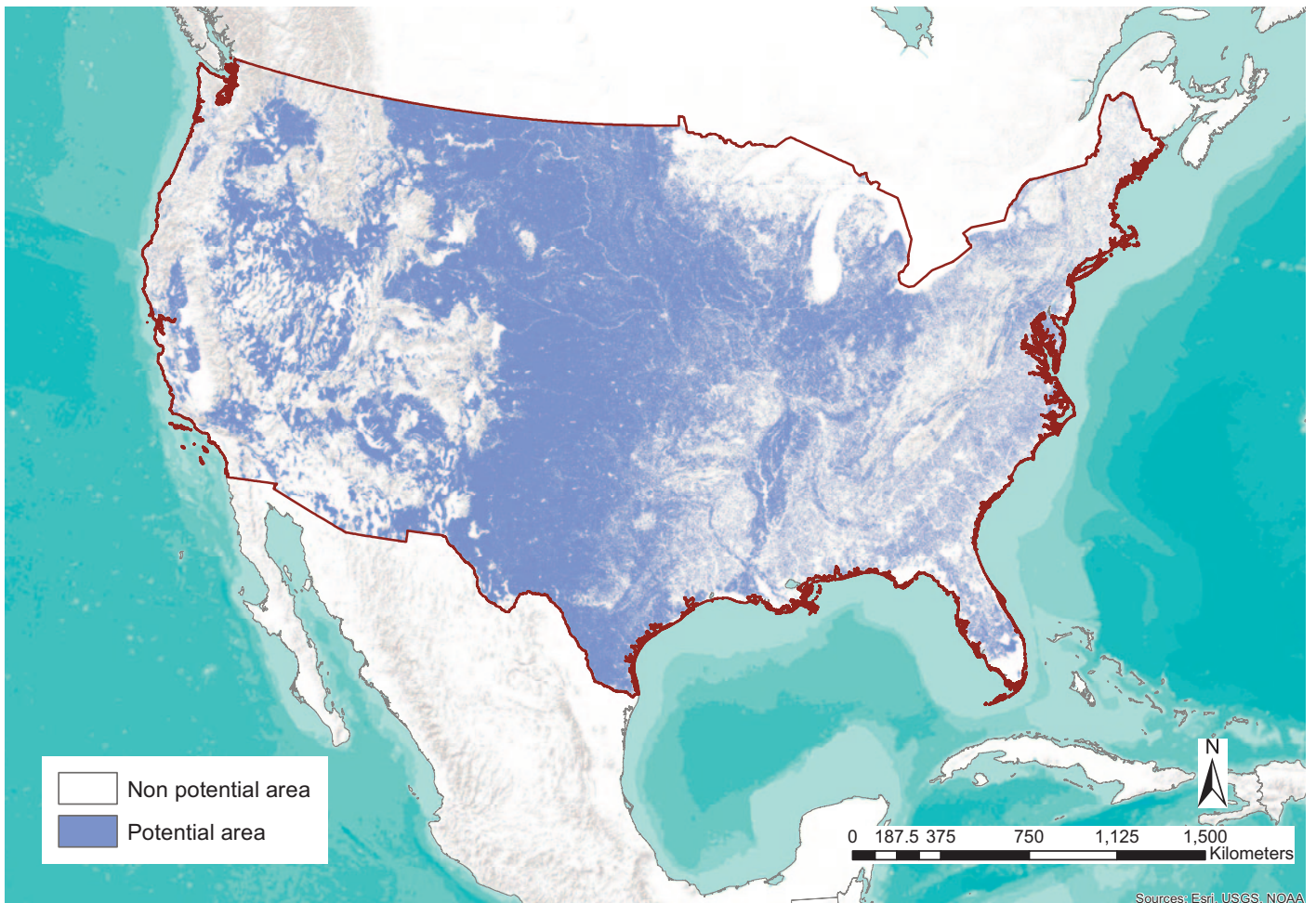
**FIGURE 47:** Wind speed 100 m (m/s)—USA, Alaska, & Hawaii



Source: Wind Solar Atlas.

