CHAPTER 3

RENEWABLE ENERGY

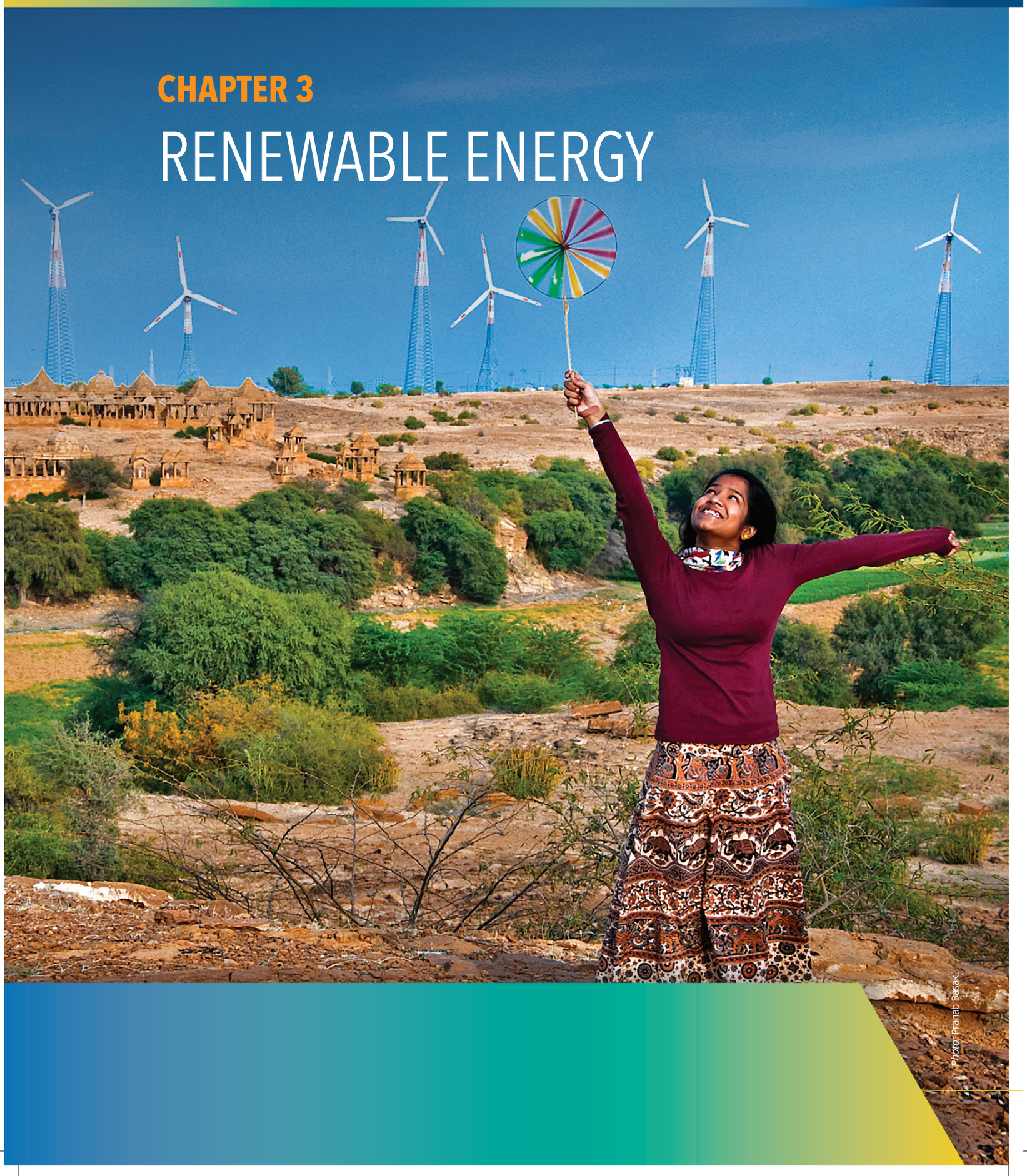


Photo: Pranab Basak

MAIN MESSAGES

- **Global trend:** The share of renewable energy (including traditional uses of biomass) in total final energy consumption is the main indicator being used to assess progress toward Sustainable Development Goal (SDG) 7.2. In 2016, the share of renewables increased at the fastest rate since 2012, up 0.24 percentage points, and reached almost 17.5% owing to rapid growth in hydropower, wind, and solar. Since 2010, renewable energy consumption has grown by 14% in absolute terms, equivalent to twice the current energy use in Turkey. The fastest penetration of renewables continued to be in electricity, which increased 1 percentage point to 24% in 2016. With this growth, the share of renewables in electricity reached the same level as renewables used for heating (including traditional uses of biomass) for the first time. Excluding traditional uses of biomass, which involves an inefficient combustion process associated with negative health and environmental impacts, the share of renewables used for heating was only about 10% at the end of 2016. The share of renewables in the energy consumed for transport remained the lowest, at 3.3%, although it had been steadily increasing since 2000.

- **2030 target:** While there is no quantitative target for SDG 7.2, the share of renewable energy would need to accelerate substantially to ensure access to affordable, reliable, sustainable and modern energy for all (according to the long-term scenarios of the International Energy Agency and the International Renewable Energy Agency).

- **Regional highlights:** Sub-Saharan Africa has the highest renewable energy share among all regions due to the large consumption of solid biomass in the residential sector, with the region's use of modern renewables significantly below the global average. In Latin America and the Caribbean, almost 30% of the share of renewables in total final energy consumption is traceable to hydropower generation in electricity and bioenergy use in industry and transport; also, the share of wind and solar photovoltaic (PV) is growing.

- **Top 20 countries:** The top 20 energy consumers account for three-quarters of global energy demand but represent only two-thirds of global renewable energy consumption. Of the six countries with renewable shares above the global average, traditional uses of biomass dominate renewable consumption in four (India, Indonesia, Nigeria, and Pakistan); in the remaining two countries, modern uses of biomass are most prevalent in Brazil and hydropower in Canada.

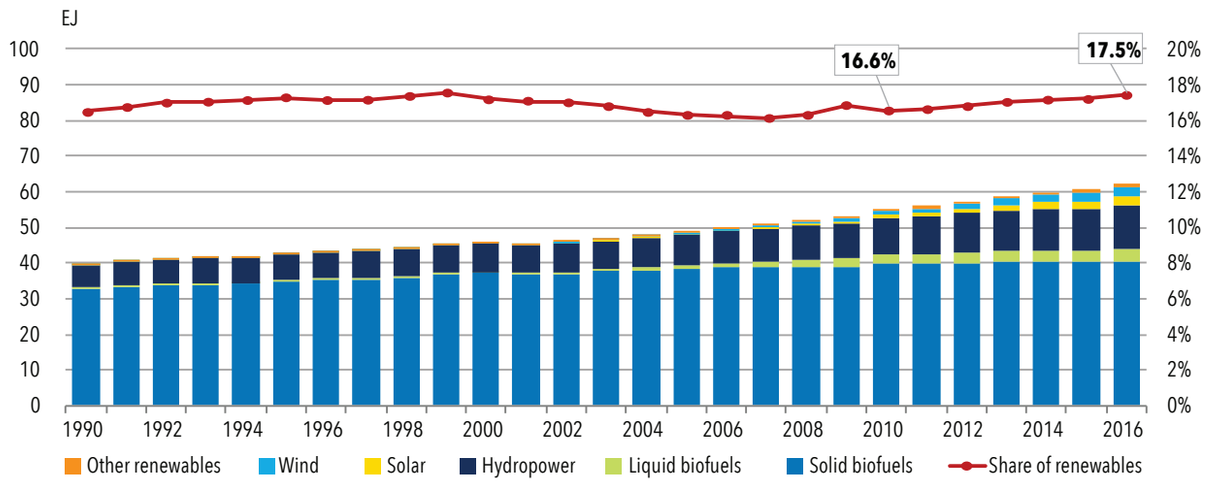
- **Electricity:** The share of renewables in electricity consumption increased by 1 percentage point to reach 24% in 2016, the fastest percentage point growth seen since 1990 and more than double that of 2015. This was driven by continuous drought recovery in Latin America; China's record-level wind capacity growth in 2015, which became fully operational in 2016; and rapid solar capacity expansion in China and the United States, which propelled solar power's rise of 30% in 2016.[27]

