

World Energy Outlook 2018

EXECUTIVE SUMMARY



International
Energy Agency
Secure
Sustainable
Together

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.

The four main areas of IEA focus are:

- **Energy Security:** Promoting diversity, efficiency, flexibility and reliability for all fuels and energy sources;
- **Economic Development:** Supporting free markets to foster economic growth and eliminate energy poverty;
- **Environmental Awareness:** Analysing policy options to offset the impact of energy production and use on the environment, especially for tackling climate change and air pollution; and
 - **Engagement Worldwide:** Working closely with association and partner countries, especially major emerging economies, to find solutions to shared energy and environmental concerns.

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



**International
Energy Agency**
Secure
Sustainable
Together

© OECD/IEA, 2018

International Energy Agency
Website: www.iea.org

Please note that this publication is subject to specific restrictions that limit its use and distribution.

The terms and conditions are available online at www.iea.org/t&c/

The European Commission also participates in the work of the IEA.

The world is gradually building a different kind of energy system, but cracks are visible in the key pillars:

- **Affordability:** The costs of solar PV and wind continue to fall, but oil prices climbed above \$80/barrel in 2018 for the first time in four years; and hard-earned reforms to fossil fuel consumption subsidies are under threat in some countries.
- **Reliability:** Risks to oil and gas supply remain, as Venezuela’s downward spiral shows. One-in-eight of the world’s population has no access to electricity and new challenges are coming into focus in the power sector, from system flexibility to cyber security.
- **Sustainability:** After three flat years, global energy-related carbon dioxide (CO₂) emissions rose by 1.6% in 2017 and the early data suggest continued growth in 2018, far from a trajectory consistent with climate goals. Energy-related air pollution continues to result in millions of premature deaths each year.

Affordability, reliability and sustainability are closely interlinked: each of them, and the trade-offs between them, require a comprehensive approach to energy policy. The links between them are constantly evolving. For example, wind and solar photovoltaics (PV) bring a major source of affordable, low-emissions electricity into the picture, but create additional requirements for the reliable operation of power systems. The movement towards a more interconnected global gas market, as a result of growing trade in liquefied natural gas (LNG), intensifies competition among suppliers while changing the way that countries need to think about managing potential shortfalls in supply.

Robust data and well-grounded projections about the future are essential foundations for today’s policy choices. This is where the *World Energy Outlook (WEO)* comes in. It does not aim to forecast the future, but provides a way of exploring different possible futures, the levers that bring them about and the interactions that arise across a complex energy system. If there is no change in policies from today, as in the *Current Policies Scenario*, this leads to increasing strains on almost all aspects of energy security. If we broaden the scope to include announced policies and targets, as in our main *New Policies Scenario*, the picture brightens. But the gap between this outcome and the *Sustainable Development Scenario*, in which accelerated clean energy transitions put the world on track to meet goals related to climate change, universal access and clean air, remains huge. None of these potential pathways is preordained; all are possible. The actions taken by governments will be decisive in determining which path we follow.

How is the world of energy changing?

In the New Policies Scenario, rising incomes and an extra 1.7 billion people, mostly added to urban areas in developing economies, push up global energy demand by more than a quarter to 2040. The increase would be around twice as large if it were not for continued improvements

in energy efficiency, a powerful policy tool to address energy security and sustainability concerns. All the growth comes from developing economies, led by India. As recently as 2000, Europe and North America accounted for more than 40% of global energy demand and developing economies in Asia for around 20%. By 2040, this situation is completely reversed.

The profound shift in energy consumption to Asia is felt across all fuels and technologies, as well as in energy investment. Asia makes up half of global growth in natural gas, 60% of the rise in wind and solar PV, more than 80% of the increase in oil, and more than 100% of the growth in coal and nuclear (given declines elsewhere). Fifteen years ago, European companies dominated the list of the world's top power companies, measured by installed capacity; now six of the top-ten are Chinese utilities.

