Energy and the Sustainable Development Goals

Can an integrated approach spur faster action?

SUMMARY

- The Sustainable Development Scenario starts with the UN Sustainable Development Goals (SDGs) most closely related to energy: achieving universal energy access (SDG 7), reducing the impacts of air pollution (SDG 3.9) and tackling climate change (SDG 13). It then works back to set out what would be needed to deliver these goals in the most cost-effective way. The benefits in terms of prosperity, health, environment and energy security would be substantial, but achieving these outcomes would require a profound transformation in the way we produce and consume energy.

- There has been some recent progress towards the three SDGs on which our Sustainable Development Scenario is based. Energy access policies continue to bear fruit, with 2017 data showing promising signs. For the first time the number of people without access to electricity fell below 1 billion, and updated data show that the number of people without clean cooking facilities is declining gradually. India completed the electrification of all villages in early 2018, and plans to achieve universal access to electricity by the early 2020s. Meanwhile over 400 million people have gained access to clean cooking since 2011 in India and China as a result of liquefied petroleum gas (LPG) programmes and clean air policies. Despite significant steps forward in Kenya, Ethiopia, Tanzania and Nigeria, more than 600 million people are still without access to electricity in sub-Saharan Africa, and nearly 2.7 billion people worldwide still do not have access to clean cooking.

- Today energy-related outdoor air pollution leads to around 2.9 million premature deaths globally, and household air pollution, mostly from smoke due to cooking, is linked to more than 2.6 million premature deaths. Significant new policies have been announced to tackle pollution, including a three-year clean air action plan in China, but sustained progress in reducing health impacts still looks a long way off. At the same time, global energy-related carbon dioxide (CO_2) emissions increased in 2017 after three years of remaining flat, driven by economic growth and a slowdown in the spread of energy efficiency policies, despite increased deployment of renewables.

- Looking forward, current and planned policies, as embodied in the New Policies Scenario, are set to fall short of achieving each of the three energy-related SDGs. By 2030, 650 million people are still without electricity access, almost all in Africa, and 2.2 billion people worldwide still cook with solid fuels. Lower levels of air pollutants are insufficient to halt an increase in premature deaths linked to outdoor air pollution, projected to rise through 2030 to reach 4 million annually by 2040. Energy-related CO_2 emissions are set to rise gradually to 35.8 gigatonnes (Gt) in 2040.

- Our Sustainable Development Scenario provides a very different perspective. Enhanced efforts deliver universal access to electricity and clean cooking facilities by 2030. Sharp reductions in emissions of air pollutants lead to significantly cleaner air, bringing considerable health benefits: premature deaths from outdoor air pollution are half a million lower in 2040 than today. As well, CO_2 emissions decline rapidly in line with the objectives of the Paris Agreement.
- Analysis of the Sustainable Development Scenario suggests that there are important synergies between the three energy-related goals at its core. Decentralised renewables mean that a least-cost approach to electricity access does not significantly increase CO_2 emissions, and a move away from traditional use of biomass for cooking means that universal energy access can reduce overall greenhouse gas (GHG) emissions. Energy access also reduces premature deaths linked to smoke from cooking by 70% compared with current pathways.
- Energy efficiency is an essential component of the Sustainable Development Scenario, contributing to all three SDGs, as well as to energy security. Stronger policy action leads to substantially higher investment in energy efficiency, such that energy demand in 2040 is close to today's level, despite economic output more than doubling. On the supply side, there is a significant shift in investment towards low-carbon sources, particularly for power generation.
- Our analysis shows that further action on key cost-effective measures for reducing CO_2 emissions can reverse the increasing trend to achieve a near-term peak in emissions. Of five key measures with no net cost, proposed by the International Energy Agency (IEA) in 2015, only increasing investment in renewables is on track; there is ample scope for additional cost-effective action to reduce methane emissions from the oil and gas sector, to phase out the most inefficient forms of coal-fired power, to reduce fossil fuel subsidies and to boost energy efficiency. Strengthening the synergies with other development goals, including reducing air pollution, could bolster implementation of these measures to go further towards the objectives of the Sustainable Development Scenario.
- The Sustainable Development Scenario now also includes a water dimension, focusing both on the water needs of the energy sector and the energy needs of the water sector. As well as achieving the SDGs on energy access, air pollution and climate change, the Sustainable Development Scenario has the lowest water withdrawals among *World Energy Outlook* (*WEO*) scenarios, due in particular to a shift from thermal power to renewables. The analysis also reveals the benefits of an integrated approach to SDG 7 on energy access and SDG 6 on clean water and sanitation: decentralised renewables deployed in rural areas for energy access can also provide clean drinking water. Achieving universal access to clean water and sanitation would add less than 1% to global energy demand in 2030.

Introduction

Energy is essential to human society and economic activity, and providing access to affordable modern energy services is a prerequisite for eliminating poverty and reducing inequalities. In addition, energy is a major source of air pollution that causes severe health problems around the world, and it is the principal global source of greenhouse gas (GHG) emissions. For these reasons, energy features prominently in the United Nations Sustainable Development Goals (SDGs), agreed by 193 nations in 2015.

This chapter presents the Sustainable Development Scenario, depicting an energy future that simultaneously delivers on the SDGs most closely related to energy: universal energy access (SDG 7), reducing impacts of air pollution (part of SDG 3) and tackling climate change (SDG 13). Recognising that energy is also fundamental to many other aspects of development, we also explore links between the energy sector and access to fresh water and sanitation (SDG 6), as well the link between energy access and gender equality.

The first part of this chapter explains the rationale for the Sustainable Development Scenario, presents its outcomes, and provides an overview of the energy sector transformation required to meet these outcomes.

The second part of the chapter contains in-depth analysis of three topical themes:

- How are current global efforts progressing towards the objectives related to energy access, air pollution and carbon dioxide (CO_2) emissions? This section tracks recent progress and examines the outlook to 2040 in our New Policies Scenario. Incorporating new data on energy access as well as emissions, it provides an essential benchmark for assessing the impact of existing and announced policies.
- What measures in the energy sector could help reduce emissions further in the short term while also helping to deliver other development goals? This section assesses progress made on five measures, the components of the "Bridge Scenario" first put forward by the IEA in a *World Energy Outlook* (*WEO*) *Special Report* (IEA, 2015), and explores the scope for exploiting synergies with other development goals and for seeking better alignment across energy policies.
- What are the interactions between energy and water in terms of development goals? This section focuses on the energy implications of achieving the objectives of SDG 6 on water and sanitation, as well as the implications of the energy choices in the Sustainable Development Scenario for water use. The analysis quantifies the water needs of the energy-related SDGs and the energy required to fulfil SDG 6, as well as the links and synergies between them.

Figures and tables from this chapter may be downloaded from www.iea.org/weo2018/secure/.

Sustainable Development Scenario

2.1 Scenario design and overview

Our Sustainable Development Scenario shows how the energy sector can achieve the objectives of the UN SDGs most closely related to energy. Introduced as an integrated scenario for the first time in the *WEO-2017*, the scenario builds on decades of IEA work on energy access, air pollution emissions and energy-related CO_2.

The Sustainable Development Scenario starts with a set of desired outcomes, as defined by the relevant SDGs (Table 2.1). It then works back to show how the energy sector would need to change to achieve those goals in an integrated and cost-effective way. To do this, we first assess implications for the energy sector of achieving universal energy access. We then consider in parallel the outcomes related to reduction of air pollution and CO_2 emissions, in order to describe in detail an energy system that delivers all three goals. Additionally, we assess the water implications of the scenario as well as the energy needs of achieving universal access to clean water and sanitation.

The scenario clearly underscores that achieving these goals would require a profound transformation of the energy sector (Table 2.2).

Table 2.1 ▷ SDG outcomes in the Sustainable Development Scenario

SDG	SDG Objective	Outcomes in the Sustainable Development Scenario
SDG 7	By 2030, ensure universal access to affordable, reliable and modern energy services.	Universal access to both electricity and clean cooking achieved by 2030.
SDG 3	Ensure healthy lives and promote well-being for all (including target 3.9, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution).	Substantial reductions in major air pollutant emissions, so that by 2040 there are half a million fewer premature deaths linked to outdoor air pollution than today, and those linked to household pollution are reduced by nearly two million.
SDG 13	Take urgent action to combat climate change and its impacts.	Energy-related CO_2 emissions peak and then decline, fully in line with the objectives of the Paris Agreement. The CO_2 emissions trajectory to 2040 is consistent with a long-term global average temperature rise of 1.7-1.8 °C above pre-industrial levels.
SDG 6	Ensure availability and sustainable management of water and sanitation for all.	Water withdrawals are lower than in other *WEO* scenarios, including climate scenarios. While SDG 6 targets are not embodied in the outcomes of the Sustainable Development Scenario, we assess what achieving SDG 6 might look like under the conditions of the scenario, and find that the energy needs of achieving universal access to water and sanitation amount to less than 1% of global energy demand.

Table 2.2 ▷ Key energy indicators for the Sustainable Development Scenario

		Sustainable Development			New Policies	
	2017	2025	2030	2040	2030	2040
Access (million people)						
Population without access to electricity	993	382	0	0	649	720
Population without access to clean cooking	2 677	1 159	0	0	2 188	1 815
Related premature deaths	2.61*	1.60	0.60	0.67	2.38	2.23
Energy-related GHG emissions (Mt)						
CO_2 emitted	32 581	29 535	25 482	17 647	34 576	35 881
CO_2 captured via CCUS	8	150	710	2 364	50	83
CH_4 emitted	128	79	49	38	115	102
of which from oil and gas operations	79	40	19	18	66	55
Air pollution						
Premature deaths from energy-related outdoor air pollution (million people)	2.93*			2.39		4.04
Share of population exposed to $PM_{2.5}$ level above WHO guideline (Asia only)**	92%	88%	82%	68%	91%	91%
Primary energy supply						
Total primary energy supply (Mtoe)	13 972	14 146	13 820	13 715	16 167	17 715
Share of non-fossil energy sources	19%	23%	28%	40%	23%	26%
Energy intensity of GDP (toe/$1 000)	110	83	68	50	80	64
Power generation						
CO_2 intensity of generation (g CO_2/kWh)	484	332	221	69	368	315
Share of low-carbon generation	35%	49%	63%	86%	46%	51%
Final consumption						
Total final consumption (Mtoe)	9 696	10 126	10 007	9 958	11 474	12 581
Share of non-combustible fuels	23%	25%	27%	33%	25%	27%
Industry						
Energy intensity (toe/$1 000 VA)	0.13	0.11	0.10	0.08	0.10	0.09
CO_2 intensity (t CO_2/$1 000 VA)	0.27	0.22	0.18	0.12	0.21	0.18
Transport						
Electric PLDVs (million)	3	69	236	933	108	304
Carbon intensity of new PLDVs (g CO_2/v-km)	170	96	57	30	111	97
Carbon intensity of freight vehicles (g CO_2/t-km)	93	74	59	39	71	60
Shipping emissions (Mt CO_2)	854	847	830	684	1 064	1 194
Aviation emissions (Mt CO_2)	925	902	871	803	1 163	1 408
Buildings						
Energy intensity of residential buildings (toe/dwelling)	1.04	0.84	0.71	0.64	0.94	0.91
Energy intensity of services buildings (toe/$1 000 VA)	0.017	0.014	0.012	0.010	0.014	0.012

*Data for year 2015. **World Health Organization guideline (average $PM_{2.5}$ concentration of 10 μg/m^3). Notes: See Annex B for details of the scenarios. Mt = million tonnes; CCUS = carbon capture, utilisation and storage; GDP = gross domestic product; $PM_{2.5}$ = particulate matter with a diameter of less than 2.5 micrometres, CH_4 = methane; WHO = World Health Organization; Mtoe = million tonnes of oil equivalent; toe = tonnes of oil equivalent; t = tonnes; $ = US dollar (2017); g = gramme; kWh = kilowatt-hour; VA = value added; PLDVs = passenger light-duty vehicles; v-km = vehicle-kilometre; t-km = tonne-kilometre.

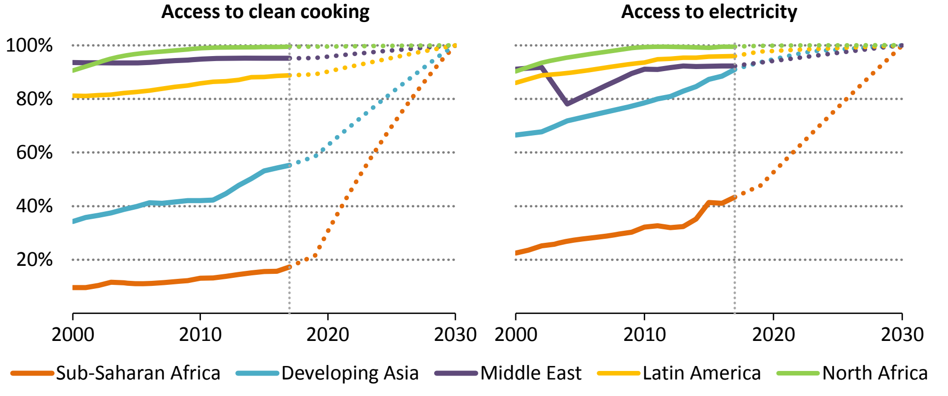
2.2 Scenario outcomes: Universal energy access

In the Sustainable Development Scenario, universal access to both electricity and clean cooking facilities is achieved by 2030, in line with target 7.1 of SDG 7 (Figure 2.1). Targets 7.2 (on renewables) and 7.3 (on energy efficiency) are also achieved in the scenario (see Chapter 6). Given expected strong population growth over that period, particularly in countries where many people still lack access, achieving universal access means a cumulative total of around 1.2 billion new electricity connections to 2030, and around 2.5 billion people gaining access to cleaner cooking facilities for the first time over the period. This reduces the health impact of air pollution, brings gender equality dividends, and is achieved without increasing GHG emissions (IEA, 2017a).

The least expensive way to achieve universal electricity access in many areas is with renewable energy sources, thanks to the declining costs of small-scale solar photovoltaic (PV) for off-grid and mini-grid electricity and the increasing use of renewables for grid-connected electricity. This is especially the case in rural areas in African countries, home to many of the people still deprived of electricity access.

The means of achieving clean cooking depends on the availability of biomass and liquefied petroleum gas (LPG) in different regions. Overall, LPG is the most cost-effective means to access clean cooking in more than half of all cases, with most of the rest moving to improved and more energy-efficient biomass cookstoves. The resulting increase in LPG demand leads to a small increase in CO_2 emissions, but the overall GHG effect is more than offset by reduced methane emissions from incomplete combustion of biomass as those using LPG turn away in many cases from burning wood and other biofuels (IEA, 2017a; Singh, Pachauri and Zerriffi, 2017).

Figure 2.1 ▷ Proportion of population with access to electricity and clean fuels for cooking in the Sustainable Development Scenario



A rapid acceleration in access rates is required, in particular for clean cooking in sub-Saharan Africa and developing Asia

2.3 Scenario outcomes: Air pollution

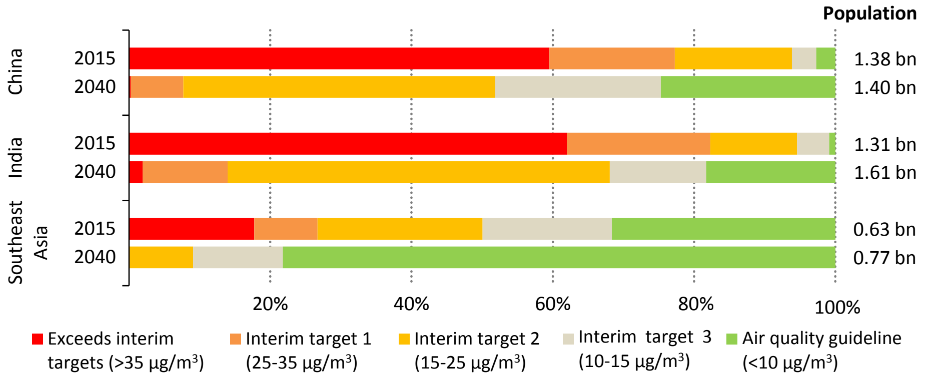
Air pollution is a major health and environmental issue. Outdoor air pollution is linked to 2.9 million premature deaths globally each year, and household air pollution, mostly from the traditional use of biomass as a cooking fuel, to more than 2.6 million premature deaths. Air pollution is the fourth-largest threat to human health globally (HEI, 2018).

In the Sustainable Development Scenario, emissions of the three major air pollutants – sulfur dioxide (SO_2), nitrogen oxides (NO_X) and fine particulate matter ($PM_{2.5}$) – decline sharply from current levels, despite global energy demand remaining nearly constant. The result is a major reduction in health impacts; premature deaths linked to outdoor air pollution fall by half a million and premature deaths from household air pollution by 1.9 million. Reduced exposure to $PM_{2.5}$ is particularly important in this respect (IEA, 2016a), and far more people enjoy lower levels of $PM_{2.5}$ in 2040 than today (Figure 2.2).

