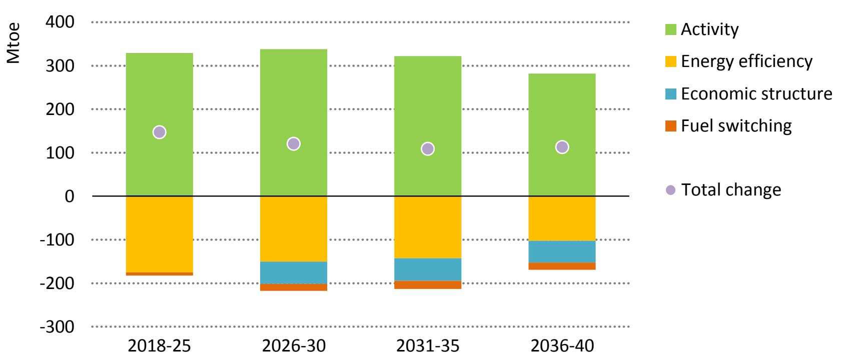
Energy efficiency and renewable energy

Driving investment and technology change

S U M M A R Y

- Global total final consumption was almost 9 700 million tonnes of oil equivalent (Mtoe) in 2017, an increase of 1.7% compared with 2016. In the New Policies Scenario, this rises to almost 12 600 Mtoe by 2040, an increase of 1.1% per year on average, while global energy intensity improves by 2.3% per year. Government policies and measures, including mandatory energy efficiency regulations, drive much of the improvement in energy intensity which curbs growth in energy consumption.

Figure 6.1 ▷ Average annual change in total final consumption by driver in the New Policies Scenario, 2018-2040



The increase in total final consumption would be around twice as large, if it was not for continued improvement in energy efficiency

- In the buildings sector – with 31% of total final consumption, the largest energy consuming end-use sector today – consumption increases by an average of 0.9% per year in the New Policies Scenario. The industry sector, which accounted for around 29% of total final energy consumption in 2017, sees growth of 1.3% per year, the fastest among the end-use sectors. Transport energy consumption increases by 1.1% on average over the period to 2040, maintaining a 29% share in total final consumption.

- In 2017, around $236 billion was invested in energy efficiency across the buildings, transport and industry sectors. In the New Policies Scenario, investment expands and reaches around $770 billion by 2040. The transport sector accounts for more than half of this investment (54%), followed by buildings (39%) and industry (7%).

- Already a major global industry, renewable energy technologies supply 45% of incremental primary energy demand to 2040 in the New Policies Scenario. China becomes the world leader in renewable energy use, followed by the European Union, the United States and India. Renewables overtake coal for power generation in the 2020s and supply 40% of electricity by 2040. Investment in renewables-based electricity rises from $300 billion in 2017 to around $410 billion in 2040. Solar photovoltaic (PV) accounts for around 35% of power generation investment.

- The use of renewables to meet demand for both heat and in transport increases in the New Policies Scenario. Renewables for heat rises by around 85% over the outlook to about 875 Mtoe in 2040. The share of renewables in transport energy demand increases steadily to reach 8% in 2040 compared with 3.5% today. Owing to energy efficiency improvements in combustion engines, biofuels deliver more useful energy over time. The contribution of renewables-based electricity increases with electric vehicle (EV) deployment and the growing share of renewables in electricity generation.

- The United Nations Agenda for Sustainable Development (2030 Agenda) includes targets to increase the share of renewables in energy supply (Sustainable Development Goal [SDG] 7.2) and improve energy efficiency (SDG 7.3). Our analysis shows energy efficiency improving by an annual average of 2.4% to 2030: this represents a near 50% improvement on recent progress, but remains below the 2.7% required to meet the SDG 7.3 target. The share of modern renewables in total final energy consumption grows to 15% by 2030 in the New Policies Scenario, well below the 22% achieved in the Sustainable Development Scenario.

- Transport is the largest oil-consuming sector today, accounting for a fifth of global energy demand and a quarter of energy-related CO_2 emissions. The car fleet increases by 80% over the outlook period, but fuel needs are less than 20% higher than today. This is a result of energy efficiency gains, and to a lesser extent, the uptake of electric cars. Higher efficiency leads to better use of biofuels, for which sustainable feedstock is limited.

- Heat demand in the buildings sector worldwide accounts for almost 75% of total final consumption in buildings, mostly for space heating. In the European Union, energy efficiency measures such as insulation and retrofitting play an important role in curbing energy demand for heating. In the New Policies Scenario, which includes a buildings retrofit rate of 2% a year, energy demand for heating in the buildings sector in European Union falls by 0.95% per year to 2040 or an overall reduction in buildings energy demand of just over 60 Mtoe.

Introduction

This chapter examines current trends in renewable energy and energy efficiency. Recent years have been characterised by strong growth in the deployment of renewable energy technologies, with the power sector leading the way. While the power sector is regularly breaking records for levels of investment and deployment, the uptake of renewables has been slower in the industry, buildings and transport sectors. Some renewable energy technologies are already competitive in existing markets; others teeter on the line between needing support and being competitive, while others clearly cannot compete today without financial support.

Along with renewables, energy efficiency needs to be one of the cornerstones of any strategy to guarantee sustainable and inclusive economic growth. It remains one of the most cost-effective ways to enhance security of energy supply, to boost competitiveness and welfare, and to reduce the environmental footprint of the energy system. Not only can the growth of carbon-dioxide (CO_2) emissions be tempered by the more efficient use of energy but energy efficiency can also improve global air quality and contribute to reducing the millions of air-pollution related premature deaths each year (IEA, 2018a).

While governments recognise the significant contributions and remaining potential of both renewables and energy efficiency gains, generally their policy approaches follow distinct paths and support measures. As the scale and pace of the deployment of each grows, the case for an integrated approach becomes more compelling. This chapter focuses on three key themes:

- The first builds on the analysis on tracking progress towards energy-related Sustainable Development Goals (SDGs) in Chapter 2 and extends this framework to the two targets aimed at increasing the share of renewables in the energy mix (SDG 7.2) and improving energy efficiency (SDG 7.3), and assesses whether the energy system is on track to meeting them.
- The role of efficiency improvements and renewables in the transport sector is the second thematic focus. Significant energy efficiency improvements have been achieved, or are in sight, thanks to new technologies, strengthened fuel-economy standards for road vehicles and new policies for the aviation and shipping sectors. Biofuel blending obligations have been the key driver for the growth of renewables in transport.
- The third theme examines the impact of recent changes to the European Union's Energy Performance of Buildings Directive (EPBD). In the European Union (EU) today, the buildings sector is the largest consumer of energy and is a major contributor to carbon dioxide (CO_2) emissions. Of the residential buildings that will be in use in 2040, it is estimated that around 60% have already been built. This underscores the important role of retrofits in EU residential buildings to go hand-in-hand with effective efficiency standards for new buildings.

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

Scenarios

6.1 Energy efficiency by scenario

Global energy intensity, defined as the ratio of primary energy supply to gross domestic product (GDP), continued to improve in 2017, reaching 110 tonnes of oil equivalent (toe) per $1 million of GDP.[1] This favourable trend stretches back two decades. Improved energy intensity is primarily the result of efficiency gains in the power and end-use sectors, together with a gradual restructuring in many regions from energy-intensive to lighter industries. Worryingly, the annual average rate of energy intensity improvement slowed to 1.7% in 2017 from 2.5% in the last three previous years. This is only half of the annual improvement required in the Sustainable Development Scenario (Table 6.1).

Table 6.1 ▷ Key energy indicators by scenario

		New Policies		Current Policies		Sustainable Development	
	2017	2025	2040	2025	2040	2025	2040
TPED (Mtoe)	13 972	15 388	17 715	15 782	19 328	14 146	13 715
Share of fossil fuels (%)	81%	78%	74%	79%	78%	77%	60%
TFC (Mtoe)	9 696	10 871	12 581	11 103	13 510	10 126	9 958
Energy intensity of GDP (2017=100)	100	82	58	84	64	75	45

Notes: TPED = total primary energy demand; Mtoe = million tonnes of oil equivalent; TFC = total final consumption.

In the absence of existing and announced efficiency measures, global energy consumption in 2040 would be almost 3 400 Mtoe higher than projected in the **New Policies Scenario**. Energy efficiency policies in developing economies account for 60% of the reduction in global energy consumption in 2040 in the New Policies Scenario, but only in the European Union, Japan, and Korea do energy efficiency gains fully offset the increase in energy demand.

The worldwide trend of enhanced energy intensity masks regional variations. In China, energy intensity improved by 3.9% in 2017, but the rate of improvement was only half that of 2016. In the United States, energy intensity improved by almost 3% in 2017 (Table 6.2).

Despite progress in many countries and regions, significant energy efficiency potential remains untapped (IEA, 2018a). In the **Sustainable Development Scenario**, the systematic pursuit of economically viable opportunities to improve efficiency keeps the increase in global final energy consumption to around 250 Mtoe in the period to 2040, compared with nearly 2 900 Mtoe in the New Policies Scenario.[2] In the Sustainable Development Scenario, energy intensity declines by 3.4% a year, compared with 2.3% in the New Policies Scenario.

1. In the *World Energy Outlook-2018*, energy intensity is calculated using GDP in purchasing power parity (PPP) terms to enable differences in price levels among countries to be taken into account. In our scenarios, PPP factors are adjusted as developing countries become richer.

2. A measure to improve energy efficiency is defined as being economically viable if the payback period is shorter than the economic lifetime of the technology or piece of equipment.

Table 6.2 ⊳ Energy intensity of GDP by scenario (toe/$1 000, PPP)

		New Policies		Current Policies		Sustainable Development	
	2017	2025	2040	2025	2040	2025	2040
North America	0.11	0.10	0.07	0.10	0.08	0.09	0.06
United States	0.11	0.10	0.07	0.10	0.07	0.09	0.06
Central and South America	0.09	0.08	0.06	0.08	0.07	0.07	0.05
Brazil	0.09	0.08	0.06	0.08	0.07	0.08	0.05
Europe	0.08	0.07	0.05	0.07	0.05	0.06	0.04
European Union	0.08	0.06	0.04	0.06	0.05	0.06	0.04
Africa	0.13	0.11	0.08	0.09	0.07	0.09	0.05
South Africa	0.17	0.15	0.10	0.16	0.12	0.14	0.07
Middle East	0.12	0.11	0.09	0.11	0.10	0.10	0.07
Eurasia	0.18	0.16	0.12	0.16	0.12	0.15	0.10
Russia	0.18	0.16	0.12	0.17	0.13	0.16	0.11
Asia Pacific	0.11	0.08	0.06	0.09	0.06	0.08	0.04
China	0.13	0.09	0.06	0.10	0.07	0.09	0.05
India	0.09	0.07	0.05	0.07	0.05	0.06	0.03
Japan	0.08	0.07	0.06	0.07	0.06	0.07	0.05
Southeast Asia	0.08	0.07	0.05	0.07	0.06	0.06	0.04
World	**0.11**	**0.09**	**0.06**	**0.09**	**0.07**	**0.08**	**0.05**

S P O T L I G H T

Efficient World Scenario: pulling the energy efficiency lever

In the 2012 edition of the *World Energy Outlook*, the International Energy Agency (IEA) produced an Efficient World Scenario, quantifying the implications for global energy use of pursuing all economically viable opportunities to improve energy efficiency, based on the technologies then available. In 2018, we updated our modelling of the Efficient World Scenario, again to show how tackling the barriers to energy efficiency investment can unleash this potential and bring significant gains for energy security, economic development and the environment (IEA, 2018a).