- **Heat:** Renewables used for heating increased only modestly (up 0.5%) to surpass 24% in 2016, led by the direct use of modern bioenergy, which accounted for half of the growth, followed by renewable district heating and direct use of geothermal and solar thermal. While traditional uses of biomass continued to decline in 2016, down by 0.5%, they still accounted for over half of renewable heat consumption. Reducing traditional uses of biomass has been an objective of policy makers, given their negative health and environmental impacts.
- **Transport:** The share of renewable energy in transport increased by 0.1% year on year to reach 3.3% in 2016. The majority of consumption was from biofuels, driven mostly by support policies in the United States, Brazil, and the European Union. Renewable electricity accounted for 8% of renewable energy consumption in transport in 2016, led by rail; the consumption of electric vehicles (EVs) has been rapidly increasing, led by China.

ARE WE ON TRACK?

In 2016, renewable energy's share of total final energy consumption increased at the fastest rate, driven by the rapid growth of hydropower and wind and solar energy the same level as in 2000 - at 17.5%.. After 2007, the share of renewable energy slowly increased after a period of modest decline, due to strong growth in coal consumption in China. In 2016 it recovered to the same level as in 2000. Overall, bioenergy accounts for 70% of global renewable energy consumption, followed by hydropower (figure 3.1).

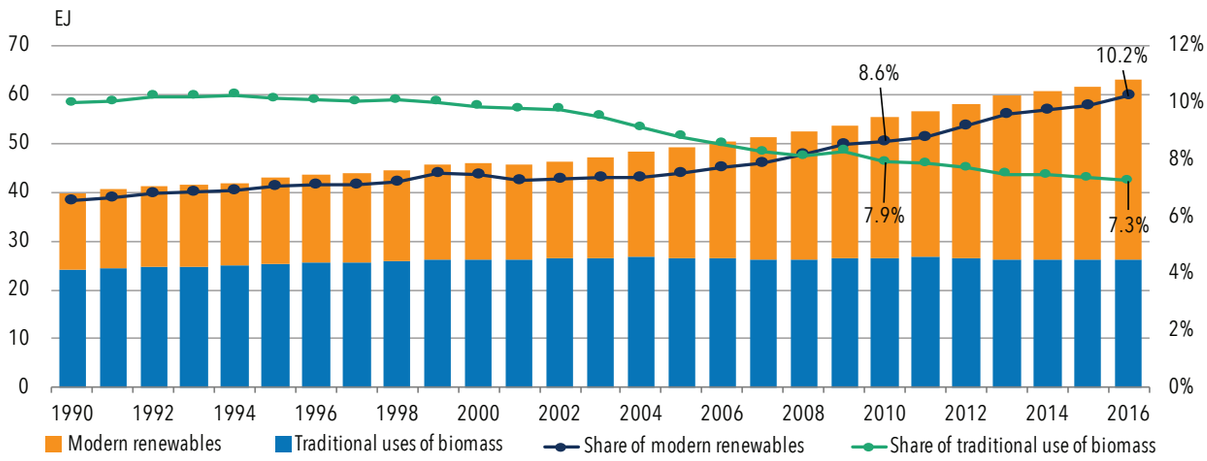
FIGURE 3.1 • RENEWABLE ENERGY CONSUMPTION BY TECHNOLOGY AND SHARE OF TOTAL ENERGY CONSUMPTION, 1990-2016



Source: IEA and UNSD.

By 2016, the share of modern renewables in total energy consumption continued to increase, up to 10.2% while the share of traditional biomass use[28] continued to decline, to 7.3%. However, both trends need to accelerate to achieve not only SDG target 7.2 for renewable energy but also SDG indicator 7.1.2 regarding access to clean fuels, including for cooking (figure 3.2).

FIGURE 3.2 • CONSUMPTION OF MODERN RENEWABLE ENERGY AND TRADITIONAL BIOMASS, 1990-2016

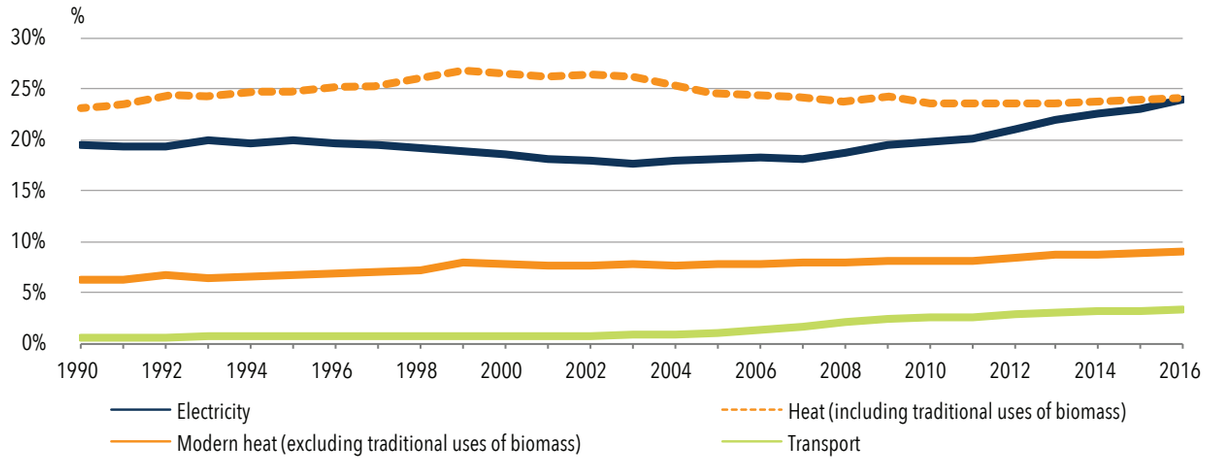


Source: IEA and UNSD.

LOOKING BEYOND THE MAIN INDICATORS

Renewable energy is consumed in direct and indirect forms for three end uses: electricity, transport, and heat.[29] The substantial increase in the share of renewable energy called for under SDG 7 commitments requires the accelerated penetration of renewables in all three end uses. The most rapid increase to date has been in electricity, which grew by 1 percentage point from 23% in 2015 to 24% in 2016. With this growth, the share of renewables in electricity reached the same level as renewables used for heating for the first time. But it should be noted that the historically high share of renewables in heat was mainly due to traditional uses of biomass for cooking and heating in low-income countries. Excluding traditional uses of biomass, the share of modern renewables used for heat remained below 10% in 2016. Renewables in transport have increased steadily since 2000 but their penetration remained the lowest in 2016, at below 4%. Liquid biofuels account for the significant majority of renewables consumed in transport. Renewable electricity for transport is also emerging thanks to the uptake of electric vehicles and electric rail lines (figure 3.3).

