Energy Efficiency

2021

INTERNATIONAL ENERGY AGENCY

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Abstract

Energy Efficiency 2021 is the IEA's annual update on global developments in energy efficiency. This year's edition explores recent trends in energy efficiency markets at the economy-wide and sectoral levels, including developments in policy and investment.

The report also focuses on the role of energy efficiency in achieving net zero emissions in the energy sector by 2050, including an examination of the crucial role of efficient appliances and equipment, as well as all major energy efficiency net zero milestones in buildings, transport and industry.

In addition, the report analyses recent trends in digital innovation, examining how digitalisation is expanding the scale and scope of energy efficiency markets and how business models are evolving to take advantage of these opportunities.

Acknowledgements, contributors and credits

This publication has been prepared by the Energy Efficiency Division (EEfD) of the International Energy Agency (IEA). The analysis was led and co-ordinated by Nicholas Howarth. The main contributors were Ahmad Al Mugharbil, Minnie Ashdown, Emi Bertoli, Ramit Debnath, Ian Hamilton, Pauline Henriot, Doyob Kim, Kevin Lane, Jihyun Lee, Jack Miller, Yannick Monschauer, Michael Oppermann, Aleksandra Paciorek, Alison Pridmore, Brendan Reidenbach, Vida Rozite, Hugo Salamanca, Mel Slade, Monica Troilo, and Fabian Voswinkel.

Keisuke Sadamori, Director of the IEA Energy Markets and Security (EMS) Directorate and Brian Motherway, Head of the Energy Efficiency Division, provided strategic guidance and input to this work. Valuable comments, feedback and guidance were provided by other senior management within the IEA, in particular, Laura Cozzi, Mechthild Worsdorfer, and Timur Guel.

Other IEA colleagues provided important contributions, including: Thibaut Abergel, Blandine Barreau, Simon Bennett, Sylvia Beyer, Stéphanie Brouckaert, Olivia Chen, Joel Couse, Daniel Crow, Tanguy De Bienassis, Chiara Delmastro, Araceli Fernandez Pales, Peter Fraser, Timothy Goodson, Craig Hart, Shai Hassid, Alejandro Cesar Hernandez, Jean-Baptiste Le Marois, Peter Levi, Rüdiger Lohse, Apostolos Petropouls, Roberta Quadrelli, Gabriel Saive, Disha Sharma, Jacopo Tattini, Jacob Teter, Peerapat Vithayasrichareon, Michael Waldron, and Daniel Wetzel.

Mitsidi Projetos provided helpful research and statistical support and Lushomo provided valuable support with visualisations.

The IEA Communication and Digital Office provided production and launch support. Particular thanks to Jad Mouawad and his team: Astrid Dumond, Tanya Dyhin, Jethro Mullen, Isabelle Nonain-Semelin, Julie Puech, Rob Stone, Gregory Viscusi and Therese Walsh. Andrew Johnston edited the report.

The report was made possible by assistance from the Ministry of Economy, Trade and Industry, Japan.

The IEA would like to thank the following experts who reviewed the report and provided valuable contributions:

Alex Ablaza (Asia-Pacific ESCO Industry Alliance), Heidelinde Adensam (Austrian Energy Agency), Marlene Arens (Heidelberg Cement), Christian Artelt (Heidelberg Cement), Peter Bach (Danish Energy Agency), Ronita Bardhan (University of Cambridge), Herberto Barrios Castillo (Ministry of Energy of Mexico), Kemal Bayraktar (International Solar Energy Society), Steven Beletich (4E TCP EDNA), Carmen Best (Recurve), Mar Blazquez Gomez (Ministry for the Ecological Transition and the Demographic Challenge, Spain), Jeferson Borghetti Soares (Energy Research Office, Brazil), Martin Bornholdt (DENEFF), Odon de Buen Rodriguez (Ministry of Energy of Mexico), Victoria Charmet (Natural Resources Canada), Chiara Dalla Chiesa (Enel X), Shubhashis Day (Shakti Sustainable Energy Foundation), Robert Deegan, (Department of the Environment, Climate and Communications, Ireland), Pierre Delforge (Natural Resources Canada), Katherine Delves (Natural Resources Canada), Thomas Deuts (Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, Austria), Shivraj Dhaka (Confederation of Indian Industry), Michael Donn (Victoria University of Wellington), Lesley Dowling (Department of Industry, Science, Energy and Resources, Australia), Bilal Düzgün (Ministry of Energy and Natural Resources), Lynette Dray (University College London), Chae-Eun Hwang (Ministry of Trade Energy and Industry Korea), Christine Egan (CLASP), Mark Ellis (Mark Ellis & Associates), Steven Fawkes (EnergyPro), Alessandro Federici (Italian National Agency for New Technologies, Energy and Sustainable Economic Development), Alessandro Fiorini (Italian National Agency for New Technologies, Energy and Sustainable Economic Development), Brian Fitzgerald (Energy Efficiency and Conservation Authority, New Zealand), S.P. Garnaik (Energy Efficiency Services Limited), Jessica Glicker (Buildings Performance Institute Europe), Matt Golden (Recurve), Shuli Goodman, (LFenergy), Sune Grollov (Velux), Lukas Gutzwiller (Swiss Federal Office of Energy), Takashi Hongo (Mitsui & Co. Global Strategic Studies Institute), Humin Hu (Climateworks Foundation), Jamie Hulan (Natural Resources Canada), Gerben Hieminga (ING Nederlands), Rod Jansen (Energy in Demand), Nigel Jollands (EBRD), Devi Laksmi Zafilus (Ministry of Energy and Mineral Resources, Indonesia), Skip Laitner (Association for Environmental Studies and Sciences), Francisco Laverón Simavilla (Iberdrola), Rob Murray-Leach (Energy Efficiency Council), Benoit Lebot (French Ministry for the Ecological and Inclusive Transition), Amory Lovins (Precourt Institute for Energy, Stanford University), Zheng Ma (SDU Health Informatics and Technology), Catherine Marchand (Natural Resources Canada), Eric Masanet (UC Santa Barbara), Tom Mathiasson (Norwegian Ministry of Petroleum and Energy), Sangeeta Mathew (AEEE), Alan Meier (LBNL), Vincent Minier (Schneider Electric), Steve Nadel (American Council for an Energy-Efficient Economy), Stephen Pantano (CLASP), Alan Pears (RMIT University), Ralf

Preussner (KfW), Oliver Rapf (Buildings Performance Institute Europe), Marc Ringel (Nuertingen Geislingen University of Applied Sciences), Chandana Sasidharan (AEEE), Ashok Sakar (World Bank), Hans-Paul Siderius (Netherlands Enterprise Agency), Koichi Sasaki (Institute of Energy Economics, Japan), Sanjay Seth (TERI), Jeremy Sung (Department of Environment, Land, Water and Planning, Victoria), Peter Sweatman (Climate Strategy & Partners), Deepak Tewari (AEEE), Harry Verhaar (Signify), and Matthias Zilbauer (KfW).

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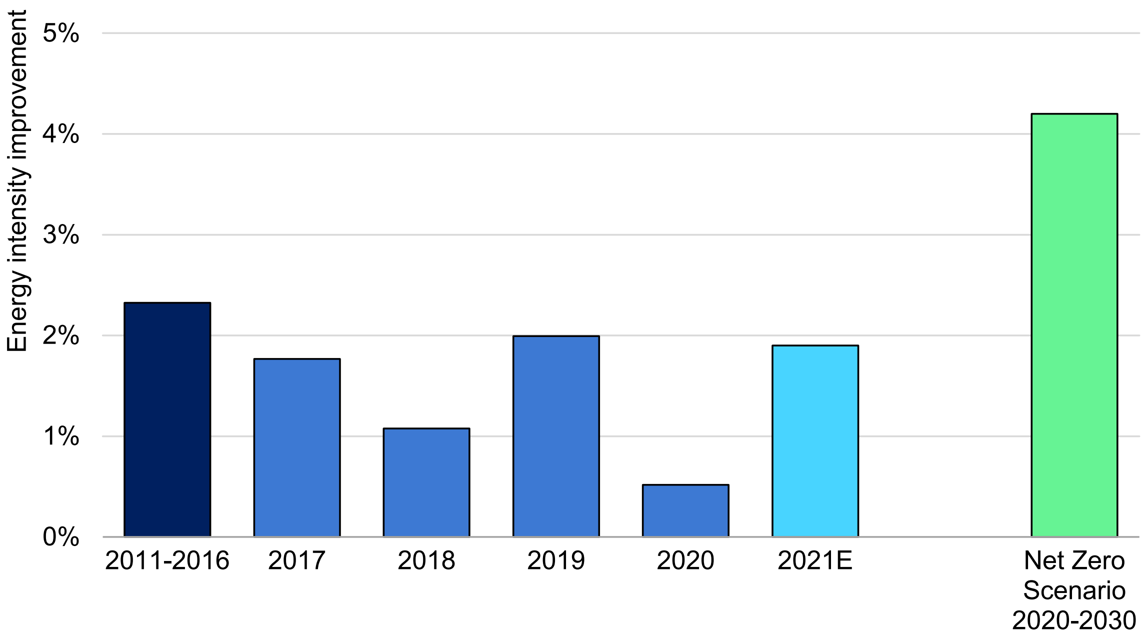
Executive summary

Energy efficiency progress recovers in 2021 but needs to double for net zero by 2050

Energy efficiency trends are expected to return to their ten year average after the worst year in a decade. However, the rate of improvement needs to double from current levels to match the gain outlined in the IEA Net Zero Emissions by 2050 Scenario. In 2021, global energy intensity – a key measure of the economy's energy efficiency – is expected to improve (that is, to fall) by 1.9% after improving by only 0.5% in 2020.

Over the past five years, energy intensity has improved on average by 1.3% a year, down from 2.3% between 2011 and 2016, and well below the 4% described in the Net Zero Emissions by 2050 Scenario over 2020-2030.

Primary energy intensity improvement, 2011-2021



Notes: 2011-2016 five-year average. 2021 estimate based on World Energy Outlook 2021. Net Zero Emissions Scenario = IEA Net Zero Emissions by 2050 Scenario, 2020-2030 intensity improvements, ten year average.

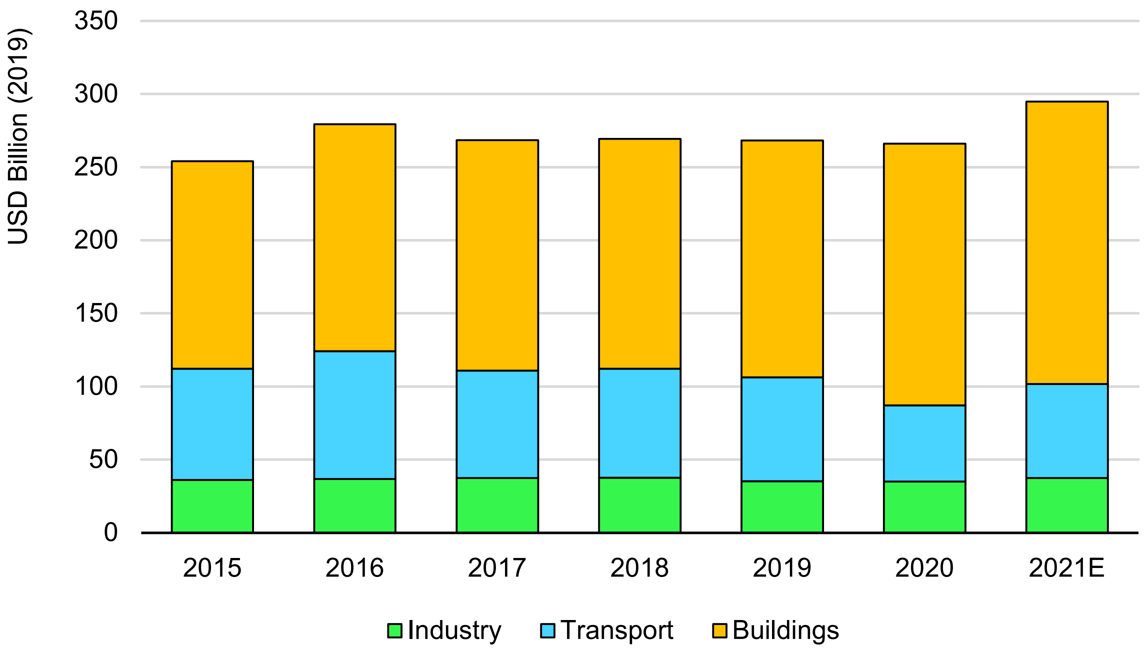
Global energy demand is expected to increase by about 4% in 2021, returning to pre-pandemic levels as economic activity rebounds. The previous year was one of the worst ever for efficiency improvement, as energy demand and prices fell, technical efficiency enhancements slowed and the balance of economic activity shifted away from less energy-intensive services, such as hospitality and tourism.

With disruptions due to Covid-19 shaping global energy and economic trends in 2020 and 2021, it is still unclear whether this year's improved energy intensity will signal the start of a sustained recovery. However, increased investment trends, rising government spending on efficiency - in large part related to recovery plans enacted in response to Covid-19 crisis, new announcements of higher climate ambition and other policy measures offer some encouraging signals.

Government policies have helped lift efficiency investment in the buildings sector

Government policies are expected to help energy efficiency investment rise by 10% in 2021 to almost USD 300 billion. However, to be consistent with levels foreseen in the IEA Net Zero Emissions by 2050 Scenario, overall annual investment would need to triple by 2030. Recent investment growth has been concentrated largely in Europe, suggesting polices are needed in other regions to achieve global climate goals.

Energy efficiency investment, 2015-2021



Note: An energy efficiency investment is defined as the incremental spending on new energy-efficient equipment or the full cost of refurbishments that reduce energy use.

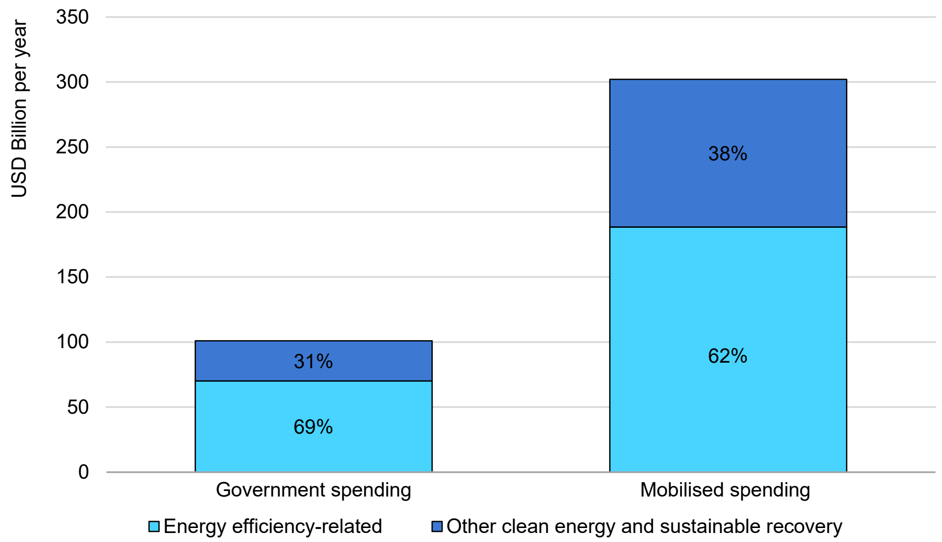
In 2020, stronger buildings efficiency programmes in Europe compensated for transport, where Covid-19 pushed down total spending. Transport efficiency investments are now recovering while buildings investments are reaching record highs.

Additional and stricter standards and regulations, higher public spending, incentive structures, and streamlined planning laws and procedures can all help lift investment and make efficiency projects more attractive to private finance. For example, the energy services market in the People's Republic of China (hereafter "China") increased its deployment of digital technologies and expanded by 12% in 2020, assisted by tax incentives.

Efficiency-related spending makes up two-thirds of government clean energy and sustainable recovery measures

Approved energy efficiency spending by governments is regionally unbalanced, with the majority of spending coming from advanced economies. There remains considerable potential for governments elsewhere to use recovery packages to boost spending, which would create jobs and promote economic growth.

Annual energy efficiency and clean energy sustainable economic recovery spending, 2021-2023



Notes: "Government spending" includes government measures highlighted in the IEA Sustainable Recovery Plan. "Mobilised spending" includes all other public and private spending on measures highlighted in the IEA Sustainable Recovery Plan mobilised by government spending. "Energy efficiency-related" includes spending on low-carbon and efficient transport and energy-efficient buildings and industry. "Other clean energy and sustainable recovery" includes low-carbon electricity, electricity networks and fuels, technology innovation and people centred transitions.

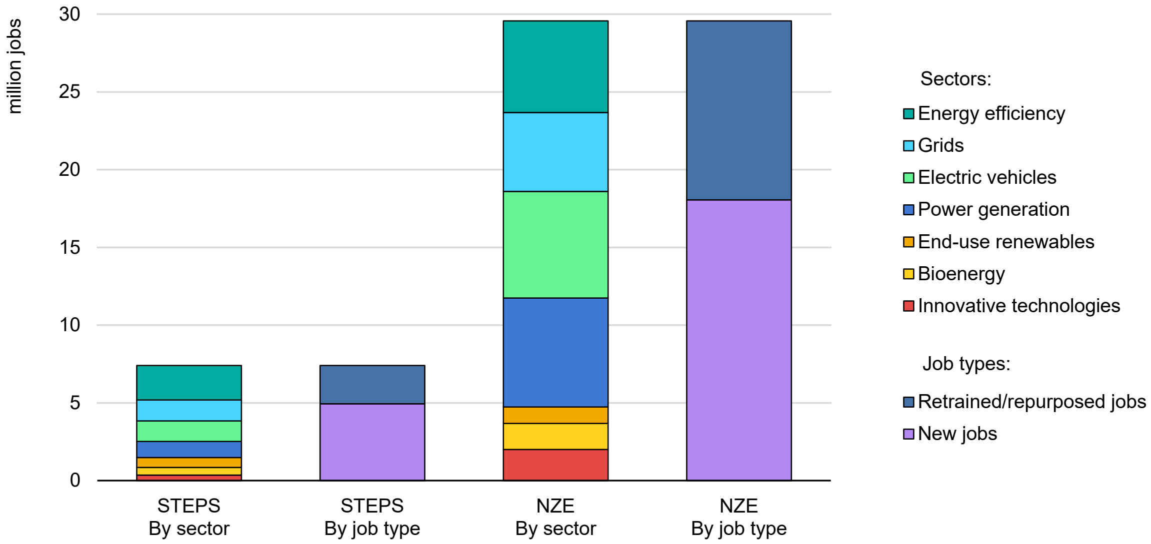
Source: IEA (2021), Sustainable Recovery Tracker.

