**CHAPTER 6** THE OUTLOOK FOR SDG 7

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## Main Messages

- Outlook for progress toward 2030 goals. The current energy and inflation crisis, triggered by the energy crisis two years after the COVID-19 pandemic, has continued to impede global progress on Sustainable Development Goal (SDG) 7. Energy security concerns sparked government responses that have accelerated the deployment of renewables and energy efficiency, improving the outlook to 2030 for SDG targets 7.2 and 7.3. This momentum is already helping curb emissions, which rose less than initially feared in 2022, with growth in solar, wind, electric vehicles, heat pumps, and energy efficiency limiting the impacts of increased coal and oil use amid the global energy crisis. Without this progress, emissions could have grown three times faster in 2022. However, price pressures, reduced household income, continued supply chain bottlenecks, and strained finances within developing economies are decelerating progress in access to electricity and clean cooking. These trends and new policies are captured under the Stated Policies Scenario of the International Energy Agency (IEA) and the Planned Energy Scenario of the International Renewable Energy Agency (IRENA), both of which depict a trajectory that is off track for achieving SDG 7. IEA's Net Zero Emissions by 2050 Scenario and IRENA's 1.5°C Scenario lay out pathways to bridge the gap and put the world's energy system on track to achieve or surpass the SDG targets most closely related to energy (those under SDG target 3.9, SDG 7, and SDG 13).<sup>74</sup>
- **Outlook for access to electricity.** For the first time in decades, the number of people without electricity access globally is likely to have increased in 2022, due to the energy crisis. IEA's Stated Policies Scenario projects that 660 million people would still lack access to electricity in 2030, of whom approximately 560 will be in Sub-Saharan Africa and approximately 70 million in Developing Asia. While there is limited progress on the horizon for countries with weak energy access-related institutions and policies, the outlook is better for countries that have strong institutional and policy support for access and have already made historic progress in bringing access to their population (e.g., Ethiopia, Senegal, and Kenya in Sub-Saharan Africa and countries in Developing Asia, which are still set to reach near-universal access by 2030). Between 2021 and 2030, 110 million people globally must be connected each year to achieve SDG target 7.1, the majority of them being in Sub-Saharan Africa.
- Outlook for access to clean cooking. According to IEA's Stated Policies Scenario, over 1.9 billion people globally would continue to rely on traditional uses of biomass, kerosene, or coal for cooking in 2030 in the absence of additional policies and measures. This reliance on polluting fuels will have dramatic consequences for the environment, economic development, and health, especially of women and children. Similarly to electricity access, clean cooking has seen limited progress due to rising energy prices, especially increases in the costs of liquefied petroleum gas (LPG) cylinders, which drove millions in Africa and Asia to revert to traditional fuels for cooking. Achieving universal access to clean cooking by 2030 requires tackling affordability and cultural barriers, as well as administrative and infrastructure barriers, although technologies to help achieve the goal are widely available. Meanwhile only one-third of the countries facing a lack of access to clean cooking have dedicated programs and policies. Sub-Saharan Africa lags behind other regions in this regard.

The majority of this chapter is based on results from IEA's World Energy Model and analysis in the World Energy Outlook (IEA 2022a), and thus uses certain geographical groupings used in the Outlook. "Developing Asia" refers to non-OECD (Organisation for Economic Co-operation and Development) Asia countries.

- Outlook for renewable energy. Several governments announced new policy packages that include substantial support for renewable energy. These contribute to the share of modern renewables in the total final energy consumption (TFEC) increasing from 12 percent in 2021 to 18 percent under IEA's Stated Policies Scenario and 16 percent in IRENA's Planned Energy Scenario by 2030. Under both scenarios, the majority of the growth in renewables-based electricity generation by 2030 is due to solar photovoltaic (PV) and wind. Although the renewable energy target under SDG 7 is not quantified, stated policies are inadequate to remain on track for achieving net-zero emissions in energy by 2050, consistent with the global objective to limit end-of-century warming to 1.5°C. IEA's Net Zero Emissions by 2050 Scenario shows that by 2030, there should be 33 percent modern renewables in TFEC. In the power sector, renewables would need to account for over 60 percent of electricity generation by 2030. Under IRENA's 1.5°C Scenario, the renewables share in TFEC and electricity generation would reach 38 percent and 65 percent respectively, by 2030. Greater efforts are also needed to increase renewables penetration in transport and heating, both directly (through the use of biofuels and biogas) and indirectly (through electrification). There are three times as many countries with renewable electricity targets as there are with renewable heat targets, even though the second group has a considerable share in TFEC.<sup>75</sup>
- **Outlook for energy efficiency.** Energy intensity –total energy supply per unit of gross domestic product (GDP)– is expected to decrease by 2 percent in 2022 after two years of slow progress during the pandemic. Surging energy costs and supply disruptions amid the energy crisis have led governments and consumers to specifically focus on improving efficiency. There has been an increase in government efforts to incentivize efficiency, including incentives for building retrofits, strengthened efficiency standards for buildings and appliances, notably, to move away from natural gas for heating, support for electric vehicles, and incentives for behavior changes to reduce energy use. These efforts are reflected under IEA's Stated Policies Scenario, according to which global energy intensity improves at 2.4 percent annually in 2021-30 from 1.8 percent in 2010-20. However, global energy intensity would need to improve at more than 3.4 percent annually to achieve SDG 7 by 2030. Under IEA's Net Zero Emissions by 2050 Scenario, this rate would increase to well over 4 percent a year, reflecting more aggressive efficiency mandates, including bans on the sale of the most inefficient equipment in the coming decade and codes mandating new buildings reach net-zero standards. Under IRENA's 1.5°C Scenario, energy intensity would need to improve at over 3 percent per year in 2020-30.
- Investment needs. Annual clean energy investments in renewable power, renewable fuels, efficiency, end-use electrification, and grids and networks, as well as access to modern energy, reached almost USD 1.2 trillion in 2021, a 15 percent growth as compared with the 2015-20 average. By 2030, annual clean energy investments under IEA's Stated Policies Scenario are expected to reach USD 2 trillion annually. However, clean energy investments would need to reach USD 4 trillion annually by 2030 under IEA's Net Zero Emissions by 2050 Scenario. Much of this investment is directed to renewables and efficiency. Reaching universal energy access by 2030 requires only a small share of this total, with annual investments of approximately USD 30 billion in electricity and USD 6 billion in clean cooking, according to IEA's Net Zero Emissions by 2050 Scenario. Under IRENA's 1.5°C Scenario, investments in energy transition technologies and related infrastructure amount to USD 4.7 trillion a year through 2030, a 150 percent increase in these types of investments compared with the Planned Energy Scenario.
- Energy projects addressing SDG 7, specifically access, still have insufficient public financing to mobilize the larger volumes of investment required to reach SDG 7. International public finance to support developing economies needs to increase. Key areas for action, especially in emerging and developing economies, include improving models of concessional finance to derisk further investment and mobilizing more private capital into climate solutions. (Chapter 5 discusses in more detail trends in international public financial flows in support of clean energy in developing countries and key areas for action.)

<sup>75 &</sup>quot;Heat" in this chapter refers to the energy consumed to produce heat for industry, buildings, and other sectors. Heat as a final energy service refers to the energy available to end users to satisfy their needs, after considering transformation losses.

# **Presentation of Scenarios**

This chapter describes the results of global modeling exercises to determine whether current policy ambitions are sufficient to meet the SDG 7 targets and identify what additional actions might be needed. It also examines what investments are required to achieve the corresponding goals. Scenarios for the targets are taken from IEA's World Energy Outlook (IEA 2022a) and IRENA's World Energy Transitions Outlook: 1.5°C Scenario (IRENA 2022). Both explore two types of scenarios: one in which energy trends evolve under today's policies and another based on policies that would deliver on all energy-related SDGs, including substantially reducing air pollution that causes deaths and illness (SDG 3.9) and taking effective action to combat climate change (SDG 13). The wide gap between the two types of scenarios is illustrated in box 6.1 (using the IEA scenarios).

IEA's Stated Policies Scenario explores how energy trends would evolve under today's policies; it does so assuming that no additional policies are implemented. It helps policy makers evaluate their current plans in order to assess whether they are sufficient to reach their long-term targets and goals. This scenario does not take countries' decarbonization pledges, Nationally Determined Contributions, or access targets as givens, but conducts bottom-up modeling that considers how policies, pricing policies, efficiency standards and schemes, electrification programs, and specific infrastructure projects would influence energy trends.