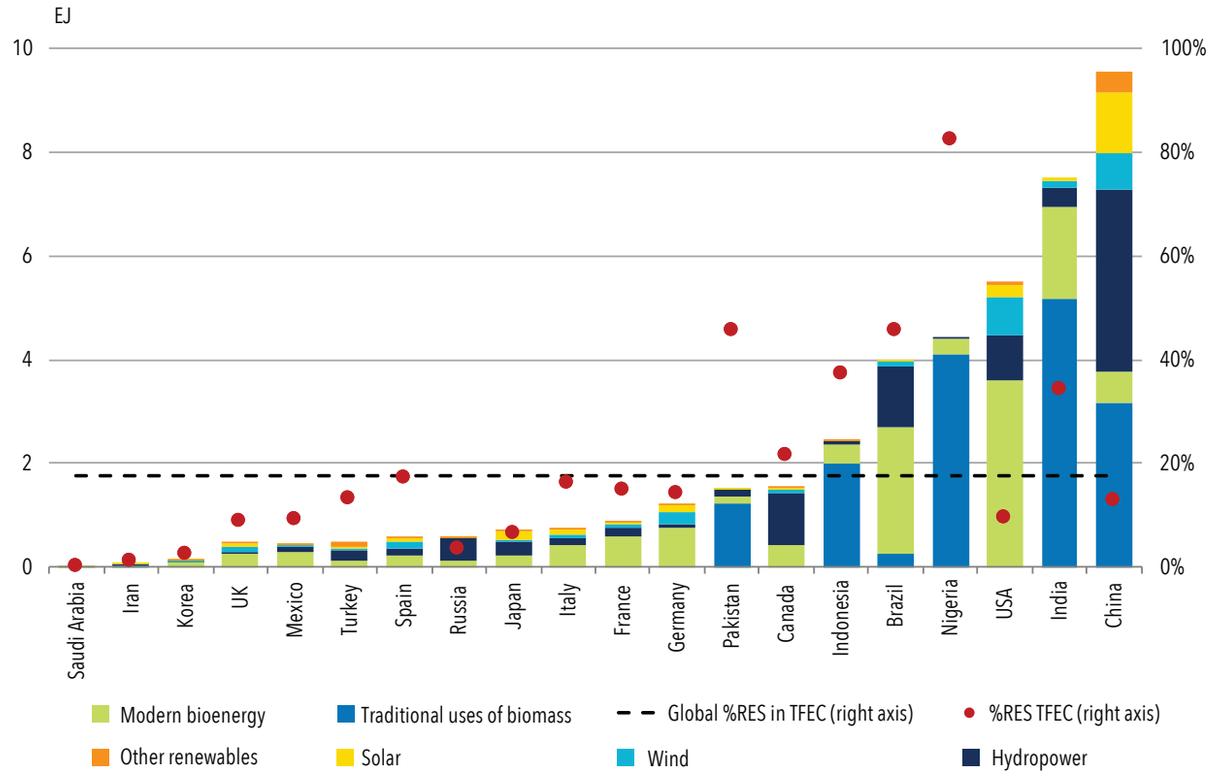
FIGURE 3.3 • THE SHARE OF RENEWABLES IN CONSUMPTION, BY TYPE OF END USE, 1990-2016



Source: IEA and UNSD.

The top 20 most energy-consuming countries account for three-quarters of global energy demand, but only two-thirds of global renewable energy consumption. Overall, China remains the largest consumer of renewable energy globally, due to the country's renewable electricity consumption. Among countries, the share of renewable consumption varies widely depending on resource availability, policy support, and the impact of energy efficiency on total energy demand growth. In 2016, only six (India, Brazil, Indonesia, Nigeria, Canada, and Pakistan) of the 20 top consumers had a renewable share larger than the global average of 17.5%. However, in four of those (India, Indonesia, Nigeria, and Pakistan), this was due to traditional uses of biomass for cooking, which declined only in Indonesia in 2016. The extensive consumption of modern bioenergy (both in power generation and biofuels production) in Brazil and of hydropower in Canada drives these two countries' above-average renewable energy shares. Excluding traditional uses, all but four countries (Nigeria, Italy, Turkey, and the Republic of Korea) saw their share of modern renewable energy increase in 2016, when eight countries had a share larger than the global average of 10.2%. Among the 20 countries, Brazil was the absolute leader with a share of modern renewables of 42% (figure 3.4).

FIGURE 3.4 • RENEWABLE ENERGY CONSUMPTION AS SHARE OF TOTAL FINAL ENERGY CONSUMPTION, BY TYPE, 2016



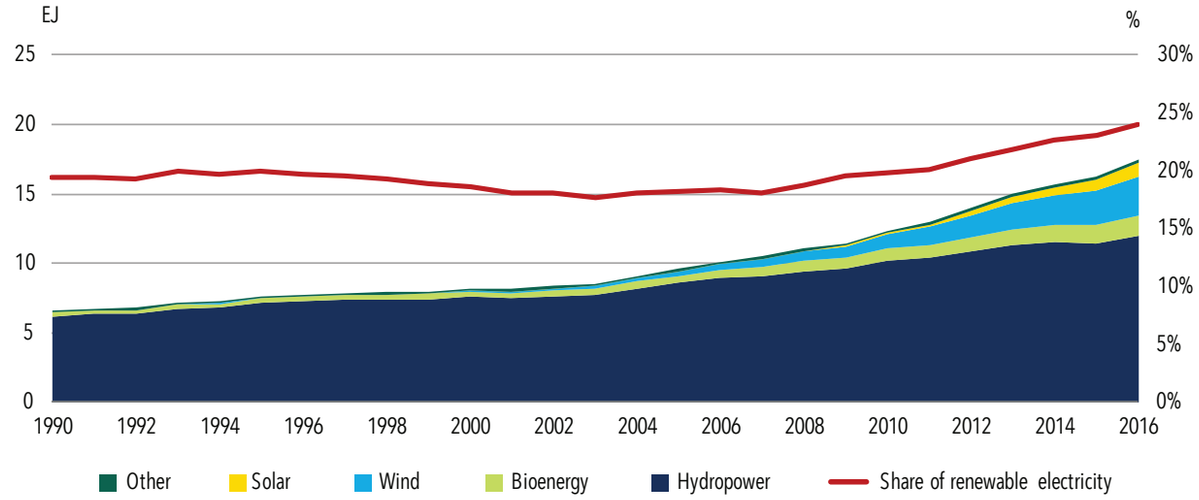
Source: IEA and UNSD.
Note: RES = renewable energy sources, TFEC = total final energy consumption.

ELECTRICITY

In 2016, renewable electricity consumption increased by almost 8%. The share of renewables grew by 1 percentage point to reach 24%. This is the fastest percentage point growth since 1990 and more than double that of 2015. Three key developments drove this trend. First, Latin America continued to recover from a severe drought, with Brazil's hydropower generation growing by 3.5% in 2016. Second, China had record-level wind capacity growth in 2015 that became fully operational in 2016. Third, solar PV consumption grew by 30% as both China and the United States doubled additions between 2015 and 2016.