Energy efficiency-related spending makes up around two-thirds of the total USD 400 billion a year mobilised by governments with their recovery measures over the next three years, as monitored by the Autumn 2021 update of the IEA Sustainable Recovery Tracker. This comprises both government spending and associated mobilised private and other public sector spending between 2021 and 2023. Measures that have been announced but yet to be confirmed of the end of October 2021, are not included and may lift efficiency spending even higher.

Enhanced investment can add four million more efficiency jobs by 2030

In the IEA Net Zero Emissions by 2050 Scenario, an early policy focus on energy efficiency would triple the number of jobs created by 2030 through increased spending on building retrofits, more efficient appliances and other measures. This includes many jobs in construction, as well as installation of heating, cooling and hot water systems. While many of these jobs match existing skill sets, governments can play a role by sponsoring training programmes to help provide wider access to opportunities and avoid skills shortages.

New workers in clean energy and related sectors and shares by sector and job type in the Net Zero Emissions by 2050 Scenario (NZE) and the Stated Policies Scenario (STEPS) in 2030



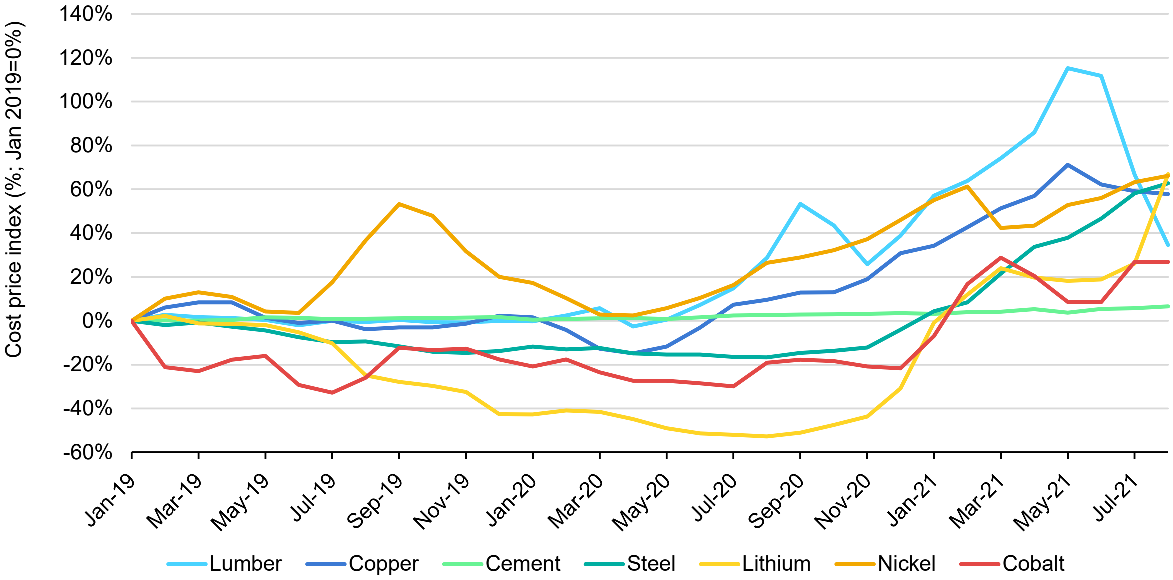
Source: IEA analysis based on IEA (2021), World Energy Outlook, 2021.

Supply chain pressures need to be watched closely

The economic recovery in 2021 has increased demand for commodities, putting pressure on supply chains, and creating shortages and bottlenecks for goods and services essential for energy efficiency investment. This has pushed up prices for everything from basic construction materials to semiconductors used in electronics and vehicles. It has also slowed down building completions in some countries due to lack of key supplies.

For example, in the second quarter of 2021 lumber prices in the United States were 120% higher than in January 2019, though have since cooled off. Steel prices in August 2021 were also more than 60% higher than in January 2019. In the United Kingdom, a survey of contractors indicated supply constraints for cement, electrical components, timber, steel and paints. Wages in the construction sector rose by up to 13% in the year to May 2021 in some markets, adding to project costs.

Price indices for key commodities linked to construction and efficient equipment, January 2019-August 2021

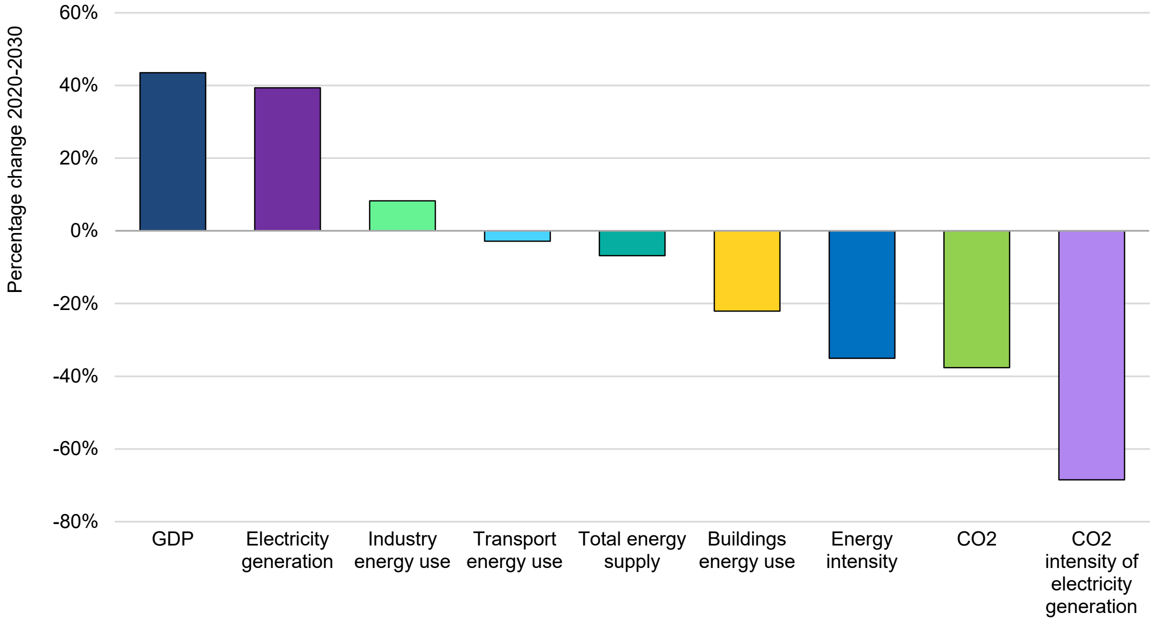


Sources: Cement, lumber, steel: Bureau of Labor Statistics (Data for the US market); copper, nickel, cobalt: IMF Primary Commodity Prices (Data for the global market); lithium: Bloomberg Lithium Carbonate 99% Min China (Data for the global market).

Energy efficiency offers some of the fastest and most cost-effective actions to reduce CO_2 emissions

In the Net Zero Emissions by 2050 Scenario, the energy intensity of the global economy improves (that is, falls) by 35% by 2030. This is driven by energy efficiency combined with related measures such as electrification and behavioural change. This enables growth in clean energy sources, such as wind and solar generation, to outpace overall demand for energy services. In this scenario, the global economy grows by 40% by 2030, driven by higher populations and income levels, but uses 7% less energy.

Macroeconomic and energy indicators in the IEA Net Zero Emissions by 2050 Scenario, 2020-2030



Notes: GDP = USD 2019 billion at purchasing power parity; electricity = electricity generation); Sectoral energy use = final energy consumption; CO_2 = energy-related CO_2 emissions; energy intensity = TES/GDP.
Source: IEA analysis based on IEA (2021), Net Zero by 2050 report.

Around 80% of the additional energy efficiency gains in the scenario over the next decade result in overall net cost savings to consumers, after accounting for both the initial cost of measures and lower operating costs. This helps lower energy bills and cushion the effects of price volatility. That is one reason why energy efficiency is front-loaded into the policy mix in the Net Zero Emissions by 2050 Scenario.

The electrification of transport, space and water heating and many industrial applications results in increased efficiency and lower emissions, but contributes to electricity generation rising by 40% by 2030 in the Net Zero Emissions by 2050 Scenario. Electric equipment is much more efficient than their equivalents powered directly by fossil fuels, with electric heat pumps, for example, being three to four times more efficient than burning fossil fuels for heat. Electricity can also be generated from renewable sources.

Behavioural change is also an important part of the scenario. These include adjusting temperatures for heating and cooling, switching transport modes, and increasing recycling.

The road to net zero involves over 40 energy efficiency milestones

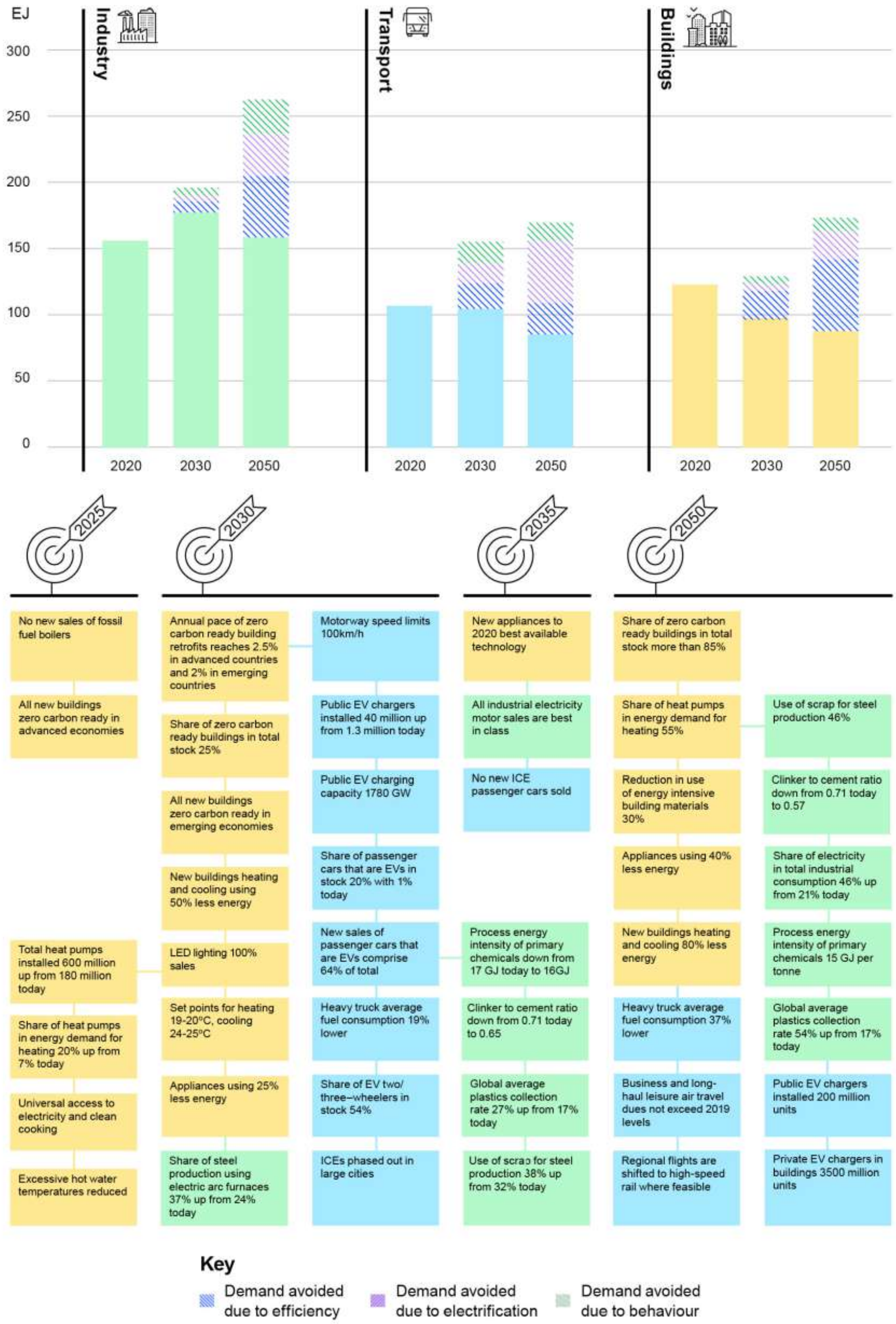
The Net Zero Emissions by 2050 Scenario involves more than 40 energy efficiency milestones without which total final energy consumption would be around 30% higher by 2030. Most of these incorporate technologically mature solutions that can be scaled up very quickly.

In the scenario, energy efficiency actions in the buildings sector deliver some of the greatest energy savings through to 2030. Increasing the share of existing buildings that are zero carbon ready from less than 1% today to around 20% by 2030 is a key milestone, as is moving to no new sales of coal and oil boilers globally from 2025. Sales of gas boilers are also banned by 2025, except where gas supply is set to be decarbonised and boilers capable of burning 100% hydrogen or another low-carbon gas are classed as zero carbon ready.

For transport, increasing fuel efficiency standards of all vehicle types is important as even in the Net Zero Emissions by 2050 Scenario, 80% of passenger cars on the road in 2030 are still powered with internal combustion engines. Sales of heavier, less efficient SUVs reached more than 40% of global sales in 2020, while electric vehicles were just 5%. More than 20 countries have recently announced plans to phase out sales of internal combustion engine vehicles, with 2035 set as the milestone for this in the scenario.

Only industrial energy consumption rises by 2030 in the Net Zero Emissions by 2050 Scenario, increasing by around 8%. Even so, substantial progress is made in material and energy efficiency to enable the global economy to produce 9% more steel, 21% more chemicals and 5% more cement per year by 2030.

Energy efficiency milestones in the Net Zero Emissions by 2050 Scenario, 2020-2050



Notes: EV = electric vehicle. ICE = internal combustion engine vehicle.
Source: IEA analysis based on IEA (2021), Net Zero by 2050 report.

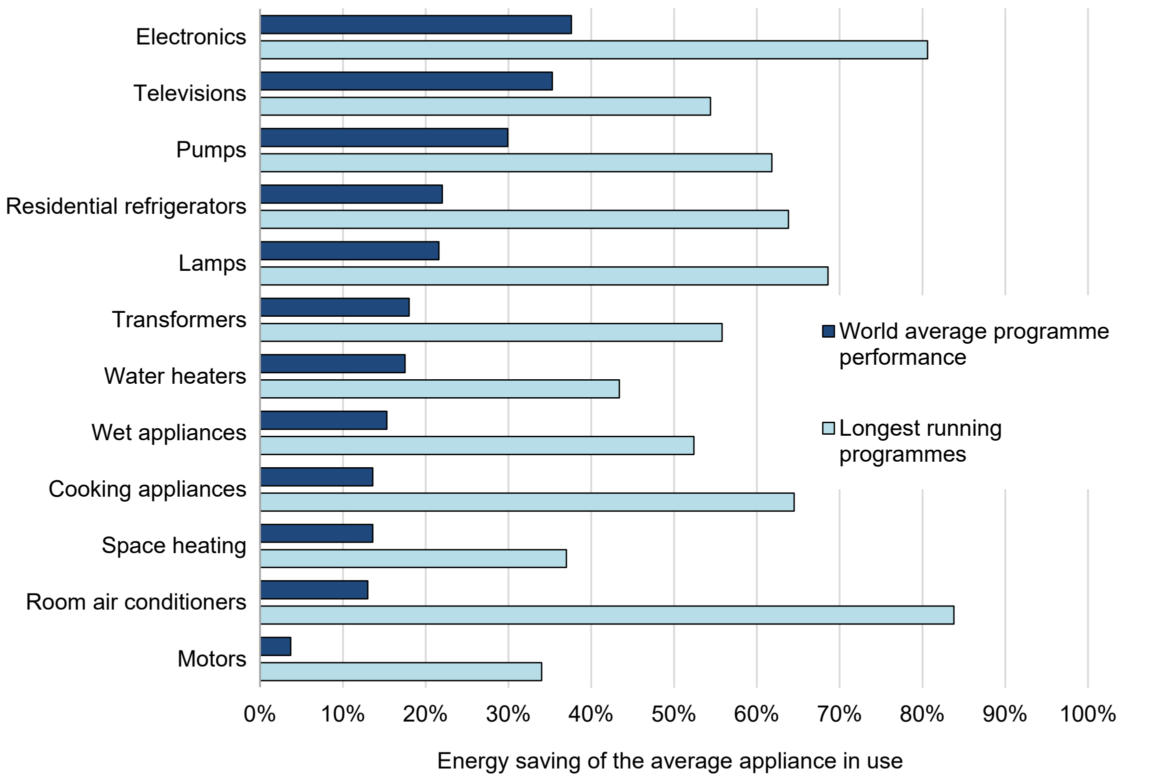
Standards have helped halve the energy consumption of key appliances in the longest-running programmes

Over 120 countries have implemented or are developing mandatory standards and labels for key appliances. Such appliance efficiency policies have helped more than halve the energy consumption of major appliances in countries with the longest-running programmes. This includes air conditioners, refrigerators, lighting, televisions, washing machines and cooking appliances.

These huge gains have been achieved even as the purchase price of such appliances fell by an average of 2-3% per year. Thus consumers have benefited from both lower appliance purchase costs and lower operating costs.

However, reaching these results takes time, because once new standards are put in place it can be many years before the existing inefficient stock is replaced. This highlights the role of incentives and replacement programmes to remove old, less efficient equipment from use faster, especially in countries with less mature programmes.

Energy savings from energy efficiency standards and labels over life of programmes



Notes: Longer-running programmes (more than 20 years) with stronger standards deliver more savings as there is more time for inefficient appliances and equipment to be replaced and for programmes to significantly lower the average stock energy consumption of that appliance class. Electronic devices include: external power supply units, monitors, DVD/VCR units and other personal electronics.