IEA's Net Zero Emissions by 2050 Scenario takes the SDG targets for 2030 and net-zero emissions in the energy sector by 2050 as its targets and works backward to determine what would be needed to achieve the outcomes in a costeffective and plausible manner.<sup>76</sup> Under this scenario, by 2030, universal access to both electricity and clean cooking would be achieved, modern renewables would reach 32 percent of TFEC, and energy efficiency gains would exceed the SDG 7 targets, with average annual improvements in global energy intensity reaching 4.3 percent a year between 2021 and 2030. After this critical near-term period, the scenario emphasizes efficiency, renewables, and clean fuels, bringing energy sector emissions to net zero by 2050 and limiting the end-of-century global temperature increase to 1.5°C over preindustrial levels.

IRENA's Planned Energy Scenario provides a perspective on energy system development based on governments' energy plans and other planned targets and policies. IRENA's 1.5°C Scenario describes an energy transition pathway aimed at limiting global average temperature increase to 1.5°C by the end of the 21st century relative to preindustrial levels. It is underpinned by six technological avenues and measures that would achieve major emissions reductions between today and 2050, paving the way toward a net-zero carbon world by mid-century. The scenario also provides insights into the socioeconomic footprint of the global energy transition.

<sup>76</sup> More information on IEA's Net Zero Emissions by 2050 Scenario can be found at https://www.iea.org/reports/world-energy-model/net-zeroemissions-by-2050-scenario-nze.

#### Box 6.1 • IEA's Announced Pledges Scenario: How government ambitions stand against SDG 7

IEA's Announced Pledges Scenario assumes that all aspirational targets announced by governments are met on time and in full, including their long-term net-zero pledges and energy-access goals.

Assuming all countries fulfilled their national climate and access pledges, the world would progress about two-thirds of the way toward achieving SDG targets 7.1 and 7.3, and 80 percent of the way toward meeting SDG target 7.2 for renewables. Comparing this trajectory to the Stated Policies Scenario highlights a growing implementation gap requiring further policies and measures by countries to reach their goals, especially for access (figure B6.1.1).





Source: IEA 2022[a].

Notes: Hundred percent advancement is achieved under the Net Zero Emissions by 2050 Scenario, which is consistent with and more ambitious than SDG 7. For access to electricity and clean cooking, the level of advancement is assessed as the number of people gaining access by 2030. For SDG target 7.2 (renewables), this is assessed as the share of renewables in TES. For SDG target 7.3 (energy efficiency), this is assessed as the average annual decrease of energy intensity.

APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario; STEPS = Stated Policies Scenario.

Of the 113 countries without universal access to electricity, only 25 have targets to reach universal access prior to or by 2030, while 29 have less ambitious targets. This leaves 59 countries without electricity access targets. Under the Announced Pledges Scenario, only two-thirds of the population still lacking access to electricity by 2030 receive it. This translates into 290 million people without access in 2030–less than half the number under the Stated Policies Scenario (660 million).

About 30 percent of countries without universal access to clean cooking have targets in place today, although only 15 percent have targets in line with SDG target 7.1. If all these targets, as stated under the Announced Pledges Scenario, are achieved, 780 million people would still be without electricity access in 2030, 60 percent less than under the Stated Policies Scenario.

Under the Announced Pledges Scenario, the share of renewables in total final energy consumption would reach 26 percent by 2030–as against 33.6 percent under the Net Zero Emissions by 2050 Scenario, but still higher than the 22.7 percent under the Stated Policies Scenario. SDG 7 has a target for substantially increasing renewables' share in the global energy mix. Significant advancement in this regard is achieved under both scenarios, highlighting current focus on related technologies.

Energy intensity under the Announced Pledges Scenario would improve on average by 3 percent every year by 2030–a significant improvement as compared with the Stated Policies Scenario (2.4 percent) but still below the 3.4 percent required to meet SDG target 7.3. Under the Net Zero Emissions by 2050 Scenario, energy intensity improves 4.3 percent on average yearly, which is more ambitious than SDG target 7.3.

# **Outlook for Access to Electricity**

IEA estimated that the number of people without electricity access global likely increased in 2022, reversing decades of decreasing trend. This increase is largely in Sub-Saharan Africa, due to reasons including supply chain disruptions and the energy crisis causing rising inflation levels and interest rates following two years of the COVID-19 pandemic. Effects included higher costs for electricity systems (e.g., according to GOGLA, solar home systems prices increased 28-36 percent between 2020 and 2022 [Lighting Global/ESMAP and others 2022]) and for financing new electrification projects, and, at the same time, a drastic increase in the number of people in extreme poverty (World Bank 2023), making it more challenging to acquire and maintain access to electricity. Investment in power infrastructures is also slowing down due to the rising debts that most utilities were already facing (IEA 2022[a]).

In the medium and long term, access to electricity is expected to improve through 2030, after the situation has stabilized. Trends vary significantly across countries, many of which will not reach universal access by 2030 under current conditions. Under the Stated Policies Scenario, 660 million people (roughly 8 percent of the global population) would remain without access by 2030, 85 percent of whom are in Sub-Saharan Africa (figure 6.1). Less than half of the countries without universal access to electricity have official targets, and only about 22 percent have targets at least as ambitious as SDG indicator 7.1.1 (see box 6.1). Countries without electrification plans and enabling frameworks are not on target. However, SDG target 7.1.1 remains within reach in countries with adequate policies, holistic electrification plans, including both grid and off-grid solutions, and sufficiently resourced implementing institutions. The IEA's Net Zero Emissions by 2050 scenario shows a pathway to achieve SDG7.1.1 where more than half of the population gaining access by 2050 do so with off-grid solutions such as mini-grids and stand-alone systems.



## Figure 6.1 • Global population without access to electricity under IEA's Stated Policies Scenario and delivery of electricity connections under IEA's Net Zero Emissions by 2050 Scenario, as of 2030

Source: IEA 2022[a].

Developing (non-OECD) Asia remains on track to reach near-universal access, with only 2 percent of the population without electricity in 2030. According to IEA's Stated Policies Scenario, the highly populated countries of Bangladesh and the Philippines are on a pathway to reach full access before 2030, whereas India and Indonesia already reached universal access. IEA's Stated Policies Scenario shows that efforts need to be stepped up in other Asian countries, such as Afghanistan, Mongolia, and Pakistan, if the region is to achieve 100 percent access in 2030. In Central and South

America, only the most remote population will remain without access by 2030, with the region reaching an access rate of 98 percent. The only exception is Haiti, one of the poorest countries in the world, which is expected to still see a large share of its population without access in 2030.

Besides improvements in policies and electrification plans in some Sub-Saharan African countries, the prospects for achieving SDG 7.1.1 remain unlikely; about 40 percent of countries do not have official electrification plans or track progress periodically.

Access to finance is often more challenging for countries that have the greatest need to improve access quickly. International support is essential especially under the current economic conditions, with concessional finance being a viable option to lower the perceived risk for private investors. However, country governments must implement robust electrification plans and allocate capital to access projects accordingly (IEA 2022[a]).

IEA's Net Zero Emissions by 2050 Scenario indicates that almost 90 percent of new connections will be renewablesbased. Although the component costs for solar and hybrid mini-grids, as well as solar home systems, increased between 20 and 36 percent in 2022, their costs are likely to begin declining in the near future.

To bridge the gap and achieve universal access by 2030, 110 million people must gain access to electricity on average every year between 2021 and 2030–80 percent of whom in Sub-Saharan Africa. Efforts needs to be increased especially in the Democratic Republic of Congo, Niger, Nigeria, Sudan, Tanzania, and Uganda, which together are home to half of the region's population projected to lack access in 2030.

Delivery technology varies by region under IEA's Net Zero Emissions by 2050 Scenario. In Sub-Saharan Africa, 42 percent of connections by 2030 would be directly to the grid, 31 percent would be connected to mini-grids, and the remainder would be stand-alone systems (mostly solar home systems). In Developing Asia, just over half of new connections would be directly to the grid, and almost a third would be connected to mini-grids.

