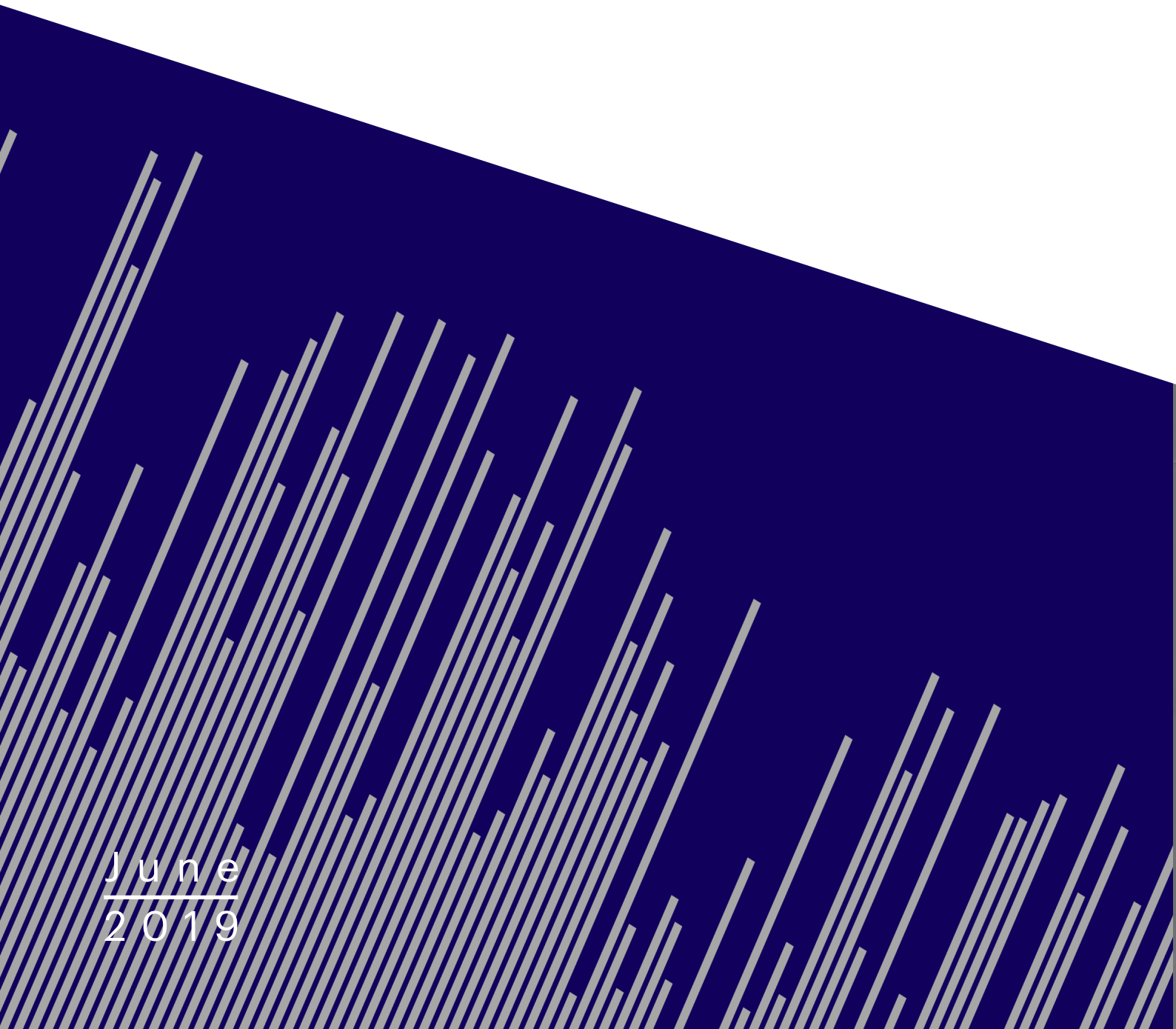
Securing Investments in Low-Carbon Power Generation Sources



June
2019

Abstract

Japan's G20 presidency 2019 asked the International Energy Agency to analyse progress in G20 countries towards securing investments in low-carbon power generation. The Japan presidency, which began on 1 December 2018 and runs through 30 November 2019, has placed a strong focus on innovation, business and finance.[1] In the areas of energy and the environment, Japan wishes to create a "virtuous cycle between the environment and growth", which is the core theme of the G20 Ministerial Meeting on Energy Transitions and Global Environment for Sustainable Growth in Karuizawa, Japan, 15-16 June 2019.

A first draft report was presented to the 2nd meeting of the G20 Energy Transitions Working Group (ETWG), held through 18-19 April 2019. This final report incorporates feedback and comments submitted during April by the G20 membership and was shared with the ETWG members.

This final report is cited in "Proposed Documents for the Japanese Presidency of the G20" that was distributed to the G20 energy ministers, who convened in Karuizawa on 15-16 June 2019.

This report, prepared as an input for the 2019 G20 ministerial meeting, is an IEA contribution; it is not submitted for formal approval by energy ministers, nor does it reflect the G20 membership's national or collective views. This report looks at one of the key challenges for the decarbonisation of the energy sector, notably in organised power markets. Based on insights from the IEA flagship publication, *World Energy Outlook 2018*, and from the recent *World Energy Investment 2019*, the report provides guidance to policy makers on how to accelerate the decarbonisation of the power sector.

[1] For an overview of the vision and priorities of the G20 Japan presidency, see www.japan.go.jp/g20japan/.

Highlights

The IEA's analysis on low-carbon power markets, including in this report, sheds light on key priority actions to accelerate energy transitions in the context of G20.

- **Current low-carbon investments are not on track.** Even if under current policies low-carbon sources are expected to be the fastest-growing source of energy until 2040, this will not be enough to fulfil the climate change mitigation goals of the Paris Agreement.

- The power sector is extremely important in the global decarbonisation effort. **While electricity's share in total final energy consumption is less than 20%, almost 40% of CO_2 emissions are attributable to the electricity sector.** Furthermore, deep decarbonisation of the electricity system is necessary if electrification in transport, industry and other sectors is to become the key to further decarbonisation.