Power sector emissions of SO_2 are almost eliminated in the Sustainable Development Scenario, with industry becoming the main source of emissions by 2040, albeit at levels less than half of today. Emissions of NO_X, which occur predominantly in the transport sector, drop by nearly half by 2040, thanks to improved pollution controls and fuel switching.

Universal access to clean cooking is instrumental in almost eliminating residential $PM_{2.5}$ emissions, with industry becoming the largest direct source of these emissions by 2040, followed by transport. Nearly a quarter of particulate emissions from transport are from non-combustion sources, such as abrasion of brakes and tyres, which are just as much of an issue with electric vehicles as with other vehicles fuelled by oil-based products.

Figure 2.2 ▷ Exposure to fine particulate pollution ($PM_{2.5}$) in selected regions, 2015, and in the Sustainable Development Scenario, 2040



The proportion of populations exposed to high levels of fine particulates drops dramatically, with far fewer people exposed to levels exceeding the lowest interim WHO target

Notes: bn = billion; µg/m³ = micrograms per cubic metre. Interim targets and Air Quality Guideline refer to World Health Organization exposure thresholds.

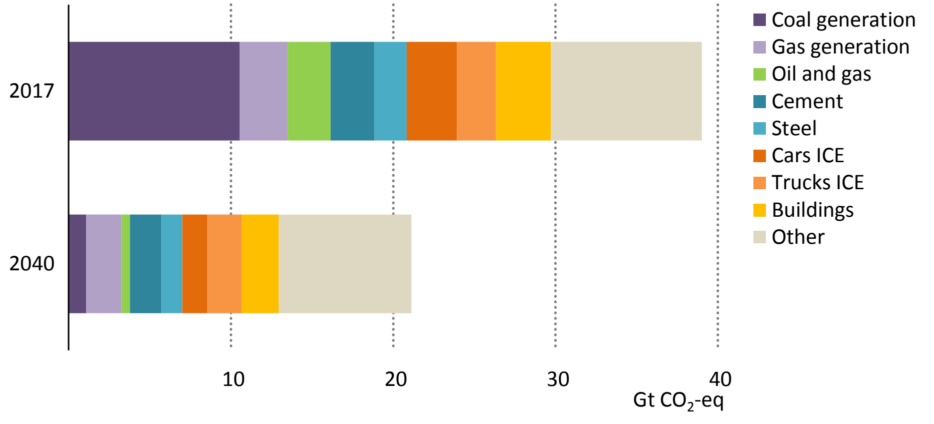
Source: IEA analysis; International Institute for Applied Systems Analysis.

2.4 Scenario outcomes: CO_2 and other GHG emissions

In the Sustainable Development Scenario, global energy-related CO_2 emissions peak around 2020 and then enter a steep and sustained decline, fully in line with the trajectory required to achieve the objectives of the Paris Agreement on climate change. By 2040, the global emissions profile is very different from today.

In 2017, GHG emissions from energy and industrial processes (including methane and nitrous oxide as well as CO_2) amounted to about 39 gigatonnes of CO_2 equivalent (Gt CO_2-eq). Three-quarters of this is accounted for by only eight source categories (Figure 2.3). The largest category by far is coal-fired power generation, with 2 053 gigawatts (GW) of capacity accounting for 27% of emissions. Buildings made up nearly 9% in 2017, followed by about 8% each for gas-fired power generation and petroleum-fueled cars (more than 1 billion cars). Emissions from cement production and oil and gas operations accounted for 7% each,[1] with trucks (202 million vehicles) making up 6% and steel around 5% of the total.

Figure 2.3 ▷ GHG emissions from selected sectors, 2017, and in the Sustainable Development Scenario, 2040



Eight source categories account for three-quarters of today's energy-related GHG emissions; power sector emissions drop by 76% by 2040 in the Sustainable Development Scenario

Notes: Includes CO_2, methane and nitrous oxide emissions from fuel combustion and CO_2 emissions from industrial processes. ICE= internal combustion engine. Other includes energy-related GHG emissions from other sectors. 100-year global warming potential of fossil methane = 30, nitrous oxide = 265.

In the Sustainable Development Scenario, GHG emissions from fuel combustion and industrial processes fall to about 21 Gt CO_2-eq in 2040. The same eight categories account for around 60% of emissions in 2040, but the split between them changes.

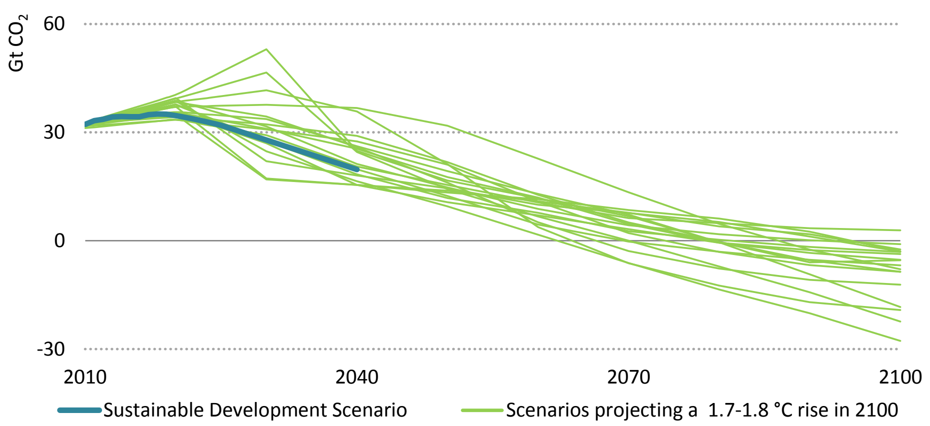
1. See Chapter 11 for a detailed life-cycle analysis of GHG emissions from the oil and gas sector, including emissions from refining and transportation of oil and gas, as well as venting of CO_2 and flaring of methane. The broader scope of that analysis results in oil and gas accounting for a higher proportion of total energy-related emissions than is reported here.

Emissions from coal-fired power fall by 90% to account for only 5% of total GHG emissions. Buildings become the largest emitter in 2040 (11%) followed by gas-fired power generation and trucks (around 10% each). Emissions from trucks nevertheless decrease in absolute terms by 15%, as efficiency improvements absorb a 40% increase in vehicle stock. Cement production accounts for 9% of emissions (of which the majority is process emissions). Emissions from cars fall by half, despite the number of cars increasing by more than 60% (of which about 50% are electric), and those with internal combustion engines (ICEs) have vastly improved efficiency (see Chapter 3). Oil and gas sector emissions reduce significantly, mostly due to improvements in the GHG intensity of supply (see Chapter 11).

The CO_2 emissions trajectory to 2040 in the Sustainable Development Scenario is lower than most published decarbonisation scenarios based on limiting long-term global average temperature rise to 1.7-1.8 °C above pre-industrial levels (Figure 2.4, CO_2 only). What happens after 2040 is also critical for the climate outcome, and a continuation of the pre-2040 emissions reduction rate in the scenario would lead to global energy-related CO_2 emissions falling to net-zero by 2070.

Maintaining or accelerating the rate of reduction of energy- and process-related emissions up to and beyond 2040 is likely to require robust technological innovation. The power sector decarbonises rapidly before 2040, highlighting the importance of other sectors, including those where emissions reductions are more challenging, such as industry and freight transport (Table 2.3). Other important sectors for innovation include carbon capture, utilisation and storage (CCUS) and so-called "negative emissions" technologies that allow CO_2 to be withdrawn from the atmosphere at scale in the second-half of the century.

Figure 2.4 ▷ CO_2 emissions in the Sustainable Development Scenario and other "well below 2 °C" scenarios (1.7-1.8 °C)



The CO_2 emissions trajectory to 2040 in the Sustainable Development Scenario is at the lower end of a range of scenarios projecting a global temperature rise of 1.7-1.8 °C in 2100

Notes: Figure shows energy-related CO_2 emissions, including CO_2 emissions from industrial processes. Scenarios projecting a median temperature rise in 2100 of around 1.7-1.8 °C above pre-industrial levels are those following Representative Concentration Pathway (RCP) 2.6 in the Shared Socioeconomic Pathways database. See https://tntcat.iiasa.ac.at/SspDb/.

Table 2.3 ▷ Energy-related CO_2 emissions by sector and fuel in the Sustainable Development Scenario

	CO_2 emissions (Mt)						CAAGR	
	2000	2017	2025	2030	2035	2040	2000-17	2017-40
By sector								
Power	9 305	13 587	10 656	7 839	5 127	3 292	2.3%	-6.0%
Industry	3 922	6 154	6 273	5 936	5 481	5 081	2.7%	-0.8%
Transport	5 757	7 986	7 932	7 326	6 373	5 563	1.9%	-1.6%
Buildings	2 714	2 997	2 767	2 593	2 367	2 202	0.6%	-1.3%
Other	1 424	1 856	1 907	1 788	1 633	1 510	1.6%	-0.9%
By fuel								
Coal	8 951	14 448	11 335	8 335	5 577	3 855	2.9%	-5.6%
Oil	9 620	11 339	10 657	9 501	8 032	6 886	1.0%	-2.1%
Gas	4 551	6 795	7 543	7 645	7 373	6 906	2.4%	0.1%
Total	**23 123**	**32 581**	**29 535**	**25 482**	**20 982**	**17 647**	**2.0%**	**-2.6%**
New Policies Scenario			*33 902*	*34 576*	*35 157*	*35 881*	*2.0%*	*0.4%*
Current Policies Scenario			*35 454*	*37 748*	*40 103*	*42 475*	*2.0%*	*1.2%*

Notes: CAAGR = compound average annual growth rate. Data are for CO_2 only and exclude process-related emissions in industry. Industry includes blast furnaces and coke ovens. Other includes energy-related emissions in energy transformation and agriculture.

2.5 Energy sector transformation in the Sustainable Development Scenario

2.5.1 *Total final consumption*

In the Sustainable Development Scenario, the world energy system undergoes a series of sustained changes from now until 2040. Energy consumption patterns shift, driven first and foremost by energy efficiency across all major sectors. The result is that total final energy consumption stays nearly flat through to 2040, despite economic output more than doubling. The importance of energy efficiency for reducing CO_2 emissions is analysed in more detail in *Energy Efficiency 2018* (IEA, 2018a).

Within this more efficient energy system, there is a general trend towards more use of electricity and increased direct use of renewable energy. The proportion of electricity in total final consumption rises from 19% today to 28% in 2040.

Industry is the only end-use sector to see a substantial increase in energy consumption from 2017 to 2040: energy efficiency gains in industry do not quite keep up with growth of industrial economic output in the Sustainable Development Scenario (Table 2.4). Across the industry sector, there is a shift away from direct use of coal towards electricity and the direct use of solar thermal and geothermal (see Chapter 9).

Total final consumption in the transport sector stays almost flat through to 2040, though its use of electricity expands on average by 11% every year. By 2040, electricity is powering more than 900 million electric cars worldwide, accounting for over 50% of the fleet. The implication of electric vehicles (EVs) for climate change efforts depends, however, on measures to decarbonise the power sector (see section 2.8.2). Oil use in transport, by far the dominant energy source for transport today, falls by nearly 40% by 2040, partly due to growth in EVs, but mostly because of improvements in the efficiency of internal combustion engines.

Improved energy efficiency means energy use in the buildings sector is close to today's level by 2040, despite a rapidly growing stock of buildings in developing countries. Electricity and district heating, already the dominant energy carriers, grow strongly, mainly because of increased appliance ownership and cooling demand. Coal and oil both decline in favour of cleaner fuels for heating. A further marked change is a sharp reduction of the traditional use of biomass for cooking, an evolution that goes hand-in-hand with energy access and helps to reduce health impacts of indoor air pollution.

Table 2.4 ▷ Total final consumption in the Sustainable Development Scenario (Mtoe)

							2017-2040	
	2000	2017	2025	2030	2035	2040	Change	CAAGR
Industry	1 863	2 855	3 121	3 155	3 162	3 197	12%	0.5%
Electricity and heat	563	908	1 013	1 027	1 034	1 053	16%	0.6%
Renewables	162	205	248	277	309	340	66%	2.2%
Coal	400	803	799	760	707	665	-17%	-0.8%
Oil	326	321	319	303	286	272	-15%	-0.7%
Gas	412	618	741	788	827	866	40%	1.5%
Transport	1 958	2 794	2 945	2 895	2 748	2 640	-6%	-0.2%
Electricity	19	33	66	130	245	364	1 020%	11.1%
Biofuels	10	86	208	280	319	351	308%	6.3%
Oil	1 871	2 567	2 500	2 243	1 877	1 581	-38%	-2.1%
Other*	58	109	172	242	307	344	217%	5.1%
Buildings	2 450	3 047	2 905	2 755	2 802	2 860	-6%	-0.3%
Electricity	579	982	1 101	1 205	1 305	1 405	43%	1.6%
District heating	143	145	143	141	137	134	-8%	-0.4%
Direct renewables**	93	152	208	256	306	358	136%	3.8%
Coal	109	127	81	55	29	13	-90%	-9.3%
Oil	346	319	280	252	221	201	-37%	-2.0%
Gas	535	665	696	703	691	672	1%	0.0%
Traditional use of biomass	646	658	396	144	112	77	-88%	-8.9%
Other TFC	765	999	1 155	1 201	1 234	1 261	26%	1.0%
Total	**7 036**	**9 696**	**10 126**	**10 007**	**9 946**	**9 958**	**3%**	**0.1%**
New Policies Scenario			*10 871*	*11 474*	*12 018*	*12 581*	*30%*	*1.1%*
Current Policies Scenario			*11 103*	*11 911*	*12 704*	*13 510*	*39%*	*1.5%*

*Other in the transport sector includes gas, hydrogen and coal. **Direct renewables in the buildings sector refers to geothermal, solar thermal and the modern use of biomass. Note: CAAGR = compound average annual growth rate; TFC = total final consumption.

2.5.2 Primary energy demand

Overall primary energy demand stays flat in the Sustainable Development Scenario, despite strong economic growth, as supply-side energy efficiency keeps pace with end-use efficiency gains (Table 2.5). The shifts in energy consumption and power generation mean that renewables increase by a factor of eight in primary energy terms by 2040 (excluding hydro and bioenergy). The uptake of modern uses of solid bioenergy increases, although the costs of ensuring low levels of air pollutant emissions constrain deployment. Traditional use of biomass declines dramatically, an effect of achieving universal energy access.

Total demand for coal (including power generation, industry, buildings and other uses) falls to less than half of today's level. Use of coal in unabated power plants (not equipped with CCUS) drops by more than 90%.

Declining demand in the transport sector means that total oil demand peaks in 2020, though its subsequent decline is slowed somewhat by continued robust demand for oil products as a feedstock for petrochemicals (see Chapter 3).

Demand for natural gas continues to grow until 2030 before flattening through to 2040. Gas use is driven primarily by heating and industrial demand, offset by slowing demand from power generation. In the Sustainable Development Scenario, there is a major reduction in methane emissions from the production and transport of natural gas (see section 2.8).

Table 2.5 ▷ Primary energy demand in the Sustainable Development Scenario (Mtoe)

							2017-2040	
	2000	2017	2025	2030	2035	2040	Change	CAAGR
Coal	2 308	3 750	3 045	2 416	1 917	1 597	-57%	-3.6%
Oil	3 665	4 435	4 334	3 985	3 515	3 156	-29%	-1.5%
Gas	2 071	3 107	3 454	3 554	3 532	3 433	10%	0.4%
Nuclear	675	688	861	1 013	1 182	1 293	88%	2.8%
Renewables*	662	1 334	2 056	2 707	3 430	4 159	212%	5.1%
Hydro	225	353	431	492	548	601	70%	2.3%
Modern biomass	377	726	976	1 132	1 283	1 427	96%	3.0%
Other	60	254	648	1 083	1 598	2 132	739%	9.7%
Traditional use of biomass	646	658	396	144	112	77	-88%	-8.9%
Fossil fuel share	80%	81%	77%	72%	65%	60%		
of which equipped with CCUS	*0%*	*0%*	*1%*	*2%*	*6%*	*10%*		
Energy intensity (toe/$1 000 GDP-PPP)	0.14	0.11	0.08	0.07	0.06	0.05	-55%	-3.4%
Total	**10 027**	**13 972**	**14 146**	**13 820**	**13 688**	**13 715**	**-2%**	**-0.1%**
New Policies Scenario			*15 388*	*16 167*	*16 926*	*17 715*	*27%*	*1.0%*
Current Policies Scenario			*15 782*	*16 943*	*18 125*	*19 328*	*38%*	*1.4%*

* Renewables excludes the traditional use of biomass. Note: CAAGR = Compound average annual growth rate; CCUS = carbon capture, utilisation and storage; toe = tonnes of oil equivalent; PPP = purchasing power parity.

