International Energy Agency (IEA) Contribution to the Talanoa Dialogue

October 2018

The energy sector is essential to achieve the long-term temperature goals of the Paris Agreement, as over two-thirds of human-caused greenhouse gas emissions and 90% of carbon dioxide (CO_2) emissions are from energy production and use. Global energy transitions are underway, but their pace is far off track from what is needed to reach Paris Agreement goals: meeting this challenge is technically and economically feasible but requires unprecedented political and technological change.

This submission draws upon the vast array of IEA efforts to provide actionable insights, all of which are also available at www.iea.org. Specifically, as the global "all of energy" authority the IEA provides **timely data** to track progress; **rigorous analysis** to provide insights into energy transitions pathways; and **real-world solutions** to help governments, companies and others to simultaneously achieve their key climate, security and affordability objectives. This submission specifically draws from IEA's Tracking Clean Energy Progress (TCEP, www.iea.org/tcep) – now a continually-updated web platform; the Global Energy and CO_2 Status Report (GECO, www.iea.org/geco); *World Energy Outlook* analysis (including the Sustainable Development Scenario); *World Energy Investment, Renewables 2018, and Energy Efficiency 2018.* Links to all relevant IEA analysis is included in the annex.

This Talanoa submission contains updated IEA-wide energy-climate data and analyses since our submission in April 2018. It introduces a unique set of key aggregate and sectoral indicators to track climate action. It also includes the latest information on development and deployment of a full range of clean energy technologies, measuring their progress today against what would be needed by 2030 to be on track to achieve the Paris Agreement goals. We also identify levers for further key opportunities at the regional and country level to inform possible enhancement of Nationally Determined Contributions (NDCs).

The IEA is pleased to submit this contribution to the Talanoa Dialogue and stands ready to further help support countries, companies and others.

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Where are we and where do we want to go?

Despite accelerating energy transitions, CO_2 emissions are rising and we are not on track to achieve the goals of the Paris Agreement

While **energy efficiency is making important inroads**, its impact is being overwhelmed by factors pushing up energy use and emissions. Policy implementation **needs to accelerate** to maintain current efficiency trends and realise efficiency's full potential. Over the last three decades, **the global energy supply has barely decarbonised**: fossil fuels remain 81% of the global energy mix, the same as in 1987. Investment trends are starting to shift away from fossil fuels, but the share of investment in clean energy and energy efficiency was less than half of the investment in fossil fuel based energy.

To reach the Paris Agreement's long-term goals the IEA's Sustainable Development Scenario (SDS) presents a future in which **climate, energy access, and air pollution goals go hand-in-hand**. **Energy efficiency and renewable energy account for 87% of the cumulative CO_2 savings to 2030** in the SDS: two areas that can deliver multiple benefits or climate change, air quality and energy access. By 2030 in the SDS:

- Energy related CO_2 emissions are 23% lower than 2017 levels.
- The carbon intensity of global energy supply drops by around 22% from current levels.
- The electrification rate increases from 19% to 23% while the share of renewable energy in final energy consumption doubles.
- Increasing energy efficiency supports a much steeper decline in energy intensity per unit GDP of 3.4% per year, double the rate experienced in 2017.
- The share of clean energy investment rises from 32% to 69% by 2030.
- The role of fossil fuels in the energy mix in the SDS, particularly coal use without CCS, diminishes quickly: a substantial decline from their position in today's energy system

Where are we headed without new policy action?

IEA's New Policies Scenario (NPS) describes a future pathway for the energy sector globally accounting for existing, planned and announced policies, including the effects of NDCs. The NPS includes countries' NDCs where they have announced concrete policy measures intended to achieve the stated NDC outcomes. The NPS therefore already includes quite a lot of additional energy transition policies that are not yet formally enacted today.

Despite this, the NPS is not compatible with reaching Paris Agreement goals: energy-related CO_2 emissions do not peak before 2040, which together with other GHG emissions set the world on course for an average temperature rise of around 2.7 degrees Celsius by 2100. Based on current and announced policies including NDCs, we will therefore fail to bend the curve quickly enough – in fact, at least two decades too late. Though the message has been repeated many times, it cannot be overstated: without additional, near-term and ambitious policy action, the long-term goals of the Paris Agreement will slip out of reach.

Key indicators of where are we and where we need to go for clean energy transitions

Tracking energy system data and indicators, at global and national levels, is essential for countries to develop and implement national policies to achieve their NDCs and long-term transitions to sustainable energy systems. Indicators underpin a country's ability to track progress to date, and can also drive ambition going forward. The IEA's key indicators of clean energy transitions reflect the most important short-term actions that policymakers can focus on to achieve long-term objectives. These indicators combine tracking of outcomes (CO_2 emissions) with tracking drivers of underlying change in emissions, creating an accessible and comprehensive tracking framework which can also help inform effective and well-coordinated policies.

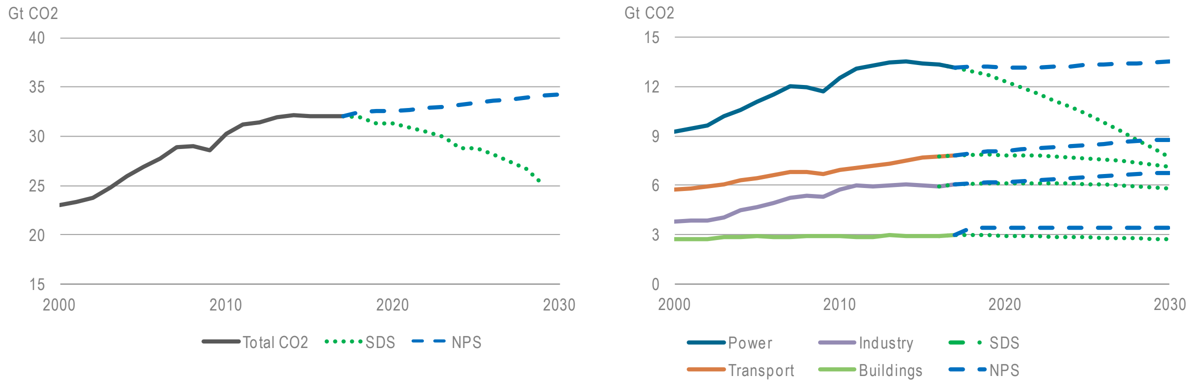
Aggregate energy sector indicators (Table 1 below) are important for providing an overall snapshot of progress – whether the entire sector is moving in the right direction. More detailed sub-sectoral indicators (Table 2) can help countries more clearly target key policy actions, including for low-carbon electricity supply, improving industrial productivity, enhancing demand for low carbon transportation modes and improving building energy efficiency. Progress in these indicators is presented in the annually updated Tracking Clean Energy Progress.

Table 1 Aggregate indicators for tracking clean energy transition progress in the energy sector

Indicator	*Measure*	*Scope*	*Type of metric*
Global fuel combustion-related CO_2 emissions	CO_2	Emissions	Output
Energy sector carbon intensity [tCO_2/(Total Final Energy Consumption)]	CO2/energy	Supply	Driver
Electricity share of total final energy consumption	%	Supply	Driver
Primary energy intensity (TPES/GDP)	Energy/$	Demand	Driver
Energy efficiency improvement rate	%	Demand	Driver
Investment share of low carbon in overall energy investment	%	Investment	Driver

Tracking historical progress and the latest trends of these key indicators in comparison to IEA's Sustainable Development Scenario (SDS) shows the magnitude of change required. The SDS charts a pathway for the global energy sector to 2030 (and beyond) that would keep the world on track to meet the long-term mitigation goals set out in the Paris Agreement, while also achieving universal access to modern energy and substantially reducing air pollution. While this submission focuses on the change needed until 2030, in line with most countries' NDCs, it is vital to ensure that the next round of NDCs are consistent with the longer-term, deeper transformation of the energy system, hopefully reflected in forthcoming long-term low greenhouse gas emission development strategies

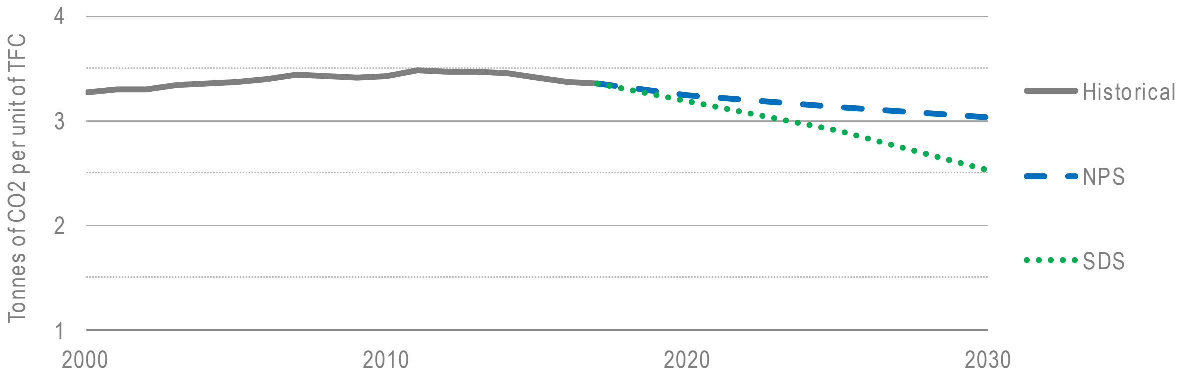
Figure 1. Total global CO_2 emissions from fuel combustion in the NPS and SDS (left) and sectoral CO_2 emissions from fuel combustionin the NPS and SDS



Source: IEA (2018). *Tracking Clean Energy Progress 2018*. IEA (2017). *World Energy Outlook 2017*.

Preliminary IEA estimates indicate a continued rise in global energy-related CO_2 emissions in 2018, following a 1.4% increase in 2017 after three years of remaining flat. Global emissions are a metric that reflects the impact of underlying drivers: the 2017 increase was the result of robust global economic growth of 3.7% and weaker energy efficiency efforts. The recent rise indicates that the emissions stall from 2014-2016 does not yet reflect a permanent peaking of emissions. Recent emissions growth stand in stark and troubling contrast to what is needed to meet Paris Agreement goals: the IEA's SDS sees energy related CO_2 emissions peak around 2020 and decline steeply after that, ending up 23% below current levels by 2030 (reaching 25.1 Gt). Cumulative emissions to 2030 are 55 Gt lower than in the NPS. This headline figure for greenhouse gas emissions is the product of a complex set of underlying changes in energy supply and demand. A wider set of energy sector indicators reflecting underlying change are therefore critical to understand where we are

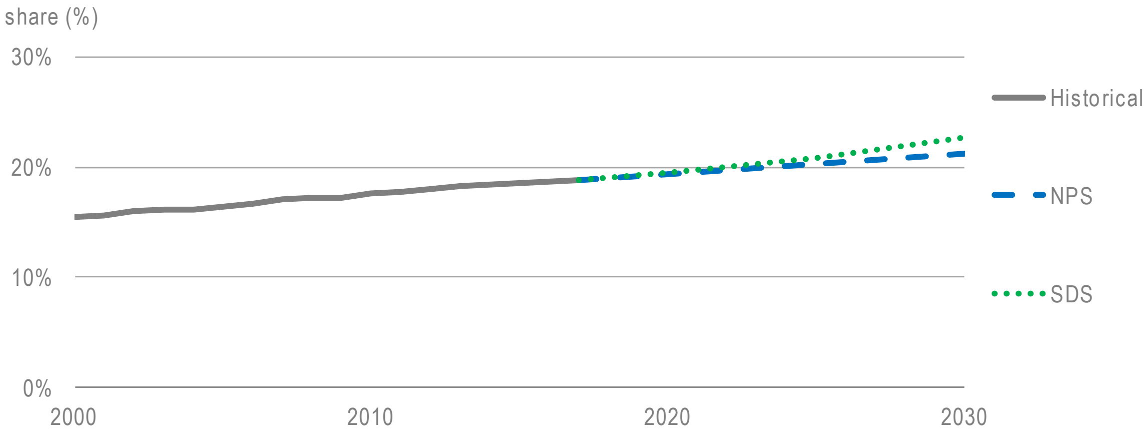
Figure 2. Energy Sector Carbon Intensity (ESCI)



Source: IEA (2018). *Tracking Clean Energy Progress 2018*.

The world's energy supply in 2017 was almost exactly as carbon intensive as in 2000. The Energy Sector Carbon Intensity (ESCI) indicator (CO_2 emissions per unit of total final energy consumption) shows the net impact of policy changes, shifts in investment and technology developments on emissions intensity in the energy sector and gives a measure of how "clean" the global energy supply is. While significant progress has been made in deploying renewables, in particular solar PV and wind, the deployment of low-carbon energy has not kept up with energy demand. The ESCI fell 3.6% since 2013, tentatively indicating that the global energy supply got a little cleaner, though the 2017 and 2018 emissions increase may pose a challenge in terms of maintaining this trend. This remains a crucial challenge: in the SDS, ESCI declines 25% by 2030 from current levels. This is achieved both through a redirection of investments in new supply to low-carbon, and accelerated phase-out or retrofit of existing high-carbon infrastructure.

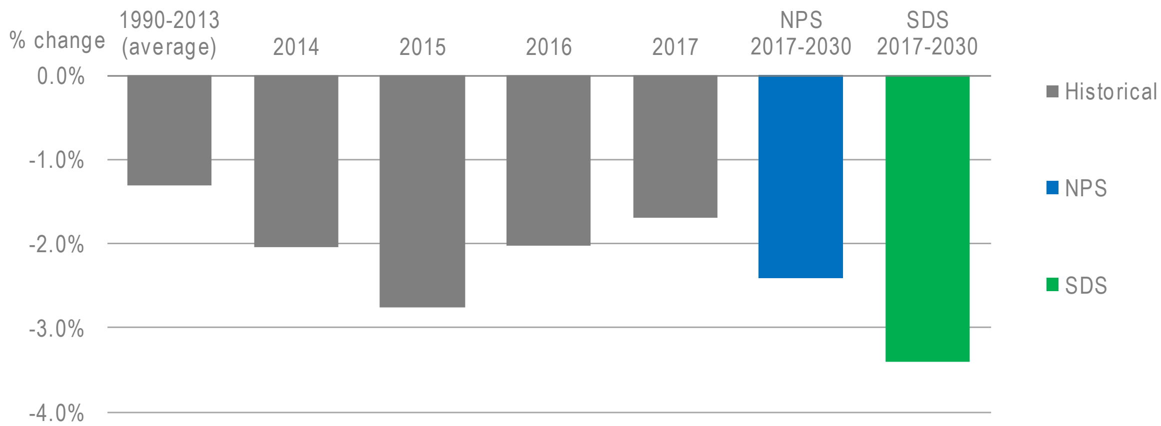
Figure 3. Share of electricity in total final energy consumption



Source: IEA (2018). *Tracking Clean Energy Progress 2018*.

The electrification of end-use sectors is an important pathway for decarbonizing the energy sector, when combined with increasing the share of low-carbon power generation. Increasing shares of electricity are being realised in transport (uptake in electric vehicles (EVs) and freight) and buildings (cooking, heating and appliances), but in industry more challenges remain. In addition to power sector decarbonisation, the share of electricity in total final energy consumption is therefore a useful indicator of progress. The share of electricity reached almost 19% in 2017, rising by 1.1% on average since 2010. It is estimated that electrification is on an upward path even with current policies (according to the NPS), but it needs to accelerate to achieve the SDS target, electrification needs to reach 23% in 2030.

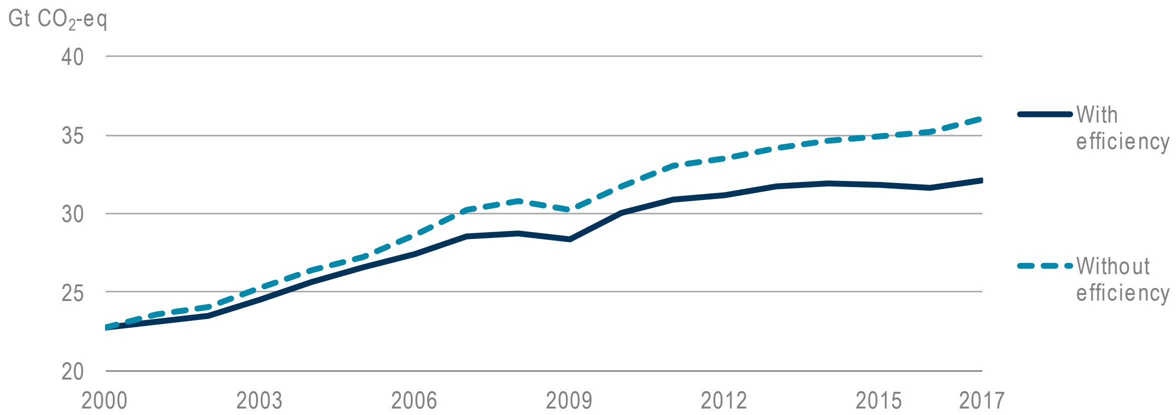
Figure 4. Average annual change in global energy intensity



Source: IEA (2018). *Tracking Clean Energy Progress 2018.*

Global energy intensity gains slowed down in 2017 for the second year in row, improving by only 1.7%. Energy intensity (primary energy demand per unit of gross domestic product, GDP) is affected by changes in both energy efficiency and structural changes in economies. The recent slowdown in improvement has been broadly caused by increased economic activity, changing consumer behaviour and a decrease in efficiency policy coverage and stringency. Energy intensity improvement had been the main driver behind the flattening of global energy-related CO_2 emissions from 2014-2016, but is now not improving quickly enough. In the SDS the total primary energy demand barely grows over today's level, as the average rate of energy intensity improvement almost doubles to 3.4% annually to 2030.