- **Low-carbon sources' total share in the energy mix has been kept at roughly the same level as in the early 2000s.** Despite the large investments in wind and solar over last ten years, these efforts have only compensated for the low growth in other sources such as nuclear and hydropower.

- Even if wind and solar PV deployment could be accelerated, **other low-carbon technologies like dispatchable renewables, nuclear power and CCUS also need to be expanded at massive scale to decarbonise the power sector**. The level of additional renewable generation sources required to achieve the Sustainable Development Scenario is already extremely high. Expanding the level even more to make up for the lack of growth or decline in nuclear power or CCUS implies enormous challenges in terms of not only additional costs but also land availability and local acceptance.

- **By 2030, expected higher shares of variable renewables in many power systems will require increased flexibility**, which could be provided from many sources, including through the investment in grid interconnection, batteries and demand response, although dispatchable power plants will remain the cornerstone of system flexibility.

- **Power market designs are crucial in achieving a low-carbon transition without compromising security of supply**. Key principles are to ensure remuneration to generation sources that reflects the economic value they provide to the power system, and to send the correct price signals for investments. Low-carbon generation technologies, which have their own technology-specific characteristics and challenges, require market systems designed to address them.

- **Government policies and actions will play crucial roles in determining power generation investments and the resulting power generation mix.** Given the central role of electricity supply in achieving a sustainable energy pathway, it will be critical for policies and measures to make a stronger push towards a rapid energy transition.

Analysis

Introduction

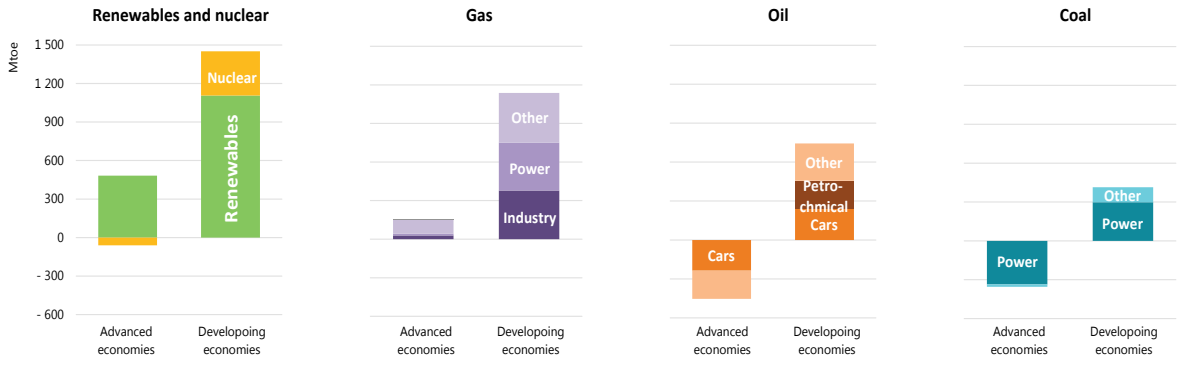
Rapid cost declines in variable renewable energy sources such as wind and solar photovoltaics (PV) have contributed to their increasing penetration in the power generation sector, accelerated by strong policy support. This is good news for clean energy transitions, but the prospects for overall energy sector decarbonisation are less certain. The following note addresses the importance of assessing the current deployment speed of low-carbon power generation sources vis-à-vis energy-related sustainability goals, including the target set in the Paris Agreement. In addition, it looks at how decarbonisation in the electricity sector can be accelerated by ensuring needed investments in low-carbon power generation sources.

Current low-carbon investments are not on track

Future energy mix

The New Policies Scenario (NPS) projections from *World Energy Outlook* (IEA, 2018a), which reflect the policy ambitions of the Nationally Determined Contributions in the Paris Agreement, show low-carbon sources – mostly renewables and partly nuclear – as the fastest-growing from now to 2040.

Figure 1. Change in global energy demand in the NPS, 2017 to 2040



Source: IEA (2018a), World Energy Outlook 2018.

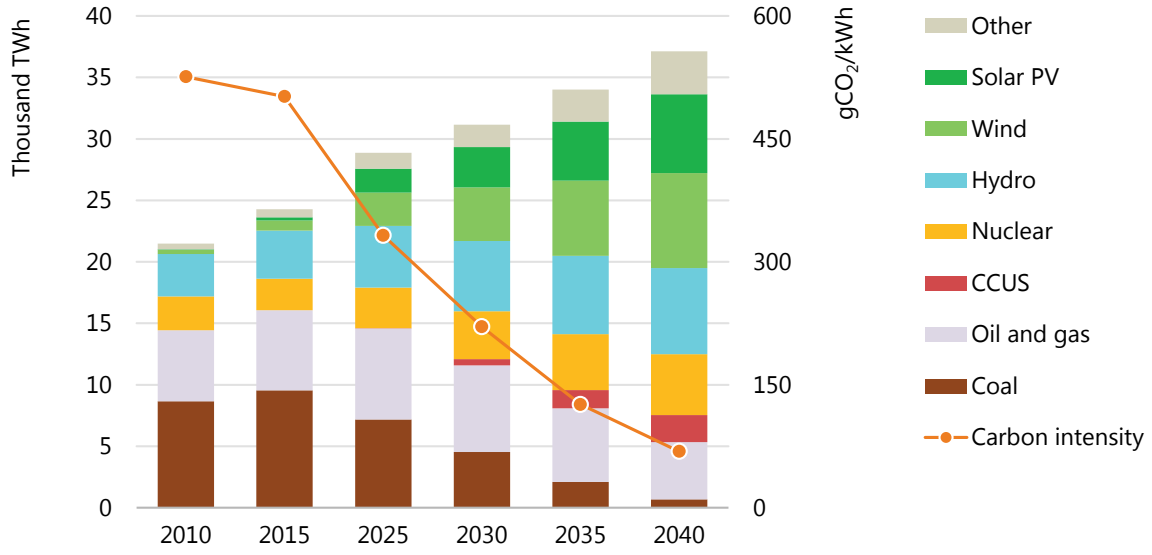
This level of clean energy investment is not enough to put the world on track to achieve the climate change mitigation goal of the Paris Agreement: at this level, global emissions in 2040 would be higher than last year's record levels of over 33 gigatonnes (Gt). The *WEO 2018* Sustainable Development Scenario (SDS) shows what would be needed to achieve the Paris Agreement and other sustainability goals. To achieve the Paris goal, CO_2 emissions must peak very soon, decline rapidly to 18 Gt per year of less by 2040, and then continue to decline thereafter to zero net emissions.