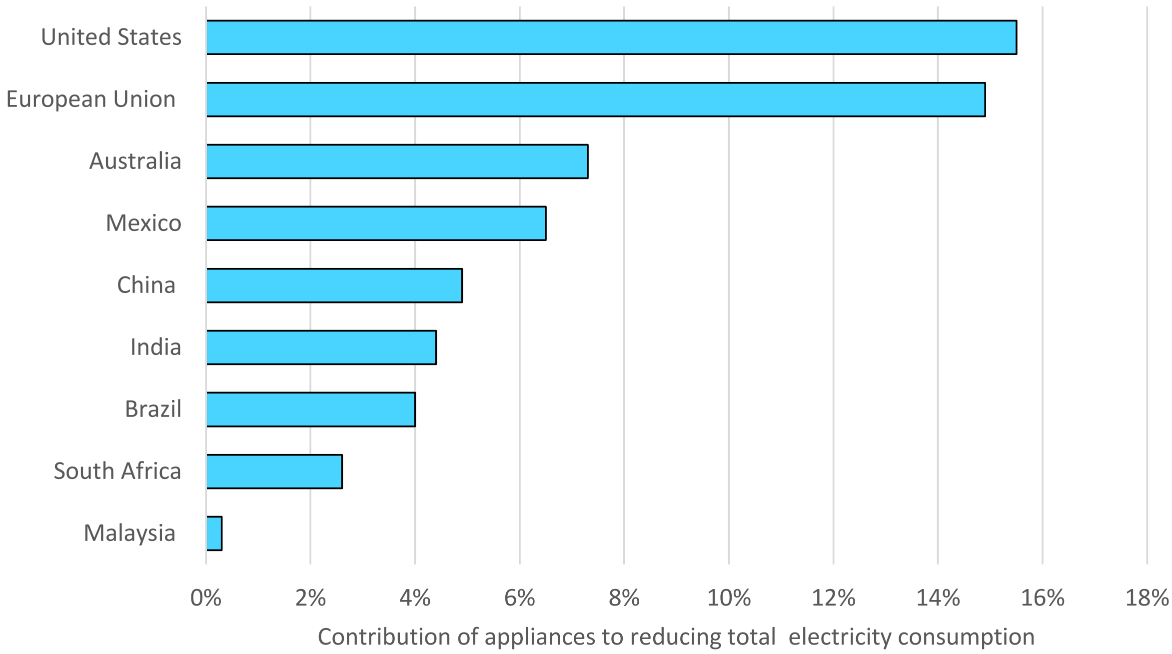
Source: IEA and 4E TCP, based on reviews of over 400 published reports covering energy efficiency standard and label programmes in a wide range of countries.

Efficiency programmes have avoided consumption equal to total wind and solar power generation

An analysis of nine large countries and regions, including China, the European Union and the United States, shows that efficiency standards helped save about 1 500 TWh of electricity per year in 2018, equivalent to that year's total generation from wind and solar in those countries.

In the countries with the longest-running programmes the effect is so large that around 15% of total electricity generation is being saved through appliance programmes. If a similar 15% improvement had been achieved by all countries, electricity consumption could have been reduced by 3 500 TWh – roughly equivalent to cutting China's current electricity consumption in half.

Impact of energy efficiency standards and labelling programmes in selected countries, 2018



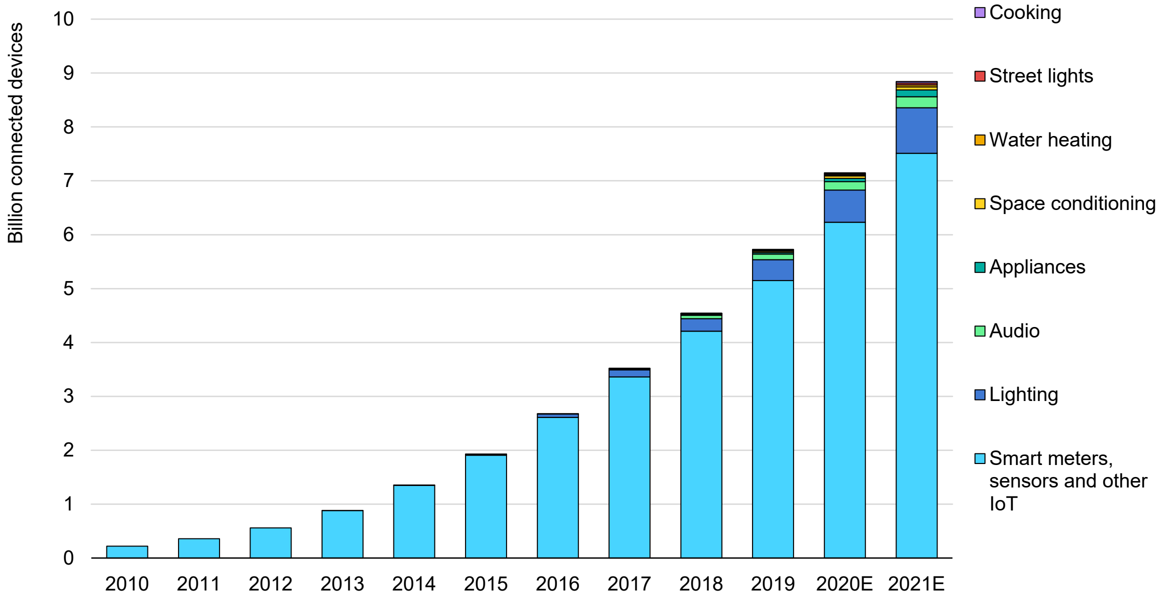
Notes: Electricity consumption savings are calculated relative to the commencement of programmes in those countries. Longer-running programmes yield higher energy savings as a greater proportion of appliances in use are covered.
Source: IEA and 4E TCP.

In November 2021, the IEA and the COP26 presidency launched the COP26 Product Efficiency Call to Action to double the efficiency of key appliances and help make it quicker, easier, and cheaper to raise climate ambition. G7 leaders had previously welcomed the Call to Action at the 2021 G7 Summit in Cornwall, focusing on lighting, refrigerators, air conditioners and industrial motor systems which together account for over 40% of global electricity demand and over 5 Gt of global CO_2 emissions a year. This is roughly equal to the United States' current total CO_2 emissions.

A new level of energy efficiency is being enabled through rapid digital technology deployment

In 2021, the stock of connected appliances, devices and sensors is expected to overtake the number of people on the planet. Over the last five years the stock of connected appliances, devices and sensors has grown by an average of around 33% per year and is expected to reach 9 billion in 2021. Most of these are measuring devices, such as sensors and smart meters, with other devices achieving market take-off more recently. For example, deployment of smart appliances is expected to double from 2020-2021 and the number of smart lighting devices is approaching 1 billion.

Stock of digitally enabled automation devices, 2010-2021



Note: 2020 and 2021 are estimates. IoT = Internet of things.
Source: IEA 4E EDNA Total Energy Model.

These trends are helping expand the benefits of energy efficiency through improved measurement and enhanced control to enable greater participation in demand response. In the Net Zero Emissions by 2050 Scenario, more than 500 GW of demand response is brought to market by 2030 to support grid stability and to match demand to times when renewable sources is at its highest.

Examples include, efficient hot water systems, smart charging of electric vehicles and other equipment incorporated into connected building energy systems. Building energy management systems have been shown to be able to deliver energy savings of 20% to 30%, arising from installing appliances that are more efficient and offer enhanced monitoring and control of energy use.

Technology innovation is also prompting policy innovation in several jurisdictions. For example, in 2021 California's Public Utility Commission moved to introduce a new metric called total system benefit to provide incentives that recognise the wider system benefits from energy efficiency via its utility energy efficiency programmes. Several countries have also recently launched digital strategies which look to address risks such as increased device energy consumption, a lack of interoperability, cyber security, and social inequality due to unequal access to digital services. The IEA Digital Demand-Driven Electricity Networks Initiative is providing a platform for governments to learn from one another and apply best practices in these areas.

Chapter 1. Recent trends

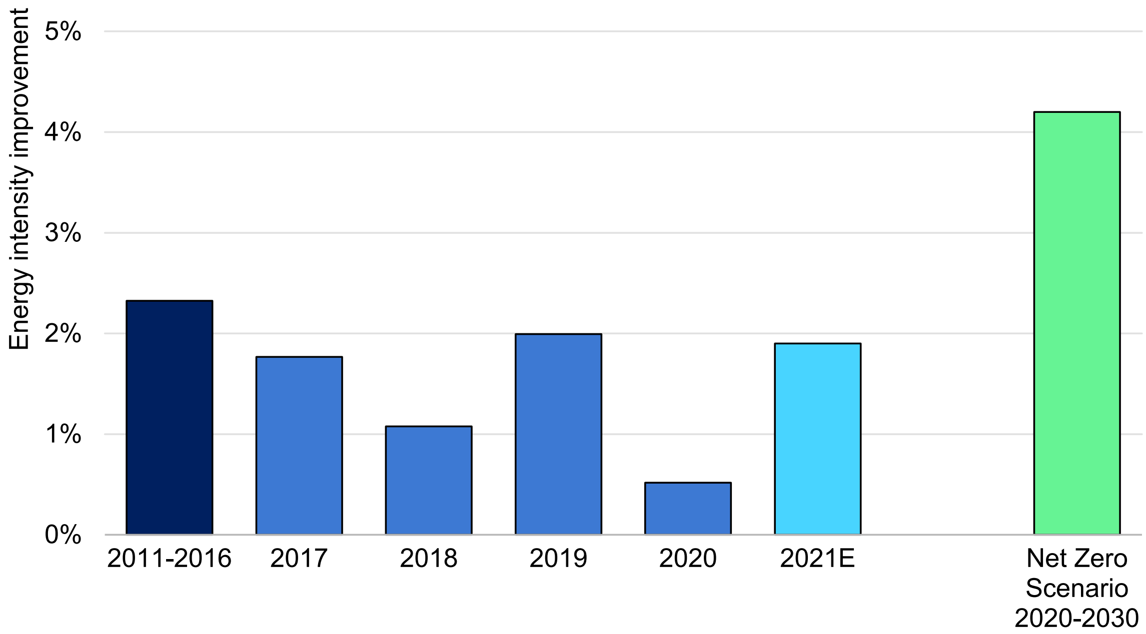
1.1 Energy intensity trends

Efficiency progress recovers in 2021 but needs to double before 2030 to reach net zero goals by 2050

Primary intensity improvement – the percentage decrease in the ratio of global total energy supply per unit of GDP – is expected to return to its 10-year average of 1.9% in 2021 after its worst year in a decade. However, this measure of energy efficiency still needs to double to match the levels outlined in the IEA Net Zero Emissions by 2050 Scenario.

The average annual energy intensity improvement for the last five years was 1.3%, down from 2.3% between 2011 and 2016 and well below the 4.2% annual rise between 2020 and 2030 described in the Net Zero Emissions by 2050 Scenario.

Primary energy intensity improvement, 2011-2021



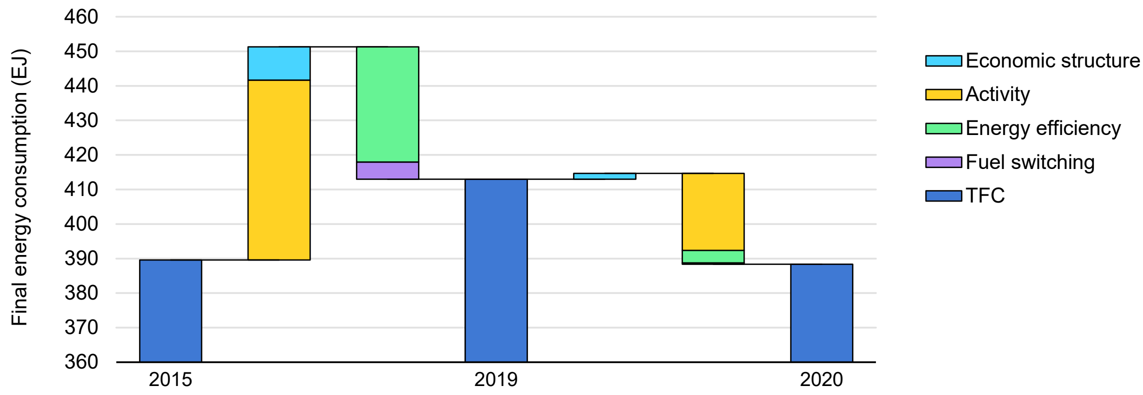
Notes: 2011-2016 five-year compound annual growth rate. 2021 estimate based on World Energy Outlook 2021. Net Zero Scenario = IEA Net Zero Emissions by 2050 Scenario, 2020-2030 intensity improvement, ten year average. Primary energy intensity = total energy supply (formerly total primary energy supply) per US dollar at purchasing power parity.

Global energy demand is expected to increase by 4% in 2021, returning to pre-pandemic levels as countries gradually emerge from lockdowns and economic activity picks up. This supported the improvement in energy intensity performance in 2021 as less energy-intensive service sectors of the economy reopened, energy prices rose, and policy makers ramped up energy efficiency programmes and spending in recovery measures.

In 2020 energy demand fell by 4% which, when combined with a 3.5% fall in global GDP in that year, contributed to make one of the worst years of energy intensity improvement in recent history, at just 0.5%. A range of factors contributed to this result, including a higher share of energy-intensive activities in the economy, a slowdown in technical energy efficiency improvements and lower energy prices.

However, even before the pandemic, energy intensity improvement had slowed. This slowdown was influenced by strong demand for energy services and a shift in economic structure towards more energy-intensive industrial production, combined with only modest avoided demand from fuel switching towards electricity and slower rates of technical efficiency improvements. For example, energy demand would have been 5% higher in 2019 if technical efficiency improvements between 2015 and 2019 had been as low as in 2020.

Decomposition of change in global total final energy consumption, 2015-2020



Note: TFC = total final energy consumption in the industry, buildings and transport sectors.
Source: IEA (2021), World Energy Model.

As it was, energy efficiency helped avoid nearly two-thirds of the potential increase in energy demand that could have occurred between 2015 and 2019 due to economic growth. There has also been a steady decline in the share of coal, oil and natural gas boilers in global heating equipment sales, which fell below 50% of total sales for the first time in 2020. Sales of more efficient electric heat pumps and renewable heating equipment such as solar hot water systems made up more than 20% of overall installations in 2020.

An important contributor to changes in economic structure which added to energy demand was strong demand for energy-intensive products in China. This growth has recently led the government to increase efforts to contain electricity consumption by restricting output of steel, aluminium and cement.

Record steel production in China puts pressure on energy intensity improvements

Constituting **around** 14% of national CO_2 emissions**, steel** output is a major focus of China's plans to achieve net zero emissions by 2060. Energy-intensive primary production, as opposed to production from scrap metal, accounts for around 80% of Chinese crude steel production, compared with around 60% for the rest of the world. Only 10% of the country's crude steel production involves electric furnaces, which are typically used when the sole metallic input is scrap.

Steel production, which meets export as well as domestic demand, increased by 7% to a record 1.1 billion tonnes in 2020, accounting for around 60% of global output. From January to April 2021, increasing demand pushed up profits in the Chinese steel industry, lifting demand for iron ore to record levels and elevating the industry to the top of the economic agenda. Demand was led by the buildings sector, infrastructure and manufacturing.

As part of its emissions reduction strategy, Beijing has pledged to limit crude steel output to the approximately 1 billion tonnes produced in 2020. However, in the first half of 2021 it ran as much as 12% above this baseline, prompting output restrictions in the second half of 2021. China's Iron and Steel Association has proposed limiting exports to prioritise domestic supply. China's leading steel producers have also set targets to achieve a peak in emissions in 2022-2023 with Baowu Steel, Ansteel Group and Baotou steel targeting carbon neutrality by 2050.

Before the pandemic, global final energy consumption increased at an average annual rate of 1.5% between 2015 and 2019. This was led by the transport sector with annual growth of 2% followed by buildings with 1.5% and industry with 1%.

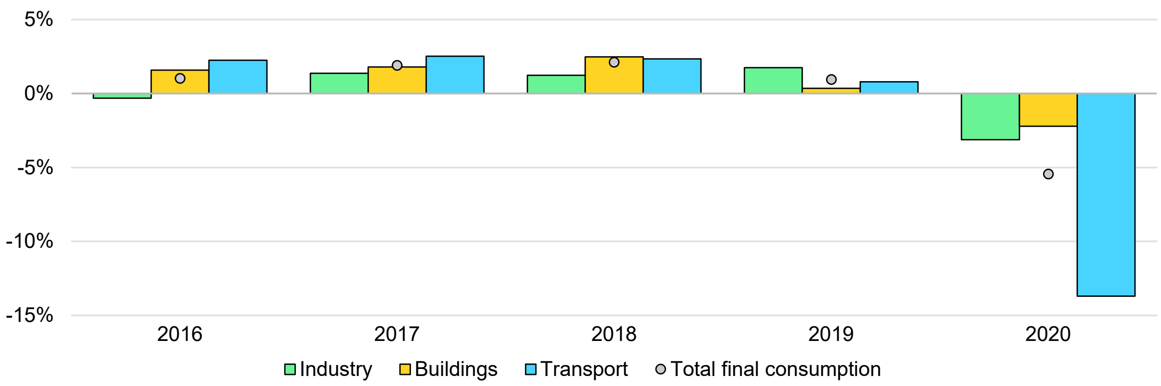
In 2020, transport was the sector that experienced the largest drop in energy consumption, falling by 14%. Lower occupancy rates in planes, trains and public transport resulted in a less efficient use of energy in the sector. Electric vehicle sales performed well in 2020, with 3 million vehicles sold, accounting for 5% of car sales worldwide. To put this in context, however, SUV sales now constitute around

40% of all passenger sales, up from just 20% ten years earlier. Such vehicles are typically heavier and less efficient, consuming around 20% more energy than medium-sized vehicles.

Restrictions to prevent the spread of Covid-19 also particularly affected GDP in less energy-intensive services sectors, such as restaurants, hospitality and recreation, lifting the relative share of more energy-intensive activities in the economy.

Final energy demand in the buildings sector was the least affected by Covid-19 restrictions in 2020, falling by just 2%. However, this is a tale of two different sectors – residential and commercial. In the United States, residential electricity demand rose by nearly 2% in 2020 while commercial demand fell by 6% as people working from home became the new norm, along with video conferencing in lieu of business travel.

Change in total final energy consumption by sector, 2016-2020



Source: IEA (2021), World Energy Model.

Industrial energy consumption fell by 3% in 2020, cushioned from the impact of restrictions by the rising share of energy-intensive activities and activity in China, which navigated the year with fewer restrictions.