Figure 5. Energy efficiency improvement rate

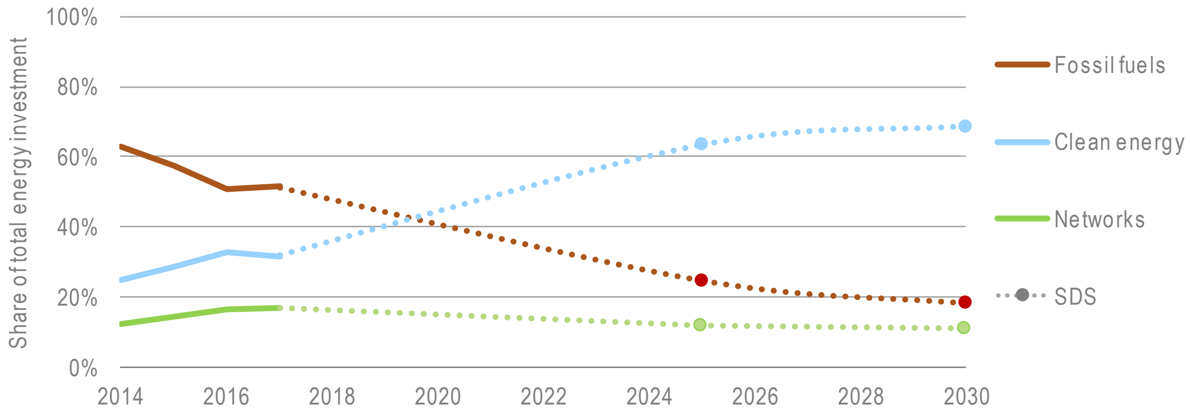


Source: IEA (2018). *Energy Efficiency 2018*.

Global energy efficiency improved by 13% between 2000 and 2017, and has been the main driver for the decoupling of economic growth and energy consumption. Without efficiency improvements since 2000, both energy use and CO_2 emissions in 2017 would have been around 12% higher. Government policy has been key to achieving these energy efficiency gains, but a recent weakening of energy efficiency policy – on both coverage and stringency

- contributed to the slower rate of global energy intensity improvement that was observed in 2017. Considerable room for policy action remains, with around 66% of global final energy consumption still not covered by mandatory efficiency codes and standards.

Figure 6. Low-carbon investment in the energy sector



Source: IEA [World Energy Investment 2018](); [World Energy Outlook 2017]()

To be able to assess the real progress on the ground, energy sector investment and the **share of clean energy investment** therein are critical to track. Total energy investment in 2017 declined for the third year in a row by 2% in real terms, partly driven by falling costs in renewables and fewer additions of coal, hydro and nuclear power capacity. Investment in solar PV rose to a record level despite falling unit costs, while the growth in energy efficiency investment slowed substantially, from 9% in 2016 to 3% in 2017. In 2017 the share of overall clean energy investment, covering both low carbon power and efficiency, declined to 32%, breaking the upward trend since 2014. In the SDS total energy investment increases by 40% from today's level, with a marked shift towards low-carbon sources: the share of clean energy investment in the energy sector more than doubles to 69% in 2030, with the share of fossil fuel investment in the energy sector falling to 18% from 60% today. While the absolute level of electricity network investment in the SDS increases, its share in total investment declines from the current rate of 17% in 2017 to 11% in 2030 due to the substantive increase in energy efficiency investment.

Where we need to go: meeting multiple energy challenges

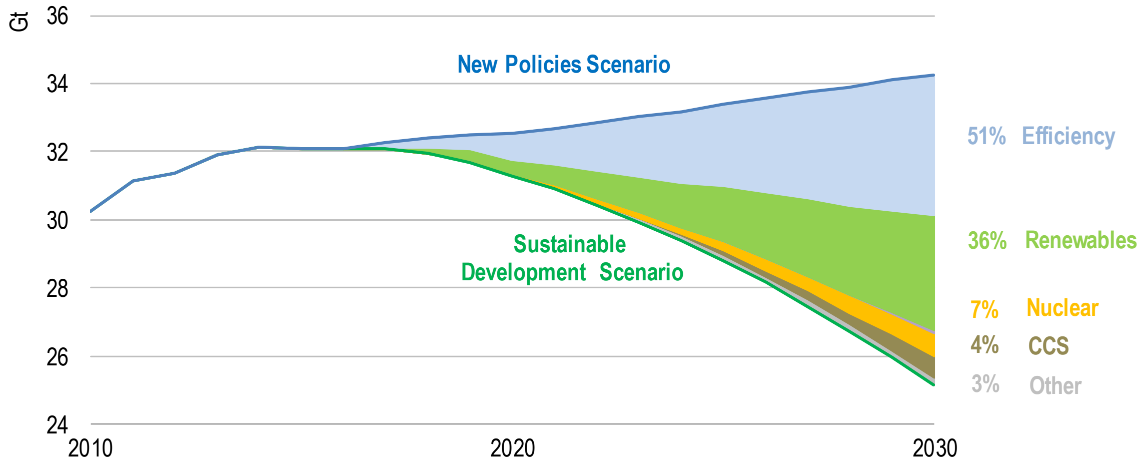
IEA's Sustainable Development Scenario (SDS) describes a pathway for the global energy sector (through to 2040) that keeps the world on track to meet the long-term mitigation goals of the Paris Agreement, while also achieving universal access to modern energy and substantially reducing air pollution (see Box). The SDS was designed to be "well-below 2 °C" scenario that is fully in line with the Paris Agreement. With the updates in understanding of "carbon budgets" as set out in the IPCC Special Report on global warming of 1.5 °C, the SDS embodies an energy transition that also keeps the door open to holding warming to below 1.5 °C[1]. Several aspects of the energy transition in the SDS similarly fall well within the range of those scenarios (for example for oil demand, and solar and wind electricity generation).

The SDS offers an integrated approach to addressing key challenges, recognizing that action against climate change must go hand-in-hand with strategies to achieve other Sustainable Development Goals, including to tackle poverty, build economic growth, promote energy security and address a range of other social and environmental

[1] Cumulative emissions to 2040 in the SDS, the final year modelled in detail in this scenario, are at the upper-end, but well within the range, of emissions from scenarios that have a median temperature rise in 2100 of less than 1.5 °C (as included in the IPCC Special Report on global warming of 1.5 °C).

protection needs. Compared to scenarios addressing only the climate mitigation objective, the SDS places a stronger emphasis on decentralised, modular low-carbon technologies (such as solar PV and wind) as a means to achieve climate, energy access, and air quality objectives. For example, there is roughly 50% more solar PV in this scenario than in previous IEA scenarios focused primarily on decarbonisation.

Figure 7. Global CO_2 emissions reductions in the New Policies and Sustainable Development Scenarios, 2010-2030



Source: IEA (2017). *World Energy Outlook 2017*.

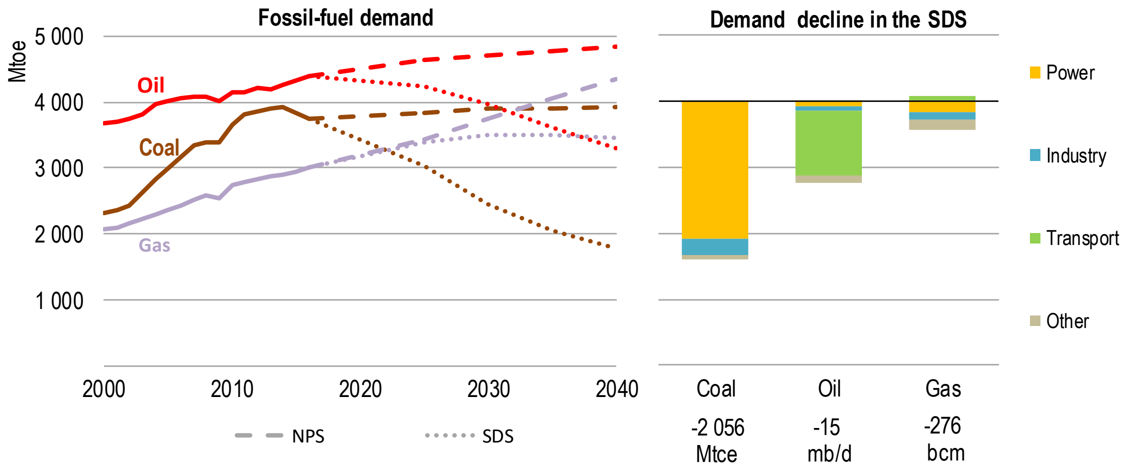
In the SDS, coal demand peaks in the very short term – by around 2020 – and is cut by one-third (to just above 3 500 million tonnes of coal equivalent) in 2030 compared with the NPS (Figure 7). While coal demand growth has been slowing, the challenge remains stark. Coal demand grew by 1% in 2017, reversing the declining trend seen over the previous two years, and the IEA forecasts stable demand for the next five years, absent a change in policy and market conditions.

87% of the coal decline in the SDS occurs in the power sector, where the share of coal is more than halved, falling to 15% in 2030 from 37% today. Phasing out unabated coal-fired power generation (i.e. without carbon capture utilisation and storage, CCUS) is a key feature of the power sector transition in the SDS; by 2030, 55 gigawatts (GW) of coal-fired generation is equipped with CCUS, albeit confined to a small number of countries (notably China and the United States).

Serving as a lower-carbon transition fuel, gas plays an important role in the SDS, growing relative to today's level as it displaces coal in both power generation, industry and domestic heating. In the power sector, gas serves as a flexible power source to support the integration of variable renewables, with the overall level of gas use in the power sector peaking just before 2030 and then beginning to decline. Gas-fired power plants start to be fitted with CCUS starting in 2025.

In the SDS, oil demand peaks soon after coal and declines to 87 million barrels per day in 2030. The majority of oil demand decline comes in the transport sector, with electric vehicles making up over 40% of new passenger car sales by 2030. The petrochemicals sector, however, is the main source of oil demand in the SDS given ongoing demand for plastics and other products.

Figure 8. Fossil fuel demand by scenario (left) and decline by sector (right) in the Sustainable Development Scenario relative to New Policies Scenario, 2030



Source: IEA (2017). *World Energy Outlook 2017*.

Sustainable Development Goals and clean energy transitions

The entry into force of the Sustainable Development Goals (SDGs) in 2016 marked a new level of political recognition of the importance of energy to development. The IEA is the lead custodian agency for tracking global progress in substantially increasing the share of renewable energy in the global energy mix and doubling on efforts in energy efficiency (SDG 7.2 & 7.3), and also co-leads the Global Tracking Framework report with the World Bank, providing a benchmark to track progress towards achieving SDG 7. IEA is also the custodian for tracking the rationalization of inefficient fossil fuel subsidies (SDG 12.c), another important level for achieving the energy transition laid out in the SDS.

The SDS was developed by the IEA to recognise the importance of the SDGs for energy transitions. The SDS combines effective action to combat climate change (SDG 13), universal access to modern energy by 2030 is achieved (SDG target 7.1), meaning 1.3 billion people gain electricity access (double as many as in the NPS) and 2.9 billion people gain access to clean cooking (two billion more than in the NPS). Other SDG 7 targets are also over-achieved in this scenario: SDG 7.2 (increasing substantially the share of renewable energy by 2030) and SDG 7.3 (doubling the global rate of energy efficiency improvement by 2030). With regards to air quality (part of SDG 3), the number of premature deaths from the impacts of outdoor air pollution is reduced by 500 000 in 2030 in the NPS, due in part to the reduction in $PM_{2.5}$ emissions which are about 60% lower.

Source: www.iea.org/sdg

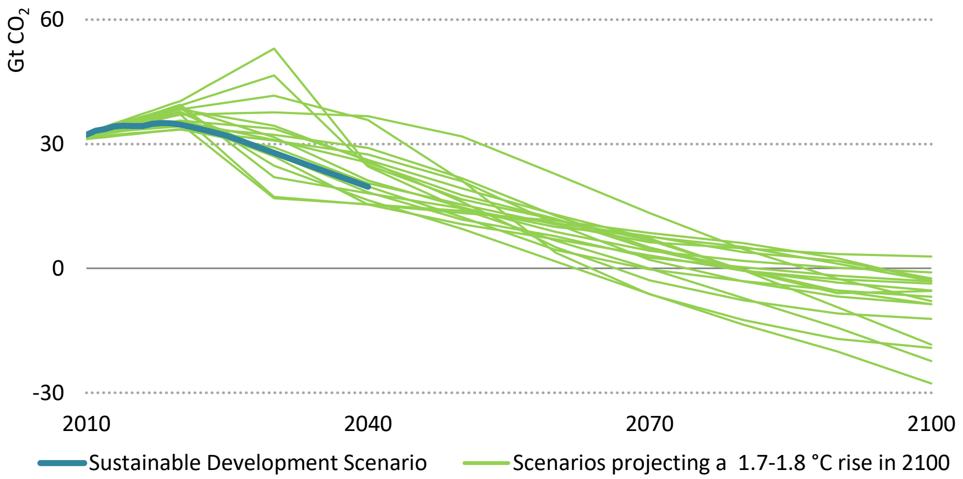
The Sustainable Development Scenario and the goals of the Paris Agreement

The SDS is fully in line with the central goal of the Paris Agreement, to keep global average temperature rise to "well below 2 °C above pre-industrial levels" and to "pursue efforts to limit the temperature increase to 1.5 °C". To achieve the temperature goal, the Paris Agreement calls for emissions to peak as soon as possible and reduce rapidly thereafter, leading to a balance between anthropogenic emissions by sources and removals by sinks (i.e. net-zero emissions) in the second half of this century. These conditions are met in the SDS: global CO_2 emissions peak around 2020 and then decline steeply to 2040, on course towards net-zero emissions in the latter half of the century.

From now until 2040 (the period covered by the model), the emissions trajectory of the SDS is at the lower end of other decarbonisation scenarios projecting a median temperature rise in 2100 of around 1.7 °C to 1.8 °C. It is also within the envelope of scenarios projecting a temperature rise below 1.5 °C.

The ultimate long-term temperature outcome will depend on the trajectory of emissions after 2040 – including when global CO_2 emissions reach net zero – as well as levels of emissions of other types of greenhouse gases. A continuation of the SDS pre-2040 emissions reduction rate would lead to global energy-sector CO_2 emissions falling to net-zero around 2070, still at the lower end of the other scenarios projecting a temperature rise of 1.7-1.8 °C. Maintaining this rate of reduction of energy- and process-related emissions after 2040 will require continued technological innovation, including for carbon capture, utilisation and storage (CCUS) and so-called negative emissions technologies that allow for CO_2 to be withdrawn from the atmosphere at scale. This underscores the importance of innovation in the SDS in the decades before 2040. Further, the science around emissions trajectories and their climate implications is still evolving, and IEA scenarios will continue to be updated in light of the latest science.

2040 emissions in IEA's Sustainable Development Scenario (SDS) are at the lower end of other "well-below 2 C" pathways



Note: Figure shows energy-related CO2 emissions, including industrial processes. Scenarios projecting a median temperature rise in 2100 of around 1.7-1.8 °C are those following Representative Concentration Pathway (RCP) 2.6 in the Shared Socioeconomic Pathways database. See https://tntcat.iiasa.ac.at/SspDb/.

The Paris Agreement is also clear that climate change mitigation objectives should be fulfilled in the context of sustainable development and efforts to eradicate poverty. The Sustainable Development Scenario explicitly supports these broader development efforts (in contrast to most other decarbonisation scenarios), in particular through its energy access and cleaner air dimensions. Good policy design can mean there is no trade-off between achieving climate objectives and delivering on energy access and air pollution goals. Achieving universal access to modern energy only leads to a small increase in CO_2 emissions (0.1%), the climate effect of which is more than offset by lower methane emissions due to a reduction in use of traditional biomass cookstoves. Further, the transition to a low-carbon economy leads to a more efficient energy system that relies less on fuel combustion; this plays a major role in improving air quality, reducing both outdoor and household air pollution.

Source: www.iea.org/weo/sds

Tracking progress: are individual sectors and technologies meeting clean energy transitions objectives?

The IEA's Tracking Clean Energy Progress provides a comprehensive and rigorous assessment of a full range of energy technologies within the sectors critical to a global clean-energy transition. It includes the most up-to-date information for where technologies are today and where they need to be according to the IEA's SDS. The IEA has developed a set of sub-sectoral level (electricity, transport, buildings, and industry in Table 2) indicators that reflect the most important short-term actions that policymakers can focus on to drive long-term clean energy transitions. These indicators create an accessible and comprehensive tracking framework for clean energy transitions.