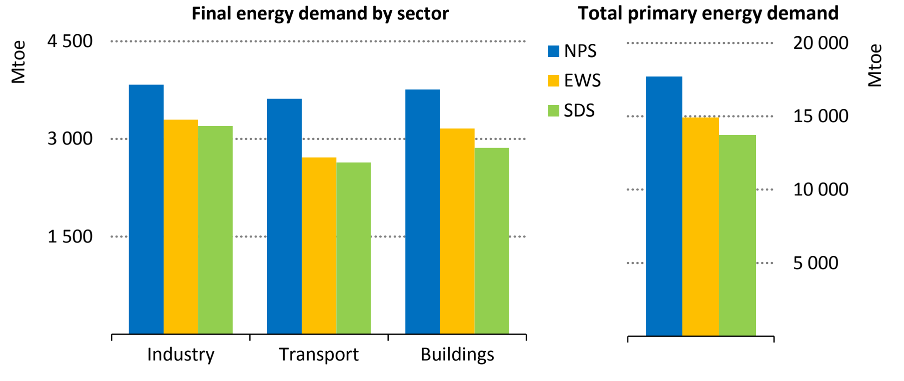
In the new Efficient World Scenario, a 3% annual rate of improvement means that the primary energy intensity of GDP is halved by 2040. This is a considerable step up from the average rate of intensity improvement of 2.3% seen in the New Policies Scenario. It has major impacts on energy consumption of every end-use sector:

- In transport, road passenger vehicles use 40% less fuel per vehicle-kilometre (vkm) travelled in 2040 compared to today. Thanks to hybridisation, and logistics efficiency improvements, road freight uses 46% less energy per tonne-kilometre (tkm) moved.

- In industry, the average energy needed to produce a tonne of crude steel in 2040 decreases by 25% from today's levels, with similar improvements in pulp and paper, thanks largely to increases in recycling rates and equipment efficiency. The most significant gains are in less energy-intensive sectors, however, largely thanks to improvements in electric motor systems and deployment of heat pumps.
- In buildings, a typical square metre of residential floor space uses 26% less energy in 2040 than today, as residential space heating is 43% and lighting around 50% less energy intensive. Average energy intensity of non-residential buildings is 37% lower in 2040 than today.

Implementation of the additional energy efficiency measures assumed in the Efficient World Scenario reduces final energy consumption by 14% in industry, 25% in transport and 16% in buildings in 2040 compared with the New Policies Scenario in 2040, driving down total primary energy demand by nearly 2 800 Mtoe.[3] While pulling the energy efficiency lever is a cornerstone of decarbonisation, alone it is not sufficient to achieve the targets of the Sustainable Development Scenario: this Scenario needs a holistic approach which goes wider than energy efficiency.

Figure 6.2 ▷ Final energy demand by sector and total primary energy demand in each scenario in 2040



The Efficient World Scenario highlights the untapped potential of energy efficiency, taking the world a long way towards the Sustainable Development Scenario

Note: NPS = New Policies Scenario; EWS = Efficient World Scenario; SDS = Sustainable Development Scenario.

3. Latest results from *WEO-2018* scenarios are used for comparison with the Efficient World Scenario. This may lead to some relatively small differences with Energy Efficiency 2018 (IEA, 2018a) which uses *WEO-2017* scenarios as a basis for comparison.

6.2 Renewables by scenario

Electricity generation from renewables has grown very rapidly in recent years, mainly owing to hydropower, wind and solar photovoltaic (PV). In 2000, solar PV accounted for only 1 TWh of electricity generation, by 2017 this had increased to 435 TWh. Wind power accounted for 31 TWh of electricity generation in 2000; by 2017 this had increased to almost 1 100 TWh. The use of renewables in heating and in the transport sector has also grown: for example, biodiesel demand in 2000 was less than 1.0 Mtoe but reached 29 Mtoe by 2017.

Today, hydropower is the largest source of renewables-based power generation, though its rate of deployment slowed somewhat in 2017 with only 25 GW of new capacity added (compared with 36 GW in 2016 and 35 GW in 2015). Wind power holds the second spot: overall wind power capacity additions declined in 2017 even though investment in offshore wind is picking up. Solar PV capacity additions expanded to 97 GW in 2017, led by China, which accounted for more than half of the increase. Electricity output from wind and solar PV combined was almost 20% higher in 2017 than in 2016. In 2017, renewable energy technologies accounted for a quarter of all electricity generation. The perspectives for growth vary considerably, depending on the policies assumed to be in place, ranging from a one-third share in 2040 in generation in the Current Policies Scenario to a two-thirds share in the Sustainable Development Scenario (Table 6.3).

In the **New Policies Scenario**, indirect use of renewables grows faster in the period to 2040 than its direct use in both heat and transport applications. In the **Sustainable Development Scenario**, additional measures to incentivise investment in renewables-based electricity, biofuels, solar heat, geothermal heat and electrification push the share of renewables to two-thirds of the power mix, 25% in heat and 22% in transport in 2040 (including indirect use in transport and heat).

The supply of heat accounted for more than half of total final consumption (almost 5 000 Mtoe) in 2017. The vast majority of heat supply today is produced from fossil fuels, with only 10% coming from renewable energy sources. Bioenergy dominates the renewable contribution to heat supply, accounting for almost 90% of the direct use of renewables-based heat in 2017, as well as almost all of its contribution in district heating systems.

The share of renewables in global heat supply increases in the New Policies Scenario by five percentage points, reaching 875 Mtoe in 2040. Around 60% of this increase is expected to take place in China, the European Union, India and the United States, which are today's largest consumers of renewables-based heat. In the Sustainable Development Scenario, the contribution of renewables to heat supply grows at a much faster rate, reaching 1 100 Mtoe and representing a quarter of overall heat demand by 2040.

The transport sector accounted for almost 8% of direct consumption of renewables in 2017. Around 1.8 mboe/d (86 Mtoe) of biofuels, the only renewable energy source used directly in the sector, were consumed in 2017; some two-thirds of this was ethanol, followed by biodiesel (one-third) and biofuels for aviation and shipping (less than 1%).

Table 6.3 ▷ World renewable energy consumption by scenario

		New Policies		Current Policies		Sustainable Development	
	2017	2025	2040	2025	2040	2025	2040
Primary demand (Mtoe)	1 334	1 855	3 014	1 798	2 642	2 056	4 159
Share of global TPED	10%	12%	17%	11%	14%	15%	30%
Traditional use of solid biomass (Mtoe)	658	666	591	666	591	396	77
Share of total bioenergy	48%	42%	32%	42%	33%	29%	5%
Electricity generation (TWh)	6 351	9 645	16 753	9 316	14 261	10 917	24 585
Bioenergy	623	890	1 427	873	1 228	1 039	1 968
Hydro	4 109	4 821	6 179	4 801	5 973	5 012	6 990
Wind	1 085	2 304	4 690	2 151	3 679	2 707	7 730
Geothermal	87	129	343	125	277	162	555
Solar PV	435	1 463	3 839	1 334	2 956	1 940	6 409
Concentrating solar power	11	34	222	30	119	54	855
Marine	1	3	52	2	29	4	78
Share of total generation	25%	32%	41%	30%	33%	38%	66%
Final consumption (Mtoe)*	930	1 309	2 113	1 259	1 838	1 510	2 977
United States	141	186	271	178	245	226	408
European Union	186	245	326	237	290	269	366
China	158	261	473	246	378	304	671
India	57	99	200	96	179	116	277
Share of global TFC	10%	12%	17%	11%	14%	15%	30%
Heat consumption (Mtoe)*	478	606	874	594	820	653	1 090
Industry**	236	288	395	289	395	302	460
Buildings and other***	242	318	478	304	425	351	630
Share of total heat demand	10%	11%	15%	11%	13%	13%	25%
Biofuels (mboe/d)****	1.8	2.8	4.7	2.5	3.5	4.4	7.3
Road transport	1.8	2.6	4.0	2.4	3.4	3.9	4.9
Aviation and shipping*****	0.0	0.1	0.7	0.0	0.1	0.5	2.3
Share of total transport demand	3%	4%	6%	4%	4%	7%	15%

* Includes indirect renewables contribution, but excludes environmental heat contribution and traditional use of solid biomass. ** Coke ovens and blast furnaces are included in the industry sector. *** Other refers to desalination and agriculture. **** In energy-equivalent volumes of gasoline and diesel. ***** Includes international aviation and marine bunkers.

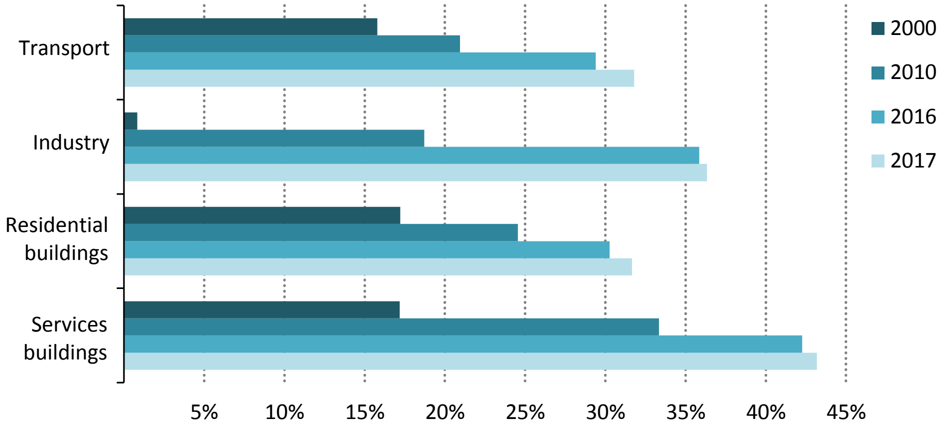
Note: TPED = total primary energy demand; TWh = terawatt-hours; Mtoe = million tonnes of oil equivalent; TFC = total final consumption; mboe/d = million barrels of oil equivalent per day.

The United States is by far the largest market for biofuels with almost half of global demand, followed by Brazil (20%) and the European Union (18%). Demand for biofuels is projected to increase in both the New Policies Scenario and the Sustainable Development Scenario (the outlook for the use of biofuels in examined in more detail in section 6.7).

6.3 Energy efficiency policies and investments

The coverage and strength of energy efficiency policies have increased in recent years (Figure 6.3). Energy efficiency policies covered one-third of final energy consumption worldwide in 2017. Almost all of the increase in coverage is attributable to more goods being covered by existing standards, rather than new standards (IEA, 2018a).

Figure 6.3 ▷ Share of global final energy consumption covered by mandatory efficiency standards by selected end-uses



Mandatory energy efficiency standards have been increasingly adopted in recent years, though the coverage varies among end-use categories

Different assumptions about efficiency policies, and consequent changes in investment flows, underpin the variations in final consumption between scenarios. Energy demand in **buildings** increases by just under 1% per year on average in the New Policies Scenario: this rise reflects growing demand for space cooling alongside increasing ownership of electric appliances and connected devices. In the Sustainable Development Scenario, thanks to strong efficiency policies including performance standards and building codes, energy consumption in the buildings sector falls by around 190 Mtoe over the outlook period.

In **industry**, the average annual increase in consumption of 2.5% since 2000 is projected to slow to 1.3% per year in the New Policies Scenario as a result of energy efficiency gains and significantly lower growth rates for output from energy-intensive industries. For example, on an average annual basis since 1990, the amount of steel produced worldwide has expanded by 3.0% and that of cement by 4.8%, but these rates slow to 0.8% per year for steel and 0.2% per year for cement in our projections. A significant contributing factor is that production of both steel and cement in China in 2040 is projected to be lower than today. Growth in industrial energy demand in the Sustainable Development Scenario slows even further, to an annual average of 0.5%.

In the **transport** sector, efficiency measures help to constrain growth in demand to around 30% in the New Policies Scenario; in the Sustainable Development Scenario it decreases by 6%, despite a large increase in demand for mobility (see section 6.7).

In 2017, $236 billion was invested in energy efficiency across the buildings, industry and transport sectors – an increase of $8 billion (or 3%) from the previous year (Table 6.4).[4] The increase was largely attributable to spending on heating, cooling and lighting in buildings (IEA, 2018b). Spending in the buildings sector is the main area for energy efficiency expenditure, which at $140 billion in 2017 accounted for 59% of total investment in energy efficiency. Spending on building envelopes (insulation, walls, roofs and windows) represented almost half of this investment in the sector.