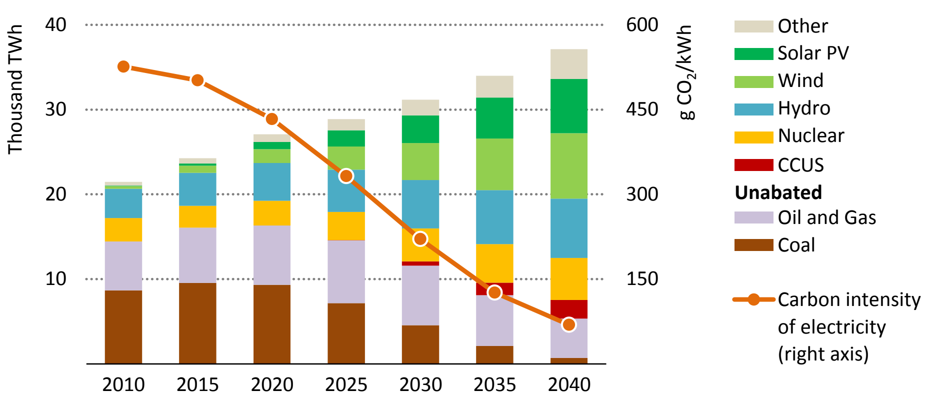
2.5.3 Power generation

With a rising proportion of electricity in final energy use, in the Sustainable Development Scenario the power sector plays an increasingly critical role in delivering the access, air pollution and climate outcomes. While total electricity generated increases by nearly 45% to reach 37 000 TWh by 2040 in the Sustainable Development Scenario, the share of renewables in generation nearly triples to 66%. The biggest growth in generation comes from solar PV, which increases by a factor of sixteen, and from wind, which increases by a factor of seven. Renewables account for more than 80% of new capacity additions by 2025.

Coal-fired power generation rapidly loses ground in the Sustainable Development Scenario. By 2040, it accounts for only 5% of total generation, and two-thirds of remaining coal generation is from plants equipped with CCUS. Plant retirements average around 60 GW per year to 2040. Natural gas-fired generation initially grows, playing a role to balance renewables and to displace coal, helped by its low air pollution emissions and lower carbon intensity.

The average carbon intensity of electricity generated continues its decline from around 500 grammes of CO_2 per kilowatt-hour (g CO_2/kWh) today to around 70 g CO_2/kWh in 2040 (Figure 2.5). The falling carbon intensity of power generation is an essential pillar of the Sustainable Development Scenario, especially with electricity playing a rapidly growing role in meeting end-use energy demands. (The role of the power sector in the Sustainable Development Scenario is explored in more detail in Chapter 9.)

Figure 2.5 ▷ Power generation and carbon intensity of electricity in the Sustainable Development Scenario



The power sector evolves rapidly with low-carbon sources accounting for 50% of power generation by 2025 and 85% by 2040

Note: TWh = terawatt-hours; g CO_2/kWh = grammes of CO_2 per kilowatt-hour; CCUS = carbon capture, utilisation and storage.

2.6 Investment in the Sustainable Development Scenario

Average annual supply-side investment in the Sustainable Development Scenario through to 2040, including fuel supply and power supply, increases by about 15% from today's level. However, this masks a significant reallocation away from fossil fuels towards renewables and other low-carbon sources, for both fuel supply and power generation (Figure 2.6).

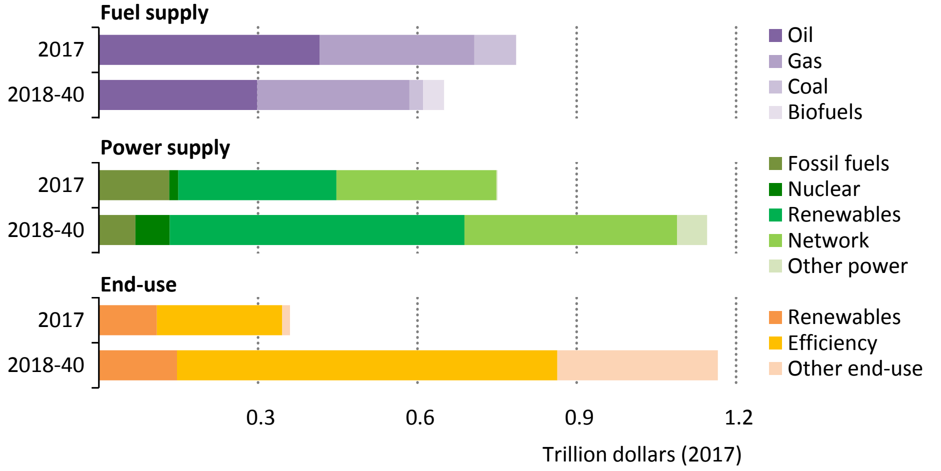
Continued investment in oil supply is required to compensate for declines in existing production; without investment, production would taper off far faster than the fall in oil demand, even in the Sustainable Development Scenario (see Chapter 3). In the case of gas, investment is also required to meet the increase in demand to 2030.

The story is different on the demand side. Annual demand-side investment needs in the Sustainable Development Scenario are more than three-times higher than today's level. This reflects the importance of energy efficiency in achieving energy transitions.

Demand-side investment needs are particularly large in the buildings and transport sectors. In buildings, this includes efficiency measures such as thermal insulation and efficient lighting, as well as measures for appliances. In transport, the investment total includes the shift towards EVs as well as the costs of more efficient internal combustion engines.

Total investment in energy to 2040 in the Sustainable Development Scenario is around 13% higher than in the New Policies Scenario. Payback periods for efficiency investments vary over time and across sectors (IEA, 2018b).

Figure 2.6 ▷ Energy sector investment in 2017 and average annual investment in the Sustainable Development Scenario, 2018-2040



Total supply-side investment stays almost at today's level, with a reallocation towards renewables. Demand-side investment increases substantially.

Note: Other power includes CCUS and battery storage. Other end-use includes CCUS in industry and alternative power trains in transport (e.g. electric cars, natural gas vehicles, fuel cell vehicles).

The investment needed to achieve universal energy access is small relative to the broader investment needs of the energy sector. Achieving universal energy access requires investment of some $55 billion per year between 2018 and 2030, the lion's share of it for electricity access. This is about 2% of the total annual energy sector investment in the scenario from today until 2030, but is almost double the investment for energy access in the New Policies Scenario, with 82% of the additional investment needed in sub-Saharan Africa.

About 25% of investment for energy access is required for infrastructure to extend and reinforce grid transmission and distribution, and to build mini-grid distribution networks to deliver universal electricity access. Nearly 70% is required for investment in new generation: of this, over three-quarters is for generation from renewable sources, mostly for mini-grid and stand-alone renewables. Only about 7% of the investment for universal access is required for clean cooking facilities.

Key themes

2.7 Tracking progress towards energy-related SDGs

The Sustainable Development Scenario outlines what is needed to deliver the agreed Sustainable Development Goals in a cost-effective manner. Current policies and trends, as embodied in the New Policies Scenario, fall a long way short of those outcomes. This is true for each of the three core dimensions of the scenario: energy access, air pollution and CO_2 emissions.

The 2018 update of the IEA's *Tracking Clean Energy Progress*[2] benchmarked global progress on a wide range of clean energy developments against the deployment levels required to achieve the three parallel outcomes of the Sustainable Development Scenario in 2025 and 2030 (IEA, 2018c). In power generation, only solar PV has been growing in line with what would be required to deliver the projected levels. On the demand side, EVs and light emitting diodes (LEDs) show recent growth rates aligned with the trajectory of the Sustainable Development Scenario. Most other energy supply and demand technologies have been developing in ways that are not in line with the vision of the Sustainable Development Scenario.

2.7.1 Progress and outlook for energy access

Status of electricity access

Our latest country-by-country assessment shows that the number of people without electricity access dipped below 1 billion for the first time in 2017.[3] The fact that 99 million people gained access to electricity during 2017 is a reflection of the ongoing strong policy

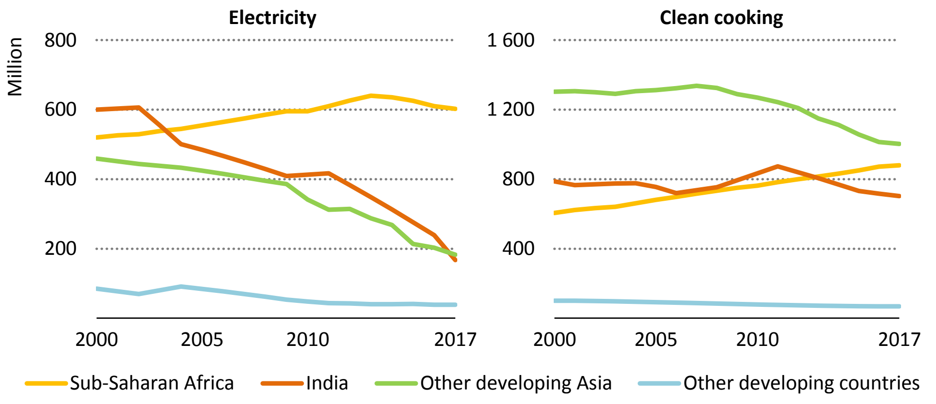
2. See: www.iea.org/tcep/.

3. Country-by-country data through 2017 and projections though 2030 on energy access can be found at: www.iea.org/sdg. The IEA's methodology for quantifying and modelling energy access can be found at: www.iea.org/energyaccess/methodology.

efforts reported in a *WEO Special Report – Energy Access Outlook 2017* (IEA, 2017a). However, the pace of progress varies greatly among regions, with around three-quarters of the 550 million people who have gained access since 2011 concentrated in Asia (Figure 2.7).

Over 900 million people have gained access to electricity in developing economies in Asia since 2000, with 91% of the region having access to electricity in 2017 compared with 67% in 2000. Nearly 60% of this progress has occurred in India, which continues to make remarkable progress towards its target to deliver universal electricity access. Many other Asian countries have also seen significant progress. In Bangladesh, electricity now reaches 80% of the population, up from 20% in 2000, and in Indonesia, the electrification rate is now nearly 95%.

Figure 2.7 ▷ Population without modern energy access



Electricity access has outpaced population growth in all world regions since 2013, but the picture is still deteriorating for clean cooking in sub-Saharan Africa

The number of people without access to electricity in sub-Saharan Africa continues to decline, albeit slowly. Over 200 million people have gained access since 2000, less than the overall population increase. As a result, there remain more than 600 million people without access, despite an increase in the access rate of 20 percentage points to 43%. Furthermore, recent efforts have been uneven, with around 60% of the progress seen since 2011 concentrated in just four countries (Kenya, Ethiopia, Tanzania and Nigeria), which together account for only 31% of the population without electricity access in sub-Saharan Africa. In Kenya, the access rate has increased by over 65 percentage points from 2000 to 73% today, and the Last Mile Connectivity Project aims to deliver universal access by 2022. In Ethiopia, electricity now reaches 45% of the population compared with 5% in 2000. The National Electrification Program, launched in 2017, outlines a plan to reach universal access by 2025, aiming to reach 35% of the population with off-grid solutions. In South Africa, while the current electrification rate is relatively high (84%) it has been declining since 2014, in large part because electrification in urban areas has not kept pace with migration from rural areas.

SPOTLIGHT

Empowering women: the link between gender equality and energy access

The proliferation of modern energy and appliances in the 20th century played a critical role in empowering women in developed countries. Achieving modern energy for all (SDG 7.1) will play an equally critical role in empowering women who do not yet have such access, helping to improve gender equality, an ambition articulated by SDG 5. The two goals are symbiotic – consideration of gender issues bolsters the success of on-the-ground universal energy access programmes. Recognition of these synergies is growing, as governments begin to consider gender issues in mainstream energy access policies (ENERGIA, World Bank and UN Women, 2018), and as the wider energy community begins to pay attention to issues of women's empowerment, education and leadership, for example through the IEA's Clean Energy Education and Empowerment Technology Collaboration Programme (C3E TCP).

A lack of modern energy access disproportionally affects women. Typically responsible for cooking, cleaning, and fetching fuelwood and water, women in developing countries suffer from exposure to household smoke, and often spend significant amounts of time on domestic chores, limiting their participation in education and economic activities. Time use surveys from Mexico reveal that women in households with a refrigerator, gas stove and washing machine spend up to seven fewer hours on domestic labour weekly than those in households without them (Orozco Corona and Gammage, 2017). The rise in female employment in advanced countries in the 20th century has been attributed to the time savings stemming from the diffusion of modern technologies within the home (Lewis, 2014), a trend which has supported economic growth and better gender equality (Tsani et al., 2013). Time saved from chores may allow more attention to child and health care, which in turn can facilitate better education and can help to drive down both child mortality and fertility rates.

For women to reap the benefits of modern energy, the provision of access needs to go beyond providing households with electricity connections. Equitable outcomes cannot be met unless modern energy is made available for a wide range of services, especially those strongly related to gendered roles in society. This requires more than a basic level of electricity supply. For example:

- Over 1.7 billion households have an electricity supply, but still rely on polluting sources for cooking. Providing clean cooking facilities costs a fraction compared to electricity access, but often is a low priority, with a few exceptions (Box 2.1).
- In rural areas, electricity for water pumps tends to prioritise agriculture. If these pumps would also provide water for domestic use, they would significantly reduce women's workload (Winther, 2006).

Further progress on making sure energy policies reduce gender inequalities can also be achieved by:

- Considering gender when designing fiscal policies, in particular fuel subsidies (Kusumawardhani et al., 2017). Recognising this, India recently introduced the Pradhan Mantri Ujjwala Yojana (PMUY) policy for LPG connections specifically targeting poorer women.
- Involving women in the energy access supply chain. This has been shown not only to give women opportunities for rewarding income generation, but also to improve community confidence in the supply chain and encourage the uptake of off-grid electricity systems and clean cooking solutions (Winther et al., 2018). Women's hands-on involvement in the technical and entrepreneurial aspects of energy supply can also challenge existing norms and empower women in decision making. For example, the Barefoot College in India trains women with little education to install and maintain solar home systems, helping to establish women as entrepreneurs and to promote female education.

Status of clean cooking access

Nearly 2.7 billion people lack access to clean cooking facilities, relying on biomass, coal or kerosene as their primary cooking fuel. In the past, progress has been very limited compared to progress in electricity access. However, this year the *WEO* reports a turning point, with updated data showing a gradual decline in the number of people worldwide without clean cooking access.

Developing Asia is home to around 65% of the global population without access, with 1.7 billion people lacking clean cooking facilities. Five-times more people lack clean cooking access than electricity in this region. However, the latest data shows promising signs, with 525 million people gaining access since 2011, compared with only 250 million between 2000 and 2011. In India and China, access rates have reached 47% and 70% respectively. In India, national data show a reduction of 14 percentage points in the share of population relying on biomass and kerosene between 2011 and 2015, with most now using LPG instead. Since 2015, government figures indicate that an additional 50 million free LPG connections have been provided to poor households via the high-profile PMUY scheme (Box 2.1). In China, natural gas infrastructure development is helping to reduce the use of biomass and kerosene. Several other countries in developing Asia are also making efforts to promote clean cooking, employing different methods depending on the national context.

The challenge in sub-Saharan Africa remains acute, with a deteriorating picture. Only 17% of the population have clean cooking access. The vast majority of the 890 million people without access rely on gathering biomass for cooking, in particular in rural areas. This damages health and impairs productivity improvements. Strong population growth means that almost 275 million more Africans now lack clean cooking access than in 2000.

Deforestation, linked to biomass collection, is also becoming a major concern: the region lost 13% of its forest area between 1990 and 2015.

However, 68 million people have gained clean cooking access in sub-Saharan Africa since 2000, mostly in Ethiopia, Ghana, Kenya, Nigeria, South Africa and Sudan. In Sudan, around half of the urban population uses domestically refined LPG for cooking, though the government seeks to import LPG to supplement local supply. In Kenya, LPG is now used by 24% of urban households. It is displacing kerosene as government initiatives aim to reduce biomass use, however, 96% of rural households still use biomass. In Ethiopia, LPG is the primary cooking fuel for less than 0.5% of households, but gains in electricity access are beginning to make an impact, with nearly a quarter of urban households cooking with electricity in 2016 compared with only 3% in 2011. In South Africa, electricity is the main clean cooking fuel, used by three-quarters of households nationally.

Box 2.1 ▻ On the boil: how are countries improving clean cooking access?

Despite slow progress globally, a number of countries are bucking the trend and making significant progress in delivering clean cooking access. Cross-analysing household surveys of cooking fuel use with national energy balances and policies reveals that governments are taking various approaches to achieve clean cooking access.

Concerned about an estimated 640 000 premature deaths annually attributed to household air pollution, the Indian government has given free LPG connections to over 50 million households living below the poverty line, providing a gas stove, one cylinder and the first fill.[4] In 2018, the government increased the ambition of the target from 50 million to 80 million households by 2020.[5] The Ujjwala scheme (PMUY) provides the subsidy directly to women's bank accounts that are linked to a national database to prevent duplication and identity theft. There is an emphasis on promoting employment through locally made equipment. The next challenge is to ensure the consistent use of LPG to displace biomass, which is typically free. Government figures show that households who have received a free connection buy around 3.5 cylinders of LPG per year, displacing around one-quarter of fuelwood in the households that have taken up the scheme, or 6% of total biomass used in India's households.