The power sector's central role in decarbonisation

The power sector is extremely important in the global decarbonisation effort. While electricity's share in total final energy consumption is less than 20%, almost 40% of CO_2 emissions are attributable to the electricity sector.

In the SDS, the power sector leads decarbonisation efforts: most of the decarbonisation of the energy system to 2040 results from the decarbonisation of the electricity system. This scenario shows that the carbon intensity of power will need to drop by over 80% by 2040 through greater deployment of low-carbon electricity generation in renewable energy, nuclear power and carbon capture, utilisation, and storage (CCUS).

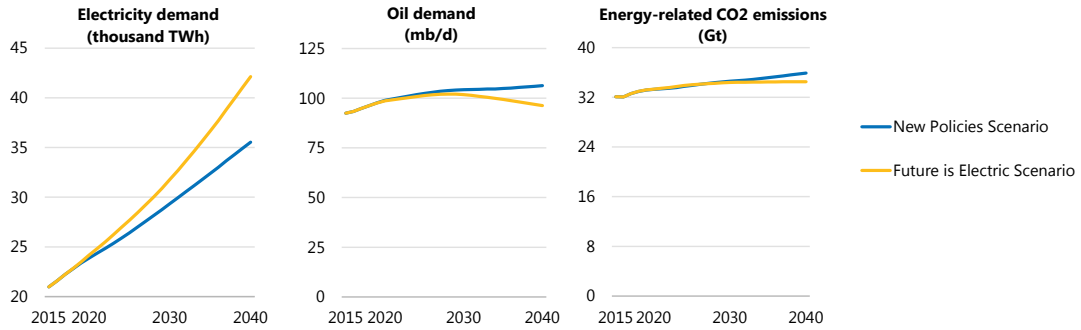
Figure 2. Power generation and the carbon intensity of electricity in the SDS



Source: IEA (2018a), *World Energy Outlook 2018*.

Deep decarbonisation of the electricity system is necessary if electrification in transport, industry and other sectors is to become the key to further decarbonisation. According to the Future is Electric Scenario in *WEO 2018* (which assumes the maximum economic deployment of electric technologies in all sectors: electricity demand, oil demand, and energy-related CO_2 emissions), additional electrification alone without deep decarbonisation of the power sector will not lead to significant carbon emissions reductions, although it could lead to an earlier peak in oil demand.

Figure 3. Electricity demand, oil demand and energy-related CO_2 emissions by WEO scenario



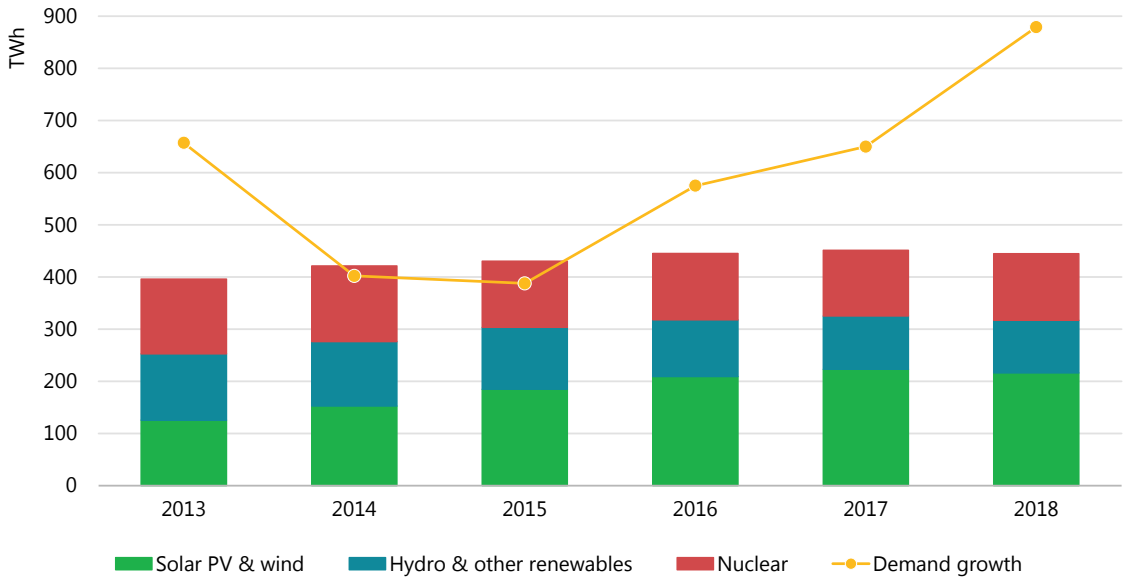
Note: TWh = terawatt hours; mb/d = million barrels per day.
Source: IEA (2018a), *World Energy Outlook 2018*.

Current level of low-carbon investments is too low

Massive investment in additional low-carbon generation sources is crucially important to achieve a sustainable energy future. In the NPS, there is very fast growth in renewables, nuclear and other low-carbon generation sources. However, the SDS would require an even faster deployment of these sources.

The key question is whether power market systems can ensure enough investments in low-carbon generation sources. Currently, the speed of growth in low-carbon investments is far lower than what is needed. The *World Energy Investment 2019* report (IEA, 2019a) showed that the expected power generation growth from low-carbon investments in 2018 was lower than electricity demand growth, thus creating room for fossil-fuel-fired power generation sources instead of decreasing them.