Table 6.4 ▷ Global annual average investment in energy efficiency in selected regions by scenario ($2017 billion)

		New Policies		Current Policies		Sustainable Development	
	2017	2018-25	2026-40	2018-25	2026-40	2018-25	2026-40
United States	42	62	85	55	72	92	156
European Union	n.a.	121	174	84	112	128	134
China	65	66	108	45	89	84	120
India	8	17	36	16	36	21	56
World	**236**	**397**	**666**	**299**	**496**	**505**	**828**
World – Cumulative		*3 173*	*9 983*	*2 391*	*7 447*	*4 038*	*12 425*

Source: 2017 data from IEA (2018b).

Spending on improved efficiency in the transport sector increased by 11% to $60 billion in 2017 compared to the previous year with expenditure on light-duty vehicles (LDVs) representing just over half of this total ($33 billion). Conversely investment in energy efficiency in the industry sector fell by 8% to $35 billion (IEA, 2018b). Worldwide, current investment in energy efficiency in the industry sector was directed more to manufacturing such as food and beverage than to energy-intensive production such as iron and steel.

In the New Policies Scenario, energy efficiency investment increases in all end-use sectors, especially in transport and buildings. Buildings account for almost 40% of the cumulative investment in energy efficiency to 2040, around 60% of which is in the residential sector. Almost 45% of this amount is for improved insulation and some 30% is for more efficient appliances. In transport, around 60% of the investment is for efficiency improvements in LDVs, and most of the rest is for other forms of road transport, though only about a quarter of this is for medium- and heavy-duty trucks. The corollary is that medium- and heavy-duty trucks remain one of the main drivers of oil demand growth by 2040.

4. An energy efficiency investment is defined as the incremental spending on new energy-efficient equipment or the full cost of refurbishments that reduce energy use. The intention is to capture spending that leads to reduced energy consumption.

6.4 Renewables policies and investments

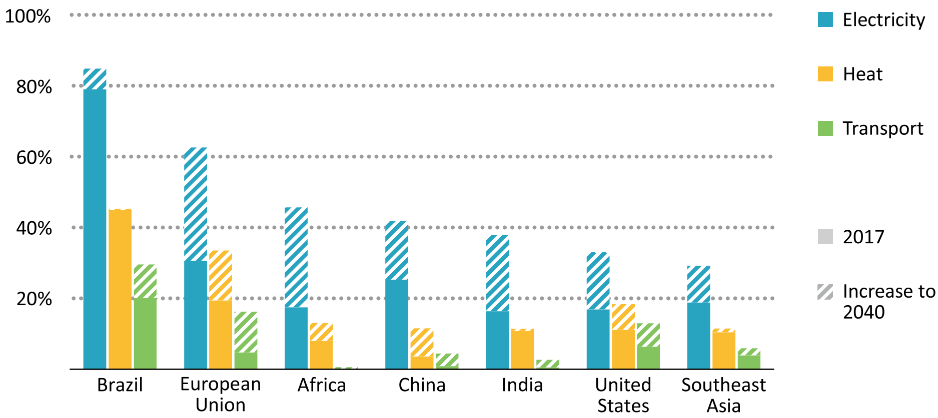
The future of renewables remains heavily dependent on the policy frameworks put in place. To date, policies that deal with the direct use of renewables in end-use sectors have received much less focus than policies for the power sector.

In 2017, targets for the renewable share of primary and final energy were in place in 87 countries, while sector-specific targets for renewable power were in place in 146 countries, for renewable heating and cooling in 48 countries, and for renewable transport in 42 countries (REN21, 2018). Furthermore, the number of countries with renewable heating targets has remained fairly constant over recent years, while the number of countries introducing renewable electricity targets has continued to grow.

In 2017, the power sector accounted for the largest share of investment in renewables, followed by heating for buildings and by biofuels for transport. Overall investment in renewables-based power was 7% less than the previous year, but lower unit costs facilitated the addition of almost 180 GW of new capacity, up 6 GW from 2016 and a new record. Investment in solar PV brought 97 GW of new capacity, a record amount, with deployment levels in China and India continuing to rise. Investment in offshore wind also rose to record levels, while investment in onshore wind fell by nearly 15% (IEA, 2018c).

In most major countries and regions, low-carbon generation investment in 2017 exceeded that for fossil fuel-based power. The main exceptions to this trend are Southeast Asia, the Middle East and North Africa.

Figure 6.4 ▷ Renewable energy share by category and region in the New Policies Scenario, 2017 and 2040*



Renewable energy contributions increase in all sectors in the main regions, dominated by the power sector

* Excludes traditional use of biomass.

In China, where renewables already account for a quarter of electricity production (largely from hydropower), the share of renewables in electricity production rises to over 40% by 2040, reflecting large investments in wind and solar PV. In India, renewables-based electricity generation increases by almost 1 500 TWh over the outlook period, also reflecting significant investment in solar PV and wind power.

Table 6.5 ▷ Global annual average renewables investment by scenario ($2017 billion)

		New Policies		Current Policies		Sustainable Development	
	2017	2018-25	2026-40	2018-25	2026-40	2018-25	2026-40
Renewables-based power generation	298	322	361	286	278	441	616
Wind	85	98	119	85	87	134	218
Solar PV	144	127	116	111	89	177	186
Transport biofuels	2	9	18	8	18	25	47
Renewable heat	109	116	127	103	111	134	154
Total	**407**	**437**	**488**	**390**	**389**	**576**	**770**
Cumulative		*3 574*	*7 600*	*3 183*	*6 110*	*4 807*	*12 246*

Note: Renewable heat includes only the direct use of renewables for heat in end-use sectors.

Source: 2017 data for renewables-based power generation from IEA (2018b).

In the **New Policies Scenario**, investment in renewable electricity generation continues to increase over the outlook period, rising from almost $300 billion in 2017 to $413 billion in 2040 (Table 6.5). Wind power and solar PV account for two-thirds of the $8 trillion cumulative global spend on renewable electricity energy generation over the outlook. Hydropower accounts for 20% of the remaining renewables-based power investment, with bioenergy and concentrating solar power (CSP) making up the balance. China, the European Union, the United States and India account for more than 60% of total investment in renewable power generation. Investments in renewable heat increase from $109 billion in 2017 to around $150 billion in 2040, a cumulative total of around $2.8 trillion. The buildings sector accounts for the majority of renewable heat investment (85%).

In the **Sustainable Development Scenario**, which includes additional policy measures to support increased deployment of renewable-based electricity across all regions, cumulative investment in renewables-based power generation is $12.8 trillion over the outlook period, with wind accounting for 34%, followed by solar PV (33%), and hydropower (18%). Investments in renewable heat rise to nearly $180 billion by 2040, a cumulative total of $3.4 trillion. The buildings sector accounts for the largest share, boosted by the introduction of mandatory energy conservation building codes, including net-zero emissions requirements for all new buildings and increased support for solar thermal and geothermal heating.

6.5 Renewables support

Key drivers of the rise in renewables include policy support and associated government financial commitments (such as feed-in tariffs and long-term power purchase agreements awarded through auctions) and cost reductions. Stable support policy frameworks, cost reductions and renewables deployment are strongly interlinked. Based on a survey of established national policies and on the known deployment of new renewable energy projects, we estimate that the cost of the support mechanisms on a global basis in 2017 for renewables-based electricity was $143 billion, 2% higher than in 2016.

Wind power and solar PV accounted for majority of non-hydro renewables output (70% of the total) and were the primary recipients of support for renewables, accruing more than 80% of the total in 2017. Bioenergy-based power plants were the third-most supported renewable energy technology, receiving more than $20 billion in 2017. After a record year of solar PV capacity additions, China became the leading provider of renewables support for the first time, ahead of Germany, United States, Japan, and Italy. Together, these five countries accounted for almost two-thirds of total financial support for renewables in 2017.

The costs of renewables support mechanisms increased only marginally relative to the rate of new generation in 2017, largely because of increases in average wholesale electricity prices in many countries, and because of declining technology costs of solar PV and wind power. Recognising these factors led some governments to scale back the unit rate of support provided.

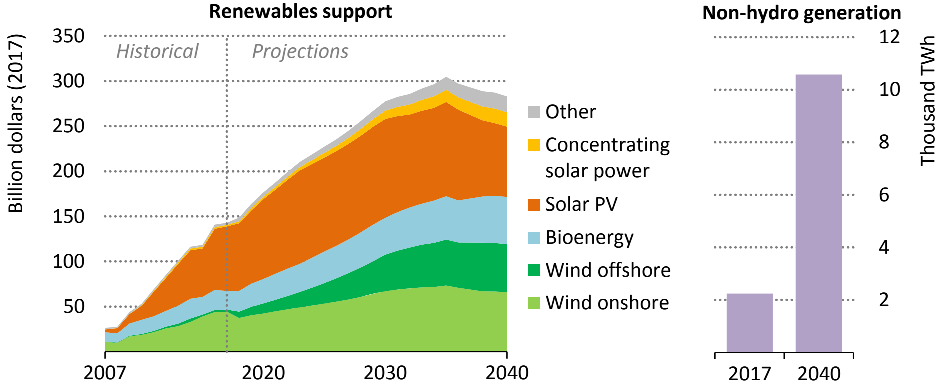
In many markets, there has been a shift to auctions for renewable energy projects and other means of awarding support on the basis of competition. In 2017, more than 20% of new solar projects that received support were selected on the basis of competition, together with about 30% of onshore wind and 50% of offshore wind projects.

Other mechanisms used to provide support for the deployment of renewables included FiTs, market premiums, green certificates and investment tax credits. Supportive frameworks may lower total project costs by enabling low-cost financing (see Chapter 7, section 7.3.2) or making available low-cost land or grid access. Renewable energy use in the transport sector is mostly supported by various biofuel mandates, greenhouse gas (GHG) reduction policies and fiscal benefits. Support for renewable heat includes feed-in tariffs and premiums, capital grants, subsidies, soft loans and tax incentives.

In the New Policies Scenario, support provided to renewables-based electricity generation peaks at around $300 billion in 2035 and then declines to about $280 billion by 2040 (Figure 6.5). Of the total cumulative support over the period from 2017 to 2040, more than three-quarters goes to solar PV and wind power, and more than 15% goes to bioenergy. By 2040, the share going to solar PV and wind decreases to 70%, while the shares going to bioenergy and concentrating solar power increase to just below 20% and just above 5% respectively.

The average support per unit of electricity generated by renewables declines dramatically in most regions to 2040, largely as a result of technology cost reductions and rising wholesale electricity prices (see Chapter 10, section 5). By 2040, the global average support per unit of output for new solar PV projects declines almost 90%, and for new wind power projects it declines by almost 70%.

Figure 6.5 ▷ Global renewables-based electricity support and non-hydro generation in the New Policies Scenario



Globally, support to renewables for power generation increases from $143 billion today to $280 billion in 2040, with generation from non-hydro renewables more than quadrupling

Key themes

In the following sections we examine in detail three key themes, each of which provide examples of the interaction between energy efficiency and renewables, and indicate the value of considering them in an integrated way.

6.6 Tracking progress in meeting sustainable development goals

The United Nations (UN) Agenda for Sustainable Development (2030 Agenda), adopted in 2015, includes the goal to "ensure access to affordable, reliable, sustainable and modern energy for all" (SDG 7). It includes a target to increase the share of renewables in the energy mix (SDG 7.2) and another that aims to improve energy efficiency (SDG 7.3). Both make a contribution to SDG 7.1 (ensuring universal access to modern energy). This section elaborates on the role of renewables and energy efficiency in the 2030 Agenda, and assesses whether the energy system is on track to meeting SDG 7.2 and SDG 7.3.