## EXAMPLE: SOLAR AND WIND POTENTIAL FOR THE USA

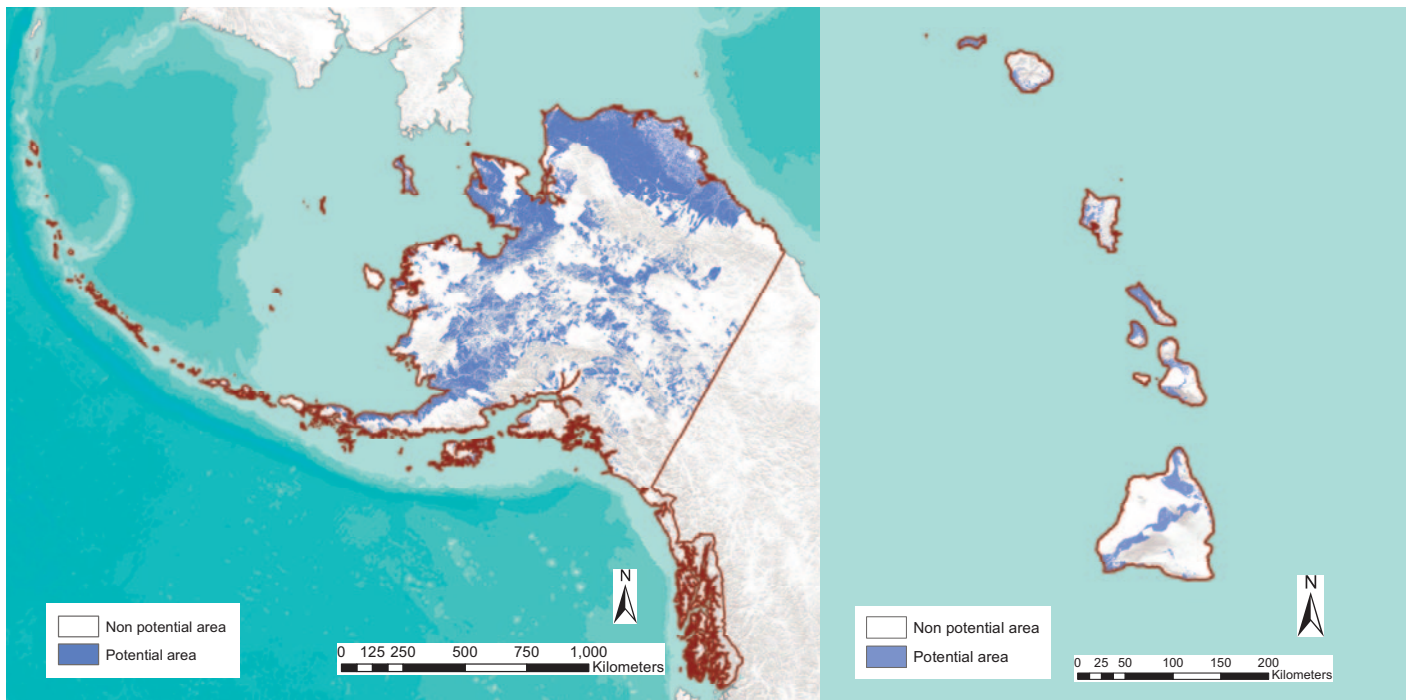
FIGURE 48: Areas of wind potential—continental USA



Source: Global Solar Atlas.



**FIGURE 49:** Areas of wind potential—Alaska & Hawaii



Source: Global Solar Atlas.

Based on the GIS mapping analysis, 3.9 million km<sup>2</sup> have land cover that is classified under the [R]ESPACE methodology as theoretically suitable for utility-scale wind power installations, which translates to a total wind potential of

19,800 TW. Compared with the USA’s installed power plant capacity of 1.2 TW in 2021, less than 10% of the total theoretical wind potential is required to provide a sufficient electricity supply.

**TABLE 15:** USA wind potential

| Fuel | Area of wind potential (km <sup>2</sup> ) | Wind potential (GW) |
|------|-------------------------------------------|---------------------|
| USA  | 3,963,311                                 | 19,816.55           |

Note: No DNI data are available for any area above the 60<sup>th</sup> median east and west.  
 Note: GW = potential area (km<sup>2</sup>) × 25 × 0.001.

## SOLAR AND WIND POTENTIAL FOR G7 AND G20 MEMBER STATES

### Solar and wind potential for G7 and G20 member states

This section provides the results of the solar and wind potential mapping analysis by region. The potentials provided are an indication of the theoretical spaces available for utility-scale solar and wind projects. Therefore, the regions indicated are by no means entirely suitable for solar and wind projects. In practise, further local mapping and on-site research are required for actual project development. Furthermore, the regional areas that are indicated as suitable for utility-scale solar and onshore wind projects overlap, so the installed capacity cannot be summed.

#### G20 solar potential

Based on the documented [R]ESPACE method, the solar and onshore wind potential of all G20 member countries has been analysed. On the territory of the G20, the total theoretical solar potentials under space-constrained conditions are listed in Table 13, and exclude protected areas, urban areas, and infrastructures such as roads, leading to a total potential of 36.8 million km<sup>2</sup> or 924,000 GW (Table 16). Under the conservative assumption that a solar photovoltaic generator produces 1,100 kWh for each installed kilowatt—which is the average value in Central Europe—the solar potential of the G20 is sufficient to supply the 2019 global electricity demand 37 times over, and 2.7% of the potentially suitable area could deliver the global electricity demand. Therefore, there is no lack of solar potential to satisfy the entire electricity demand of the G20, even under the assumption that the demand will increase significantly over the next 30 years.