The shale revolution continues to shake up oil and gas supply, enabling the United States to pull away from the rest of the field as the world's largest oil and gas producer. In the New Policies Scenario, the United States accounts for more than half of global oil and gas production growth to 2025 (nearly 75% for oil and 40% for gas). By 2025, nearly every fifth barrel of oil and every fourth cubic metre of gas in the world come from the United States. Shale is adding to the pressure on traditional oil and gas exporters that rely heavily on export revenues to support national development.¹

The energy world is connecting in different ways because of shifting supply, demand and technology trends. International energy trade flows are increasingly drawn to Asia from across the Middle East, Russia, Canada, Brazil and the United States, as Asia's share of global oil and gas trade rises from around half today to more than two-thirds by 2040. But new ways of sourcing energy are also visible at local level, as digitalization and increasingly cost-effective renewable energy technologies enable distributed and community-based models of energy provision to gain ground.

The convergence of cheaper renewable energy technologies, digital applications and the rising role of electricity is a crucial vector for change, central to the prospects for meeting many of the world's sustainable development goals. This vista is explored in detail in the *WEO-2018* special focus on electricity.

Electricity is the star of the show, but how bright will it shine?

The electricity sector is experiencing its most dramatic transformation since its creation more than a century ago. Electricity is increasingly the "fuel" of choice in economies that are relying more on lighter industrial sectors, services and digital technologies. Its share in global final consumption is approaching 20% and is set to rise further. Policy support and technology cost reductions are leading to rapid growth in variable renewable sources of generation, putting the power sector in the vanguard of emissions reduction efforts but requiring the entire system to operate differently in order to ensure reliable supply.

In advanced economies, electricity demand growth is modest, but the investment requirement is still huge as the generation mix changes and infrastructure is upgraded.

1. See the *WEO-2018 Special Report, Outlook for Producer Economies*.

Today's power market designs are not always up to the task of coping with rapid changes in the generation mix. Revenue from wholesale markets is often insufficient to trigger new investment in firm generation capacity; this could compromise the reliability of supply if not adequately addressed. On the demand side, efficiency gains from more stringent energy performance standards have played a pivotal role in holding back demand: eighteen out of the thirty International Energy Agency member economies have seen declines in their electricity use since 2010. Growth prospects depend on how fast electricity can gain ground in providing heat for homes, offices and factories, and power for transportation.

A doubling of electricity demand in developing economies puts cleaner, universally available and affordable electricity at the centre of strategies for economic development and emissions reduction. One-in-five kilowatt-hours of the rise in global demand comes just from electric motors in China; rising demand for cooling in developing economies provides a similar boost to growth. In the absence of a greater policy focus on energy efficiency, almost one-in-every-three dollars invested in global energy supply, across all areas, goes to electricity generation and networks in developing economies. This investment might not materialise, especially where end-user prices are below cost-recovery levels. But in highly regulated markets there is also a risk that capacity runs ahead of demand: we estimate that today there are 350 gigawatts of excess capacity in regions including China, India, Southeast Asia and the Middle East, representing additional costs that the system, and consumers, can ill afford.

Flexibility is the new watchword for power systems

The increasing competitiveness of solar PV pushes its installed capacity beyond that of wind before 2025, past hydropower around 2030 and past coal before 2040. The majority of this is utility-scale, although investment in distributed solar PV by households and businesses plays a strong supporting role. The *WEO-2018* introduces a new metric to estimate the competitiveness of different generation options, based on evolving technology costs as well as the value that this generation brings to the system at different times. This metric confirms the advantageous position of wind and solar PV in systems with relatively low-cost sources of flexibility. New solar PV is well placed to outcompete new coal almost everywhere, although it struggles in our projections to undercut existing thermal plants without a helping hand from policy. In the New Policies Scenario, renewables and coal switch places in the power mix: the share of generation from renewables rises from 25% today to around 40% in 2040; coal treads the opposite path.

The rise of solar PV and wind power gives unprecedented importance to the flexible operation of power systems in order to keep the lights on. There are few issues at low levels of deployment, but in the New Policies Scenario many countries in Europe, as well as Mexico, India and China, are set to require a degree of flexibility that has never been seen before at such large scale. The cost of battery storage declines fast, and batteries increasingly compete with gas-fired peaking plants to manage short-run fluctuations in supply and demand. However, conventional power plants remain the main source of system flexibility, supported by new interconnections, storage and demand-side response. The European Union's aim to achieve an "Energy Union" illustrates the role that regional integration can play in facilitating the integration of renewables.