As a co-custodian agency for SDG targets 7.2 and 7.3, the IEA has a key role in providing the methodological basis and data for the indicators used to track annual country-by-country progress, and is mandated to report country-level progress each year to the United Nations.[5] In support of the first UN review of SDG 7 at its High-level Political Forum in July 2018, the IEA made country-by-country data and projections for all SDG 7 targets available for free online.[6] The IEA also co-leads the *Tracking SDG 7* report, a joint report of the SDG 7 custodian agencies, which provides a consolidated benchmark tracking annual progress on the targets of SDG 7.

Table 6.6 ▷ SDG 7 targets for energy access, renewable energy and energy efficiency

Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all			
Target		**Indicator**	
7.1	By 2030, ensure universal access to affordable, reliable and modern energy services.	**7.1.1**	Proportion of population with access to electricity.
		7.1.2	Proportion of population with primary reliance on clean fuels and technologies.
7.2	By 2030, increase substantially the share of renewable energy in the global energy mix.	**7.2.1**	Renewable energy share in total final energy consumption.
7.3	By 2030, double the global rate of improvement in energy efficiency.	**7.3.1**	Energy intensity measured in terms of primary energy and gross domestic product.

It is important to note that the indicators used to track progress towards the SDGs differ from the usual WEO definitions. For SDG 7.2.1, the share of renewables in total final energy consumption is calculated as the direct and indirect renewable energy consumed over total final energy consumption, excluding non-energy uses. It, however, includes the traditional use of biomass, which the IEA usually does not consider as renewable. In the remainder of this section, modern renewables is used when the traditional use of biomass is not included. For SDG 7.3.1, energy intensity is calculated against a GDP expressed in 2010 dollars.

Renewables and energy efficiency targets on the 2030 Agenda

SDG 7.2 and 7.3 are integral components of the UN 2030 Agenda. They reflect the way in which the SDGs were formed to include root factors rather than headline indicators of sustainable development. Energy efficiency and renewable energy together contribute more widely to the SDGs in a number of ways:

- Both help to reduce greenhouse gas (GHG) and air pollutants, and therefore contribute to climate (SDG 13) and air pollution (SDG 3) goals (See Chapter 2).
- Both are essential for modern energy access. Renewables are set to deliver many new electricity access connections by 2030 (in the Sustainable Development Scenario, they

5. The SDG 7 custodian agencies are the IEA, IRENA, United Nations Statistics Division, the World Bank and the World Health Organization.

6. See www.iea.org/sdg.

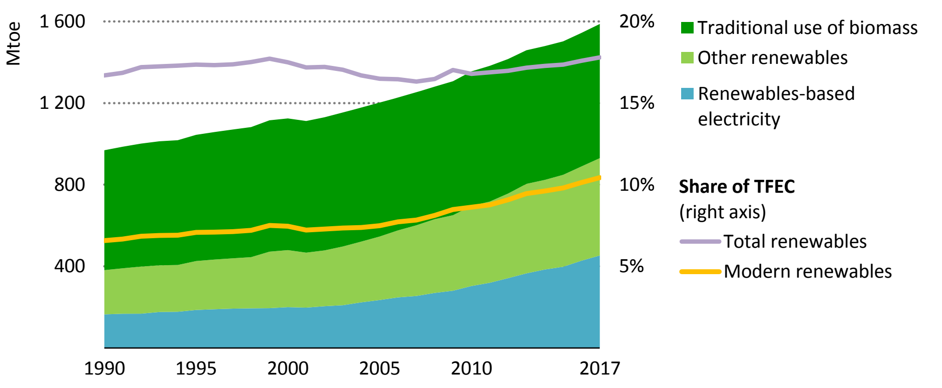
deliver more than three-quarters of new electricity access connections), and energy-efficient appliances help people to make the most of their electricity access. Energy access in turn supports other development priorities, including poverty reduction, provision of health facilities and gender equality (IEA, 2017a).

- Beyond the SDGs, both increased energy efficiency and use of renewable energy can also provide other benefits, for example, by reducing fuel imports, improving energy security, and providing local employment.

Progress and policy efforts towards meeting the renewable energy target (SDG 7.2)

The share of modern renewables in total final energy consumption has been growing since the 1990s, reaching 10% in 2017 (Figure 6.6). Renewables-based electricity generation (now a quarter of total generation) accounts for just over 55% of the increase in renewables energy use since 2000. Hydro, wind and bioenergy account for most of this, but solar has contributed one-quarter of the growth in electricity generation from renewables in the last three years. Bioenergy accounted for nearly 90% of the direct use of renewables in 2017, with 50% of it consumed in North America and Europe.

Figure 6.6 ▷ Renewables in total final energy consumption



The growth of renewables has outpaced the rate of increase of energy consumption but traditional use of biomass still accounts for 7% of global final energy consumption

Note: Mtoe = million tonnes of oil equivalent; TFEC = total final energy consumption, which excludes non-energy use.

These figures exclude the traditional use of biomass (fuelwood, charcoal and organic waste used as the main cooking fuel for 2.3 billion people), most of which is used in developing Asia and sub-Saharan Africa (see Chapter 2). This solid biomass is consumed primarily in inefficient and poorly ventilated cookstoves in developing countries, and is a major contributor to air pollution and premature deaths worldwide. Although the traditional use of biomass has been growing in absolute terms, its growth has been slower than that of modern renewables and it now accounts for 7% of total final consumption, down from 9% in 2000.

Although lagging behind policies promoting electricity (see Chapter 8, section 3), there have been some notable recent policy developments related to renewable energy in transport and heating in selected countries (Table 6.7).

Table 6.7 ▷ Selected policies for renewable energy in transport and heat announced or introduced since mid-2017

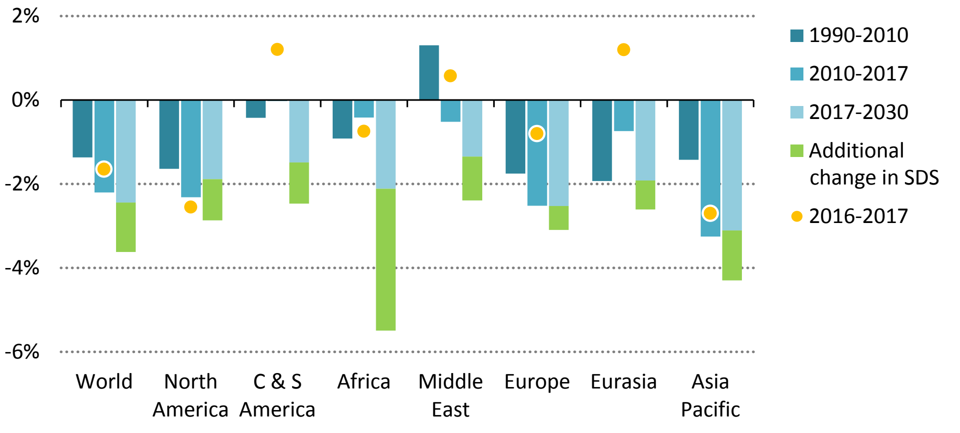
Region	Sector	Policy
Brazil	Transport	RenovaBio introduces a target for the overall decarbonisation of the transport sector by 2028, and includes sub-targets for fuel distributors.
Canada	Transport	Phases 1 and 2 of the Electric Vehicle and Alternative Fuel Infrastructure Initiative allocates $140 million over six years (2016-2022) to support infrastructure deployment and demonstrations in the areas of electric vehicles and alternative fuels (e.g. natural gas, hydrogen).
China	Transport	Implementation of the Expansion of Ethanol Production and Promotion for Transportation Fuel plan, jointly announced by a number of government agencies and ministries, sets a goal to achieve the use of 10% ethanol (E10) nationwide by 2020.
European Union	Heating/ cooling	The European Union established a new, binding renewable energy target of 32% of gross final consumption of energy by 2030, including a review clause by 2023. The 2030 goal includes a target of 1.3 percentage point increase each year in heating and cooling from renewable sources.
India	Transport	A new national biofuels policy was approved in 2018. It includes several measures to support biofuel production and to widen the permitted feedstock base for ethanol production, including additional tax incentives and investment support of around $700 million over six years.
	Heating	The National Biogas and Manure Management Programme established an annual target of launching around 65 000 biogas plants in 2018.
United Kingdom	Transport	The Renewable Transport Fuel Obligation, which regulates biofuels used for transport and non-road mobile machinery, was amended to require suppliers to ensure the fuel mix is at least 12.4% renewables by 2032, up from 4.75% and with an interim target of 9.75% by 2020.

Progress and policy efforts towards increasing energy efficiency (SDG 7.3)

Global energy intensity, defined as the ratio of primary energy supply to GDP, is the indicator used to track progress on global energy efficiency (SDG 7.3). The original target was an annual reduction of 2.6% although the world has fallen short of this goal since it was announced: the annual reduction in 2017 was only 1.7% (Figure 6.7). This shortfall means that the required rate of intensity improvement has risen to 2.7% for the remaining years to 2030.

Energy efficiency gains in recent years have largely been achieved through measures introduced by governments. These have included fiscal measures (such as tax relief on residential renovations and electric vehicle purchases) and mandatory energy efficiency regulations (such as minimum performance standards, fuel-economy standards, building energy codes and industry targets), as well as public financing and the use of market-based instruments, such as tradable certificates linked to energy saving obligations for utilities. Price effects, technological change and advances in energy management in the industrial and buildings sectors are also delivering efficiency improvements. Table 6.8 highlights some recent energy efficiency policy measures.

Figure 6.7 ▷ Annual average change in energy intensity by region



Recent improvements in energy intensity have been strong, yet are not sufficient to meet the 2030 SDG target

Notes: SDS = Sustainable Development Scenario; C & S America = Central and South America. The 2017-2030 projections are based on the New Policies Scenario.

Table 6.8 ▷ Selected energy efficiency policies announced or introduced since mid-2017

Region	Sector	Policy
Brazil	Cross-sector	New standards adopted for electric motors and ceiling fans. Consultations held on stronger minimum energy performance standards for refrigerators, freezers, air conditioners and distribution transformers; adoption likely in 2018.
Canada	Buildings	The Buildings Strategy was endorsed by federal and provincial First Ministers in August 2017 and efforts to support its implementation are underway. The Energy Efficient Buildings RD&D programme was launched in 2017: it supports the development and implementation of building codes for existing buildings and new net-zero buildings.
	Transport	The Pan-Canadian Framework on Clean Growth and Climate Change outlines a strategy to reduce emissions from the transportation sector by setting and updating vehicle emissions standards and improving the efficiency of vehicles, using cleaner fuels, shifting towards lower emitting types of transportation, and increasing the uptake of zero-emission vehicles.