TABLE 16: Solar potentials of G20 member countries

|                                         | Solar potential area (km <sup>2</sup> ) utility-scale photovoltaic | Solar potential (GW) |
|-----------------------------------------|--------------------------------------------------------------------|----------------------|
| <b>Europe</b>                           |                                                                    |                      |
| Austria                                 | 25,218                                                             | 630                  |
| Belgium                                 | 278                                                                | 7                    |
| Bulgaria                                | 48,902                                                             | 1,22.55              |
| Croatia                                 | 23,074                                                             | 577                  |
| Cyprus                                  | 4,978                                                              | 124                  |
| Czech Republic                          | 30,917                                                             | 773                  |
| Denmark                                 | 9,807                                                              | 245                  |
| Estonia                                 | 11,534                                                             | 288                  |
| Finland*                                | -                                                                  | -                    |
| France (G20 & G7)                       | 265,673                                                            | 6,642                |
| Germany (G20 & G7)                      | 57,837                                                             | 1,446                |
| Greece                                  | 57,180                                                             | 1,429                |
| Hungary                                 | 60,830                                                             | 1,521                |
| Ireland*                                | -                                                                  | 0                    |
| Italy (G20 & G7)                        | 158,793                                                            | 3,970                |
| Latvia                                  | 9,921                                                              | 248                  |
| Lithuania                               | 7,588                                                              | 190                  |
| Luxembourg                              | 244                                                                | 6                    |
| Malta                                   | 210                                                                | 5                    |
| Netherlands                             | 496                                                                | 12                   |
| Poland                                  | 97,703                                                             | 2,443                |
| Portugal                                | 48,594                                                             | 1,215                |
| Romania                                 | 132,969                                                            | 3,324                |
| Slovakia                                | 19,919                                                             | 498                  |
| Slovenia                                | 5,249                                                              | 131                  |
| Spain                                   | 269,061                                                            | 6,727                |
| Sweden                                  | 29,140                                                             | 729                  |
| <b>EU27 total</b>                       | <b>1,376,111</b>                                                   | <b>34,403</b>        |
| United Kingdom (G20 & G7)               | 1,134                                                              | 28                   |
| Russia (G20)                            | Not available                                                      | Not available        |
| <b>Africa &amp; Middle East</b>         |                                                                    |                      |
| Saudi Arabia (G20)                      | 2,039,070                                                          | 50,977               |
| South Africa (G20)                      | 1,264,979                                                          | 31,624               |
| <b>Americas</b>                         |                                                                    |                      |
| Canada (G7 & G20)                       | 1,950,839                                                          | 48,771               |
| United States of America (G7 & G20)     | 4,287,785                                                          | 107,195              |
| Mexico (G20)                            | 1,423,200                                                          | 35,580               |
| Brazil (G20)                            | 3,821,191                                                          | 95,530               |
| Argentina (G20)                         | 2,682,500                                                          | 67,062               |
| <b>Asia &amp; Australia</b>             |                                                                    |                      |
| Turkey (G20)                            | 527,730                                                            | 13,193               |
| South Korea (G20)                       | 50,692                                                             | 1,267                |
| China (G20)                             | 8,710,257                                                          | 217,756              |
| India (G20)                             | 2,837,208                                                          | 70,930               |
| Indonesia (G20) IESR data <sup>38</sup> | 188,162                                                            | 7,714                |
| Japan (G7 & G20)                        | 94,878                                                             | 2,372                |
| Australia (G20)                         | 6,478,611                                                          | 161,965              |
| <b>Total G7 (excluding EU27)</b>        | <b>6,816,939</b>                                                   | <b>170,423</b>       |
| <b>Total G20 (excluding EU27)</b>       | <b>36,840,539</b>                                                  | <b>924,022</b>       |

\* Due to the lower average solar radiation, it is assumed that no utility scale solar project will be installed, however the solar potential is sufficient for small to medium size solar roof top systems.

38. The solar photovoltaic data for Indonesia is taken from the following Indonesian analysis: IESR (2021). Beyond 443 GW: Indonesia's infinite renewable energy potentials. Institute for Essential Services Reform.

## G20 wind potential

The onshore wind potential of the G20 is smaller than the solar potential, but is nonetheless able to generate 18 times the current global electricity demand. Under the assumption that an average wind turbine operates with a capacity factor of 34% (3,000 h/a), the wind potential of the G20 should be able to generate 553,000 TWh.

The combined solar and wind potentials of the G20 are sufficient to generate over 50 times the current global electricity demand. About 2% of the theoretical solar and wind areas could supply the global electricity demand. The potential for onshore wind and roof-top solar would come on top of this.