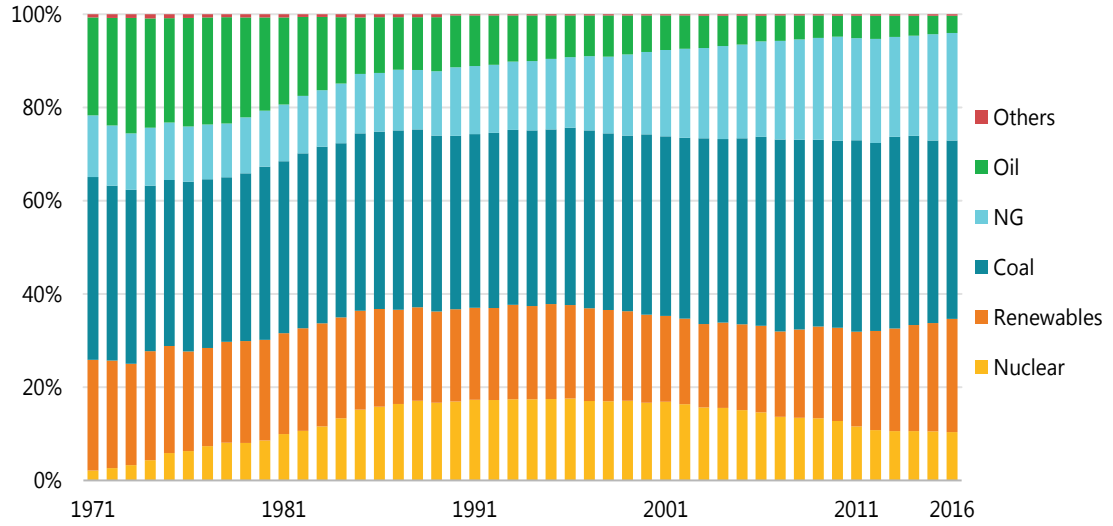
Figure 4. Expected power generation growth from low-carbon investments vs demand growth



Source: IEA (2019a), *World Energy Investment 2019*.

Another metric is the share of low-carbon generation in the entire power generation mix. As can be seen in Figure 5, despite the large investments in wind and solar over last ten years, these efforts have only compensated for the low growth in other sources such as nuclear and hydropower. Low-carbon sources' total share in the energy mix has been kept at roughly the same level as in early 2000s.

Figure 5. Share of energy sources in global electricity generation



Note: CCUS = carbon capture, utilisation and storage.
Source: IEA (2019b), *Nuclear Power in a Clean Energy System*.

Wind and solar PV deployment needs to accelerate

Wind and solar PV have seen impressive growth due to strong policy support as well as drastic declines in their costs. The 2018 online IEA report, *Tracking Clean Energy Progress* (IEA, 2018b) categorises solar PV as the only renewable energy technology that is "green" and on a sustainable track; wind technology was downgraded to "yellow", meaning that more efforts needed. It should be noted that the term "on a sustainable track" means that the technologies are on track to fulfil their role in the SDS – not that they can do the heavy lifting if other low-carbon technologies fall behind.

Solar PV marked a record capacity growth of 98 GW and generated 460 TWh of electricity in 2017. While solar PV is on track to meet the SDS target, solar PV generation is required to achieve more than 2 700 TWh in 2030.

Onshore wind capacity growth, on the other hand, declined by 10% in 2017, marking the second year in a row of decline. Offshore wind grew 32% in generation to reach 51 TWh, with almost 4 GW capacity additions in 2017. The SDS includes continuous growth in new build wind capacity to maintain an annual generation growth of 6% through 2030 to reach more than 4 350 TWh, from 1 085 TWh in 2017. This growth requires that both onshore and offshore projects are developed at a rapid pace, more than twice the current level.

Renewables 2018 (IEA, 2018c) forecasts that wind and solar PV will grow very fast during its forecast period between 2018 and 2023. But, stronger policies to accelerate their deployment would be needed to stay on a sustainable energy path. *Renewables 2018* sets up an "accelerated

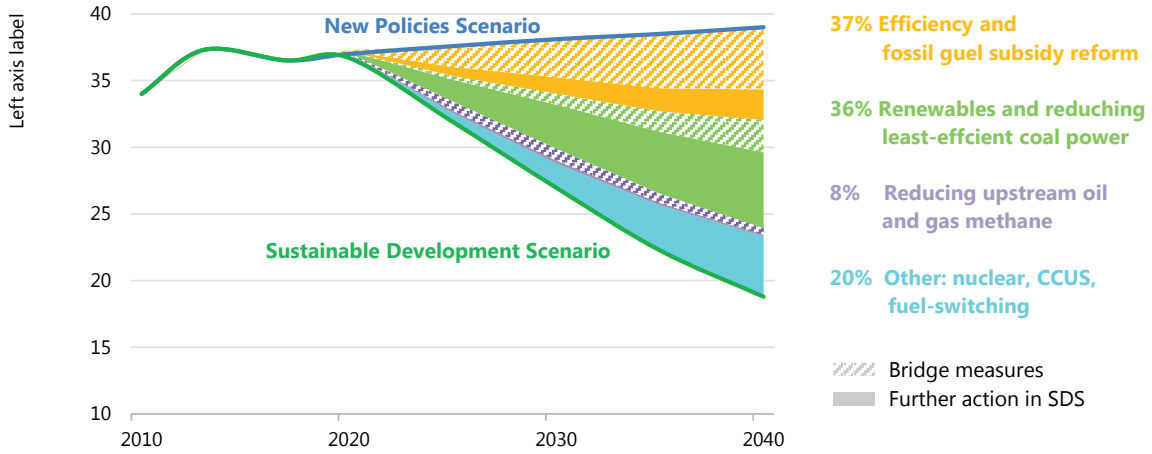
case" that assumes that governments introduce measures to tackle policy and regulatory uncertainties as well as grid integration and financing challenges before 2020. Renewables expansion in the electricity sector could be 25% higher, with additional renewable capacity reaching 1.3 TW in the 2018-23 period. This level of additional growth is necessary to put the renewable electricity sector fully on track to meet long-term climate and sustainability goals.