Hydropower remained the largest source of renewable electricity, accounting for 68% of all renewable electricity consumption in 2016. However, it played a much smaller role than in 2010 (down from 82%) due to the rapid increase of solar PV and wind generation, which grew ten- and threefold over the same period, respectively. This rapid growth was mainly driven by policy support around the world and recent cost reductions. Since 2010, generation costs of solar PV declined on average by 80% and onshore wind by 20%. The shift from government-set tariffs (feed-in tariffs, premiums) to competitive renewable energy auctions with long-term power purchase agreements played an important role in accelerating the cost reductions. Auctions also helped governments contain renewable support costs through volume control mechanisms. Still, wind remained the second-largest source of renewable electricity, followed by bioenergy, solar, geothermal, and ocean technologies (figure 3.5).

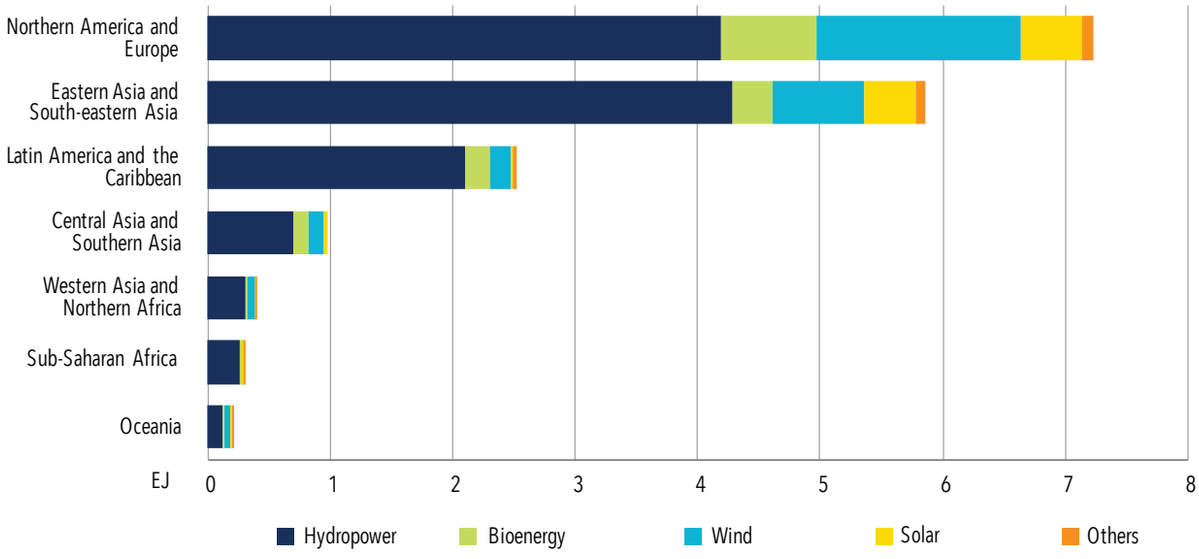
FIGURE 3.5 • GLOBAL RENEWABLE ELECTRICITY CONSUMPTION BY TECHNOLOGY, 1990-2016



Source: IEA and UNSD.

Resource availability and policy support explain regional differences in renewable electricity consumption (figure 3.6). In Northern America and Europe, wind, bioenergy, and solar PV had already reached a significant level of deployment thanks mainly to 2020 targets for renewable energy in the European Union and tax incentives in the United States. However, Asia also experienced substantial wind and solar expansion driven by ambitious targets in China and India. In Latin America and the Caribbean, hydropower remained the largest renewable electricity source but bioenergy and wind were expanding rapidly, bringing diversification. While hydropower was the largest source of renewable electricity in Africa, governments have been introducing policies to increase wind and solar deployment as associated technologies become more affordable.

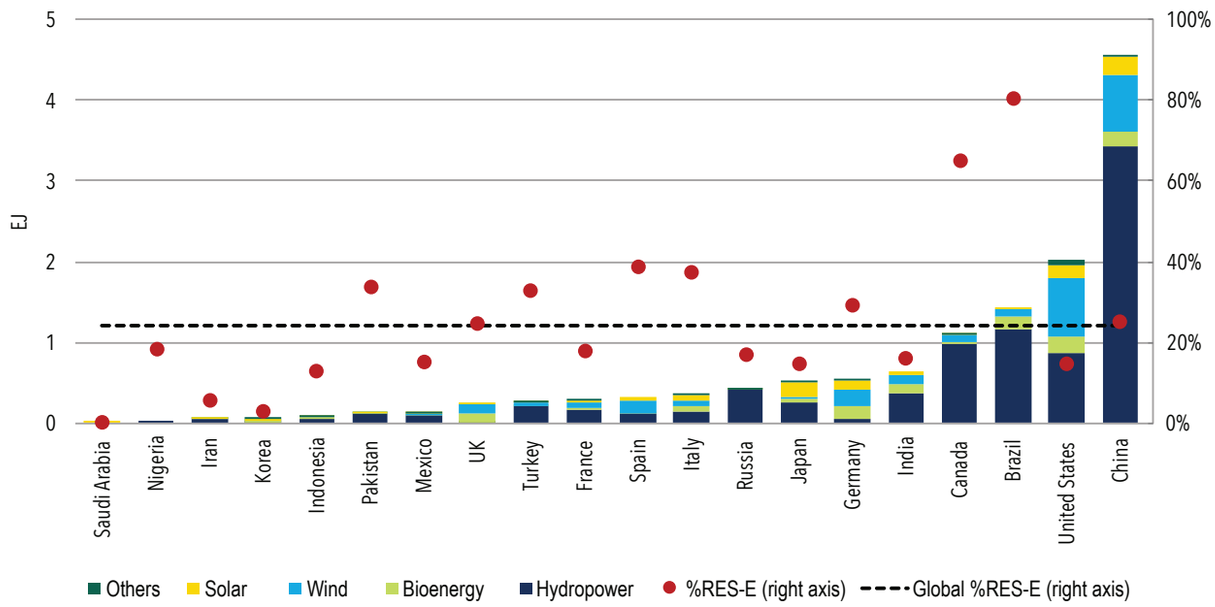
FIGURE 3.6 • RENEWABLE ELECTRICITY CONSUMPTION BY REGION, 2016



Source: IEA and UNSD.

Among the top 20 energy consumer countries, the share of renewables in electricity varied significantly, from less than 1% to over 80%; however, higher shares existed outside these countries (figure 3.7). Renewables accounted for over 95% of electricity generation in countries where abundant hydropower resources had already been exploited, such as in Norway, Paraguay, Uruguay, Ethiopia, Costa Rica, and Nepal. In most European countries, variable wind and solar electricity accounted for the majority of renewables. For example, the share of variable renewable electricity had already exceeded 50% in Denmark and ranged between 15% and 25% in Ireland, Germany, Spain, Italy, and the United Kingdom. Going forward, increasing shares of variable renewables will push up the importance of cost-effective policies that foster system integration.