In Bangladesh, surveys show that reliance on biomass, now at 77%, fell by nine percentage points between 2011 and 2016. Use of natural gas has increased, and it is now the main cooking fuel for over 20% of households. The promotion of natural gas for domestic purposes is relatively unusual in developing countries. Now that the government seeks to secure gas supply for industrial development and power generation, it plans to refocus support for households on LPG, which can reach villages

4. http://www.pmujjwalayojana.com/.

5. https://energy.economictimes.indiatimes.com/news/oil-and-gas/omcs-defer-loan-amount-recovery-from-ujjwala-beneficiaries-for-next-6-refills/63433001.

without a piped supply of gas, given adequate transport infrastructure. The main national development finance institution, Infrastructure Development Company Ltd. (IDCOL), also promotes improved cookstoves in support of the target of 100% coverage by 2030 set out in Bangladesh's Country Action Plan for Clean Cookstoves.

In Myanmar, policy makers are promoting clean cooking in part because of the high rate of deforestation, which has reached an annual rate of 2%. Reliance on biomass fell from 94% of the population in 2009 to 76% in 2015, with biomass mainly replaced by electricity. The government is now subsidising LPG connections to free up electricity supply and further move away from biomass use.

In sub-Saharan Africa, few countries have reached a high level of LPG penetration, but several have set ambitious goals. In Cameroon, where the LPG penetration rate is currently 21%, the government has published the region's first "masterplan" setting out concrete measures to increase the share of households using LPG, targeting 58% by 2030. Motivated by development, health and deforestation concerns, the planning process involves six ministries and many national and international stakeholders. LPG currently only reaches 2% of rural households, compared to 39% in urban areas. Fuelwood and other biomass made up 93% of total final consumption in rural Cameroon in 2014, the same share as 2000.

Can we infer a "recipe for success" in delivering clean cooking access? Most progress has taken place in lower middle-income countries where incomes are rising, and have involved targeted government support for clean cooking fuels. Making clean fuels affordable is key – it is difficult to motivate people to give up a free fuel (which biomass typically is in rural areas, except for the opportunity cost of the time spent gathering the fuel). Subsidies for the initial outlay in equipment in particular are often necessary to make clean cooking affordable. What remains a concern is the lack of examples of low-income countries making significant progress.

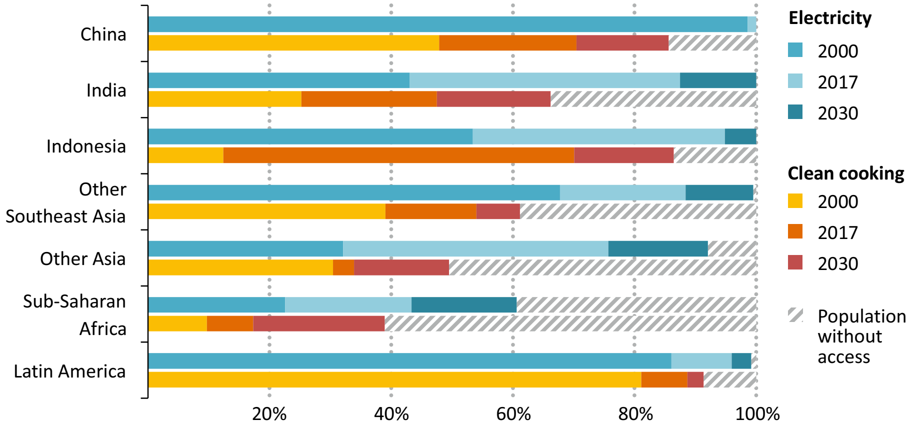
Outlook for energy access

In the New Policies Scenario, the number of people without access to electricity declines to around 650 million in 2030 and then rises again to 720 million in 2040 (staying at around 8% of the global population). Continued progress in developing Asia sees the region reach an electrification rate of 99% by 2030, with universal access by the mid-2020s in India and Indonesia (Figure 2.8). In sub-Saharan Africa, the population with access to electricity more than doubles from today's level, but those without access continue to number around 600 million in the face of rapid population growth and uneven progress across the region.

Annual electricity access investment averages $30 billion. Cumulative additional capacity for electricity access totals 108 GW, nearly 40% of which takes the form of grid extensions powered through centralised generation. Renewables play an increasingly important role, accounting for 70% of new electricity connections between now and 2030, nearly half of which are for off- and mini-grid solar PV.

The number of people in the New Policies Scenario without access to clean cooking facilities falls to 2.2 billion in 2030 and 1.8 billion in 2040. Developing Asia still hosts the largest population without access in 2040. In China, access to clean cooking is slow to reach the last 10-15% of the population, leaving 105 million people without access in 2040, the majority relying on biomass. In India, the access rate is 76% by 2040, which means around 390 million remain without access. In sub-Saharan Africa, the switch to clean cooking turns a corner around 2030, so that by 2040 fewer than 820 million people do not have clean cooking access. Globally, average annual investment in clean cooking facilities from 2018-30 is $1 billion.

Figure 2.8 ▻ Progress since 2000 and outlook to 2030 for electricity and clean cooking access in the New Policies Scenario



While universal access to electricity is within reach for many parts of Asia, sub-Saharan Africa risks being left behind, and global progress on clean cooking access lags

Overall, the New Policies Scenario points to a world where energy access is not universal by 2030. Without modern energy for all, other development objectives will be much harder, and perhaps impossible, to meet, notably objectives concerned with improving health outcomes and gender equality. There are many opportunities for further action on energy access: for example, only 30% of access deficit countries currently have established a policy environment that fosters electrification (World Bank, 2018). Box 2.2 outlines priority policy areas to achieve universal access by 2030. Universal energy access is an essential part of the African Union's Agenda 2063 goal to harness all African energy resources to ensure modern, efficient, reliable, cost effective, renewable and environmentally friendly energy to all African households.

Box 2.2 ▷ How to accelerate progress on energy for all? Priority actions for the first UN review of SDG 7

In 2018, the IEA provided technical input in collaboration with other agencies to the High-Level Political Forum, in which the United Nations reviewed progress on SDG 7 for the first time. The following actions were identified as priorities (United Nations, 2018):

Electricity access

- Elevate universal access to electricity on the political agenda, backing up commitments with strategic planning, clear policies and dedicated institutions.
- Identify strong national champion institutions for electrification, with a clear mandate, necessary authority and resources, and thorough accountability.
- Establish de-risking tools, affordable financing and a clear enabling policy framework to attract private investment. To achieve the estimated $51 billion per year investment necessary to deliver universal access, private investment is needed to complement public spending.
- Consider other development goals in household electrification strategies, including opportunities for energy access to stimulate sustainable economic activity.
- Take into account the dynamic and integrated nature of energy demand and storage in electrification planning, and ensure technical standards and energy efficiency in end-use appliances.
- Address affordability by lowering upfront costs with targeted financing and subsidies, harnessing new business models such as the pay-as-you-go model and integrating energy-efficient appliances with access solutions.

Clean cooking access

- Prioritise clean cooking solutions in policy making, and translate global commitments into concrete evidence-based policies and plans.
- Mobilise funds from various stakeholders to scale up promising enterprises, increase consumer choice and financing, and stimulate additional private investment.
- Engage diverse public and private stakeholders across the development and climate spectrum, as successful clean cooking solutions are inherently cross-sectoral; mainstream clean cooking in relevant development interventions, such as those impacting health, gender, climate and environment.
- Move people towards clean cooking solutions that meet local cultural and social needs, with women involved in designing and delivering solutions. Resources are needed to spur innovation and identify affordable and scalable solutions.
- Improve monitoring of household energy use to accurately track, measure impact, and assess progress towards achieving universal access.

2.7.2 Progress and outlook for air pollution

Recent progress

Local air pollution is an increasingly prominent policy priority in many countries. Premature deaths linked to air pollution now amount to 2.9 million from outdoor air pollution, and a further 2.6 million from household pollution.

While urban air pollution is a major issue all around the world, it has become particularly pressing in big cities in major developing countries. In 2016, the World Health Organization (WHO) reported that half of the world's top twenty most polluted cities (measured by particulate concentrations) were in India (WHO, 2016). In this context, a number of major new policy measures have been announced since the *WEO-2017*. In July 2018, for example, China announced a new three-year action plan. The plan covers the whole country, with a particular focus on the Beijing-Tianjin-Hebei region. As well as setting targets for pollution levels, the plan aims to curb coal use for new industrial capacity and to promote low-emissions vehicle production and use. China has also implemented a new plan for 2017-21 to support cleaner heating in 14 northern provinces with substantial current coal heating demand.

Globally, transport is a major contributor to air pollution, in particular accounting for around half of current global NO_X emissions. The effects of pollution from transport are especially important in cities, where there are large numbers of people and vehicles in close proximity. As a result, transport pollution standards are increasingly being adopted at the city government level, as well as nationally. The C40 Cities Initiative "Fossil-fuel-free streets declaration" was signed by the leaders of 26 major cities across six continents in 2018. It declares their commitment to allow only zero-emissions bus sales by 2025 and to establish fossil fuel-free districts by 2030. A number of city governments have also put forward specific future access restrictions for conventional vehicles, including for diesel cars in Paris and Rome as soon as 2024, with Paris extending the ban to petrol cars by 2030.

China, India, Brazil and other countries meanwhile continue to tighten emissions standards for both light- and heavy-duty vehicles. For example, the newly released China VI standard requires all new diesel heavy-duty vehicles (HDVs) introduced to the market after July 2021 to have diesel particulate filters and to be soot-free, affecting around 15% of global HDV sales anticipated in 2021.

The power sector remains a major source of sulfur pollution, mostly due to emissions of SO_2 from coal-fired power generation. Many countries already have strong regulations in place to limit and further decrease SO_2 emissions from coal, and, in some cases, existing regulations are being strengthened. At the 2018 National People's Congress of China, the government reiterated its commitment to air pollution controls. Korea has announced stronger regulations on coal-fired power plants, which are expected to significantly reduce emissions of fine particulates.

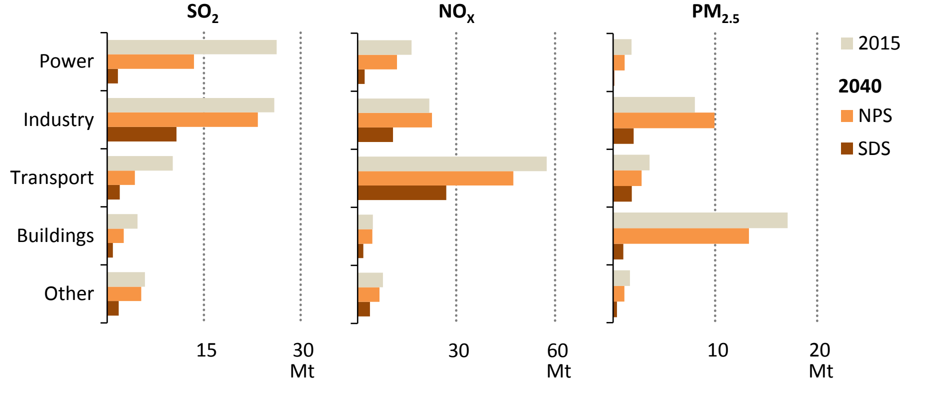
Air pollution regulations in industry have also been tightened. In India, for example, new standards are now in place for ceramics, foundries, glass, lime kiln and reheating furnaces, as well as industrial boilers. In the European Union, the Medium Size Combustion Plants Directive was due to be transposed by member states in 2017, while the Best Available Techniques reference document for large combustion plants was published in 2017, with expectations that member states implement standards within four years.

Future outlook

These new policies, adding to an already rich landscape of air pollution policies, mean that total levels of all major pollutants are set to fall in absolute terms in the New Policies Scenario, even as energy demand continues to grow strongly (Figure 2.9).

However, these reductions are much less than in the Sustainable Development Scenario, and are insufficient to prevent continued severe health effects of air pollution. The relationship between levels of emissions of air pollutants and human health is complex, depending on atmospheric conditions, and exposure levels and timing (IEA, 2016a). Overall, the number of premature deaths from outdoor air pollution actually rises in the New Policies Scenario, increasing to 4 million per year by 2040. The health impacts of indoor air pollution are also set to remain severe in the New Policies Scenario, with 2.2 million premature deaths still in 2040, due in large part to particulate emissions from cooking smoke, a direct result of a lack of access to clean cooking facilities (see section 2.7.1).

Figure 2.9 ▷ Air pollution emissions by sector and scenario, 2015 and 2040



Pollutant emissions generally fall in the New Policies Scenario, but in most cases by much less than in the Sustainable Development Scenario

Notes: NPS = New Policies Scenario; SDS = Sustainable Development Scenario. Industry includes fuel combustion in the industry sector and transformation processes other than power generation.

Source: IEA analysis; International Institute for Applied Systems Analysis.

2.7.3 Progress and outlook for CO_2 emissions

Recent progress

2

The latest IEA *Global Energy and CO_2 Status Report* showed that global energy-related CO_2 emissions rose in 2017 after three years of remaining flat.[6] This increase was due to a combination of factors, including strong economic growth – as despite a weakening link, emissions growth is still related to economic activity – as well as continued low oil and gas prices, and a slowdown in the spread of energy efficiency standards.

The upward trend was not universal around the world. Energy-related CO_2 emissions dropped in the United States, largely due to the increased use of renewables. Emissions increased in most other regions, with 75% of the increase occurring in Asia. In China, the economy grew by 7%, while emissions grew by 2%, with the lower rate of emissions growth reflecting changes in the economy as well as increased use of renewables and coal-to-gas switching (described in the *WEO-2017* [IEA, 2017b]).

There have been a number of policy changes targeting CO_2 emissions since the *WEO-2017*. In the European Union, substantial reforms to the EU Emissions Trading System were agreed. These have led to an increase in the price of permits, and are expected to result in the current surplus of permits reducing rapidly over coming years. National GHG reduction targets up to 2030 were also agreed for the sectors not covered by the EU Emissions Trading System. In China, a national emissions trading system was announced in late 2017, and a pilot phase for the power sector will begin in 2019. In Canada, as part of the Pan-Canadian Framework on Clean Growth and Climate Change, the federal government announced national carbon pricing measures as a backstop for provinces and territories that do not introduce their own measures.

An increasing number of countries are also introducing specific taxes on carbon, often in the context of delivering on their pledges to combat climate change (OECD, 2018). Argentina, Singapore and South Africa have proposed carbon taxes to be implemented in 2019. Argentina's tax targets emissions from transport fuels and coal and aims to cover 20% of the country's GHG emissions, with a gradually increasing tax rate. Singapore will apply a tax on facilities with emissions of 25 thousand tonnes of CO_2-equivalent (kt CO_2-eq) or more per year, with rates increasing over time.

Many other policies indirectly influence CO_2 emissions, ranging from subsidies to market mechanisms to regulations. These include demand-side policies, such as for energy efficiency, as well as supply-side technology and market policies. Policies targeting air pollution can also influence CO_2 emissions, as discussed in the next section. Examples of policy announcements since the *WEO-2017* with an important bearing on CO_2 emissions include: reforms of fossil fuel subsidies (see section 2.8.1); changes in feed-in tariffs and other price support policies (such as the cap on solar PV projects in China, described in Chapter 8); and updates to overall energy mandates and targets (such as the newly agreed

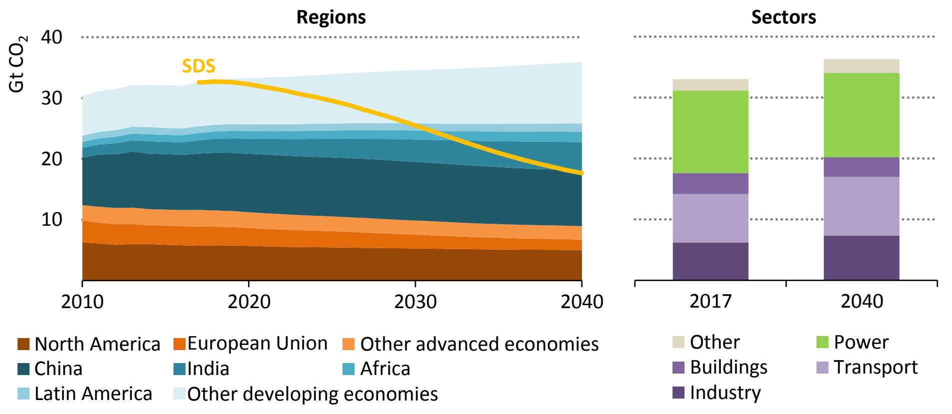
6. See www.iea.org/geco.

renewables and energy efficiency targets in the European Union). Some ambitious new energy efficiency policies have been implemented, including India's tightened emissions standards for both light-duty vehicles (LDVs) and HDVs, and the EU's update to the Energy Performance of Buildings Directive that mandates that member states implement transitions towards "nearly zero-energy buildings".