**The G20 has sufficient solar and wind potential to move towards a 100% renewable energy supply.**

**TABLE 17:** Wind potentials of G20 member countries

|                                         | Area of wind potential (km <sup>2</sup> ) | Wind potential (GW) |
|-----------------------------------------|-------------------------------------------|---------------------|
| <b>Europe</b>                           |                                           |                     |
| Austria                                 | 15,343                                    | 77                  |
| Belgium                                 | 15,648                                    | 78                  |
| Bulgaria                                | 19,343                                    | 97                  |
| Croatia                                 | 11,989                                    | 60                  |
| Cyprus                                  | 1,466                                     | 7                   |
| Czech Republic                          | 36,803                                    | 184                 |
| Denmark                                 | 29,651                                    | 148                 |
| Estonia                                 | 16,493                                    | 82                  |
| Finland                                 | 54,186                                    | 271                 |
| France (G20 & G7)                       | 249,777                                   | 1,249               |
| Germany (G20 & G7)                      | 139,764                                   | 699                 |
| Greece                                  | 16,835                                    | 84                  |
| Hungary                                 | 51,436                                    | 257                 |
| Ireland                                 | 47,478                                    | 237                 |
| Italy (G20 & G7)                        | 49,817                                    | 249                 |
| Latvia                                  | 30,918                                    | 155                 |
| Lithuania                               | 37,242                                    | 186                 |
| Luxembourg                              | 650                                       | 3                   |
| Malta                                   | 145                                       | 1                   |
| Netherlands                             | 21,140                                    | 106                 |
| Poland                                  | 131,281                                   | 656                 |
| Portugal                                | 34,003                                    | 170                 |
| Romania                                 | 80,620                                    | 403                 |
| Slovakia                                | 12,360                                    | 62                  |
| Slovenia                                | 1,807                                     | 9                   |
| Spain                                   | 165,152                                   | 826                 |
| Sweden                                  | 70,156                                    | 351                 |
| <b>EU27 total</b>                       | <b>1,341,500</b>                          | <b>6,708</b>        |
| United Kingdom (G20 & G7)               | 119,881                                   | 599                 |
| Russia (G20)                            | Not available                             | Not available       |
| <b>Africa &amp; Middle East</b>         |                                           |                     |
| Saudi Arabia (G20)                      | 1,964,284                                 | 9,821               |
| South Africa (G20)                      | 1,051,763                                 | 5,259               |
| <b>Americas</b>                         |                                           |                     |
| Canada (G7 & G20)                       | 3,410,681                                 | 17,053              |
| United States of America (G7 & G20)     | 3,963,311                                 | 19,817              |
| Mexico (G20)                            | 611,628                                   | 3,058               |
| Brazil (G20)                            | 1,880,615                                 | 9,403               |
| Argentina (G20)                         | 3,113,501                                 | 15,568              |
| <b>Asia &amp; Australia</b>             |                                           |                     |
| Turkey (G20)                            | 229,396                                   | 1,147               |
| South Korea (G20)                       | 16,262                                    | 81                  |
| China (G20)                             | 7,915,029                                 | 39,575              |
| India (G20)                             | 1,017,154                                 | 5,086               |
| Indonesia (G20) IESR data <sup>39</sup> | 105,042                                   | 24,926              |
| Japan (G7 & G20)                        | 35,166                                    | 176                 |
| Australia (G20)                         | 6,126,725                                 | 30,634              |
| <b>Total G7 (excluding EU27)</b>        | <b>7,968,397</b>                          | <b>39,842</b>       |
| <b>Total G20 (excluding EU27)</b>       | <b>24,092,682</b>                         | <b>184,400</b>      |

39. The wind potential data for Indonesia is taken from the following Indonesian analysis: IESR (2021). Beyond 443 GW: Indonesia's infinite renewable energy potentials. Institute for Essential Services Reform.

# G20 Policy Recommendations

# 04

Wind turbines,  
Taichung, Taiwan.  
© Shutterstock.com  
/higrace

Our recommendations focus on the targets that G20 nations must set to ensure that the development of renewable energy is accelerated to meet climate change targets. Consequently, this is not a comprehensive set of recommendations.

However, the policy recommendations are based on the G20 Leaders Declaration of July 2017, as defined in the *G20 Hamburg Climate and Energy Action Plan for Growth* ('G20 Action Plan')<sup>40</sup>. The G20 Action Plan consists of the following six parts:

- A** Nationally determined contributions.
- B** Development of long-term strategies to ensure low greenhouse gas emissions.
- C** A reliable and secure framework for the energy sector transition.
- D** Enhancing climate resilience and adaptation efforts.
- E** Aligning finance flows.
- F** Global action and transformation in other fora and processes.

Furthermore, it defines the way forward and encourages an on-going 'dialogue with civil society stakeholders from the public and business sectors, NGOs, academia and think tanks'. The following recommendations and policy measures should contribute to future G20 debates.

## Qualitative measures

Other complementary measures are required, which have been highlighted by international energy institutions undertaking large-scale policy reviews (see IEA 2021d; IRENA 2021b; IRENA, IEA & REN21 2020). These include:

- streamlining permission processes to accelerate the deployment of renewable energy;
- a drive for mass electrification, electric vehicles, and heat pumps to increase the reach of renewable electricity;
- improving policy and investment certainty, while scaling-up delivery mechanisms, such as feed-in tariffs, standardized power purchase agreements (PPAs) or reverse auctions;
- developing a skilled workforce and managing the supply chain pressures to facilitate growth;
- instituting measures for the integration of renewable energy, including building transmission and distribution networks, grid modernisation, and system flexibility;
- developing sectoral policies to implement targets, such as regulation, financial incentives, and policy support to catalyse the growth of renewable heating and cooling; and,
- building social licence for renewable energy, via the complimentary implementation of policies that enable private as well as small and medium enterprises (SME's) to participate economically in renewable energy projects. Programs such as feed-in tariffs have proven to gain more acceptance for renewable energy projects among communities and civil societies, while policies that exclude SME's often lead to a decline of social acceptance for renewables.

