Taking action to stay within 1.5°C

Transforming the global energy system to combat climate change

Ørsted

> " Replacing fossil fuels with green energy is the main lever to combat climate change

Henrik Poulsen
CEO, Ørsted

Let's speed up green energy action to stay within 1.5°C

Climate change is the defining challenge of our time. Since the beginning of the industrial age, global greenhouse gas emissions have skyrocketed, and despite profound and repeated warnings from science, as a global community we have not yet managed to break the trend of increasing emissions.

We have 10 years to halve global emissions if we want to keep global warming within 1.5°C above pre-industrial levels. To preserve our shared home, planet Earth, and enable our children and grandchildren to live and prosper in a world that offers the same conditions for life as they are today, we must act now.

Looking at the numbers, it is clear why we have a problem. Almost 75% of global emissions come from the use of energy, mainly due to the burning of fossil fuels for power, heat, cooling, transportation, and industrial processes. We have built our modern societies on fossil fuels, and to bring down emissions we need a new way of producing energy.

At Ørsted our vision is to create a world that runs entirely on green energy. In this paper we present our view on what it takes to speed up the transformation of the global energy system to limit global warming to 1.5°C.

The good news is that we already know the solution: green energy. Today, green power from solar and wind energy has already become cheaper than new-built coal, gas and nuclear plants. This is a breakthrough. Transforming from fossil fuels to green energy to stay within 1.5°C is no longer a question of technical feasibility or financial viability. It is about having the ambition and will to make the necessary decisions sooner rather than later.

The power system is crucial to driving out fossil fuels across all energy-consuming sectors. To stay within 1.5°C, the world will need to double the projected rate of green power build-out to 2030, and triple the projected retirement rate of coal-fired power plants. In addition, we need to increase the share of green electricity in the global energy system. Electricity currently only has a 20% share of all energy use, but this could increase to 50% in 2050 through intensified green electrification. Meanwhile, we need to keep global energy consumption in check by boosting energy efficiency.

Speeding up the green transformation of the global energy system is crucial to combatting climate change, but will also improve our quality of life in many other ways. We can save 4 million lives per year through improved air quality, countries can achieve greater energy independence, millions of new green jobs can be created, and more people can get access to electricity through locally harvested energy sources.

It is inherently difficult to predict the future, but we know the future we want for ourselves, our children, and coming generations. As Abraham Lincoln said: "The best way to predict the future is to create it yourself".

That is what we are trying to do at Ørsted. Every decision we make, every day, must bring us one step closer to our vision of a world that runs entirely on green energy. Over the past decade, we have transformed our business from black to green energy. Since 2006, we have reduced our emissions by 83%, and by 2025 our energy production will be essentially carbon neutral. Our transformation has not been easy. But it has been necessary to leave behind a dying business model based on fossil fuels, and to create a new model, which is environmentally and financially sustainable.

We have written this paper to share our view on what it takes to speed up the transformation of the global energy system. Our analysis is based on credible and known sources, but we acknowledge that future projections are inherently uncertain. We do not intend to provide all answers on what it takes to limit global warming to 1.5°C, but we do want to stress the importance of a much faster transition from fossil fuels to green energy, and that we already have the necessary technologies at our disposal.

Henrik Poulsen
CEO, Ørsted

If you've only got five minutes

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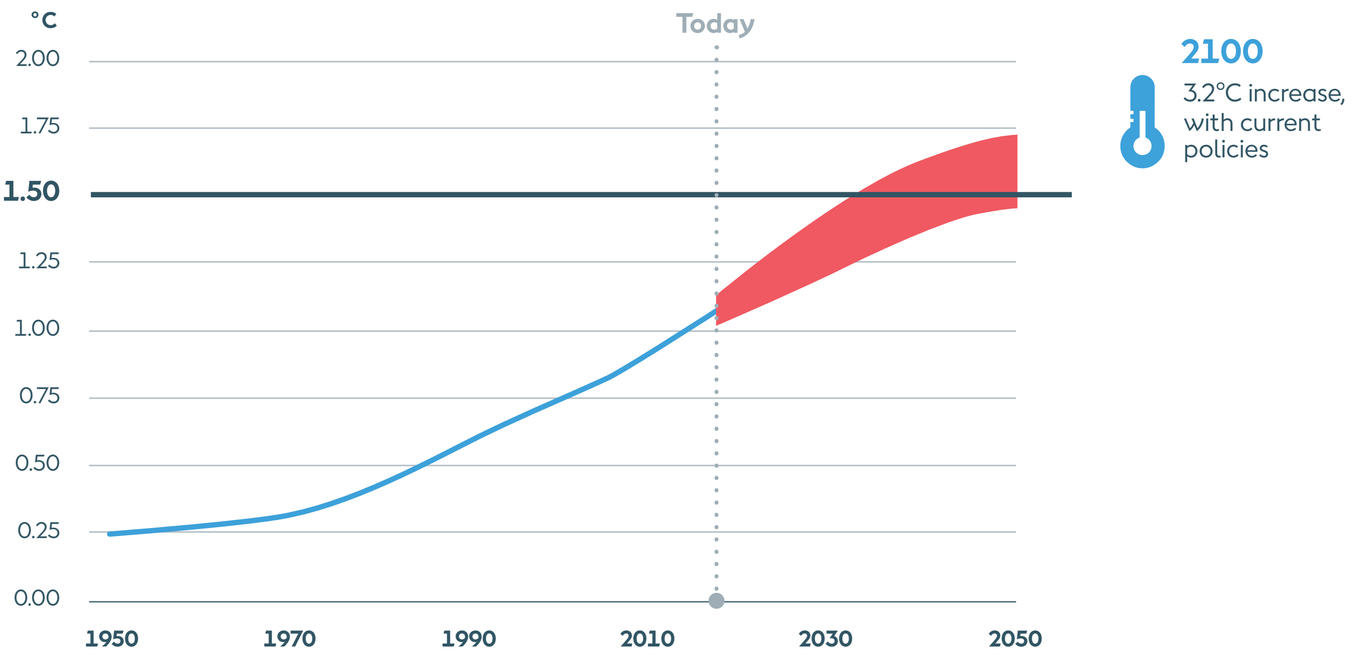
The defining challenge of our time

Global temperature increase since pre-industrial times



This figure is representative of modelled temperature data from the following sources: NOAA (2019) 2018 Annual Global Climate Report; IPCC (2013) Climate Change 2013: The Physical Science Basis; Climate Action Tracker (2019) Warming Projections Global Update. Temperature increase is shown as a global mean change since pre-industrial times (1850-1900) as defined by the IPCC.

Our shared home, planet Earth, is under growing pressure from climate change caused by increasing concentrations of greenhouse gases in the atmosphere. Global temperatures have already risen 1.1°C since the pre-industrial period[1], and 18 of the 19 warmest years on record have occurred since 2000, with average temperatures over the past 4 years being the highest ever recorded[2]. Our climate and the conditions for life on Earth are changing, and it is scientifically proven that man-made global warming is responsible for many of these changes[3].

We are already experiencing the consequences of climate change: more wildfires, droughts, floods, extreme heat, accelerated sea level rise, crop failures, irreversible loss of biodiversity and signs of increased migration. According to the IPCC, the frequency and intensity of these events are only going to increase as temperatures rise[4].

To avoid catastrophic consequences for nature, humans, the economy, and our societies, we all have to drastically accelerate action to mitigate climate change. Without further action, temperature increases are on track to reach 1.5°C between 2030 and 2052, and exceed 3°C by 2100 – if not sooner[5].

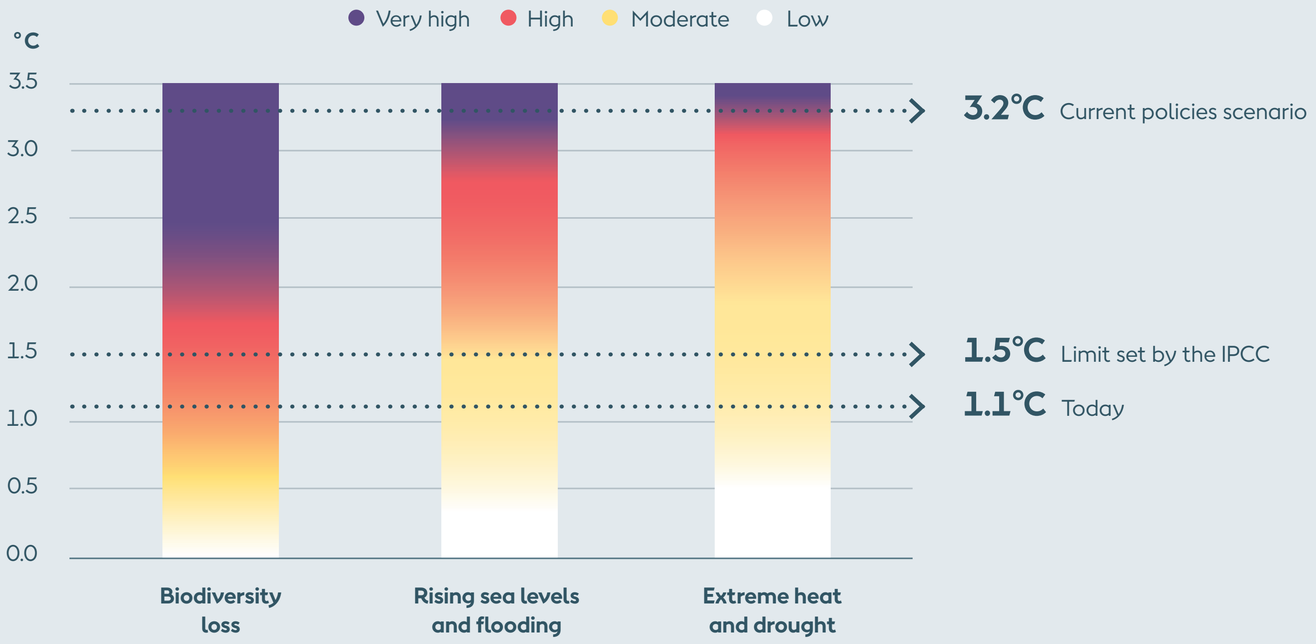
Higher temperatures put pressure on our global ecosystems

The IPCC has stated that the pressure on our global ecosystems increases as temperatures rise. Higher temperatures will result in higher risks of severe and widespread occurrences of biodiversity loss, rising sea levels, flooding, extreme heat, droughts, and other natural phenomena that will lead to more damage, economic loss, and will have an adverse effect on human lives. Higher temperatures will also result in declining marine fisheries, further declining coral reefs, species loss, and reduced crop yields, among other consequences[6].

The rationale for keeping global temperature rise below 1.5°C is clear. According to the IPCC, the consequences of a 2°C or higher temperature rise are significantly less certain as the increasing temperature may trigger several tipping points such as thawing of permafrost that releases large amounts of methane gas, melting of ice caps, contraction of the snow cover that reflects heat from the sun, disruption of ocean circulation and reduction of the ocean's ability to absorb carbon[7]. These irreversible natural processes would likely result in significantly warmer temperatures and have catastrophic consequences for life on Earth. However, if greenhouse gas emissions are reduced rapidly, it is still possible to limit global warming to 1.5°C[8].