In spite of the urgent need to accelerate the pace of renewable sources deployment, 2018 was the first year since 2001 that growth in renewable power capacity failed to increase from the previous year's level. New net capacity from solar PV, wind, hydro, bioenergy, and other renewable power sources increased by about 180 Gigawatts (GW) in 2018, the same as 2017.

Generation diversity with low carbon

It must be noted, however, that even if wind and solar PV deployment could be accelerated, other low-carbon technologies like nuclear power and CCUS also need to be expanded at massive scale to decarbonise the power sector. This is evident in the *WEO 2018* analysis on cost-effective ways to fill the gap between the NPS and SDS and thus put the world on the SDS path.

Figure 6. Global CO_2 and CH_4 emissions in the New Policies and Sustainable Development Scenarios



Note: CH_4 = methane.
Source: IEA (2018a), *World Energy Outlook 2018*.

The level of additional renewable generation sources required to achieve the SDS is already extremely high. Expanding the level even more to make up for the lack of growth or decline in nuclear power or CCUS implies enormous challenges in terms of not only additional costs but also land availability and local acceptance.

Energy security issues should also be addressed here. Security lies in diversity. Many countries or electricity markets have tried to achieve this diversity in the generation mix by relying upon coal, gas, renewables (e.g. hydropower, wind, solar, biomass), nuclear power, and other sources. While continuing to expand the deployment of variable renewables such as wind and solar should be welcomed as additional indigenous energy sources, countries should also do their best to maintain and improve power generation diversity and to avoid excessive dependence on a single generation source.

Nuclear

Nuclear power plants currently generate more than 10% of global electricity supply, and its share in low-carbon generation is close to 30%. The outlook for investments in nuclear power plants, particularly in advanced economies, is highly uncertain. More countries have adopted liberalised and unbundled electricity market systems; the perceived cost competitiveness of nuclear projects compared with renewables and gas-fired power plants has deteriorated substantially; and social acceptance of nuclear projects in general has worsened dramatically as a result of the Fukushima Daiichi Nuclear Power Plant Accident in 2011. While nuclear power production in advanced economies is set to decline slightly by 2040 under current and proposed policies, current trends, coupled with the lack of explicit policy support, could mean a much sharper decline. Without further lifetime extensions or new projects, nuclear power production in advanced economies would drop by two-thirds by 2040. This would result in additional cumulative emissions of 3 900 $MtCO_2$ from these economies, or 5%, over the next two decades, despite robust growth of renewables and investments in energy efficiency to meet policy ambitions.

Dispatchable renewables: Hydropower, geothermal, bioenergy, and concentrated solar power

Renewable generation sources other than wind and solar PV are not growing fast enough; thus, in the TCEP they are categorised as either "more efforts needed" or "not on track".

- Hydropower generation increased by 0.5% in 2017, with capacity growth declining for four consecutive years (2014-17). Hydropower needs to grow by nearly 40% to reach more than 5 800 TWh by 2030 to remain on the path to achieve SDS levels.
- Geothermal is not on track, having generated only 85 TWh in 2017 while the SDS requires more than 290 TWh of generation in 2030. Technology-specific challenges have hampered the growth of deployment.
- Bioenergy power generation grew by 10% in 2017, but this growth was slower than in previous years. While it is forecast to grow by 6% per year over the next five years, this is not enough to reach the SDS target of more than 1 100 TWh by 2030.
- Concentrated solar power (CSP) generated 13.4 TWh in 2017, which is not on track to reach the more than 280 TWh in 2030 as required by the SDS.

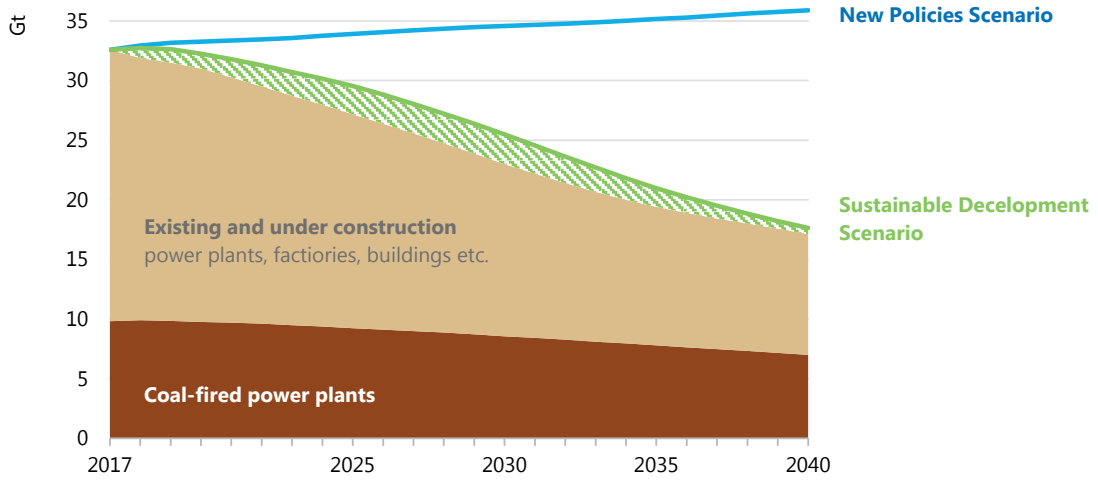
These are dispatchable renewable sources, whose growth is needed to not only achieve emission targets but also to facilitate the balancing of electricity systems.

Carbon capture, utilisation and storage

Carbon capture, utilisation and storage (CCUS) remains far off track from the 2030 goal, which requires capturing and storing 1.5 Gt of CO2 emissions from coal and gas-fired power plants. Only two large-scale CCUS projects were in operation in the power sector at the end of 2017, with a combined capture capacity of 2.4 million tonnes (Mt) of CO2 per year.