Our report instead focuses on eight recommendations for setting renewable energy targets in G20 nations and their achievement.

40. G20 Germany 2017/Hamburg; Annex to G20 Leaders Declaration G20 Hamburg Climate and Energy Action Plan for Growth; [https://www.g20germany.de/Content/DE/\\_Anlagen/G7\\_G20/2017-g20-climate-and-energy-en\\_\\_\\_blob=publicationFile&v=6.pdf](https://www.g20germany.de/Content/DE/_Anlagen/G7_G20/2017-g20-climate-and-energy-en___blob=publicationFile&v=6.pdf).

## QUALITATIVE MEASURES

| Recommendation                                                                                                                                                             | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>Recommendation 1:</b><br/>G20 should set a renewable electricity target of 70% by 2030.</p>                                                                          | <p>Based on the documented projections, the authors recommend a G20 renewable electricity target of 70% for 2030.</p> <p>IRENA (2022) has recommended a global target of 65% by 2030.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <p><b>Recommendation 2:</b><br/>G20 should set a renewable final energy target of 60% by 2030.</p>                                                                         | <ul style="list-style-type: none"> <li>• The share of renewable electricity is increasing, but progress in increasing the shares of renewable energy in the heating and transport sectors is too slow or even stagnant. Therefore, the development of the renewable energy shares in primary and total energy consumption has been very slow.</li> <li>• G20 nations must set higher targets as the starting points to dramatically increase the shares of renewables in their final and total energy consumption.</li> <li>• IRENA (2022) has recommended a global target of 38% renewable energy as the share of the total final energy consumption by 2030.</li> </ul>                                                                                                                                                                                                                                                        |
| <p><b>Recommendation 3:</b><br/>G20 nations should review and set targets for renewable heating. The authors recommend a renewable heating target of 55%–60% for 2030.</p> | <ul style="list-style-type: none"> <li>• The IEA (2021d: 16) forecasts that the share of renewable energy in global heat consumption will only increase from 11% (2020) to 13% (2026).</li> <li>• As IRENA, IEA, &amp; REN21 (2020: 19) have noted: ‘despite its potential for advancing the energy transition, the use of energy for heating and cooling has received relatively little attention from policy makers.’</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <p><b>Recommendation 4:</b><br/>Each G20 nation should set a long-term 100% renewable electricity target.</p>                                                              | <ul style="list-style-type: none"> <li>• All nations should have a 100% renewable electricity target date, with variations between nations depending on local factors, such as National Determined Contributions (NDCs), renewable energy resources, etc.</li> <li>• Electricity is one of the easiest sectors for abatement, and a target date will facilitate least-cost planning, investment, and policy-making, and also complementary measures that address employment impacts, build social licence, and maintain energy system security. Immediate action is essential in building alternative employment strategies and planning a secure energy system.</li> <li>• For rich nations (UK, Germany, and Canada), the benchmark has been set at 2035.</li> <li>• For other G20 nations, the date will be later, commensurate with their circumstances and NDCs, but setting a target date is an important step.</li> </ul> |
| <p><b>Recommendation 5:</b><br/>G20 governments should set targets for 100% renewable energy and zero emissions for their own operations.</p>                              | <ul style="list-style-type: none"> <li>• Decarbonizing electricity consumption for the operations of government is ‘low-hanging fruit’ and an opportunity for governments to accelerate the transition, encourage innovation, and set best practice standards.</li> <li>• Only the United States has committed to 100% renewable energy for its operations, to date.</li> <li>• All governments should commit to 100% renewable electricity for their own operations, accelerated energy efficiency, and a net zero emissions target.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                 |