Future Outlook

After taking into account all relevant policies and commitments, the New Policies Scenario projects CO_2 emissions continuing to grow through to 2040.[7] This is a very different trajectory to the steep reductions embodied in the Sustainable Development Scenario (Figure 2.10).

Figure 2.10 ▷ CO_2 emissions by region and sector in the New Policies Scenario



CO_2 emissions continue to rise through to 2040, with particular growth seen in the transport and industry sectors

Notes: SDS = Sustainable Development Scenario. Shows CO_2 emissions from fuel combustion only.

Overall, projected CO_2 emissions are higher in the short term than they were in the 2017 New Policies Scenario, but mid-term plans lead to slower growth in emissions through the 2020s in this year's *Outlook*. The net effect is that emissions in 2040 in the New Policies Scenario are broadly similar to the *WEO-2017* projection.

The outlook for CO_2 emissions in the New Policies Scenario varies considerably across regions. In the European Union, the implementation of the new Clean Energy Package sees

7. The New Policies Scenarios takes into account countries' Nationally Determined Contributions (NDCs), insofar as policies or other implementing measures have been announced to ensure the achievement of those NDCs. Some NDCs contain specific CO_2-related objectives and policies, others contain targets related to specific energy technologies or efficiency, and yet others contain both types of goals.

emissions reduce from 2017 levels by 29% in 2030 and by 45% in 2040, led by power sector emissions cuts. In the United States, emissions decline by 15% from 2017 levels by 2040: power sector emissions fall due to wider use of cost-competitive wind, solar and gas, while emissions from transport overtake those from the power sector in 2020. China's emissions grow slowly in the New Policies Scenario through to 2030 and then begin to decline. India's emissions continue to grow to 2040, but at a slower rate than recent years.

One key international policy announcement since the *WEO-2017* is the agreement by members of the International Maritime Organization (IMO) to reduce total CO_2 emissions from shipping by at least 50% from the level of 2008 by 2050. This ambitious goal is not yet supported by concrete measures to enforce its achievement, and so is not included in the New Policies Scenario. The implications of the target are however included in the Sustainable Development Scenario.

2.8 Boosting efforts to meet the energy-related SDGs

The previous section emphasised that the world is not on track to achieve the energy-related SDGs and that global CO_2 emissions started rising again in 2017. To help inform decision making on actions to reverse these trends, this section provides quantitative assessments of concrete policy actions that offer scope for: (i) further developing measures proven to be cost effective for reducing CO_2 emissions, focusing on those in the IEA's 2015 "Bridge Scenario"; (ii) maximising synergies between different sustainable development objectives; (iii) ensuring alignment across the energy sector.

2.8.1 Revisiting the Bridge Scenario – five cost-effective measures for near-term action

As countries prepared their (Intended) Nationally Determined Contributions (NDCs) in the run up to the Paris Agreement in 2015, the IEA identified five measures that could provide cost-effective opportunities to achieve a peak in energy-related GHG emissions (IEA, 2015). Three years later, we take 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 analysis is also relevant for the Talanoa Dialogue of the UN Framework Convention on Climate Change, a stocktaking process that aims to reveal opportunities for increasing the ambition of national climate change mitigation contributions for the period to 2030.

The five measures, endorsed by energy ministers[8], are:

- Increasing energy efficiency in the industry, buildings and transport sectors.
- Increasing investment in renewable energy technologies (including hydropower) over time.

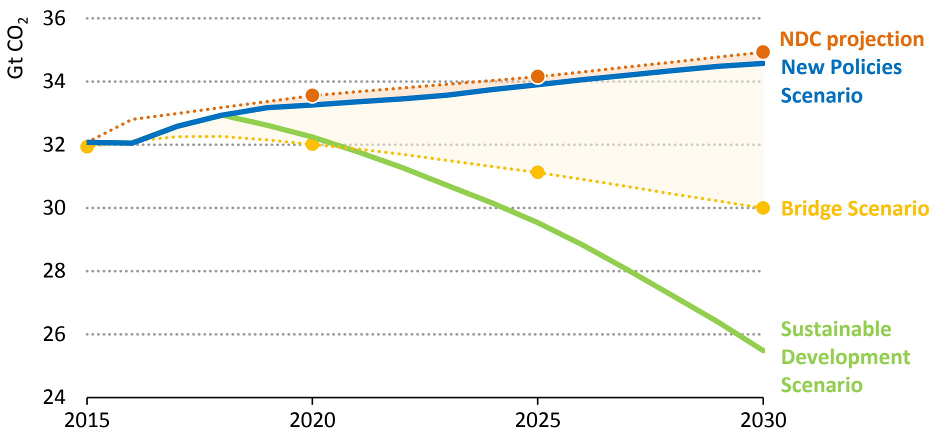
8. For the ministerial statement, see: www.iea.org/media/news/2015/press/IEA_Ministerial_Statement_on_Energy_and_Climate_Change.pdf.

- Phasing out the use of the least-efficient coal-fired power plants.
- Gradual phasing out of inefficient fossil fuel subsidies to end-users.
- Reducing methane emissions from oil and gas production.

These five measures were incorporated into the "Bridge Scenario" which showed that, if implemented universally, the measures would lead to a peak in energy-related GHG emissions at no net cost, thereby keeping the door open to accelerate reductions in line with global climate change goals.

Nevertheless, the 2018 update of our New Policies Scenario, incorporating current policies and plans, shows that energy-related CO_2 emissions are expected to be only slightly lower in 2030 than the level implied when the NDCs were submitted in the context of the Paris Agreement in 2015 (Figure 2.11). In aggregate terms, therefore, countries appear to be on course with what they planned in their international commitments, but emissions are higher than the level of the Bridge Scenario and far from the trajectory implied by the goals of the Paris Agreement. The picture varies across regions. The latest New Policies Scenario projection for the European Union shows emissions in 2030 about 7% below the level estimated in 2015, with reductions led by the power sector. Likewise, projected emissions in China in 2030 are now 5% lower than the level we projected in 2015 based on China's NDC submission, despite GDP projections for 2030 having risen, with lower emissions stemming from the power and industry sectors.

Figure 2.11 ▷ CO_2 trajectories relative to aggregate emissions levels implied by NDCs, 2015-2030

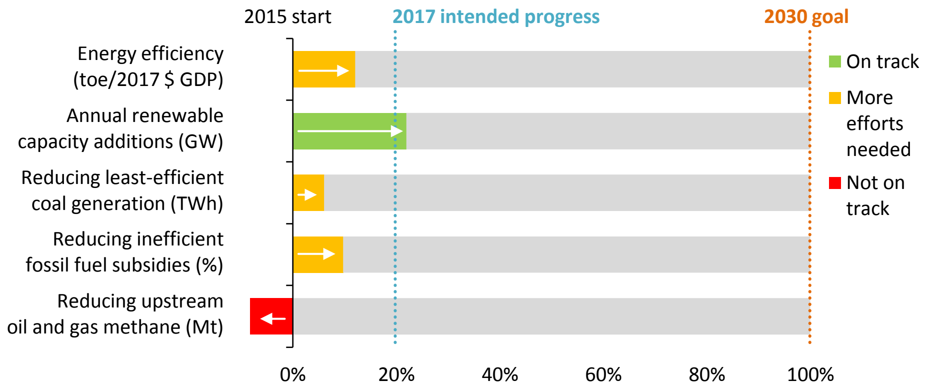


CO_2 emissions are currently higher than the level projected in the Bridge Scenario, and on a trend far from the trajectory of the Sustainable Development Scenario

Notes: NDC = Nationally Determined Contributions. Shows CO_2 emissions from fuel combustion only.

The rise in CO_2 emissions in 2017 means that global CO_2 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. Taking a look at the five measures in the Bridge Scenario shows that progress has been mixed (Figure 2.12). Only investment in renewables, 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 is close to being on track, but policy efforts appear to be slowing. Some progress has 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 almost no progress on the measure.

Figure 2.12 ▷ Progress on key measures for achieving a peak in energy-related GHG emissions in the Bridge Scenario, 2015-2017



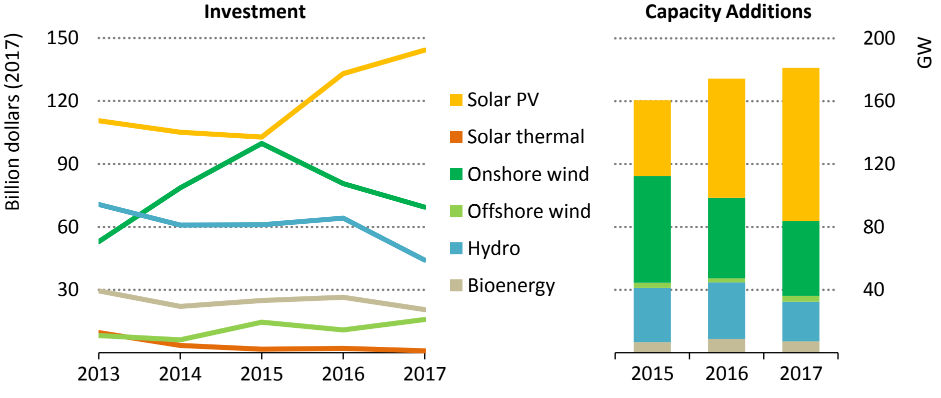
Progress on the five measures is mixed; investment in renewables in power generation is on track with the Bridge Scenario, but efforts on other measures lag

Energy efficiency improvements have slowed over the last two years. Energy intensity, a proxy for energy efficiency measured in energy consumption per unit of economic output, has seen year-on-year improvement slow to 1.7% in 2017 (IEA, 2018d). While policy coverage rates have increased steadily since 2013 for industrial electric motors, electric appliances and heating, other dominant end-uses such as space cooling and refrigeration have seen little increase in policy coverage (IEA, 2018a). Further progress has the potential to reduce CO_2 emissions in cost-effective ways while also improving energy security.

Renewable energy investment in the power sector totalled $300 billion in 2017, 6% less than in 2016 and slightly lower than 2015 (IEA, 2018e). However, declining technology costs mean that capacity additions of renewables still rose in 2017 by 3% to 178 GW (including 97 GW of solar PV). Capacity additions are therefore outstripping the rate implied by the investment objective stated in the Bridge Scenario, even though actual investment numbers are lower.

Different renewables technologies have seen varying trends since 2015. Investment in solar PV increased by an annual average of 18%, encouraged by falling costs and continuing policy support. Rapid solar growth has offset declines in capacity additions of other renewables (Figure 2.13). Deployment of offshore wind capacity increased to over 18 GW in 2017, boosted by public-private initiatives in countries bordering the North Sea in Europe (IEA, 2018f). By contrast, investment in onshore wind and hydro both decreased.

Figure 2.13 ▷ Renewable electricity investment and capacity additions, 2013-2017

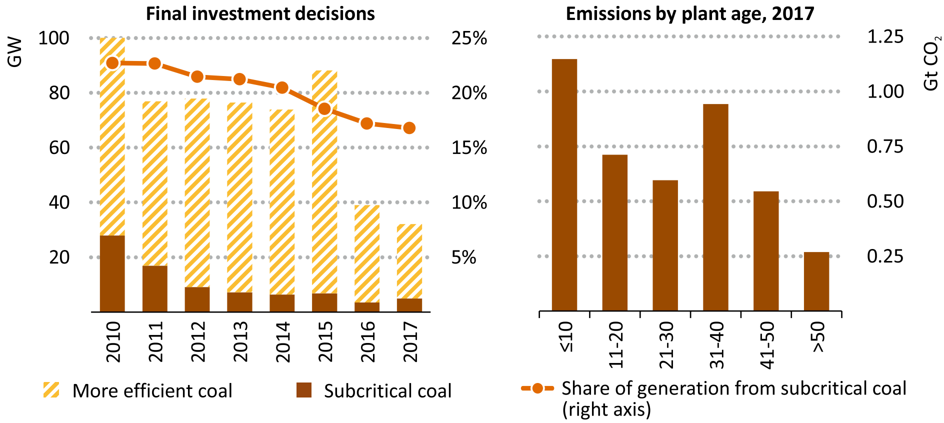


Growth in solar PV investment offsets declines in other technologies. Overall, renewable energy capacity additions expand even with lower total investment levels.

Phasing out of least-efficient coal-fired power plants has made some progress. Globally, generation from subcritical coal plants has decreased by an annual average of 2% since 2015, though it still contributes 17% of electricity generation. Mostly this is due to a reduction in operating hours of subcritical plants, as capacity so far remains nearly constant. There has nevertheless been a marked decrease in planned investment for new subcritical coal in the last two years (Figure 2.14). However, subcritical technology is still prevalent in emerging economies, and many of the plants are young. Around 9 GW of new subcritical coal capacity was added in 2017, 95% of which was in Asia, and about 45% of all subcritical coal capacity currently in operation is less than 20 years old. This implies a potential to influence CO_2 trajectories far into the future, in the absence of further measures to reduce operational hours or encourage early retirements (see Chapter 7).

Progress is also evident in actions to **phase out fossil fuel consumption subsidies**. Many countries have initiated fossil fuel subsidy reforms, including several producer economies (Box 2.3). The level of subsidies has decreased by 4% since 2015, although the proportion of global energy-related CO_2 emissions covered by fossil fuel subsidies has remained unchanged at around 13%. Reform measures had been facilitated by relatively low international oil and gas prices in the last few years (Figure 2.15), but in 2017 higher oil prices led to a partial rebound in total subsidy value. The 15% rise in subsidies was however considerably less than the 25% rise in oil price. In mid-2018, there were signs of a slow-down in reform efforts. Further and deeper reforms would reduce government spending pressures while also creating a price environment that facilitates long-run decarbonisation.

Figure 2.14 ▷ Tracking subcritical coal-fired power investment and CO_2 emissions



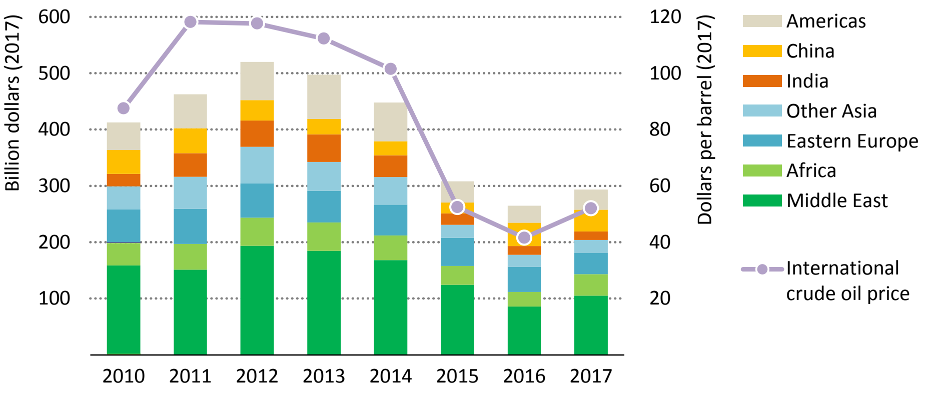
Investment in and generation from subcritical coal plants have declined, but the young fleet will generate for years to come absent further actions towards phase out

Box 2.3 ▷ Recent progress on fossil fuel consumption subsidies

In 2016, India introduced a direct cash transfer scheme for residential kerosene consumers and launched a programme to raise kerosene prices progressively. East and Southeast Asia have also had several subsidy reforms in recent years: for example, Malaysia abolished gasoline and diesel subsidies, and raised electricity tariffs in 2014, and then increased domestic gas prices for the power and industrial sectors in late 2016 (though some changes are foreseen in 2018).

Saudi Arabia introduced price increases for gasoline, natural gas and electricity in 2015, which have contributed to an annual average 13% reduction in subsidies. Kuwait, Iran, Qatar, Egypt and Algeria have also all reformed their subsidies or raised domestic fossil fuel price caps in recent years. Although the value of consumption subsidies in the Middle East decreased by 15% between 2015 and 2017, the region still accounts for 35% of the global total.

Figure 2.15 ▷ Fossil fuel consumption subsidies in selected regions



Subsidies increased slightly in 2017, but by less than the rise in oil price

Methane emissions from the oil and gas sector have increased by an average 2% each year since 2015, reaching 79 Mt in 2017. Over 80% of the emissions arise from upstream processes, 36 Mt from oil and 29 Mt from natural gas. Methane (CH_4) emissions continue to track levels of oil and gas production, particularly for upstream gas, but there is significant potential to decouple methane emissions from fuel production, and to do so in a cost-effective way. Up to 45% of oil and gas sector methane (43 Mt) could be eliminated at no net cost (see Chapter 11, section 11.4.1). Green completions, whereby methane is recovered from flowback fluids after hydraulic fracturing is complete, have proven especially effective. Methane's high global warming potential and short half-life means that reductions would have a real impact in the short term.