IEA's Net Zero Emissions by 2050 Scenario proposes a sustainable pathway to achieve universal access to electricity by 2030. However, this implies that governments and donors increase the access focus of development plans and programs. This includes addressing affordability issues (which remain the primary reason behind people not getting electricity access or not benefiting from it), supporting the stand-alone and mini-grid sectors, implementing tracking and monitoring, and use of geospatial data and models as the basis for electrification planning, and, finally yet importantly, creating and providing resources to entities in charge of implementing these plans. Low-capacity off-grid energy solutions, such as small off-grid solar systems, will play an important role, particularly in reaching households in remote areas, but planning must include a strategy to support these households to benefit from energy services by stimulating household and productive uses demand and so gradually extending access through the use of bigger systems or connections to mini-grids or the national grid.

SDG 7.1.1 is achievable in theory with strong electrification plans. Between 2015 and 2019, seven countries in Sub-Saharan Africa (e.g., Côte d'Ivoire, Gambia, Kenya, and Rwanda) reached or surpassed the required progress levels. However, in 22 other countries, representing more than half the population without access in the region (including Chad, the Democratic Republic of Congo, Madagascar, Malawi, Mozambique, and Niger), there has been an increase in the number of people without access in the same period (IEA 2022b). Many of the successful electrification plans aim to maximize the benefits of energy access by considering the needs of health facilities, schools, agricultural enterprises, and similar organizations alongside those of households. Under the Net Zero Emissions by 2050 Scenario, achieving universal access to electricity by 2030 requires an annual investment of USD 30 billion through 2030 on generation, electricity networks, and decentralized solutions through smart and efficient integrated delivery programs. However, in 2019, only approximately USD 10 billion were spent on improving electricity access globally. Recent trends reveal an increase in domestic public financing, which is helping mobilize more private finance (SEforALL 2021). Ultimately, energy access must look beyond basic access to electricity and facilitate the increasing use of energy services sufficient to underpin socioeconomic prosperity and well-being, as also illustrated by the World Bank Multi-Tier Framework.

## **Outlook for Access to Clean Cooking Fuels and Technologies**

Recent decades saw a decline in the number of people without access to clean cooking globally. This decline reflects efforts to reduce the reliance on biomass among vulnerable populations, with the aim of improving indoor air quality, at the same time reducing the time spent gathering fuel, and curbing deforestation and greenhouse gas emissions from the incomplete combustion of biomass. Forest degradation, sometimes leading to outright deforestation, is yet another grave consequence of the unsustainable harvesting of fuelwood, chiefly for producing charcoal, to be used in cities.

Progress has been uneven and was primarily driven by countries in Asia (e.g., China, India, Indonesia, and so on), whereas Sub-Saharan Africa saw a continued increase in the number of people without access to clean cooking. The current energy crisis and the related inflationary environment in the wake of the COVID-19 pandemic have exposed consumers to a dual threat of reduced income and higher prices of clean cooking fuel (e.g., LPG). Some countries have implemented policies to counter this trend, although millions, especially in Sub-Saharan Africa, have reverted to traditional uses of biomass. This led improvements to slow down between 2020 and 2022. Although progress is expected to return to historical levels in certain regions, the outlook for clean cooking remains of serious concern: under today's policies, the world would be far from achieving universal access to clean cooking solutions by 2030, with 1.9 billion people still without access (figure 6.2).





Source: IEA 2022[a].

Note: The number of people without access to clean cooking in 2030 is significantly lower than that in previous editions of the World Energy Outlook. This is due to a downward revision in the historic number of people cooking with traditional biomass in China. This revision by the World Health Organization is based on recent surveys.

LPG = liquefied petroleum gas.

In 2030, the population without access to clean cooking solutions is projected to be divided almost equally between Developing Asia and Sub-Saharan Africa. In Developing Asia, the projected access rate in 2030 is 81 percent, leaving 821 million people without access. Significant progress is projected for India, where the number of people without access is expected to reduce from 504 million in 2022 to 323 million in 2030, indicating an access rate of 80 percent from the current rate of approximately 68 percent.

To achieve the objective of the Net Zero Emissions by 2050 Scenario in line with SDG 7, every household in the world would have access to clean cooking by 2030. To do that a set of different clean cooking technologies and fuels needs to be deployed (figure 6.2). A significant increase in policies and investments will be required to support the above achievement, which would provide over 290 million people with access to clean cooking solutions each year.

Achieving the objective of the Net Zero Emissions by 2050 Scenario and SDG 7.1.2 would require rapid ramp-up of access programs to reduce the upfront cost of stoves while ensuring affordability of clean cooking fuels, train people to use new cooking equipment safely and effectively, and deliver awareness programs (e.g., cooking classes or recipes that help adapt culinary practices to improved cookstoves). Supporting infrastructure (e.g., fuel delivery and storage systems, a stable supply chain of cooking equipment within the country, and workers to help administer the above programs) also needs to be ramped up (IEA 2021) to ensure accessibility and sustainably of supply. Many regions have scalable LPG solutions but lack consistently available fuel distribution services; also, LPG remains exposed to market prices, leaving users vulnerable to price spikes without government intervention. Alternative fuels for cooking, such as biogas, must also play a role in rural areas, but biodigesters to produce biogas require support to cover the high upfront cost, the availability of sufficient feedstock, and training on their use and maintenance. Electric cooking appliances such as microwaves or electric pressure cookers represent an increasingly popular mode of clean cooking, particularly in urban areas and areas powered with grid electricity. A World Bank report, for example, compared the cost of cooking with electricity with cooking with other fuels in Kenya (ESMAP 2020). At the time of publication, in September 2020, electric stoves were found to be only marginally more expensive than LPG stoves. However, with current surges in LPG prices and advances in electric stoves, electric cooking will continue to be increasingly attractive.

In some countries, utilities and off-grid solution providers offer all-electric cooking bundles and programs, since increasing electric cooking can increase the profitability of providing electricity access. Improved biomass stoves (ISO Tier > 1) are of fundamental importance to reach SDG 7.1.2, especially in rural areas, and fuels such as ethanol can help cover gaps in certain regions. Reaching universal access to clean cooking by 2030 requires an all-solutions approach to meet the diverse needs in different countries and in rural and urban environments.

# **Outlook for Renewable Energy**

SDG target 7.2 calls for a substantial increase in the share of renewable energy in the energy mix. Although it does not specify a quantitative objective, long-term scenarios charting various paths for the energy sector to reach net zero by 2050 find that renewables would need to constitute a third of TFEC by 2030 to be on track.

Despite the impact of the current energy crisis and the COVID-19 pandemic on supply chains and components costs, the outlook for renewables under IEA's Stated Policies Scenario and IRENA's Planned Energy Scenario remains positive in all regions, due to supportive policies. Under IEA's Stated Policies Scenario, the share of all renewables (including traditional uses of biomass) in TFEC is projected to increase from 18.5 percent in 2021 to 23 percent in 2030, and the share of modern renewables is projected to increase from 12 percent in 2021 to 18 percent in 2030. These projections are higher than in previous outlooks because many countries accelerated renewable energy projects as part of their plans to increase energy security amid the current energy crisis. By contrast, IRENA's Planned Energy Scenario sees the share of modern renewables in TFEC increasing to 16 percent in 2030, due to much wider deployment of renewables in the power sector and in end-use electrification.

Power-sector renewables remain the fastest-growing source of energy globally. Renewable sources of electricity remained resilient during the recent crisis period, experiencing only minor setbacks. Besides short-term concerns about supply chains, renewables annual capacity additions in 2021-30 are poised to more than double the 2015-20 trends, thanks to increased government plans to expand renewables projects. This growth will be driven by solar PV and wind. By 2025, renewables will surpass coal as the primary means of producing electricity. Of the renewable sources of electricity, solar PV would be the strongest performer, meeting almost half (46 percent) of the increased electricity demand over the period. It is closely followed by wind (42 percent). Hydropower would remain the largest low-emission source of electricity globally through 2030. It would also provide flexibility and other power system services.

Direct uses of renewables have grown steadily but slowly in end-use sectors. Modern bioenergy would account for the largest share of growth in end-use renewables through 2030. In the transport sector, liquid biofuels see strong growth, although their use will be limited if new blending requirements are not adopted in places where they do not currently exist. The transport sector would also see increased use of electricity, which will result from electromobility leveraging the increasing renewables share in the mix. The use of renewables also increases for heating in the industry and buildings sectors, with modern bioenergy accounting for the largest share of the growth, driven by renewables requirements in Europe and some pilots in China. There is also an increase in the demand for biogas and modern bioenergs for heating, driven by growth in industry (IEA 2022[a]).