| Recommendation                                                                                                                                                 | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><b>Recommendation 6:</b><br/>Each G20 nation should set binding energy efficiency targets.</p>                                                              | <ul style="list-style-type: none"> <li>• Energy efficiency is an essential complement to renewable energy. There are extensive cost-effective opportunities across all G20 nations to reduce the cost and accelerate the speed of decarbonization.</li> <li>• Energy efficiency targets compel action, create an effective signal for investment, and create an effective benchmark for areas that are harder to measure and track than renewable energy.</li> <li>• Across most G20 nations, there is a patchwork of targets and policies—few have a comprehensive set of targets, and most are voluntary and lack strong mechanisms for implementation. Most recent investment has been concentrated in Europe (IEA 2021c: 9).</li> <li>• The IEA (2021b: 17) has called for ‘a relentless focus on energy efficiency’ and states that estimated global energy intensity must improve by 4% per annum to meet its net zero emissions scenario—a major acceleration from the average improvement of 1.3% per annum over the past 5 years (IEA 2021c: 8). IRENA (2022) has recommended an increase in the rate of improvement in energy intensity of 2.5% by 2030.</li> <li>• Energy efficiency has been a key priority of G20 energy programmes over the past decade and a natural area for leadership by the G20. All G20 nations must commit to reviewing and setting energy efficiency targets across all sectors and to accelerating initiatives to meet these targets.</li> </ul> |
| <p><b>Recommendation 7:</b><br/>Each G20 nation should model and set energy storage targets.</p>                                                               | <ul style="list-style-type: none"> <li>• Each nation must develop a plan for efficiently and securely integrating renewable energy into energy systems, including ‘a huge build-out of electricity infrastructure and all forms of system flexibility’ (IEA 2021: 17).</li> <li>• Large-scale development of storage, including battery storage, pumped hydro storage, and hydrogen, is essential for the integration of renewable energy.</li> <li>• Although a range of scenarios has been developed by energy market institutions and planners (e.g., a European Commission study found the EU needs 108 GW of battery storage to achieve its 2030 targets), the only nation to set an energy storage target to date is Italy.</li> <li>• Each G20 nation should model and set energy storage targets underpinned by comprehensive strategies to rapidly scale-up energy storage.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <p><b>Recommendation 8:</b><br/>Each G20 nation should have a transition authority responsible for monitoring and evaluating progress towards all targets.</p> | <ul style="list-style-type: none"> <li>• Good governance is an essential element of achieving ambitious targets.</li> <li>• Where no institutions or governance are in place to monitor, evaluate, or revise targets and their achievement, there can be problems of fragmentation and/or co-ordination and policy drift—a luxury that we cannot afford if a 2°C warming target (and most certainly a 1.5°C warming target) is to be achieved. Rapid adjustment in response to events will be an important component of the successful achievement of targets.</li> <li>• Several G20 nations have established transition authorities, such as the UK Climate Change Authority and Canada’s Net Zero Advisory Body, which provide models for bodies with public authority to oversee energy and climate transitions.</li> <li>• Each G20 country should review its governance arrangements and establish a transition institution with the authority and resources from governments to monitor and evaluate progress and develop on-going recommendations on targets and policies.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                           |

## QUANTITATIVE MEASURES

### Quantitative measures

Based on the projections documented in Chapter 2, this section provides an overview of the estimated renewable energy targets by country and/or region for primary energy, electricity, heat, and transport.

**TABLE 18: Renewable energy target projections—Primary energy for member countries of the G7 and G20**

| Renewable energy target projections - Primary energy | Unit | 2019         | 2025         | 2030         | 2040         | 2050        |
|------------------------------------------------------|------|--------------|--------------|--------------|--------------|-------------|
| Argentina (G20)                                      | %    | 9.1%         | 32.9%        | 47.3%        | 90.5%        | 100%        |
| Australia (G20)                                      | %    | 7.3%         | 47.3%        | 64.3%        | 93.4%        | 100%        |
| Brazil (G20)                                         | %    | 46.8%        | 64.9%        | 74.9%        | 92.7%        | 100%        |
| Canada (G20) & (G7)                                  | %    | 16.5%        | 44.5%        | 58.3%        | 93.2%        | 100%        |
| China (G20)                                          | %    | 9.6%         | 47.7%        | 66.5%        | 96.9%        | 100%        |
| EU27 (G20) & (G7)                                    | %    | 16.0%        | 41.9%        | 54.6%        | 91.2%        | 100%        |
| France (G20) & (G7)                                  | %    | 10.6%        | 34.1%        | 46.7%        | 93.1%        | 100%        |
| Germany (G20) & (G7)                                 | %    | 15.4%        | 48.8%        | 61.1%        | 90.9%        | 100%        |
| India (G20)                                          | %    | 25.8%        | 38.8%        | 48.9%        | 96.1%        | 100%        |
| Indonesia (G20)                                      | %    | 13.2%        | 44.3%        | 64.2%        | 89.3%        | 100%        |
| Italy (G20) & (G7)                                   | %    | 18.6%        | 36.9%        | 45.9%        | 86.7%        | 100%        |
| Japan (G7 & G20)                                     | %    | 6.4%         | 37.3%        | 51.7%        | 88.0%        | 100%        |
| South Korea (G20)                                    | %    | 2.0%         | 46.9%        | 65.8%        | 94.9%        | 100%        |
| Mexico (G20)                                         | %    | 9.0%         | 31.8%        | 45.7%        | 85.8%        | 100%        |
| Russia (G20)                                         | %    | 2.8%         | 35.6%        | 51.6%        | 94.0%        | 100%        |
| Saudi Arabia (G20)                                   | %    | 0.0%         | 47.4%        | 67.2%        | 94.0%        | 100%        |
| South Africa (G20)                                   | %    | 6.7%         | 34.5%        | 50.6%        | 78.2%        | 100%        |
| Turkey (G20)                                         | %    | 15.3%        | 48.6%        | 65.7%        | 91.8%        | 100%        |
| United Kingdom (G20) & (G7)                          | %    | 12.8%        | 48.0%        | 64.1%        | 89.7%        | 100%        |
| United States of America (G20) & (G7)                | %    | 8.1%         | 36.9%        | 50.9%        | 90.5%        | 100%        |
| <b>G7</b>                                            | %    | <b>9.9%</b>  | <b>48.1%</b> | <b>65.5%</b> | <b>92.2%</b> | <b>100%</b> |
| <b>G20</b>                                           | %    | <b>10.5%</b> | <b>45.9%</b> | <b>63.5%</b> | <b>94.6%</b> | <b>100%</b> |