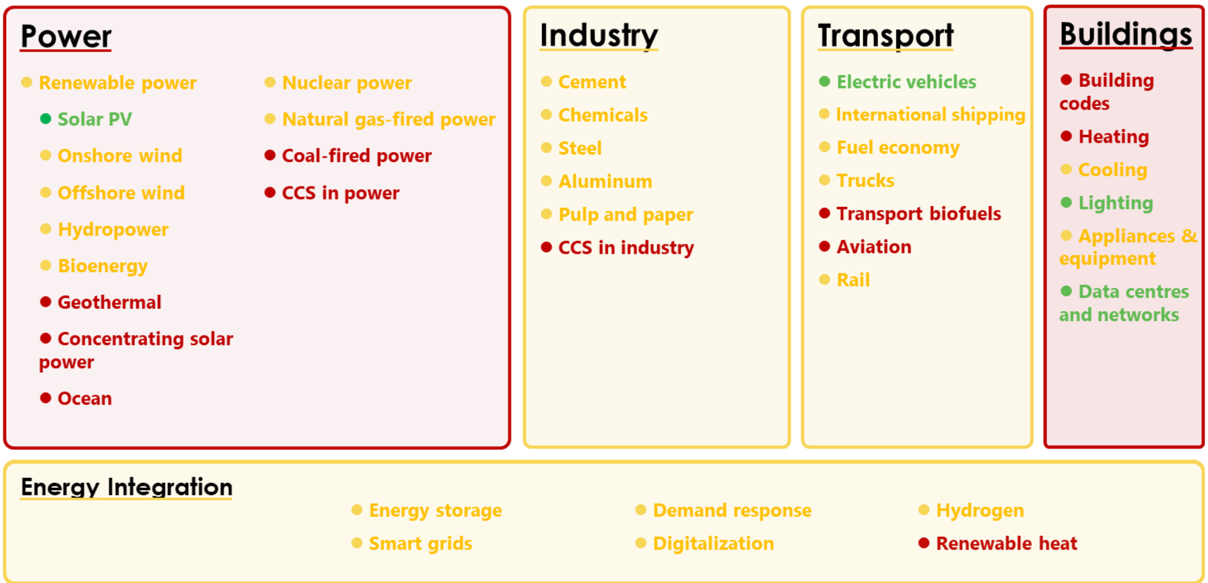
Table 2. Indicators of energy transition outcomes and drivers for understanding current progress and driving future action

Sector	*Indicator*	*Measure*	*Scope*	*Type of metric*
Transport	**Transport CO_2 emissions**	CO_2	Emissions	Output
	Total transport-related final energy consumption per GDP	Energy/USD	Demand	Driver
	Energy efficiency policy coverage in transport (% of new vehicle sales covered by regulations)	%	Demand	Driver
	Share of EVs in new vehicles sales	%	Demand	Driver
	Share of biofuels use in transport (of total liquid fuels)	%	Demand	Driver
Industry	**Industry CO_2 emissions**	CO_2	Emissions	Output
	Industrial productivity: industrial value added/final industrial energy use	USD/energy	Demand	Driver
	Mandatory policy coverage of industrial energy use	%	Demand	Driver
	CO_2 intensity of industrial energy use	CO_2/energy	Supply	Driver
Buildings	**Buildings CO_2 emissions**	CO_2	Emissions	Output
	Buildings sector energy performance (intensity) (total final energy used per m^2 in the buildings sector)	Energy/m^2	Demand	Driver
	Mandatory Energy efficiency policy coverage of buildings energy use	%	Demand	Driver
Power	**Power CO_2 emissions**	CO_2	Emissions	Output
	Share of low-carbon power generation in overall power generation	%	Supply	Driver
	Average CO_2 intensity of electricity generation (gCO_2/kWh)	CO_2/energy	Supply	Driver
	CO_2 intensity of power generation from new investments (gCO_2/kWh)	CO_2/energy	Investment	Driver
	Share of new low-carbon power generation investment in overall new power generation investment	%	Investment	Driver

Are clean energy technologies on track?

Some technologies have made tremendous progress in 2017 – particularly solar PV, LEDs for lighting and EVs in transport – but most are not on track with the energy transformation depicted in the SDS. Energy efficiency improvements have slowed and progress on key technologies like carbon capture and storage remains stalled.

Figure 9. Tracking Clean Energy Technology Progress 2010: only 4 out of 38 technologies are on track



Note: For each technology, TCEP examines recent sectoral trends, the latest developments and current policy ambition to determine progress against meeting low-carbon technology development pathways. The ultimate evaluation of whether a technology or sector is on track (green), needs further improvement (orange) or is not on track (red), is based on a wide variety of quantitative data and analysis as well as expert judgment.

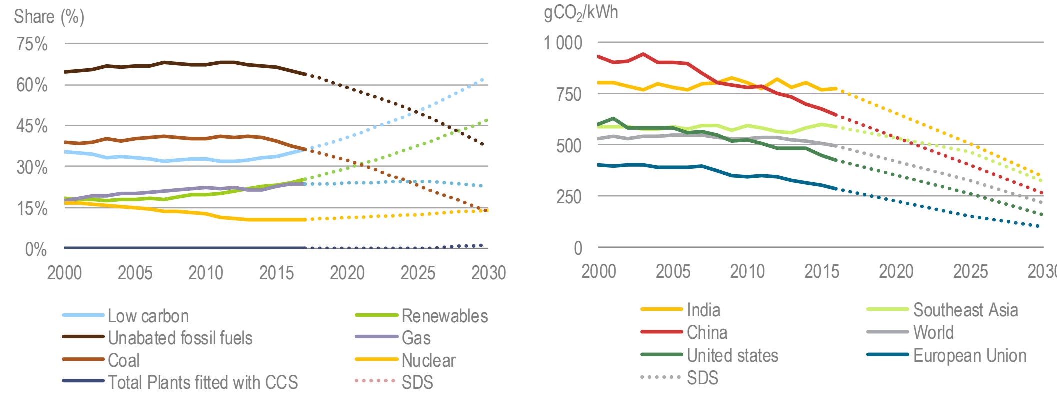
● On track ● More efforts needed ● Not on track

Is the power sector on track?

The share of electricity produced from low-carbon technologies – including renewables, nuclear and carbon capture and storage – is an effective measure of how clean power sector generation is becoming (and is more insightful than measuring only total capacity per technology). Around one third (35%) of generation came from low-carbon sources in 2017, with the share of renewables reaching 25% and nuclear declining to 10% (Figure 10). In the SDS, the share of generation from low-carbon technologies increases to nearly two-thirds (63%) in 2030. Wind and solar PV account for almost 60% of this growth by 2030. Achieving this will require a significant shift in the type of capacity that is added to the power system in the coming decade and beyond. In the SDS, solar PV and wind become the fastest growing technologies, with 1 550 GW and 1 310 GW respective capacity additions from today to 2030.

Following this pathway can result in significant reductions in the sector's carbon intensity, which has been declining since 2010, but stalled in 2017, estimated to remain at 491 gCO2/kWh (global average). To be on track with the SDS scenario, however, global carbon intensity needs to more than halve by 2030 (to reach 220 gCO2/kWh), a decline of 5.6% a year.

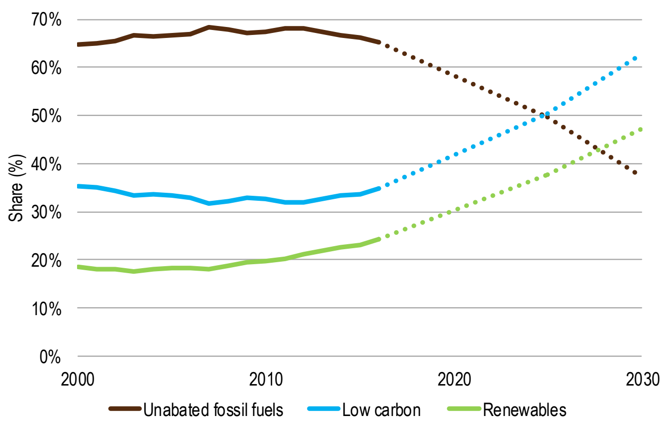
Figure 10. Share of electricity generation from power technologies (left) and Carbon intensity of electricity generation in selected regions (right)



Source: IEA (2018). *Tracking Clean Energy Progress 2018*.

Looking at power technologies in detail, no technology is on track to meet the SDS goals, and two technologies – coal-fired power and carbon capture, utilisation and storage – are well off track. While renewables are making strong progress, particularly solar PV (which is the only renewable technology on track), overall renewables remain off track and much more needs to be done to decarbonise the power sector in line with the SDS goals.

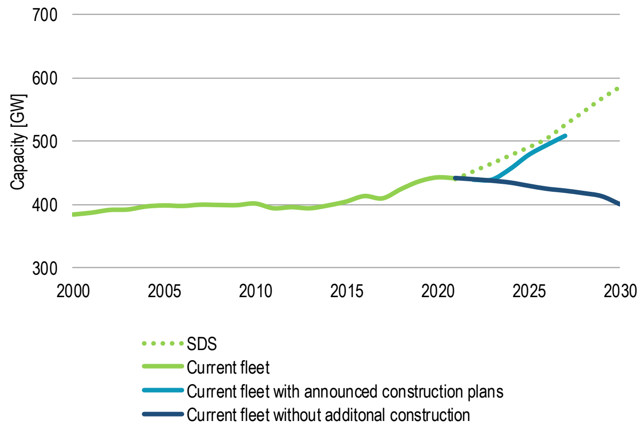
Figure 11. Renewable power — Share of renewables in power generation historically and in the SDS



● More efforts needed

In 2017, renewable electricity generation grew by 6% and reached more than a quarter of global power output, thanks to the rapid growth of wind and solar PV technologies. Renewable power generation as a whole still needs to increase to reach the levels in the SDS. Net annual capacity additions for all technologies need to accelerate to ensure renewable generation increases by 6.5% annually over 2017-30, while the share of renewables in global electricity generation must reach 46% by 2030, from 25% in 2017. Read more about renewables

Figure 12. Nuclear power — Projected vs target capacities

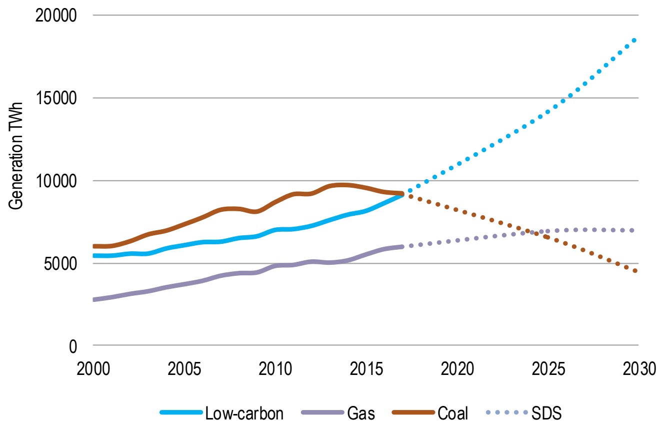


● More efforts needed

In 2017, new nuclear power capacity dropped sharply to only 3.6 GW. Construction starts, a proxy for final investment decisions, remained low. Declining investment, announced phase-out policies and planned retirements, combined with only 56 GW of nuclear capacity under construction in 2017, suggest that meeting the goal of 185 GW of net increase needed by 2030 will be very challenging. Looming construction decisions by China, India and Russia in 2018-2020 will play a major role in whether nuclear power

will meet the SDS targets in 2030 and beyond.
[Read more about nuclear power]

Figure 13. Natural gas-fired power — Evolution of gas power generation historically and in the SDS

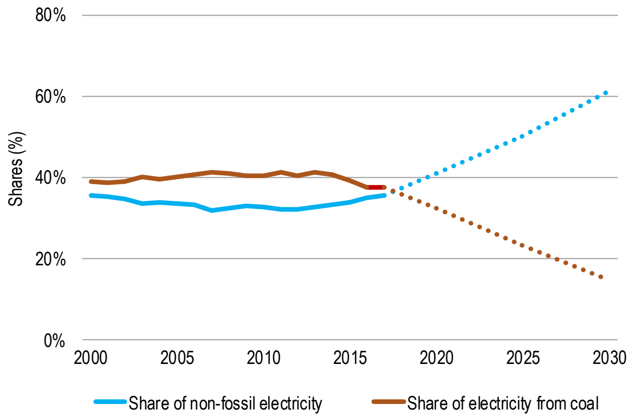


● More efforts needed

Growth in gas-fired power generation slowed down to 1.6% in 2017, as lower generation in the United States offset growth around the world. At this rate of growth, gas-fired power is not on track with the SDS. As a transition fuel and a flexible power source to facilitate the integration of variable low-carbon renewable generation, gas follows a growth trajectory until 2027 in the SDS but then decline steadily after this peak.

[Read more about natural gas-fired power]

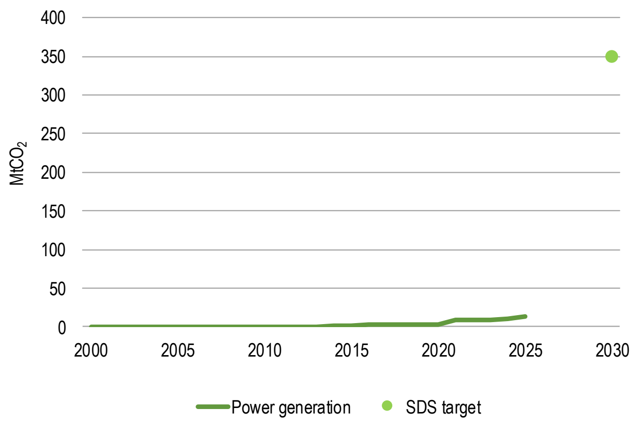
Figure 14. Coal-fired power — Share of coal power generation historically and in the SDS



● Not on track

Unabated coal generation (that is, from plants without CCUS) increased by 3% in 2017, remaining the largest source of power generation with a share of around 37%. This more than offset the 2016 decline, due mainly to strong growth in Asia and particularly China and India. That said, investments in coal power dropped by one-third in 2017, and final investment decisions for new plants continue to decline. Unabated coal generation needs to decrease by 5.6% per year until 2030 to meet the SDS target.
[Read more about coal-fired power]

Figure 15. Carbon capture, utilisation and storage (CCUS) in power historically and in the SDS



● Not on track

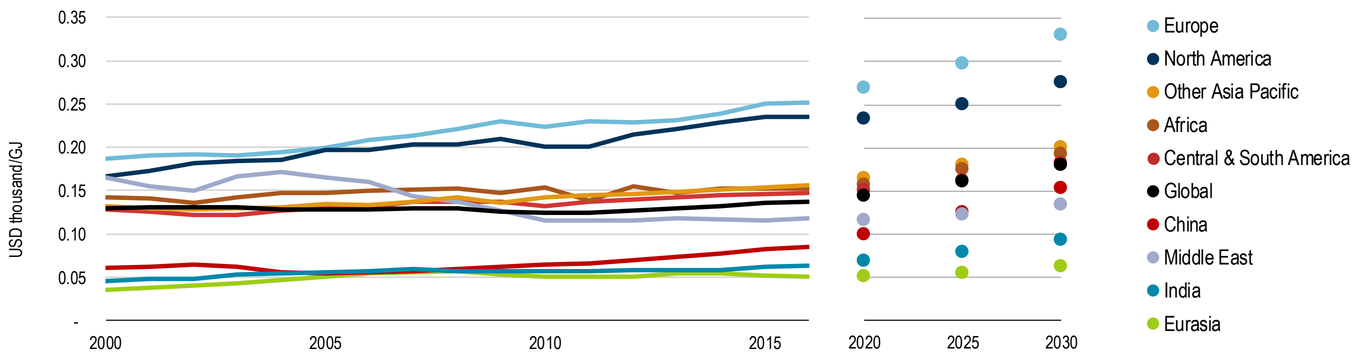
With only two large-scale carbon capture, utilisation and storage (CCUS) power projects in operation at the end of 2017, with a combined capture capacity of 2.4 Mt CO_2 per year, CCUS in power remains well off track from the level seen in the SDS {350 Mt CO_2 per year by 2030}.

[Read more about CCUS in power]

Is the industry sector on track?

Decoupling of industrial activity from CO_2 emissions is critical to meet SDS targets, which envisions a peak in emissions prior to 2025 despite expected industrial production growth. The global average direct CO_2 emissions intensity of industrial energy use would need to fall annually by 0.8% from 2016 to 2030, requiring in particular a shift away from coal towards natural gas, bioenergy and electricity. Improving energy efficiency and shifting towards best available technologies contribute to reducing emissions and improving industrial productivity. In the SDS, annual global industrial productivity (value-added per unit of energy used), increases 2.0% from 2016 to 2030, an accelerated rate compared to the 1.6% growth observed in recent years[2] (Figure 16).

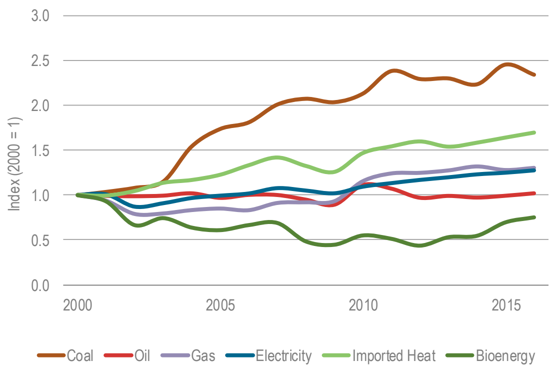
Figure 16. Industrial productivity (industrial value-added per unit of energy used) by region, SDS



Source: IEA (2018). *Tracking Clean Energy Progress 2018*.

Continued improvement across all industrial sub-sectors and technologies is needed to achieve objectives for the sector.

Figure 17. Chemicals and petrochemicals — Global final process energy demand in chemicals and petrochemicals



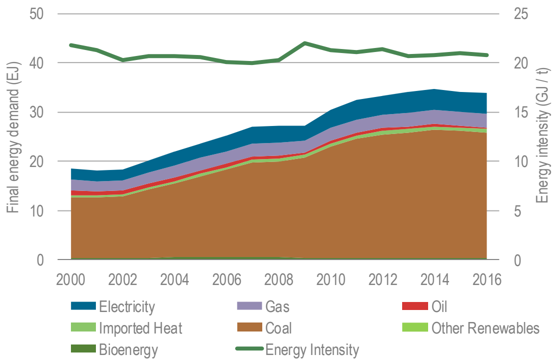
More efforts needed

The sector's process energy consumption grew at an annual rate of 2% and its direct energy-related CO_2 emissions grew 2.5% between 2000 and 2016. The increase in CO_2 intensity of process energy has been mainly driven by shifts towards heavier feedstocks in some regions.

Read more about chemicals and petrochemicals

Figure 18. Iron and Steel — Energy demand and intensity in the iron and steel sector

[2] From 2010 to 2016

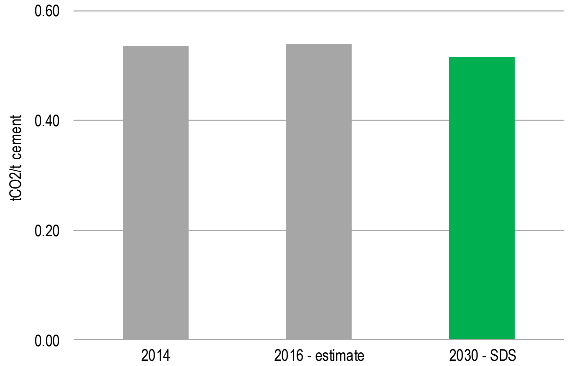


● More efforts needed

In 2016, the energy intensity of crude steel fell by 1%, compared to an average 0.4% annual decline from 2010 to 2016. Between 2016 and 2030, the energy intensity of crude steel needs to decline by 1.2% annually to be in line with the SDS. This per-tonne decrease is especially important as global steel production continued to grow by 0.5% in 2016 and initial estimates indicate stronger growth in 2017.