1.2 Energy efficiency finance and investment

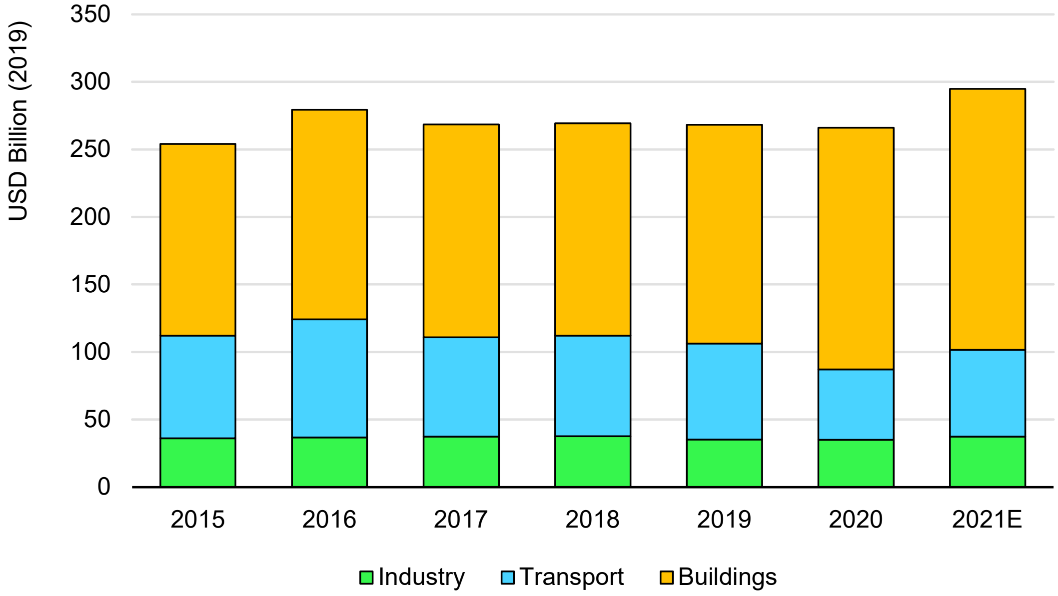
In the last two years, energy efficiency investment in buildings reached record levels

In 2021, total energy efficiency investments are expected to increase by 10% to just above USD 290 billion, boosted by the scaling up of existing government efficiency programmes, recovery measures and economic recovery in the transport and buildings sector.

Investment in energy efficiency measures in buildings is expected to rise in 2021 by 20% compared with 2019, to just over USD 190 billion. Transport energy efficiency investment is estimated to be still 9% below 2019 levels at around USD 60 billion, while industrial efficiency investment is expected to remain steady at around USD 40 billion.

Despite the Covid-19 crisis, overall energy efficiency investment was stable in 2020 at nearly USD 270 billion, but trends differed widely across sectors and regions. Unprecedented growth in the buildings sector outweighed a heavy decrease in transport efficiency investments, while spending in the industry sector remained largely unchanged.

Global investment in energy efficiency by sector, 2015-2021



Notes: An energy efficiency investment is defined as the incremental spending on new energy-efficient equipment or the full cost of refurbishments that reduce energy use. The intention is to capture spending that reduces energy consumption. Under conventional accounting, part of this is categorised as consumption rather than investment.

While global building activity contracted over much of 2020, buildings energy efficiency investments in Europe increased strongly enough to boost global investments in this area by 11% to nearly USD 180 billion. Most of this increase was due to the scaling up of efficiency policies put in place before 2020. In Germany, for example, the buildings programmes of the state-owned development bank KfW doubled in volume. Covid-19-related government recovery measures such as the Superbonus programme in Italy or the France Relance recovery plan also helped to increase investment levels.

Scaling up energy efficiency investments in Germany

Germany's spending on energy efficiency in buildings grew strongly in 2020 mainly because the state-owned development bank KfW doubled its efficient construction and renovation investments to EUR 30 billion, accounting for a sixth of the year's global buildings-related energy efficiency spending.

While some of this investment was recovery spending, the majority was due to major changes agreed in 2019 to make energy efficiency programmes for buildings more attractive. Key changes included increased maximum funding amounts for residential buildings, as well as higher investment and loan repayment grants, which in most cases led to negative interest rates on loans. The enhanced policies resulted in particularly strong growth rates for construction of energy-efficient new buildings, which now makes up two-thirds of KfW's buildings financing volume, up from 40% in 2018.

Additional changes including increases to maximum loan amounts, financial support, simplified processes and greater support for the use of efficient prefabricated building elements came into effect in 2021. A single application now covers financing requests for several energy efficiency measures and smart home improvements, including renewable energy-based heating systems with energy efficiency guiding building owners through projects.

Investors can now choose between reduced interest loans from KfW and direct grants provided through the Federal Office for Economic Affairs and Export Control (BAFA). In both cases, financial support increases with the efficiency level of the building or heating system.

Repayment grants range from 15% to 25% of the total support, depending on the efficiency class of the building, and reach up to 50% for renewables-based heating systems. For example, investment grants up to EUR 37 500 are available for the most efficient new buildings, which require 60% less energy than reference buildings and include solar PV, battery and heat recovery ventilation systems. For retrofits reaching the highest standard, homeowners can receive up to EUR 75 000 in repayment or investment grants.

However, some projects that received funding in 2020 and 2021 have faced material supply shortages and financial difficulties among homeowners because of the Covid-19 crisis. As a result, efficiency upgrades may be less ambitious than initially planned. Other challenges include reaching more low-income households, whose use of heat pumps has been limited.

In other regions, however, efficiency spending in buildings has fallen, or grown more slowly. In the United States, no additional funding was directed towards energy efficiency investment in 2020 beyond existing programmes, although recovery measures included large elements of efficiency-related spending in 2021. In Asia, growth in buildings efficiency spending in China, Japan and Korea balanced out declines in other countries. In India, construction activity decreased by around 15% in 2020 as corporate and household budgets came under severe constraints.

Transport efficiency investments were around USD 50 billion in 2020, a 26% drop from 2019, influenced by a slowdown in global car sales. This fall was cushioned by a rise in electric vehicle sales in China and Europe, supported by recovery spending such as the European Union's Recovery and Resilience Facility and electric vehicle purchase subsidies in France, Germany, Spain and the United Kingdom. For the first time since 2015, electric vehicle sales in Europe outpaced those in China.

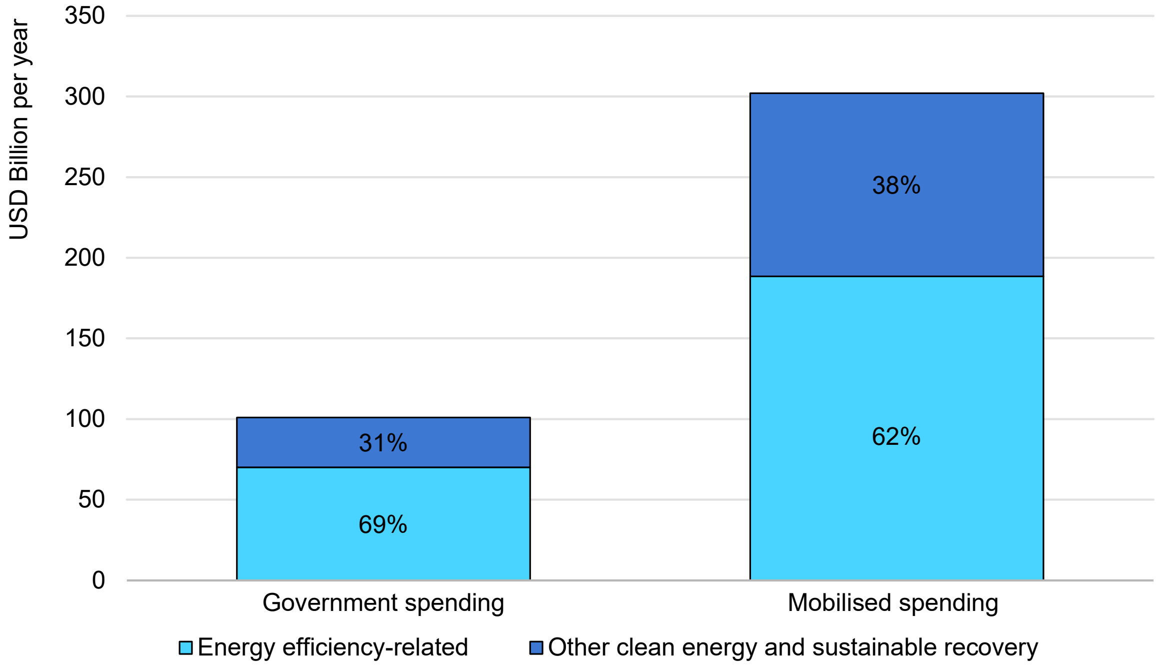
Efficiency-related spending makes up two-thirds of new clean energy recovery financing

In July 2021, the IEA released its Sustainable Recovery Tracker to assess national recovery measures against the categories depicted in the IEA Sustainable Recovery Plan. The tracker found that as of the end of October 2021 annual average investment – including government spending and total public and private investment mobilised by that spending – is likely to increase clean energy and sustainable recovery spending by around USD 400 billion per year between 2021 and 2023. Initial government spending represents 28% of this three-year average.

Of this anticipated USD 400 billion in annual investment over the next three years, almost USD 260 billion per year is expected for energy efficiency measures in buildings, industry and low-carbon transport, including related areas such as electric vehicle charging and urban transit infrastructure. This comprises around

USD 70 billion in annual direct government spending and almost USD 190 billion in private mobilised spending and constitutes around two-thirds of the total extra clean energy recovery investment expected to be spent between 2021 and 2023.

Annual energy efficiency and clean energy economic recovery spending, 2021-2023



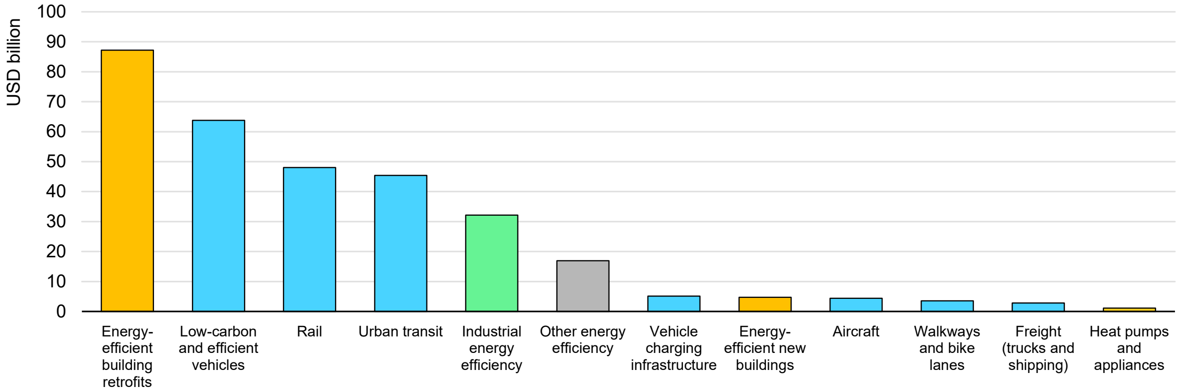
Notes: "Government spending" includes government measures highlighted in the IEA Sustainable Recovery Plan. "Mobilised spending" includes all other public and private spending on measures highlighted in the IEA Sustainable Recovery Plan mobilised by government spending. "Energy efficiency-related" includes spending on low-carbon and efficient transport and energy-efficient buildings and industry. "Other clean energy and sustainable recovery" includes low-carbon electricity, electricity networks and fuels, technology innovation and people centred transitions.
Source: IEA (2021), Sustainable Recovery Tracker.

Total approved government energy efficiency-related spending in the 2021-23 period and beyond comprises over USD 310 to USD 315 billion in the measures approved as of the end of October 2021. European Union countries account for around 65% of this total. Examining the sectoral breakdown of the global total, transport-related spending comprises 55%, buildings 30% and industry 10%and other efficiency-related measures 5%.

Around USD 170 to USD 175 billion of total government investment has been committed towards transport-focused energy efficiency. Low-carbon and energy-efficient vehicles and charging infrastructure make up almost two fifths of this. Rail and urban transit projects (such as bus, light rail and metros) make up just over half of transport-related energy efficiency spending.

Around USD 95 billion of global government investment is targeted for energy-efficient buildings and appliances, especially building retrofits. Recovery measures from Europe have dominated this spending representing around four-fifths of total announced global public investment.

Total energy efficiency-related government clean energy recovery spending, 2021-onwards



Note: This figure and section include government recovery spending from 2021 and beyond, and announced to the end of October 2021, based on measures highlighted in the IEA Sustainable Recovery Tracker.
Source: IEA (2021), Sustainable Recovery Tracker.

Considerable government spending announced but yet to be approved as of the end of October 2021 have not been included in this total, notably in France, India, Japan and the United States. The US Infrastructure Investment and Jobs Act, approved since, contains USD 550 billion in new investments, of which the clean energy components are also not included in this total. These would increase government spending on energy efficiency even further.

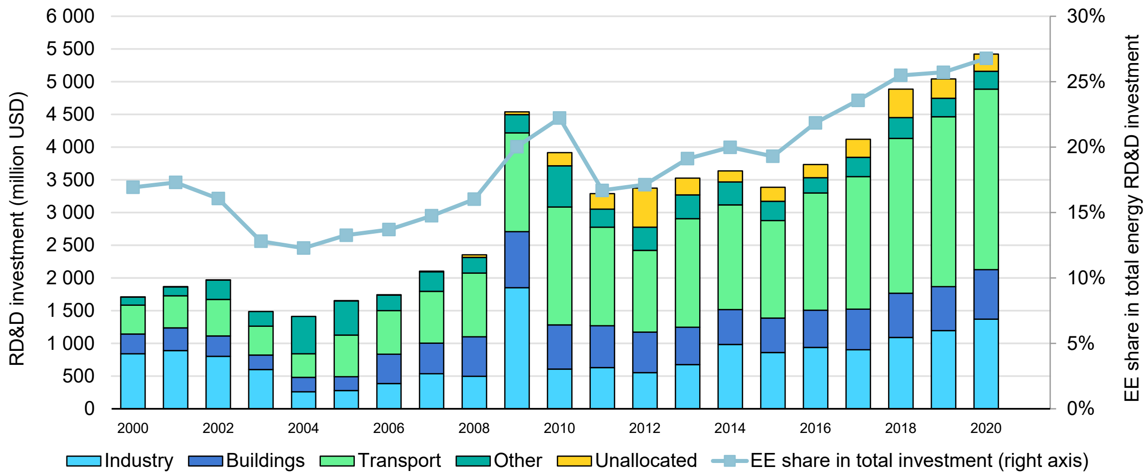
This recovery spending could bring advanced economies quite close to the levels envisaged in the IEA Sustainable Recovery Plan; however, at a global level a significant gap remains. For example, based on current approved spending for energy efficiency-related activities, there is still a gap of about 60% to meet the levels of funding outlined in the Sustainable Recovery Plan.

Additional economic recovery investment at the subnational or municipal levels is not captured in this analysis. For example, the Tokyo Metropolitan Government's 2021 budget has allocated USD 350 million for zero-emission support, including LED lighting promotion, energy conservation and electric vehicle support.

Government-related energy efficiency RD&D spending focuses on transport and industry sectors

Governments and state-owned enterprises have significantly increased their spending in research, development and demonstration (RD&D) in energy efficiency. In IEA member countries, investments reached USD 5.5 billion in 2020, an increase of two-thirds compared to 2015 and a tripling since 2000, led by spending in the transport and industrial sectors. Not since stimulus measures following the global financial crisis of 2008 has government efficiency RD&D spending reached these levels. Energy efficiency has also risen as a share of total government energy RD&D spending, increasing to around 27% in 2020, up 7% from five years earlier.

Government energy efficiency RD&D spending in IEA member countries, 2000-2020



Chinese energy service companies experience strong growth

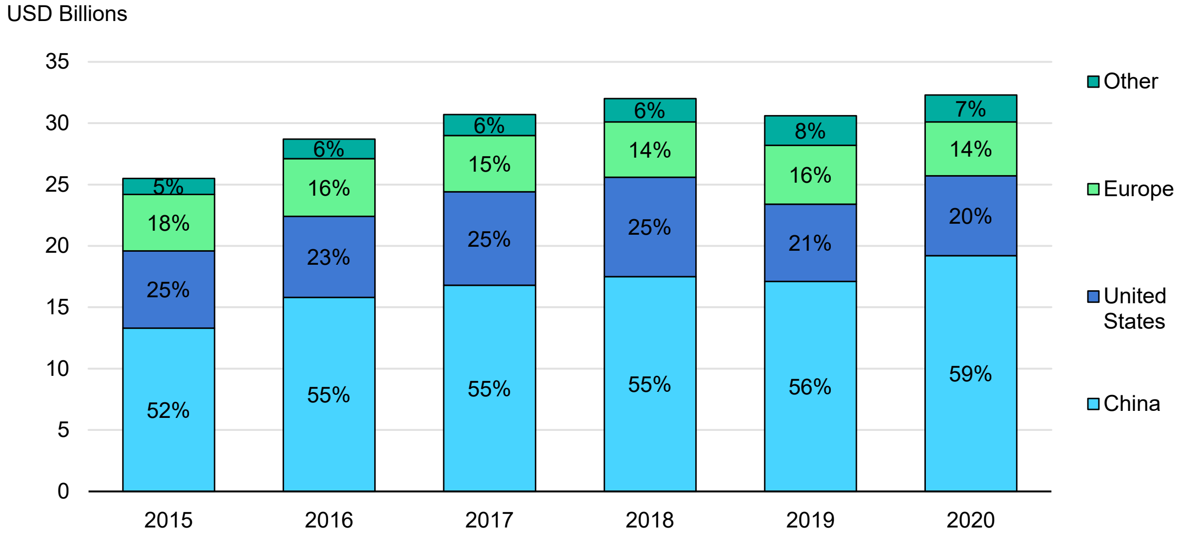
Energy service companies (ESCOs) provide energy solutions ranging from generation and supply to energy efficiency and retrofitting projects. ESCOs help consumers identify, finance and implement projects, thereby making it easier to invest. In particular, they can reduce the burden of making upfront capital expenditures and facilitate access to commercial financing.

The global ESCO market as a whole increased by around 6% in 2020 to USD 33 billion. This growth was mainly centred in China, where investment rose by 12% despite the pandemic. Other major ESCO markets, including the United

States, European markets and emerging markets and developing economies, either remained flat or contracted.