At the Paris climate conference, COP 21, in 2015, the world's leaders made a historic agreement to keep global temperature increases well below 2°C and preferably below 1.5°C. In 2018, the IPCC emphasised the importance of adhering to the 1.5°C limit to avoid substantially exacerbating the damaging effects of climate change.

Impacts on ecosystems from higher global average temperatures



Sources: IPCC (2018) 1.5 Special Report, Global Warming of 1.5°C; Climate Action Tracker (2019) Warming Projections Global Update.
Current policies presently in place around the world are projected to result in approx. 3.2°C global warming by 2100.
'Very high': Very high risks of severe impacts and presence of significant irreversibility or climate-related hazards.
'High': Severe and widespread impacts/risks.
'Moderate': Impacts are detectable and moderately attributed to climate change.
'Low': No impacts detectable and attributed to climate change.

We need to halve global emissions by 2030

Despite the near unanimous global support to fight climate change, global emissions are still on the rise, and the concentration of greenhouse gases in the atmosphere has never been higher. In 2018, annual global greenhouse gas emissions reached an estimated 54 gigatonnes, the highest level ever recorded.

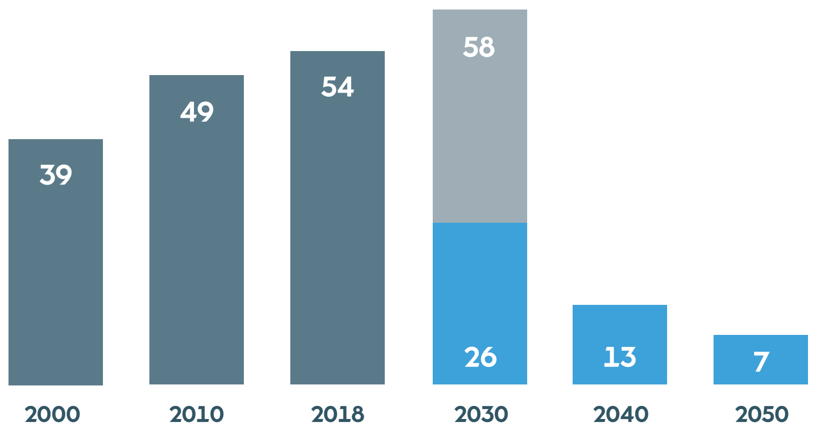
Without further action, emissions are projected to increase in the coming years, which is in stark contrast to what is required. To keep global warming below 1.5°C, greenhouse gas emissions need to be reduced from 54 to 26 gigatonnes by 2030, and approach net zero by 2050. Reaching 'net zero' means that actual emissions do not need to reach zero, as long as any remaining emissions are balanced by removing carbon from the atmosphere. For example, in 2050 it would be possible to absorb emissions of around 7 gigatonnes per year if our planet's ability to act as a 'carbon sink', capturing carbon dioxide, is preserved and enhanced.

Of the 54 gigatonnes of greenhouse gases emitted today, approximately 40 gigatonnes or 73% are related to energy, mainly the combustion of fossil fuels (coal, oil and natural gas). The majority of these emissions can be attributed to electricity and heat production, transportation and energy used for manufacturing and construction.

The largest individual source of emissions is electricity and heat production, accounting for 17 gigatonnes of total emissions, while more than 8 gigatonnes can be attributed to transportation. Emissions from 'other fuel combustion and fugitive emissions' include early-stage emissions from coal mining and some non-CO_2 emissions from the combustion of fossil fuels.

Annual global greenhouse gas emissions
GtCO2e/year

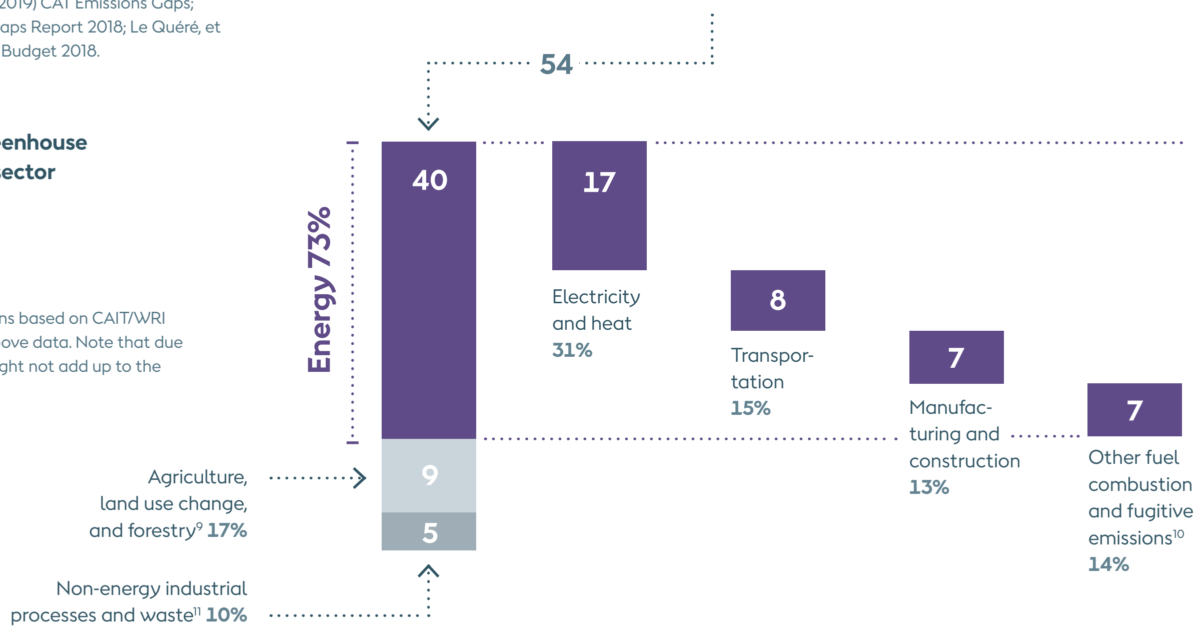
- Projected emissions
- Required emissions to keep global warming within 1.5°C



Sources: Own calculations based on data from: Climate Action Tracker (2019) CAT Emissions Gaps; UNEP (2018) Emissions Gaps Report 2018; Le Quéré, et al. (2018) Global Carbon Budget 2018.

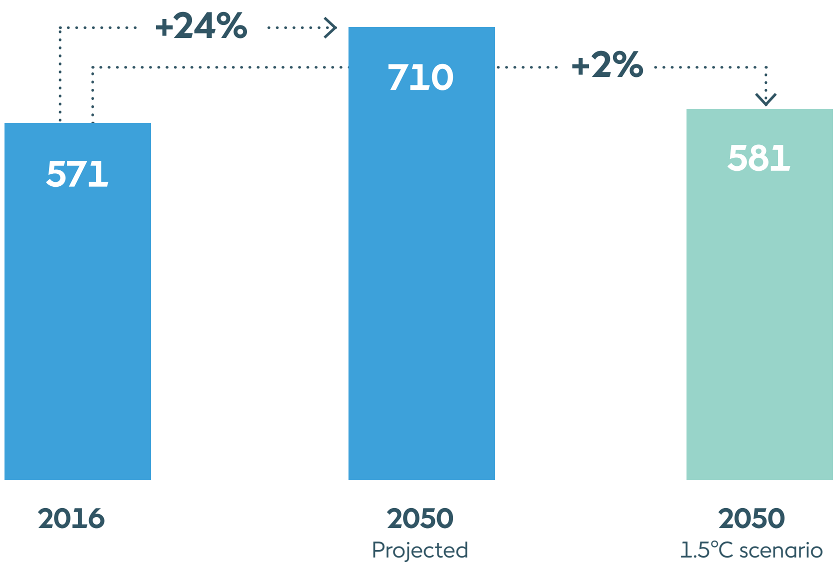
Annual global greenhouse gas emissions by sector
GtCO2e/year

Sources: Own calculations based on CAIT/WRI (2014) combined with above data. Note that due to rounding, numbers might not add up to the total amount.



The need for increased energy efficiency

Global supply of energy now and in 2050
Exajoules/year



Sources: IRENA (2019) Global Energy Transformation – Roadmap for 2050 (2019); IPCC (2018) 1.5 Special Report, Global Warming of 1.5°C.

The less energy we use globally, the easier it will be to decarbonise the energy system in time. However, without substantial improvements in energy efficiency, a combination of increased living standards and global population growth of 2 billion people will cause energy demand to grow a projected 24% by 2050. This is equivalent to adding twice the current energy use of the USA to the world's current use of energy.

Keeping global energy consumption at the current level would be possible with a global energy intensity[12] improvement of 3.2% per year towards 2050 – up from the current 2.3%[13]. This can be achieved through accelerated energy efficiency, especially in buildings, alongside electrification. As an example, an electric vehicle is 3 to 4 times more energy efficient than a conventional combustion engine car. Similarly, heat pumps are also more efficient than conventional heating.

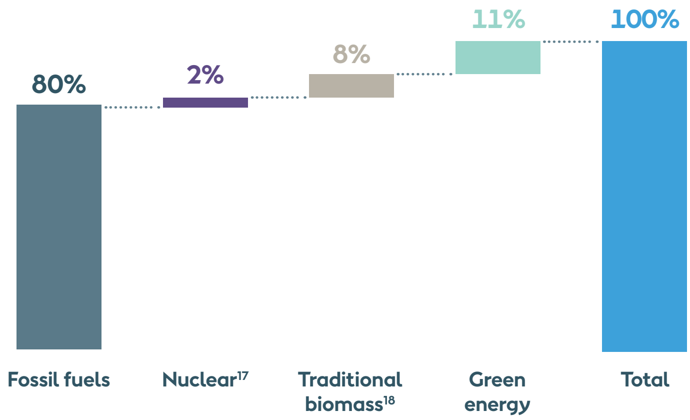
Scenarios that limit global warming to an average of 1.5°C necessitate that global energy consumption in 2050 remains at roughly the same level as today, with a green energy share of 60% or more[14]. If overall energy consumption increases substantially, the total share of green energy must be even higher than 60% in 2050 to limit global warming to 1.5°C. This underlines the importance of increased energy efficiency.

Green energy must replace fossil fuels in our global energy system

The global energy system includes all uses of energy for power, transportation, heating, cooling, and industrial processes. Today, around 80% of the world's consumption of energy is based on fossil fuels (coal, oil, and gas), while the share of green energy[15] is approaching 11%, up from 8% in 2010[16].

The increasing share of green energy in the global energy system comes from new additions of wind power, solar power, hydro power, and bioenergy, which have added to existing hydro power and bioenergy capacity. However, the overall increase in the share of green energy has been moderate since the use of fossil fuels has also increased in absolute terms, due to a surge in global energy demand caused by population and economic growth.