Analysis in *WEO 2018* shows that more than 90% of the total CO2 emissions allowed in the SDS are already locked in by existing energy-related infrastructures that include young coal-fired power plants in Asia. CCUS retrofitting could effectively free up a substantial portion of CO2 emissions and give the world some room for manoeuvering.

Figure 7. Global energy-related CO_2 emissions



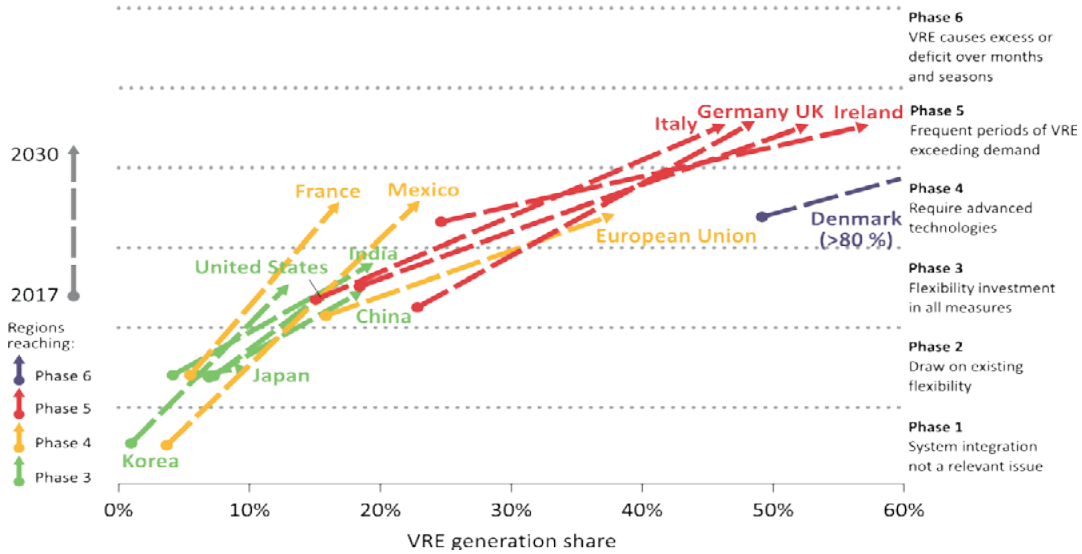
Source: IEA (2018a), *World Energy Outlook 2018*.

There are some positive signs: 45Q tax credits in the United States were extended to provide additional revenue for CCUS projects, and other countries such as Canada, the People's Republic of China ("China"), Norway and the United Kingdom are also stepping up CCUS deployment efforts.

Increasing requirements for investments in flexibility

WEO 2018's NPS anticipates significant system integration challenges in the future. In 2017, variable renewables accounted for less than 10% of electricity supply in the United States, China and India, and close to 15% in the European Union. By 2030, these power systems are projected to reach much higher shares of variable renewables, levels at which experience is limited to date

Figure 8. Phases of integration with variable renewables share in NPS, 2030



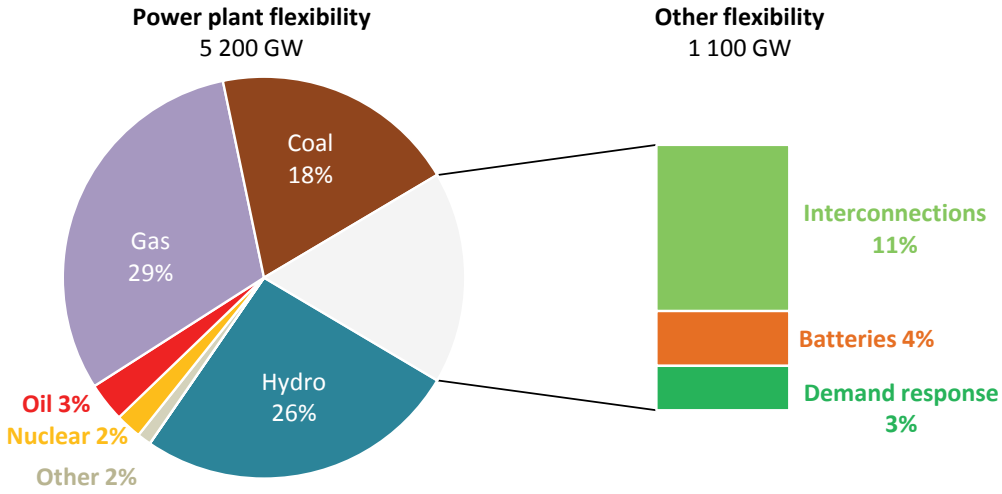
Note: VRE = variable renewable energy.

Source: IEA (2018a), *World Energy Outlook 2018*.

The SDS will increase the level of difficulty to much higher levels. This high penetration of variable renewable generation sources like wind and solar would inevitably lead to lower share of generations from dispatchable sources like coal and gas power plants. In particular, the role of gas-fired power plants will become even more important at least for a while in providing flexibility to the power systems. Ideally such fossil fired power generations should be further decarbonised with CCUS. Nuclear's role as low-carbon dispatchable generation sources should be recognised in this context as well. It would be technically difficult and/or much costly to maintain a stable operation of power systems without them.

There are high expectations to energy storage and demand side response with developments including battery cost declines and progress in information technologies. These new sources of power system flexibilities would work well for hourly fluctuations in electricity supply, but would require extremely large volumes it they were to take care of days of low power production from variable renewables, let alone seasonal changes in output levels. *WEO 2018* expects massive growth in flexibility from grid interconnection, batteries and demand responses, but dispatchable power plants will remain the cornerstone of system flexibility.

Figure 9. Sources of flexibility in the global power system in the NPS, 2040



Source: IEA (2018a), *World Energy Outlook 2018*.