During 2020, the ESCO market became increasingly disrupted due to physical lockdown restrictions. ESCOs in Middle East countries such as Saudi Arabia and the United Arab Emirates reported increased awareness of the need for efficient ventilation and cooling, and associated benefits for indoor comfort and health, which boosted business.

Global ESCO market growth, 2015-2020



Source: IEA Annual ESCO market surveys.

The Chinese ESCO association EMCA reported that ESCOs quickly turned to using online tools and remote controls to keep their clients engaged and their business operations as robust as possible. Chinese ESCOs used 2020 as an opportunity to update their business models through greater use of smart tools and technologies. The Chinese government also introduced additional tax incentives in May 2020 to encourage ESCO business development and innovation.

Energy Efficiency Services Limited – the Indian Super ESCO

In 2009, the Indian government set up Energy Efficiency Services Ltd under the National Mission on Enhanced Energy Efficiency. Energy Efficiency Services Ltd has implemented large-scale energy efficiency projects through financing models like bulk procurement for lower prices, revenue sharing and public subsidies. The flagship programmes include UJALA for domestic LEDs, Street Light National Programme, Building Energy Efficiency Programme, Smart Meter National Programme, E-Vehicle Programmes and decentralised solar programmes.

These programmes have resulted in over 50 000 GWh of annual electricity savings, as well as creating jobs and boosting living standards. Energy Efficiency Services Ltd has distributed over 360 million LED bulbs to domestic consumers and installed over 12 million LED street lights in Indian municipalities in the last five years

The Building Energy Efficiency Programme was launched in 2017 to promote efficient retrofits of commercial buildings in industry, government and other institutions, including large public buildings like railway stations. The programme employs demand aggregation of efficient equipment purchasing to negotiate lower prices for its projects, lowering costs for the public budget. By September 2021 the programme had completed projects in almost 7 000 buildings, with another 4 000 under way. Completed projects are saving 224 GWh in energy per year and emissions of 184 kt CO_2-eq. Investment volumes were USD 270 million between 2017 and March 2020.

1.3 Energy efficiency policy updates

As more countries raised climate policy ambition in advance of the 2021 UN Climate Change Conference (COP26), energy efficiency policies gathered pace.

EU “Fit-for-55” package targets milestones on path to 2050

The European Union revised its Energy Efficiency Directive in July 2021 as part of the “Fit-for-55” Package, which aims to reduce greenhouse gas emissions by 55% by 2030. The package includes a set of concrete policy measures for the medium-term to meet the European Union’s net zero by 2050 pledge as part of the European Green Deal. The European Commission is aiming to reduce final energy consumption by 36% and primary energy consumption by 39% by 2030 compared with 2007.

Member states now must achieve new savings of 1.5% of final energy consumption a year between 2024 and 2030, twice the current rate of 0.8%. The increased primary energy consumption targets translate into energy intensity improvements of 3.2% per year by 2030. Building on the Renovation Wave Strategy, the aim is to renovate at least 3% of the total floor area of all public buildings annually and use higher shares of renewable energy. Further reforms will come by the end of 2021 with the revised Energy Performance of Buildings Directive.

Chile passes new wide ranging energy efficiency legislation

Chile passed new energy efficiency legislation in January 2021, creating the overarching institutional structure to accelerate progress on energy efficiency across key sectors of the economy. The Energy Efficiency Law's headline target is a 10% reduction in economy-wide energy intensity by 2030 compared with 2019, delivered through a series of statutory five-year energy efficiency plans. The law sets new requirements for standards and labelling, buildings, transport, efficient and smart cities, industrial efficiency, and public sector leadership. Key policies enshrined within the law include a mandate for large energy consumers to implement power management systems and report their consumption to the Energy Ministry; new energy efficiency standards for vehicles traded within the country; and energy performance labelling on new houses. The law establishes a governance structure to drive ambition, and monitor and evaluate progress

Standards and labels are a keystone of energy efficiency policy

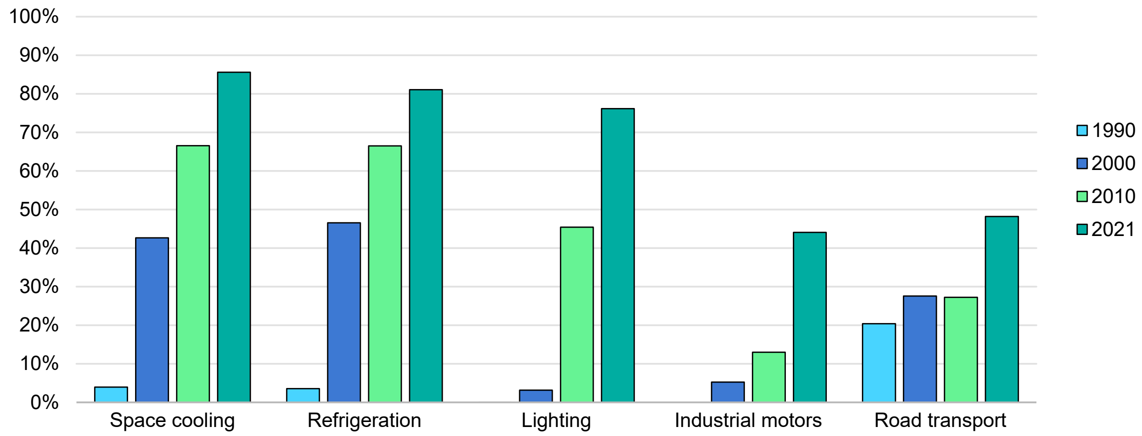
In recognition of their substantial cost-effective energy savings potential and other benefits, more than 100 countries now use mandatory energy efficiency performance standards and/or energy labels for air conditioners, refrigeration, lighting, industrial motors and passenger cars. However, policies are still absent in a range of markets where growth in ownership of appliances is fastest. Additional or expanded standards and labelling schemes are under development in over 20 countries, mainly in Asia and East and Southern Africa.

While this section focuses on policies covering the key end uses outlined above, performance standards and labels apply to more than 100 types of appliances and equipment in the commercial, industrial and residential sectors. However, policy coverage is lower for most of these products. For example, only 40-50 countries have implemented minimum performance standards for washing machines, dishwashers or TVs. As a result, expanding programmes in countries with existing policies for only a limited number of products to cover such appliances offers significant scope for driving further efficiency gains.

Such policies were adopted early in Europe and North America, and now cover a high proportion of key energy-consuming end uses in these regions. However, there is a wide range of variation in the coverage and strength of programmes in different countries. Significant scope exists for enhanced international co-operation in this area to help governments bring in new standards, learn from past experience and adopt best practices.

If ambition levels are regularly adjusted to reflect latest technological progress, performance standards and labels can achieve substantial reductions in energy consumption, as long-established programmes have proven over recent decades. Furthermore, once the programmes are successful, comparative energy labels will need to be regraded. This has recently happened in the European Union, where the mandatory energy label was regraded to an A-G scale for a range of products. The upgrade to the label was also accompanied by the introduction of QR codes linking to the European Product Registry for Energy Labelling.

Global energy use coverage of mandatory standards or comparative labels for key end uses, 1990-2021



Note: Coverage for space cooling, refrigeration and lighting is shown for residential sectors.
Source: IEA analysis based on CLASP Policy Resource Center and other sources.

Space cooling

Mandatory air conditioner standards now cover 85% of global space cooling energy consumption, up from two-thirds in 2010. Additional minimum energy performance standards are under development in more than 20 countries. Standards and labels have recently been strengthened in Australia, Brazil, China and India. India also introduced voluntary labels for light commercial air conditioners in 2020. Benin (2020) and Rwanda (2021) introduced mandatory policies, bringing the global count of countries with minimum energy performance standards to 83 and comparative labels to 75.

Recent cooling policy and technology highlights

India's Energy Efficiency Services Ltd recently launched a Super-efficient Air Conditioning programme to make more efficient devices affordable for the general population through bulk procurement. This helped bring to the market an air conditioner that is around 20% more energy-efficient than the average five-star rated air conditioner available on the market that uses Low Global Warming Potential refrigerants. Energy Efficiency Services Ltd has deployed over 10 000 units after procuring a bulk order of 50 000 units.

International progress on climate-friendly refrigerants

In 2016, 197 countries agreed, through the Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer, to phase down the production and use of hydrofluorocarbons (HFCs). The Amendment came into force in 2019 and regulates HFCs used as refrigerants in space cooling, refrigeration and other air conditioning technologies.

The Kigali Amendment continues to gather momentum with 127 countries having ratified in the second half of 2021, up from around 100 in July 2020. This has been achieved with the support of the Kigali Cooling Efficiency Program (K-CEP), now known as Clean Cooling Collaborative and the Efficient Cooling Initiative.

This work includes a facility to help governments scale-up climate-friendly cooling solutions as part of Nationally Determined Contributions (NDCs) submitted at COP26 in Glasgow. To date 55 countries have committed to reduce cooling emissions in either their NDCs or long-term climate plans.

The winners of the Global Cooling Prize were announced in 2021 as part of a multi-year international initiative spearheaded by the Rocky Mountain Institute, the government of India and Mission Innovation. The prize was aimed at encouraging and recognising game-changing technologies, with a total of USD 3 million in prize money on offer.

139 participants from 31 countries competed for the prize, ranging from small start-ups to large companies. Participants were evaluated based on the overall climate impact of their projects, including energy use and refrigerant used, maximum

power consumption of the units and their production costs. Eight finalists were selected to test their projects under real-world conditions. This included assessing performance under different humidity conditions, a consideration not often reflected in testing and rating standards. After the testing phase in the final, in April 2021 two participants were awarded the prize.

Gree, the world's largest manufacturer of residential air conditioners, in partnership with Tsinghua University, was selected as a winner with an entry which utilises renewable photovoltaic direct-driven technology to power a unit with three "climate smart" modes. These make use of vapour compression refrigeration, evaporative cooling and ventilation – that can operate individually or in parallel, depending on the outside weather conditions.

Daikin, in collaboration with Nikken Sekkei, was selected as the other joint winner with an entry that used a multi-split method to connect two indoor units with one outdoor unit. This takes advantage of control sensors to help optimise refrigerant flow rates depending on operating conditions and takes advantage of evaporative cooling to improve the system's efficiency.

The Million Cool Roofs Challenge is another global cooling-related competition underway in 2021 looking to award USD 2 million to assist and recognise technologies that enable the rapid, scale-up of highly solar-reflective "cool" roofs. It is particularly focused on developing countries that suffer heat stress and lack access to cooling services and is a project of the Kigali Cooling Efficiency Program (K-CEP) in collaboration with the Global Cool Cities Alliance, Sustainable Energy for All and Nesta Challenges. The prize comes amidst growing recognition of the importance of "cool" roofs and moves in 2021 in some jurisdictions to ban dark roofs that contribute to heat island effects.

Refrigeration

Policy coverage of minimum energy performance standards and comparative labels for residential refrigerators and freezers has remained relatively stable in recent years. However, Sri Lanka introduced mandatory minimum energy performance standards and labels in 2020.

At the moment, 76 countries have such policies in place, covering over 80% of global refrigeration energy consumption, up from two-thirds in 2010. In one recent update, Mexico harmonised its minimum energy performance standards and labels for refrigerators and freezers with those in the United States and Canada.

To keep up with evolving technology, the European Union implemented major updates of performance requirements and labels in March 2021. New refrigerators now have to be 75% more efficient than 10 years ago, while labels have been rescaled to allow consumers to identify top-performing products more easily. The labelling requirements have also been extended to refrigeration appliances used in shops and vending machines.

When the previous European labelling regulation entered into force in 2010, no models qualified for the A+++ class, and the share of A++ models was less than 10%. However, by 2017, over 50% of refrigerator models were in the top two label categories.

Lighting

Eighty-nine countries have minimum efficiency requirements for lighting products and 61 countries use comparative labels. Minimum energy performance standards now cover just over 75% of global energy use for lighting, an improvement of more than 30 percentage points since 2010. Additional mandatory lighting policies are under development in several countries in Asia, East Africa, Latin America and the Caribbean.

Minimum energy performance standards and labels have recently been updated in the European Union, where new thresholds came into force in September 2021. Further scheduled updates in 2023 will phase out most halogen lamps and the traditional fluorescent tube lighting, which are common in offices. As with refrigerators and other products, EU labels will be rescaled to a new scale from A to G and include a QR-code which allow consumers to quickly access additional efficiency information via a smart phone.

Building codes

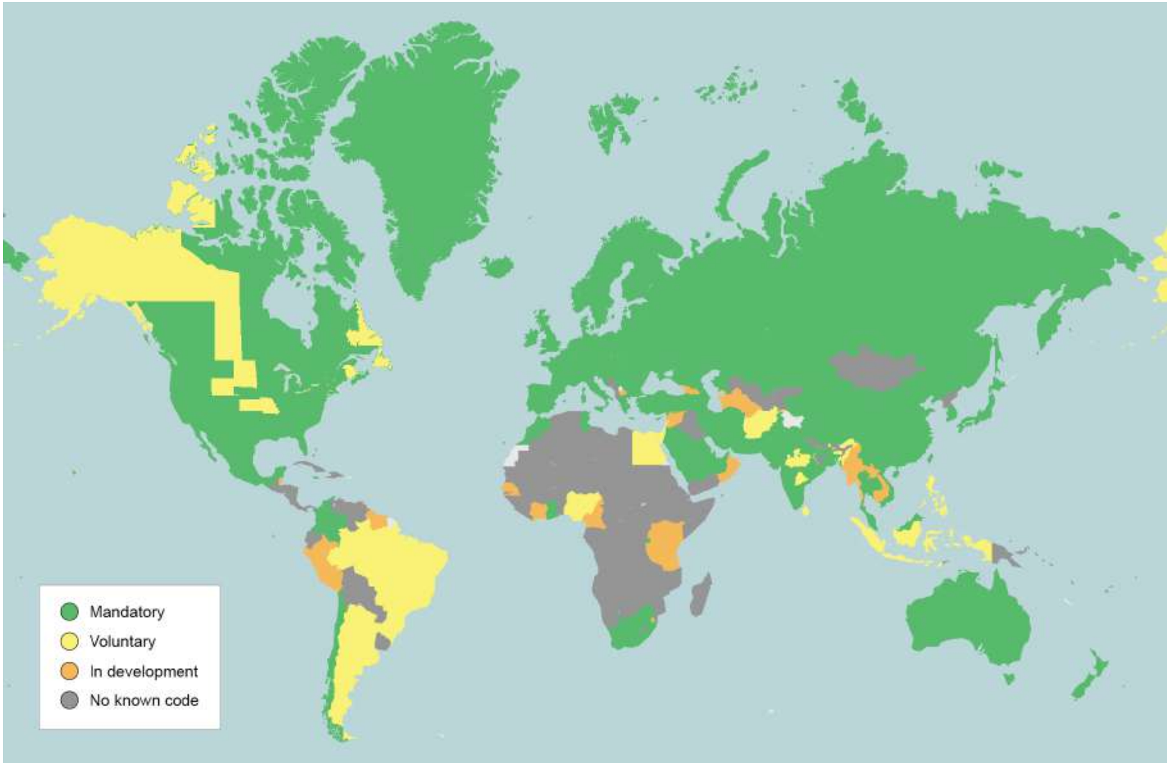
Building energy codes can be an effective policy tool to promote energy efficiency improvements in residential and non-residential buildings alike. Such codes set minimum energy performance standards for new buildings, and many also have policy triggers to ensure that major refurbishments or renovations bring buildings up to code. Building energy codes typically cover the operational energy use of buildings, but embodied emissions from the construction of buildings are beginning to be covered in some codes to meet zero carbon ready standards.

Tracking energy codes for new buildings

Regions	Mandatory	Voluntary	In development	No known code	Total
Africa	4	3	8	39	54
Americas	6	2	12	15	35
Asia	21	6	6	13	46
Europe	35		1	7	43
Oceania	3		3	10	16
Total	69	11	30	84	194

As of November 2021, 80 countries had mandatory or voluntary building energy codes on the national or subnational level, out of which 54 countries had mandatory codes on the national level for both residential and non-residential buildings.

Coverage of energy codes for new buildings, 2021



Note: Building codes relating to specific cities are not shown.

Around two-thirds of countries still lack mandatory building codes, meaning that more than 3 billion m^2 were built in 2020 without mandatory energy performance requirements, an area equivalent to Korea's entire building stock.

Towards an energy-efficient mortgage standard for buildings in the European Union

European residential buildings are worth EUR 17 trillion and represent around half of European wealth, as well as being home to 220 million households. However, roughly 75% of buildings in the European Union are not energy-efficient, with around 90% expected to still be in use in 2050. The European Energy Performance of Buildings Directive aims to support the renovation of existing buildings to be energy-efficient and decarbonised by 2050 with new buildings to be nearly-zero energy buildings from January 2021.

In the European Union banks hold around EUR 7 trillion of mortgages over the building stock and are starting to set dates for upgrading the homes they lend against to the European Union Energy Performance Certificate grade A.

To assist with this task the idea of a Mortgage Portfolio Standard has been proposed to require the energy performance of a bank's portfolio of financed buildings to meet stronger building standards by specific dates and help deliver the European Union's renovation wave policy.

Source: Climate Strategy and Partners, Underwriting the Renovation Wave with Mortgage Portfolio Standards for Energy Efficiency, June 2021.

Road transport

Unlike appliances and industrial motors, there are more countries with comparative labelling schemes (45) than efficiency performance/fuel economy standards (40) for new passenger light-duty vehicles. However, no new schemes have appeared since 2017.

Even though the number of countries where standards are in operation is small, because the main vehicle markets are covered nearly 90% of new sales of passenger light-duty and 80% of new sales of heavy-duty vehicles are governed by fuel economy standards. This is key progress, particularly for the heavy-duty vehicle sector, where coverage was only 50% in 2016. New standards for trucks are under development in several emerging economies and Korea.

However, it takes time for new policies to affect the total vehicle stock, as only a small share of vehicles are replaced by new models each year. Standards for passenger cars, for example, now cover nearly two-thirds of their global energy use, up from 50% a decade ago.

For some developing countries which are yet to put standards in place the import of second-hand vehicles is a major feature of their market with many of these imports no longer complying with the standards of the exporting country.