Current global energy mix
% of total final energy consumption, 2017



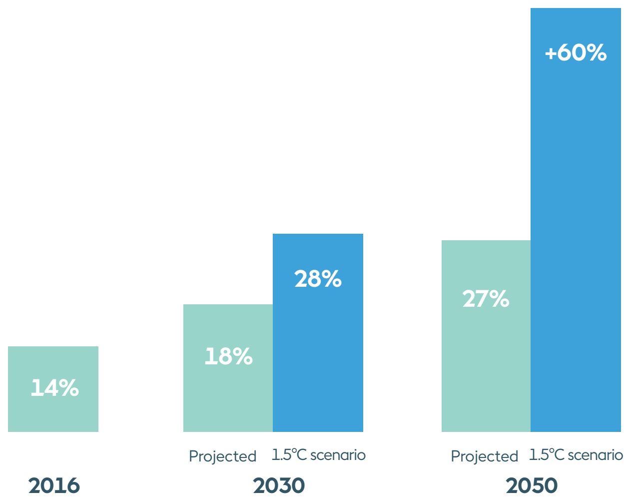
Source: REN21: Renewables 2019 – Global Status Report.
Numbers are rounded, which explains why they add up to 101%.

The global share of green energy should reach more than 60% by 2050 to stay within 1.5°C

The current build-out of green energy is simply insufficient to limit global warming to 1.5°C. Without additional action, the share of green energy is projected to reach around 27% of global energy supply by mid-century.
In this scenario, average global temperature increase could exceed 1.5°C and approach 2°C by 2050, and put the world on a path to a temperature increase of at least 3°C by the end of the century[19].

If we are to limit global warming to 1.5°C however, we must dramatically increase the global share of green energy to at least 60% by 2050[20]. This will require an increase in the share of green energy by almost 1.5 percentage points each year.

Projected vs. required green share in the global energy supply

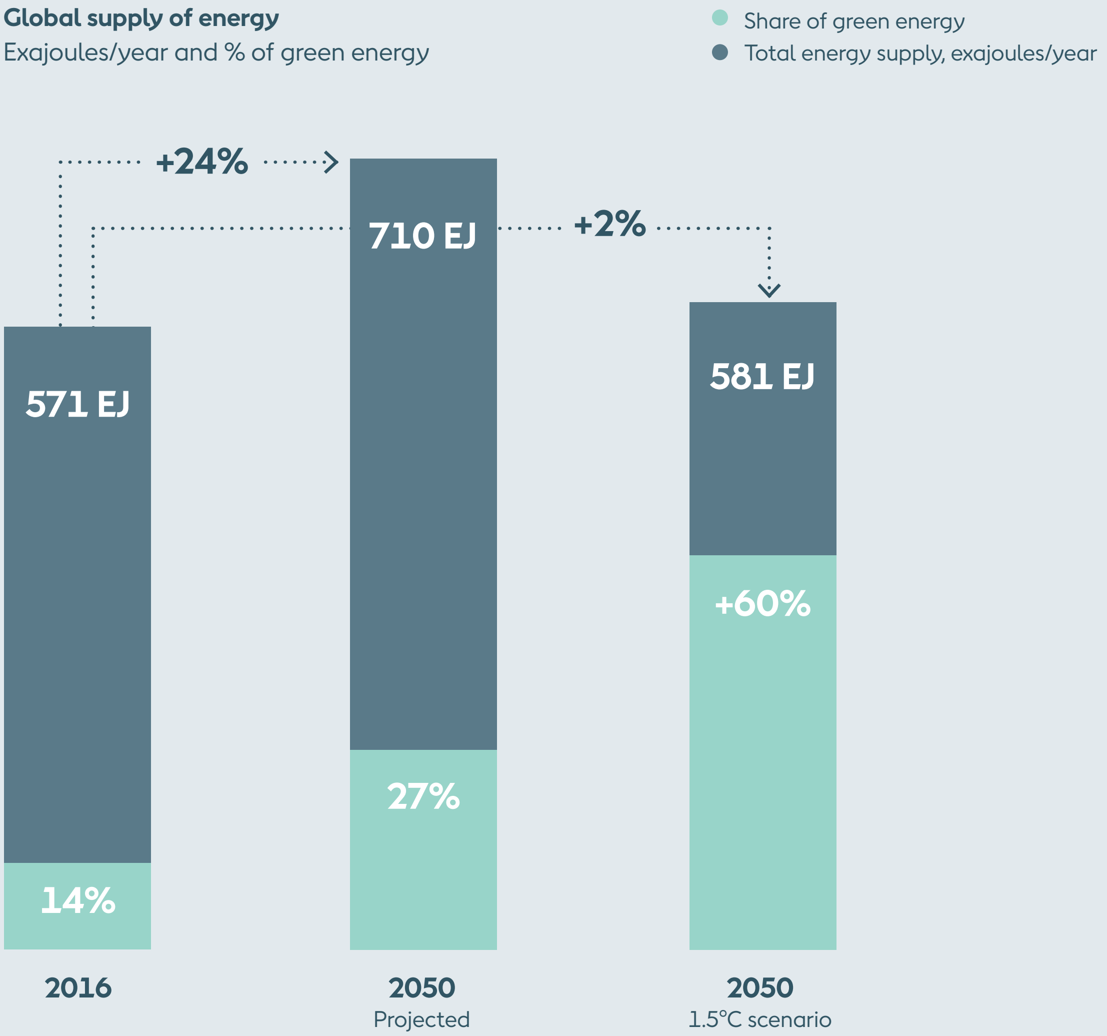


Sources: IRENA (2019) Global energy transformation: A roadmap to 2050; IPCC (2018) 1.5 Special Report, Global Warming of 1.5°C. Due to challenges in obtaining coherent data, the chart 'Current global energy mix' is based on final energy consumption (11% share of green energy), while this chart and the chart on page 11 are based on total primary energy supply (14% share of green energy). The numbers based on supply are used to be able to compare with IPCC projections.

Transforming the global energy system

If we stay on the current trajectory with existing policies and rates of change, energy demand will continue to increase and fossil fuels will remain dominant in our energy system. In this scenario, we will likely overshoot the critical 1.5°C mark between 2030 and 2052[21]. In the future we should all be striving towards, science suggests that energy efficiency can keep global energy demand at the same levels as today, while green energy rapidly replaces fossil fuels in our global energy system. By taking these steps, we can halve emissions by 2030, and give ourselves the best chance of halting runaway climate change. On the following pages, we explain why we believe that the power sector holds the key to achieving this goal.

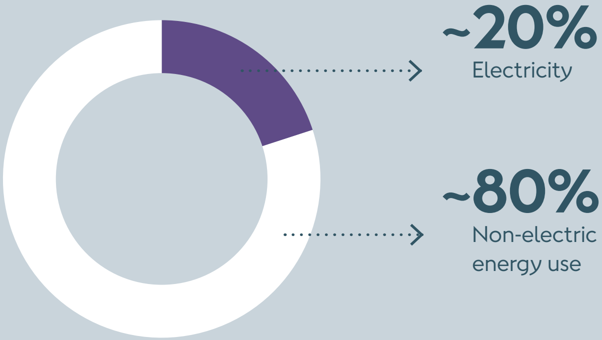
Global supply of energy
Exajoules/year and % of green energy



Sources: IRENA (2019) Global energy transformation: A roadmap to 2050;
IPCC (2018) 1.5 Special Report, Global Warming of 1.5°C.

The power sector is key to decarbonising energy

The global energy system



Source: REN21 (2019) Renewables 2019 – Global Status Report.

The power sector currently only accounts for around 20% of global energy use, whereas the remaining 80% can be attributed to non-electric heating, cooling, transportation, and various industrial processes.

However, all of these sectors hold a significant potential for electrification. Having 'cracked the code' for green power at scale, which is now cheaper in many countries than electricity based on fossil fuels, the power sector is expected to be instrumental in transforming the global energy system from black to green energy, and driving down carbon emissions at the necessary speed.

To achieve a profound decarbonisation of the global energy system, the world will need significant and simultaneous action in three major areas:

1. Green electrification is needed to phase out fossil fuels

With solar and wind power now cost competitive, we must rapidly electrify the transportation, industry, and building sectors using green power to decarbonise the global energy system.

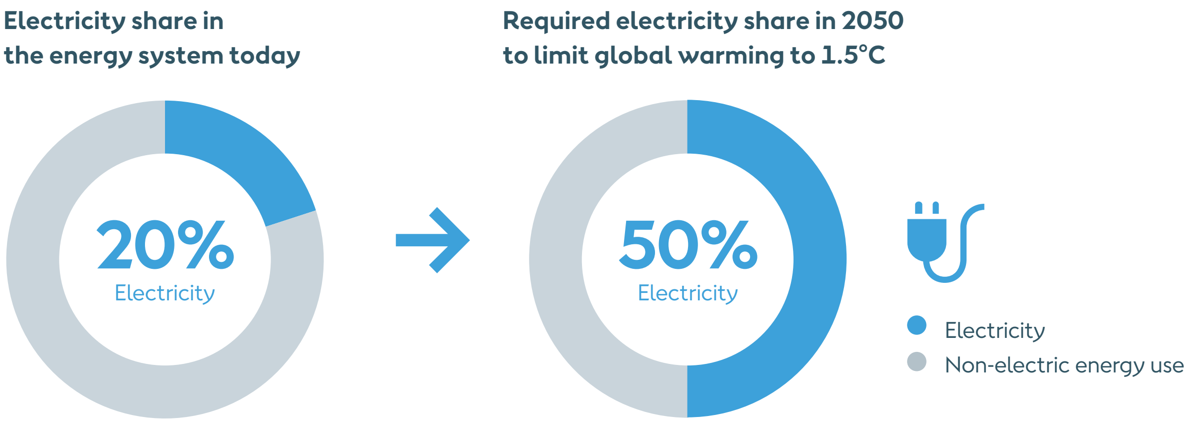
2. Accelerating the phase-out of fossil fuels, especially coal

To cut global carbon emissions, we need to phase out fossil fuels, most importantly coal, much faster than the current projected retirement rate.

3. Speeding up the build-out of green power

To replace fossil fuels in the global energy system and increase the share of green power, we must build out green power production capacity at a far quicker speed than today.

Green electrification is needed to phase out fossil fuels

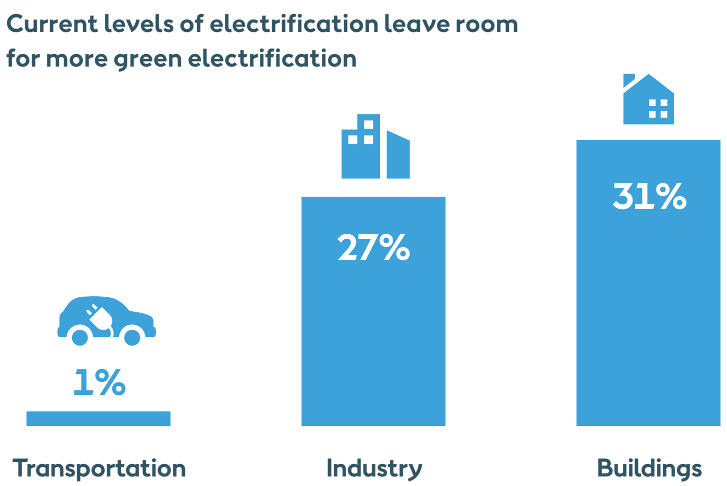


Sources: IRENA (2019) Global Energy Transformation – A roadmap to 2050; IPCC (2018) 1.5 Special Report, Global Warming of 1.5°C.