FIGURE 3.7 • RENEWABLE ELECTRICITY CONSUMPTION BY COUNTRY AND TYPE OF ENERGY, 2016



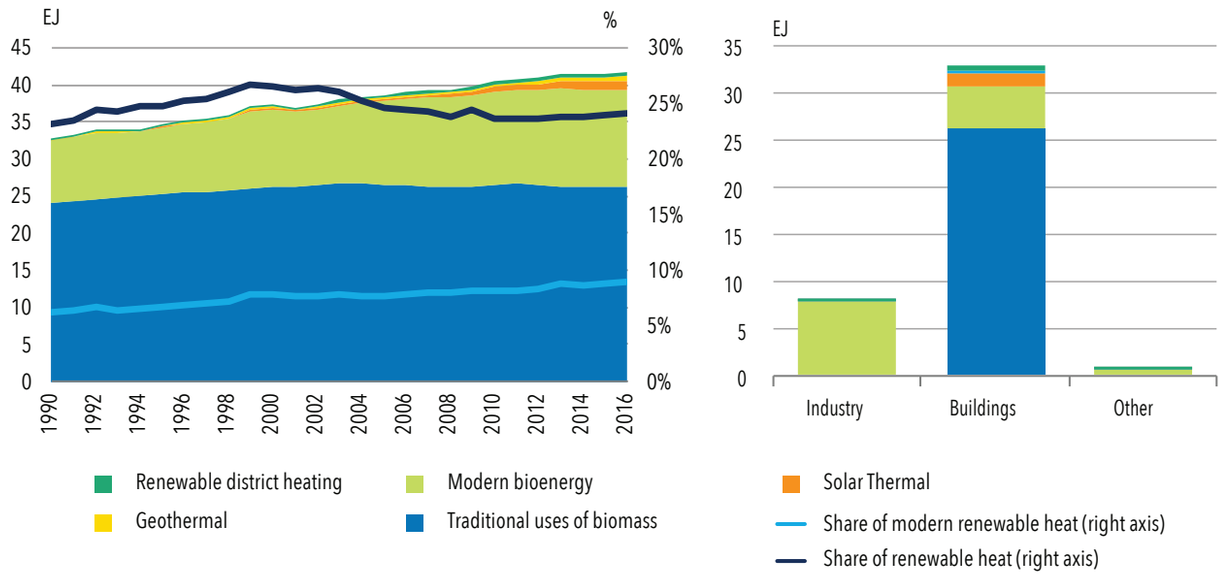
Source: IEA and UNSD.
Note: RES = renewable energy sources, RES-E = renewable electricity.

HEAT

The share of renewable heat increased by 0.1% over 2015-2016 to reach 24.1% in 2016 (figure 3.8). The increase in renewable heat consumption was led by the direct use of modern bioenergy, which accounted for half of the growth, followed by renewable district heating, and direct use of geothermal and solar thermal. While the traditional uses of biomass continued to decline in 2016, down by 0.5%, they still accounted for over half of renewable heat consumption worldwide. Reducing these has been an objective of policy makers, given the negative health and environmental impacts associated with them.

Bioenergy continued to be the renewable most often consumed for heat in 2016, in both direct and district heating applications, accounting for 95% of renewable heat consumption, including traditional uses. The second-largest source was solar thermal. A majority of the latter is used directly in small domestic systems for providing hot water, although larger-scale systems for industrial applications and district heating systems are being implemented. Geothermal, the smallest source of renewable heat, is used mostly for bathing, swimming, and space heating, with a significant share of the world's consumption concentrated in China and Turkey.

FIGURE 3.8 • RENEWABLE HEAT CONSUMPTION, 1990-2016, AND BY SECTOR IN 2016

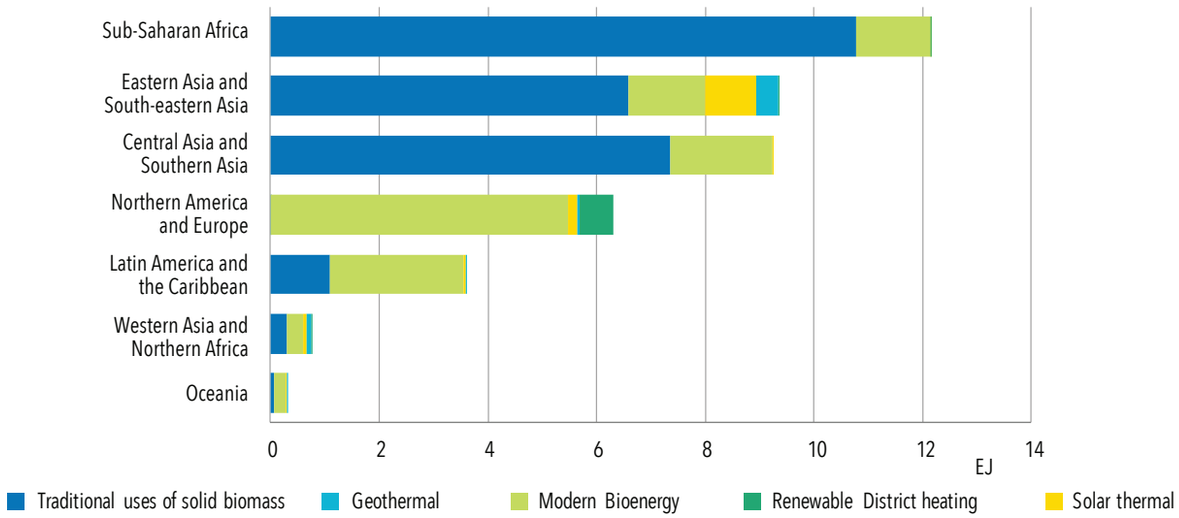


Source: IEA and UNSD.

A majority of renewable heat consumption occurred in the buildings sector because of traditional uses of biomass (80%) in residential housing. Excluding these, industry represents the largest consumer of modern renewable heat, which is dominated almost exclusively by bioenergy. Most of the consumption was in sectors where there are significant amounts of biomass and waste residues produced on site (e.g., wood and wood products, paper, food, and tobacco). Conversely, the majority of solar thermal and geothermal applications was for hot water, space heating, and, in some cases, swimming pool heating in the buildings sector. Their deployment for industrial applications has been limited given the temperature requirements for process heat (often above 400°C) and the cost differentials with other competing technologies.

The largest regional consumers of renewable heat in 2016 were Sub-Saharan Africa and Asia, due to the traditional uses of solid biomass in the residential sector (e.g., for heating and cooking with inefficient traditional techniques such as a three-stone fire). Excluding these, the regions with the largest renewable heat consumption were Northern America and Europe. In the European Union, modern renewable heat consumption has been driven by a 20% binding regional target for renewables by 2020. Europe is also the world's largest consumer of renewable heat via district heating, which in 2016 accounted for 14% of its renewable heat, led by Germany, France, and the Nordic countries (figure 3.9).