Phase-outs of internal combustion engine vehicles

To facilitate take up of electric vehicles, more than 20 countries have announced the full phase out of internal combustion engine vehicle sales, ranging from as early as 2025 in Norway to 2050 in Costa Rica. The European Union targets a ban of internal combustion engine car sales by 2035 as part of the new “Fit-for-55” Package. In addition, around 13 of the world’s top internal combustion engine vehicle manufacturers have announced plans to only sell electric cars in the future with some phasing out internal combustion engine production as soon as 2025.

Labels and standards are also being more widely adopted for two- and three-wheeled vehicles. Viet Nam has mandated fuel consumption labelling for motorbikes from 2020 onwards, one of the first countries to do so. China already mandates fuel consumption standards for two and three-wheeled vehicles, with new standards coming into effect in July 2020.

Once in place, standards can be gradually strengthened. New targets for passenger light-duty vehicles have been set in recent years in key markets including China, Japan, Korea, the European Union and the United States. Required annual improvement rates to meet targets over the coming years range from 2.9% in Japan and over 4% in the European Union to 4.4% in China and 5.5% in the United States, where final rules will be established in December 2021. However, baseline performance levels differ widely. In the European Union, for example, standards are the most stringent and play a significant role in promoting electric car sales.

Industrial electric motors

Around 40% of energy use of industrial motors is now covered by mandatory performance standards, up from 15% ten years ago. Three-quarters of the 57 countries with minimum energy performance standards for industrial electric motors implemented their standards in the 2010s. Ukraine is the most recent country to implement standards, which came into operation in September 2021.

Pakistan was the first country to introduce minimum energy performance standards and labels for refurbished second hand-motors in 2021. Though initially a voluntary programme it will eventually transition to compulsory registration and IE3 minimum performance requirements in 2023.

Currently only 11 countries make use of mandatory comparative labels to encourage sales of more efficient industrial motors. Eight additional countries offer voluntary comparative or endorsement labelling. The use of energy labelling should not preclude the use of nameplates being affixed to motors. Ideally, such nameplates would be IEC 60034-30-1 conformant.

In contrast to many other key end uses, minimum energy performance standards for industrial electric motors rely on internationally harmonised efficiency levels, the IE1 to IE4 classes governed by the International Electrotechnical Commission. This approach provides many benefits for manufacturers and industrial facilities. Many countries have recently strengthened standards and extended scopes.

In China, Colombia, the European Union and countries applying EU rules, for example, new motors on sale in the most important product categories have had to meet at least the IE3 efficiency level since mid-2021, which is now a mandatory requirement in 45 countries. From 2023 onwards, some motor types will have to meet IE4 requirements in the European Union, Norway, Switzerland, Turkey and the United Kingdom.

Seizing opportunities to boost industrial energy efficiency

Energy management systems, which help businesses identify opportunities to adopt and improve energy-efficient technologies, have been successfully implemented in a wide range of countries. However, there is only a small number of mandatory energy efficiency policies targeting the industry sector beyond such management systems, mandatory energy audits and minimum energy performance standards for industrial electric motors.

Mandatory audits and energy management systems

Examples of mandatory audit requirements can be found both in emerging markets such as in Tunisia and Morocco and in advanced economies such as the

European Union. Although necessary, such measures are only the first steps towards a clearer, more defined path to improve energy efficiency in the industry sector. To enable the next steps, it is important to develop sub-sectoral targets and create an environment that fosters energy efficiency through a policy package combining regulation, information measures and incentives.

India's Perform, Achieve and Trade scheme

The Perform, Achieve and Trade (PAT) scheme sets mandatory energy intensity improvement targets for large energy users in energy-intensive sectors. The scheme provides incentives for overachievement by allowing the trading of energy-saving certificates. The first cycle of the scheme (2012-2015) targeted large energy-intensive industries such as iron and steel, aluminium and cement. It managed to reduce the energy consumption of more than 400 covered entities by 5.3%, above the initial target of 4.1%. Subsequent cycles extended the scheme to further sectors and covered additional entities such as smaller energy users.

China's "100,1 000,10 000" industrial enterprises programme

First introduced in 2006 and extended in 2011 and 2017, the Key Energy-Consuming 100, 1 000, 10 000 Organisations Action sets mandatory energy-intensity improvement targets for the largest energy-consuming enterprises in China, most of which are in the industry sector. Targets have been set at the national level and then passed down to local levels for action by individual companies. The programme, one of the largest in the world in terms of impact, is linked to strong policies to support the development of energy service companies. The previous programmes – the Top 1 000 Enterprises Energy Saving Programme and the Top 10 000 Programme – both surpassed their energy reduction goals, while the current "100, 1 000, 10 000" programme is still in its early phase.

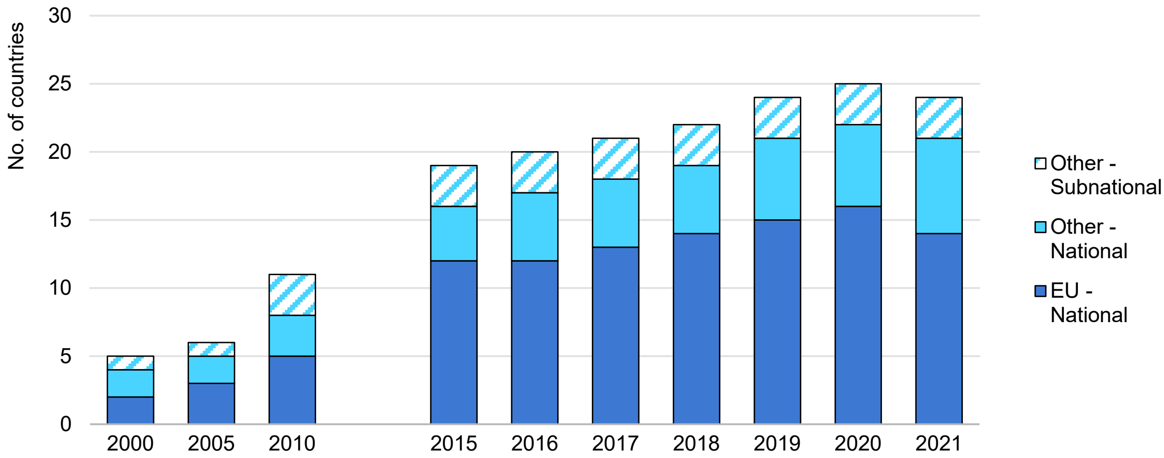
Energy efficiency obligation schemes now cover a fifth of global energy use

Energy efficiency obligation programmes, known as energy efficiency resource standards in the United States, are market-based schemes that require energy companies to achieve an energy efficiency target. Typically this target is defined as a set amount of energy savings but schemes vary widely in terms of primary policy goals, design and implementation.

Twenty-four countries use energy efficiency obligation schemes to drive energy efficiency improvements, including 14 in EU countries and subnational programmes in Australia, Canada and the United States. Together these programmes cover nearly a fifth of global energy use. The longest-running schemes have provided substantial reductions in energy consumption over their lifetimes.

The European Union introduced energy efficiency obligations as the default policy instrument of the Energy Efficiency Directive, which came into force in 2014. However, member states can opt for alternative measures. In the obligation period of the revised Energy Efficiency Directive, from 2021 to 2030, the energy efficiency obligation has been maintained as the default instrument, building upon positive experiences from 2014 to 2020. Denmark, however, replaced its energy efficiency obligation in 2021 with a tender-based scheme for energy efficiency improvements in industry, service businesses and buildings. Recent developments in Australian subnational energy efficiency obligations include new targets for the scheme in Victoria and the introduction of a peak demand reduction scheme in New South Wales.

Countries with energy efficiency obligation schemes, 2000-2021



International energy efficiency cooperation receives a boost

New Energy Efficiency Hub to foster stronger engagement

The Energy Efficiency Hub was established in 2019 as a vehicle for international collaboration on energy efficiency. The Hub Secretariat is hosted by the IEA. The members of the Hub are Argentina, Australia, Brazil, Canada, China, Denmark, the European Union, France, Germany, Japan, Korea, Luxembourg, Russia, Saudi Arabia, the United Kingdom and the United States. The Hub will work through task groups focused on topics of interest to the members, sharing data, research and best practice. In 2021, the Hub established its first task groups, including the Digitalisation Working Group and the Top Tens Task Group, which works to identify best available technologies and practices. It also incorporated the Super-Efficient Equipment and Appliance Deployment Initiative (also an initiative of the Clean Energy Ministerial, and co-ordinated by the IEA, which will play a major role in progressing the COP26 Product Efficiency Call to Action, discussed further in Chapter 2.

G7 and G20 countries emphasise energy efficiency and digitalisation in supporting energy security and net zero goals

The G7 achieved a milestone at its 2021 summit by collectively committing to reach net zero emissions by 2050. In the summit communiqué, the G7 noted the IEA Net Zero by 2050 Roadmap and pledged to increase efforts on energy efficiency as well as other clean energy technologies. This included welcoming the goal of the IEA Super-Efficient Appliance Deployment Initiative to double the efficiency of lighting, cooling, refrigeration and motor systems sold by 2030, which is featured in a special focus in Chapter 2 of this report.

For the first time in G20 history, the group's Energy Transitions and Climate Sustainability Working Group Meetings were held jointly, underlying the pressing need to act urgently to accelerate clean energy transitions to reach net zero emissions, while also ensuring energy security.

Cities were one of the main priorities of the Italian Presidency of the G20. To support this priority, the IEA provided analysis on how national governments can help cities accelerate clean energy transitions by using energy efficiency and digitalisation, in its special report Empowering Cities for a Net Zero Future: Unlocking resilient, smart, sustainable urban energy systems. The report identifies high-level recommendations that national policy makers can consider to accelerate net zero transitions and leverage cities' full potential to reduce emissions, regardless of local contexts.

Another major priority of the Italian Presidency of G20 was energy security in the context of clean energy transitions and net zero emissions pathways. The IEA supported this process by updating the G20 energy collaboration principles endorsed at the G20 Brisbane Leaders' Summit in 2014. The IEA report G20 Energy Security of Clean Energy Transitions recognises energy efficiency as the "first fuel" to achieve secure clean energy transitions. The report emphasises the importance of accelerating the uptake of efficient technologies and practices, while recognising the central role of people for the success of clean energy transitions.

G20 members recognised the key role of energy efficiency in clean energy transitions and the role of the IEA initiative Digital Demand-Driven Electricity Networks, supported by Italy. The G20 also endorsed the Smart, Resilient and Sustainable Cities Action Plan, which will support energy efficiency actions and measures in cities.

1.4 Other market trends

Growth in energy efficiency start-ups helps drive innovation

Despite the Covid-19 pandemic, venture capital investments in clean energy start-ups remained strong in 2020, and continued this momentum in the first half of 2021. While venture capital investments in energy efficiency start-ups remain small relative to the much larger sums mobilised in other efficiency areas, such as for building retrofits, they are critical to support the entrepreneurs developing new innovative products and services needed to meet net zero ambitions.

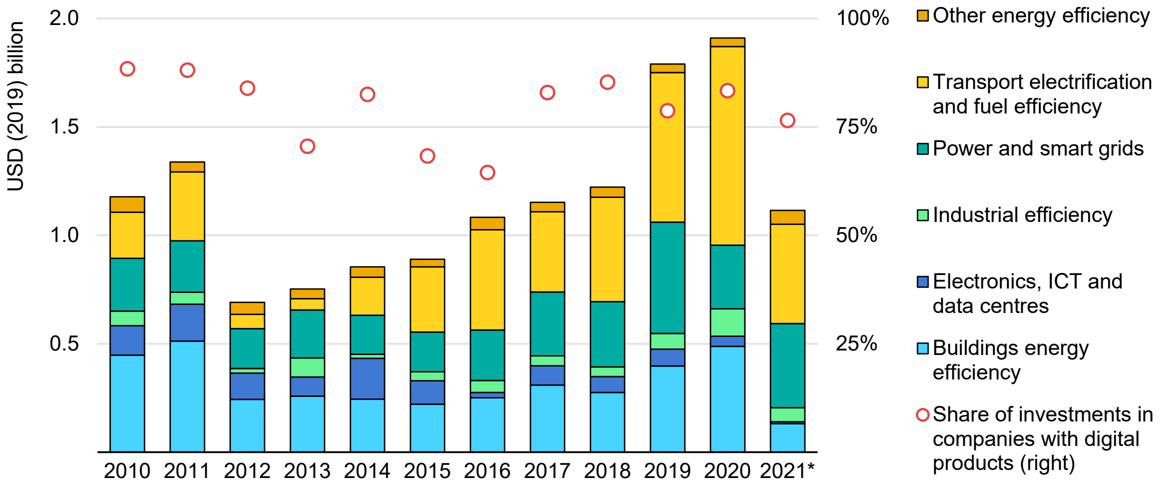
In 2020, early-stage investments in companies developing technologies relevant to energy efficiency – such as in buildings, industry, the power sector and smart grids, transport and vehicle electrification – increased by 7% to about USD 1.9 billion, a new high for the last ten years.

The increase was mostly due to greater investments in electric mobility start-ups, which attracted about USD 900 million, illustrating investor interest in this sector. Building efficiency start-ups also attracted strong funding, accounting for about USD 500 million. Although industrial efficiency attracted less money than other end-use sectors, as in previous years – about USD 125 million in 2020 – investments have nearly doubled relative to 2019. Companies developing technologies for power and smart grids raised much less money in 2020 than in 2019, with investments falling back to 2017-2018 levels at about USD 300 million.

Early-stage venture capital investments in energy efficiency start-ups are concentrated in just a few places. Between 2018 and 2020, companies headquartered in the United States attracted 50% of such financing rounds, followed by European (30%) and Chinese companies (7%).

Start-ups often seek to expand their business to overseas markets as they grow, but this process is uncertain and lengthy. As a result, there are still significant opportunities for entrepreneurs in many countries where few innovative energy efficiency companies exist, especially in emerging and developing economies. In some instances, companies may seek to replicate or adapt successful technology concepts or business models developed elsewhere. Proven concepts and business models typically lower the perceived risk for investors, especially when emerging products or solutions are readily available through international trade.

Global early-stage venture capital investments in clean energy start-ups active in fields of energy efficiency, by technology area, 2010-2021



Notes: Buildings energy efficiency includes building envelopes, heating and cooling, energy management systems, lighting and smart devices for residential and commercial buildings. ICT refers to information and communication technology products not otherwise included in buildings-related technologies. Early-stage investments include seed, series A and B financing rounds. The figure excludes outlier investments of above USD 150 million in a single deal that distort annual trends. These aggregated to about USD 400 million in 2010, USD 2.2 billion in 2016, USD 850 million in 2017, USD 5.7 billion in 2018, USD 1.0 billion in 2019, USD 350 million in 2020 and USD 3.3 billion in 2021, the bulk of which took place in transport electrification. The share of investments in digital companies is calculated excluding transport companies, as shared mobility and other digital-based technologies and solutions are typically excluded from the sample. 2021*: Preliminary data to mid-July 2021 are included.

Source: IEA analysis based on Cleantech Group, i3 database.

Covid-19 is changing energy use in buildings

The way building and energy use patterns have changed during Covid-19 has been greatly affected by the timing of local lockdowns, restrictions on in-person activities and the number of occupants allowed in buildings.

The trend to work at home – requiring energy for daytime comfort in homes – continues. For countries reopening workplaces there is likely a growth in energy demand in office buildings but not necessarily a corresponding reduction in residential demand.

Reopening strategies vary greatly across the world and global building energy demand will continue to be shaped by local conditions. In Korea, non-residential energy demand fell by 5% for electricity and 11% for gas. In Spain, electricity consumption decreased during lockdown by 13.5% (compared with the previous three years), with larger midday plateaus. In Brazil, public administrative buildings showed a 38% reduction in energy use during lockdown, and elementary and nursery schools showed a 50% reduction.

Many employees expect that hybrid and remote working arrangements will become more normal. For example, 44% of UK employees expect to work in the office three days or fewer, with this expectation strongest among younger employees.

A recently released study by the Building Owners and Managers Association International showed that building users expect that the average number of full-time office workers will decrease from 70% before the pandemic to 43% over the next 12-18 months, but that only a quarter of the workforce will seek to telework full-time or most of the time. It also found that only 37% of building and business managers expected to need to reassess their need for space, despite the uncertainty in workplace requirements.

Adding to future working patterns, expectations around safety protocols and ventilation will see buildings requiring potentially longer hours for cleaning schedules and more energy dedicated to facilitating high levels of air exchange and thermal comfort expectations. Other issues include more segmented work shifts and breaks, demand for more space for work areas and congregation space, and new circulation protocols.

The ventilation rate in a building is now seen as a key parameter in managing and mitigating the risk of Covid-19 transmission in indoor spaces. Different buildings require a range of treatments and air flow rates to reflect their varying requirements for fresh air and thermal comfort. Public spaces and high-risk environments require greater levels of fresh air flow and air conditioning.

Increased ventilation raises buildings' energy consumption

Guidance to building managers that they should improve their ventilation to reduce Covid-19 transmission does not on the whole specify expected ventilation rates. Typically, office ventilation systems have been designed to deliver a ventilation rate of 10 litres per second per person (l/s/person). A high internal air quality scenario is 15 l/s/person. Moving from 10 l/s to 15 l/s would increase the sensible heat needed to maintain a thermally acceptable environment by 50%, or 240 kWh per person. Given that the European Union estimates that non-residential buildings use 250 kWh/m^2, this additional energy use represents 10% increase in the total energy consumption of a representative non-residential building in a city such as London.

However, some have suggested that in response to the Covid-19 threat the air change rate should increase by up to ten times, which would have substantially larger implications for the thermal load and energy consumption of a building than the 10% increase estimated above.

As well as protecting against Covid-19, increased ventilation rates have a range of other benefits. For example, pre-pandemic, it was shown that increasing office ventilation rates from 8 l/s/person to 15 l/s/person could provide a USD 37 billion economic benefit in the United States due to factors such as increased productivity and lower incidence of sick building syndrome.

The US Centers for Disease Control and Prevention recommend opening windows, using fans to increase airflow, and reducing or eliminating recirculation of air through heating, cooling and air conditioning systems. The UK-based Chartered Institution of Building Service Engineers recommends that mechanical ventilation systems should be run at a higher volume flow-rate, with recirculation avoided as much as possible, and identifies poorly ventilated spaces as a route for airborne transmission. The American Society of Heating, Refrigerating and Air-Conditioning Engineers recommends running heating, cooling and air conditioning systems for longer, even continuously, and increasing filtration.