The share of generation from nuclear plants – the second-largest source of low-carbon electricity today after hydropower – stays at around 10%, but the geography changes as generation in China overtakes the United States and the European Union before 2030. Some two-thirds of today's nuclear fleet in advanced economies is more than 30 years old. Decisions to extend, or shut down, this capacity will have significant implications for energy security, investment and emissions.

How much power can we handle?

A much stronger push for electric mobility, electric heating and electricity access could lead to a 90% rise in power demand from today to 2040, compared with 60% in the New Policies Scenario, an additional amount that is nearly twice today's US demand. In the *Future is Electric Scenario*, the share of electricity in final consumption moves up towards one-third, as almost half the car fleet goes electric by 2040 and electricity makes rapid inroads into the residential and industry sectors. However, some significant parts of the energy system, such as long-distance road freight, shipping and aviation, are not “electric-ready” with today's technologies. Electrification brings benefits, notably by reducing local pollution, but requires additional measures to decarbonise power supply if it is to unlock its full potential as a way to meet climate goals: otherwise, the risk is that CO₂ emissions simply move upstream from the end-use sectors to power generation.

Where does the rise of electricity, renewables and efficiency leave fossil fuels?

In the New Policies Scenario, a rising tide of electricity, renewables and efficiency improvements stems growth in coal consumption. Coal use rebounded in 2017 after two years of decline, but final investment decisions in new coal-fired power plants were well below the level seen in recent years. Once the current wave of coal plant projects under construction is over, the flow of new coal projects starting operation slows sharply post-2020. But it is too soon to count coal out of the global power mix: the average age of a coal-fired plant in Asia is less than 15 years, compared with around 40 years in advanced economies. With industrial coal use showing a slight increase to 2040, overall global consumption is flat in the New Policies Scenario, with declines in China, Europe and North America offset by rises in India and Southeast Asia.

Oil use for cars peaks in the mid-2020s, but petrochemicals, trucks, planes and ships still keep overall oil demand on a rising trend. Improvements in fuel efficiency in the conventional car fleet avoid three-times more in potential demand than the 3 million barrels per day (mb/d) displaced by 300 million electric cars on the road in 2040. But the rapid pace of change in the passenger vehicle segment (a quarter of total oil demand) is not matched elsewhere. Petrochemicals are the largest source of growth in oil use. Even if global recycling rates for plastics were to double, this would cut only around 1.5 mb/d from the projected increase of more than 5 mb/d. Overall growth in oil demand to 106 mb/d in the New Policies Scenario comes entirely from developing economies.

Natural gas overtakes coal in 2030 to become the second-largest fuel in the global energy mix. Industrial consumers make the largest contribution to a 45% increase in worldwide

gas use. Trade in LNG more than doubles in response to rising demand from developing economies, led by China. Russia remains the world's largest gas exporter as it opens new routes to Asian markets, but an increasingly integrated European energy market gives buyers more gas-supply options. Higher shares of wind and solar PV in power systems push down the utilisation of gas-fired capacity in Europe, and retrofits of existing buildings also help to bring down gas consumption for heating, but gas infrastructure continues to play a vital role, especially in winter, in providing heat and ensuring uninterrupted electricity supply.

Where are we on emissions and access – and where do we want to be?

The New Policies Scenario puts energy-related CO₂ emissions on a slow upward trend to 2040, a trajectory far out of step with what scientific knowledge says will be required to tackle climate change. Countries are, in aggregate, set to meet the national pledges made as part of the Paris Agreement. But these are insufficient to reach an early peak in global emissions. The projected emissions trend represents a major collective failure to tackle the environmental consequences of energy use. Lower emissions of the main air pollutants in this scenario are not enough to halt an increase in the number of premature deaths from poor air quality.

In 2017, for the first time, the number of people without access to electricity dipped below 1 billion, but trends on energy access likewise fall short of global goals. The New Policies Scenario sees some gains in terms of access, with India to the fore. However, more than 700 million people, predominantly in rural settlements in sub-Saharan Africa, are projected to remain without electricity in 2040, and only slow progress is made in reducing reliance on the traditional use of solid biomass as a cooking fuel.