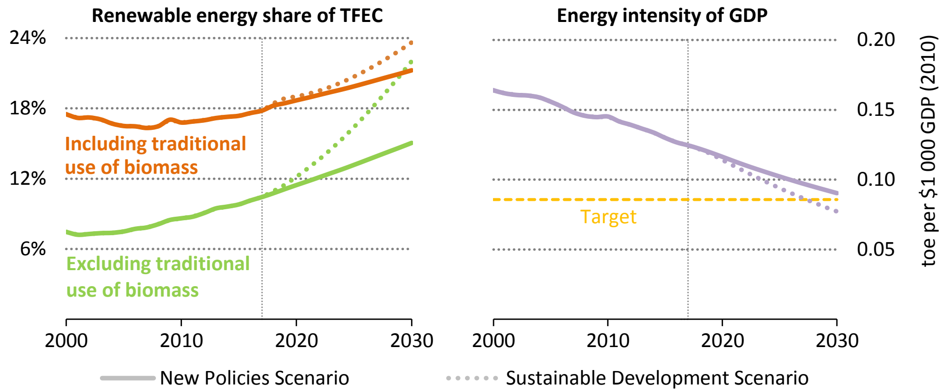
Table 6.8 ▷ Selected energy efficiency policies announced or introduced since mid-2017 (continued)

Region	Sector	Policy
China	Cross-sector	Development of the "100, 1 000, 10 000" programme, building on the Top 10 000 initiative, which mandates energy savings across a range of sectors. In parallel, ongoing expansion in coverage and scope of minimum energy performance standards for appliances.
European Union	Cross-sector	Energy efficiency measures agreed as part of the EU Clean Energy Package, notably revision of the EU Energy Efficiency Directive with binding target for 32.5% EU-wide energy efficiency improvement relative to current projected values by 2030.
	Buildings	The Revised Energy Performance of Buildings Directive (EPBD) includes an obligation for member states to develop long-term renovation strategies and "smart readiness" measures including at least one electric vehicle charging point for buildings with more than ten parking spaces.
	Transport	14% share of renewables in total transport energy consumption.
India	Cross-sector	Development of the National Energy Plan links efficiency to energy security and aligns with its Nationally Determined Contributions under the Paris Agreement. In parallel, revision of building codes and appliance standards to improve energy efficiency, as well as continuation and broadening of the Perform, Achieve, Trade (PAT) efficiency certificate trading scheme for energy-intensive industries.
Indonesia	Transport	Full tax relief for vehicles under the low-cost green car programme, which covers small cars with 20 km/litre fuel economy for spark ignition engines up to 1 200 cc or compression ignition engines up to 1 500 cc.
	Appliances & equipment	New minimum energy performance standards as well as progressive updates, alongside a labelling system for residential air conditioners.
Italy	Cross-sector	Target of 10 Mtoe reduction in final energy consumption by 2030, featuring tax breaks and loan guarantees for residential energy efficiency investments.
Malaysia	Cross-sector	National Energy Efficiency Action Plan 2016-2025 featuring sectoral targets including government-building retrofits, ISO 50001 energy management standards for companies and smart meters in industry.
Mexico	Cross-sector	Additional instruments in energy transition law, including consumption monitoring for high energy consumers, mandating regular evaluation of energy efficiency standards every three years, and voluntary agreements coupled with energy efficiency excellence awards.
United Kingdom	Cross-sector	UK Clean Growth Strategy, featuring a target of 20% efficiency improvement in business and industry by 2030, alongside energy efficiency obligations for utilities as well as funds for innovation in low-carbon heating and public sector efficiency improvements.
United States	Buildings	California introduced new building codes featuring tighter efficiency standards, requirements for solar photovoltaic systems and measures to promote building electrification through heat pumps and battery storage.

Are we on track to meet the renewables and energy efficiency SDG targets?

In the New Policies Scenario, the share of modern renewables increases to 15% of total final energy consumption in 2030. Electricity generation from renewables overtakes coal in the 2020s and supplies around 36% of electricity by 2030. Growth is not confined to the power sector: the direct use of renewables for heating and transport also increases significantly. In our Sustainable Development Scenario, modern renewables reach 22% of final energy consumption in 2030. In some countries and regions the rate of progress is far from the substantial increase required to meet the SDG (Figure 6.8).

Figure 6.8 ▷ Progress towards SDG 7.2 and 7.3 in the New Policies and Sustainable Development scenarios



Renewables and efficiency are cornerstones of the Sustainable Development Scenario

Note: TFEC = total final energy consumption, which excludes non-energy use.

While intensity improvements accelerate in most regions in the New Policies Scenario, they accelerate fastest in developing economies. In Developing Asia, for example, energy intensity improves at an annual rate of 3.3%. A number of significant energy efficiency policies , which have recently been agreed or are currently under development, are expected to boost energy intensity reduction. These include new policy packages announced by the European Union and China, and plans to strengthen mandatory energy performance regulations in various regions. As a result, overall global energy intensity in the New Policies Scenario is expected to decrease by 2.4% per year on average between 2017 and 2030. This is a faster rate than has been achieved in recent years, but falls short of the 2.7% annual improvement required in the SDG 7.3 target, and the 3.6% annual improvement needed to achieve the Sustainable Development Scenario.

6.7 *Efficiency and use of renewables in the transport sector*

Transport accounts for a fifth of global energy demand today and is responsible for a quarter of energy-related carbon dioxide (CO_2) emissions. More than 95% of today's transport sector emissions are from oil. Demand for the transport of people and of goods is projected to increase significantly through to 2040 as a result of both population and economic growth. There remains large untapped potential for energy efficiency improvements in transport – e.g. via increased efficiency of internal combustion engines (ICEs), friction reduction or hybridisation – and to switch to alternative renewable fuels, which have been fostered in many countries.

Policies promoting energy efficiency are the main lever in place for reducing vehicle fuel consumption and to minimise related pollution (Table 6.9). These generally take the form of efficiency or GHG emissions performance standards that establish targets for maximum fuel consumption for cars and other vehicles, and efforts to promote greater use of public transportation and better urban planning.

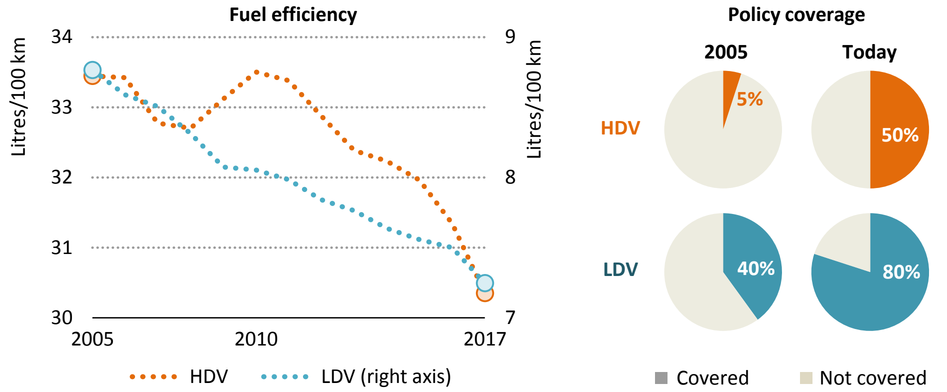
Table 6.9 ▷ Recent policy developments related to efficiency and biofuels in transport by selected region

Region	Energy efficiency policy
China	Update of passenger car fuel-economy standards to include the new energy vehicle mandate.
European Union	Political agreement about the extension of CO_2 standards to LDVs. Plans for implementation of CO_2 emission standards for HDVs.
India	Entry into force of HDV fuel-economy standards in April 2018.
United States	Revision of Corporate average fuel-economy standards (CAFE) for model years 2022-2025.
Region	**Biofuels policy**
Canada	Clean Fuel Standard: target of abating 30 million tonnes of carbon emissions by 2030. Biojet fuel challenge launched in August 2018.
Brazil	RenovaBio, a new national biofuel policy, includes sub-targets for fuel distributors to increase the supply of biofuels.
Colombia	Increase in ethanol and biodiesel blending mandates to 10% for most of the country.
European Union	14% share of renewable energy in the transport sector by 2030, with a non-food based biofuels target of 3.5% by 2030. Implementation of additional sustainability criteria for biofuels limiting imports of feedstock with risk of deforestation.
India	Ambition for a 20% ethanol blend in gasoline and 5% blend of biodiesel in diesel by 2030. Promotion of industrial development of advanced biofuels.
United Kingdom	Long-term framework for growth of renewable energy in transport: 12.4% in 2032 of which 2.8% must come from advanced biofuels.
United States	Renewable Fuel Standard update: 73 billion litres of renewable fuels in 2018 and 136 billion litres by 2022.

Notes: LDVs = light-duty vehicles; HDVs = heavy-duty vehicles. See Chapter 8 for recent electric vehicles policy developments.

Mandatory fuel-economy standards for light-duty vehicles (LDVs), which account for almost 45% of all transport energy use, are now in force in 38 countries. Mandatory fuel efficiency standards for LDVs apply to over 80% of new LDV sales worldwide: the number of new LDVs covered by standards quadrupled from 2005 to 2017.[7] Fuel-efficiency standards for heavy-duty vehicles[8] (HDVs) currently are in place in only five countries, although they cover around half of new HDV sales today.[9] Coverage of fuel-efficiency standards for HDVs will jump by up to 8% when the new European Union CO_2 emissions standards currently under discussion enter into force. These standards will first apply to heavy-duty trucks and then be extended to smaller trucks, buses, coaches and semi-trailers.

Figure 6.9 ▷ Evolution of average fuel efficiency and efficiency standards coverage of new sales by selected modes



The average fuel efficiency of new vehicles has improved substantially due to wider policy coverage and more stringent performance requirements

Note: Litres/100 km = litres of gasoline equivalent per 100 km driven; HDV = heavy-duty vehicles; LDV = light-duty vehicles.

The average fuel efficiency of new vehicles has improved significantly in recent years, although there are signs that progress is now slowing (Figure 6.9). Existing policies have delivered important improvements in the average fuel economy of LDVs, with an average 1.5% annual rate of improvement over the 2005 and 2015 decade. Between 2005 and 2008, the global average annual rate of improvement was 1.8%, but it fell to 1.1% between 2014 and 2015, then to 0.5% in 2016.

7. Light-duty vehicles include passenger and commercial cars, sports utility vehicles and light-duty trucks.

8. Heavy-duty vehicles include buses, coaches, medium- and heavy-duty trucks and account for around 30% of transport energy demand.

9. Canada, China, India, Japan and United States.

Meanwhile, the average test-cycle CO_2 emissions of new cars sold in 2017 in the European Union deteriorated for the first time to 118.5 grammes of carbon dioxide per kilometre (g CO_2/km), compared with the 2021 target of 95 g CO_2/km (European Environment Agency, 2018). The main reason is a shift from diesel to gasoline cars: the latter accounted for more than half of the new cars sold for the first time since 2010. In the United States, fuel economy also degraded in 2017, reflecting a surge in sales of light truck and sports utility vehicle (SUVs) and a slide in the sales of lighter cars. SUVs have quickly gained market share in China and India as well, where they account for around 42% and 33% respectively of new car sales.

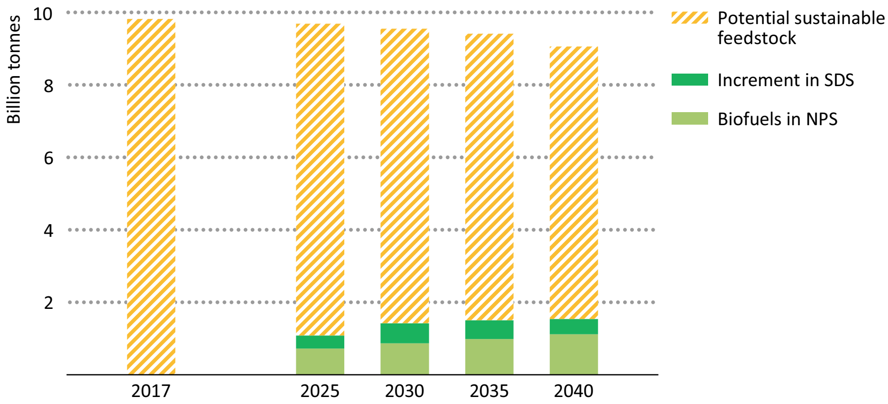
Box 6.1 ▷ Advancing advanced biofuels

Currently around 1.8 million barrels of oil equivalent per day (mboe/d) of biofuels are produced globally, predominantly using "conventional" methods of production. Concerns have been raised about its sustainability in some countries: the feedstocks required can compete with food production for agricultural land and there can be a large increase in CO_2 emission intensity associated with land clearing and cultivation. As a result, there is increased interest in advanced biofuels, which can avoid these concerns. Various materials can be used: waste oils, animal fats, lignocellulosic material such as agricultural and forestry residues and municipal wastes, and all are the subject of current research programmes. If successful, the results of these research programmes could lead to huge potential increases in biofuel production. We estimate that today there are around 10 billion tonnes of lignocellulosic "sustainable" feedstock that could be used for biofuels production worldwide (Figure 6.10).[10] The 4.7 mboe/d of biofuel production in the New Policies Scenario in 2040 would need around 12% of the available feedstock (if it were to be produced entirely using advanced technologies). Even the 7.3 mboe/d of biofuel production in the Sustainable Development Scenario would need 14% of the available feedstock.