Pursuing a roadmap for rapid decarbonisation aligned with the 1.5°C target is projected to increase electricity's share of total energy consumption by a factor of 2.5 from 20% to around 50% in 2050[22], making electricity the dominant global energy carrier.

Decarbonisation through electrification makes sense for two reasons. First, due to the rapidly decreasing cost of solar and wind power, there is a significant potential for cost-effective substitution of other types of energy with green power. In most parts of the world today, establishing new solar and wind power capacity is cheaper than building new coal and gas-fired power plants, with the price of wind and solar power capacity continuing to fall[23].

Second, decarbonisation of the global power sector is more advanced than in other energy-consuming sectors, with just over a quarter of the global electricity supply sourced from green power. This makes electrification a key driver to decarbonising transportation, buildings, and industry, primarily through direct electrification. While direct electrification can replace fossil fuels in many cases, it is not always applicable, and therefore indirect electrification – for example through power-to-X technologies[24] – will also be needed to help decarbonise areas such as heavy transport and some industrial processes.

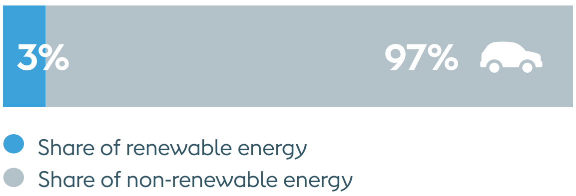


Source: IRENA (2019) Global Energy Transformation – A roadmap to 2050.

Significant decarbonisation potential across sectors

The majority of the energy being used for transportation, industry, and buildings is derived from fossil fuels. The power sector will play a key role in decarbonising these sectors both directly and indirectly, but other solutions are also needed to reduce emissions.

Transportation

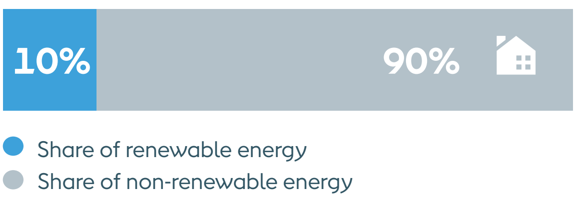


Transportation has the lowest share of energy use from electricity, but electrification holds significant potential to replace oil as the main fuel for cars, trains, buses, and near-shore shipping. Bloomberg New Energy Finance estimates that the first electric vehicles will achieve price parity with conventional combustion engine vehicles from 2022[25]. Synthetic fuels derived from green power and biofuels can help decarbonise some of the harder-to-abate modes of transportation such as aviation, long-range shipping and heavy-duty road transport.

Industry

Industry depends on fossil fuels for both fuel and feedstocks, and it will be challenging to fully decarbonise this sector. However, green on-site power production, electric boilers, furnaces and smelters, heat pumps, and power to gas from renewables are all electricity-based solutions that will help reduce emissions by replacing oil, gas and coal in industrial production processes. Furthermore, increased resource efficiency and new technologies can help reduce emissions in some of the harder-to-abate industries such as cement, steel, and plastic production.

Buildings

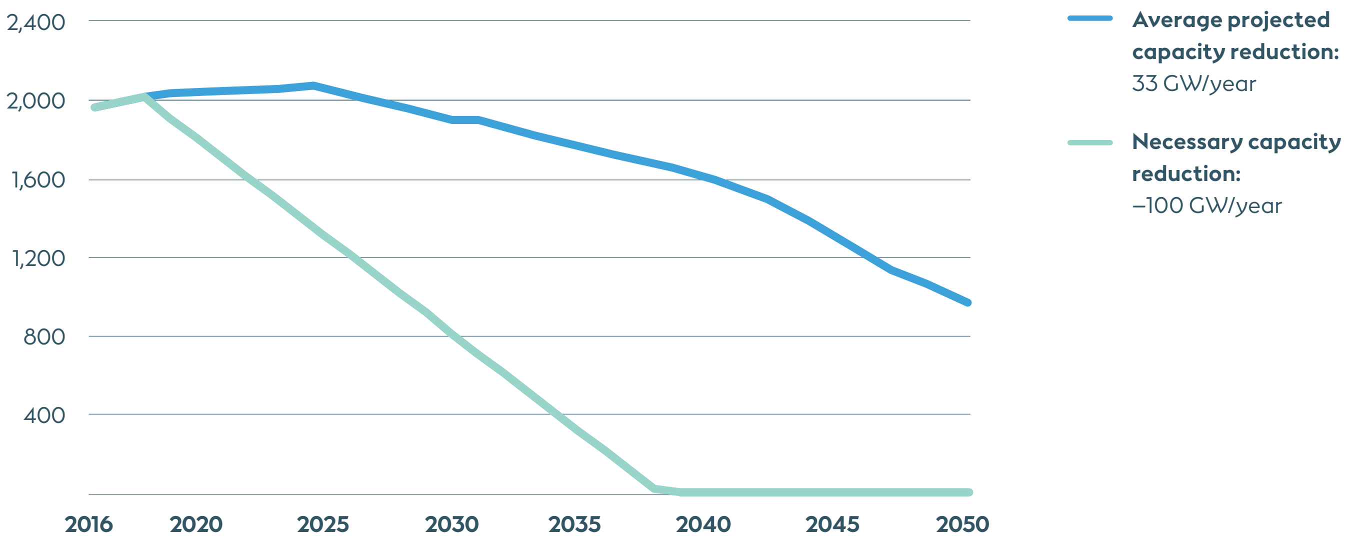


Buildings will benefit greatly from switching to heat pumps for space heating and hot water as these are 3 to 4 times more efficient than conventional forms of space heating. Some harder-to-abate areas in buildings could reduce emissions through waste reduction, more reuse, and increased material efficiency. Furthermore, there is a large untapped potential to reduce energy use in buildings by increasing energy efficiency through smart buildings, heat pumps, better insulation, and other solutions.

Sources: IRENA (2019) Global Energy Transformation – Roadmap for 2050; REN21 (2019) Renewables 2019 – Global Status Report.

Accelerating the phase-out of fossil fuels, especially coal

Coal needs to be phased out three times faster than projected
GW



Source: Bloomberg New Energy Finance (2019) New Energy Outlook 2019; Carbon Tracker Initiative (2018), Powering down coal. The necessary coal capacity reduction has been plotted based on the findings of Carbon Tracker Initiative, which states that to meet the Paris Agreement, 100GW of coal will need to be retired each year towards 2040.

The third lever that must be deployed to limit global warming to 1.5°C is to phase out fossil fuels, especially coal, from power production much faster than today. Coal is the dominant fossil fuel in the global power system, producing 37% of electricity worldwide. However, as the most carbon intensive fossil fuel, burning coal accounts for 72% of emissions from the power sector[26]. When adding natural gas and oil to the equation, a total of 63% of global power is derived from these 3 fossil fuels.

To have any realistic chance of limiting global warming to 1.5°C, the global power production relying on coal needs to be more than halved from 2,000GW to 800GW by 2030, meaning that at least 100GW of coal-fired power plants should be retired every year, according to projections by Carbon Tracker Initiative[27]. By the late 2030s, production capacity based on coal should be completely phased out.

However, current projections show that the global coal-fired capacity will remain roughly the same as today in 2030, and there will still be a sizeable 800GW of coal-fired production capacity in the global power mix by 2050[28]. This is inconsistent with commitments made under the Paris Agreement and will put global warming on a trajectory to far exceed 2°C.

This current pathway is a result of insufficient action to retire existing coal-fired power plants, as well as a planned coal build-out of more than 400GW – twice the current coal-fired capacity of Europe – in the next 30 years[29]. Governments need to stop constructing new coal-fired power plants and take steps to phase out existing plants at a much higher rate than today.

Newly constructed coal-fired power plants risk becoming stranded assets due to new carbon pricing regimes, air pollution regulation and decreasing green energy prices. An estimated 35% of the current coal-fired capacity already has higher operating costs than new green power capacity. By 2030 this figure could to increase to 96% of all coal-fired capacity[30].

Speeding up the build-out of green power

Fossil fuels still dominate power production with a 63% share globally. To phase out fossil fuels from the global energy system and cut emissions in half by 2030, the build-out of green power production capacity must be accelerated dramatically.

With more than 1,000GW of capacity added in the past seven years, green power is growing quickly and now accounts for 26% of global power production. This brings the total installed capacity of green power to approximately 2,400GW. Wind and solar power alone now account for more than 1,000GW, which corresponds to five times Germany's total power production capacity[31].

The current speed of green power build-out is, however, not enough to limit global warming to 1.5°C. Continuing business as usual will lead to an estimated share of green power of 38% by 2030 and 55% by 2050. However, the IPCC estimates that the renewable share of power needs to reach 52% by 2030 and 77% or more by 2050 to limit global warming to 1.5°C.

These projections generally assume that by 2050, countries that have already come far in their green transition will source 100% green power or be very close to achieving that, allowing some developing countries to have a share of green power below the global average.

Dramatic increase in global power capacity needed by 2050

If we translate the global power demand to the required capacity build-out, it is clear that it will be necessary to increase the global installed green power capacity significantly. Today, we have 2,400GW of green power production capacity installed globally. Business as usual projections point to more than 10,000GW of installed green power by 2050[32].

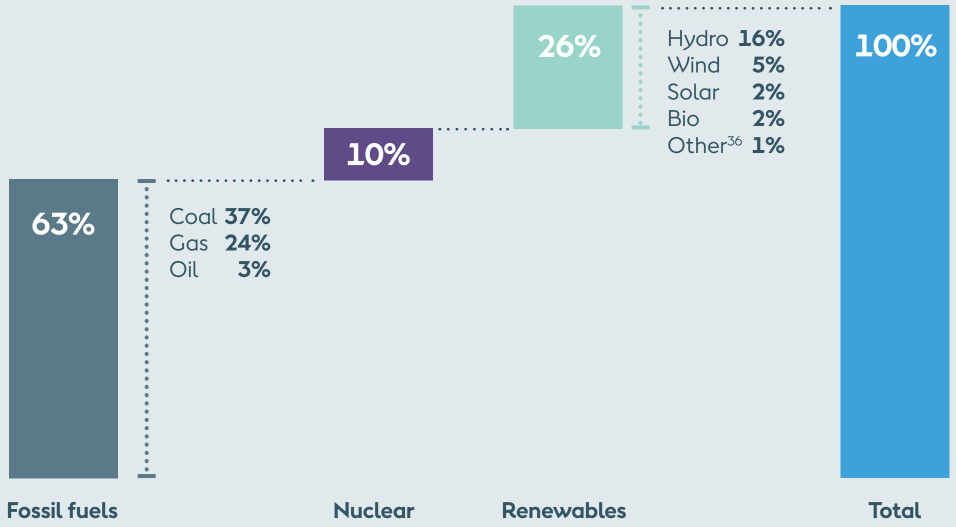
Different estimates exist of how much green power production capacity is needed by 2050 to keep global warming below 1.5°C. IRENA's 'well-below 2°C' scenario calls for a total of 18,000GW of green power capacity[33]. Another scenario from Teske (2019) aiming for 1.5°C calls for almost 26,000GW of green power capacity by 2050[34]. According to these projections, current global power capacity must be increased by a factor of between 7 and 11, meaning that the current build-out projections for 2050 must be doubled or tripled.