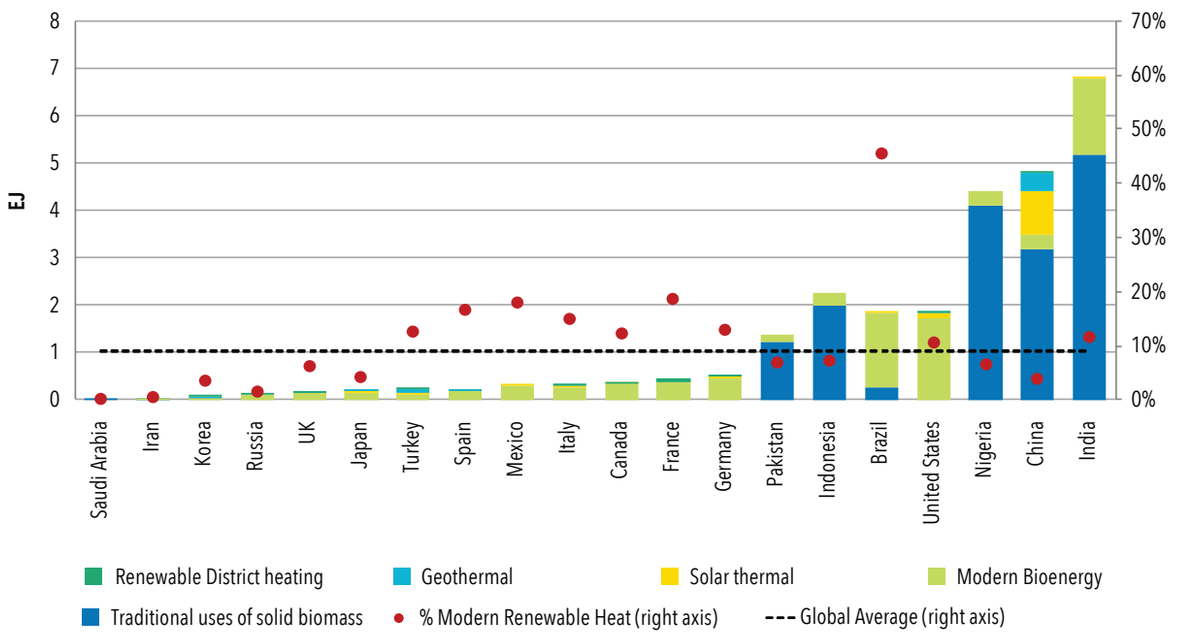
FIGURE 3.9 • RENEWABLE HEAT CONSUMPTION BY REGION, 2016



Source: IEA and UNSD.

Half of the world's renewable heat consumption was concentrated in six countries in 2016: India, China, Nigeria, Indonesia, Brazil, and the United States (figure 3.10). The United States was the largest consumer of modern renewable energy for heat, thanks to the use of bioenergy in the industry sector. China led the world in solar thermal consumption, although growth in new installations had slowed in previous years amid a weakening in policy support for low-cost systems and shifts in end-user preferences to other technologies for hot water. Of the top 20 energy consumers, 10 had a share of modern renewable heat larger than the global average, with the largest share in Brazil, thanks to the widespread use of bagasse from sugar and ethanol production.

FIGURE 3.10 • RENEWABLE HEAT CONSUMPTION BY COUNTRY AND BY TECHNOLOGY, 2016



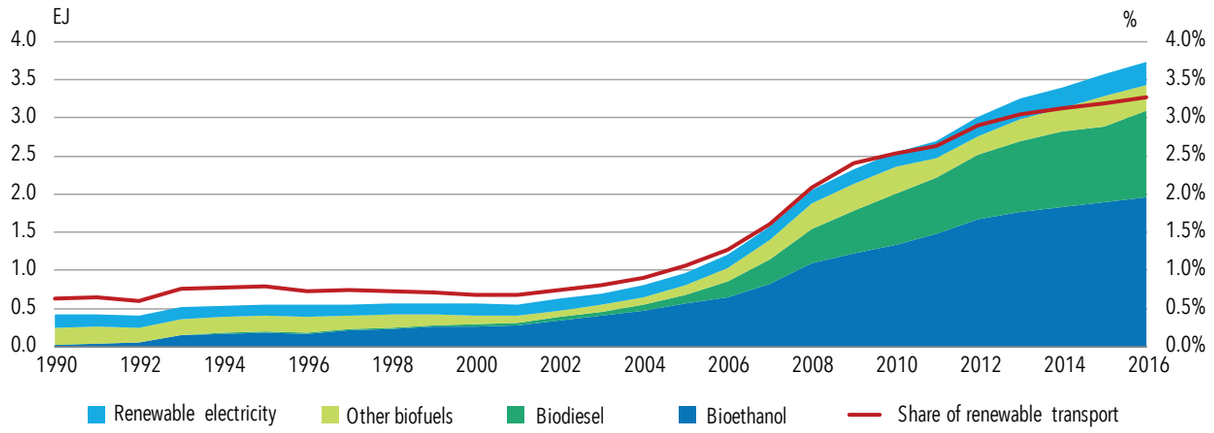
Source: IEA and UNSD.

TRANSPORT

Transport is the end use with the lowest renewable energy share. This increased by 0.1% year on year to reach 3.3% in 2016 (figure 3.11). The majority of renewable energy consumed (92% in 2016) was policy driven and came in the form of biofuels—mainly crop-based ethanol and biodiesel blended with fossil fuels used for transport. The remainder is from renewable electricity.

Renewable energy in transport more than doubled over 2007-2011 (from 1.3% to 2.6%), driven by a robust expansion of ethanol markets in the United States and Brazil, as well as growing biodiesel consumption in the European Union. In the next five-year period, ending in 2016, renewable fuel consumption only marginally outpaced growth in demand for fossil fuels, resulting in a relatively slower increase in the share of renewables in transport. This was primarily due to slower growth in ethanol consumption in the United States.

FIGURE 3.11 • RENEWABLE FUEL CONSUMPTION IN TRANSPORT, 1990-2016

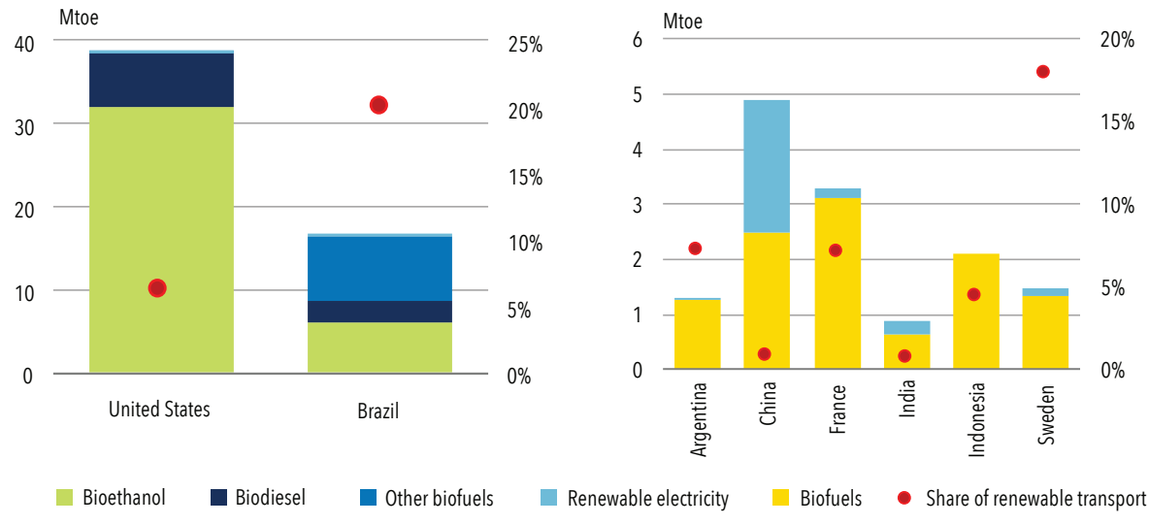


Source: IEA and UNSD.
Note: Biogasoline refers to fuel ethanol blended with gasoline. The significant majority (e.g., 98% in 2016) of "other biofuels" is unblended hydrous ethanol consumption in Brazil.

The most common policy measure employed to encourage renewables in transport is a mandated renewable share of fuel demand, or a biofuel share of gasoline or diesel (termed a "biofuel mandate"). As of 2016 such mandates had been established in around 70 countries. Most mandates stipulate a blending share of less than 10% biofuel with fossil fuels used for transport.[30] Fiscal incentives are also used in many countries to aid the cost-competitiveness of renewable fuels and stimulate demand.

The United States and Brazil combined accounted for over 60% of renewable energy in transport in 2016 (figure 3.12). Brazil is responsible for the lion's share of this: over 70% of its gasoline vehicles are flexible fuel, enabling unblended bioethanol consumption and higher blending shares.