While large volumes of advanced biofuels could be produced sustainably, their development and deployment has been slowed by their costs (relative both to conventional biofuels and oil). Conventional biofuel feedstocks can often be harvested close to production centres; they have a higher energy content, and they often have a low level of contaminants so handling and treatment can be relatively inexpensive and simple. In contrast, advanced biofuel feedstock tends to be spread over a larger geographic area and of variable quality. Producing a barrel of advanced biodiesel costs around $140/barrel today. Assuming that these results in no net CO_2 emissions, a carbon tax above $150 per tonne of CO_2 would be required for such a biodiesel to be cost-competitive with diesel refined from crude oil. The future of advanced biofuels therefore will depend critically on continued technological innovation to reduce production costs as well as stable and long-term policy support.

10. Sustainable in this context means that the feedstock has near-zero life-cycle GHG emissions, that it does not compete with food for agricultural land, and that it does not have other adverse sustainability impacts (such as reducing biodiversity). The sustainable level of wood feedstock estimated here is below annual forest growth rates to ensure that forest levels are preserved.

Figure 6.10 ▷ Sustainable feedstock available and levels needed to cover total biofuel consumption by scenario



The availability of sustainable feedstock using advanced processes is much higher than the levels required for biofuel production in the New Policies Scenario

Note: Feedstock consumption levels shown would cover conventional and advanced biofuel production.

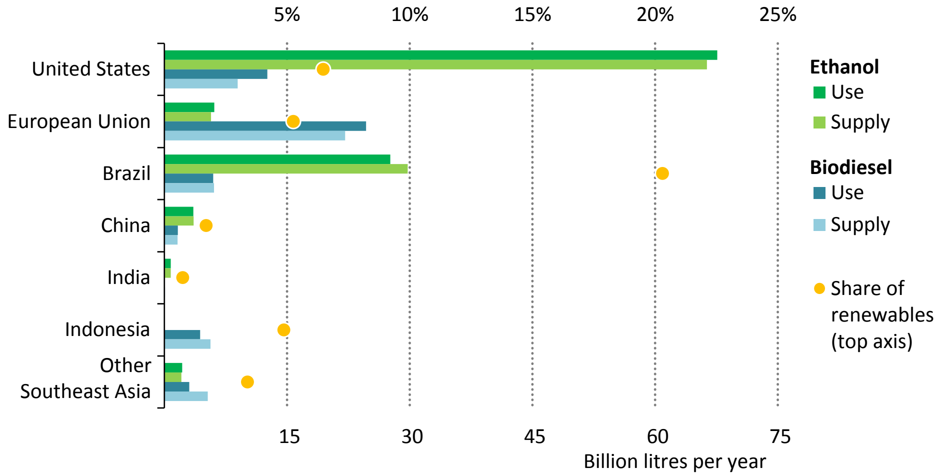
Global transport biofuel consumption increased by more than 5% in 2017 to reach 150 billion litres, of which three-quarters is ethanol.[11] Biofuel promotion policies are now in place in 68 countries. The United States is the only country to set absolute consumption targets through its Renewable Fuel Standard II, with an overall target of 73 billion litres in 2018 and 136 billion litres in 2022. Most other countries have set objectives in the form of blending mandates. The United States remains the leader in ethanol use and supply, followed by Brazil, the country with the highest blending rate. The European Union is the third-largest producer of ethanol and is the leading biodiesel producer and consumer.

A proposed EU Renewables Energy Directive, which is currently under discussion, would set a specific target of a 14% share of renewable energy in the transport sector, and a 3.5% sub-target for advanced biofuels by 2030. In Brazil, the RenovaBio policy, which is similar to California's Low-Carbon Fuel Standard, sets GHG emissions reduction targets for fuel distributors and may lead to the doubling of Brazilian ethanol production capacity by 2030 (Empresa de Pesquisa Energética, 2017). It also aims to revitalise the domestic ethanol industry by assigning carbon intensity to transportation fuels.

From 2000 to 2017, the deployment of fuel-economy standards helped to offset around 1.2 mb/d of oil, and 1.8 mboe/d of biofuels were consumed, mainly in road vehicles. Government policies were largely responsible for these advances, and policy development will inevitably have an important bearing on future developments.

11. In energy terms, biofuel consumption is 86 Mtoe, of which two-thirds is ethanol.

Figure 6.11 ▷ Biofuels production, consumption and share of renewable energy in transport energy use in selected regions, 2017



The United States leads the ethanol market while the European Union is the biodiesel leader. Brazil surpasses 20% of renewable energy use in the transport sector.

Outlook for energy efficiency and renewables in transport

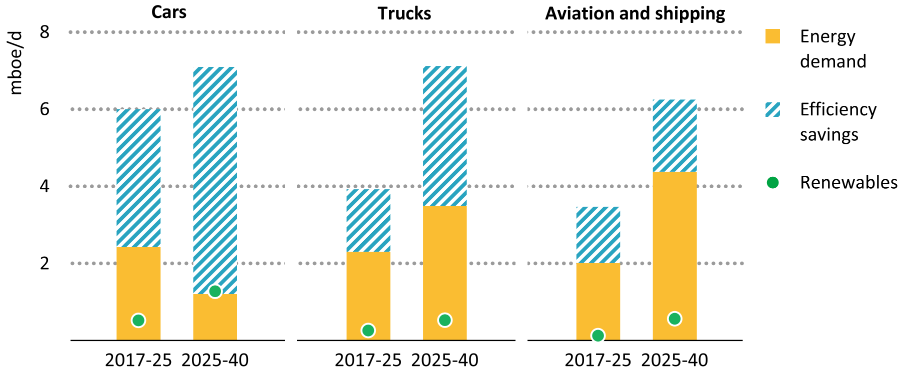
In the New Policies Scenario, energy efficiency improvements in vehicles come from technical improvements such as a downsizing of the engine or reducing tyre friction. Efficiency gains in the transport sector also derive from structural change such as shifts to electric vehicles, and from system enhancements such as better logistics management that optimise the use of the variety of truck types to achieve a higher energy efficiency per unit of transport activity (Figure 6.12).[12]

In the New Policies Scenario, the efficiency of the global average gasoline car is 8.3 litres per 100 kilometres (L/100 km) in real-driving conditions in 2025 and 6.6 L/100 km in 2040, compared to 9.9 L/100 km today. Energy efficiency, and to a lesser extent the uptake of electric vehicles, mean that an increase of 80% in the size of the car fleet between now and 2040 leads to an increase in energy use of less than 20%. Energy savings in trucks come both from improvements in logistics – higher reliance on heavy-duty vehicles together with increased load per vehicle – and engine enhancements (see Chapter 3 for the impact on oil demand). Logistics improvements are driven by cost minimisation, including from more efficient use of central warehouses and backhauling. The energy efficiency of the global average heavy-duty truck sold in 2040 improves by 15% compared with today, but overall

12. Modal shift, e.g. switching from a private vehicle to public transportation is also an important driver for energy efficiency in transport and is included in the Sustainable Development Scenario.

freight efficiency increases by a third. Aviation and shipping efficiency improvements lead to energy savings of more than 3 mboe/d by 2040: there are few fuel substitution options for oil in aviation and shipping.

Figure 6.12 ▷ Change in energy demand and energy efficiency savings for selected transportation modes in the New Policies Scenario



Energy efficiency is key to curbing transport energy demand in the New Policies Scenario

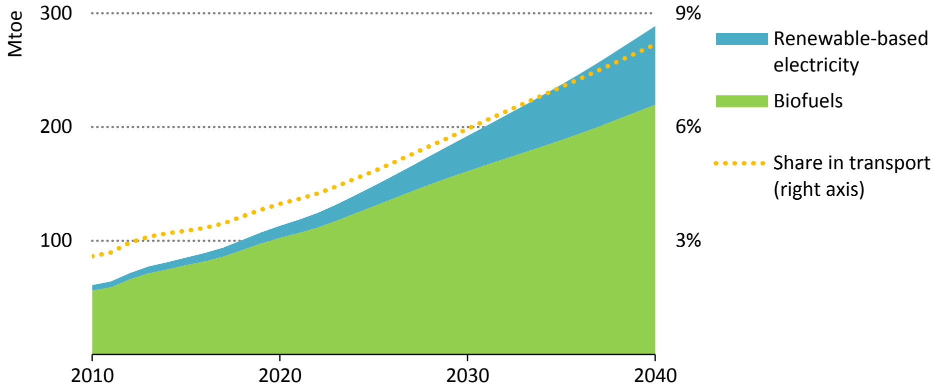
Note: Energy efficiency improvements are calculated compared with the efficiency level in the first year of the period.

The use of renewable energy in the transport sector increases in the New Policies Scenario. From 2017 to 2025, biofuel use worldwide increases at a rate of 5% each year, influenced by the extension to 2030 of the Renewable Energy Directive in the European Union[13] and policies to promote biofuels in transport in Latin America, the United States and China. The annual rate of growth of biofuels use slows to 3.5% between 2025 and 2040 as the use of gasoline and diesel levels off. This is particularly true in the European Union, where transport biofuel consumption plateaus after 2030. An increase in the use of advanced biofuels in aviation and shipping is not enough to offset the slowdown in consumption from road transport (see Box 6.1).

As electric vehicles and the share of renewables in electricity generation expand, the contribution of renewables in transport grows strongly. Today, electricity generated from renewable sources accounts for less than a tenth of renewable energy use in the total transport sector, including rail and road. This share barely increases to 2025, but then rises to reach 25% by 2040 (Figure 6.13). China accounts for 40% of the growth in renewables-based electricity in transport between now and 2040 in the New Policies Scenario, with the European Union accounting for 25%, and India and the United States just below 10% each.

13. For the EU target of 14% of renewable energy share in transport to be achieved, it will require a quick ramp up of advanced biofuel production, owing to the cap on conventional biofuel blending rate.

Figure 6.13 ▷ Renewable energy consumption in the transport sector by source and share in the New Policies Scenario



Renewable energy meets 8% of demand in the transport sector in 2040 with renewables-based electricity accounting for a quarter of renewables use in transport

In the New Policies Scenario, road vehicles powered by renewables – cars, trucks, buses and two/three wheelers – account for almost 15% of the total distance driven in 2040, of which over half is attributable to renewables-based electricity. This may seem surprising given that the share of direct and indirect renewables in transport fuel consumption in 2040 is around 8% (Figure 6.13). It reflects the importance of electric bikes and scooters in China and their low energy consumption. Even when cars alone are considered, renewable energy represents 11% of car fuel consumption, but 14% of kilometres driven. This is largely thanks to the higher efficiency of electric engines relative to conventional ICEs: electricity represents a quarter of the total renewable energy used in transport in 2040, but accounts for more than a third of kilometres travelled.