Our Sustainable Development Scenario provides an integrated strategy to achieve energy access, air quality and climate goals, with all sectors and low-carbon technologies – including carbon capture, utilisation and storage – contributing to a broad transformation of global energy. In this scenario, the power sector proceeds further and faster with the deployment of low-emissions generation. Renewable energy technologies provide the main pathway to the provision of universal energy access. All economically viable avenues to improve efficiency are pursued, keeping overall demand in 2040 at today's level. Electrification of end-uses grows strongly, but so too does the direct use of renewables – bioenergy, solar and geothermal heat – to provide heat and mobility. The share of renewables in the power mix rises from one-quarter today to two-thirds in 2040; in the provision of heat it rises from 10% today to 25% and in transport it rises from 3.5% today to 19% (including both direct use and indirect use, e.g. renewables-based electricity). For the first time, this *WEO* incorporates a water dimension in the Sustainable Development Scenario, illustrating how water constraints can affect fuel and technology choices, and detailing the energy required to provide universal access to clean water and sanitation.

Can oil and gas improve their own environmental performance?

Natural gas and oil continue to meet a major share of global energy demand in 2040, even in the Sustainable Development Scenario. Not all sources of oil and gas are equal in their

environmental impact. Our first comprehensive global estimate of the indirect emissions involved in producing, processing and transporting oil and gas to consumers suggests that, overall, they account for around 15% of energy sector greenhouse gas emissions (including CO₂ and methane). There is a very broad range in emissions intensities between different sources: switching from the highest emissions oil to the lowest would reduce emissions by 25% and doing the same for gas would reduce emissions by 30%.

Much more could be done to reduce the emissions involved in bringing oil and gas to consumers. Many leading companies are taking on commitments in this area that, if widely adopted and implemented, would have a material impact on emissions. Reducing methane emissions and eliminating flaring are two of the most cost-effective approaches. There are also some more “game-changing” options, including the use of CO₂ to support enhanced oil recovery, greater use of low-carbon electricity to support operations, and the potential to convert hydrocarbons to hydrogen (with carbon capture). Many countries, notably Japan, are looking closely at the possibility of expanding the role of zero-emissions hydrogen in the energy system.

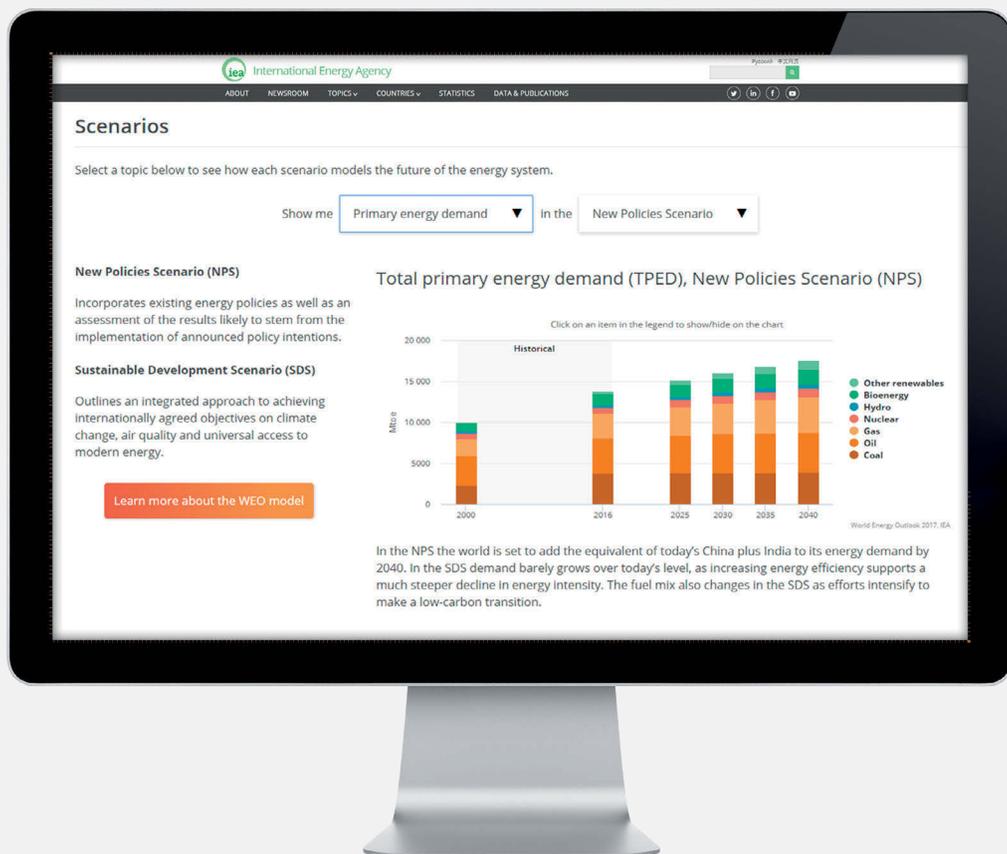
Is investment in fossil fuel supply out of step with consumption trends?