Read more about iron and steel

Figure 19. Cement — Direct CO_2 intensity of cement

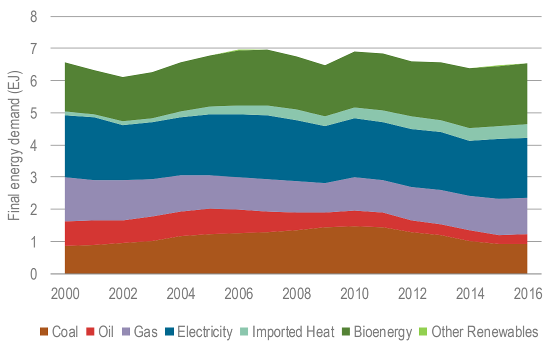


● More efforts needed

From 2014 to 2016, the direct CO_2 intensity of cement showed little change, as thermal energy efficiency improvements were offset by a slight increase in the global clinker-to-cement ratio. To meet the IEA SDS objectives, the direct CO_2 intensity of cement needs to decline by 0.3% annually through to 2030, even as cement production is expected to grow.

Read more about cement

Figure 20. Pulp and paper — Global final energy demand

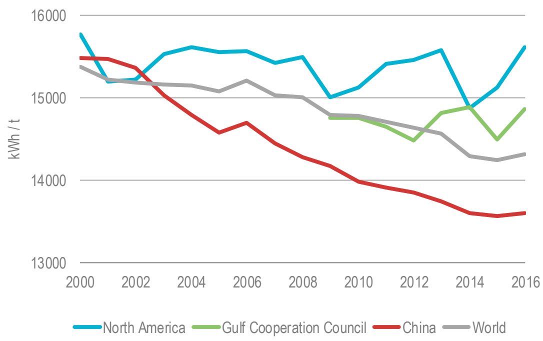


● More efforts needed

Final energy use in pulp and paper making fell by 0.05% a year globally between 2000 and 2016 while paper and paperboard output increased at an annual rate of 1.4%. To meet SDS objectives, energy use in the sector needs to decline by 0.3% annually by 2030 globally for an expected increase in paper and paperboard production of 1.0% annually.

Read more about pulp and paper

Figure 21. Aluminium — Electricity intensity of primary production

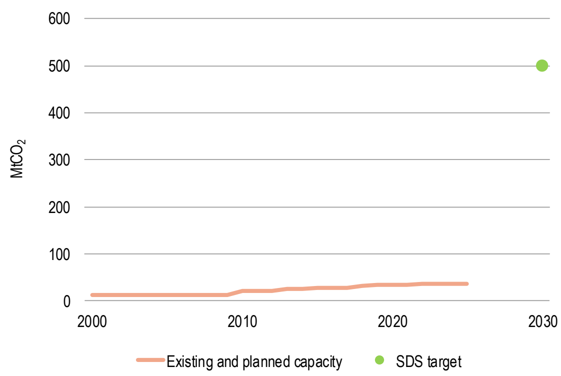


● More efforts needed

The energy intensity of aluminium production declined by 1.7% in 2016, compared to a 1.9% annual reduction from 2010 to 2016. As almost half of global production, based in China, already reached best-performing levels for primary production in 2014, a more moderated annual decline of 1.2% is needed to meet the SDS objectives by 2030. However, the global proportion of aluminium production from recycled scrap needs to increase considerably to 46%.

Read more about aluminium

Figure 22. CCUS in industry — planned and SDS target



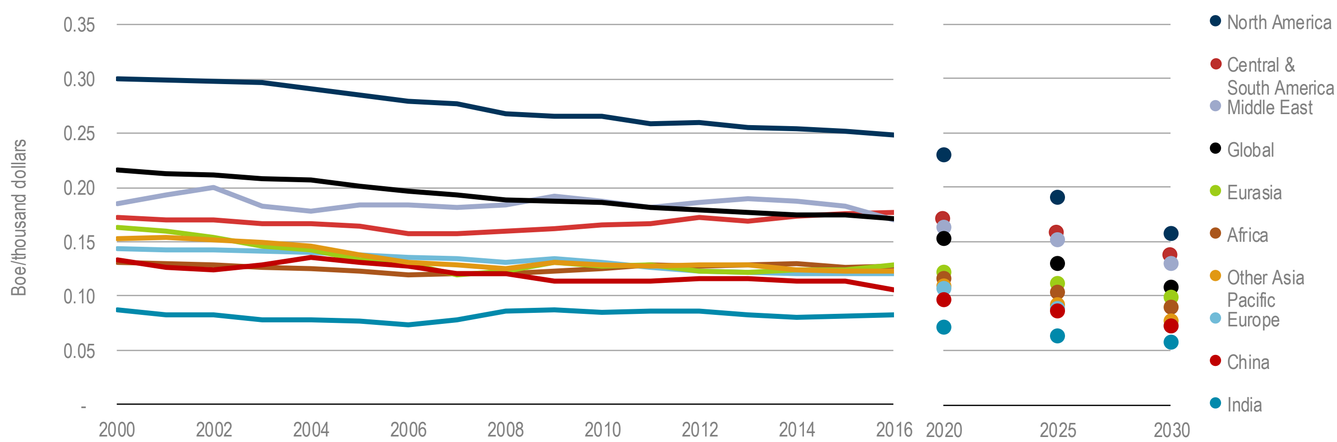
● Not on track

In 2017, one additional industrial project linked to bioenergy came into operation (in the U.S.), bringing the total number of global CCUS projects in industry and fuel transformation to 15. Only one large industrial CCUS project has received a final investment decision since 2014, an additional signal that industrial CCUS remains far off-track from the SDS target. CCUS is one of the few existing technology options that can significantly reduce more stubborn CO_2 emissions from industry.
[Read more about CCUS in industry]

Is the transport sector on track?

The transport sector has entered a critical transition period: over the next decade existing measures to increase efficiency and reduce energy demand must be deepened and extended in order to reach the SDS goals. Any delay would require stricter measures beyond 2030, which could noticeably increase the cost of reaching climate targets. As a cross-cutting indicator of required change, the reduction in annual average global transport energy intensity (measured as energy use per GDP) must more than double from an average decline of 1.5% between 2000 and 2017 to 3.4% by 2030 (Figure 23).

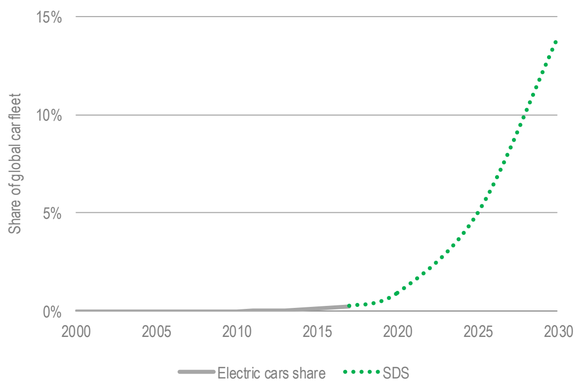
Figure 23. Energy intensity of the transport sector across regions (energy use per GDP)



Source: IEA (2018). *Tracking Clean Energy Progress 2018*.

The coverage of energy efficiency policies in transport is an important indicator to assess efficiency advances. The most promising developments are in light-duty vehicles (LDVs), which still account for about 47% of the sector's energy use and 46% of its emissions, despite some indications of decoupling with economic growth in high-income countries. In addition to the improvement in efficiency, it is important to track indicators of technological change across all transport technologies. Greater electrification of transport modes, accompanied by power sector decarbonisation, play a crucial role for achieving the SDS goals. Electric light-duty vehicles (EVs) stock on the road keeps growing, as EVs continue to be the only transport technology on track to reach the IEA's 2030 SDS targets.

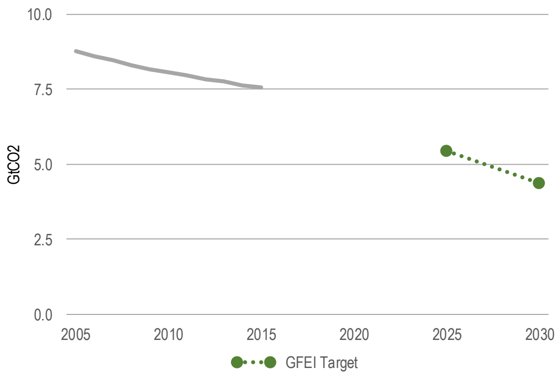
Figure 24. Electric vehicles — Electric car share in the SDS



● On track

2017 witnessed record global sales of electric cars (1.1 million), leading to a global stock of over 3 million. Global sales increased 54% in 2017, helping EV sales remain on track to reach the levels embodied in the SDS. China accounted for nearly half of electric car sales, with Norway having the highest per capita ownership. Nonetheless, to achieve levels projected in the SDS tremendous additional progress is needed: the EV stock would have to reach more than 240 million by 2030, making up 14% of the global car fleet compared to 0.3% today. Read more about electric vehicles

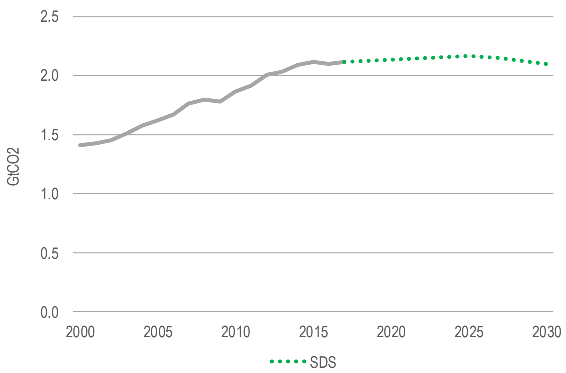
Figure 25. Fuel economy of new cars & vans (light-duty vehicles)



● More efforts needed

Fuel economy standards delivered a 1.5% annual average decline in fuel consumption per kilometre by new cars and vans between 2005 and 2015. To get on track with the SDS by 2030, which aligns with the Global Fuel Economy Initiative (GFEI) target, annual improvements of 3.6% are needed.
Read more about fuel economy

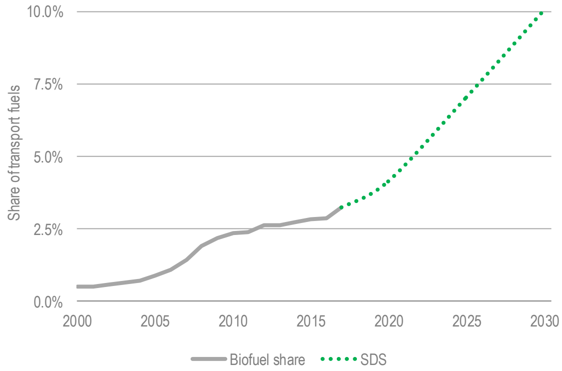
Figure 26. Trucks & buses — Emissions from heavy-duty vehicles



● More efforts needed

Emissions have grown faster for heavy-duty vehicles (HDVs) than for any other transport mode – 2.4% annually since 2000. On a positive note, more countries are implementing new fuel economy and CO_2 emissions standards for HDVs. New policies in India and the European Union, for example, will increase policy coverage from 42% of new sales in 2017 to an estimated 57% in 2018. That said, overall policy coverage for HDVs lags behind light-duty vehicles.
Read more about trucks and buses

Figure 27. Transport biofuels

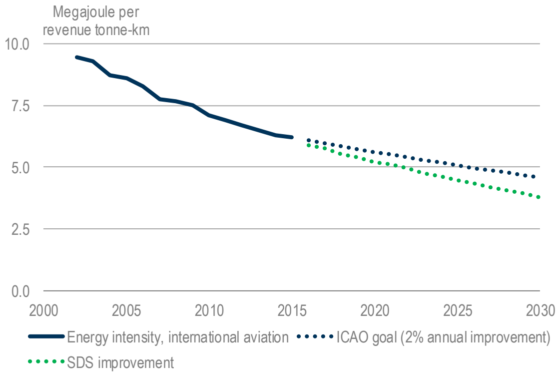


● Not on track

Transport biofuels consumption increased by 7% from 2010 to 2017, reaching 3% share of transport fuel demand. Use of biofuels triples in the SDS by 2030, driven by cost reductions of advanced biofuels, widespread sustainability governance and more adoption in aviation and marine transport. To be on track with the SDS, it needs to increase to 10% of all transport fuel demand by 2030.

Read more about biofuels for transport

Figure 28. Aviation — Energy intensity of international aviation

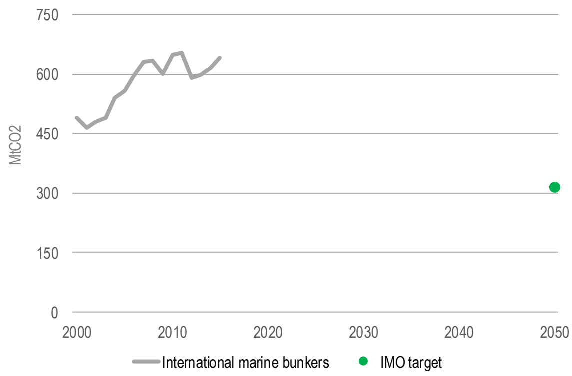


● Not on track

Both global passenger and freight activity have more than doubled since 2000, and demand for air travel is expected to remain strong in the future To put aviation on track with the SDS by 2030, an annual decrease of over 3% in energy intensity is necessary.

Read more about aviation

Figure 29. International shipping — CO_2 emissions from international shipping

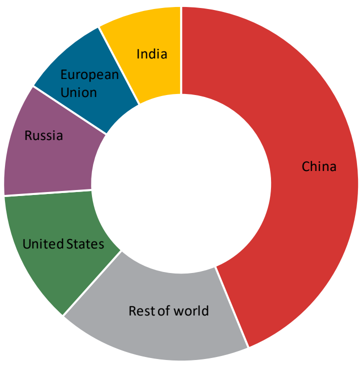


● More efforts needed

This year the International Maritime Organization (IMO) adopted an agreement that aims to reduce GHG emissions by at least 50% by 2050 compared with a 2008 baseline. The agreement also includes carbon intensity reduction targets for 2030 and 2050. As the first global climate framework for shipping, this is an historical milestone to facilitate the transition of international shipping towards clean energy and increased sustainability.

Read more about international shipping

Figure 30. Rail — Share of railway CO_2 emissions in 2015 by selected region



● More efforts needed

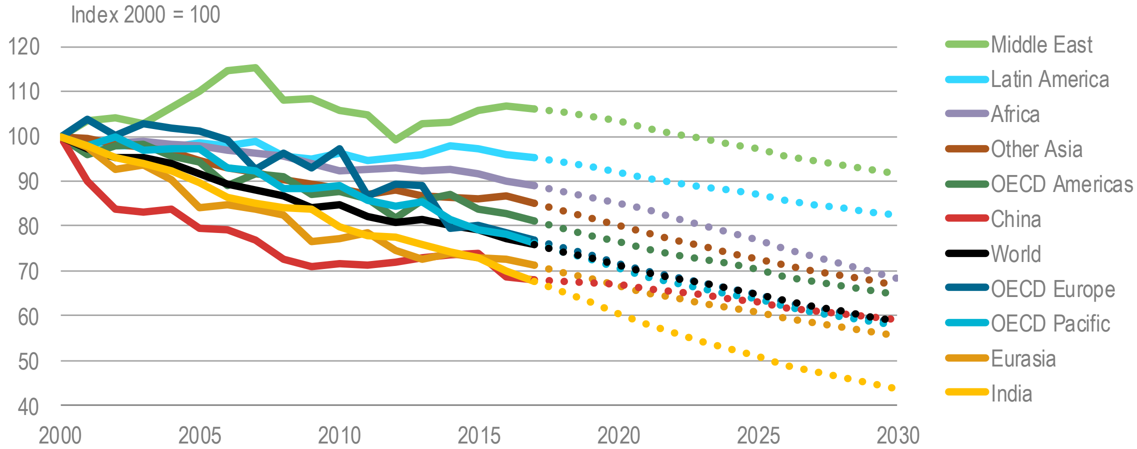
The build-out of urban and suburban rail infrastructure, including metro-, light- and commuter-rail as well as high-speed rail, progressed rapidly in recent years, especially in China, India and other emerging Asian economies. Across both passenger and freight rail, efficiency improvements (per km travelled) of 2% are needed to achieve levels projected in the SDS.

Read more about rail

Is the buildings sector on track?

Improvement in energy intensity in buildings, defined as energy use per m^2, in the SDS needs to accelerate to at least an average annual rate of 1.9% globally to 2030, from a current rate of improvement in intensity of 1.6% (Figure 31). This is needed for intensity to keep pace with expected growth in floor area during that period, noting floor area has grown by as much as 2.8% a year since 2000, offsetting energy intensity improvements. While this acceleration in energy intensity improvement may seem marginal, in some of the critical emerging markets, particularly Africa (dark green line), Latin America (light purple line) and other developing Asia (brown line), the rate of change needs to double or more in coming years. This is equally true for major developed economies, which would need to significantly step up deep energy renovations of existing buildings.

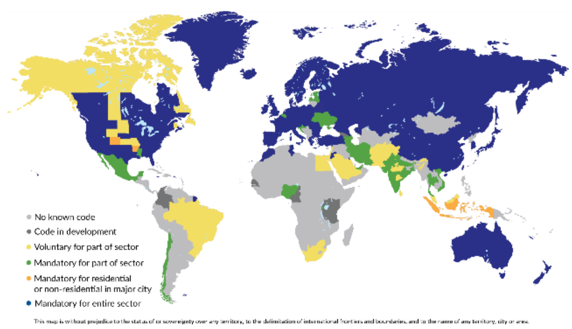
Figure 31. Decline in building sector energy intensity (total final energy used per m2 in the buildings sector), historical and in the Sustainable Development Scenario, 2000–2030



Source: IEA (2018). *Tracking Clean Energy Progress 2018*.