The need for accelerated green power build-out towards 2030

To achieve the green power build-out needed by 2050, rapid action between now and 2030 is needed. IRENA projects that 2,800GW will be added to the global power mix by 2030, reaching 5,200GW of installed capacity. However, this is not enough to limit global warming to 1.5°C. For that to happen, IRENA estimates that around 7,800GW of green power production capacity must be installed by 2030.

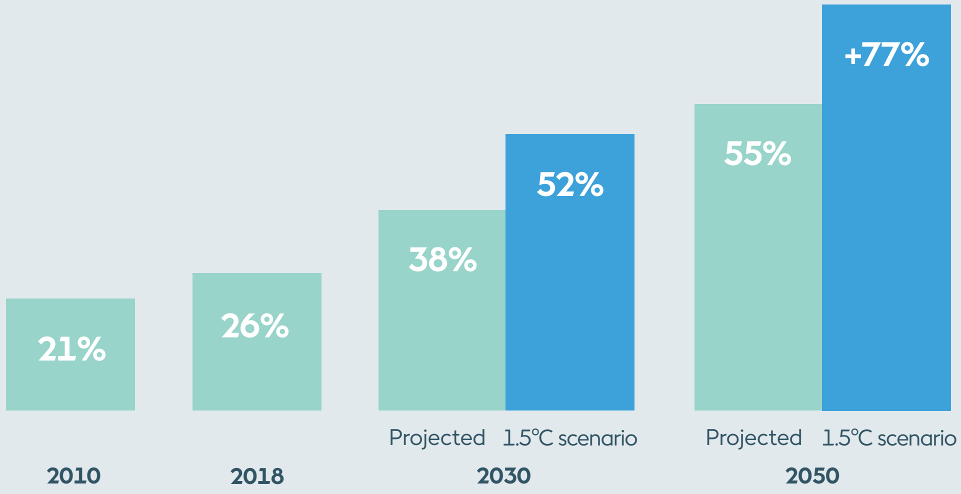
This leaves a gap of 2,600GW between the projected and the required capacity. In other words, the world will need to double the planned build-out of green power to meet the 1.5°C scenario. This means that the required annual build-out must be almost 450GW compared to the projected annual build-out of 235GW. In comparison, a total of approximately 187GW of green power production capacity was added in 2018[35].

Energy sources in global power generation, 2018



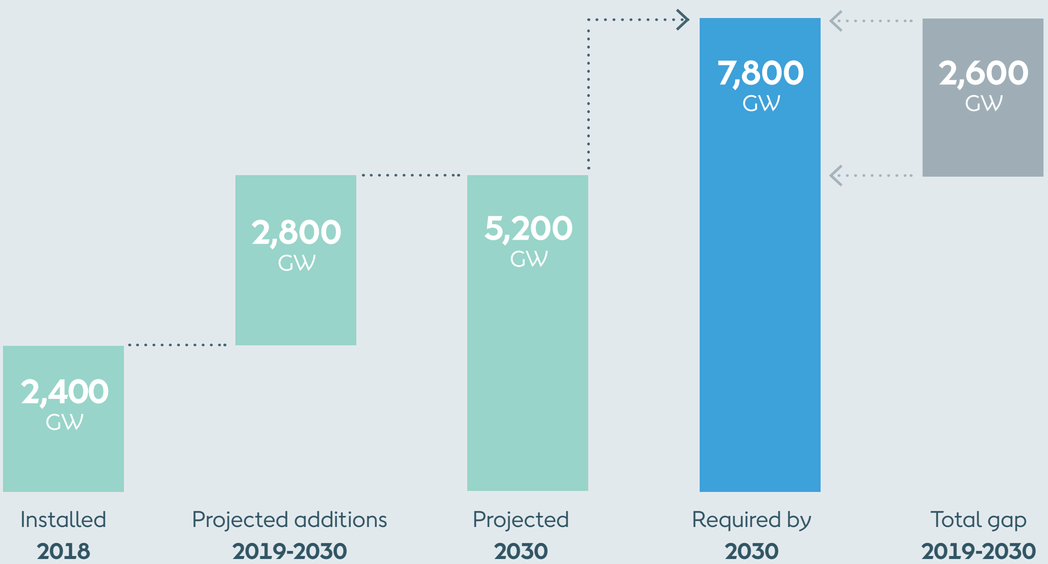
Sources: Bloomberg New Energy Finance (2019) New Energy Outlook 2019. Note that due to rounding, percentages may not total 100%.

Green share of global power generation



Sources: IRENA (2019) Global energy transformation – A roadmap to 2050; IPCC (2018) 1.5 Special Report, Global Warming of 1.5°C; Bloomberg New Energy Finance (2019) New Energy Outlook 2019.

Green power capacity towards 2030



Sources: IRENA (2019) Global energy transformation – A roadmap for 2050; Bloomberg New Energy Finance (2019) New Energy Outlook 2019.

Key questions about green power

Tackling the defining issue of our time and limiting global warming to 1.5°C requires us to halve global carbon emissions by 2030. To achieve our goal, we must rapidly phase out coal and other fossil fuels, and build out green power capacity, transitioning to a green energy system supported by increased energy efficiency and electrification.

We already have the green energy technologies available to make the transition to a low-carbon, reliable and safe energy system. However, some technology components still need to reach full commercial maturity.

Applying the power of scale to these technologies, we can make the required step change in the global energy supply while creating a greener, healthier, and more prosperous world. On the following pages, we address some key questions about the role of green power in our energy system.

What are the technologies in the future green energy system?

Green generation

- Offshore wind power
- Onshore wind power
- Solar power
- Solar thermal
- Hydro power
- Bioenergy
- Geothermal
- Other emerging technologies

Storage, flexibility, and carriers

- Interconnectors
- Renewable hydrogen
- Batteries and other storage
- Smart grids
- Heat pumps
- EVs
- Intelligent demand flexibility
- Other emerging technologies

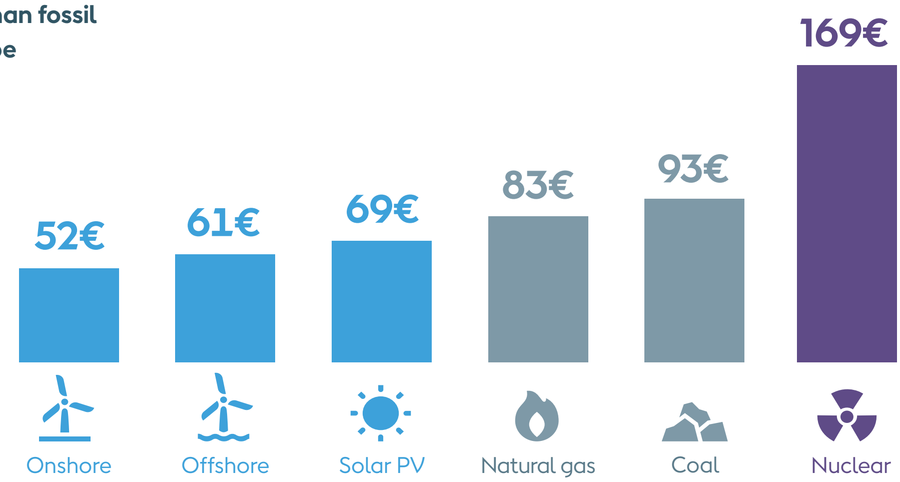
Is green power too expensive?

The cost of building solar power, onshore wind, and offshore wind has declined rapidly in recent years. Green power from solar and wind energy is now cheaper than power from fossil fuels in most parts of the world. The energy technologies which will form the backbone of a future green power system are therefore already available to be deployed at scale.

This cost reduction is a key reason why electricity is projected to emerge as the main carrier of energy globally. Green power is outcompeting newly built fossil-based power in Northwestern Europe and is now also cheaper than coal-fired power plants in the USA.

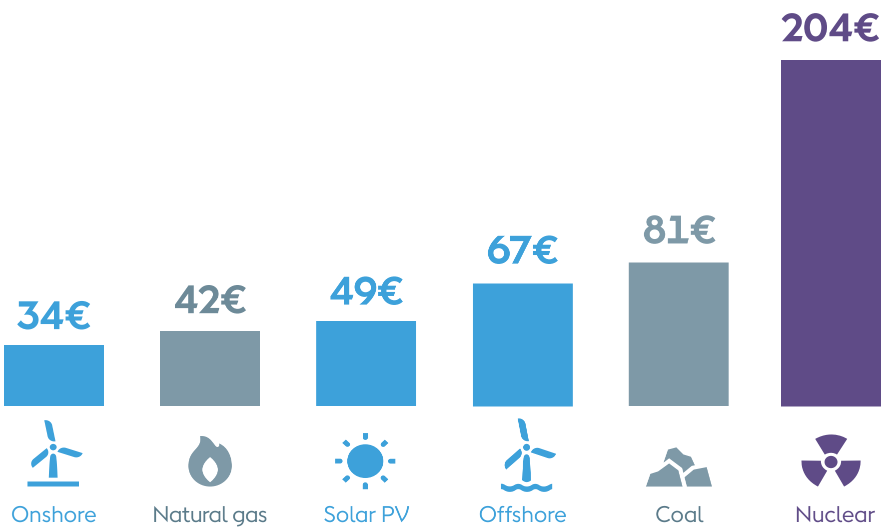
Solar and wind power is expected to become even cheaper, while the price of power from fossil fuels is expected to increase in many regions due to carbon taxes that put a price on the externalities of the environmental and health-related impacts caused by burning fossil fuels. With that in mind, it not only makes sense to install green instead of black power capacity from a climate and public health perspective, but also from a financial perspective.

Solar and wind power are now cheaper than fossil and nuclear power in Northwestern Europe
EUR/MWh, 2018 prices



Source: Bloomberg New Energy Finance – 2H 2018 LCOE Update, current LCOE.