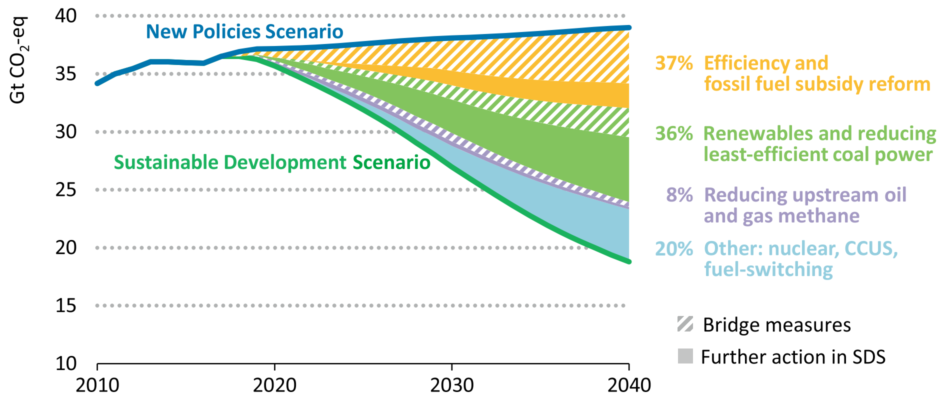
Several recent commitments have been made from the private sector. Sixteen major companies recently signed a voluntary commitment regarding the "guiding principles on reducing methane emissions across the natural gas value chain". Additionally, in 2018 the Oil and Gas Climate Initiative, with a membership covering 30% of global oil and gas production, established a collective target to reduce the average methane intensity of upstream operations by one-fifth by 2025. There has also been progress on the regulatory side, such as new federal requirements in Canada.

Extending the bridge to a more sustainable future

Together, full implementation of the five measures proposed in the Bridge Scenario in 2015 would achieve a peak in energy-related CO_2 and methane emissions, but would account for less than half of the CO_2 and methane savings needed by 2030 to achieve the objectives of the Sustainable Development Scenario (Figure 2.16). While an early peak in emissions is important, the subsequent trajectory towards net-zero emissions will be central to achieve the objectives of the Paris Agreement (Box 2.4).

For countries to move beyond the Bridge Scenario and towards the trajectory of the Sustainable Development Scenario, where would the other half of the emissions reductions come from? Around a third of the additional reductions in the Sustainable Development Scenario come from other low-carbon energy sources such as continued use of nuclear power in countries where it is acceptable, as well as from fuel switching to less carbon-intensive fuels and the deployment of CCUS. The remaining two-thirds come from going further with the Bridge Scenario measures, implying a range of further sector and country-specific policies in support of these measures.

Figure 2.16 ▷ CO_2 and methane emissions reductions by measure in the Sustainable Development Scenario relative to the New Policies Scenario



Implementation of five measures at no net economic cost would bridge less than half of the gap between current trends and a Paris Agreement trajectory

Notes: Gt CO_2-eq = gigatonnes of CO_2 equivalent; CCUS = Carbon, Capture, Utilisation and Storage; SDS = Sustainable Development Scenario; 100-year global warming potential of methane = 30.

The measures are clearly interlinked. Improving end-use efficiency remains the most prominent driver of CO_2 reductions and it is directly supported by phasing out fossil fuel consumption subsidies (which by their nature encourage consumption). Investment in renewables is by itself the second-largest source of savings, but it cannot be seen in isolation of action to phase out the most inefficient coal plants, as part of a combined strategy for reducing the carbon intensity of power generation. Together these four types of measures make up more than 70% of the gap between the New Policies and Sustainable Development scenarios. One avenue for ensuring better cost-effectiveness of emissions savings is to look beyond the measures individually to consider how they interact, as well as factors such as competition with other economic and social development priorities. The next two sections aim to shed light on where countries can build on synergies with other development goals, and how an approach to energy sector policy alignment can optimise CO_2 savings.

Box 2.4 ▷ Framing low-carbon pathways: an evolving challenge

In the Paris Agreement, 195 countries agreed to the ambitious objective of "holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C". This high-level objective is challenging to interpret because it spans a range of outcomes. Moreover, attributing a long-term temperature outcome to any particular pathway for energy-related GHGs is not straightforward, and is becoming increasingly challenging.

The concept of a "carbon budget" has long been used to link emission levels and long-term climate outcomes. A carbon budget is based on the near-linear relationship between the global temperature increase and cumulative CO_2 emissions (see for example IEA, 2016b). It provides an easily conveyed metric that simply explains the importance and urgency of tackling climate change, but is not without challenges.

The recent Intergovernmental Panel on Climate Change (IPCC) special report on the impacts of global warming of 1.5 °C (IPCC, 2018) provided new, and generally much higher, estimates of the remaining CO_2 budget than those previously used in the literature, such as the budgets reported by the IPCC Fifth Assessment Report (IPCC, 2014). An additional challenge with estimating the remaining global carbon budget is that it applies only to CO_2, meaning that additional assumptions are required about other GHG emissions such as nitrous oxides and methane, as well as other air pollutants having climate effects, such as black carbon and various aerosols.

While carbon budgets provide a useful high-level indicator that illustrates the need for emissions reductions, the inherent uncertainty makes it challenging to attribute a specific budget (or a specific emissions pathway) to a particular temperature outcome. This in turn increases the challenge of using and interpreting carbon budgets for policy makers seeking to establish explicit emission reduction targets or objectives. Increasing attention is therefore focusing on alternative means to assess and compare the level of ambition of energy-related CO_2 emissions reduction targets. The Paris Agreement itself sets three parameters for emissions trajectories: that GHG emissions peak soon, enter a steep decline and ultimately reach net-zero in the second-half of this century. A number of other factors are important to clarify fully any emissions pathway, such as the reduction in non-CO_2 emissions and the magnitude of carbon sinks or other means to remove CO_2 from the atmosphere. However, focusing on the date when CO_2 emissions fall to zero, and stages to get there, could provide a more concrete goal for policy makers to define the ambition of their emission reduction pathways.

The CO_2 emissions trajectory of the Sustainable Development Scenario is lower than most published decarbonisation scenarios aiming for a temperature rise of well below 2 °C (see Figure 2.4). The scenario implies a profound and rapid shift on both the demand and supply sides of the energy sector, with the result that CO_2 emissions peak soon and then decline rapidly on a course towards net-zero emissions by 2070.

2.8.2 Exploiting synergies with other energy-related SDGs

An important finding of the Sustainable Development Scenario is that different energy-related development goals have a number of points in common. Analyses of the scenario indicate that the trade-offs between different objectives are smaller than often assumed, and that in some cases there are significant opportunities to exploit synergies between policies targeting the different objectives. Understanding these interactions can help inform choices about effective policies so as to minimise trade-offs and make the most of the synergies between different energy-related SDG objectives. This goes well beyond the three core dimensions of the Sustainable Development Scenario (Spotlight).

SPOTLIGHT

How does the Sustainable Development Scenario relate to other aspects of energy and sustainable development?

The role of the energy sector in sustainable development goes much further than the three core dimensions of the Sustainable Development Scenario. As access to modern energy is an essential tool for alleviating poverty, energy has a key role to play in the overarching goal of SDG 1, ending poverty everywhere. Affordability therefore needs to be at the heart of energy transition strategies. Additionally, other key energy interactions with the SDGs include:

- Water and sanitation (SDG 6): covered in detail in section 2.9.
- Sustainable cities and communities (SDG 11): With 4.2 billion people living in cities today, urban areas account for 75% of global energy consumption and 70% of global GHG emissions (UNDESA, 2018). As the proportion of the global population living in urban areas increases, the interactions between urbanisation and access to energy, air pollution and climate action will intensify. The Global Covenant of Mayors for Energy and Climate now brings together over 9 000 cities committed to climate mitigation. More and more cities have committed to 100% renewable energy targets, with important implications for national energy policies. Climate change also poses a direct threat to future city livelihoods. Many high-density cities are located in low-lying coastal regions, vulnerable to storm surges and sea-level rise. By 2030, climate change could force up to 77 million urban residents into poverty (World Bank, 2018). This highlights the close links between targets SDG 13.1 (on strengthening resilience to climate change) and SDG 11.5 (on reducing human casualties and economic losses caused by disasters).
- Responsible consumption and production (SDG 12): Considerable economic activity currently depends on materials produced through energy-intensive processes; cement, iron and steel, chemicals and aluminium account between them for 17% of total CO_2 emissions. In some cases, material efficiency measures can help to reduce energy use: for example, vehicles can be made more fuel efficient through

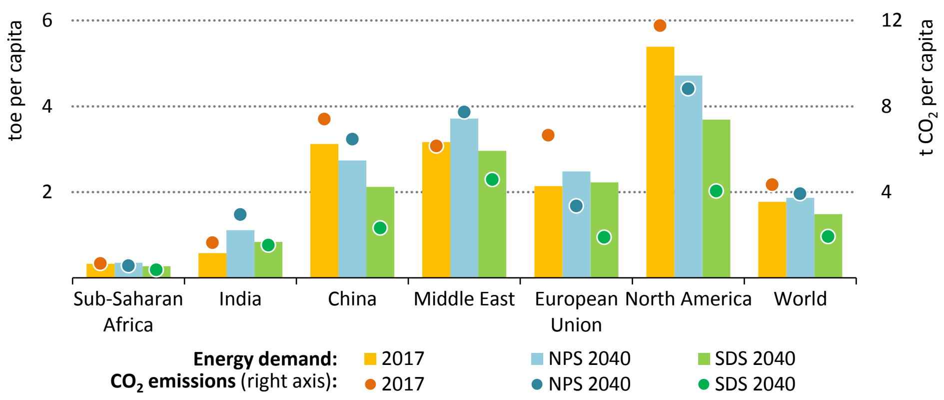
light-weighting (IEA, 2018b). However, energy efficiency is sometimes achieved at the expense of material efficiency – for example, reducing energy demand in buildings through better insulation requires more materials. Increased recycling also has energy implications. Enhanced recycling of plastics can act to reduce growth in oil demand from the petrochemical industry, set to be one of the biggest continued drivers of oil consumption over the coming decades (IEA, 2017b). This is reflected in the Sustainable Development Scenario, where a doubling of recycling collection rates relative to the New Policies Scenario leads to a reduction in oil demand of 1.5 mb/d by 2040 (IEA, 2018g).

Can pursuing energy access be beneficial for climate action?

As most new electricity connections to date have been achieved through grid-connected electricity powered by coal, the traditional assumption has been that action on energy access comes at the expense of action on climate change. However, IEA analysis has shown that this is not the case for access to either electricity or clean cooking. The *Energy Access Outlook 2017* (IEA, 2017a) found that pursuing a least-cost strategy for closing the energy access gap has no negative impact on the climate. Indeed, there may actually be a net climate benefit in displacing the traditional use of biomass for cooking. There are a number of factors underlying this finding:

- First, the amount of modern energy needed to satisfy household needs is small, contributing a negligible increase in energy demand. Even assuming that every household's energy consumption reaches the regional average around a dozen years after gaining access, the additional demand only amounts to 338 TWh in 2030 in the Sustainable Development Scenario, or 1.1% of the global total. LPG use for clean cooking access has a similarly small impact, requiring around 1 mb/d, or 0.8% of global oil demand in 2030. Further, people living in sub-Saharan Africa, the region with the highest access deficit, currently emit on average 13-times less energy-related CO_2 emissions per capita compared with advanced economies. In the Sustainable Development Scenario, despite universal energy access being achieved everywhere, the gap only closes to eight-times in 2040 (Figure 2.17).
- Second, recent changes in technology costs and improvements in low-carbon technologies are set to make new access connections less emissions-intensive than previously. Renewables are the most cost-effective route for around three-quarters of those gaining access in the Sustainable Development Scenario. Energy-efficient appliances are helping to bring down the cost and energy intensity of providing access, and helping to make off- and mini-grid uptake more affordable to households. There is evidence that energy efficiency is increasingly considered in the context of new access connections – LED lightbulbs are now regularly packaged with solar home systems, and larger energy-efficient appliances are also beginning to penetrate the market. For example, MKopa, the largest solar home system company in East Africa, is beginning to sell super-efficient televisions with their off-grid bundle.

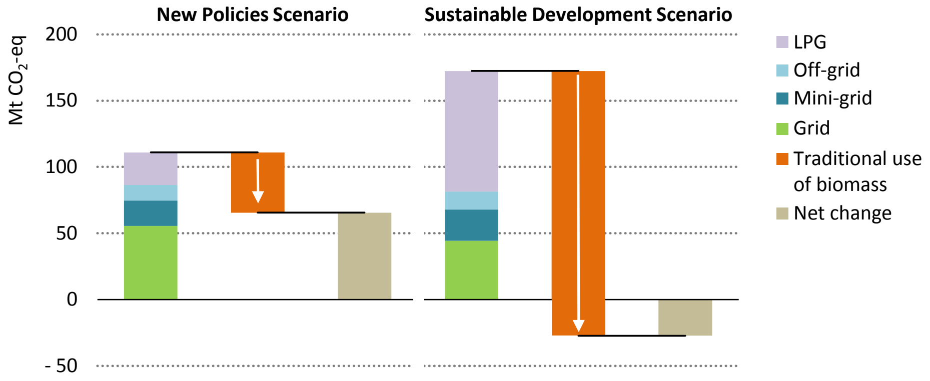
Figure 2.17 ▷ Total primary energy demand and CO_2 emissions per capita by selected region and scenario



Achieving universal access to modern energy does not increase the (already very small) CO_2 footprint of the population living in sub-Saharan Africa

Notes: NPS = New Policies Scenario; SDS = Sustainable Development Scenario. Total primary energy demand excludes traditional use of biomass.

Figure 2.18 ▷ Energy access-related GHG emissions from electricity and clean cooking access by scenario



Higher CO_2 emissions from increased fossil fuel consumption for access are more than offset by a reduction in other GHGs, notably methane, from traditional use of biomass

Notes: Mt CO_2-eq = million tonnes of CO_2 equivalent. The reduction in emissions from the traditional use of biomass assumes an average emission factor of 11.1 kt CH_4/Mtoe (265 kg CH_4/terajoule [TJ]), which is at the lower end of the default IPCC range (100 to 900 kg/TJ). 100-year global warming potential of methane from biomass = 28, nitrous oxide = 265. Other non-CO_2 forcers such as black carbon may also have an effect, but are not included here.

- Third, the increase in emissions from higher end-use consumption can be more than offset by emissions savings from fuel switching. The traditional use of biomass is associated with high levels of GHG emissions, mainly in the form of methane and to a lesser extent nitrous oxide. While the range of uncertainty is high, even a conservative calculation shows a net climate benefit from switching to LPG and other modern cooking fuels, including electricity and natural gas (Figure 2.18). The real benefit may be greater, as we do not account for the fact that biomass and charcoal for cooking often exacerbate deforestation and associated environmental and water stresses. Similarly, a reliable electricity connection typically displaces kerosene, candles, generators and batteries, all of which are inefficient and polluting as well as relatively expensive. Overall, CO_2 emissions are lower in 2040 in sub-Saharan Africa in the Sustainable Development Scenario than in the New Policies Scenario.

Can efforts to tackle air pollution be beneficial for climate change?

Sources of energy-related air pollution have traditionally been tackled by measures that reduce, control or ban emissions of major pollutants, whether through improved combustion techniques, "end-of-pipe" removal of pollutants through scrubbers and filters or compulsory fuel switching. Such measures can be costly, and can result in an energy efficiency penalty, meaning that slightly more fuel is required to deliver the same energy output once the end-of-pipe measure is in place. This means that reducing air pollution could lead to an increase in energy use and in CO_2 emissions, all else being equal. In addition, some local pollutants such as SO_2 actually have a cooling effect on the climate, so reducing their concentration can run counter to reductions of CO_2 and other GHGs. At the same time, there are potential synergies at the energy systems level between action to reduce air pollution and action to reduce CO_2 emissions.

In the Sustainable Development Scenario, CO_2 emissions are reduced concurrently with emissions of air pollutants, while also achieving universal energy access. The scenario therefore incorporates both strong climate ambition and strict regulation of pollution. To what extent do the air pollution gains come from end-of-pipe measures, and to what extent from measures that avoid air pollution while also contributing to climate ambition?