Heat pump deployment is ramping up, supported by electrification policies

Heat pumps are a key technology to increase efficiency and phase out the use of fossil fuels for space heating and other end uses. The number of installed heat pumps has grown by 10% per year over the last five years to reach 180 million in use in 2020. In the Net Zero Emissions by 2050 Scenario, the stock of installed heat pumps reaches 600 million by 2030.

Nearly 20 million households purchased heat pumps in 2019, with demand centred in the major heating markets of Europe, North America and the colder parts of Asia. In Europe, heat pump sales increased by around 7% to 1.7 million units in 2020, and heat pumps now heat 6% of all buildings. In 2020, heat pumps overtook gas to become the most common heating technology in newly built homes in Germany. This brought the estimated stock of heat pumps in Europe to nearly 14.86 million units.

In the United States, spending on residential heat pumps increased by 7% from 2019 to USD 16.5 billion with heat pumps representing around 40% of heating systems installed in new single-family houses completed between 2014 and 2020. In new multi-family homes, heat pumps are the most common technology used. In the Asia-Pacific region, investment in heat pumps rose by 8% in 2020.

The push to make heat pumps the standard heating appliance in building energy codes is an important part of accelerating technology adoption. For example:

- The California building energy code will make highly efficient electric heat pumps the baseline technology for code compliance from 2023, with new home builders facing more stringent energy performance measures if a heat pump is not installed.
- Massachusetts has also adopted a higher performance and all-electric standard for its Stretch Code, acknowledging the critical role of heat pumps in meeting advanced energy efficiency levels.
- Many jurisdictions in the United States continue to focus on electrification using building codes. For example, Seattle has announced a widespread ban on fossil fuel heating for new construction, along with requirements for electrification, through the Seattle Energy Code.
- Ireland's plan to install 600 000 heat pumps by 2030 includes an installation grant of up to 30% of the eligible costs and ongoing support, including a goal to replace 400 000 old and inefficient boilers.
- The United Kingdom has put forward a Heat and Buildings Strategy and aims to install more than 600 000 heat pumps per year by 2028 – an ambitious target that will rely on both fiscal incentives and regulatory phase- out of fossil fuel boilers.
- New York State has also committed USD 454 million through to 2025 to increase the uptake of heat pumps for residential and commercial properties to support its target of achieving net zero by 2050.
- British Columbia offers 0% interest loans for switching from fossil fuel heating systems to heat pumps.

Utility-based programmes that target customers with information and incentives have also been effective at increasing adoption. For example:

- The Efficiency Maine Trust has installed more than 60 000 units since 2013 assisted by heat pump programmes and a recent doubling of demand during the Covid-19 pandemic as people sought to improve both thermal comfort and system performance at home.
- In Canada, the New Brunswick utility Énergie NB Power has also recently set its standard for the New Home Energy Savings Programme as requiring to be electrically heated by electric heat pumps, boilers or furnaces.

- Since January 2020, the Victorian Energy Upgrades programme in Australia has supported over 20 000 upgrades to replace electric resistance water heaters with efficient heat pumps.

Despite these improvements in major markets, heat pumps only meet 7% of global building heating demand. To scale-up the adoption of heat pumps, policies could encourage the availability of quality products and support the capacity of skilled labour to install systems. Improving the energy efficiency of building envelopes is also a major factor to consider alongside heat pump installation to ensure that systems are effective at heating homes and are not oversized.

As economy recovers, supply chain pressures threaten to dilute energy efficiency impact

The economic recovery in 2021 has increased demand for commodities and put pressure on supply chains, creating shortages and bottlenecks in everything from basic construction materials through to semiconductor chips used in electronics and vehicles. Shortages have pushed up prices, increasing the costs of construction projects and appliances that are critical for improving energy efficiency, and potentially diluting the energy efficiency impact of every dollar spent.

While low interest rates and government recovery spending helped to avert the worst effects of the Covid-19 economic downturn, concerns are emerging that they will exacerbate supply constraints in the economy. There is also strong debate over the degree to which cost pressures represent a temporary post-Covid-19 bump in inflation or a more long-term structural phenomenon.

One of the most affected sectors is of supreme importance for energy efficiency progress: construction. While lockdown restrictions have curbed construction activity in some jurisdictions, elsewhere construction has been deemed an essential sector. As one of the world's largest employers, construction directly accounts for around 8% of global jobs and has strong links with other sectors.

For example, the return to growth in global construction has put pressure on supply chains in some markets as rising costs and shortages of some materials, labour and skills constrain activity. As investment ramps up, such pressures will need to be watched closely to ensure quality is maintained and building code implementation rigorously enforced.

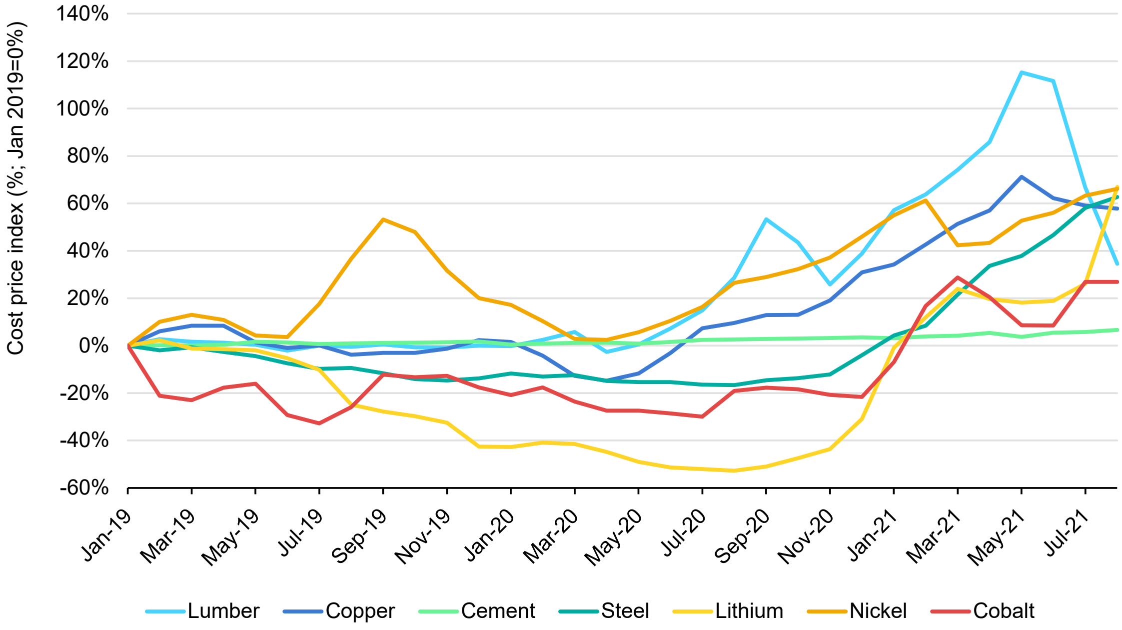
The impact of Covid-19 on the supply and demand of construction goods and services is greatly affected by local market conditions. These include a backlog in construction projects, restricted availability and increasing costs of contractors and skilled labour, trade restrictions and border closures, and shifting health and safety protocols and laws for construction sites. A divergence has also appeared between residential construction demand, which has recovered in many markets, and non-residential demand, which is still depressed.

For example, in the second quarter of 2021 lumber prices in the United States were 120% higher than in January 2019 due to sawmill disruptions, bushfires and an increased demand for home renovation and home construction. While they have since fallen, the high cost of lumber purchased during this period of high prices will continue to be passed on to construction projects for some time. Steel prices in August 2021 were 63% higher than in January 2019. Cement has risen more moderately, by 7% from pre-Covid-19 levels.

In Sweden, the construction cost index for materials transport and contractors' costs in May 2021 increased by an average of 7% from a year earlier, while labour and wages increased by 12.6%. In the United Kingdom, the construction industry is expanding at the fastest pace in 24 years. A survey of contractors showed continued supply constraints for cement, electrical components, timber, steel and paints and several UK firms cited shortages of materials and components as their primary constraint over the next year.

Copper is an important component of electric motors. After falling 15% at the start of the Covid-19 crisis in April 2020, prices had risen 71% by May 2021.

Price indices for key commodities linked to construction and efficient equipment, January 2019-August 2021



Sources: Cement, lumber, steel: Bureau of Labor Statistics (Data for the US market); copper, nickel, cobalt: IMF Primary Commodity Prices (Data for the global market); lithium: Bloomberg Lithium Carbonate 99% Min China (Data for the global market).

In its report on critical minerals, the IEA has highlighted the potential of a mismatch emerging between the world's strengthened climate ambitions and the availability of minerals essential to realising those ambitions. Batteries require three main metals – lithium, nickel and cobalt – which make up over 30% of electric vehicle costs. An indicator for a potential mismatch are prices for those commodities. For example, between January 2021 and August 2021 prices rose by 66% for lithium and 27% for cobalt. The price of nickel was also up by 66% between May 2020 and August 2021.

Another key supply chain pressure has been the semiconductor chip market, with factories struggling to meet demand since the end of 2020. These devices are used widely in electrical vehicles and a range of electrical appliances. Year-on-year price increases ranged up to 50% for some types of chips in August 2021. The supply shortage has caused car makers around the world to decrease production. It is estimated that the chip shortage will lead to a reduction of 7.7 million car sales in 2021, with revenue losses of USD 210 billion.

Another indicator of supply chain pressures has been shipping costs, which have risen almost 400% over the last year because of Covid-19 restrictions and other disruptions. The increase in container freight rates is pushing up product prices for bulk commodities and manufactured goods used in construction. Rising shipping costs are also an indicator of the supply chain stress experienced in some markets in getting access to materials and equipment needed to complete construction projects on time.

Chapter 2. Energy efficiency and net zero by 2050

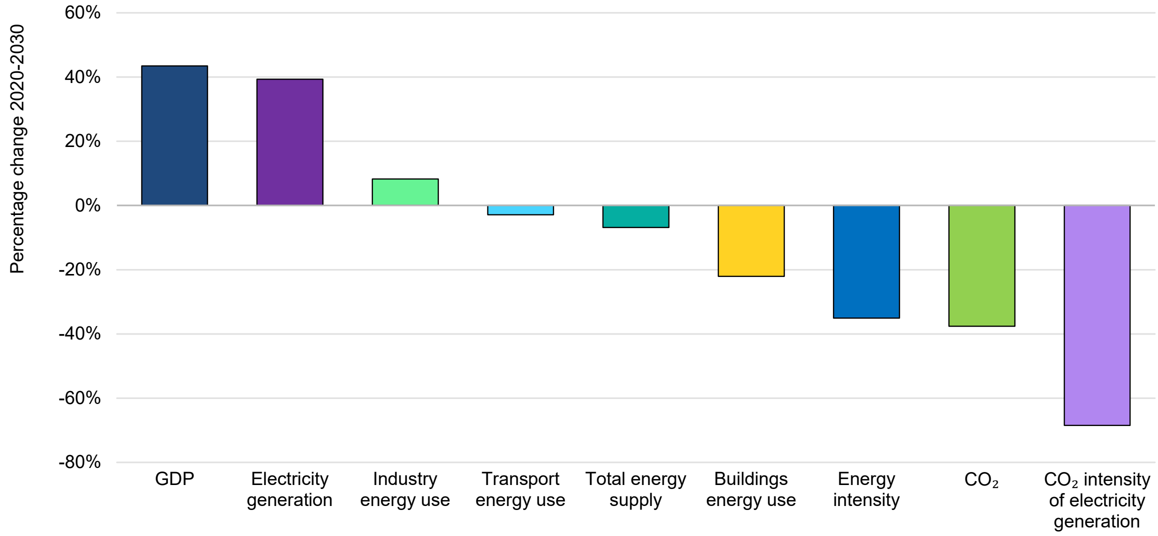
2.1 The role of energy efficiency in net zero

The world could be one-third more efficient by 2030

In the IEA Net Zero Emissions by 2050 Scenario, energy efficiency is the key factor that enables growth in clean energy sources to outpace growing demand for energy services. In the scenario, the global economy grows by 40% by 2030, driven by higher populations and rising incomes, yet it uses 7% less primary energy.

In the scenario, the world becomes one-third more energy-efficient, with primary energy intensity falling by 35%, equivalent to an annual improvement of 4% per year to 2030. To deliver this result, a massive and unprecedented transition towards greater energy efficiency in buildings, transport and industry is needed.

Macroeconomic and energy indicators in the IEA Net Zero Emissions by 2050 Scenario, 2020-2030



Notes: GDP = USD 2019 billion, purchasing power parity; buildings, transport and industry energy use: total final energy consumption; energy intensity = total energy supply/GDP. CO_2 = emissions from fuel combustion and industrial processes.
Source: Analysis based on IEA (2021), Net Zero by 2050.

This transition will also require a broadening of energy efficiency's role through digitally enabled, grid-integrated technologies such as smart meters, appliances and devices. Such advances are essential to provide the power system flexibility needed to support higher deployment of variable renewable energy sources.

To enable the transition, the electrification of transport, building heat and lower-temperature heat in industry will be important. Electrical equipment is not only generally much more efficient but also offers the potential to be powered with renewable energy sources. For example, electric heat pumps are three to four times more efficient than fossil fuel-powered boilers and electric vehicles can be more efficient on a well-to-wheel basis, if powered with renewable energy.

The electricity sector is currently the largest source of CO_2 emissions, accounting for 41% of the 34 Gt CO_2 emitted worldwide in 2020, with about 70% of these emissions coming from coal-fired power stations. In the Net Zero Emissions by 2050 Scenario, electricity generation rises by almost 40% to account for increasing electrification of end uses such as transport and heat.

In the scenario, this large increase in power generation takes place as final energy consumption slowly declines by 6% over the decade then from 2030 stabilises at that level. This result is achieved through efficiency measures, the electrification of transport and heat, and behavioural change.

The scenario envisages that policy and technology measures in the buildings sector will enable immediate and rapid improvements in the energy efficiency of buildings, particularly from large-scale retrofit programmes that comply with zero carbon ready building standards. As a result, total final energy consumption falls in the buildings sector by 22% by 2030 even as the number of households globally rises by 15% and the average floor area expands by 22% for households and 18% for commercial buildings.

For transport, energy efficiency, electrification and behaviour change measures enable final energy consumption to fall by 3% by 2030. This occurs even though 11% more car passenger kilometres and 26% more plane passenger kilometres are travelled and 48% more tonne kilometres are moved by truck and 43% by ship.

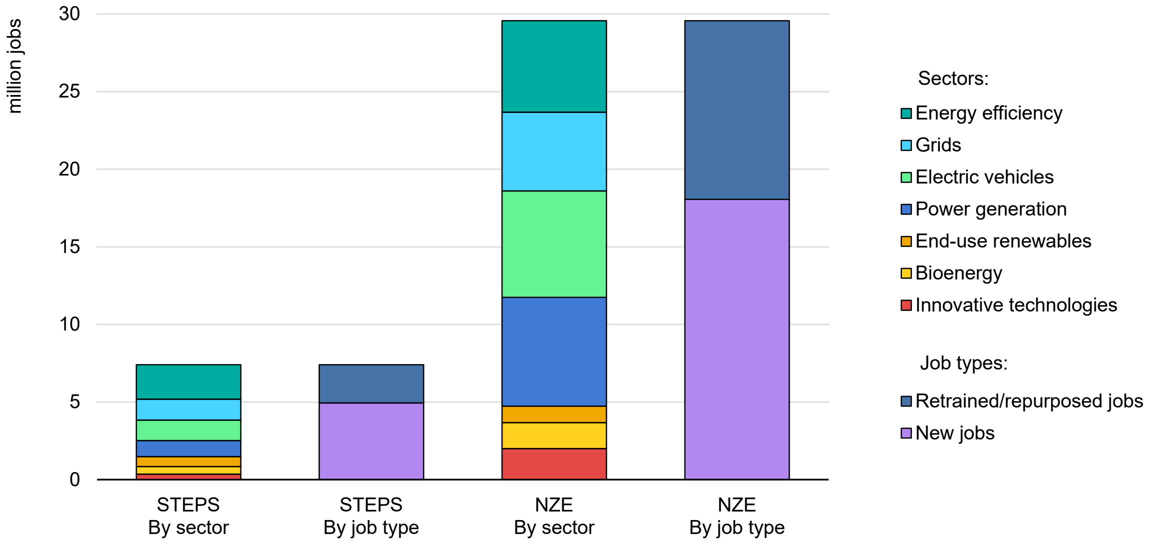
Only industrial energy consumption rises by 2030 in the IEA Net Zero Emissions by 2050 Scenario, by around 8%. Even so, substantial progress in material and energy efficiency enables the global economy to produce an extra 9% of steel, 21% of petrochemicals and 5% of cement per year in the year 2030 compared with 2020.

Without the contribution of energy efficiency, electrification and behavioural change, total final energy consumption would be around 30% higher in 2030. Energy efficiency and behavioural change in buildings and transport provide around two-thirds of these savings to 2030.

Enhanced investment in energy efficiency can create nearly 6 million jobs by 2030

A major benefit of a more efficient energy system in the IEA Net Zero Emissions by 2050 Scenario is the job creation potential of increased spending on more efficient appliances, vehicles, building retrofits and new construction. When taking into account announced policies currently being implemented, energy efficiency provides more than 2 million additional jobs by 2030, more than any other clean energy technology. In the Net Zero Emissions by 2050 Scenario employment opportunities are almost three times larger at 6 million additional jobs.

New workers in clean energy and related sectors and shares by sector and job type in the Net Zero Emissions by 2050 Scenario (NZE) and the Stated Policies Scenario (STEPS) in 2030



Source: Analysis based on IEA (2021), World Energy Outlook.

Many of these jobs will be based in the construction and manufacturing sectors and will be able to draw on a pool of already skilled labour. However, the scale of the investment required will likely require expanded participation in the labour force to meet the increased demands of new building and manufacturing activity. Some specific training is likely to be required for more complex tasks such as installing heat pump instead of conventional boilers. Governments can help the labour force gain such skills by facilitating training or sponsoring energy efficiency programmes that provide reskilling and upskilling opportunities.