The outlook for growth for end-use renewables depends to a large extent on further policy action at a time of economic difficulty and competing budgetary pressures. There is a risk that some targets may not be enforced, but end-use renewables can be a part of the toolkit for improving energy security especially when they are sourced locally. Supportive policies may play an important role in new policy packages, especially for transport biofuels, which would support agricultural production as well as emissions reductions.

## **INSIGHTS ON BRIDGING THE GAP FROM IEA'S NET ZERO EMISSIONS BY 2050 SCENARIO**

The projected increases in the use of renewable energy that are likely to occur under stated policies fall short of what is required to achieve global goals for climate protection and sustainable development. Under IEA's Net Zero Emissions by 2050 Scenario, use of renewables increases twice as rapidly as under stated policies. Under this more ambitious scenario, modern renewables would reach just over one-third of TFEC in 2030 (figure 6.3).





Source: IEA 2022[a].

CCUS = carbon capture, utilization, and storage; NZE = Net Zero Emissions by 2050 Scenario; STEPS = Stated Policies Scenario.

As can be seen in figure 6.3, the share of renewables-based electricity generation would grow the fastest: from the current 28 percent to just over 60 percent by 2030, or almost 18 percentage points higher than in the Stated Policies Scenario. Globally, renewables-based electricity generation would grow 12 percent a year to approximately 23,065 terawatt-hours (TWh) by 2030. This would result from unprecedented capacity additions of solar PV and wind, reaching annual averages of, respectively, 430 gigawatts (GW) and 240 GW between 2021 and 2030 (figure 6.4). Annual investment in renewables-based power would triple over the decade to over USD 1.2 trillion a year by 2030; this would be supported by additional spending on expanding and modernizing electricity networks and battery storage and enhancing the operational flexibility of existing assets to better integrate renewables.





Under IEA's Net Zero Emissions by 2050 Scenario, increased electrification of energy end uses is a primary means to increase renewables' share in TFEC. The share of electricity in final energy demand would increase to 31 percent by 2030, compared with about 24 percent under the Stated Policies Scenario. Electrification of transport and heat would be the primary drivers of this growth.

Direct use of renewables, principally liquid biofuels, would account for, on average, 12 percent of road transport fuel; combined with growing electrification, the share of renewables in transport would increase to nearly 17 percent by 2030 (IEA 2022[a]).

The use of renewables for heat applies to space and water heating, cooking, industrial processes, and other uses. The heat can be provided directly by bioenergy, solar thermal, or geothermal or indirectly through electricity and district heat produced from renewable sources. Switching to direct use of renewables–through use of solar thermal water heating, biomass, and low-carbon gases, for example–would also reduce the use of fossil fuels. In 2021, renewables accounted for 9 percent of the total energy consumed for heating worldwide. By 2030, this share would increase to 20 percent under the Net Zero Emissions by 2050 Scenario.

Source: IEA 2022[a].

GW = gigawatt; NZE = Net Zero Emissions by 2050 Scenario; PV = photovoltaic; STEPS = Stated Policies Scenario.

The share of traditional uses of biomass in TFEC would decline to 5 percent by 2030 under the Stated Policies Scenario marking only a 1 percentage point decrease from 2021 levels and due to low achievements in clean cooking access. Under the Net Zero Emissions by 2050 Scenario, traditional uses of biomass would be phased out completely, since developing countries would replace them with more modern and efficient fuels and technologies.

Across regions, variations in energy policy, socioeconomic trends, and natural resource endowments result in different growth trajectories for renewables. Developing economies would account for over 80 percent of the growth in electricity generation through 2030 under the Stated Policies and almost 90 percent of this growth in the Net Zero Emissions by 2050 Scenario. Under the Stated Policies Scenario, renewables-based electricity generation would grow from 10 percent in the Middle East and 16 percent in Northern Africa, at the low end, to over 80 percent in Central and South America, where hydropower is the backbone of the power mix. Under the Net Zero Emissions by 2050 Scenario, the share of renewable electricity generation would increase in every region, approaching or surpassing half of all electricity generation by 2030 in many regions.

IEA's Net Zero Emissions by 2050 Scenario sees the supply of low-emissions hydrogen<sup>77</sup> increasing from 0.3 million metric tons (Mt) today to 90 Mt in 2030 and 450 Mt in 2050, reaching 10 percent of TFEC. Achieving net-zero emissions by 2050 would also require carbon-capture technologies. Under the Net Zero Emissions by 2050 Scenario, carbon dioxide (CO2) captured using carbon capture, utilization, and storage, as well as CO2 removal (CDR) technologies, would amount to just above 1.2 metric gigatons (Gt) in 2030, excluding nature-based measures.

### **INSIGHTS ON BRIDGING THE GAP FROM IRENA'S 1.5°C SCENARIO**

IRENA's 1.5°C Scenario requires a significant scale-up of renewable energy and energy-efficient solutions but also other energy transition technologies and related infrastructure. It entails a transformation of how societies consume and produce energy. The decade to 2030 will be crucial for scaling up no-regret options. IRENA's 1.5°C Scenario details six key performance indicator categories, which provide a broad overview of the required level of transition (figure 6.5). This includes scaling the renewable energy share in TFEC to 28 percent and in electricity generation to 65 percent by 2030, with a corresponding increase in the share of energy supplied from electricity to 30 percent. Investments in improving energy efficiency need to increase by a factor of 9. Clean hydrogen production would need to increase to over 150 Mt by 2030. Finally, some investment in CDR technologies will also be required, namely, in hard-to-decarbonize sectors, such as industry.

To Low-emissions hydrogen refers to hydrogen that is produced from water using renewables- or nuclear-based electricity or derived from fossil fuels with minimal methane emissions and processed in facilities equipped to avoid CO2 emissions, for example, using carbon capture, utilization, and storage technologies with a high capture rate. Low-emissions hydrogen is also derived from bioenergy. In this report, the total demand for low-emissions hydrogen is greater than the total final consumption of hydrogen, because the former additionally includes hydrogen inputs to produce low-emissions hydrogen-based fuels and biofuels, and generate power, and also for oil refining, and for producing hydrogen and consumed on-site in industry.

#### Figure 6.5 • Key performance indicators for IRENA's 1.5°C Scenario in 2030

		Recent years	2030
KPI.01	Electricity generation will need to expand from 26 900 TWh in 2019 to more than 42 100 TWh by 2030, with 65% of the total electricity supply in 2030 coming from renewable sources, compared with 26% in 2019.	26%	65 %
KPI.02	The share of renewable energy in total final energy consumption (TFEC) must increase from 19% in 2019 to 38% by 2030.	19%	38%
KPI.03	Average annual investment in improving energy intensity must increase by a factor of 9 by 2030, implying a 5% decrease in TFEC in 2030 from 2019 levels.	ca. 250 USD billion/yr	<b>ŠŠŠŠŠ</b> >2260 USD billion/yr
KPI.04	The share of direct electricity in TFEC must increase from 21% in 2019 to 30% by 2030.	21%	30 %
KPI.05	The production of clean hydrogen and its derivative fuels must ramp up from negligible levels in 2020 to 154 Mt by 2030.	0.8 Mt	154 мt
KPI.06	The total CO <sub>2</sub> captured from CO <sub>2</sub> removal and storage measures must be aggressively scaled up to reach 2.2 Gt CO <sub>2</sub> by 2030, up from 0.04 Gt in 2020.	0.04 Gt	2.2 Gt

Source: IRENA 2022.

CO2 = carbon dioxide; Gt = metric gigaton; KPI = key performance indicator; Mt = million metric tons; TWh = terawatt-hour.

Advancing the energy transition at the needed pace and scale would require almost complete decarbonization of the electricity sector by mid-century. Under the 1.5°C Scenario, rapid electrification of heat and transport applications along with the increased green hydrogen production would drive a significant growth in electricity demand. By 2030, renewables would supply 65 percent of the total electricity needs (figure 6.6). Such a transition in the global electricity sector could be realized by accelerating the deployment of all forms of renewable power technologies, including wind (onshore and offshore), solar PV, hydro, biomass, and geothermal. At the same time, additional flexibility in the power sector will be required. Although the types of technologies and solutions are specific to power systems, key technologies include storage, greater interconnection, market and regulatory reforms, and demand response, among many others.