Significant progress is needed across all buildings technologies to meet the SDS goals, particularly building envelopes and heating. Cooling and appliances are both showing improvement, but significant policy effort will be needed to put these technologies on track to SDS goals. Only lighting is on track to meet the SDS goals

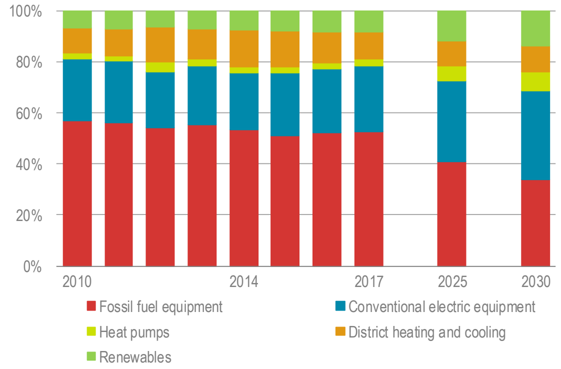
Figure 32. Building Envelopes



● Not on track

Globally, 2/3 of countries lacked mandatory building energy codes in 2017, meaning that more than the current floor area of the US will be built using less efficient technologies over the coming decade. To achieve the SDS outcomes, the area covered by new high-efficiency buildings needs to increase from 75 million m^2 being annually built today to more than 2 billion m^2 by 2030. Deep energy renovation of existing stock also needs to more than double within the coming decade (from a current rate of less than 1%). [Read more about building envelopes]

Figure 33. Heating — Sales of heating technologies

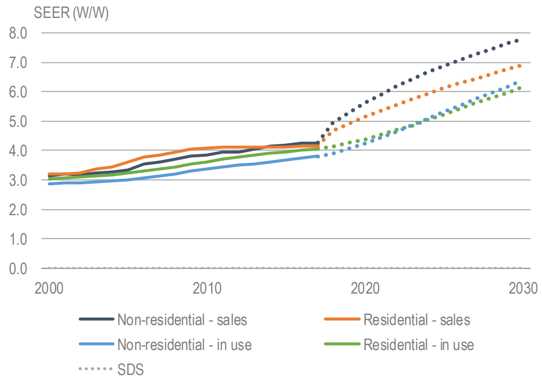


● Not on track

Sales of heat pumps and renewable heating equipment have increased by around 5% per year since 2010, reaching 10% of overall sales in 2017. Fossil-fuel equipment still represents 50% of sales; less-efficient, conventional electric heating equipment represents another 25%. To be in line with the SDS, the share of heat pumps, renewable heating and modern district heating needs to triple to reach more than one-third of new sales by 2030.

Read more about heating

Figure 34. Cooling — Average seasonal energy efficiency ratios of sales and stock to 2030

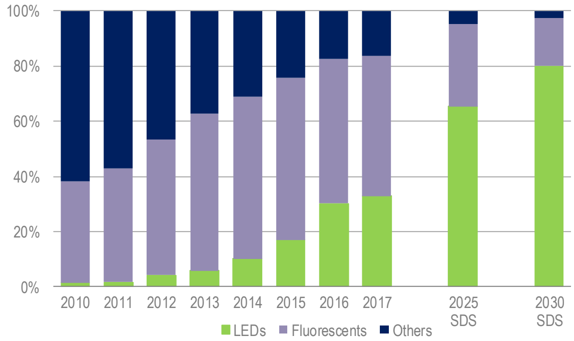


● More efforts needed

Energy demand for cooling is the fastest growing end-use in buildings, with sales rising three times faster than efficiency improvements. To put cooling on track with the SDS, minimum energy performance standards need to push markets to improve AC performance by more than 50% by 2030.

Read more about cooling

Figure 35. Lighting — Residential lighting sales by type

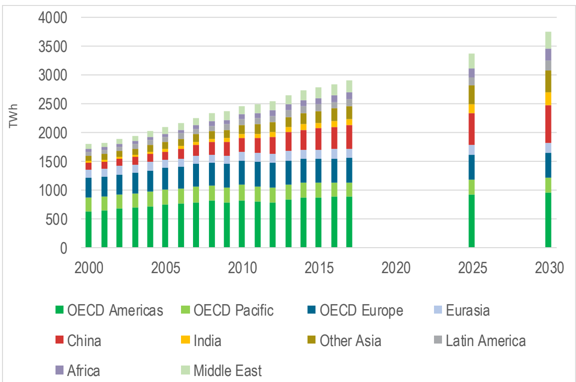


● On track

2016 and 2017 were a critical turning point for energy-efficient lighting, with sales of light-emitting diodes (LEDs) reaching one-third of market sales, thanks to major reductions in costs, improved quality and greater options for lighting applications. Sales of LEDs are on track with the SDS, although this will still require a 250% increase in LEDs' share of sales by 2030.

Read more about lighting

Figure 36. Appliances and equipment — Household appliance energy use by region

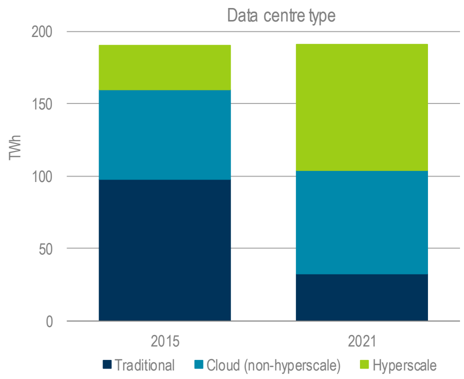


● More efforts needed

Energy use by household appliances continues to grow, reaching 2 900 TWh in 2017, or nearly twice as much as the electricity used in Africa and the Middle East. Only a third of appliance energy use today is covered by standards and labels, and coverage is poor in markets expected to grow rapidly in the next decade. Plugged and connected devices, which are proliferating rapidly, continue to go unregulated in most countries. All countries should consider adopting energy performance standards while increasing stringency of existing policies and extending coverage to a wider array of products.

Read more about appliances and equipment

Figure 37. Data centres and networks — Global data centre electricity use



● On track

Digitalization – notably the strong growth in internet traffic, the proliferation of connected devices, and the increasing data intensity of digital media – is driving an exponential growth in demand for data centre and network services. Data centres and networks together account for about 2% of global electricity demand, with huge strides in energy efficiency helping to keep electricity demand flat. Digital companies running the world's largest data centres have also been leaders in corporate renewables procurement, accounting for more than half of total corporate renewable energy PPAs over the past three years.

Read more about data centres and networks

WHERE ARE WE? and WHERE DO WE WANT TO GO?

KEY OPPORTUNITIES:

To meet Paris Agreement goals, IEA analysis identifies two key areas of opportunity: (1) increasing energy productivity – the amount of economic growth spurred by each unit of energy consumed – through accelerated energy efficiency, and (2) the deployment of renewable energy, in particular decentralised solar PV and wind. Energy efficiency and renewable energy account for 87% of the cumulative CO_2 savings to 2030 in the IEA's Sustainable Development Scenario: two areas that can deliver multiple benefits for climate change, air quality, and energy access.

KEY CHALLENGES:

Over the last three decades, the global energy supply has barely decarbonised; that is, each unit of energy supplied has on average resulted in the same amount of CO_2 emissions. While certain types of low carbon technologies, such as solar PV and wind in electricity, have grown rapidly in recent years, this has been offset by slower growth in other low-carbon technologies such as hydropower, nuclear, carbon capture utilisation and storage, and slow uptake of low carbon energy in transport and heating.

In a Paris Agreement-compatible world, the role of fossil fuels in the energy mix, particularly coal use without CCS, diminishes quickly: a substantial decline from their position in today's energy system. This poses particular challenges for countries and regions that are currently highly dependent on fossil fuels, although technology innovation and energy efficiency can help reduce costs of fossil fuel transition.

For further information:

Tracking Clean Energy Progress (TCEP) 2018

Global Energy and CO_2 Status Report 2018

World Energy Investment 2018

Energy Efficiency 2018

Renewables 2018

World Energy Outlook 2017 (*World Energy Outlook 2018* released November 2018)

Energy Efficiency Indicators 2017 (*Energy Efficiency Indicators 2018* released December 2018

Energy Technology Perspectives 2017

Perspectives for the Energy Transition (2017)

How do we get there?

Key Messages:

Energy transitions consistent with meeting Paris Agreement goals, universal access to modern energy, and significant reduction in air pollution can be realised at a modest global cost. As technology and fuel costs decline, these goals can be achieved with only 13% additional investment in the energy sector by 2030 relative to investments expected under current trends, albeit with a significant shift towards clean energy technologies. Well-integrated policy packages can be used to re-direct investment toward energy efficiency and low carbon energy supply.

As countries reflect on their new or updated NDC targets for 2030, they could consider:

- Strategies to peak energy related emissions and to realise cost effective energy efficiency potential
- Expected technology costs in 2030, not just today's costs
- What changes in energy investment patterns are consistent with the long-term goals of the Paris Agreement
- What forward-looking indicators can be used to track progress of energy sector transition and inform national policymaking
- How to integrate energy policy and technology components
- Where ambition could be enhanced with greater national capacity

The stated goals of the Talanoa Dialogue are to "take stock of the collective efforts of Parties in relation to progress towards the Paris Agreement long-term goal" and to "inform the preparation of nationally determined contributions (NDCs)". To address the latter, the IEA presents key questions that country policymakers could consider to inform the development of the next round of increasingly ambitious NDCs. These questions address the need for countries to have strong understanding of technology options including costs, low carbon policy expertise, and robust data and indicators to drive forward progress. To shed light on each question at the global level, we share some insights from IEA analysis, though we invite countries to address these questions based on their national circumstances.

1. Revisiting the IEA "Bridge Scenario": cost-neutral measures for a near-term CO_2 emissions peak

As countries prepared their (Intended) Nationally Determined Contributions (NDCs) in the run up to the Paris Agreement in 2015, the IEA identified five cost-neutral measures that could lead to a peak in energy-related GHG emissions (IEA, 2015). These measures were incorporated into a "Bridge Scenario", so called because achieving a peak in emissions would keep the door open to accelerate reductions in line with global climate change goals. Three years later, the World Energy Outlook 2018 (www.iea.org/weo) takes stock of progress on these measures and re-evaluate their potential contributions to CO_2 and methane abatement by 2030, as well as the part they could play in further action towards achieving the Sustainable Development Scenario.

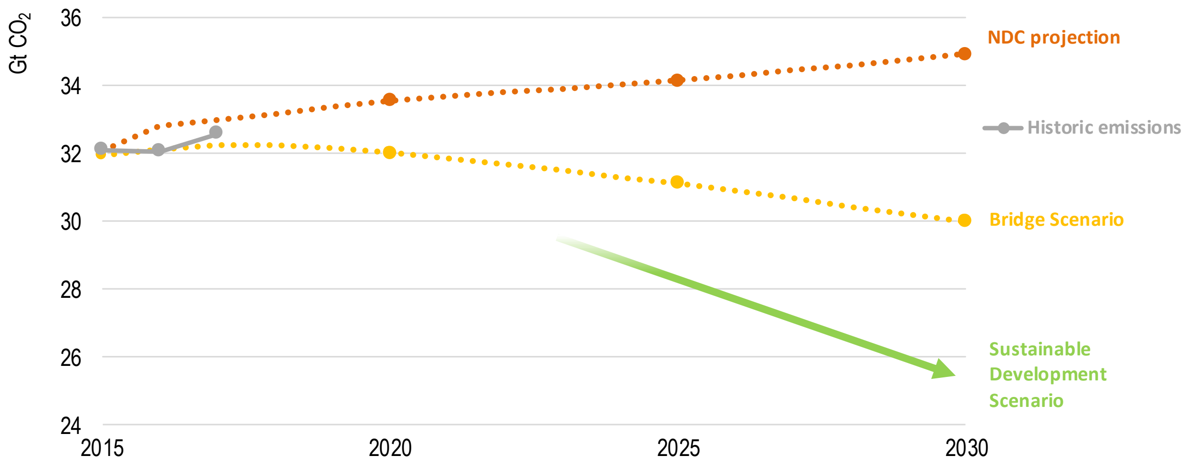
The five measures are:

- Increasing energy efficiency in the industry, buildings and transport sectors.
- Increasing investment in renewable energy technologies in the power sector (including hydropower).
- Phasing out the use of least-efficient coal-fired power plants.
- Gradual phasing-out inefficient fossil fuel subsidies to end-users.

- Reducing methane emissions from oil and gas production.

The Bridge Scenario projected a marked departure from the aggregate emissions trajectory implied by the NDCs submitted by countries in the context of the Paris Agreement in 2015 (Figure 38). While emissions in 2015 and 2016 were in line with the Bridge trajectory, the rise in CO_2 emissions in 2017 means that global emissions were about 330 Mt CO_2 above the level that would have been achieved if the Bridge Scenario measures had been expeditiously implemented from 2015, and far from the trajectory of the SDS.

Figure 38. CO_2 emissions trajectories relative to aggregate emissions levels implied by Nationally Determined Contributions

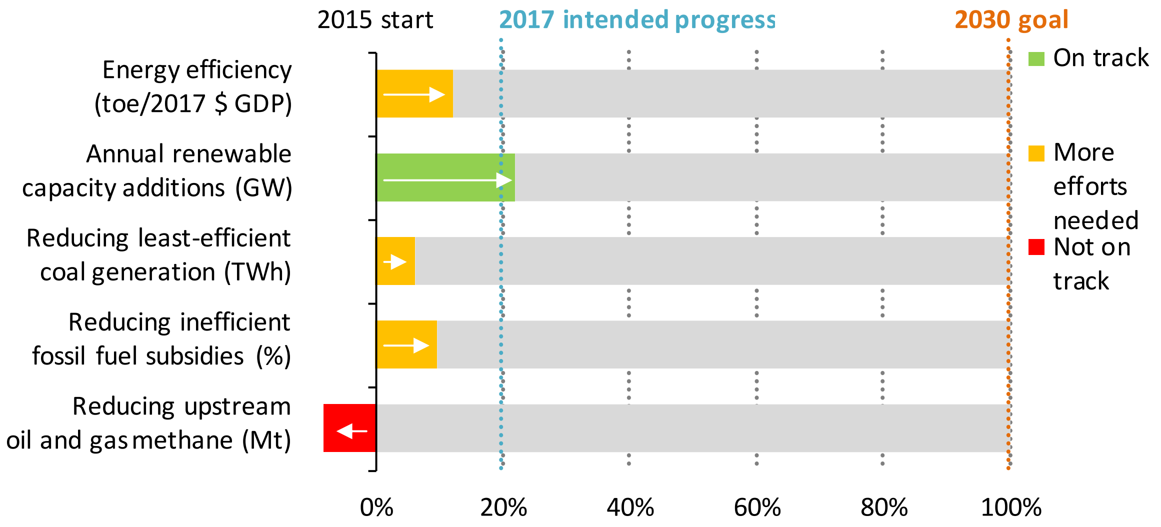


Source: Adapted from WEO 2018 (released 13 November 2018)

Taking a look at the five measures in the Bridge Scenario shows that progress has been mixed (Figure 39). Only investment in renewables for power generation, measured by capacity additions, is in line with what was originally projected in the Bridge Scenario for 2017. Progress on phasing out least-efficient coal has been steady, but well below the rate set out in the Bridge Scenario. Energy efficiency has made some progress, but policy efforts appear to be slowing. Some progress has also been made on phasing out inefficient fossil fuel subsidies, but less than was projected in the Bridge Scenario. Estimates of methane emissions from oil and gas operations have risen over the period in proportion to production, implying no progress on this measure.

This mixed progress highlights that significant potential remains for countries to take urgent near-term policy actions that would, collectively, lead to a peak in emissions with not net cost to the economy. It is important to note also that achievement of the Bridge Scenario does not guarantee progress towards the ultimate outcomes of the Sustainable Development Scenario.

Figure 39. Progress against the IEA's Bridge Scenario measures

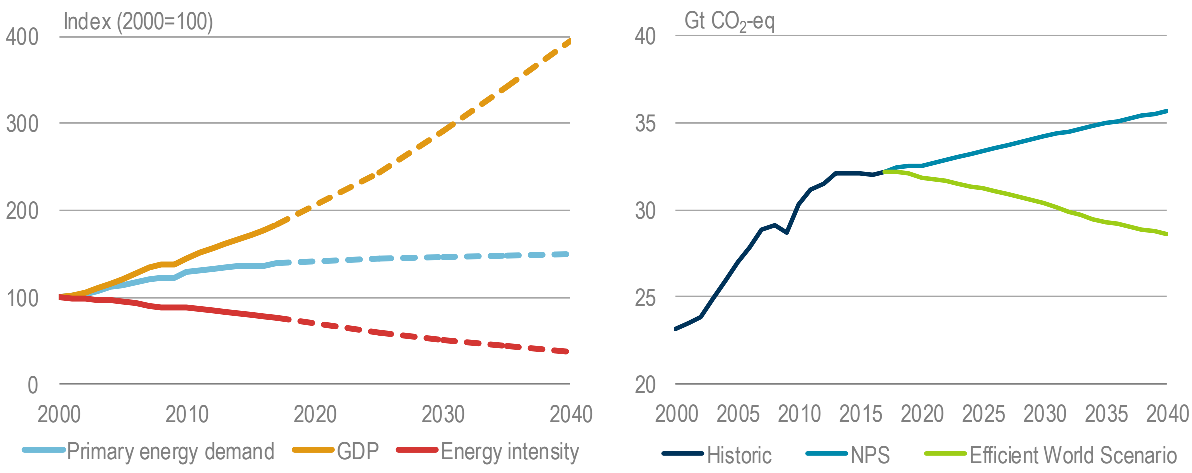


Source: WEO 2018 (released 13 November 2018)

2. How to realise cost-effective energy efficiency potential?

Energy efficiency has potential to provide more than 51% of the abatement required by 2030 to be in line with the Paris Agreement. To examine in more detail the role of energy efficiency within the SDS, the IEA has developed an Efficient World Scenario (EWS), published in *Energy Efficiency 2018*. The EWS shows what could happen if all available and cost-effective energy efficiency measures were implemented between now and 2040. The EWS shows that efficiency alone could limit the increase in primary energy demand to levels only marginally higher than those today at the same time as global gross domestic product (GDP) doubles (Figure 40). This would result in a peak in energy-related greenhouse gas emissions before 2020 and subsequent fall by 12% in 2040 compared with today. The EWS would also help to achieve the UN Sustainable Development Goals (SDGs) and create multiple benefits for economies, households and the environment.