FIGURE 3.12 • RENEWABLE ENERGY IN TRANSPORT AND RENEWABLE SHARE IN SELECTED COUNTRIES, 2016



Source: IEA and UNSD.

Sweden has also achieved a large share of renewable energy in transport. This has been achieved through reductions in energy, carbon dioxide taxation, waivers for biofuel vehicles that favor the consumption of high-level blend fuels, and legislation ensuring that service stations supply renewable fuels. Most renewable fuel consumption is currently in road vehicles, with minimal use in aviation and maritime transport. This is due to there being fewer economical and technically viable renewable fuels, compounded by less policy support for their use in these long-haul sectors.

In 2016, renewable electricity in transport was mostly for rail, with a smaller but growing share for road electric vehicles, including cars, buses, and two- and three-wheeler vehicles. Much of this last category was driven by the pressing need to increase air quality in cities. The global electric car stock surpassed 2 million vehicles in 2016. China is unique in the world for its significant transport fuel demand: half of its share of renewable energy in transport was due to electricity in 2016.

POLICY RECOMMENDATIONS AND CONCLUSIONS

Renewables have experienced remarkable progress over the past decade, driven by policy support, innovation, technological advancement and sharp cost reductions. However, this development has not been homogenous across countries and sectors. Renewables still face persistent policy and financial challenges, and sometimes technological barriers. Policies have so far mostly focused on renewable electricity, while relatively few countries have implemented policies for the use of renewables for heating and transport. Greater effort is still required to increase the share of renewables in the global energy mix, together with energy efficiency, to meet the SDGs. To this end, a combination of policy measures is needed to focus on creating an enabling environment for deployment, integrating renewables into consumers' daily lives and systems, and directly supporting deployment in all end-uses. The long-term stability of targets and policies is key to ensuring investor confidence and continued growth. At the same time, policies need to continuously adapt to changing market conditions, to achieve greater cost-competitiveness and improved integration of renewables into the system. Enabling policies contribute to a wider scope for renewable energy development. These include policies that issue clear signals to stakeholders (e.g., clearly defined targets, environmental and climate policies and regulations), level the playing field for renewables (e.g., fossil fuel subsidy reforms, carbon pricing policies), ensure the reliability of technology (e.g., quality and technical standards, certificates), facilitate access to affordable financing at multiple levels, manage land use, and support labor market needs and new skills (through direct measures, education, and training).

Policies that are driving the energy transition must consider renewables' integration into the broader energy system. Integration policies support the incorporation of renewables and energy efficiency in the heating and cooling, transport, and power end uses; in the larger energy and economic system; and in consumers' daily lives. As such, policies are needed to ensure the development of needed infrastructure (e.g., transmission and distribution networks, charging stations for electric vehicles, district heating infrastructure) to enhance system flexibility (e.g., support for energy storage, demand-side management); to promote sector coupling; and to support research, development, and demonstration.

Some measures can support the processes of both enabling and integrating renewable energy. These include the establishment of a supportive governance and institutional architecture (e.g., streamlined permitting procedures, dedicated institutions for renewables), programs that seek to raise consumers' awareness and induce behavioral change, and the coupling of renewable energy policies with livelihood development.

POLICIES FOR RENEWABLES IN HEATING

The heating end-uses have received little attention from policy makers although they account for half of global energy consumption. Traditional uses of biomass still account for the majority of renewable energy consumption in heating, and are linked to air pollution and negative health impacts. In order to ensure access to affordable, reliable, sustainable, and modern energy for all, policies need to promote modern uses of clean energy especially among energy vulnerable groups in developing countries.

Policies and measures are crucial to decarbonize heat end-uses, starting from dedicated short- and long-term targets and strategies to achieve them. However, approaches will necessarily vary across countries, reflecting specific energy contexts and barriers. For instance, renewable heat policy priorities depend on whether there is a significant district heating infrastructure (as in the Nordic countries and in some Chinese provinces) or whether there is a competing gas infrastructure (as in Italy, the Netherlands, or the United Kingdom).

A range of policy instruments may be adopted, often in combination. Carbon or energy taxes can incorporate externalities and offer important price signals to level the playing field with fossil fuels. They have been critically important to the penetration of renewable heat in the Nordic countries. Fiscal and financial incentives can be used to reduce cost gaps between renewables and fossil fuel technologies to create a level playing field such as

in China, Germany, and France. Heat-generation-based incentives have also been applied in the United Kingdom, providing support over longer periods. Mandates and building obligations, such as for solar water heaters in Brazil, China, Italy, and Spain, can provide deployment certainty and create domestic markets. Finally, building codes can support renewable heating and cooling by setting energy performance requirements. They provide an opportunity to align energy efficiency with renewable energy requirements, which is crucial to leverage synergies. Best practice examples include building codes in Canada, India, and Sweden that require both high levels of energy efficiency and low-carbon heat solutions, or incentive schemes, as in Germany, that offer a bonus when energy efficiency and renewable heat measures are deployed together.

POLICIES FOR RENEWABLES IN TRANSPORT

The share of renewable energy for transport is far lower than for heat and electricity end uses. The decarbonization of transport depends on numerous types of policy interventions. These include avoidance strategies (reducing unnecessary travel), improving the modal mix (increasing the use of public transport), enhancing vehicle efficiency, and fuel switching. As such, the use of renewables in the transport sector, whether through biofuels, vehicles powered with renewable electricity, or renewable-energy-based synthetic fuels is part of a larger policy challenge.

In general, transport policies should aim to overcome key barriers, such as the immaturity or relatively higher cost of certain fuels or vehicles, inadequate energy infrastructure, sustainability considerations for certain biofuel production pathways, and the need for consumers to embrace new technologies and systems.

The goal of policy support for biofuels is not limited to decarbonization, and encompasses facilitating demand for agricultural commodities and enhancing security. Governance is essential to ensure that scaling up biofuel consumption delivers tangible social, economic, and environmental benefits, including the reduction of life-cycle greenhouse gas emissions. Policy makers must establish frameworks to ensure that only sustainable biofuels receive policy support.

Blending mandates have been the principal means of policy support for biofuels to date. Notable examples include Brazil, China, and many European Union Member States. Fiscal incentives are also used in many countries to improve renewable fuels' cost-competitiveness and stimulate demand, such as in Brazil, France, and Thailand.

Most mandates stipulate a biofuel blend share with fossil transport fuels of below 10%. To facilitate higher sustainable biofuel blend shares, and therefore more renewable energy in transport, a transition toward a greater proportion of suitable (e.g., flexible fuel) vehicles and the use of "drop in" biofuels are necessary.

A shift toward advanced biofuels over time is desirable. Advanced biofuels are sustainable fuels produced from non-food-crop feedstock (therefore mitigating the impacts of land-use changes), which are capable of significantly reducing life-cycle greenhouse gas emissions compared with fossil fuel alternatives. Advanced biofuel costs are currently high. Policies to encourage technology learning and production scale-up are needed to lower these. Examples include advanced biofuel quotas and financial de-risking measures. Advanced biofuels will be particularly valuable in aviation and shipping, where electrification remains a challenge.

Policy frameworks that stipulate reductions in the average life-cycle carbon intensity of transport fuels have been introduced in some countries and regions. A notable example is California's Low Carbon Fuel Standard. These technology-neutral approaches drive innovation to maximize the reduction of carbon dioxide emissions from renewable fuels relative to cost.