#### Figure 6.6 • Electricity generation and capacity by source in 2018, 2030, and 2050 under IRENA's 1.5°C Scenario

Source: IRENA 2022.

1.5-S = 1.5°C Scenario; CSP = concentrated solar power; GW = gigawatt; PV = photovoltaics; RE = renewable energy; TWh = terawatt-hour; VRE = variable renewable energy.

Direct electricity consumption in end-use sectors would increase to 31,000 TWh by 2030, compared with approximately 23,000 TWh in 2020. This increase in electricity demand will be seen across all sectors, even though transport will by far see the largest growth. In addition to the rapid growth in direct electrification needs, 3,100 TWh would be needed to produce green hydrogen by 2030. In total, direct and indirect electrification would have a 32 percent share in the final demand in 2030, an increase from approximately 21 percent in 2020.

Under the 1.5°C Scenario, the transport sector, and in particular road vehicles, would see rapid transition over the decade. The stock of electric cars would grow from 26 million in 2022 (estimated) to over 380 million by 2030. The share of electricity in final transport energy consumption would grow from 1 percent in 2020 to over 9 percent by 2030.

Direct uses of renewables (e.g., bioenergy, solar thermal, and geothermal) are needed to bring much-needed solutions to hard-to-electrify energy services in the transport, buildings, and industry sectors. Under the 1.5°C Scenario, direct uses of renewable fuels in final energy would need to grow to 55 exajoules (EJ) in 2030, up from 45 EJ in 2020.

Under IRENA's 1.5°C Scenario, clean hydrogen production would grow from under 1 million metric tons today to 154 million metric tons by 2030.<sup>78</sup> This hydrogen would largely be used in industrial applications in the corresponding decade, although a small quantity would be used in the transport and buildings sectors.

<sup>78</sup> Clean hydrogen here refers to the combination of hydrogen produced by electrolysis powered from renewables (green hydrogen) and hydrogen produced from natural gas in combination with carbon capture and storage by steam methane reforming (blue hydrogen).

## **Box 6.2** • Linkages between SDG 7 and SDG 12: Circular economy and end-of-life management for solar photovoltaic (PV) technologies

Solar PV is expected to play a pivotal role in energy transitions and support progress toward SDG 7 and SDG 13 on climate change, as highlighted in this section. However, solar PV modules currently have an estimated average service lifetime of 25-30 years, after which their performance can deteriorate and they can be prone to failure. Increasing quantities of solar PV equipment will thus reach the end of their lifetime in upcoming years: according to IRENA's estimates, following a pathway compatible with the 1.5°C Scenario, cumulative solar PV waste would exceed 3.9 million metric tons by 2030 and could reach more than 212 million metric tons globally by 2050 (IRENA 2023).

In line with SDG 12 ("responsible consumption and production"), these end-of-life flows of solar PV equipment need to be managed proactively with a circular economy perspective.<sup>a</sup> In this light, solar PV design and manufacturing based on circular approaches through reduced requirement of toxic and critical material and increased durability, performance, and recyclability of PV panels, as well as reuse of PV modules and components, can reduce material flows and relevant impacts on the environment. Moreover, the benefits of recycling are manifold: recycling provides an alternative to landfilling and associated environmental pollution and health issues. It also provides an opportunity to recover valuable elements and secure a reliable secondary source of raw materials, helping avoid adverse environmental, social, and health impacts associated with raw material mining. It can also generate employment opportunities and support local economic activity.

IRENA estimates that by 2030, about 1.2 million metric tons of material can be recycled from solar PV waste, and 17.7 million metric tons by 2050. This recovered material could comprise a significant share of the future total material demand. Assuming systematic collection of end-of-life modules and recovery rates of 85 percent, the recycling of solar PV modules could meet almost 70 percent of the silver demand and more than 20 percent of the demand for aluminum, copper, glass, and silicon. While recovered materials do not yet generate sufficient revenue to offset the costs of the recycling processes,<sup>b</sup> they could nevertheless represent a significant market value, accounting for about USD 0.5 billion by 2030, USD 3.3 billion by 2040, and more than USD 8.8 billion by 2050 (IRENA 2023).

However, there are barriers to address in order to tap the potential of solar PV recycling. These include technical challenges (e.g., inefficient recycling technologies), and lack of the required infrastructure, logistics, and services; lack of information and data on the accurate composition of PV modules, as well as the estimated quantities and location of to-be-decommissioned PV panels, and their time to decommissioning; unclear regulations; low market confidence for project investors or potential second-hand panel users; and lack of profitability. Industry and industry associations can initiate voluntary programs to encourage and promote circularity practices, such as recycling programs or circularity-based product design. Voluntary industrial standards could also be used to enable companies' action that supports a circular economy for solar PV (IRENA 2023).

Since PV recycling is yet to be a profitable business, policies and measures are urgently needed to address barriers and promote circular economy pathways. Currently, only about 62 policies and programs from 16 countries are focused on the circular economy of solar PV panels; these are primarily led by governments, industry, and industry associations. Available policy tools for governments include landfill bans, extended producer responsibility, exemption from regulations, government guidance, financial and fiscal support, product labeling, recycling programs, and working groups. Examples can be found in Canada, China, the European Union, the Republic of Korea, Japan, and the United States. It is particularly crucial to develop and implement comprehensive regulatory frameworks to define stakeholders' responsibilities, financing models, and the minimum requirements for collection and recycling. These should cover PV recycling processes as well as module designs for easier recyclability of future end-of-life equipment. Finally, recycling policies should be complemented by strategies to extend a module's overall service lifetime through reuse, repair, and manufacturing.

a. Circular economy principles include the reduction of consumption initially, for instance, by reducing energy and material needs through sufficiency and efficiency measures. They then imply strategies to increase product lifetimes, for instance, by repairing and reusing solar PV equipment, and recovering materials through recycling processes.

b. For example, in the United States, recycling costs range from USD 15 to USD 45 per solar panel, which exceeds the value of the recovered material, which currently stands at USD 2 in the country. Meanwhile, disposal at nonhazardous landfills can cost less than USD 1 per panel and less than USD 5 per panel at hazardous waste landfills (Curtis and others 2021).

Under the 1.5°C Scenario, the role of CDR is limited to targeting process emissions from cement, iron and steel, hydrogen, and chemical production, with limited deployment for waste incinerators. Total CO2 captured from carbon capture and storage, carbon capture and utilization, bioenergy coupled with carbon capture and storage, and other CDR measures<sup>79</sup> must be scaled up aggressively to reach 2.2 metric gigatons of carbon dioxide (GtCO2) by 2030, from 0.004 GtCO2 in 2019.

To ensure the energy transition is sustainable as renewable energy deployment accelerates, it will also be critical to adopt circular economy approaches and plans for the end-of-life management of different renewable energy technologies. Box 6.2 provides more insights on this topic, focusing on the solar PV sector.

# **Outlook for Energy Efficiency**

Global energy intensity, measured by the ratio of the total energy supply and GDP, is the key indicator to measure global progress on energy efficiency. The ongoing energy crisis is expected to contribute to improving this metric by 2 percent in 2022 after two years of slow progress. Surging energy costs, energy security concerns, and supply disruptions and looming shortages have as a matter of fact brought sharp focus on efficiency improvement, with governments worldwide looking to energy-saving measures to shield consumers from rising prices and secure supply. This follows a significant slowdown caused by the COVID-19 pandemic and a stronger-than-expected rebound in energy consumption in 2021. Early estimates for 2022 indicate, therefore, a slight recovery, with energy intensity improving at a rate of 2 percent. Greater attention to energy efficiency policies and retrofits incentives in Europe, Northern America, and Eastern Asia enhances the outlook towards 2030 to 2.4 percent under the Stated Policies Scenario; this is slightly stronger than progress on energy intensity over the decade ending 2020 (figure 6.7).





Source: IEA 2022[a].

NZE = Net Zero Emissions by 2050 Scenario; SDG = Sustainable Development Goal; STEPS = Stated Policies Scenario.

<sup>79</sup> CDR measures and technologies include nature-based measures such as reforestation, as well as direct carbon capture and storage, bioenergy with carbon capture and storage, and other approaches that are currently experimental.