Figure 40. Global primary energy demand, GDP and energy intensity historically and in the Efficient World Scenario, 2000-40 (left) and global energy-related CO_2 emissions historically and in the New Policies Scenario and Efficient World Scenario, 2000-40 (right).



Source: IEA (2018) (Energy Efficiency 2018)

Unlocking the cost-effective energy efficiency potential of the EWS will require targeted policy measures, combining regulation, incentives, market-based instruments, information and capacity building measures and other tools. The opportunities for efficiency gains in the EWS and the policy measures enabling these gains constitute the IEA's Efficient World Strategy, which maps out priority sectors, technologies and policy actions (Table 3).

Policy design and implementation are crucial to implement the strategy. Policy needs to be tailored, dynamic and supported; ambitious measures need appropriate monitoring, evaluation and enforcement to maximise the effectiveness of energy efficiency policy, and to increase ambition as technology develops and costs fall.

Table 3. Key components of the IEA's Efficient World Strategy

Sector	Opportunity in the EWS	Government policy actions
Transport	• Energy demand could stay flat, despite doubling activity levels. • Passenger cars and trucks offer two-thirds of potential savings.	• Improve coverage and strength of transport policies for cars and trucks and non-road modes. • Provide incentives to support uptake and sustainable use of efficient vehicles.
Buildings	• Building space could increase by 60% for no additional energy use. • Space heating, cooling and water heating offer 60% of potential savings.	• Put in place comprehensive efficiency policies, targeting both new and existing building stock and appliances. • Incentives to encourage consumers to adopt high efficiency appliances and undertake deep energy retrofits.
Industry	• Value-added per unit of energy could double. • Less energy-intensive industry offers 70% of potential savings.	• Expanded and strengthened standards for key industrial equipment, including electric heat pumps and motors. • Incentives to encourage the adoption of energy management systems.
Investment	• Investment must immediately double, and double again after 2025. • Transport sector presents largest investment opportunity.	• Build scale and momentum in financing using programmes and incentives to increase activity. • Market-based instruments to encourage investment and business model innovation.

For further information:

Energy Efficiency 2018

3. How much are clean energy technology costs expected to decline in the future?

The accelerated development and deployment of clean energy technologies is crucial to realising cost-effective low carbon energy transitions. As technology costs continue to decline and as more becomes economically possible, ambition can be further raised.

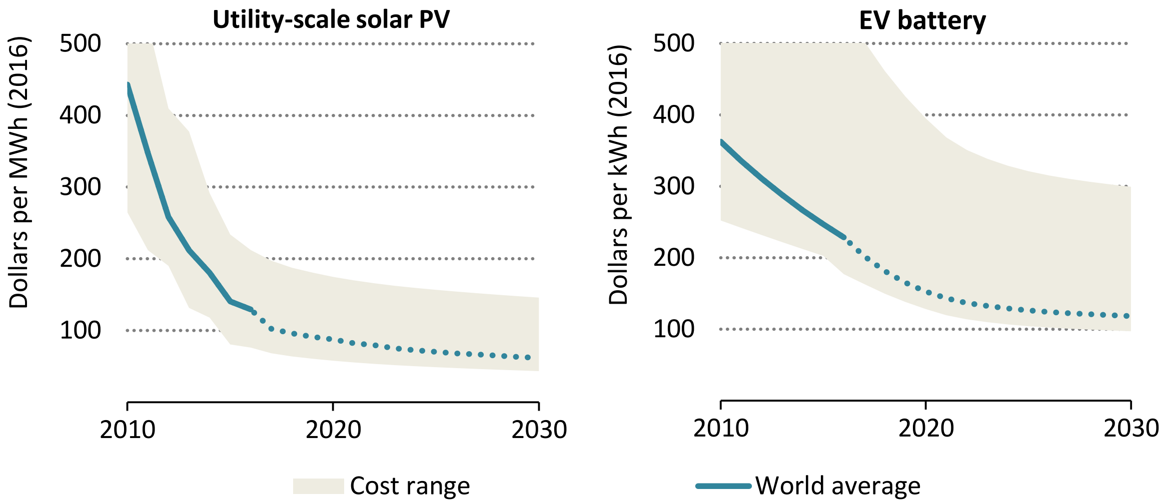
Past declines in the costs of certain renewable energy technologies – namely solar photovoltaic (PV) technology and on-shore and off-shore wind – have been well publicised. Looking ahead in the next five years (2018-2023), IEA *Renewables 2018* forecasts that global average generation costs (levelised costs of electricity, LCOE[3]) are expected to drop by a further 40% for offshore wind, followed by solar PV (25%), and onshore wind (6%). Specific costs will vary widely based on the project size (capacity) and by country, including associated policy and regulatory frameworks. Towards 2030, costs are expected to continue declining. For instance, in the IEA's New Policies

[3] Levelised cost of electricity is calculated as the average lifetime levelised costs on the basis of the costs for investment, operation and maintenance, fuel, carbon emissions and decommissioning and dismantling (IEA, 2015).

Scenario (NPS)[4] costs for new utility-scale solar PV and electric vehicle batteries approximately halve from 2016 to 2030 (Figure 9).

While the rates of cost reductions will vary across technologies and regions, policy support at all levels of technology innovation will accelerate cost declines. Policy support remains critical even where technologies reach price parity with fossil fuel-based technologies. The competitiveness of power generation technologies depends not only on the technology costs, but also the value provided to the system and any additional integration costs. As such, there is a continued role for policy makers to deliver the pace of clean energy deployment and decarbonisation needed, as well as taking steps to tap all sources of flexibility necessary to successfully integrate variable renewables into the power mix and ensure the reliability of electricity supply.

Figure 41. Global average cost reductions of utility-scale solar PV and EV batteries in the New Policies Scenario, 2010-2030



Notes: Levelised cost of electricity are presented for solar PV and investment costs are presented for EV batteries.
Source: IEA (2017). *World Energy Outlook 2017*.

IEA's new Innovation Tracking Framework identifies key long-term "technology innovation gaps" that need to be filled in order to meet long-term clean energy transition goals.

The Framework identified around 100 innovation gaps across 35 key technologies and sectors, highlighting where R&D investment or general innovation activity needs improvement. Identifying these gaps involved examining the following essential aspects of innovation: investment patterns; key initiatives from the private and/or public sector; and general technology improvement using key metrics. Taking the example of one innovation gap - the need to develop batteries with lower cobalt and lithium content – the Tracking Framework assess: (taking as an example):

- The key improvement metric/focus (e.g. metal intensity of the most advanced battery).
- How the challenge is currently being tackled (e.g. overall level of R&D funding and current progress by battery manufacturers), and key initiatives in place and over the past year.
- The stakeholder landscape - key actors, public/private/academia.
- Opportunities for international initiatives such as multilateral collaborations (e.g. Mission Innovation, Breakthrough Energy Coalition)

[4] In the New Policies Scenario, accounting only for implemented and announced policies. In a scenario with strengthened policy support, technology costs would be expected to decline further.

The Innovation Tracking Framework, which will be progressively expanded and updated, builds upon leading IEA in-house knowledge and data on technology innovation and investment; a rich history in technology roadmapping; extensive energy technology trend analysis; and the IEA's unique Technology Collaboration Programmes.

For more information:

Technology Roadmaps, a set of 21 roadmaps identifying priority actions for governments, industry, financial partners and civil society to advance development of a wide range of technologies.

Renewables 2018 (Market *analysis and forecast from 2018 to 2023)*

Global EV Outlook 2017 (*Global EV Outlook 2018* released May 2018)

World Energy Outlook 2017 (*World Energy Outlook 2018* released November 2018)

Energy Technology Perspectives 2017

Innovation Tracking Framework

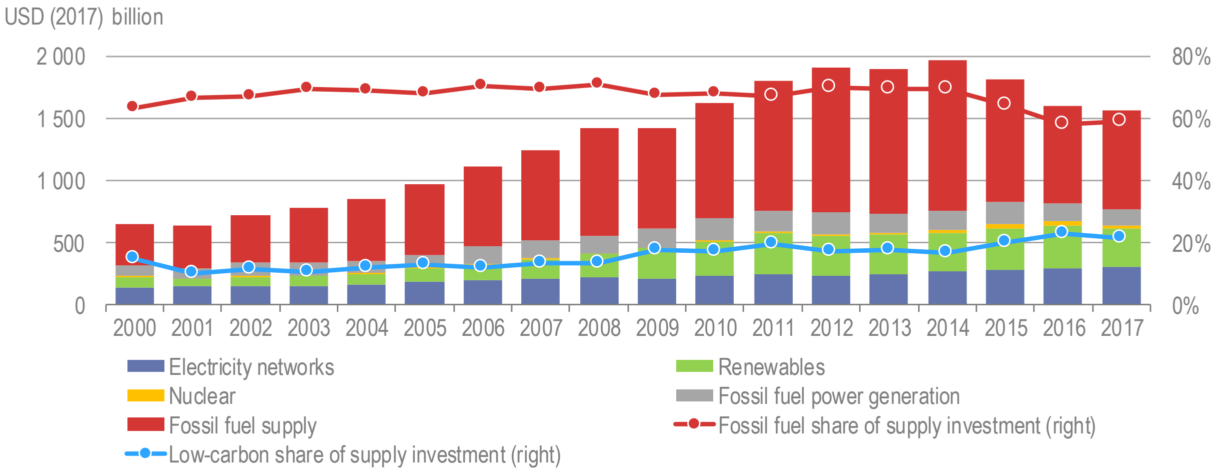
4. How do investment patterns need to change to reach Paris Agreement goals?

Total energy investment in 2017 declined for the third year in a row by 2% in real terms, partly driven by falling costs in renewables and fewer additions of coal, hydro and nuclear power capacity. The growth in energy efficiency investment slowed substantially, from 9% in 2016 to 3% in 2017.Shifting investment decisions are strongly visible in the power sector as the share of low carbon power sources in power generation investment rose to over 70%. Solar PV investment rose to record levels, representing 8% total energy investment worldwide, even as unit costs fell by nearly 15% on average.

At the same time, fossil fuels (coal, oil, and natural gas supply and fossil-fuel based power plants) still received the majority of overall energy sector investment. The share of energy sector investment in fossil fuels began to drop in 2015 and 2016 after more than a decade of holding steady, but rose slightly to 59% in 2017 as spending in upstream oil and gas increased modestly (Figure 42).

Government policies play an increasing role in influencing the allocation of capital across the energy sector. In terms of the ownership of energy capital, the share of state-owned enterprises (SOEs) has expanded in the past five years to reach above 40% in 2017, with fossil fuel investments increasingly dominated by SOEs. Although private entities own nearly 85% of investments in renewables and energy efficiency, government policies and regulatory frameworks influence nearly all financing decisions.

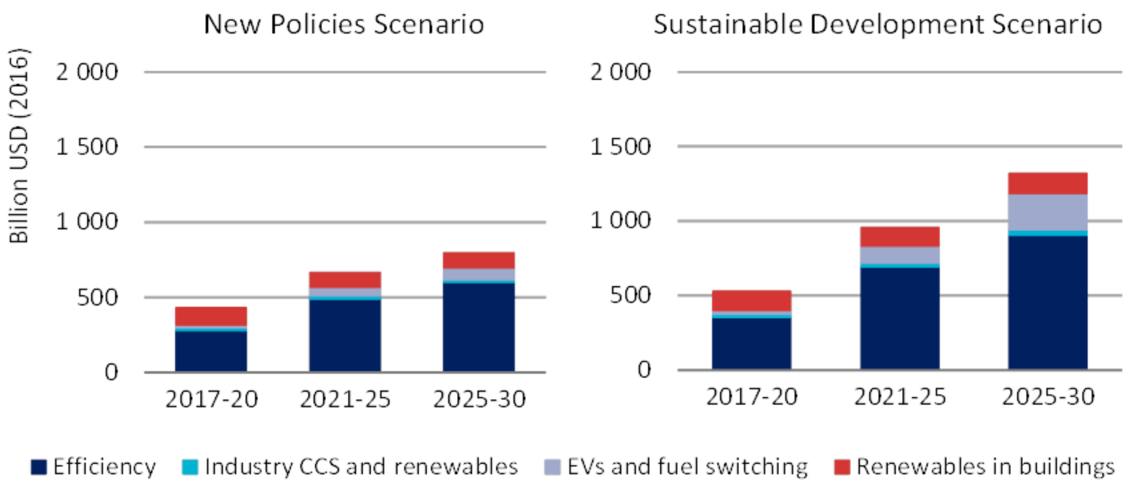
Figure 42. Global investment in energy supply by fuel



Source: IEA *World Energy Investment 2018*.

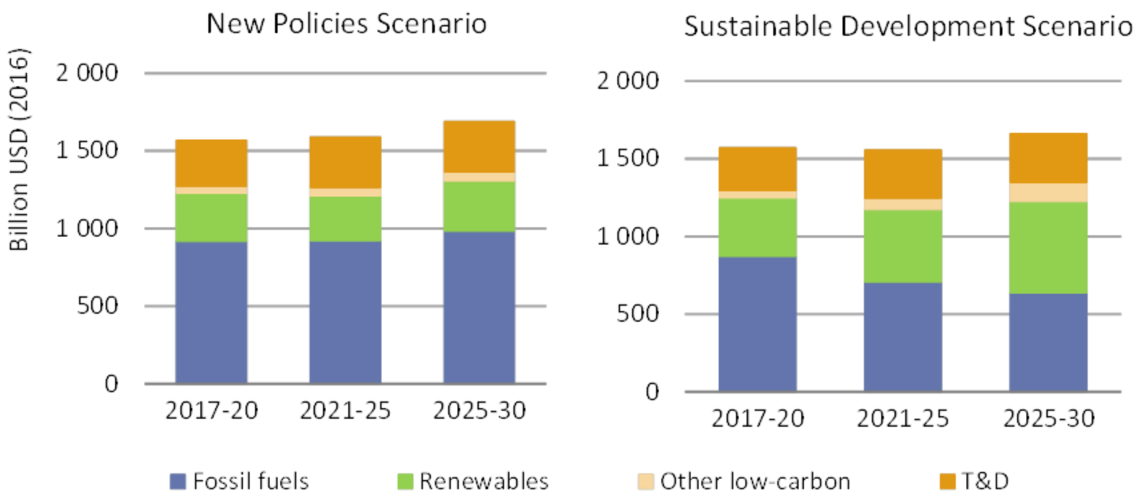
In IEA's Sustainable Development Scenario (SDS), only 13% additional investment in energy is required to 2030, a net of USD 4 trillion, relative to investment that would be required under current trends in the New Policies Scenario (NPS). Within this overall envelope, annual supply-side investment to 2030 remains relatively flat from today's levels, although a substantial shift occurs in where investment is directed. There is a strong shift away from fossil-fuel supply and fossil-fuel power generation, for which investment reduces by USD 2.8 trillion through 2030, towards low-carbon power supply and improving the energy efficiency of end-use sectors (Figures 42 and 43). In energy supply, from 2017 to 2030, investment in renewable power rises 65%, alongside a decline in upstream coal, oil, and gas investment by 20% and decline in fossil fuel power generation investment by around 60%.

Figure 43. Estimated annual average investment in energy end-use sectors in the New Policies Scenario and Sustainable Development Scenario, 2017-2030



Data surce: IEA (2017). *World Energy Outlook 2017*.

Figure 44. Estimated annual average investment in energy supply in New Policies Scenario and Sustainable Development Scenario, 2017-2030



Data source: IEA (2017). *World Energy Outlook 2017. Note: T&D is transmission and distribution in the electricity sector*

In the power sector, pursuing the SDS trajectory will require investments of about USD 12.5 trillion to 2030, with an average of USD 900 billion per year invested in new power plants and networks as well as refurbishing and upgrading ageing infrastructure. Power plant investments will be dominated by renewables, which account for three quarters of the total investment to 2030. At the technology level, current investment in solar PV is broadly consistent with the IEA's SDS, however investments in other low-carbon technologies including wind power, hydroelectric and nuclear electricity, and carbon capture and storage currently fall short. If investments in the latter technologies do not accelerate, solar PV would need to scale up even further to make up the difference and to enable achievement of Paris Agreement goals.

Finally, investment in technology innovation is a critical element of driving longer term decarbonisation, but could take longer to bear fruit in terms of measurable CO_2 impact. Examples include EVs and solar PV, which after decades of research are now starting to be deployed on a much wider scale.
IEA's most rigorous and timely innovation analysis ever in TCEP 2018 indicates a 13% estimated increase for government low-carbon energy RD&D spending in 2017, following a fall in 2016. Governments play an indispensable role in clean energy RD&D as a vital source of long-term, patient finance and because many societal benefits (reducing GHG emissions and local pollution) are not yet sufficiently valued by markets.