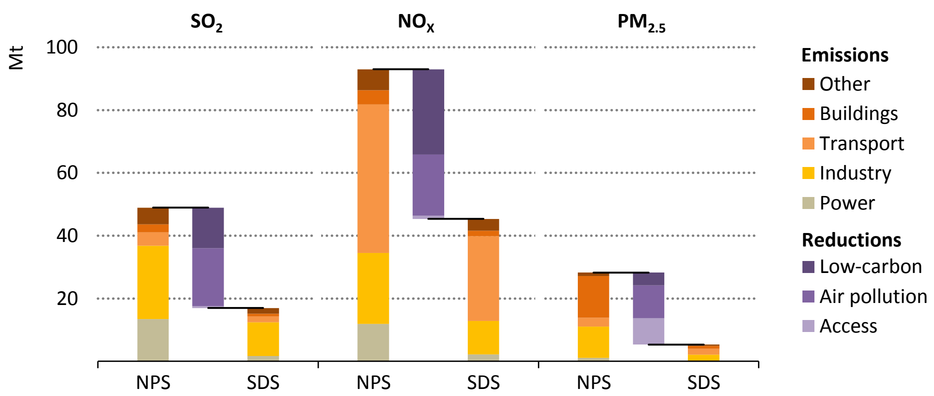
The answers vary by pollutant and by sector (Figure 2.19):

- For NO_X, low-carbon measures, including renewables and efficiency, account for more than half of all reductions in the Sustainable Development Scenario relative to the New Policies Scenario. The transport sector is currently the biggest contributor to NO_X emissions, and this is set to remain the case despite ambitious plans to reduce emissions in the New Policies Scenario. The additional NO_X reductions from the transport sector in the Sustainable Development Scenario are largely driven by energy efficiency and switching to electric vehicles – considered a low-carbon measure – rather than by additional end-of-pipe regulation.
- For SO_2, around 40% of the reductions in the Sustainable Development Scenario over and above those in the New Policies Scenario are attributable to low-carbon measures. By 2040, the majority of additional reductions in SO_2 emissions occur in the power

and industry sectors. In the power sector, significant policies for end-of-pipe pollution control are already included in the New Policies Scenario, and remaining savings are largely due to expanded use of renewables. Industry, however, is more reliant on pollution control measures.

- For $PM_{2.5}$ emissions, more than half of current emissions are in the buildings sector, almost entirely due to smoky indoor environments in countries where many people still cook with solid fuels. The proportion is set to remain almost unchanged in the New Policies Scenario. In the Sustainable Development Scenario, universal energy access leads to an almost total elimination of $PM_{2.5}$ emissions in buildings and to a slight reduction in CO_2 emissions. Efforts to increase energy access are well aligned with this particular pollution goal.

Figure 2.19 ▷ Drivers of pollutant emissions reductions in the Sustainable Development Scenario relative to the New Policies Scenario



Low-carbon measures, rather than measures specific to air pollution, account for 57% of NO_X and 40% of SO_2 emissions reductions

Note: Industry includes fuel combustion and process emissions.

Source: IEA analysis; International Institute for Applied Systems Analysis.

This analysis shows that, in countries where reducing health impacts of air pollution is an urgent issue, low-carbon measures that reduce the overall quantity of fossil fuels being used – including energy efficiency measures on the demand side, and a shift to renewables on the supply side – are likely to be an important part of an action plan to tackle those health-related impacts.

2.8.3 Aligning energy policies to unlock faster CO_2 reductions

Energy technology is changing fast, opening new opportunities to make rapid progress on reducing CO_2 emissions in parallel with other development objectives. These opportunities will not be realised without the alignment of policy making across the energy system (IEA, 2017c). This section highlights the importance of some of these policy areas, and makes links with other parts of this *Outlook* where they are covered in more detail (including the focus on electricity in Part B).

Key energy policy areas in terms of alignment include:

- **Electricity demand and supply policies**: In the Sustainable Development Scenario, a combination of energy efficiency and increased use of electricity, in particular for transport, leads to a higher percentage of electricity in the energy mix than in the New Policies Scenario. The share of electricity increases substantially across all end-use sectors, and the increasing role of electricity has clear potential benefits for end-users. However, the potential for electrification to contribute to radically reducing CO_2 emissions – and to some extent air pollutants – can only be realised in parallel with concerted action in the power sector. Chapter 9 explores the importance of this alignment in more detail.
- **Optimisation and flexibility in the power system:** Policies supporting investment in renewable electricity capacity additions are not in themselves sufficient to drive emissions reductions. Support for renewable electricity has led to rapidly rising installed capacity of variable renewables in many countries, but the impact on CO_2 emissions has been much more modest. What counts is not theoretical capacity but actual electricity generation from renewables. Improving the capacity factors of renewables, for example through lower curtailment of renewable electricity generation, relies on action to improve the flexibility of the power system, through some combination of electricity storage, demand-side response, improved grid infrastructure and use of dispatchable power generation technologies. Chapters 8 and 9 discuss strategies for increased power system flexibility.
- Lifecycle emissions in the **transport sector**: Policy discussions tend to focus on technology-based measures such as encouraging fuel switching and improving fuel efficiency. The CO_2 impact of fuel switching depends very much on the lifecycle emissions of the alternative fuel, e.g. the carbon intensity of electricity generation or of biofuel production. Chapter 6 discusses this in more detail.
- **Changes in mobility patterns:** A shift to a less carbon-intensive transport sector depends on understanding behavioural choices, which in turn depends partly on the quality of transport options available in different countries. This goes far beyond energy modelling. Nevertheless, for the first time this *World Energy Outlook* explores the implications of “avoid” and “shift” policies on the composition of transport demand. “Avoid” policies are those that either reduce the need for mobility altogether, for example through more compact urban design, or by providing incentives to eliminate unnecessary journeys. “Shift” policies are those that encourage different forms of transport. In the Sustainable Development Scenario, avoid and shift policies lead to a decrease in global CO_2 emissions of 3% of total transport emissions by 2040. This is due to a reduction in passenger car stock of 200 million cars in favour of light two/three wheel vehicles and public transport. The effect is partly offset by an increase in public transport use, including rail, but the overall CO_2 benefit is still notable.

- **International transport:** The international nature of both aviation and shipping has traditionally made it difficult to reach alignment on regulatory measures, especially since their long-distance nature reduces the low-carbon options. IMO member countries have now agreed on a reduction of at least 50% in total GHG emissions from international shipping by 2050. The International Civil Aviation Organisation has agreed to aim for carbon-neutral growth from 2020, and has initiated the Carbon Offsetting and Reduction Scheme for International Aviation in support of this target. The International Air Transport Association has also proposed a roadmap for carbon-neutral growth from 2020, and a reduction in net aviation CO_2 emissions of 50% by 2050 from 2005 levels.

2.9 Water-energy nexus and SDG 6

Today, more than 2.1 billion people lack access to safe drinking water. More than half the global population – about 4.5 billion people – lacks access to proper sanitation services (UN Water). More than a third of the global population is affected by water scarcity. Roughly 80% of wastewater is discharged untreated, adding to already problematic levels of water pollution. Around 200 million hours are spent every day collecting water, overwhelmingly by women and children, and almost 850 000 people die each year from diarrhoea related to unsafe drinking water and poor sanitation (UNICEF, 2016a).

Box 2.5 ▷ Targets in SDG 6, clean water and sanitation for all

6.1: Universal and equitable access to safe and affordable drinking water for all.

6.2: Universal access to adequate and equitable sanitation and hygiene for all, and end open defecation, paying special attention to the needs of women and girls.

6.3: Improve water quality by reducing pollution, halve the proportion of untreated wastewater and substantially increase recycling and safe reuse globally.

6.4: Increase water use efficiency across all sectors, ensure sustainable withdrawals and supply for freshwater to address water scarcity and lower number of people suffering from water scarcity.

6.5: Implement Integrated Water Resource Management at all levels.

6.6: Protect and restore water-related ecosystems.

6 A/B: Expand international co-operation and capacity building support to developing countries and strengthen participation by local communities.

Note: This analysis focuses on the first four targets, outlined in green.

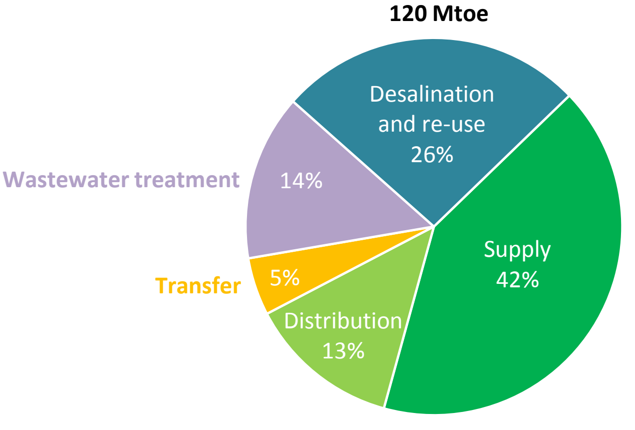
Source: UNDESA (n.d).

One of the 17 UN SDGs – SDG 6 – seeks to address these challenges and provide clean water and sanitation for all by 2030 (Box 2.5). As past *World Energy Outlooks* have shown, water and energy questions are fundamentally intertwined. With both water and energy needs set to increase, the interdependencies between energy and water are likely to intensify. How this nexus is managed will have significant implications for economic and social development, and the achievement of the UN SDGs.

2.9.1 Energy for water to achieve SDG 6

The provision of freshwater from surface water, groundwater or desalination, its transport and distribution, and the collection and treatment of water and wastewater all depend on energy.[9] The water sector globally uses roughly 120 Mtoe per year, almost as much energy as Australia (Figure 2.20). More than half of this is in the form of electricity (850 TWh), representing around 4% of global electricity consumption. Water supply and wastewater treatment are the two largest consumers of electricity in the water sector today. The remaining 50 Mtoe is used for desalination and diesel pumps.

Figure 2.20 ▷ Global energy use in the water sector, 2016



The amount of energy consumed in the water sector is almost equivalent to the entire energy demand of Australia

Notes: Supply includes water extraction from groundwater and surface water as well as water treatment. Transfer refers to large-scale inter-basin transfer projects.

Sources: IEA analysis; IEA (2016c); Luck, et al. (2015); Bijl, et al. (2016); Wada, et al. (2016).

9. For an in-depth look at the water-energy nexus, including the energy requirements for the water sector, see *WEO-2016 Special Report: Water-Energy Nexus* (IEA, 2016c) available free at: www.iea.org/water.

By 2030, the amount of energy consumed by the water sector in the Sustainable Development Scenario – without additional effort to achieve SDG 6 – would increase by around 50%, with upward pressure coming from several sources:

- Desalination: An increased reliance on desalination to bridge the water supply gap in water-scarce regions, such as the Middle East and North Africa, is the single largest element that propels energy consumption higher. Desalination is an energy-intensive process, though the amount of energy required depends on the technology used (see Chapter 2 in *Outlook for Producer Economies* [IEA, 2018h]).
- Large-scale water transfer projects: Pumping water from areas of abundance to areas of scarcity, such as the South-North Water Transfer Project in China, is another significant source of energy demand growth in the water sector.
- Wastewater treatment: The increased collection of wastewater and rising water quality standards pushes up energy demand, but efficiency improvements temper overall growth.
- Water supply and distribution: Energy use declines in these sectors as they become more efficient, as diesel pumps are slowly replaced by more efficient electric ones, and as the water supplies start to include more water from desalination and more re-used water.

The 2018 UN High-Level Political Forum concluded that, despite progress, the world is far from on track to achieving SDG 6. This analysis shows that providing access for all can be achieved without a dramatic increase in global energy consumption.[10] This is because the additional water demand from meeting target 6.1 is only a fraction of global water demand today, and because the energy intensity of many of the technologies and solutions available for meeting targets 6.1-6.3 is low, especially in rural areas.

Target 6.1: Universal access to clean drinking water

Of the 2.1 billion who do not have access to safely managed drinking water today[11], around 1.6 billion must walk to get their water[12] while almost 600 million drink directly from an unprotected well, spring or surface water, risking illness from contaminated water (WHO/UNICEF JMP). India has the largest total number of people without access, followed by Ethiopia, Nigeria and China. Sub-Saharan Africa is home to nine of the ten countries with

10. While the SDG targets 6.1-6.3 are not embedded in the Sustainable Development Scenario, the remaining analysis in this section provides a what if case to assess what the additional energy needs of achieving these targets might be under the framework of the Sustainable Development Scenario.

11. Safely managed drinking water is defined as use of an improved drinking water source that is located on premises, available when needed and free from contamination. According to the World Health Organization (WHO) and United Nations Children's Fund (UNICEF), improved water solutions include piped water, boreholes or tubewells, protected dug wells and springs, rainwater and packaged or delivered water.

12. Around 1.3 billion people without access have a basic water service that is an improved drinking water source that can be collected in 30 minutes or less round trip. About 300 million people must travel more than 30 minutes to get their water, classified as a limited service.

the lowest rates of access to clean water—just a quarter of its population has access to safely managed drinking water. Elsewhere, almost two-thirds have access in Central and South America and almost 60% have access in Eastern and South-eastern Asia.

A majority of those who achieve access to safely managed drinking water in the Sustainable Development Scenario gain it with solutions that require energy. Despite this, providing clean drinking water for all by 2030 in the Sustainable Development Scenario would add less than 2 Mtoe to global energy demand, amounting to less than 1% of total energy demand for the water sector in 2030.[13]

In urban areas, most of the remaining 600 million who lack access are likely to rely on piped water supplies and connect to an existing water utility. Improvements to the quality and reliability of services are also required: in South Africa for example, a fifth of households already with municipal piped water regularly had interruptions lasting more than two days (Slaymaker and Bain, 2017). The suite of technologies used in rural areas to provide access to the 1.5 billion currently without access to safe drinking water is unlikely to resemble that used in urban areas, as the lower population density is likely to make the cost of constructing similar water systems uneconomic. Currently, a majority of those in rural areas use either a rope and bucket, often collecting water from a contaminated unsealed well, or a hand pump. However, the average lifespan of these hand pumps are only one-to-five years and they often break—it is estimated that 40% of all hand pumps in sub-Saharan Africa are out of action at any one time (Rural Water Supply Network, 2009; UNICEF, 2016b).

In the Sustainable Development Scenario, solutions that do not require energy, such as protected wells and hand pumps, are part of the answer, together with water purification methods such as gravity-driven water filtration systems and solar disinfection. However, as many of those without access to drinking water in rural areas also lack electricity, there is an opportunity to use plans for the provision of electricity in pursuit of SDG 7 (energy for all) to provide access to safely managed drinking water (Figure 2.21).[14] As a result, in the Sustainable Development Scenario, almost two-thirds of those who gain access in rural areas to safely managed drinking water do so through electrified solutions.

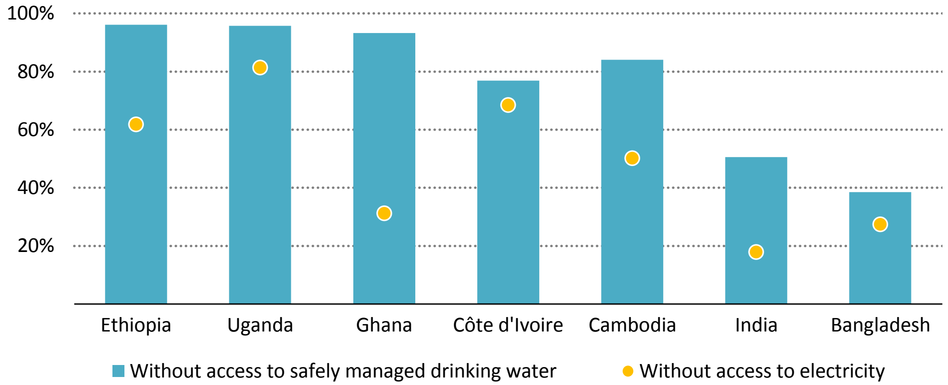
For areas where it is too expensive for the main grid to reach, community solar-powered water pumps are one option to replace labour-intensive hand pumps or more expensive diesel pumps. While the initial investment for solar pumps is higher, they are more durable and have lower operating costs than diesel pumps. Solar pumps range in size—a typical mid-size system is about 1-3 kilowatt peak (kWp)—and can provide up to 250 000 litres of water per day—enough to provide water to 5 000 people per day (Noble, 2012). However, their deployment will depend on a range of local factors such as solar irradiation, depth of pumping, water demand, financing and local capacity for maintenance. There is also a

13. Assuming the minimum baseline water consumption of 50 litres/day per person as recommended by the United Nations and the WHO.

14. See section 2.2 for more on energy access and SDG 7.

risk that, unless proper pricing signals and policy instruments are in place, the use of these pumps could spur unsustainable levels of water withdrawals.

Figure 2.21 ▹ Share of population without access to electricity or water in rural areas today



Almost two-thirds of those without access to clean drinking water in rural areas also lack access to electricity, opening opportunities to co-ordinate solutions

Sources: IEA analysis; WHO/UNICEF JMP.

While there are many water filtration solutions available that require no or minimal energy, the use of energy can help increase their reliability and the amount of clean water available at a given point in time. For example, mini-grids – which provide electricity to almost 45% of those who gain access in rural areas in the Sustainable Development Scenario – can be used to power filtration technologies to produce clean drinking water. Reverse osmosis (RO) systems are another promising solution: they are efficient even at a small scale and are increasingly economic when paired with mini-grids. In India, some private companies are integrating RO filtration systems with solar mini-grids. Under one business model, consumers pay $3 per month for 20 litres of clean water per day. A 10 kilowatt (kW) solar RO system runs 10-15 hours a day and provides 2 000 litres of clean water each hour, serving 1 000 homes daily (Power for All, 2017).