Policies aimed at supporting renewable-powered electric transportation have only recently emerged. These can include targets, regulations, and mandates for concrete goals and policy deliverables, as well as financial incentives to make electric vehicles competitive with conventional vehicles. For instance, a long-term commitment from national policy makers helped Norway (the country with the highest EV penetration in the world to date) successfully deploy electric vehicles, using incentives and tax exemptions to close the purchase price gap in relation to conventional vehicles.

POLICIES FOR RENEWABLE ELECTRICITY

The share of renewable electricity has been growing much faster than renewable heat or transport. Policy has driven much of this growth, with many countries setting targets for renewable electricity and implementing a range of policy measures. While increasingly cost-competitive renewables—especially solar PV and wind—are rapidly transforming power systems worldwide, reforms in market design and policy frameworks will be needed going forward. Such measures are crucial to ensure investment at scale both in the new renewable capacities and in the power system flexibility needed to integrate high shares of variable renewables in a reliable and cost-effective manner.

Different policy instruments have been used to support renewable electricity deployment through different stages of technological maturity. Options include administratively set feed-in tariffs or premiums, renewable portfolio standards, quotas and tradeable green certificate schemes, net metering, tax rebates, and capital grants. Some of these instruments have been introduced in parallel. Recently, auctions (centralized, competitive procurement of renewables) have become increasingly widespread and have been instrumental in discovering renewable energy prices and containing policy costs in many countries, especially for solar PV and wind. However, the success of such policies in achieving deployment and development objectives relies on their design. Careful tailoring of policy to the local context and regulatory framework is needed to accelerate the energy transition. In addition to governmental action, voluntary and corporate purchase programs for renewable energy are becoming an important part of the energy transition.

Increasingly, distributed generation, which can increase the resilience of the electricity system, is supported through net metering and net billing. However, careful consideration is needed to avoid jeopardizing the electricity network's cost-recovery rates and creating cross-subsidization among those customers who self-consume and those who do not.

The most common support mechanisms for renewable electricity today were designed for small shares of renewable energy in the power system, without properly accounting for the interactions between variable technologies and power market design. With the increasing share of wind and solar PV in electricity generation, an appropriate market design is needed to reduce barriers. But system-friendly renewable incentives do exist; examples include Mexico's auction system, which aims to recognize the locational and time value of energy production, and Denmark's support scheme, designed to promote the use of turbines with smoother energy output.

Small shares of variable renewable energy (VRE) do not pose particular challenges at the system level. Priority areas are connection requirements, grid codes, and the updating of system operations. European countries incorporated VRE in their system operations. As VRE shares increase, policies ensuring investment in all forms of flexibility become crucial. Key policies and measures might include to (i) enhance power plant flexibility (China aims for one-fifth of installed coal-fired capacity by 2020); (ii) unlock demand-side management (for example, by allowing the participation of pools of consumers in the system services market, as in California); (iii) support energy storage (as with Germany's offer of low-interest loans and grants for PV-battery systems); and (iv) improve grid infrastructure (the United Kingdom's RIIO program guarantees the best investments for the network at a fair price, setting clear performance targets for operators).

As the transport, heating and cooling, and power sectors become increasingly interdependent, cross-linking decision making and policy design so both are beneficial across sectors will be crucial. For example, the success of EV deployment will critically depend on the strengthening of electricity distribution networks and smart charging systems at the local level. Conversely, these actions will enable the use of EV batteries, and the integration of more solar and wind power in the system.

METHODOLOGY

TABLE 3.1 • DEFINITIONS

Renewable energy sources (RES)	Total renewable energy from: hydro, wind, solar photovoltaic, solar thermal, geothermal, tide/wave/ocean, renewable municipal waste, solid biofuels, liquid biofuels, and biogases.
Renewable energy consumption	Final consumption of direct renewables plus the amount of electricity and heat consumption estimated to have come from renewable energy sources.
Direct renewables	Renewables energy sources that can be used directly: solid biofuels, liquid biofuels, biogases, solar thermal, geothermal energy and renewable municipal waste.
Total final energy consumption (TFEC)	The sum of the final energy consumption in the transport, industry, residential, services and other sectors (also equivalent to the total final consumption minus non-energy use).
Traditional uses of biomass	Final consumption (as estimated, not measured directly) of traditional energy uses of biomass. Biomass energy uses are considered traditional when biomass is consumed in the residential sector in countries that are not a part of the Organisation for Economic Co-operation and Development (OECD). The International Energy Agency accounts for the following categories: primary solid biofuels and charcoal.
Modern renewable energy consumption	Renewable energy consumption minus traditional consumption/uses of biomass.

METHODOLOGY FOR MAIN INDICATOR: SHARE OF RENEWABLE ENERGY IN TOTAL FINAL ENERGY CONSUMPTION

The indicator used in this report to track SDG 7.2 is the share of renewable energy in total final energy consumption. Data from the International Energy Agency (IEA) and United Nations Statistics Division (UNSD) energy balances are used to calculate the indicator according to the formula:

$$\%TFEC_{RES} = \frac{TFEC_{RES} + \left(TFEC_{ELE} \times \frac{ELE_{RES}}{ELE_{TOTAL}}\right) + \left(TFEC_{HEAT} \times \frac{HEAT_{RES}}{HEAT_{TOTAL}}\right)}{TFEC_{TOTAL}}$$

where the variables are derived from the energy balance flows (TFEC = total final energy consumption as defined in table 3.1, ELE = gross electricity production, HEAT = gross heat production) and their subscripts correspond to the product categories.

The denominator is the TFEC of all energy products (as defined in table 3.1) while the numerator, the renewable energy consumption, is defined as: the direct consumption of renewable energy sources plus the final consumption of gross electricity and heat that is estimated to have come from renewable sources. This estimation allocates the amount of electricity and heat consumption to renewable sources based on the share of renewables in gross production in order to perform the calculation at the final energy level.

METHODOLOGY FOR ADDITIONAL METRICS BEYOND THE MAIN INDICATOR

The amount of renewable energy consumption can be divided into three end uses, referring to the energy service for which the energy is consumed: electricity, heat, and transport. These are calculated from the energy balance and are defined as follows:

Electricity refers to the amount of electricity consumed in all sectors excluding transport. Electricity used for heat-raising purposes is included because official data on the final energy service are unavailable.

Heat-raising refers to the amount of energy consumed for heating purposes in all sectors excluding transport. It is not equivalent to the final energy end-use service. It is also important to note that in this chapter in the context of an "end use," heat-raising refers to the purpose and does not refer to the energy product "heat" used in the formula above.

Transport refers to the amounts of energy consumed in the transport sector, including electricity. Electricity used in the transport sector is mostly in the rail and road sectors (and in some cases, pipeline transport). The amount of renewable electricity consumed in the transport sector is estimated based on the share of renewable electricity in gross production.

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ENDNOTES

27 Some of the analysis in this chapter is based on data and analysis in the report Renewables 2018: Market Analysis and Forecast from 2018 to 2023 (IEA 2018).

28 Solid, locally resourced biomass—such as wood, charcoal, agricultural residues, and animal dung—is converted by low-income households into energy through basic techniques, such as a three-stone fire. Its use for heating and cooking in the residential sector is often inefficient and associated with negative impacts on human health and the environment.

29 Heat refers here to the amount of energy consumed for heating purposes in industry and other sectors, not to the final end-use service.

30 The share is measured either by energy potential or volume.