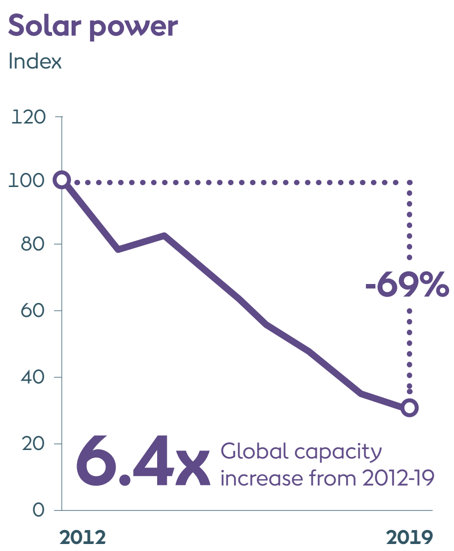
Solar and wind power are cost competitive with fossil power in the USA
EUR/MWh, 2018 prices

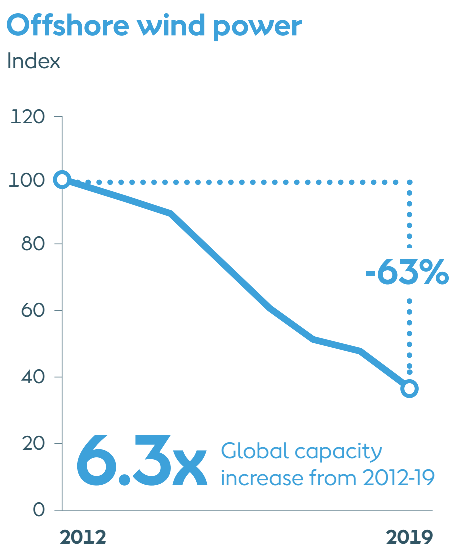


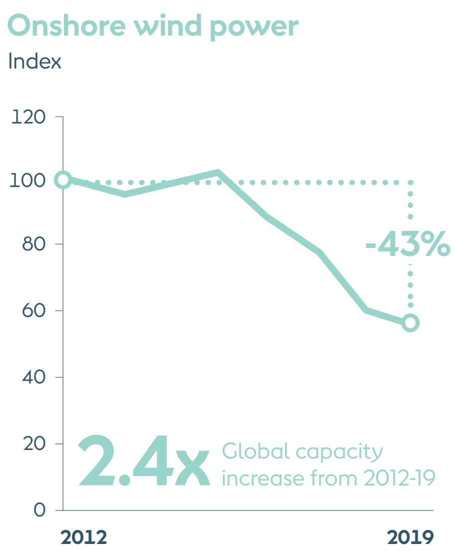
Source: Bloomberg New Energy Finance – 2H 2018 LCOE Update, current LCOE.

How can economies of scale reduce costs?

Experience shows that green technologies can quickly become more cost-efficient with scale
Global green power cost reductions







Source: Bloomberg New Energy Finance (2019) New Energy Outlook 2019.

Limiting global warming to 1.5°C through electrification of the global energy system using green power requires rapid global deployment of green energy technologies at scale. Scaling up both onshore wind, offshore wind, and solar power so that they become the backbone of a green power system instead of coal will lead to further cost reductions. It will also be important to leverage scale when it comes to green technologies such as hydrogen or batteries that are needed to manage the variable nature of solar and wind energy, but these technologies have yet to become cost competitive.

The steep cost reductions of solar and wind power over recent years provide lessons into the power of scale. Clear and ambitious political targets for the build-out of solar and wind power have allowed the industry to invest and scale up, reducing the cost of green energy through innovation across the entire value chain.

Case example: bringing down the cost of offshore wind power
The development of offshore wind power shows how constructive interplay between visionary policymakers and industry can mature an industry and lead to substantial cost reductions.

Governments in Northwestern Europe have ensured demand and volume through long-term green energy build-out targets and dedicated support schemes. This has created a long-term market outlook with increasing volumes, enabling industry to commit to developing offshore wind farms at unprecedented dimensions, reaping the economies of scale. This has unlocked technological innovation and supply chain build-out to further mature the technology.

As a result, the cost of offshore wind energy has fallen by 63% since 2012, making offshore wind power cheaper to install than coal-fired or gas-fired power plants in Europe. This competitive price is now allowing governments to set even more ambitious targets, creating a virtuous cycle of further cost reductions.

How do we ensure a reliable power system with variable green power?

Power systems across the world are currently transitioning from being dominated by baseload fossil fuel power generation to increasing levels of variable green power from wind and solar energy. So far, the integration has generally been successful, but a common concern is whether a power system based on fluctuating solar and wind power can provide a stable supply of power throughout the day and year.

It is important to acknowledge that integrating very large shares of variable green power does pose a challenge. But it is a challenge that to a large extent can be overcome using technologies that are already commercially available and technologies that are known but have to be made more cost competitive.

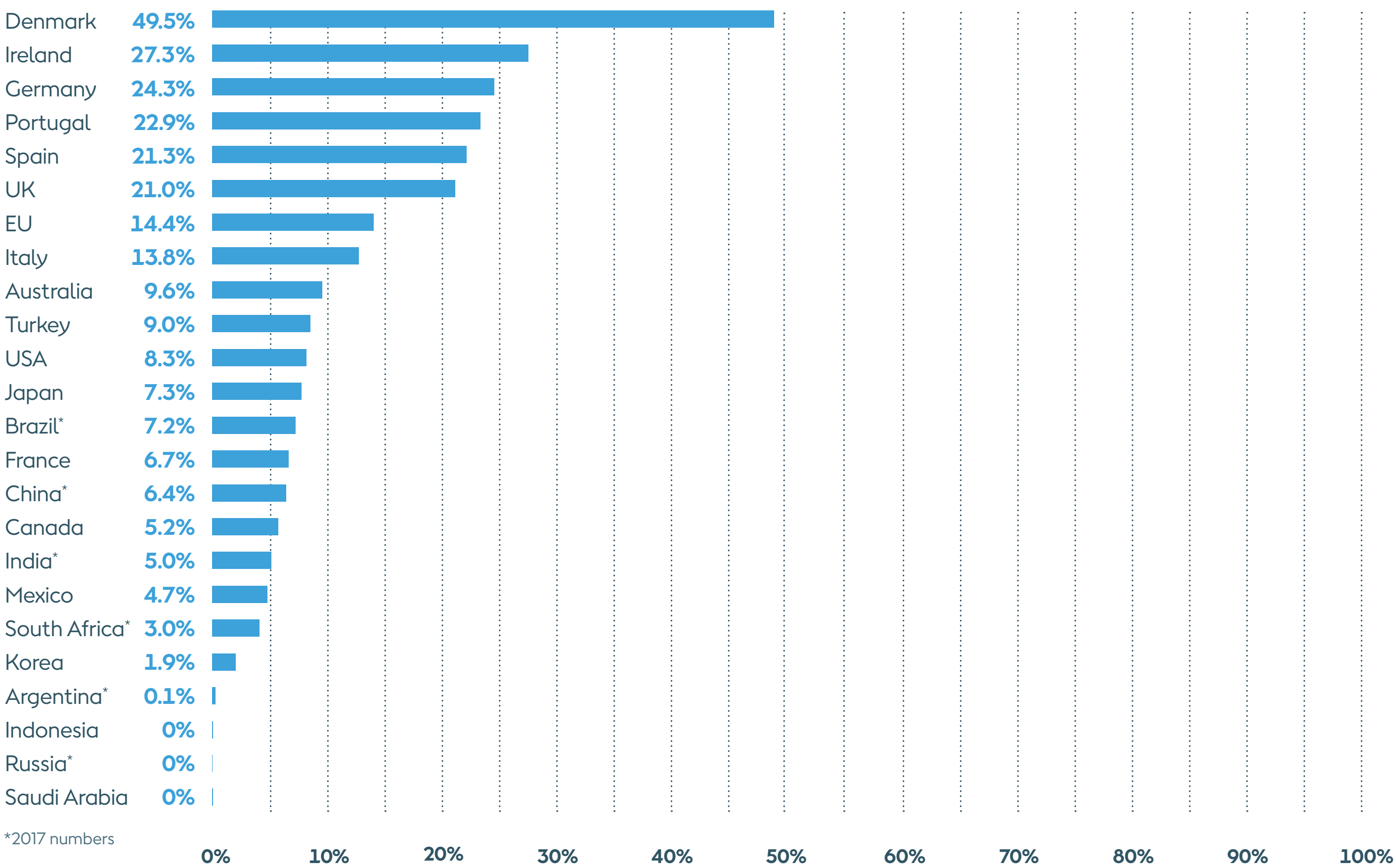
There is a large potential to establish more wind and solar power

Most countries around the world still have the potential to materially increase the share of green energy, such as wind and solar power, in their power systems before variability becomes a challenge. As an example, the USA gets only 8% of its electricity from solar and wind energy, and many countries have even lower levels of variable green power.

The potential for build-out of variable solar and wind power is greater still when taking into account electrification of transportation, buildings, and industry. As such, the build-out of solar and wind power will be absorbed by electrification, leaving an even bigger potential to expand green power capacity.

Variable green energy share of total electricity generation

G20 members and selected countries, 2018



Source: The International Energy Agency (2019) World Energy Balances.

Whilst being perceived as variable, wind energy is in fact relatively consistent, particularly offshore wind power, where the newest farms have capacity factors above 50%. IEA now concludes that offshore wind power's high capacity factors and lower variability make it comparable to baseload technologies, placing it in a category of its own – a 'variable baseload technology'[37]. Additionally, wind and solar energy complement each other well, as wind speeds are generally higher at night and in the winter when there are fewer hours of sunlight.

Mature and commercially viable solutions already exist to manage fluctuations from wind and solar energy
When the levels of solar and wind energy in the electricity mix become so high that their variable nature poses a challenge, a number of cost-effective solutions can be deployed to support the security of supply. Denmark, for example, has pushed its share of variable green power – from notably wind power – up to almost half of the country's power production; a share that is only increasing.

To accommodate a higher share of variable green power, Denmark has significantly increased flexibility within the power system. One tool to achieve this flexibility is increased interconnection between countries. The interconnector being established between Denmark and the United Kingdom is a good example of how to balance out varying wind conditions between the two countries. The interconnection between the wind-dominated Danish grid and the hydro-dominated Norwegian grid also leads to better utilisation of both renewable resources. A key enabling factor in this regard is a well-functioning European Internal Energy Market, which facilitates barrier-free trade of electricity across Europe's borders. Additionally, Denmark has benefitted from increasingly flexible power stations when integrating variable power.

Other mature and cost competitive solutions that can support the balancing of energy systems with increasing levels of variable green electricity, include:

- Pumped hydro energy storage
- Demand-side flexibility, such as intelligent demand reduction in large industrial installations during peak hours
- Dispatchable baseload power from hydro power and sustainably sourced bioenergy
- Natural gas, which can act as a transition fuel by providing dispatchable baseload power. Over time, natural gas can be replaced by biogas and other solutions

Solutions can help further increase the variable share of green power
There is a need for other solutions to take the share of variable green power even further than that of e.g. Denmark and take the next step in transitioning to a green energy system. Many of these technologies are known but are not yet cost-effective or available at commercial scale, limiting their current impact.