Our improved estimate for corporate clean energy R&D investment shows that while corporate clean energy R&D dropped slightly in 2017, the five-year trend shows 5% annual growth. Growth in corporate clean energy R&D is dominated by transport and complemented by digital efficiency technology plays, while renewable hardware has not received a similar boost and remains lower than 2014. The trend in rising R&D spending by the automotive sector faltered in 2017 but is expected to pick up again in coming years. Clean energy VC investment is on a rising trajectory. USD 2.5 billion was invested in 2017, following a spike in big deals in clean transport in 2016.

For further information:

World Energy Investment (2018)

World Energy Outlook 2017 (*World Energy Outlook 2018* released November 2018)

Perspectives for the Energy Transition (2017)

Tracking Clean Energy Progress 2018

3. How can indicators be used to guide policy action?

The set of key indicators presented in Tables 1 and 2 were developed by the IEA as a part of the *Tracking Clean Energy Progress*, and reflect important areas for policymakers to focus their short-term efforts to deliver long-term clean energy ambition objectives. They include indicators for tracking progress of both desired outcomes (e.g. CO_2 emissions) and the underlying drivers of energy transitions (e.g. investment in clean energy, share of low carbon capacity additions in power generation, or facilitating the electrification of end uses). These driver indicators can help identify where potential for further ambition exists within country NDCs, and help ensure that very long-lived energy sector infrastructure expansion is compliant with clean energy transition objectives. Aggregate energy sector indicators are important for the latter purpose, while more specific sub-sectoral indicators can help countries with the former.

Tracking indicators beyond CO_2 emissions enables a more complete understanding of energy transitions, including actions that may not produce short-term CO_2 benefits but are fundamental for longer-term transitions. An example is clean energy investment, which may produce a delayed (but potentially high) CO_2 emissions impact. IEA analysis of investment activity indicates the increased deployment of low-carbon energy sources and switching from coal to gas – the primary drivers of global emissions levelling off between 2014-2016 – largely benefited from projects launched several years prior to this when market conditions were much more favourable than today.

Tracking progress with the set of indicators outlined earlier can furthermore serve to identify 'blind spots' in the energy sector. These are technologies or subsectors that have received less attention than others despite their rising importance. Examples include trucks, cooling, petrochemicals or modern bioenergy. In these areas, there is either high potential for further uptake or leeway to realise significant efficiency gains, which can help speed up efforts in both carbon mitigation and clean energy transitions.

For further information:

Tracking Clean Energy Progress (TCEP) 2018

Energy Efficiency Indicators 2017 (*Energy Efficiency Indicators 2018* released December 2018)

Global Energy and CO_2 Report 2018

World Energy Outlook 2017 (*World Energy Outlook 2018* released November 2018)

4. How can an integrated policy and technology approach deliver additional benefits?

A fundamental message emerging from all facets of IEA analysis is the need for an integrated approach to drive and accelerate clean energy transitions, with regards to both energy technologies and policy. One key reason for taking a holistic perspective to energy transitions is that action to address climate change must be contextualised within a country's priorities to tackle a range of other social, economic and environmental challenges. Meeting multiple objectives requires a portfolio of policies and technologies based on a country's national context. Indeed, the term "transitions" suggests that some technologies and sectors may growth while others decline. Focused attention is needed to support and re-train affected workers and to manage associated negative impacts, for instance, possible changes in energy costs for end users.

As seen previously, the IEA's Sustainable Development Scenario (SDS) takes this approach, offering an integrated approach for achieving the long-term mitigation goals of the Paris Agreement, as well as the goals of universal access to modern energy and substantially reducing air pollution.

For further information:

World Energy Outlook 2017 (*World Energy Outlook 2018* released November 2018)

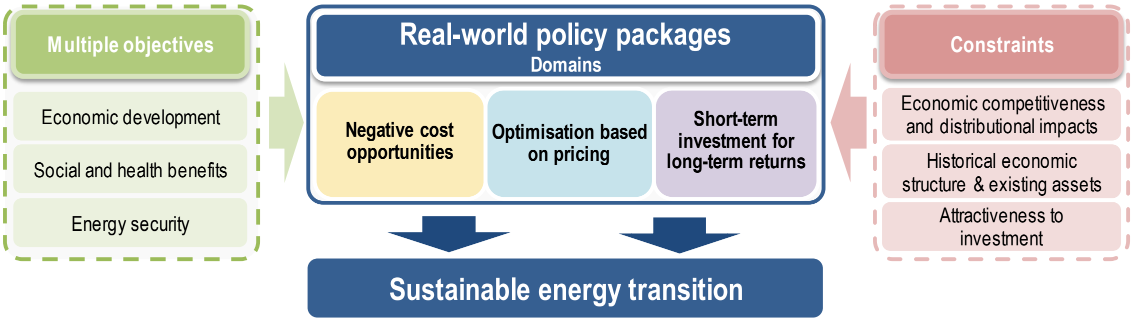
Real world policy packages for sustainable energy transitions (2017)

Capturing the Multiple Benefits of Energy Efficiency (2015)

Policy Packages for clean energy transitions

A variety of integrated policy tools will be critical to drive successful clean energy transitions. Policy packages are needed to achieve a whole-scale shift in energy systems in all sub-sectors with key elements covering three domains: 1) negative cost opportunities (e.g. energy efficiency standards), 2) optimisation based on pricing (e.g. carbon pricing) and 3) short-term investment for long-term returns (e.g. support for technology innovation) (Figure 45). For example, policies driving electrification will produce greater environmental benefits if implemented alongside ones to decarbonise electricity supply. In addition, declines in upstream fossil fuel investment may align with a low-carbon pathway, but may also create energy security risks if not accompanied by measures to address rising energy demand.

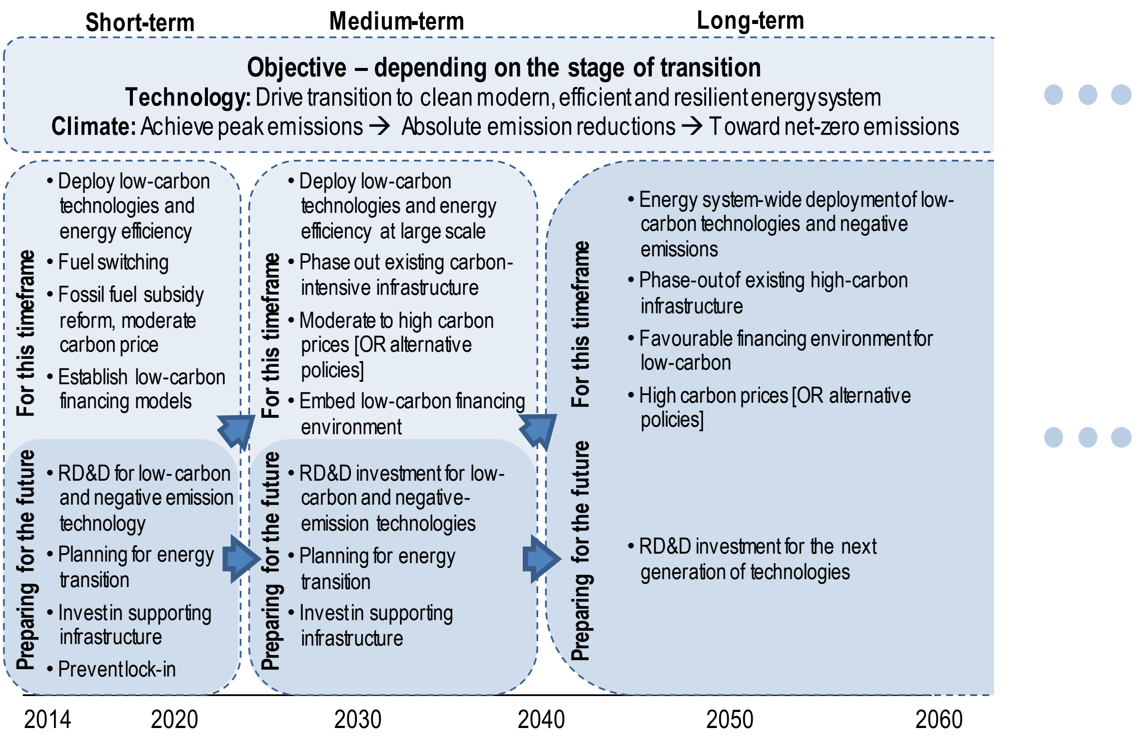
Figure 45. Comprehensive policy packages for clean energy transitions cover three domains and are shaped by national objectives and constraints



Source: IEA (2017c). *Real world policy packages for sustainable energy transition*.

Integration of policies across time scales is critical. As countries develop the next round of NDCs, it will be important to align these commitments with short-term (pre-2020) action as well as longer term (e.g. mid-century) pathways and goals. By creating consistent and predictable policy signals across time scales, both the effectiveness and cost efficiency of energy transitions can be enhanced by avoiding lock-in of high carbon assets and implementation of conflicting policies. As Figure 46 shows, comprehensive policy package needs to contain a mix of policy drivers that prepare countries for the future envisaged under their long-term low greenhouse gas emission development strategies.

Figure 46. Indicative policy packages pathways for clean energy transitions



Source: IEA (2017c). Real world policy packages for sustainable energy transition.

Although energy transitions do not rely on any individual policy, IEA analysis highlights the importance of certain key domestic policy measures. In the Sustainable Development Scenario compatible with meeting the Paris Agreement goals, carbon price levels by 2030 reach USD 75/tonne in key emerging countries and USD 100/tonne in advanced economies. Fossil fuel subsidies are removed by 2035 at the latest, with many countries having fully phased them out by 2025. To support accelerated deployment of renewable energy and energy efficiency improvement, extensive electricity market reforms and infrastructure investment for large-scale renewables integration, and stringent low-carbon and energy efficiency mandates will also be important.

For further information:

World Energy Investment 2018

Perspectives for the Energy Transition (2017)

Real world policy packages for sustainable energy transitions (2017)

Renewable and Energy Efficiency Integration

Integrated technology approach

Many low carbon energy transitions will feature more diverse and renewable energy sources and rely more heavily on distributed generation, which will need to be better integrated and managed from a systems perspective. Low carbon fuel sources will also be needed for a host of end use sectors, including renewable heat for buildings and industry and biofuels in transport. This can increase efficiency and decrease system costs, and it will require a broader range of technologies and fuels. However, success depends not only on individual technologies but also on how the overall energy system functions based on a portfolio of diverse technologies that fit a country's particular context. A key challenge for energy policy makers will be to move away from a siloed, supply-driven perspective towards one that enables systems integration including enhanced demand response.

An integrated technology approach also requires acting on various time dimensions, based on the level of technology maturity. Technologies at early stages of development, such as carbon capture and storage and advanced biofuels, require strengthened support now to accelerate their development through the stages of technology innovation to ensure at-scale deployment when needed. Support for mainstream technologies takes a different form, for example, variable renewables require action to support system integration and flexibility including for grid infrastructure and market reform.

International collaboration can help share technology best practices and accelerate innovation. For example, the IEA Technology Collaboration Programmes (TCPs) have been bringing together 6,000 experts from 55 countries, including governments, key companies, and top research institutions to accelerate energy technology innovation around the world. In the context of an increasingly complex and multi-lateralised global energy landscape, the breadth of TCPs' analytical expertise is a unique asset to accelerate energy transitions worldwide.

For further information:

Energy Technology Perspectives 2017

Status of Power System Transformation 2017

Digitalization and Energy 2017

Renewable and Energy Efficiency Integration

Technology Collaboration Programmes

5. How could ambition be enhanced with greater national capacity?

As described above, integrated approaches can lead to policies having greater impact, being more adaptable and being easier to sustain over time. Doing so can, however, require a much greater degree of consultation and co-ordination within national governments, as well as with sub-national governments and a broader set of key stakeholders. In addition, it requires being able to assess different technology options appropriate to a country's domestic context and having the tools to explore pathways for future climate-compatible development.

All this requires building up of various types of technical knowledge and capacities, which in many countries has taken considerable time and resource. For countries seeking to design and implement an integrated policy approach, international collaboration, co-operation and support can therefore be an important means for gathering the appropriate expertise and knowledge, as well as building or strengthening various capacities.

In the context of the UNFCCC and the Paris Agreement, as well as beyond it, providing such support to countries is rightfully growing in importance, and will hopefully continue to be strengthened through various capacity-building initiatives, as well as funding sources such as the Green Climate Fund and the Global Environment Facility.

For several years, the IEA has also contributed to such efforts, working with countries to build capacities for energy data, statistics and analysis to support policy making. IEA has various long standing collaborations with major emerging economies, including the Energy Efficiency in Emerging Economies (E4) programme, the Grid Integration of Variable Renewables (GIVAR) programme, various Clean Energy Ministerial work streams, and a wide variety of other IEA training and capacity-building activities.

The IEA Clean Energy Transitions Programme (CETP), launched in November 2017 with the support of 13 IEA members, is leveraging IEA's unique energy expertise across all fuels and technologies to accelerate global clean-energy transitions, particularly in major emerging economies. The EUR 30+ million programme is providing cuttingedge technical support to governments whose energy policies will significantly impact the speed of, and prospects for, a global transition toward more sustainable energy production and use, including reductions in greenhouse gas emissions in line with the objectives of the Paris Agreement. Key countries of focus include Brazil, China, India, Indonesia, Mexico and South Africa, as well as other IEA Association and Partner countries and regions where the programme can have high impact. The CETP focuses on six thematic areas, covering data and statistics; energy efficiency; electricity transitions and renewable energy (including system integration); policy advice and modelling; energy transitions in sectors; and technology development and innovation.

Under the CETP, IEA is supporting emerging economies through deep and sustained partnerships with governments, including through tailored and collaborative analytical work, technical co-operation, training and capacity building, strategic dialogues, secondments and implementation of joint work programmes. Examples of activities being developed under the CETP include working with emerging economies to: develop and refine data collection practices and surveys; inform and track progress of national energy efficiency programmes; assess options for enhancing the flexibility of electricity systems and increasing the share of renewables in their energy matrix; explore different options for developing long-term low-carbon energy transition pathways as well as improving modelling capabilities; provide advice on clean energy transitions in sectors such as transport and industry; and better understand RD&D spending and how this can be best channelled toward nationally-relevant innovation.

In addition, IEA work under the CETP also involves extensive convening to bring experts and policy-makers together, increasing political will, ensuring knowledge sharing, enhancing local capacities as well as the strengthening of expert networks both within and among countries. The IEA's CETP efforts are also aligned and enhanced through the enlargement of the IEA family of countries over the past two years to include new Association countries such as Brazil, China, India, Indonesia, Morocco, Singapore, and Thailand. In implementing the CETP, the IEA is also aiming to work in even greater partnership with other relevant organisations with relevant and complementary capabilities.

HOW DO WE GET THERE?

KEY OPPORTUNITY:

Energy transitions consistent with meeting Paris Agreement goals, universal energy access to modern energy, and significant reduction in air pollution can be realised at a modest global cost. As technology and fuel costs decline, these goals can be achieved with only 13% additional investment in the energy sector by 2030, relative to the investment implied by current and announced policies. Well-integrated policy packages can be used to re-direct investment toward energy efficiency and low carbon energy supply.

KEY CHALLENGE:

Applying an integrated policy approach to achieve a diverse and integrated technology portfolio for successful clean energy transitions requires significant national co-ordination and capacity, including domestic technology and policy expertise. Sharing international best practices and advice can help.

For further information:

Clean Energy Transitions Programme

Clean Energy Transitions Programme launch document and announcement (2017)

IEA Training and Capacity Building

Energy Efficiency in Emerging Economies (E4) Programme

IEA Technology Collaboration Programmes (TCPs): the 38 TCPs operating today span across the full range of energy technologies, from CCS to buildings, from smart grids to energy efficiency, from fusion to bioenergy

World Energy Outlook and Energy Technology Perspectives

System Integration of Renewables

Technology Roadmaps, a set of 21 roadmaps identifying priority actions for governments, industry, financial partners and civil society to advance development of a wide range of technologies, and other work on Clean Energy Technologies

Annex: relevant IEA analysis

1. IEA Latest

- Market Report Series: Energy Efficiency 2018
- Market Report Series: Renewables 2018
- Market Report Series: Renewables 2018 - Executive Summary
- 20 Renewables Energy Policy Recommendations (2018)
- The Future of Petrochemicals: *Towards more sustainable plastics and fertilisers* (2018)
- World Energy Investment 2018 - Executive Summary
- CO_2 Emissions from Fuel Combustion Highlights 2017; Data (.xls)
- World Energy Outlook 2018 (released date 13 November)
- World Energy Outlook 2017 - Executive Summary
- Energy Technology Perspectives 2017 - Executive Summary
- Tracking Clean Energy Progress 2018
- Digitalization & Energy (2017)
- Global EV Outlook 2017

- Key World Energy Statistics 2017
- World Energy Balances 2017 (Overview)
- Electricity Information 2017 (Excerpt)
- Renewables Information 2017 (Overview)

- World Energy Outlook 2017 Special Report: South East Asia
- World Energy Outlook 2017 Special Report: Energy Access Outlook 2017 – From Poverty to Prosperity
- World Energy Outlook 2017 China Energy Outlook
- World Energy Outlook 2016 Special Report - Energy and Air Pollution
- World Energy Outlook 2015 Special Briefing for COP21
- World Energy Outlook 2015 Special Report - Energy and Climate Change

- Insights Series: Getting Wind and Sun onto the Grid (2017)
- Insights Series: Market-based Instruments for Energy Efficiency (2017)
- Insights Series: Real-world policy packages for sustainable energy transitions (2017)
- Insights Series: Renewable Energy in Industry Manufacturing (2017)
- Insights Series: The Future of Trucks (2017)
- Insights Series: Tracking Fossil Fuel Subsidies in APEC Economies (2017)
- Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System (2017)
- Status of Power System Transformation 2017

- Energy Policies Beyond IEA Countries: Mexico 2017 Review
- Energy Policies of IEA Countries: Greece Review 2017
- Energy Policies of IEA Countries: Hungary 2017 Review
- Energy Policies of IEA Countries: New Zealand 2017 Review
- Energy Policies of IEA Countries: Norway 2017 Review