As with energy access, providing access to clean water is just a start. Ensuring it is reliable, affordable and able to scale up to meet continued demand from rising standards of living and population growth is another challenge. Off-grid solutions tend to be more cost effective for areas of low population density, and they provide almost a third of all new electricity access in rural areas. However, growing household water demand is likely in time to require a higher energy load than can be met by many of today's off-grid systems.[15]

15. Such as the off-grid systems that provide a basic bundle of energy services, including several lightbulbs, task lighting, phone charging and a radio.

Approaching water and electricity access in an integrated way may shift the emphasis away from off-grid solutions towards mini-grid or grid-connected solutions, especially where water services can provide an "anchor load" for power generation and assist with balancing and storage. This will require a well-designed regulatory framework that allows for the integration of decentralised solutions into the grid should it arrive. Better co-ordination between stakeholders in the water and energy communities on funding, technology deployment, stakeholder engagement and capacity building, will also be important.

Targets 6.2 and 6.3: Sanitation for all and halving the proportion of untreated wastewater

Today, over 60% of the global population lacks access to safely managed sanitation,[16] and just 20% of wastewater is collected and treated. This is damaging to human health, the environment and the provision of clean drinking water and it creates a strong link between the SDG targets on sanitation and wastewater (6.2 and 6.3) and the target on fresh water (6.1).

Roughly half of those without safely managed sanitation (4.5 billion people) lack even basic sanitation. A majority of those without basic sanitation use rudimentary latrines such as a slab or a bucket (890 million) or practice open defecation (890 million people, mostly in rural areas) (WHO/UNICEF JMP). Almost 60% of the latter live in India and 25% in sub-Saharan Africa (UN Water, 2017).

Improper sanitation management is both a rural and an urban challenge. In urban areas, where almost 2.3 billion people still lack access to safely managed sanitation, the provision of sanitation, and the treatment and management of municipal and industrial wastewater is a critical part of broader questions of urban design and management. The energy consumed by water and wastewater utilities can account for 30-50% of municipal energy bills. The increase in wastewater treatment capacity to meet SDG 6 could therefore have a significant impact on a municipality's energy expenditure, and those costs may in some cases be passed on to consumers (depending on how or if water is priced). It could also have an impact on efforts to combat climate change. It is estimated that the wastewater sector accounts for 3% of GHG emissions, while the emissions from untreated wastewater are three-times higher than conventional wastewater treatment plants (US EPA, 2008; International Water Association, 2018).

Focusing on municipal wastewater management provides a useful illustration of how technology choices can influence the additional electricity demand required to meet targets 6.2 and 6.3:

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16. Defined as an improved sanitation facility that is not shared with other households and where excreta are disposed of in situ or transported and treated off-site. Improved facilities include flush/pour to piped sewer systems, septic tanks or pit latrines, ventilated improved pit latrines, composting toilets or pit latrines with slabs.

- If cities modelled new centralised wastewater capacity needs on today's blueprint for wastewater management, the amount of electricity consumed for urban municipal wastewater treatment could increase by more than 680 TWh over the period to 2030.[17]
- Instead, if cities deploy economically viable energy efficiency technologies in all new centralised wastewater facilities – the pathway pursued in the Sustainable Development Scenario – the increase in electricity consumption could be reduced by around 10%. This would involve the deployment of variable speed drives, fine bubble aeration and more efficient compressors; better sludge management; and more efficient pipes and pipe maintenance for wastewater pumping. This pathway also sees higher rates of energy recovery; 30% of the electricity needed to meet the targets could be generated from the wastewater itself compared to just 6% if the current blueprint for wastewater management is used.
- A third possibility, at the frontier of today's technology, is for cities to build energy neutral or energy-positive facilities, where the energy needs of a treatment facility are entirely satisfied by own-generation, with the potential to produce more energy than needed through energy recovery. If all the new capacity implemented these additional energy efficiency measures, the amount of electricity consumed for urban municipal wastewater treatment would increase by less than 460 TWh over the period to 2030 – 30% less than projected in the Sustainable Development Scenario (Figure 2.22). Additionally, if new capacity was equipped with energy recovery units for biogas and a high efficiency combined heat and power unit, utilities could generate 50% more electricity than they need and sell the excess. While this represents an upper boundary and would not be a viable option for all utilities, it highlights the potential opportunities that exist for tempering rising energy demand from meeting SDG 6.

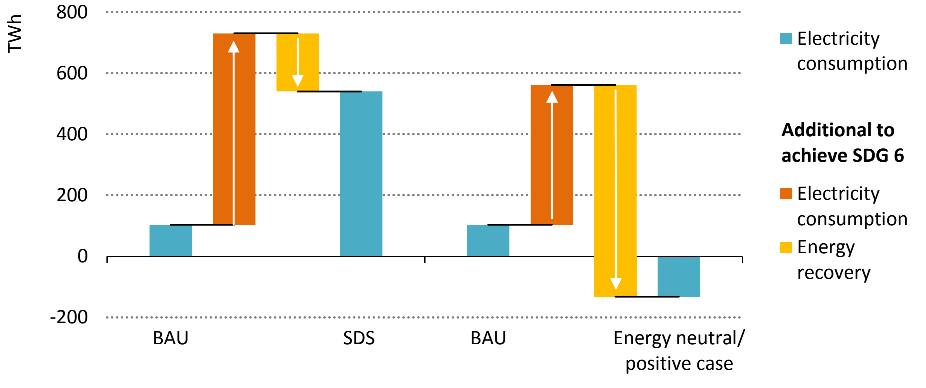
Increasing the collection and treatment of wastewater in more efficient, energy producing wastewater treatment plants would not only lower energy demand but could also lead to lower GHG emissions. However, the implementation of technologies to improve process efficiency and harness the embedded energy in wastewater will not happen on its own. Improved technology options are capital intensive, so questions of affordability and financing need to be addressed to ensure widespread deployment. Regulations on water quality, appropriate pricing mechanisms for water and electricity, land availability and the development of natural gas infrastructure (so that utilities can offload or sell their excess biogas) are also vital parts of the picture.

In rural areas, providing access for the remaining 2.2 billion people without access to safely managed sanitation continues to rely on more decentralised technologies and solutions that require no energy such as bio-latrines, pour-flush toilets and ventilated improved

17. This represents an upper bound for additional electricity demand as it assumes that all of those without access in urban areas will gain it via a centralised wastewater treatment plant.

latrines, but the safe collection, disposal and treatment of waste remains a challenge. Just as in urban areas, biogas presents an opportunity to utilise waste to generate energy that could reduce indoor air pollution, help prevent deforestation, save women time and contribute towards the achievement of SDG 7.1.2 (clean cooking for all). Biogas can be generated at a household or community level from anaerobic digestion and used for a variety of domestic energy needs. Biogas digesters are often too expensive for most households – costing anywhere from $100 to $1 000, depending on their size – plus there are other barriers related to scalability, proper installation and maintenance, and local circumstances. Efforts to scale up the use of anaerobic digesters as a solution to SDG 6.2 (sanitation for all), however, could provide additional impetus for biogas to become a larger part of the solution to SDG 7.1.2 (clean cooking for all) by lowering costs and providing an incentive to address the other barriers. If waste from all those who lack access to safely managed sanitation in rural areas today was captured and digested, the biogas potential could be roughly 20-50 billion cubic metres (bcm). This could be enough to provide a clean cooking fuel to around 60-180 million households.[18]

Figure 2.22 ▷ Electricity consumption in urban municipal wastewater treatment facilities from achieving SDG targets 6.2 and 6.3 in 2030



SDG 6 could dramatically increase electricity consumption in municipal wastewater utilities, but energy efficiency and recovery measures could offset additional demand

Notes: BAU = the amount of electricity consumed (less 60 TWh from energy recovery) from municipal wastewater treatment excluding SDG 6 in 2030 in the Sustainable Development Scenario. SDS = total electricity consumption from urban municipal wastewater treatment plants in the Sustainable Development Scenario if SDG 6 were achieved. Energy neutral/positive case = total electricity consumption from urban municipal wastewater treatment plants in the Sustainable Development Scenario if all new capacity built to achieve SDG 6 was energy neutral or energy-positive. The negative values indicate that more energy is generated than needed and can be sold.

18. This is based on an assumed consumption of roughly 3.64 megajoules per meal per household from Fuso Nerini et al., (2017).

2.9.2 *Water for energy to achieve SDG 6*[19]

Target 6.4: Reduce water scarcity, improve water use efficiency

SDG 6 is not just about supplying water and sanitation: it is also about ensuring that water is used more efficiently. If current consumption patterns persist, global water demand could exceed total supply by 40% in 2030 (International Resource Panel, 2016). The energy sector's share of total global water use today is relatively low – accounting for roughly 10% of total global withdrawals and 3% of consumption[20] – but demand from the energy sector could be reduced further. Changes in the fuel and technology mix, improving power plant efficiency, deploying advanced cooling systems, and making better use of non-freshwater and water recycling can all help the energy sector improve its water use efficiency and contribute to target 6.4.

Efforts to take urgent action on climate change (SDG 13), if not properly managed, could limit efforts on target 6.4. In a scenario aimed at reaching climate goals (but not factoring in linkages to other SDGs)[21], water withdrawals by the energy sector in 2030 rise slightly relative to the New Policies Scenario, and consumption increases by around 10 bcm (Figure 2.23). This is because some low-carbon fuels and technologies such as nuclear, concentrating solar power (CSP), biofuels and carbon capture are relatively water-intensive. This means that, in areas where water resources are scarce, decarbonisation efforts could exacerbate water stress or be limited by it.

Shifting the emphasis away from an approach focused only on decarbonisation towards an integrated approach to the SDGs, as in the Sustainable Development Scenario, results in significantly lower water withdrawals in 2030 compared with the New Policies Scenario (-20%). This makes the Sustainable Development Scenario the best option of those assessed here for achieving target 6.4 and for reducing the energy sector's vulnerability to potential water disruptions (such as drought) and to the effects of climate change on water availability.[22] If not properly managed, however, the higher level of consumption (+10% relative to the New Policies Scenario) could constrain technology or fuel choices or increase the potential for competition over water resources in some regions. This underlines the importance of factoring water use into energy policy decisions (Spotlight).

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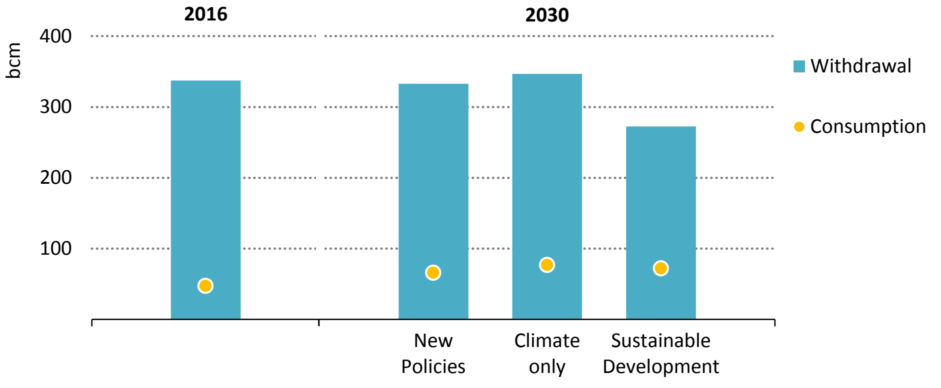
19. Analysis in this section focuses on freshwater use.

20. Water withdrawals are defined as the volume of water removed from a source and are always greater than or equal to water consumption. Water consumption is defined as the volume withdrawn that is not returned to the source (i.e. is evaporated or transported to another location) and is by definition no longer available for other users.

21. From 2008 to 2016, the *WEO* presented the 450 Scenario to highlight the policy, technology development and investment required to meet global climate change goals.

22. It is expected that climate change will alter the intensity, frequency, seasonality and amount of rainfall as well as the temperature of the resource, which may reduce the ability of power plants to discharge cooling water into these water bodies.

Figure 2.23 ▷ Global water use by the energy sector by scenario



A focus on an integrated approach rather than just a decarbonisation approach results in the lowest level of water withdrawals in 2030

Notes: New Policies = New Policies Scenario; Sustainable Development = Sustainable Development Scenario. Results for 2030 for the climate only scenario are from the *WEO* water-energy work in 2016, which was the last year that the *WEO* produced the 450 Scenario, a scenario meeting global climate goals.

S P O T L I G H T

A current of change for the energy sector's water use?

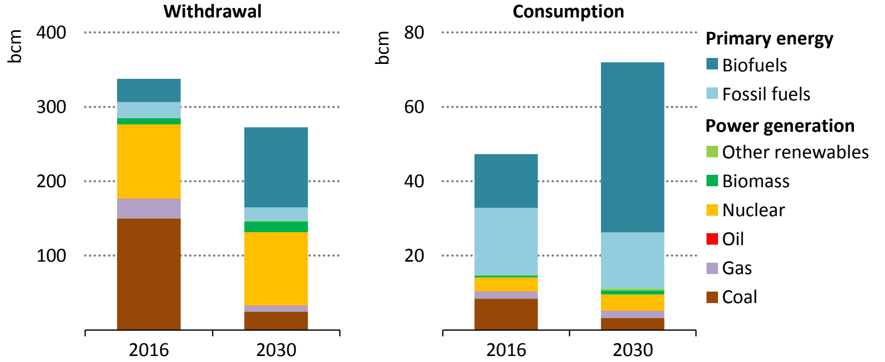
Water is needed for all phases of energy production, and it has become increasingly important to consider water needs when assessing the physical, economic and environmental viability of energy projects. In 2016, the energy sector withdrew around 340 bcm of water and consumed roughly 50 bcm.[23] The power sector is responsible for the majority of water withdrawals, with coal-fired power generation using once-through cooling systems accounting for over one-third of energy-related water withdrawals. Primary energy production is responsible for over two-thirds of water consumption, with the production of fossil fuels and biofuels responsible for roughly 40% and 30% of energy sector water consumption respectively.

In the Sustainable Development Scenario, global freshwater withdrawals in the energy sector decline to reach roughly 275 bcm in 2030, while consumption rises 50% to reach almost 75 bcm in 2030 (Figure 2.24). Increased energy efficiency, the move away from coal-fired power generation, and the increased deployment of solar PV and wind

23. The *WEO* does not present ranges for withdrawals and consumption for hydropower. While a majority of the water withdrawn is returned to the river, hydropower's water consumption varies depending on a range of factors. Thus, the amount consumed is site specific and a standardised measurement methodology is not yet agreed, though academic papers are beginning to develop methodologies.

power all contribute to overall lower water withdrawals in the energy sector. However, a rise in power generation from nuclear, bioenergy and CSP sources, together with increased use of CCUS and expanded biofuels production, contribute to increases in both withdrawal and consumption.

Figure 2.24 ▷ Global water use in the energy sector by fuel and power generation type in the Sustainable Development Scenario



The technology and policy choices in the Sustainable Development Scenario lower the energy sector's water withdrawals by 20%, but increase consumption by 50%

Notes: Other renewables include wind, solar PV, CSP and geothermal. Hydropower is excluded.

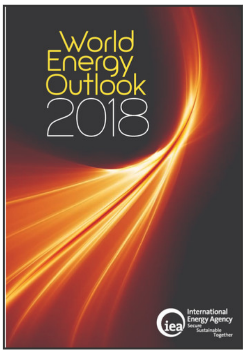
While the energy sector has a direct impact on water, the reverse is also true: the availability of water can influence the type of cooling system used. Once-through technologies are the most efficient and have the lowest capital costs, but have the highest water withdrawal rate; wet-tower cooling withdraws less water but consumes more; and dry cooling uses very little water but is the most expensive and the least efficient. Our analysis shows that, in areas where the level of water stress rises by 2030, more new power generation capacity is built with wet-tower cooling or dry cooling systems.[24] This helps with progress towards SDG target 6.4 because it lowers water withdrawals in the power sector by around 50% and water consumption by 25% by 2030.

24. Level of water stress is estimated using the business-as-usual scenario for water stress for today and 2030 from the World Resource Institute's Aqueduct Water Risk Atlas.

2.9.3 Energy, water and an integrated approach to sustainable development

The interactions between energy and water highlight the importance of an integrated approach to sustainable development. Energy is vital to provide water and sanitation, but the Sustainable Development Scenario underscores that achieving SDG 6 does not have a large impact on the global energy balance. Ensuring 2.1 billion people have access to clean drinking water, 4.5 billion have safely managed sanitation, collecting and treating more wastewater and using water more efficiently adds less than 1% to global energy demand in the Sustainable Development Scenario in 2030.

Our analysis highlights a range of potential synergies between SDGs 6 and 7. In rural areas, considering water supply needs when planning electricity provision can open different pathways for both, which can in turn bring down the cost of electricity for households. The production of biogas from waste can facilitate cleaner cooking in households that currently rely on wood and charcoal for cooking. When wastewater management in urban areas requires new infrastructure, integrating energy efficiency from the start can have a significant impact on the energy and GHG emissions footprint of the wastewater sector. As such, integrated thinking is essential to avoid unintended consequences and to mitigate future stresses on both sides of the energy-water nexus.



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