The improvement under the Stated Policies Scenario came against the backdrop of a previous slowdown, which occurred in the wake of strong improvements in energy intensity in the mid-2010s. That slowdown was in large part triggered by the significant slowdown caused by the COVID-19 pandemic, as well as by slower trends in China, where modern production processes have now replaced inefficient industrial capacity after decades of progress in the latter's phaseout. Recent increased action has helped compensate for the slowdown, although annual improvements are still far below where they need to be. Annual improvement until 2030 would now need to average 3.4 percent, as compared to only 1.8% in the 2010-20 period, if the world is to meet the SDG 7.3.

The lingering effects of the energy crisis are deemed to have helped overall energy efficiency-related investments increase by 16 percent in 2022, to just over USD 560 billion. This has reversed the effects caused by the pandemic on the previous trends under the Stated Policies Scenario. In addition, the large increase in industrial activity in China due to increased demand for durable goods worldwide during the pandemic subsided during 2022.

Volatile fuel prices have meanwhile also informed global policy responses and had an important influence on the rate of energy efficiency improvements. Before the onset of the energy crisis, many energy-importing countries were already implementing policies to shield consumers from price spikes in natural gas (concentrated in Europe), coal (concentrated in China), and LPG (concentrated in developing economies). These price shocks had resulted in many governments providing financial support, which is draining government coffers and driving a renewed zeal for energy efficiency projects. Enhanced energy efficiency mandates and incentives could however be seen as a more economical alternative to household price supports and could inform the next phase of recovery response measures, alongside mandates for fuel storage facilities, the increased use of renewables, and extensions of the life of existing plants, all of which are under consideration in many countries to reduce dependence on oil and gas, especially Europe. In developed economies, higher energy prices also drive energy efficiency investments and behavioral changes focused on reducing consumption by private sectors and by citizens in their homes.

Energy efficiency is one of the building blocks of IEA's Net Zero Emissions by 2050 Scenario. The COVID-19 pandemic resulted in a decline of TFEC in 2020 and 2021, but it is now set to recover. Under IEA's Net Zero Emissions by 2050 Scenario, accelerated improvements in energy efficiency would occur across all energy end uses and would cause global energy to peak before 2025 and decline rapidly thereafter. To realize the Net Zero Emissions by 2050 Scenario, the world must overshoot SDG target 7.3, improving energy intensity by 4.3 percent between 2021 and 2030, instead of the 3.4 percent needed to reach the target. This acceleration would require more stringent standards and incentives as well as bans on the sale of inefficient stock.

Under IEA's Net Zero Emissions by 2050 Scenario, global energy supply would decline 5.3 percent between 2021 and 2030, with advanced economies leading the way. This would decrease the total energy supply by 14 percent over this period. This decline would occur despite strong economic growth highligting the importace of energy efficiency in the scenario.

Early implementation of efficiency improvements across all sectors is essential to move to a more sustainable trajectory. In the transport sector, improvements in efficiency mean that on average, conventional passenger cars sold in 2030 would consume 30 percent less energy than they did in 2019, and new trucks would consume 20 percent less fuel. By 2030, electric cars would account for over 60 percent of car sales (up from 4.6 percent in 2020), and fuel cell or electric vehicles would account for 30 percent of heavy truck sales (up from less than 0.1 percent in 2020). Meanwhile, other modes of transportation common in developing countries would also see efficiency improvements. For example, electric two/three-wheelers would see sales growth from 17 percent of the total today to 77 percent by 2030 under the Net Zero Emissions by 2050 Scenario in emerging economies. Under the Net Zero Emissions by 2050 Scenario, by 2030, over 80 percent of household appliances and air conditioners sold in advanced economies will feature the most efficient technologies available as of 2025 limiting electricity demand from the building sector. Emerging markets and

developing economies will reach this 80 percent level by the mid-2030s. In industry, industrial facilities will become more efficient due to the deployment of improved electric motors, heat pumps, and agricultural irrigation pumps, and the wider implementation of energy management systems.

IEA's Net Zero Emissions by 2050 Scenario also requires ramping up energy efficiency programs to incentivize efficiency-focused construction of new buildings and retrofits. These programs would also help manufacturers accelerate upgrades to production lines so as to produce more efficient equipment. Efficiency improvements across all end uses in the buildings sector, as well as the achievement of universal access to clean cooking, would cause a decline in the total energy demand by almost a quarter in residential buildings between 2020 and 2030, despite a 25 percent increase in the provision of energy services due to population and economic growth. In the existing buildings stock, deep energy retrofits can reduce energy use by more than 60 percent. Approximately 30 percent of the global building stock that will exist in 2030 is yet to be built. In some countries, including India, the figure is over 50 percent. However, nearly three-quarters of countries do not have mandatory energy codes for new buildings. Under the Net Zero Emissions by 2050 Scenario, all countries would introduce mandatory energy-related building codes, and existing codes would become more rigorous. This will reduce the average energy intensity of new buildings by nearly 50 percent over 2020-30.

Under IRENA's 1.5°C Scenario, energy intensity would need improve at an average annual rate of over 3 percent per year in 2020-30. To realize this, investments in improving energy efficiency need to increase by a factor of 9. A key step in this regard is the deployment of energy efficiency measures that improve technical efficiency (e.g., more efficient boilers, air conditioners, motors, heat pump systems, and appliances), as well as the deployment of technologies that promote end uses that consume renewables directly (e.g., solar thermal). In the buildings sector, all new construction would need to be designed to achieve zero-energy consumption standards from 2030 onward. For existing buildings, the rate of renovation would need to double, to 2 percent of the buildings stock a year, through 2030.

## **Investments Needed to Achieve SDG 7**

Annual clean energy investments to reach SDG 7, which include renewable power, renewable fuels, efficiency, enduse electrification, and grids and networks, increased by 15 percent in 2021 as compared with the 2015-20 average. It reached almost USD 1.2 trillion. These investments were key to step up progress in renewables and energy efficiency, and partial offset the increased use of coal and oil. Without the record advancement in clean energy in 2021-22, emissions could have grown three times.

Annual clean energy investments averaged about USD 1 trillion between 2015 and 2020, although outlooks from both IEA and IRENA emphasize the urgency of scaling up investments in the energy transition. Under IEA's Net Zero Emissions by 2050 Scenario, clean energy investments as defined above must average at USD 2.3 trillion a year and reach USD 4 trillion between 2021 and 2030 to achieve the SDG 7 targets (figure 6.8), while clean energy investments under the Stated Policy Scenario would average at USD 1.4 trillion between 2022 and 2030.

The majority of the investment to meet SDG 7 under the Net Zero Emissions by 2050 Scenario would be directed toward the generation of renewable electricity (including storage) and end-use efficiency, which account for USD 948 billion and USD 590 billion a year, respectively. Renewables-based power investment needs to be supported by an additional average annual spending of USD 500 billion on the expansion and modernization of electricity networks.

Under IEA's Net Zero Emissions by 2050 Scenario, average annual investment of approximately USD 30 billion and USD 6 billion, respectively, would be required from 2021 to 2030 to achieve full energy access and clean cooking access in developing economies. More than half of this investment would have to be in Sub-Saharan Africa (IEA 2022[a]), although Developing Asia would see the bulk of investment in clean cooking access. These investments for access represent only 10 percent of the annual spending of the upstream oil and gas sector; they are within reach of the international community.

The financial resources available for advancing electricity and clean cooking access have been inadequate to achieve full access. In 2019, investments in electricity access represented only a third of the required levels and were focused on a few countries (IEA 2022[a]). Even more concerning were investments in access to clean cooking in the same year, which represented only a fraction of the required levels (in Africa, they would need to increase 15 times the current levels (IEA 2022[b])). International support through development aid and multilateral development banks will be essential to mobilize, and boost, access- and other energy-related investments and derisk them for private and local actors in emerging markets and developing economies.





Source: IEA 2022[a].

NZE = Net Zero Emissions by 2050 Scenario; STEPS = Stated Policies Scenario.

Under IRENA's 1.5°C Scenario, annual investment in renewables, efficiency, related electricity infrastructure/grids and flexibility measures, and hydrogen and biofuel supply would amount to USD 4.7 trillion (USD2015) a year through 2030 (figure 6.9).