Today’s flow of new upstream projects appears to be geared to the possibility of an imminent slowdown in fossil fuel demand, but in the New Policies Scenario this could well lead to a shortfall in supply and a further escalation in prices. The risk of a supply crunch looms largest in oil. The average level of new conventional crude oil project approvals over the last three years is only half the amount necessary to balance the market out to 2025, given the demand outlook in the New Policies Scenario. US tight oil is unlikely to pick up the slack on its own. Our projections already incorporate a doubling in US tight oil from today to 2025, but it would need to more than triple in order to offset a continued absence of new conventional projects. In contrast to oil, the risk of an abrupt tightening in LNG markets in the mid-2020s has been eased by major new project announcements, notably in Qatar and Canada.

Government policies will shape the long-term future for energy

Rapid, least-cost energy transitions require an acceleration of investment in cleaner, smarter and more efficient energy technologies. But policy makers also need to ensure that all key elements of energy supply, including electricity networks, remain reliable and robust. Traditional supply disruption and investment risks on the hydrocarbons side are showing no signs of relenting and indeed may intensify as energy transitions move ahead. The changes underway in the electricity sector require constant vigilance to ensure that market designs are robust even as power systems decarbonise. More than 70% of the \$2 trillion required in the world’s energy supply investment each year, across all domains, either comes from state-directed entities or responds to a full or partial revenue guarantee established by regulation. Frameworks put in place by the public authorities also shape the pace of energy efficiency improvement and of technology innovation. Government policies and preferences will play a crucial role in shaping where we go from here.

Explore the data behind the World Energy Outlook 2018



www.iea.org/weo

Visit our website to explore key findings and scenario outcomes
from the *World Energy Outlook 2018*.

In addition, those that purchase the book will have access to a new *World Energy Outlook* online database that includes the scenario results, full energy balances for key regions, and over 300 downloadable figures and tables.

This publication reflects the views of the IEA Secretariat but does not necessarily reflect those of individual IEA member countries. The IEA makes no representation or warranty, express or implied, in respect of the publication's contents (including its completeness or accuracy) and shall not be responsible for any use of, or reliance on, the publication. Unless otherwise indicated, all material presented in figures and tables is derived from IEA data and analysis.

This publication and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.

IEA/OECD possible corrigenda on: www.oecd.org/about/publishing/corrigenda.htm

IEA Publications
International Energy Agency
Website: www.iea.org
Contact information: www.iea.org/about/contact
Layout in France by DESK, November 2018

Cover design: IEA, photo credits: Shutterstock

World Energy Outlook 2018

What do today's energy policies, policy ambitions and technology trends tell us about the future? Is the world getting closer or is it moving away from meeting energy-related sustainable development goals?

Drawing on the latest data on energy markets and technology trends, this year's *World Energy Outlook* – the gold standard of long-term energy analysis – provides detailed analyses of these fundamental issues to 2040, covering all fuels, technologies and regions.

Electricity is the special focus of the 2018 edition. The share of electricity in global energy use is growing while the rise of low-carbon technologies is prompting a major transformation in the way electricity is generated. What might tomorrow's power sector look like? How can it ensure reliable supply while reducing emissions?

WEO-2018 also asks what can be done to reduce the environmental footprint of the world's oil and gas supply.

For more information, please visit: iea.org/weo/