Examples of technologies that are yet to become fully commercialised include:

- Grid-scale batteries that will help balance short-term supply and demand. Batteries have experienced an 85% price reduction in the past 8 years[38], but prices must continue to fall for grid-scale batteries to become widespread
- Hydrogen based on green power can help decarbonise harder-to-abate sectors through indirect electrification and in the long term potentially feed energy back to the grid during times of peak demand
- Smart grids and other solutions for demand-side and supply-side flexibility such as flexible EV charging and EVs being able to deliver power back to the grid

Experience shows that such green technologies can rapidly become more cost competitive when they are deployed at scale.

With electrification of other sectors, the traditional outlets for power use will increasingly be supplemented by outlets that will likely be much more flexible, such as EVs, heat pumps, electrified industrial processes and production of renewable hydrogen. This means that the future system will have much more flexibility on the demand side, making it easier to integrate more variable green power. There are many obstacles that have to be overcome and new solutions that need to be developed and matured, but there is reason to be optimistic about solving the complex challenges that a global system dominated by variable power poses.

A greener, healthier, and more prosperous world

Limiting global warming to 1.5°C through electrification and green energy build-out brings significant benefits for the environment and climate. In addition, making the switch from a black to a green energy system also brings a number of other material and societal benefits.

Accelerating the global transformation from black to green energy can:[39]

Save up to 4 million lives a year due to cleaner air

- Each year, around 7 million people die from diseases related to indoor and outdoor air pollution[40]
- Accelerating the transition to clean energy and improving air quality could save up to 4 million lives a year by 2030[41]

Help deliver electricity to the people who do not currently have power

- Almost one billion people have no access to electricity, which negatively impacts public health, education and economic growth[42]
- Investing in distributed green solar energy is key in areas with non-existent or weak power grids, ensuring that green power can reach all corners of the world and all of the 8.5 billion people that will be inhabiting planet Earth, in 2030

Improve energy independence for more people and countries

- More than two thirds of countries in the world are not self-sufficient in meeting their own energy needs[43]
- A faster build-out of renewables could save energy-importing G20 countries alone USD 1.95 trillion in energy imports in 2050[44]

Deliver sustainable growth

- Investing in transforming the energy system could boost global GDP by as much as 2.5% by 2050[45]
- The increase is mainly due to investments in the energy system, carbon tax changes and future reduced energy expenditure

Create 37 million new jobs globally

- Accelerated climate action could lead to a net employment gain of up to 37 million jobs in 2030[46]
- This is more than the entire labour force of the United Kingdom

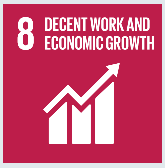
Increasing the share of green energy is necessary to achieve the Sustainable Development Goals

Combatting climate change by deploying more green energy helps preserve and improve sustainable food production systems, safeguards crop yields, and reduces food insecurity.

Shifting from fossil fuels to green energy cuts air pollution, which can save millions of lives, and improve health and well-being around the world.

Mitigating climate change through green energy will reduce the climate-related impacts on water availability in regions threatened by water scarcity.

Transforming the energy system will give more people greater access to locally sourced energy that is safe, affordable, and clean.



Accelerated climate action can lead to sustainable economic growth and the creation of new green jobs within areas such as energy production and energy efficiency.

Deploying more green energy can help to build more liveable cities with low-carbon transport systems and improved air quality.

Reducing emissions from the energy sector, through green energy expansion, is the main lever to combatting climate change.

Carbon emission reductions are important to decreasing the ocean acidification, which is crucial to preserving marine resources and habitats, such as coral reefs.

Shifting from black to green energy can enhance the protection of the Earth's ecosystems and biodiversity as many species' natural habitats are endangered by climate change.

Who can help speed up green action and how?

Limiting catastrophic climate change requires action at all levels of society, from governments and companies to investors and individuals. While each of us can and must make changes in our daily lives to limit our consumption of carbon-intensive goods and services, such changes alone will not be sufficient to halt runaway climate change. 73% of global emissions come from energy because 80% of global energy supply comes from fossil fuels. To reduce global emissions at the rate required by science, we need our energy systems to shift from a reliance on fossil fuels to using renewable, green energy. To effectively tackle climate change, we must transform the global energy system from black to green.

We all have a role to play:

Energy companies
- Invest more in the build-out of green energy
- Phase out coal-fired power plants faster
- Innovate and scale new technologies to support an entirely green energy system

Policymakers
- Make ambitious energy and decarbonisation plans aligned with the 1.5°C target
- Speed up the phase-out of coal-fired power plants
- Accelerate the build-out of green energy
- Pursue faster green electrification to help decarbonise transport, buildings, and industry
- Introduce policies to boost energy efficiency across sectors

Businesses
- Buy green power from green energy companies
- Reduce emissions from production, feedstocks, and throughout the supply chain
- Cut emissions to what is required to limit global warming to 1.5°C

Investors
- Shift capital to ESG investments[47]
- Ask companies to reduce their emissions in line with what is required by science
- Integrate climate-related disclosure in reporting

Individuals
- Demand policies that keep global warming below 1.5°C
- Buy green power
- Choose sustainable products and services from green companies
- Invest in companies and pension funds that are aligned with the 1.5°C target
- Choose sustainable modes of transportation and make sure your home is energy efficient

We realise that these are not easy actions to take. They all require transformational change that profoundly challenges the way that the economy, businesses and investors operate today. But it is worth keeping in mind that the main barriers to speeding up the transition to green energy are not lack of mature or cost-effective solutions, or that limiting global warming to 1.5°C will leave society worse off financially. On the contrary, the barriers to taking the necessary action comes from the inclination of humans to use a short-term rather than a long-term perspective.

The way forward

Replacing fossil fuels with green energy is the single most important lever to put us on a path to halving global emissions by 2030 and reaching net zero emissions by 2050, thereby limiting global warming to 1.5°C. To that end, the global use of energy will need to be held in check by increased energy efficiency. Green electricity is expected to emerge as the main carrier of energy, potentially moving from a 20% to a 50% share of the global energy supply. This means that transforming the power sector from black to green will help drive down emissions across the entire energy system through green electrification of transportation, buildings and industry.

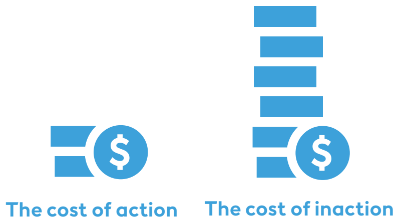
Solar, onshore, and offshore wind energy can provide the backbone of the future decarbonised energy system if they are scaled up globally as all three technologies are mature and cost competitive due to remarkable cost reductions in recent years.

A much higher penetration of variable power from solar and wind energy will pose challenges in terms of maintaining a stable energy supply, but it should not stop countries from pushing ahead and building out green energy at a much higher speed than today. For many countries there is plenty of room for building out green power before intermittency becomes a challenge, and when that does happen, cost-competitive technologies exist that can be deployed to balance supply and demand in the power system.

To reach a totally green power system will, however, require additional balancing technologies such as batteries and hydrogen. These technologies are expected to experience further significant cost reductions in the years to come. Valuable lessons can be learned from the cost reduction journey of solar and wind power on how to harness the power of scale to deploy these technologies globally and help mature and reduce the cost of emerging technologies such as batteries and hydrogen. Governments need to set ambitious and clear targets with appropriate long term policies that enable the energy industry to invest in and expand the scale of green technologies. Greater volume leads to more learning, and with that innovation costs are reduced.

Today, we already have the solutions at our disposal to limit global warming to 1.5°C. They are cost-effective or can be made so with the right public policy approach. If we deploy them, we will not only see benefits for the climate and our planet, but also for our society and the economy. What is needed now is to speed up the deployment of green technologies.

Action is cheaper than inaction



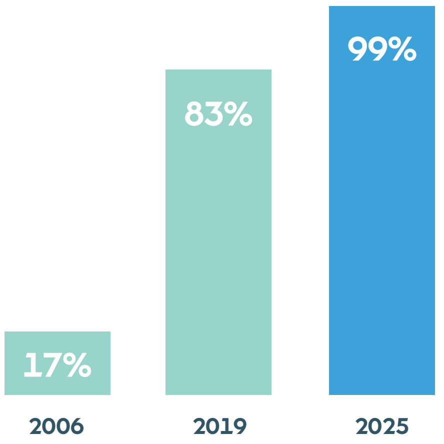
Besides the inherent benefits of preserving our shared home, planet Earth, there is a strong business case for taking climate action. IRENA estimates that savings from speeding up the global green energy transition are at least 3 times higher than the energy investments required to reduce emissions in line with the Paris Agreement[48]. The projected savings from acting on climate change are achieved through avoided costs caused by sea level rise, floods, droughts and air pollution-related illnesses.

The IPCC also estimates that there is a lot to gain economically from limiting global warming to 1.5°C as the damage caused by a 1.5°C scenario will be USD 15 trillion less than that caused in a 2°C scenario[49].

A warming climate means risks of unforeseen and irreversible natural consequences that could lead to global warming of 3°C or higher. The costs of such a scenario are not easy to predict, but one study finds that unhalted climate change could reduce global GDP by 7% by 2100[50]. In such a situation, a rational economic logic would force us to make the necessary investments as an insurance to avoid costs of unimaginable magnitude and scale. Exactly because no one knows what the cost of climate change will be, it seems prudent to do all we can now to preserve a habitable planet for our children and grandchildren.

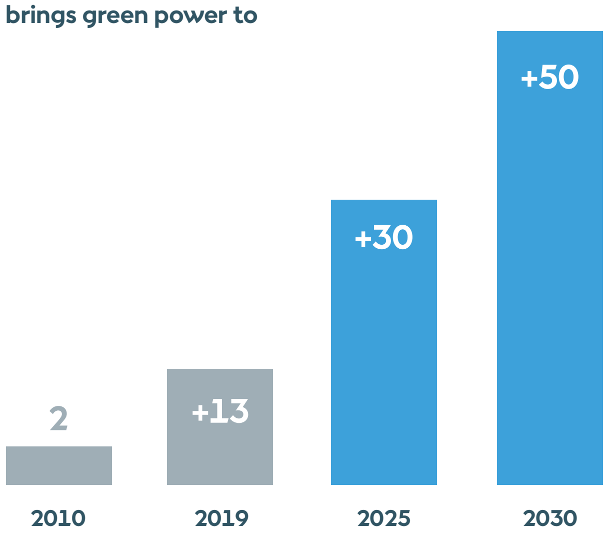
Our experience in transitioning from black to green energy

Ørsted's share of green power and heat



Source: Ørsted. Note that 2019 numbers are for 9M 2019.

Million people that Ørsted brings green power to



Source: Ørsted. Past and present numbers are based on onshore and offshore capacity, while goals for 2025 and 2030 will include all green power generation technologies in our portfolio by then. 2019 numbers are for H1.