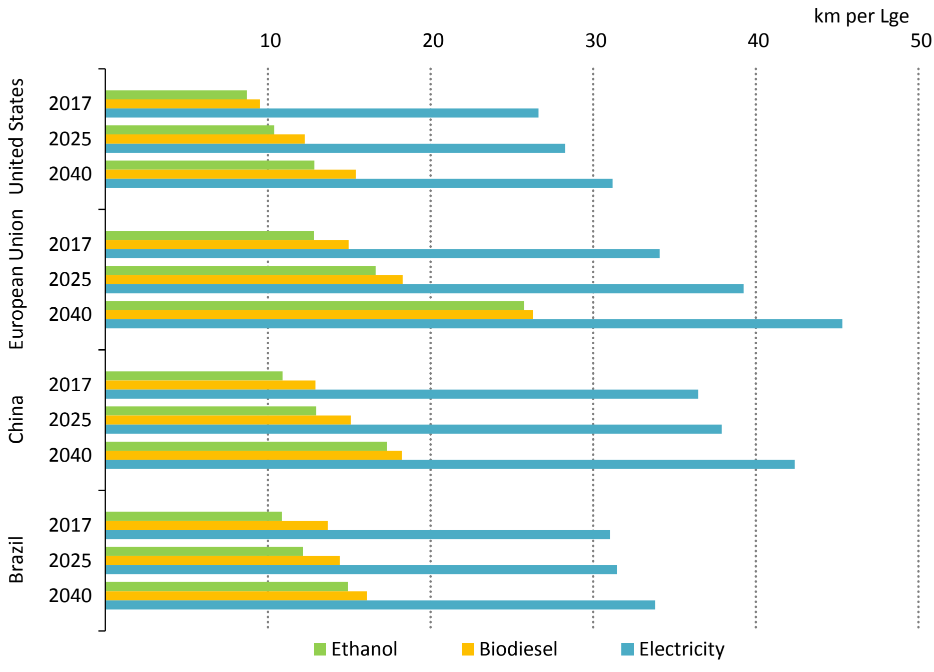
When discussing the comparative advantage of biofuels and electricity, energy efficiency is an important benchmark, expressed as the number of kilometres driven per unit of energy used by the car engine (Figure 6.14). In the New Policies Scenario, the gap in energy efficiency between gasoline and biodiesel narrows over time owing to the higher efficiency potential of gasoline ICEs.[14] Electric engines are about twice as efficient as conventional engines today. Regional differences are also important in the New Policies Scenario, especially for conventional ICEs. The European Union does well in terms of ICE energy efficiency, as it is characterised by a market of relatively small cars and stringent fuel-economy standards.

Even though electric engines are more efficient than conventional ones, there are also energy efficiency improvements in the use of biofuels in transport in the New Policies Scenario. This is important, not least because sustainable feedstock for advanced biofuel production is limited and is in competition with other uses, such as biochemistry, power

14. Gasoline ICE refers to spark ignition engine, and diesel ICE refers to compression ignition engine.

generation or heat production (see Chapter 11). Energy efficiency improvements in the European Union mean that drivers in 2040 use 20% less ethanol or biodiesel per kilometre than in 2025.

Figure 6.14 ▷ Kilometres driven on ethanol, biodiesel and electricity by an average car with the energy equivalent of one litre of gasoline



Energy efficiency improvements help to make the best of biofuels use. Electric cars are more efficient than an internal combustion energy run on renewables.

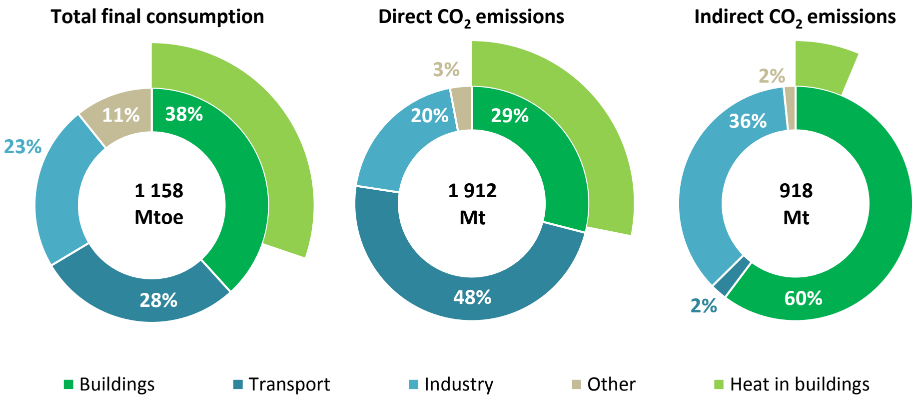
Notes: Lge = litre of gasoline equivalent. For ethanol, the average is determined for conventional and hybrid gasoline cars. For biodiesel, the average is determined for conventional and hybrid diesel cars. For electric vehicles, the average is determined for battery electric and for plug-in hybrid electric (for the latter, only the share that drives on electricity). Projection numbers are based on the New Policies Scenario.

6.8 Buildings: a key component of the energy transition in Europe

In the European Union, the buildings sector is responsible for a particularly large share of final energy demand today compared with other regions. The European Union (EU) has adopted a range of targets to facilitate a clean energy transition. This section explores the key role that efficiency measures and renewable heat in the buildings sector will play in order to achieve these targets.

Buildings represent almost 40% of total final consumption in the European Union, with transport accounting for 28% and industry for 23% (Figure 6.15). Heat demand in the buildings sector accounts for almost 80% of this, mostly in the form of space heating and generally using fossil fuels. Two-thirds of energy consumption in buildings sector is in the residential sector. Buildings account for almost 30% of direct CO_2 emissions in the European Union (i.e. not including indirect emissions from the use of electricity and district heating) compared with a worldwide figure of 17%. As the buildings sector also accounts for almost 60% of EU electricity consumption, it is also responsible for an important share of indirect CO_2 emissions.

Figure 6.15 ▷ Total final consumption and related emissions in the European Union by sector in 2017



Buildings, and in particular heating in buildings, account for the biggest sectoral share of final consumption and related carbon emissions in the European Union

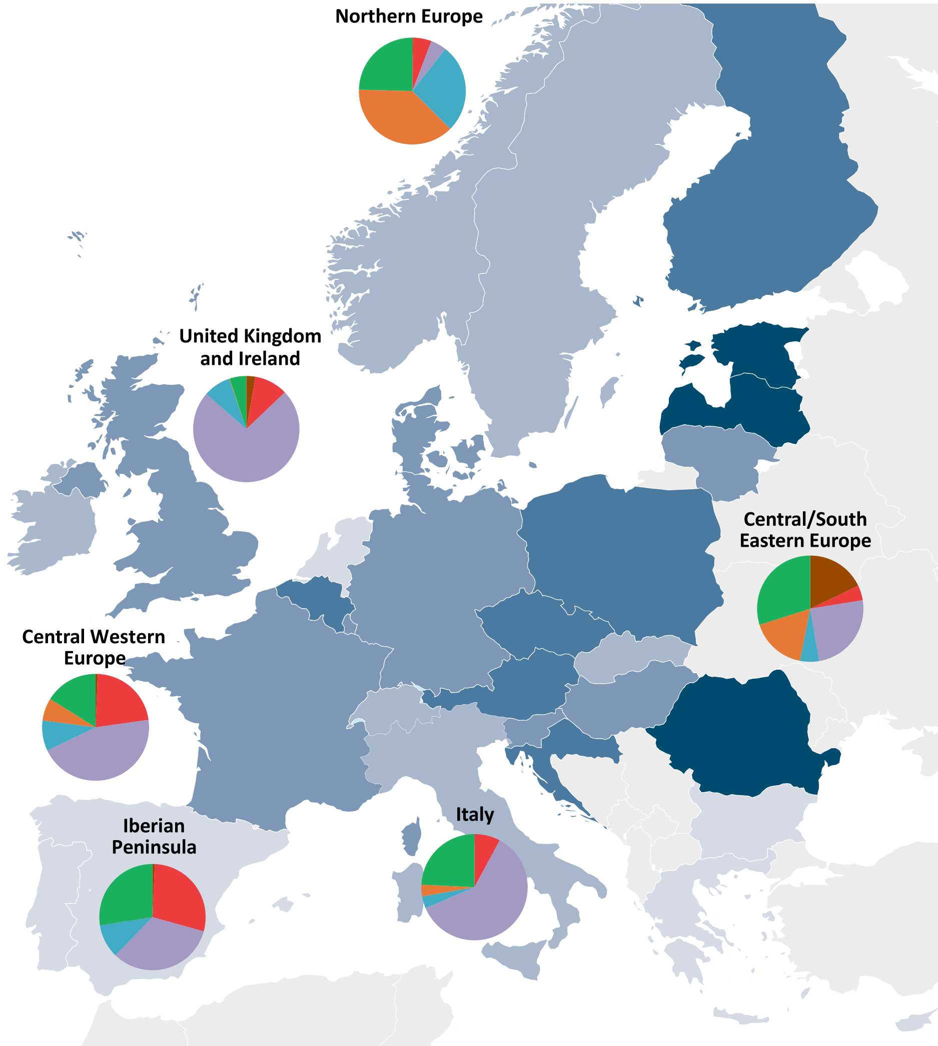
Note: Mtoe = million tonnes of oil equivalent; Mt = million tonnes.

There are a range of policies and measures in place in different European Union countries to control energy demand in buildings. Nordic countries in particular place strong emphasis on high insulation standards in new buildings, and they have also made a strong push in recent decades to improve insulation levels in existing buildings, especially in Sweden and Denmark (Figure 6.16). As a result, they consume less energy per unit of floor area to meet their heating needs than some countries with warmer climates. Finland has the highest number of heating degree days (HDD) among EU countries, but its energy consumption for heating per floor area is equivalent to Belgium which has half the number of HDD.[15, 16] Some Central European and Mediterranean countries, for example Austria and Croatia, consume more energy per unit of floor area than the Nordic nations, despite their relatively milder climates.

15. Heating degree days measure the deviation of temperatures from a reference point in a given location over a specified period. The more extreme the outside temperature, the higher the number of degree days.

16. The building stock of Finland is much younger than in Belgium: around a third of residential buildings in Belgium were built before 1945, this share is only 12% in Finland.

Figure 6.16 ▷ Energy use for residential heating, 2017



Energy intensity for heating varies widely from less than 100 kWh/m² to above 200 kWh/m² as a result of different climates and levels of buildings insulation

Notes: kWh = kilowatt-hours. Energy use for heating includes both space and water heating. The six regional groupings are defined in Annex C.

Cost-effective efficiency gains can be achieved by improving both the energy efficiency of buildings and end-use equipment. Building codes are the preferred tool for ensuring that efficiency is incorporated in new construction and building retrofits. Mandatory energy performance standards play an important role by establishing performance requirements for the equipment used to meet space and water heating demand. Energy labels for buildings and equipment help to raise consumer awareness of the energy efficiency characteristics of their purchasing decisions.

Nearly zero-energy buildings – how much energy do they consume?

Today all of the EU countries have building codes that contribute to reducing energy consumption in new construction. As from 2021, all new building construction will be required to meet "nearly zero-energy buildings" (NZEB) standards.[17] While the standards differ from country to country, most require that total buildings energy consumption should be around 50 kilowatt-hours per square metre per year (kWh/m²/year) in primary energy terms (Table 6.10). This represents a 70% reduction relative to the current average energy intensity of the EU residential buildings stock, which is around 170 kWh/m²/year (in primary energy terms).

6

In addition, in many countries, NZEB standards also require that energy demand be met by renewable energy, either directly (by using solar thermal or geothermal) or indirectly (using electricity or district heating that are produced from renewable sources). A switch to electric or district heating options and to direct use of renewable options such as biomass boilers or solar thermal are other options which may reduce energy demand and carbon emissions.

Table 6.10 ▷ NZEB requirements for selected European Union countries

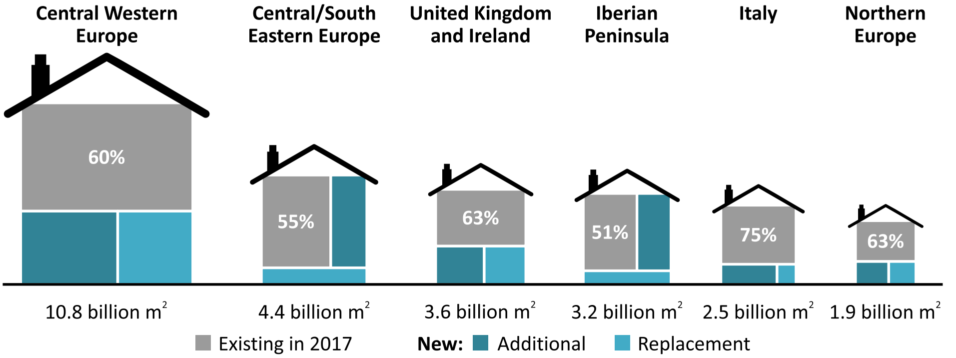
	Year of enforcement		NZEB definition for buildings (kWh/m²/year)			
	Public	Private	New buildings		Existing buildings	
			Residential	Non-residential	Residential	Non-residential
Austria	2019	2021	160	170	200	250
Czech Republic	2016-18	2018-20	75-80%*	90%*	75-80%*	90%*
Denmark	2019	2021	20	25	20	25
France	2011	2013	40-65	70-110	80	60%*
Germany	2019	2021	40%*		55%*	
Hungary	2019	2021	50-72	60-115		
Italy	2019	2021				
Netherlands	2019	2021	25	25		
Poland	2019	2021	60-75	45-70		
Sweden	2019	2021	30-75	30-105		
United Kingdom	2016-18	2016-19	40-45			

* Primary energy maximum measured against that of the building stock.