Central role of governments

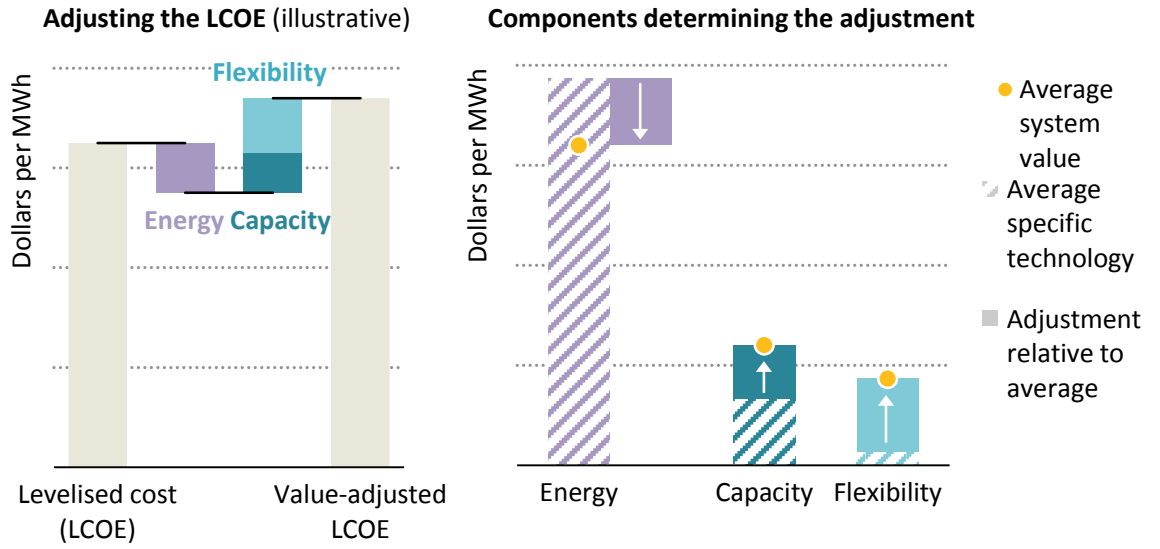
As shown above, the progress in decarbonisation in power generation sources are not only too slow to achieve emission targets but also lack balance with only solar PV on track or close to be so, while many other low-carbon and dispatchable technologies either need more efforts or are not on track.

Technology neutral incentives for these low-carbon sources such as carbon pricing, should always be the primary tools to be considered while these incentives should be substantial and give long-term assurance to give investor enough confidence for large-scale investments that require long years to recover.

Power market designs are crucial in achieving a low-carbon transition without compromising security of supply. Key principles are to ensure remuneration to generation sources that reflects their system values, and to send the correct price signals for investments. The current remuneration

systems of many power markets are not well-equipped to evaluate flexibility and capacity contributions of generation sources and should explore new ways to do so. Price signals should be time- and location-specific to guide investments in optimal ways. VALCOE, the value-adjusted levelized cost of electricity, proposed in the *WEO 2018* is a new concept intended to contribute to such efforts by governments and power market participants. It enables a comparison of power generation technologies that considers their contributions to the energy supply, system adequacy, and the flexibility that ensures reliability of supply.

Figure 10. Illustrative example of going beyond the LCOE to the value-adjusted LCOE



Note: LCOE = levelised cost of energy; MWh = megawatt hours.
Source: IEA (2018a), *World Energy Outlook 2018*.

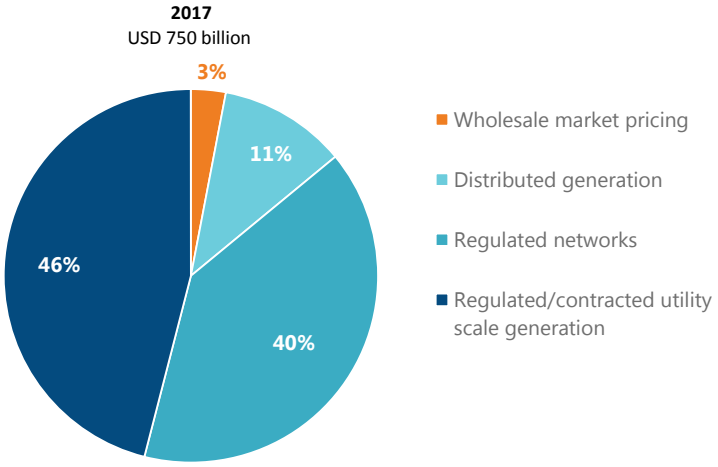
Many markets have introduced capacity market or targeted reserve systems as a safety net for ensuring capacity adequacies. Governments and market players should explore new and improved market designs by learning from other countries' successes and failures.

Low-carbon generation technologies, which have their own technology-specific characteristics and challenges, therefore require market systems designed to address them. As electricity markets in many countries shift to more liberalised and unbundled systems, investments in low-carbon power generation sources that are by nature capital-intensive has become increasingly difficult. Government interventions such as feed-in tariffs, net metering requirements, and renewable portfolio standards have been effective in supporting growth in the deployment of wind and solar PV, and many countries are now moving to power purchase agreements with auctions. Projects that require large-scale funding and a long recovery period, such as large-scale hydropower, geothermal and nuclear, would require stronger government intervention to mitigate the higher degree of risk and uncertainties. Examples of the forms that such government interventions could take include loan guarantees (by the government); long-term price guarantees such as contract for difference; inclusion in the regulated asset base; and direct investment by state entities.

Even existing low-carbon assets can suffer from changes in market conditions that were not envisaged at the time of investment as in the case of nuclear assets in the United States. Modest support schemes to ensure the utilisation of existing assets often can provide cost-effective means for decarbonisation or avoiding extra CO_2 emissions.

One important point to be noted is that the vast majority of investments in the power sector are not happening by remuneration from competitive market arrangements. *World Energy Outlook 2018* shows that over 95% of power sector investments in 2017 rely on regulation or contracts beyond the wholesale market for their remuneration.