At Ørsted, we have first-hand experience of what it takes to transition from black to green energy. Only a decade ago, oil, gas, and coal were our core business. We were one of the most coal-intensive utilities in Europe with an expanding oil and gas production business. The emissions from our coal-fired combined heat and power plants accounted for one third of all Danish carbon emissions. But we decided to phase out fossil fuels and significantly expand our production of green energy.

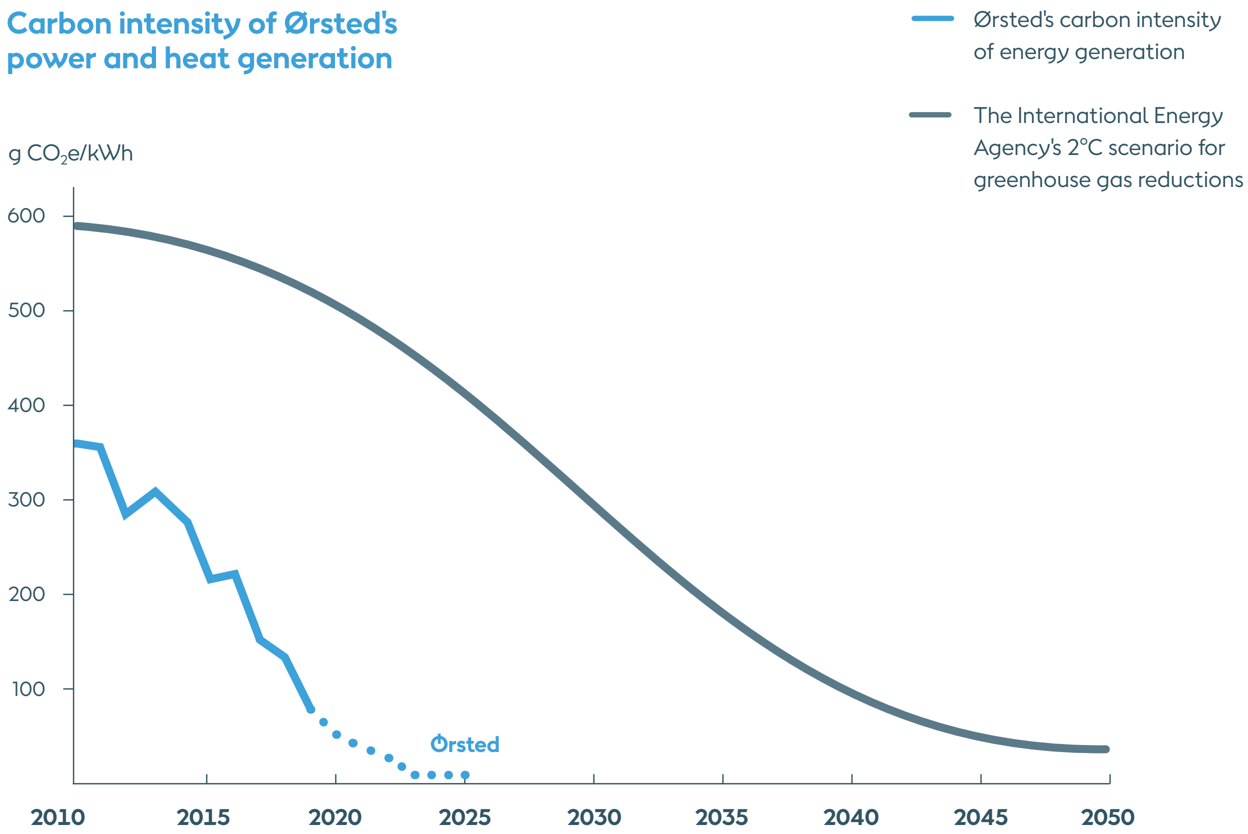
Since then, we have reduced carbon emissions by phasing out our use of fossil fuels. We have divested our oil and gas production. And since 2006, we have reduced our consumption of coal by more than 80%.

We have reduced our greenhouse gas emissions by 83% since 2006, and by 2025 our power and heat production will have become essentially carbon neutral. It means that we are 27 years ahead of schedule if we were to adhere to the requirements for emission reductions in a 2°C scenario. Today, Ørsted is a global green energy company and has been named the most sustainable energy company in the world[51].

By 2023, we will stop using coal altogether. Alongside phasing out fossil fuels we have built up the world's leading offshore wind energy business, which has made us one of the world's leading renewable energy companies. Our offshore wind farms in Europe, the US and Asia now bring green power to over 13 million people. Our share of green energy today sits at 83%, up from just 17% in 2006. By 2030, our ambition is for the renewable energy we have installed to bring green power to more than 50 million people.

Our investments in offshore wind power, totalling more than $20 billion since 2010 along with our partners, have been instrumental in developing the offshore wind industry from a niche to a global and rapidly growing industry with the potential to deliver green energy to hundreds of millions of people.

Carbon intensity of Ørsted's power and heat generation



Source: Ørsted; IEA (2018) World Energy Outlook.

We are now also looking beyond our energy generation and operations to reduce emissions throughout our value chain and have set a target to halve our indirect emissions by 2032 compared to 2018. These emissions come from our supply chain and the energy products we buy and sell in the energy markets. As of 2021, Ørsted will no longer buy or lease fossil-fuelled vehicles, and in 2025, our car fleet will be 100% electric.

Our transformation has not been easy, but it has been necessary. Our old fossil fuel-based business model was eroding, and we needed to replace it with a model that was both financially and environmentally sustainable. We like to think that we are proof that it is possible to change profoundly within a decade. Needless to say, it will require transformation on a much bigger scale to halve global emissions by 2030 through accelerated build-out of green power.

What we are talking about here is nothing short of fully decarbonising a global economy that has been built on fossil fuels since the late 18th century. However, the tools required to push the transformation forward are at our disposal. It is now a matter of our willingness to assume responsibility for the long-term health of our shared home, planet Earth, and take action without further delay.

References and notes

Click on the reference number
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5 Climate Action Tracker (2019) Warming Projections Global Update.
6 IPCC (2018) Special Report: Global Warming of 1.5°C.
7 IPCC (2018) Special Report: Global Warming of 1.5°C.
8 IPCC (2018) Special Report: Global Warming of 1.5°C.
9 Emissions from "land use change and forestry" reflect the flux between carbon emissions and absorptions from aerobic and anaerobic processes caused by land clearing, abandonment, shifting, harvesting and deforestation of forest land, cropland, and grassland.
10 "Other fuel combustion" refers to emissions of CH_4 and N_2O from fossil fuel combustion and incomplete combustion of fuels such as charcoal or fuel wood. "Fugitive emissions" relates to emissions from natural gas flaring/venting in association with oil production, CH_4 and N_2O from oil & natural gas systems, and CH_4 and N_2O from coal mining.
11 Emissions from "Non-energy industrial processes and waste" refer to CO_2, N_2O and CH_4 emissions that result from cement and chemical production, and other industrial processes, as well as CH_4 and N_2O emissions from landfill, wastewater and sewage.
12 Energy intensity is a measure of the energy efficiency of an economy and is measured as the quantity of energy required per unit of GDP.
13 IRENA (2019) Global Energy Transformation – Roadmap for 2050.
14 IPCC (2018) Special Report: Global Warming of 1.5°C; IRENA (2019) Global Energy Transformation – Roadmap for 2050.
15 Green energy in this paper is defined as energy from renewable resources, excluding traditional biomass.
16 REN21 (2019) Renewables 2019 – Global Status Report.
17 Nuclear power is also an emission-free power source, but should not be expected to play an increasing role in global decarbonisation due to high costs and nuclear waste issues. In some countries it will continue to feature as a part of the energy mix to achieve carbon neutrality.
18 Traditional biomass refers to wood fuels, agricultural by-products and dung, mostly burned for cooking and heating purposes. Its use is generally viewed to be unsafe and unsustainable.
19 Climate Action Tracker (2019) Warming Projections Global Update.
20 The exact share will depend on several factors including: population and economic growth; energy intensity improvements; the role of nuclear; and the extent carbon dioxide removal (CDR) utilisation. Many scenarios are reliant on CDR to some extent, but as CDR solutions are currently based on undeveloped and uncertain technologies, it is unwise to rely heavily on such solutions.
21 Climate Action Tracker (2019) Warming Projections Global Update.
22 The 1.5°C compatible scenarios assessed by IPCC assume electrification rates varying from 34% to 71%. 50% is the share required in the "well-below 2°C" scenario from IRENA (2019) Global Energy Transformation – Roadmap for 2050.
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46 New Climate Economy (2018) Unlocking the Inclusive Growth Story of the 21st Century. Even though going green is a no regret move with net benefits for employment and the economy it's important to ensure a just transition within and among countries to handle loss of jobs in some industries and support the countries that are facing the biggest challenges in going from black to green.
47 Environmental, social, and governance (ESG) criteria are an increasingly popular way for investors to evaluate companies in which they might want to invest.
48 IRENA (2019) Global Energy Transformation – Roadmap for 2050.
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This paper contains certain projections, roadmaps and forward-looking statements. Ørsted has based these on the best available data and projections, including on what is necessary to limit climate change to 1.5°C. While Ørsted believes that the estimates, projections and roadmaps reflected in this paper are reasonable, they may prove to be incorrect, and actual outcomes may materially differ due to a variety of factors. Unless required by law, Ørsted is under no duty and undertakes no obligation to update or revise any forward-looking statement after the distribution of this paper, whether due to new information, future events or otherwise.

It is important to note that while the focus of this paper – the transition from black to green energy – is of critical importance, it is far from the only measure required to combat climate change and limit global temperature rise to 1.5°C. It is also vital to tackle emissions from other sectors that are beyond the scope of this paper, including agriculture, land use, waste, and non-energy related industrial processes.

Get in touch

Get in touch if you have any questions or enquiries about the content of this paper.

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About this paper

With this paper, Ørsted wants to illustrate that it is possible to halve global emissions by 2030 and limit global warming to 1.5°C, protecting our shared home from runaway climate change. We have the solutions – notably cost-competitive solar and wind energy – required to decarbonise the energy system, which is the biggest contributor to global warming.

However, these solutions need to be scaled globally and it needs to happen quickly. The actions that policymakers, investors, energy companies and businesses need to take to accelerate the green energy build-out are not easy, but they are necessary.

We like to think that our ability to transform from a company with coal, oil and gas at its core to the world's most sustainable energy company within a decade is proof that profound change is possible. Now, we would like to share our experience on how to make that change happen.

About Ørsted

Ørsted is a global green energy company headquartered in Denmark with the vision of a world that runs entirely on green energy. Ørsted is the global market leader in offshore wind power and offers large-scale and cost-competitive offshore wind energy, onshore wind energy, and solar energy that reduce emissions, improve air quality, and provide local jobs.

Ørsted also operates sustainable bioenergy plants, offers green power purchase agreements, and explores renewable hydrogen and battery solutions. Ørsted has reduced its greenhouse gas emissions by 83% since 2006 and will be essentially carbon neutral by 2025.