In the power sector, increasing renewables generation capacity would require investment of USD 1.1 trillion a year. Additional investments of USD 0.6 trillion a year would also be required for related infrastructure, including grid extension and grid flexibility measures. The measures would range from better forecasting of renewable power generation to integrated demand-side flexibility and stationary battery storage, among others.

Substantial investment would also be required outside the power sector. The buildings sector would require significant energy efficiency investments (amounting to USD 1.6 trillion a year), aside from large investments (amounting to USD 0.15 trillion per year) in heat pumps. Energy efficiency will receive a considerable share of investments in the buildings sector. Meanwhile, energy efficiency investments in transport and industry would need to increase to USD 0.7 trillion per year, and investments in direct uses of renewables (solar thermal, geothermal, etc.) and fuels (bioenergy and others) across all sectors would need to increase to USD 0.29 trillion per year. Investments in electrolyzers, hydrogen supply infrastructure, and renewables-based hydrogen feedstocks would average USD 0.17 trillion a year. These sectors would need to see average annual investments of over USD 3 trillion per year.

Figure 6.9 • Average annual investments by technology and measures required between 2021 and 2030 under IRENA's 1.5°C Scenario



<b>End uses and district heat</b>		Annua	average in	vestments	(USD bil	lion/yr)			
Renewables end uses and	Biofuels - supply	2	124						x51.5
district heat	Renewables direct uses and district heat	3	1 161	I					x5.3
Energy efficiency	Buildings		139				>	155	6 x 11.2
	Industry	45					549		x12.1
	Transport	65	155						x2.4
Electrification	Charging infrastructure	2	6						x43.2
	Heat pumps	12	154						x12.8
Innovation	Hydrogen - electrolysers and infrastructure Hydrogen-based ammonia and methanol Bio-based ammonia Bio-based methanol	8 45 22 12	8						
Carbon removals, capture and storage	CO <sub>2</sub> removals, capture and storage (CCS, BECCS)	41							
Circular economy	Recycling and bio-based products	25							
<ul> <li>Historical, pre-Covid investments, 2017-19</li> <li>1.5°C Scenario investments, 2021-30</li> <li>x 10.2 Scaling factor comparing growth for the 2017-19 period with the 2021-30 level</li> </ul>		0 100 200 300 Total - end uses and DH 2017-19 2996 USD billion/ year				400 500 600 Total - end uses and DH 2021-30 3018 USD billion/ year			

#### Source: IRENA 2022.

BECCS = bioenergy coupled with carbon capture and storage; CCS = carbon capture and storage; CO2 = carbon dioxide; CSP = concentrated solar power; DH = district heating; PV = photovoltaic.

Beyond investments in technology, policy makers also need to invest in implementing the required policy and regulatory framework to enable the energy transition. Beyond deployment policies, policies supporting the integration of energy transition-related technologies into the energy system are needed along with supporting policies for a conducive environment for the energy transition. Importantly, wider policies are needed to address structural challenges to realize the benefits of the energy transition, including the opportunity to create new jobs (box 6.3).

#### Box 6.3 • Linkages between SDG 7 and SDG 8: A focus on jobs

Achievement of SDG 7 is closely linked to the employment-related targets under SDG 8, which promotes full and productive employment and decent work for all. Between 2012 and 2021, jobs in the renewable energy sector increased from 7.3 million to 12.7 million (IRENA 2014; IRENA and ILO 2022). The energy transition will create millions of jobs, although accelerating the transition at the scale and speed to achieve climate goals and development objectives depends on creating a skilled workforce that taps a diverse pool of talents. IRENA estimates that jobs in the overall energy sector could increase to 139 million by 2030 following an ambitious pathway suitable for limiting temperature increases to 1.5°C. This is 31 percent more than the estimated jobs under current plans and commitments in the energy sector by 2030. The number of jobs in the renewable energy sector would increase from 12.7 million today to 38.2 million in 2030, more than double the projected 17.4 million jobs under current plans. Additionally, a projected 74 million jobs would be created in energy efficiency, electric vehicles, power systems/flexibility, and hydrogen (IRENA 2022).

However, the impact of the energy transition on the labor market would be manifold: it would lead to not only job creation but also outright job loss, apart from relocation and transformation. Misalignments would likely occur across different dimensions: job losses could exceed job gains at any given time (temporal). Further, there could be uneven job gains geographically, with more job creation in one country and more job losses in another (space). Also, the current skills of the labor force could be inadequate to meet the needs of the energy transition (educational). Further, changes in value and supply chains could affect sectors (sectoral).

How well a country responds to these structural changes will depend on a variety of factors, for example, its economic structure, demographics, skill base, and chosen policies, among others. Countries can design social and labor market responses informed by earlier national employment assessments to prepare for the transition's job impacts. Policy makers should develop an overarching just transition framework designed to restructure the economy and labor market and to complement their strategies for climate action. These frameworks must be based on national development objectives, specifically, maximizing employment and income opportunities while minimizing socioeconomic disruptions to the extent possible (IRENA and ILO 2022).

Efforts need to focus as much on the quality of jobs as on their quantity. Decent jobs are those that give fair compensation and have safe workplaces, where rights are respected. This entails adopting and implementing international labor standards, institutionalizing labor rights, and creating conditions that allow for unionization and collective bargaining arrangements within industries to ensure fair labor practices (ILO 2023).

Similarly, ensuring equal rights and adequate opportunities for women, youth, minorities, and marginalized groups is critical. Doing so contributes to SDG 5 on gender equality and SDG 10 on reducing inequality. Policies are needed to overcome barriers to entering the workforce, as well as to job retention and career advancement. Furthermore, industries must create supportive networks and systems to train and mentor women, youth, and minorities, to further develop their skills and participation.

Finally, important questions concern the geographies in which jobs will be created. Currently, China, Brazil, India, the United States, and members of the European Union lead in equipment manufacturing, project engineering, and installations. The bulk of renewable energy employment is in Asian countries, which accounted for 63.6 percent of jobs in 2021 (IRENA and others 2022). Especially in traditionally disadvantaged regions, local industrial capacity needs to be leveraged to enjoy the socioeconomic benefits of the energy transition. The renewables industry needs to support local value chains to stimulate local economies. Farsighted industrial policies can enable sustainable socioeconomic development in the long run. These may involve education and training programs for employees in specific sectors, supplier development programs, business incubation initiatives, incentives for small and medium enterprises, and the promotion of industrial clusters. Such policies can also contribute to creating the structural underpinnings for robust supply chains through infrastructure investments, an increase in local firms' access to finance and information, and an improvement in capacities across the value chain and, ultimately, the realization of SDG 7 and SDG 8 (IRENA and ILO 2022).

# Conclusion

The energy sector continues to receive support through innovative policies and technologies, but the COVID-19 pandemic and the current energy crisis set progress back in ways that were not foreseen in 2019. Not only are current and planned policies not aligned to achieve SDG 7, but progress toward some targets has also been even slower than before.

For the first time in decades, the number of people without electricity access globally might have grown in 2022. At the same time, there has been a considerably higher perceived risk of lending money to a number of developing countries, making it more expensive for them to raise debt finance for energy technologies and improve energy access.

Meanwhile, the outlook looks more positive for renewables and efficiency. Low oil and gas prices were originally projected to be a barrier to the uptake of clean energy technologies and energy efficiency under IEA's Stated Policies Scenario. However, rising prices in 2022 and renewables- and efficiency-focused recovery plans in key economies made the outlook for renewables and efficiency stronger than it was a year ago. Recent price spikes and the crisis in Ukraine have also increased uncertainty in global oil and gas markets, putting renewed pressure on net importers to reduce exposure. Renewables, efficiency, and electrification are likely to play major roles in the policy responses to these events. These responses need to be substantial and reach beyond advanced economies if the world is to achieve the energy-related SDGs.

Continued efforts are also required to double the global annual energy intensity improvement rate to an average of 3.4 percent if the world is to achieve SDG target 7.3. The ongoing slump in economic activity and lingering economic uncertainty are likely to result in slower turnover of capital stock, but the inclusion of provisions for efficiency in some countries' economic recovery packages partially offsets that effect. Solar PV and wind remain the fastest-growing sources of energy globally. More policy support for renewable integration, electrification, and decarbonization will be needed to align with the Net Zero Emissions by 2050 and 1.5°C scenarios.