2. Modelling the Energy Sector Decarbonisation Transition

- Energy Technology Perspectives 2017 - Executive Summary
  - Translations: Chinese, French, German, Japanese, Korean, Portuguese, Russian, Spanish
- Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System (2017)
- Tracking Clean Energy Progress 2017
- World Energy Outlook 2017 - Executive Summary
  - Translations: Arabic, Chinese, French, German, Italian, Japanese, Russian, Spanish, Korean, Polish
- World Energy Outlook 2017 Special Report: South East Asia

- World Energy Outlook 2017 Special Report: Energy Access Outlook 2017 – From Poverty to Prosperity
    - Translations (Executive Summary): French; Italian
- Energy, Climate Change and Environment: 2016 Insights
- World Energy Outlook 2016 - Executive Summary
- Energy Technology Perspectives 2016 - Executive Summary
    - Translations: Chinese; French; German; Japanese; Portuguese; Russian; Spanish
- Solutions, analysis, and data for the global energy transition (2016)
- Tracking Clean Energy Progress 2016: IEA Input to the Clean Energy Ministerial
- WEO 2016 Special Report - Energy and Air Pollution
    - Executive Summary: English; Chinese; French
- WEO 2016 Special Report - Mexico Energy Outlook
    - Executive Summary: English; Spanish
- Energy Matters (2015)
- Track the energy transition: Where we are, how we got here, and where we need to be (2015)
- WEO 2015 Special Briefing for COP21
- WEO 2015 Special Report - Energy and Climate Change
    - Executive Summary: English; Chinese; French; German; Japanese; Korean; Polish; Portuguese; Russian; Spanish; Turkish
- WEO 2015 Special Report - India Energy Outlook
- WEO 2015 Special Report - Southeast Asia Energy Outlook
- WEO 2014 Special Report: Africa Energy Outlook
- WEO 2014 Special Report: World Energy Investment Outlook
- WEO 2013 Special Report: Redrawing the Energy-Climate Map
- WEO 2013 Special Report: Southeast Asia Energy Outlook

3. Statistics and Indicators

- CO_2 Emissions from Fuel Combustion Highlights 2017
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- Key World Energy Statistics 2017
- World Energy Balances 2017 (Overview)
- Electricity Information 2017 (Excerpt)
- Renewables Information 2017 (Overview)
- Natural Gas Information: Overview (2017)
- Coal Information: Overview (2017)
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- Tracking Clean Energy Progress 2017
- International Comparison of Light-Duty Vehicle Fuel Economy 2005-2015 Ten Years of Fuel Economy Benchmarking (2017)
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- Energy Efficiency Indicators: Essentials for Policy Making (2014)
    - Translations: Chinese; Spanish; Russian
- Energy Efficiency Indicators: Fundamentals on Statistics (2014)
    - Translations: Chinese; Spanish; Russian
- Energy, Climate Change, and Environment: 2014 Insights
- Development of Energy Efficiency Indicators in Russia (2011)
- Energy Statistics Manual (2005)

4. Climate Policy for the Energy Sector

- Insights Series: Getting Wind and Sun onto the Grid (2017)
- Insights Series: Real-world policy packages for sustainable energy transitions (2017)
- Energy, Climate Change and Environment: 2016 Insights
- Solutions, analysis, and data for the global energy transition (2016)
- Tracking Clean Energy Progress 2016: IEA Input to the Clean Energy Ministerial
- WEO 2016 Special Report - Energy and Air Pollution
  - Executive Summary: English; Chinese; French
- Complementary measures for decarbonisation (2015)
- Energy Matters (2015)
- Making the energy sector more resilient to climate change (2015)
- WEO 2015 Special Briefing for COP21
- WEO 2015 Special Report - Energy and Climate Change
- Capturing the Multiple Benefits of Energy Efficiency (2015)
- Emissions Trading in the People's Republic of China: A Simulation for the Power Sector (2014)
- Energy, Climate Change, and Environment: 2014 Insights
  - Executive Summary translations: Chinese; Japanese
- Energy Policy Highlights (2013)
- Managing interactions between carbon pricing and existing energy policies (2013)
- WEO 2013 Special Report: Redrawing the Energy-Climate Map
- Electricity in a Climate-Constrained World - Data & Analyses (2012)
- Policy Options for Low-Carbon Power Generation in China: Designing an emissions trading system for China's electricity sector (2012)
- Energy Efficiency and Carbon Pricing (2011)
- Interactions of Policies for Renewable Energy and Climate (2011)
- Summing up the Parts: Combining Policy Instruments for Least-Cost Climate Mitigation Strategies (2011)

5. Financing the Energy Transition

- World Energy Investment 2017 - Executive Summary
  - Translation: Chinese; Japanese; Korean
- Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System (2017)
- World Energy Investment 2016 - Executive Summary
  - Translation: Chinese
- WEO 2014 Special Report: World Energy Investment Outlook
- Mobilising investment in energy efficiency: Economic instruments for low-energy buildings (2012)
- Plugging the Energy Efficiency Gap with Climate Finance (2012)
- Policy Pathways: Joint Public Private Approaches for Energy Efficiency Finance (2011)

6. Energy Transition in Emerging Economies

- Market Report Series: Energy Efficiency 2018
- District Energy Systems in China Options for Optimisation and Diversification (2017)
- Digitalization and Energy - Executive summary - Chinese (2017)
- Market Report Series: Energy Efficiency 2017 - Indonesia Focus - Bahasa Indonesia (2017)
- Energy Technology Perspectives 2017 - Executive Summary
- Energy Efficiency Outlook for India – Sizing up the opportunity (2017)
- Insights Series: Tracking Fossil Fuel Subsidies in APEC Economies (2017)
- Prospects for Distributed Energy Systems in China (2017)
- World Energy Outlook 2017 Special Report: Energy Access Outlook 2017 – From Poverty to Prosperity
  - Translations (Executive Summary): French; Italian
- World Energy Outlook 2017 Special Report: South East Asia
- World Energy Outlook 2017 China Energy Outlook
- World Energy Outlook 2016 - Executive Summary
- Energy Policies of IEA Countries - Turkey 2016 Review

- Energy Technology Perspectives 2016 - Executive Summary
    - Translations: Chinese; French; Portuguese; Russian; Spanish
- Medium-Term Energy Efficiency Market Report 2016
- Medium-Term Energy Efficiency Market Report 2016 - Special Report - Energy Efficiency in China (Chinese) (2016)
- Medium-Term Renewable Energy Market Report 2016 Executive Summary
- Partner Country Series - Boosting the Power Sector in Sub-Saharan Africa: China's Involvement (2016)
    - Translation: Chinese (促进撒哈拉以南 非洲电力发展 中国的参与)
- Partner Country Series - China's Engagement in Global Energy Governance (2016)
    - Translation: Chinese (中国参与全球 能源治理之路)
- Partner Country Series - Clean Energy Technology Assessment Methodology Pilot Study: Belarus (2016)
- Partner Country Series - Clean Energy Technology Assessment Methodology Pilot Study: Kazakhstan (2016)
- Partner Country Series - Clean Energy Technology Assessment Methodology Pilot Study: Morocco (2016)
- Partner Country Series - Fossil Fuel Subsidy Reform in Mexico and Indonesia (2016)
- Partner Country Series - Thailand Electricity Security Assessment (2016)
    - Translation: Thai
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    - Executive Summary: English; Chinese; French
- WEO 2016 Special Report - Mexico Energy Outlook
    - Executive Summary: Spanish
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  - Translation: Chinese (面向中国煤炭未来发展)
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- Technology Roadmap: Carbon Capture and Storage in Industrial Applications - Chinese version (2011)
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- The Future of Cooling: Opportunities for energy-efficient air conditioning
- Market Report Series: Energy Efficiency 2017
- Market Report Series: Energy Efficiency 2017 - Indonesia Focus - Bahasa Indonesia (2017)
- Energy Efficiency Outlook for India – Sizing up the opportunity (2017)
- Insights Series: Market-based Instruments for Energy Efficiency (2017)
- Policy Pathways Brief: Modernising Building Energy Codes (2017)
- Policy Pathways Brief: Monitoring, Verification and Enforcement (2017)
- Policy Pathways Brief: Joint Public-Private Approaches for Energy-Efficiency Finance
- Policy Pathways Brief: Building Energy Performance Certification (2017)
- Medium-Term Energy Efficiency Market Report 2016
- Medium-Term Energy Efficiency Market Report 2016 - Special Report - Energy Efficiency in China (Chinese) (2016)
- The Clean Energy Technology Assessment Methodology: A Methodology for Assessing Renewable Energy and Energy Efficiency Technology Markets (2016)
- Achievements of appliance energy efficiency standards and labelling programs (2015)
- Building Energy Performance Metrics (2015)
- Enabling Renewable Energy and Energy Efficiency Technologies: Opportunities in Eastern Europe, Caucasus, Central Asia, Southern and Eastern Mediterranean (2015)
- Energy Efficiency Policy Priorities - Ukraine (2015)
- Energy Efficiency Policy Recommendations for Latin America and the Caribbean (2015)
  - Translation: Spanish
- Partner Country Series - Energy Use in the Chinese Building Sector (2015)
- Policy Pathways: Accelerating Energy Efficiency in Small and Medium-sized Enterprises: Powering
- SMEs to catalyse economic growth (2015)
  - Translation: Russian
- Policy Pathways: Modernising Building Energy Codes (Turkish) (2015)
- Regional EEPR: Southeast Asia Region (2015)
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- Energy Efficiency Indicators: Essentials for Policy Making (2014)
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- Policy Pathways: Energy Management Programmes for Industry: Gaining through saving (2012)
- Policy Pathways: Improving the Fuel Economy of Road Vehicles - A policy package (2012)
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- Energy Efficiency and Carbon Pricing (2011)
- Policy Pathways: Joint Public Private Approaches for Energy Efficiency Finance (2011)
- Saving Electricity in a Hurry (2011)
- Technology Roadmap: Energy Efficient Buildings: Heating and Cooling Equipment (2011)
- Policy Pathways: Monitoring, Verification and Enforcement - Improving compliance within equipment energy efficiency programmes (2010)

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- Carbon Capture and Storage: The solution for deep emissions reductions (2015)
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- Global Action to Advance Carbon Capture and Storage - a focus on industrial applications (2013)
- Methods to Assess Geological CO_2 Storage Capacity: Status and Best Practice (2013)
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- A Policy Strategy for Carbon Capture and Storage (2012)
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- Facing China's Coal Future: Prospects and Challenges for Carbon Capture and Storage (2012)
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- Technology Roadmap: Carbon Capture and Storage in Industrial Applications (2011)
    - Translation: Chinese
- Cost and Performance of Carbon Dioxide Capture from Power Generation (2010)

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- Insights Series: Renewable Energy in Industry Manufacturing (2017)
- Market Report Series: Renewables 2017 - Executive Summary
- Renewables Information 2017 (Overview)
- How2Guide for Bioenergy Roadmap Development and Implementation (2017)
- Technology Roadmap: Delivering Sustainable Bioenergy (2017)
- Medium-Term Renewable Energy Market Report 2016 Executive Summary
- Next Generation Wind and Solar Power From Cost to Value (2016)
- Re-powering Markets: Market design and regulation during the transition to low-carbon power systems (2016)
- The Clean Energy Technology Assessment Methodology: A Methodology for Assessing Renewable Energy and Energy Efficiency Technology Markets (2016)
- Enabling Renewable Energy and Energy Efficiency Technologies: Opportunities in Eastern Europe, Caucasus, Central Asia, Southern and Eastern Mediterranean (2015)

- Medium-Term Renewable Energy Market Report 2015
- Heating Without Global Warming - Market Developments and Policy Considerations for Heat (2014)
- Linking Heat and Electricity Systems (2014)
- Technology Roadmap: Energy Storage (2014)
- Technology Roadmap: How2Guide for Wind Energy Roadmap (2014)
- Technology Roadmap: Solar Photovoltaic Energy (2014)
- Technology Roadmap: Solar Thermal Electricity (2014)
- Technology Roadmap: Wind Energy (2013)
- Technology Roadmap: Bioenergy for Heat and Power (2012)
- Technology Roadmap: Biofuels for Transport - Chinese (2012)
- Technology Roadmap: Hydropower (2012)
- Technology Roadmap: Solar Heating and Cooling (2012)
- Deploying Renewables (2011)
- Harnessing Variable Renewables (2011)
- Integration of Renewables - Status and Challenges in China (2011)
- Interactions of Policies for Renewable Energy and Climate (2011)
- Solar Energy Perspectives (2011)
- Technology Roadmap: Biofuels for Transport (2011)
- Technology Roadmap: China Wind Energy Development Roadmap 2050 (2011)
    - Translation: Chinese
- Technology Roadmap: Geothermal Heat and Power (2011)
- Technology Roadmap: Concentrating Solar Power (2010)

10. Technology Partnerships and Development

- Global EV Outlook 2017
- Status of Power System Transformation 2017
- Technology Roadmap: Delivering Sustainable Bioenergy (2017)
- Tracking Clean Energy Progress 2017
- Partner Country Series - Clean Energy Technology Assessment Methodology Pilot Study: Belarus (2016)
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- Solutions, analysis, and data for the global energy transition (2016)
- Technology Collaboration Programmes: Highlights and Outcomes (2016)
- The Clean Energy Technology Assessment Methodology: A Methodology for Assessing Renewable Energy and Energy Efficiency Technology Markets (2016)
- Tracking Clean Energy Progress 2016: IEA Input to the Clean Energy Ministerial
- Technology Roadmap: How2Guide for Smart Grids in Distribution Networks (2015)
- Technology Roadmap: Hydrogen and Fuel Cells (2015)
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    - Translation: Chinese
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    - Translation: Chinese; Russian; Arabic
- Technology Roadmap: Energy Storage (2014)
- Technology Roadmap: How2Guide for Wind Energy Roadmap (2014)
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- Technology Roadmap: Energy and GHG Reductions in the Chemical Industry via Catalytic Processes (2013)
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- Technology Roadmap: Bioenergy for Heat and Power (2012)
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- Technology Roadmap: Energy Efficient Buildings: Heating and Cooling Equipment (2011)
- Technology Roadmap: Geothermal Heat and Power (2011)
- Technology Roadmap: Smart Grids (2011)
  - Translation: Chinese
- Technology Roadmap: Concentrating Solar Power (2010)
- Technology Roadmap: Cement (2009)

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- Electricity Information 2017 (Excerpt)
- Next Generation Wind and Solar Power From Cost to Value (2016)
- Partner Country Series - Boosting the Power Sector in Sub-Saharan Africa: China's Involvement (2016)
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- Partner Country Series - Development Prospects of the ASEAN Power Sector: Towards an Integrated Electricity Market (2015)
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- Seamless Power Markets: Regional Integration of Electricity Markets in IEA Member Countries (2014)
- Technology Roadmap: Energy Storage (2014)
- Technology Roadmap: How2Guide for Wind Energy Roadmap (2014)
- Technology Roadmap: Solar Photovoltaic Energy (2014)
- Technology Roadmap: Solar Thermal Electricity (2014)
- Secure and Efficient Electricity Supply: During the Transition to Low Carbon Power Systems (2013)
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- Technology Roadmap: Wind Energy (2013)
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- Technology Roadmap: Hydropower (2012)
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- Saving Electricity in a Hurry (2011)
- Technology Development Prospects for the Indian Power Sector (2011)
- Technology Roadmap: Geothermal Heat and Power (2011)
- Technology Roadmap: Smart Grids (2011)
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- Cost and Performance of Carbon Dioxide Capture from Power Generation (2010)
- Technology Roadmap: Concentrating Solar Power (2010)

12. Buildings

- Market Report Series: Energy Efficiency 2018
- The Future of Cooling: Opportunities for energy-efficient air conditioning
- Policy Pathways Brief: Modernising Building Energy Codes (2017)
- Policy Pathways Brief: Monitoring, Verification and Enforcement (2017)
- Market Report Series: Energy Efficiency 2017
- Medium-Term Energy Efficiency Market Report 2016
- Building Energy Performance Metrics (2015)
- Partner Country Series - Energy Use in the Chinese Building Sector (2015)
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- Transition to Sustainable Buildings: Strategies and Opportunities to 2050 (2013)
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- Market Report Series: Energy Efficiency 2018
- The Future of Petrochemicals: *Towards more sustainable plastics and fertilisers* (2018)
- Insights Series: Renewable Energy in Industry Manufacturing (2017)
- Market Report Series: Energy Efficiency 2017
- Medium-Term Energy Efficiency Market Report 2016
- Policy Pathways: Accelerating Energy Efficiency in Small and Medium-sized Enterprises - Powering SMEs to catalyse economic growth (2015)
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- Energy Transition for Industry: India and the Global Context (2011)
- Technology Roadmap: Carbon Capture and Storage in Industrial Applications (2011)
- Technology Roadmap: Cement (2009)

14. Transport

- Market Report Series: Energy Efficiency 2018
- Nordic EV Outlook (2018)
- Global EV Outlook 2018
- Insights Series: The Future of Trucks (2017)
- International Comparison of Light-Duty Vehicle Fuel Economy 2005-2015 Ten Years of Fuel Economy Benchmarking (2017)
- Policy Pathways Brief: Improved Urban Transport Systems for Sustainable Cities (2017)
- Market Report Series: Energy Efficiency 2017
- Global EV Outlook 2016: Beyond One Million Electric Cars
- Medium-Term Energy Efficiency Market Report 2016
- Technology Roadmap: How2Guide for Smart Grids in Distribution Networks (2015)
- Technology Roadmap: Hydrogen and Fuel Cells (2015)
- Global Land Transport Infrastructure Requirements: Estimating road and railway infrastructure capacity and costs to 2050 (2013)
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- Policy Pathways: Improving the Fuel Economy of Road Vehicles - A policy package (2012)
- Technology Roadmap: Fuel Economy of Road Vehicles (2012)
- Technology Roadmap: Biofuels for Transport (2011)
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