Figure 11. Global power sector investment in 2017

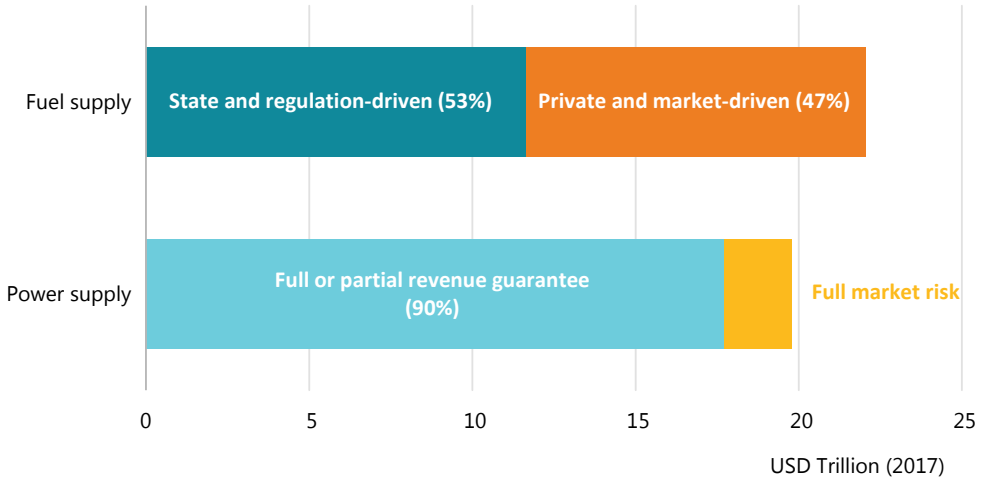


Source: IEA (2018a), *World Energy Outlook 2018*.

In countries organised around competitive wholesale markets, prices of electricity on short-term markets are currently too low to provide an incentive to invest in the capital-intensive assets such as renewables and nuclear power.

In the long term, *WEO 2018* also estimates in the NPS that 90% of investments in power supply will be backed by full or partial revenue guarantees in some form, and only 10% will be based on full market risk. The majority of investment in fuel supply is strongly influenced by government decisions, which means that fully 70% of all energy supply investment is linked to regulation.

Figure 12. Cumulative investment needs in the NPS, 2018 to 2040



Source: IEA (2018a), *World Energy Outlook 2018*.

Government policies and actions will play crucial roles in determining power generation investments and the resulting power generation mix. Given the central role of electricity supply in achieving a sustainable energy pathway, it will be critical for policies and measures to make a stronger push towards a rapid energy transition.

Conclusion

The current pace of investments in low-carbon power generation sources is far too slow to achieve the emission targets in Paris Agreement and deliver a sustainable energy future.

Governments should not be lulled into complacency by the current growth in wind and solar PV. They should improve the systems for the deployment of these technologies, taking full advantage of the decline in costs, and accelerate the deployment of other dispatchable renewables.

Governments should do their best to ensure diversity in generation sources in the decarbonised power generation fleet of the near future. Governments that choose to use nuclear power should introduce measures to use existing nuclear plants to the extent possible while ensuring the maximum level of safety. New nuclear technologies such as small module reactors should be accelerated and efficient regulatory systems for them established.

A high share of variable renewables calls for corresponding sources of flexibility in the system. Governments should improve power market designs so that remuneration to generators reflects their system values, recognising the contribution made to the stability of the systems.

In many countries with liberalised and unbundled electricity markets, additional measures to ensure investments in needed capacities, such as capacity market mechanisms and reserve capacity systems, have been introduced. Countries should continue efforts to monitor how such measures function and improve them.

References

IEA (International Energy Agency) (2019a), *World Energy Investment 2019*, Paris.

IEA (2019b), *Nuclear Power in a Clean Energy System*, Paris.

IEA (2018a), *World Energy Outlook 2018*, Paris.

IEA (2018b), *Tracking Clean Energy Progress*, www.iea.org/tcep/, Paris.

IEA (2018c), *Renewables 2018: Analysis and Forecasts to 2023*, Market Reports Series, Paris.

General annex

Abbreviations and acronyms

CCUS	Carbon capture, utilisation, and storage
CSP	Concentrated solar power
IEA	International Energy Agency
LCOE	Levelised cost industry
NPS	New Policies Scenario
PV	Photovoltaic
SDS	Sustainable Development Scenario
TCEP	*Tracking Clean Energy Progress*
USD	United States dollar
VALCOE	Value-adjusted levelized cost of electricity
VRE	Variable renewable energy
WEO	*World Energy Outlook*

Units of measurement

CH_4	methane
CO_2	carbon dioxide
gCO_2/kWh	gramme of carbon dioxide per kilowatt hour
Gt	gigatonne
GW	gigawatt
GWh	gigawatt hour
Mb/d	million barrels per day
Mt	million tonnes

$MtCO_2$	million tonnes of carbon dioxide
Mtoe	million tonnes of oil equivalent
MW	megawatt
MWh	megawatt hour
TWh	terawatt hour

Table of contents

List of figures

INTERNATIONAL ENERGY AGENCY

The IEA examines the full spectrum of energy issues including oil, gas and coal supply and demand, renewable energy technologies, electricity markets, energy efficiency, access to energy, demand side management and much more. Through its work, the IEA advocates policies that will enhance the reliability, affordability and sustainability of energy in its 30 member countries, 8 association countries and beyond.

IEA member countries:

Australia
Austria
Belgium
Canada
Czech Republic
Denmark
Estonia
Finland
France
Germany
Greece
Hungary
Ireland
Italy
Japan
Korea
Luxembourg
Mexico
Netherlands
New Zealand
Norway
Poland
Portugal
Slovak Republic
Spain
Sweden
Switzerland
Turkey
United Kingdom
United States

The European Commission also participates in the work of the IEA

IEA association countries:

Brazil
China
India
Indonesia
Morocco
Singapore
South Africa
Thailand

International Energy Agency

IEA Publications

International Energy Agency

Website: www.iea.org

Contact information: www.iea.org/about/contact

Typeset in France by IEA – June 2019

Cover design: IEA