Getting on track to meet SDG 7 depends partly on how governments continue to support clean energy and energyaccess investments. In advanced economies, initial support from recovery plans needs to evolve to more nuanced support that relies less on direct cash injections and more on derisking and guarantees to continue advancing these objectives. More pressingly, significant investments are needed in the energy transition in emerging markets and developing economies, especially in light of diminishing fiscal leeway. International support will be essential to not only directly mobilize investments but also catalyze higher private capital participation by derisking clean energy projects.

As policy makers chart the path ahead, it is worth bearing in mind that an energy transition ambitious enough to achieve SDG 7 can also help meet other social and economic objectives. With holistic policies in place, the energy transition can foster sustainable economic growth, create jobs, and improve welfare as emphasized throughout this report.

# **Methodological Notes**

All investment figures from IEA scenarios are in constant 2021 USD at market exchange rate. Investment figures from IRENA scenarios are in constant 2015 USD at market exchange rate.

### **IEA METHODOLOGY**

The analysis presented in this chapter is based on results from the World Energy Model (WEM) and IEA's analysis in the World Energy Outlook (WEO). Detailed documentation of the WEM methodology can be found at https://www.iea.org/reports/world-energy-model/documentation#abstract.

IEA models two scenarios. The Stated Policies Scenario is designed to provide decision-makers with feedback about their current course based on the stated policy ambitions. This scenario assumes that the COVID-19 pandemic was brought under control in 2021. It incorporates IEA's assessment of stated policy ambitions, including the energy components of announced stimulus or recovery packages (as of mid-2020) and the Nationally Determined Contributions under the Paris Agreement. Broad energy and environmental objectives (including country net-zero targets) are not automatically assumed to be met. They are implemented in this scenario to the extent that they are supported by specific policies, funding, and measures. The Stated Policies Scenario also reflects progress with the implementation of corporate sustainability commitments.

The Net Zero Emissions by 2050 Scenario is a normative IEA scenario that shows a narrow but achievable pathway for the global energy sector to achieve net-zero CO2 emissions by 2050, with advanced economies reaching net-zero emissions in advance of others. This scenario also achieves the key energy-related SDGs, achieving universal energy access by 2030 and major improvements in air quality. The scenario is consistent with limiting the global temperature rise to 1.5°C without a temperature overshoot (with a 50 percent probability), in line with reductions assessed by the Intergovernmental Panel on Climate Change in its Special Report on Global Warming of 1.5°C. This scenario is based on the following assumptions:

- Uptake of all available technologies and emissions reduction options is dictated by cost, technology maturity, policy preferences, and market and country conditions.
- All countries cooperate toward achieving net-zero emissions worldwide.
- An orderly transition occurs across the energy sector. It ensures the security of fuel and electricity supply at all times, minimizes stranded assets where possible, and avoids volatility in energy markets.

## **METHODOLOGY FOR ACCESS TO ELECTRICITY AND CLEAN COOKING**

The projections presented in the WEO and in this chapter focus on two elements of energy access, households' access to electricity and clean cooking facilities, which are measured separately. IEA maintains databases on the levels of national, urban, and rural electrification rates. For the proportion of the population without access to clean cooking, the main sources are the World Health Organization's Household Energy Database and IEA's Energy Balances. Both databases are regularly updated and form the baseline for WEO energy-access scenarios to 2040.

The projections under the Stated Policies Scenario consider current and planned policies; recent progress; and population growth, economic growth, urbanization rate, and the availability and prices of different fuels. The Net Zero Emissions by 2050 Scenario identifies least-cost technologies and fuels to reach universal access to both electricity and clean cooking facilities. For electricity access, the analysis incorporates a Geographic Information Systems model based on open-access geospatial data, with technology, energy prices, electricity-access rates, and demand projections from the WEM. This analysis was developed in collaboration with the KTH Royal Institute of Technology, Division of Energy Systems Analysis (KTH-dESA), in Stockholm. Further details about the IEA methodology for energy-access projections can be found at https://www.iea.org/articles/defining-energy-access-2020-methodology.

## **METHODOLOGY FOR RENEWABLE ENERGY PROJECTIONS**

Annual updates to WEO projections reflect the broadening and strengthening of policies over time, including renewables policies. Projections for renewable electricity generation are derived in the renewables submodule of the WEM, which projects the future deployment of renewable sources for electricity generation and the required investment. The deployment of renewables is based on an assessment of the potential of each source and its cost (bioenergy, hydropower, photovoltaic, concentrated solar power, geothermal electricity, wind, and marine) in each of the 25 WEM regions. In all scenarios, IEA modeling incorporates a process of learning by doing that affects costs. The model calculates deployment and the consequent yearly investment required for each renewable source in each region by including financial incentives for using the renewables, as well as nonfinancial barriers in each market; technical and social constraints; and the value added to systems by each technology in terms of energy, capacity, and flexibility.

### **METHODOLOGY FOR ENERGY EFFICIENCY PROJECTIONS**

Energy intensity calculated as Total Energy Supply [TES] divided by GDP, is the key indicator for energy efficiency. Assumptions for short- to medium-term economic growth are largely based on estimates prepared by the Organisation for Economic Co-operation and Development, International Monetary Fund, and World Bank. Over the long term, growth in each WEM region is assumed to converge to an annual long-term rate, which depends on demographic and productivity trends, macroeconomic conditions, and the pace of technological change.

TES growth is based on the growth of Total final energy demand, which is calculated as the sum of energy consumption for each end use in each final demand sector. At least six types of energy are shown in each subsector or end use: coal, oil, gas, electricity, heat, and renewables. The main oil products, LPG, naphtha, gasoline, kerosene, diesel, heavy fuel oil, and ethane, are modeled separately for each final demand sector.

In the majority of equations, energy demand is a function of activity variables that are driven by the following factors:

- Socioeconomic variables: GDP and population are important drivers of sectoral activity variables that determine energy demand for each end use within each sector.
- *Prices for end users:* Historical time series data for coal, oil, gas, electricity, heat, and biomass prices within each sector are compiled based on IEA's Energy Prices and Taxes database and several external sources. Prices for end users are then used as explanatory variables affecting the demand for energy services.
- Technological parameters include recycling in industry and material efficiency.

All 25 WEM regions for energy demand are modeled in considerable sectoral and end-use detail:

- Industry is separated into six subsectors (with the chemicals sector disaggregated into six subcategories).
- Buildings energy demand is segregated into demand of residential and services buildings, which are then separated into six end uses. Within the residential sector, appliances' energy demand is segregated into four types of appliances.
- Transport demand is segregated into nine modes, with considerable detail for road transport.

## **IRENA METHODOLOGY**

### **IRENA** scenarios

IRENA's scenarios outlined in this report were developed by the Renewable Energy Roadmaps (REmap) team at IRENA's Innovation and Technology Centre, in Bonn. Since 2014, this team has produced a succession of road maps with ambitious pathways for deploying low-carbon technologies to create a clean, sustainable energy future at the global, regional, and country levels.

The findings in this report are based on IRENA's 2022 flagship publication World Energy Transitions Outlook: 1.5°C Pathway. The Planned Energy Scenario provides a perspective on energy system developments based on governments' energy plans and other planned targets and policies that were in place as of early 2022. The 1.5°C Scenario describes an energy transition pathway aligned with the ambition of limiting the average end-of-century global temperature increase to 1.5°C relative to preindustrial levels. For more information on the scenarios, methodology, and scope of this work, please visit www.irena.org/remap.

### **IRENA** socioeconomic modeling

IRENA has been analyzing the socioeconomic implications of transition road maps since 2016. Its methodology uses a global econometric model with high regional and sectoral resolution (E3ME, from Cambridge Econometrics) to holistically capture multiple interactions between energy transition road maps with its accompanying policy baskets and global and national economic systems.

The resulting socioeconomic footprint is evaluated at a high level of detail, generating insights that inform policy making for a successful transition. Socioeconomic footprint results include GDP (aggregated economic activity), employment (economy wide and with high resolution within the energy sector), and welfare (using an index with five dimensions, economic, social, environmental, distributional, and access, each informed by two indicators).

A detailed drivers' methodology is used to facilitate understanding of the mechanisms producing the socioeconomic footprint results. Clearer insights on the links between transition goals and policies and their resulting impacts are provided.

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