**TABLE 19: Renewable energy target projections—Electricity generation for member countries of the G7 and G20**

| Renewable energy target projections - Electricity generation | Unit | 2019         | 2025         | 2030         | 2040         | 2050        |
|--------------------------------------------------------------|------|--------------|--------------|--------------|--------------|-------------|
| Argentina (G20)                                              | %    | 20.1%        | 49.3%        | 60.2%        | 96.4%        | 100%        |
| Australia (G20)                                              | %    | 17.2%        | 56.2%        | 71.0%        | 97.7%        | 100%        |
| Brazil (G20)                                                 | %    | 65.3%        | 89.3%        | 92.0%        | 99.0%        | 100%        |
| Canada (G20) & (G7)                                          | %    | 60.3%        | 75.3%        | 80.7%        | 99.0%        | 100%        |
| China (G20)                                                  | %    | 22.7%        | 65.7%        | 81.3%        | 99.4%        | 100%        |
| EU27 (G20) & (G7)                                            | %    | 30.3%        | 52.7%        | 62.3%        | 97.6%        | 100%        |
| France (G20) & (G7)                                          | %    | 22.7%        | 30.5%        | 43.1%        | 99.1%        | 100%        |
| Germany (G20) & (G7)                                         | %    | 38.4%        | 57.3%        | 67.0%        | 97.4%        | 100%        |
| India (G20)                                                  | %    | 15.3%        | 39.1%        | 47.4%        | 58.7%        | 100%        |
| Indonesia (G20)                                              | %    | 14.9%        | 48.2%        | 64.2%        | 86.6%        | 100%        |
| Italy (G20) & (G7)                                           | %    | 31.7%        | 56.5%        | 62.0%        | 95.1%        | 100%        |
| Japan (G7 & G20)                                             | %    | 16.4%        | 40.8%        | 51.6%        | 94.5%        | 100%        |
| South Korea (G20)                                            | %    | 4.3%         | 46.7%        | 64.6%        | 98.1%        | 100%        |
| Mexico (G20)                                                 | %    | 13.9%        | 39.3%        | 53.6%        | 92.7%        | 100%        |
| Russia (G20)                                                 | %    | 17.6%        | 40.4%        | 53.3%        | 96.4%        | 100%        |
| Saudi Arabia (G20)                                           | %    | 0.1%         | 40.3%        | 62.4%        | 95.2%        | 100%        |
| South Africa (G20)                                           | %    | 5.1%         | 28.5%        | 44.1%        | 72.5%        | 100%        |
| Turkey (G20)                                                 | %    | 43.6%        | 73.7%        | 84.8%        | 99.1%        | 100%        |
| United Kingdom (G20) & (G7)                                  | %    | 37.7%        | 59.6%        | 71.4%        | 98.0%        | 100%        |
| United States of America (G20) & (G7)                        | %    | 17.6%        | 33.0%        | 46.6%        | 95.7%        | 100%        |
| <b>G7</b>                                                    | %    | <b>22.5%</b> | <b>56.4%</b> | <b>70.5%</b> | <b>98.2%</b> | <b>100%</b> |
| <b>G20</b>                                                   | %    | <b>28.3%</b> | <b>52.3%</b> | <b>71.2%</b> | <b>98.4%</b> | <b>100%</b> |

## QUANTITATIVE MEASURES

**TABLE 20: Renewable energy target projections—Space and process heat for member countries of the G7 and G20**

| Renewable energy target projections - Space heat and process heat | Unit | 2019         | 2025         | 2030         | 2040         | 2050        |
|-------------------------------------------------------------------|------|--------------|--------------|--------------|--------------|-------------|
| Argentina (G20)                                                   | %    | 4.4%         | 26.0%        | 38.2%        | 89.4%        | 100%        |
| Australia (G20)                                                   | %    | 17.5%        | 46.3%        | 57.5%        | 92.5%        | 100%        |
| Brazil (G20)                                                      | %    | 51.5%        | 65.5%        | 73.3%        | 91.4%        | 100%        |
| Canada (G20) & (G7)                                               | %    | 14.0%        | 33.8%        | 44.3%        | 91.9%        | 100%        |
| China (G20)                                                       | %    | 10.8%        | 40.3%        | 55.2%        | 85.7%        | 100%        |
| EU27 (G20) & (G7)                                                 | %    | 18.0%        | 39.4%        | 48.3%        | 90.8%        | 100%        |
| France (G20) & (G7)                                               | %    | 17.4%        | 31.7%        | 37.1%        | 86.3%        | 100%        |
| Germany (G20) & (G7)                                              | %    | 13.6%        | 38.1%        | 48.7%        | 91.8%        | 100%        |
| India (G20)                                                       | %    | 45.7%        | 68.4%        | 78.8%        | 96.7%        | 100%        |
| Indonesia (G20)                                                   | %    | 33.8%        | 56.0%        | 61.6%        | 84.9%        | 100%        |
| Italy (G20) & (G7)                                                | %    | 14.6%        | 28.4%        | 33.9%        | 88.7%        | 100%        |
| Japan (G7 & G20)                                                  | %    | 4.6%         | 29.8%        | 40.6%        | 83.6%        | 100%        |
| South Korea (G20)                                                 | %    | 2.6%         | 35.0%        | 48.7%        | 91.7%        | 100%        |
| Mexico (G20)                                                      | %    | 21.6%        | 38.9%        | 48.5%        | 84.4%        | 100%        |
| Russia (G20)                                                      | %    | 1.4%         | 43.7%        | 60.6%        | 95.8%        | 100%        |
| Saudi Arabia (G20)                                                | %    | 0.0%         | 38.5%        | 56.7%        | 93.7%        | 100%        |
| South Africa (G20)                                                | %    | 17.5%        | 44.0%        | 57.6%        | 94.6%        | 100%        |
| Turkey (G20)                                                      | %    | 9.0%         | 49.7%        | 63.6%        | 95.8%        | 100%        |
| United Kingdom (G20) & (G7)                                       | %    | 7.7%         | 23.5%        | 30.8%        | 88.8%        | 100%        |
| United States of America (G20) & (G7)                             | %    | 11.9%        | 32.1%        | 42.1%        | 92.4%        | 100%        |
| <b>G7</b>                                                         | %    | <b>11.6%</b> | <b>31.4%</b> | <b>40.6%</b> | <b>90.7%</b> | <b>100%</b> |
| <b>G20</b>                                                        | %    | <b>15.8%</b> | <b>43.2%</b> | <b>57.0%</b> | <b>92.5%</b> | <b>100%</b> |