17. For public buildings, they need to meet NZEB requirements by end of 2018.

New buildings represent an important opportunity to achieve lower heating intensity, but 60% of the residential buildings that will be in use in the European Union in 2040 have already been built (Figure 6.17). A key policy challenge is therefore to improve energy efficiency of the existing building stock.

Figure 6.17 ▷ Residential floor area by region in the European Union in 2040



Around 60% of the residential buildings stock in the European Union in 2040 exists today

Notes: m^2 = square metres. The size of the house figure is relative to the total buildings stock in terms of floor area.

Retrofitting ageing building stock and equipment is a key element

Addressing efficiency improvements in existing buildings is essential to achieving the European Union's energy efficiency targets. Much of the existing building stock across the region is more than 50 years old. In 2018, the European Union updated the EPBD (Energy Performance of Buildings Directive), which focuses on efforts to both decarbonise and reduce energy demand in buildings and will require an acceleration of deep-retrofits.[18] The EPBD instructs member states to develop and implement strategies to make all buildings NZEBs by 2050, whilst also decarbonising building energy demand. Policies for energy efficiency in buildings in EU countries have largely focused on codes for new construction because of the practical difficulties associated with retrofitting existing buildings and the high upfront costs of deep retrofit options. One notable policy challenge is the "split incentive" issue wherein building owners may not have incentive to retrofit properties that are rented. Moving towards a more modular retrofit industry with fewer disturbances for building occupants is likely to be critically important to improve retrofit rates.

Unlocking the energy efficiency potential of existing buildings is especially important in countries with slow turnover of the building stock. In Italy and Hungary, for example, more than 70% of the residential building stock in 2040 is already in place. Retrofitting existing buildings, including the improvement of insulation and replacing inefficient equipment, can

18. See http://europa.eu/rapid/press-release_IP-18-3374_en.htm.

provide significant efficiency gains. Retrofits are most effective in terms of efficiency and cost when a suite of different measures, for example greater insulation and air sealing, as well as the replacement of electric resistance heaters with heat pumps, are implemented in parallel (IEA, 2013). This is known as a deep retrofit, which can often achieve reductions in space heating energy demand on the order of 50% or more.[19] The EU's EPBD focuses on efforts to both decarbonise and reduce energy demand in buildings and will require an acceleration of deep retrofits.

Moving towards near-zero emissions for the overall buildings stock

Building retrofits also provide the opportunity to move towards near-zero emissions by combining energy efficiency measures with a switch to renewable energy options for heating (direct or indirect). Today, 1.5% of European households use solar thermal for water heating purposes, and biomass boilers represent 15% of energy consumption for residential space and water heating. There is scope to increase this and also to increase the use of renewables indirectly through the development of district heating networks that are powered by renewables (currently 10% of EU energy demand for heating in buildings is met through district systems, of which 30% of the heat supplied comes from renewable sources) or through the use of heat pumps (currently 3% of EU energy demand for heating in buildings is from heat pumps).

Heat pumps offer significant benefits. The efficiency of a heat pump can be more than three-times that of a conventional gas boiler at the end-use level. Even after allowing for losses in the generation, transmission and distribution of electricity, a heat pump can reduce primary energy use by an average of more than 35% relative to a conventional gas boiler. The high upfront costs of heat pumps and associated work (for example to replace pipes) constitute a barrier for many households to invest, but costs are expected to decline with increasing heat pump deployment, leading to the technology becoming competitive with gas boilers by around 2025 (see Chapter 9).

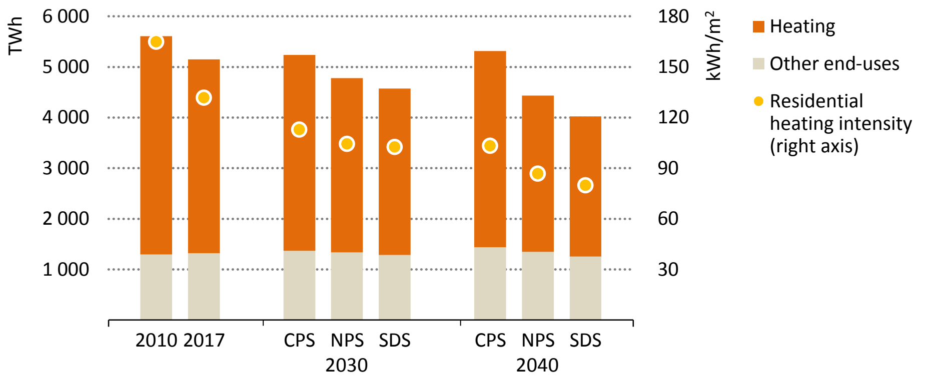
There are already some useful examples of good practice, such as the minimum level of building energy performance of rentals in Germany or the *Crédit d'impôts* (up to 30% of the investment made prior to year-end 2018 in improving the energy performance of a home are eligible for a tax credit) in France. Generally it makes sense to couple a building retrofit with installation of a heat pump, so as to obtain the maximum benefit from the efficiency of the heat pump by connecting it to a low temperature heating system in a well-insulated building. Further deployment of electricity for heating though the use of heat pumps or district heating systems needs to be planned in line with the evolution of the electricity system to make sure that the electrification of heating does not negatively impact system operations and costs.

19. There is no formal definition for deep retrofit but it generally encompasses only high levels of insulation such as roof and wall insulation and at least double-glazed windows.

Correct implementation of the EPBD can lead to long-term savings

In the New Policies Scenario, energy demand in the buildings sector in the Europe Union falls by 0.65% annually to 2040, despite an increase in the number of households and building floor area (Figure 6.18). Most of the savings are achieved through the annual renovation of 2% of the buildings stock from 2020 onwards. Additional savings come from the turnover of old equipment, the switch to other fuels such as solar thermal for water heating and the increased penetration of heat pumps. Energy demand for heating in the European Union declines by 0.95% a year in the New Policies Scenario and the average energy intensity of space and water heating equipment reduces by 35% in the period to 2040.

Figure 6.18 ▷ Energy consumption in buildings by end-use and residential heating intensity by scenario in the European Union



A retrofit rate of 2% could deliver large savings in energy for heating in buildings

Notes: TWh = terawatt-hour; kWh/m² = kilowatt-hour per square metre. The Current Policies Scenario (CPS) assumes a 0.8% retrofit rate; the New Policies Scenario (NPS) assumes a 2% retrofit rate after 2021 and the Sustainable Development Scenario (SDS) assumes a 2.5% retrofit rate from 2021 to 2025 and 4% afterwards. All the scenarios include measures other than retrofit, but retrofit has the highest impact on energy use in buildings between the scenarios.

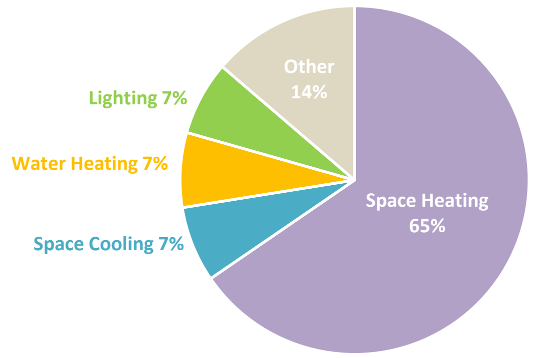
Coal and oil use in buildings in the European Union has declined by 23% and 21% respectively since 2010. This trend accelerates the New Policies Scenario, with demand for coal and oil combined falling to around 10 Mtoe by 2040 compared to over 60 Mtoe today. Natural gas has a prominent role in heating demand in the European Union, and is affected by the new regulatory requirements in the revised EPBD. In the New Policies Scenario, demand for gas in the buildings sector is 140 billion cubic metres (bcm), 45 bcm lower than today.

The Current Policies Scenario, which does not include any new policies and assumes a 0.8% retrofit rate (this rate varies from 0.4 to 1.2% depending on the country), sees a small increase in energy consumption in the buildings sector in 2030 compared to today's level. This increase continues to 2040, with energy demand in the buildings sector being 3% higher compared with today's level. The Sustainable Development Scenario assumes a retrofit rate of around 4% and energy demand in buildings declines by more than 20% over the period to 2040. Most of the savings come from heating, as high efficiency standards are assumed for appliances.

Box 6.2 ▷ Digitalization – an opportunity to further increase energy savings

The new Energy Performance of Buildings Directive in the European Union includes provisions on digitalization and smart buildings, alongside an initiative for rating the "smart readiness" of buildings. The directive points to the potential value of smart technologies for buildings, such as the installation (where economically viable) of building automation and control systems and devices that regulate temperature at room level. Active controls in the different end-uses within buildings can result in large energy savings; sensors and smart meters have a key role to play in monitoring energy use and identifying the most cost-effective opportunities (Figure 6.19). According to the current EU Energy Label legislation (Regulation 811/2013), temperature controls can add up to five percentage points to the efficiency of a space heater.

Figure 6.19 ▷ Energy savings by end-use from smart controls in the European Union in the New Policies Scenario, 2040



Smart controls could help to avoid more than 50 Mtoe of energy demand in buildings in the European Union by 2040, or around 15% of energy consumption in buildings

Note: Other includes appliances, cooking and other services.

Source: IEA (2017b).

OUTLINE

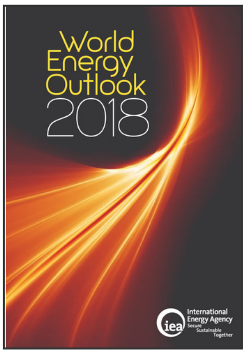
This special focus looks at different aspects of electricity in turn.

Chapter 7 presents an overview of electricity in the global energy system today, covering key electricity demand and supply developments. It describes the current state and range of options for flexibility in energy systems; analyses the latest investment trends, players and implications on market security; and takes stock of power sector pollutant emissions.

Chapter 8 looks at how the current electricity trends discussed in Chapter 7 might develop in the future. It focuses on the results of the New Policies Scenario, which looks at the outlook for electricity demand and supply to 2040 on the basis of currently announced policies and plans. It also discusses the outlook for flexibility solutions such as storage, demand-side response and smart grids to meet growing needs. It includes two regional deep dives into the European Union and India.

Chapter 9 starts from the recognition that electricity demand growth is uncertain and could be accelerated by policy actions beyond those in the New Policies Scenario. It explores, for the first time, a Future is Electric Scenario – an alternative future for electricity to complement the IEA's central electricity outlook by exploring key policy uncertainties – which looks at what might happen if demand for electricity was indeed to grow faster than in the New Policies Scenario, with a focus on what it might mean for different end-use sectors and regions, and on the possible implications for electricity supply and energy systems. It also draws on key results from the Sustainable Development Scenario to investigate the role of electricity in achieving long-term sustainability.

Chapter 10 stands back and looks at the wider implications of the expanding role of electricity as discussed in the preceding chapters. It focuses on three crucial topics: security, affordability and environmental impact. It considers the role of electricity in achieving environmental goals. It analyses ways to enable efficient power sector investment in competitive markets, and highlights key uncertainties resulting from the pace of deployment of new technologies that may necessitate change to business models. It concludes by looking at the affordability of electricity for consumers.



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