**TABLE 21: Renewable energy target projections—Transport for member countries of the G7 and G20**

| Renewable energy target projections - Transport | Unit | 2019        | 2025         | 2030         | 2040         | 2050        |
|-------------------------------------------------|------|-------------|--------------|--------------|--------------|-------------|
| Argentina (G20)                                 | %    | 8.0%        | 37.3%        | 53.4%        | 84.5%        | 100%        |
| Australia (G20)                                 | %    | 0.6%        | 50.0%        | 70.2%        | 87.7%        | 100%        |
| Brazil (G20)                                    | %    | 19.9%       | 51.3%        | 65.7%        | 87.8%        | 100%        |
| Canada (G20) & (G7)                             | %    | 3.7%        | 48.8%        | 68.0%        | 87.2%        | 100%        |
| China (G20)                                     | %    | 1.9%        | 43.7%        | 63.0%        | 89.0%        | 100%        |
| EU27 (G20) & (G7)                               | %    | 5.6%        | 48.0%        | 66.5%        | 83.8%        | 100%        |
| France (G20) & (G7)                             | %    | 6.9%        | 48.4%        | 66.5%        | 82.9%        | 100%        |
| Germany (G20) & (G7)                            | %    | 5.1%        | 48.4%        | 67.2%        | 84.6%        | 100%        |
| India (G20)                                     | %    | 1.2%        | 44.9%        | 65.4%        | 89.9%        | 100%        |
| Indonesia (G20)                                 | %    | 7.0%        | 40.2%        | 64.6%        | 90.2%        | 100%        |
| Italy (G20) & (G7)                              | %    | 4.2%        | 43.9%        | 61.7%        | 80.1%        | 100%        |
| Japan (G7 & G20)                                | %    | 0.9%        | 42.2%        | 61.0%        | 78.0%        | 100%        |
| South Korea (G20)                               | %    | 1.7%        | 50.5%        | 70.6%        | 88.6%        | 100%        |
| Mexico (G20)                                    | %    | 0.0%        | 30.1%        | 47.5%        | 77.4%        | 100%        |
| Russia (G20)                                    | %    | 1.2%        | 44.8%        | 61.8%        | 90.1%        | 100%        |
| Saudi Arabia (G20)                              | %    | 0.0%        | 41.5%        | 62.2%        | 87.8%        | 100%        |
| South Africa (G20)                              | %    | 0.1%        | 31.1%        | 48.3%        | 77.8%        | 100%        |
| Turkey (G20)                                    | %    | 0.8%        | 41.0%        | 61.2%        | 87.4%        | 100%        |
| United Kingdom (G20) & (G7)                     | %    | 4.2%        | 45.7%        | 64.6%        | 81.4%        | 100%        |
| United States of America (G20) & (G7)           | %    | 5.5%        | 48.7%        | 67.6%        | 86.0%        | 100%        |
| <b>G7</b>                                       | %    | <b>5.0%</b> | <b>47.6%</b> | <b>66.3%</b> | <b>84.6%</b> | <b>100%</b> |
| <b>G20</b>                                      | %    | <b>4.6%</b> | <b>43.7%</b> | <b>62.4%</b> | <b>86.0%</b> | <b>100%</b> |

# F20

The Foundations Platform F20 is a network of more than 75 foundations and philanthropic organizations from different parts of the world.

F20 is calling for joint, transnational action towards sustainable development, along positive transformation examples to provide pathways towards solutions of today's most pressing challenges - climate change and a just transition towards sustainable development, based on renewable energy. F20 wants to be part of the solution and builds bridges between civil society, the business and financial sectors, think tanks and politics - within the G20 countries, between them and beyond.

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