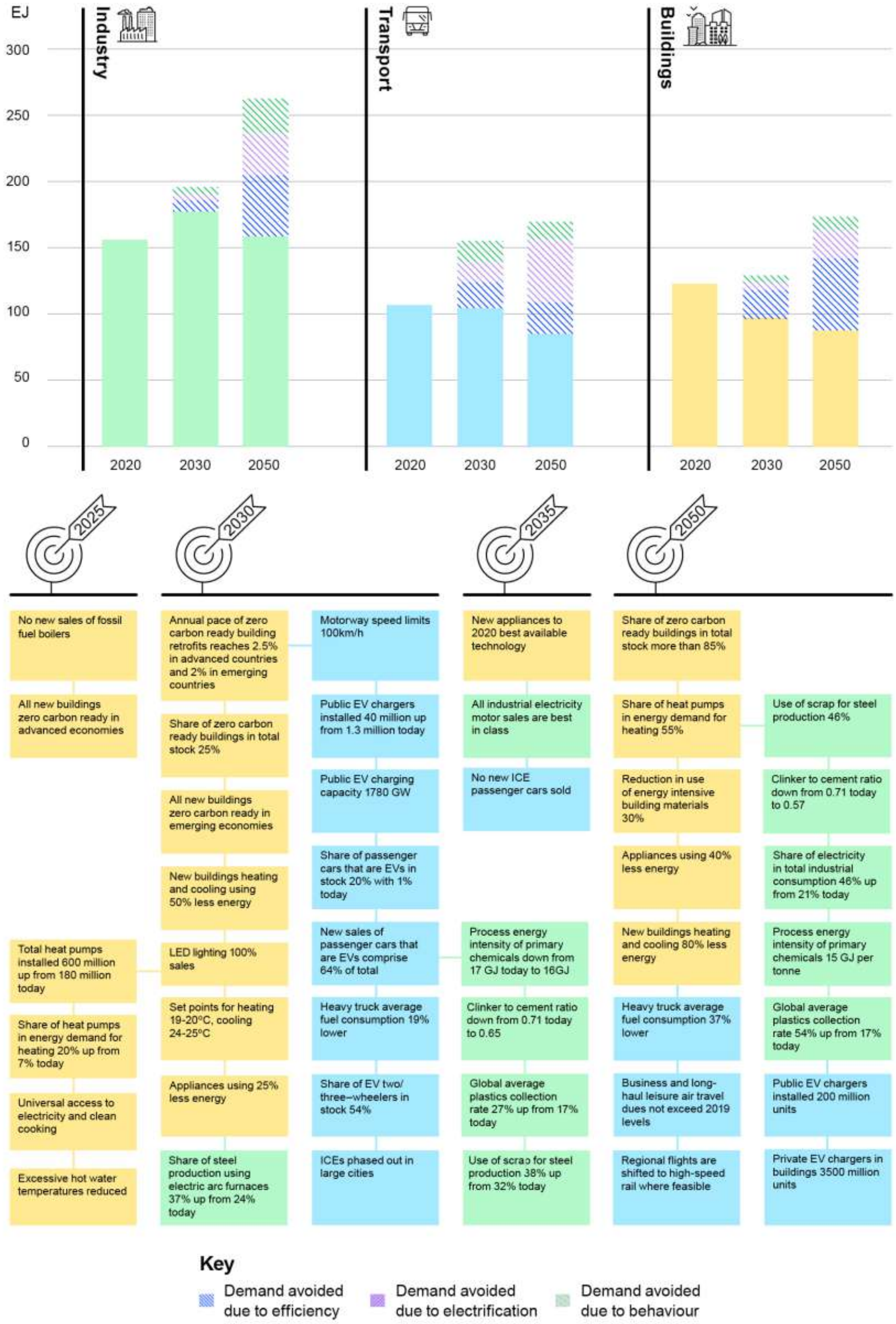
Over 40 energy efficiency milestones identified

The Net Zero Emissions by 2050 Scenario involves more than 40 energy efficiency milestones that incorporate technologically mature solutions that can be put into effect today and scaled up very quickly. Around 80% of the additional energy efficiency gains in the scenario over the next decade result in cost savings to consumers, lowering energy bills and helping to cushion the effects of unexpected spikes in sometimes volatile energy prices. Because of this, energy efficiency is frontloaded into the policy mix in the Net Zero Emissions by 2050 Scenario.

The contribution of energy efficiency and associated measures to avoided energy demand in the Net Zero Emissions by 2050 Scenario is well within the scope of comparable scenarios from the Intergovernmental Panel on Climate Change (IPCC). These scenarios, in the IPCC's special report Global Warming of 1.5°C, have at least a 50% chance of limiting the average rise of global temperatures in 2100 to 1.5°C, and achieve net zero energy sector and industrial process CO_2 emissions by 2050.

Total final energy consumption in 2050 in the IPCC scenarios ranges from 300 exajoules (EJ) to 550 EJ, compared with around 410 EJ in 2020. The Net Zero Emissions by 2050 Scenario foresees final energy consumption of 340 EJ in 2050. While governments could still achieve climate targets with less energy efficiency than in the Net Zero Emissions by 2050 Scenario, they would need to ensure much wider deployment of other clean energy solutions that are more expensive.

Energy Efficiency Net Zero Emissions by 2050 Scenario milestones, 2020-2050



Notes: EV = electric vehicle. ICE = internal combustion engine vehicle.
Source: Analysis based on IEA (2021), Net Zero by 2050.

2.2 Appliances

Standards have helped halve the energy consumption of key appliances in the longest-running programmes

Electricity generation is currently the largest source of energy-related CO_2 emissions, accounting for 41% of the 34 Gt CO_2 emitted worldwide in 2020. In 2021, global electricity demand is set to increase by close to 5%. A rise of this magnitude means that, despite record additions, renewable energy supply cannot keep up. This has resulted in increasing calls on fossil fuels and rising CO_2 emissions from the electricity sector, which are set to rise by 3.5% in 2021.

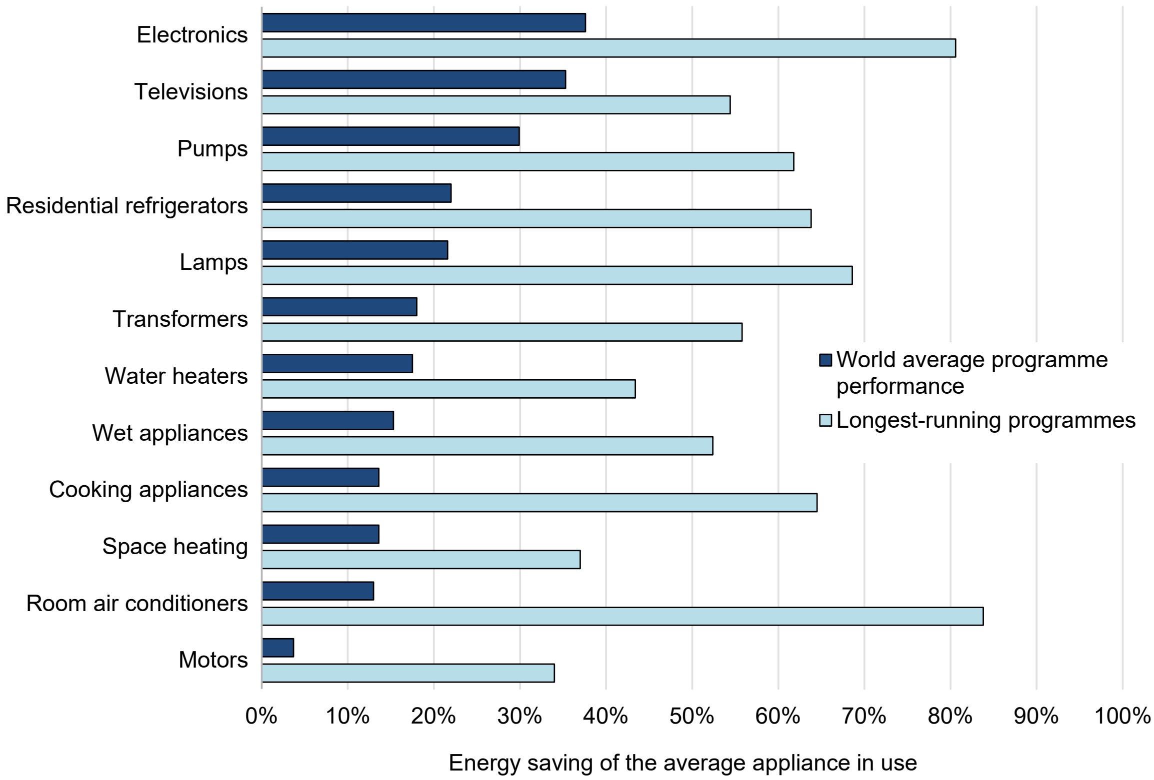
More than 40% of this electricity energy consumption is for just four end uses – industrial electric motor systems, air conditioners, refrigeration and lighting. These four uses also contribute over 5 Gt of CO_2 emissions a year – roughly equal to the United States' current total CO_2 emissions. This underscores just how important energy efficiency standards and labels can be to slow electricity demand growth and allow renewable energy to replace fossil fuels, rather than just going towards meeting the need for higher electricity demand.

Levels of ownership and use of such appliances are set to grow as the world gets wealthier, warmer, more urbanised and populous. For example, global energy demand for cooling could triple between 2020 and 2050 as air conditioning becomes more affordable to greater numbers of people in emerging economies.

Long-running appliance efficiency policies have helped to halve the average energy consumption of many common appliances in use such as refrigerators, air conditioners, lighting, televisions, washing machines and cooking appliances. These huge gains have been achieved even as the price of these appliances has fallen by an average of 2% to 3% per year, suggesting that more stringent policy settings could curb CO_2 emissions further while still benefiting consumers. For example, in the United States the energy-efficient standards and labels programme is producing net annual fuel savings of around USD 40 billion in 2020 or a reduction in the average annual household fuel bill of USD 320.

Minimum energy performance standards, for example, set a threshold for energy efficiency for specific products sold in a market. Energy labels, meanwhile, help consumers to choose more efficient products. In the Net Zero Emissions by 2050 Scenario, by 2025 around 80% of all appliances and air conditioners sold in advanced economies are using today's best available technologies, with emerging economies meeting this milestone in 2030.

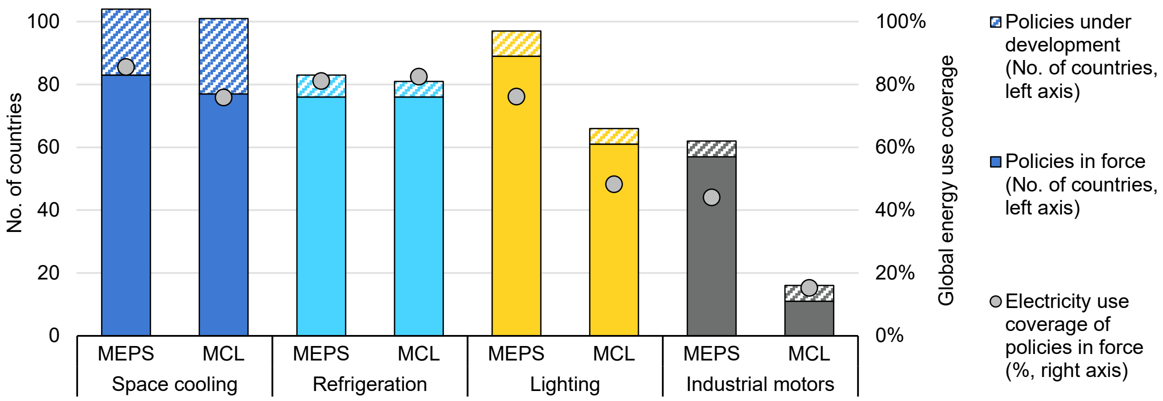
Energy savings from energy efficiency standards and labels over life of programmes



Notes: Longer-running programmes (more than 20 years) with stronger standards deliver more savings as there is more time for inefficient appliances and equipment to be replaced and for programmes to significantly lower the average stock energy consumption of that appliance class. Electronic devices include: external power supply units, monitors, DVD/VCR units and other personal electronics.
Source: IEA and 4E TCP.

Together, energy efficiency standards and labelling programmes have been cornerstones of many countries' energy efficiency policy for several decades. More than 100 countries currently use mandatory energy efficiency standards or labels for air conditioners, refrigeration, lighting or industrial motors with another 20 countries having such programmes currently under development. While a considerable number of countries across all regions have implemented mandatory appliance standards and labels, significantly fewer industrial electric motors are covered by minimum energy performance standards. For example, over 80% of global energy use for air conditioners and refrigerators is currently covered by minimum energy performance standards, compared with less than half of the energy use for industrial motors. A range of additional standards and labelling schemes are currently under development, for example in East and Southern Africa, but standards are still absent in a range of markets where growth in ownership of air conditioners and other appliances is fastest.

Global coverage of mandatory minimum energy performance standards and mandatory comparative labels, 2021



Notes: Coverage for space cooling, refrigeration and lighting is shown for residential sectors. Global electricity use coverage is shown by end-use. MEPS = Minimum energy performance standards. MCL = Mandatory comparative labels.

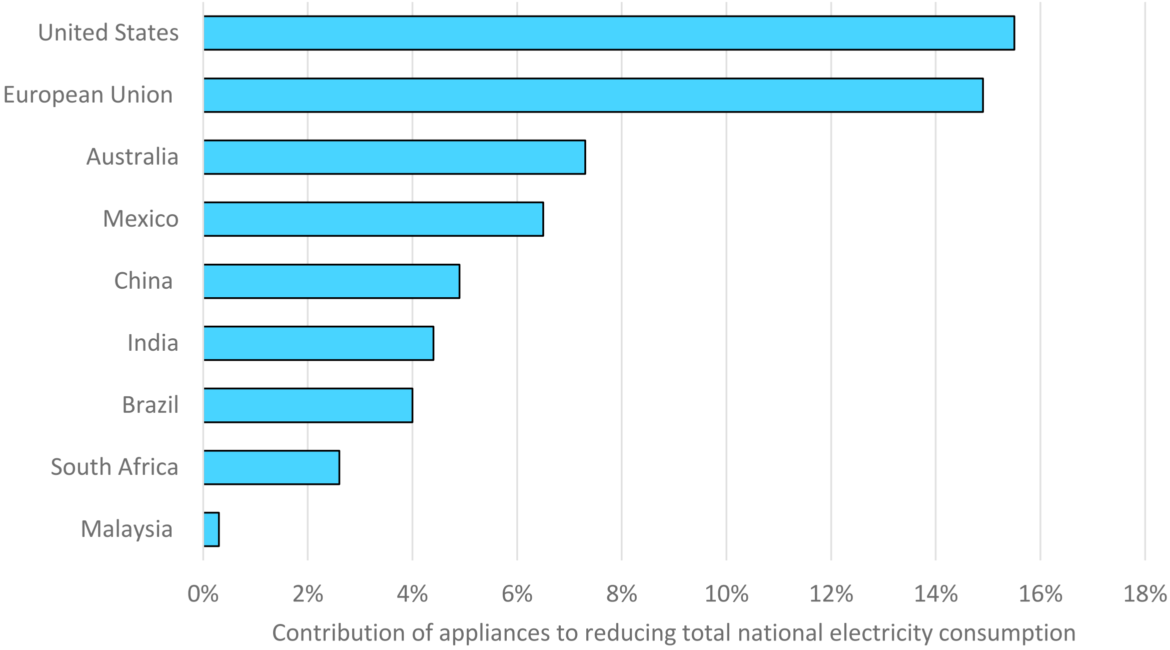
Avoiding electricity consumption equivalent to total wind and solar power generation

When designed and implemented well, standards and labelling programmes increase efficiency in highly cost-effective ways. A recent assessment by the IEA and 4E Technology Collaboration Programme showed that in 2018, in the nine countries or regions for which there were data, including China, the European Union and the United States, standards and labelling saved over 1 500 TWh of electricity consumption. This is equivalent to the total electricity generation of wind and solar energy in those jurisdictions during that year.

Because these products account for a significant proportion of total electricity use, making them more efficient can rein in total electricity demand. The countries with the longest history of applying minimum energy performance standards have achieved electricity savings of around 15% of total electricity consumption per year and reduced national energy-related CO_2 emissions by 7-10%. Savings increase each year as older, less efficient stock is replaced with equipment that meets higher efficiency standards.

If a similar 15% improvement had been achieved by all countries, a reduction of current electricity consumption in the order of 3 500 TWh per year could have been achieved in 2020 – roughly equivalent to cutting China's current total electricity consumption in half.

Impact of energy efficiency standards and labelling programmes in selected countries and regions, 2018



Notes: Electricity consumption savings are calculated relative to the commencement of programmes in those countries. Longer-running programmes yield higher energy savings as a greater proportion of appliances in use are covered. Data for Japan and India under development.
Source: IEA and 4E TCP.

Countries are coming together to deliver higher ambition

The Super-Efficient Equipment and Appliance Deployment (SEAD) Initiative is a collaboration between over 20 governments, the IEA and other partners to accelerate and strengthen the design and implementation of energy efficiency policies for appliances and equipment – particularly lighting, industrial motor systems, air conditioning and refrigeration. SEAD is working with member countries and partners to provide knowledge and tools to improve policy, raise awareness about the importance of high-efficiency appliances, identify energy-saving technologies and offer technical expertise.

In November 2021, the IEA and the COP26 presidency launched the COP26 Product Efficiency Call to Action to double the efficiency of key appliances and help countries raise ambition more quickly, more easily and at lower cost. G7 leaders had previously welcomed the Call to Action at the 2021 G7 Summit in Cornwall. The objectives of the Call to Action are to:

1. Set countries on a trajectory to double the efficiency of key products sold globally by 2030 – industrial motor systems, general lighting service lamps, residential air conditioners and residential refrigerator/freezers.

2. Support the delivery of national climate change targets.
3. Provide consumers and businesses with more efficient products that are affordable and cost-effective to own and operate.
4. Stimulate innovation and provide businesses with export opportunities.
5. Promote a dual course of action making products both energy-efficient and climate-friendly by reducing the use of refrigerants in cooling appliances

The IEA is developing a simple tool to help countries improve the ambition of appliance efficiency policy: the energy performance ladder. The ladder brings together different appliance efficiency policies under a single consistent set of performance thresholds. SEAD is working with member countries to support the use of the ladder to increase efficiency ambition across a greater number of markets. The initiative also aims to promote new digital tools and business models to improve the efficiency of key appliances and unlock the wider system benefits they present.

2.3 Buildings

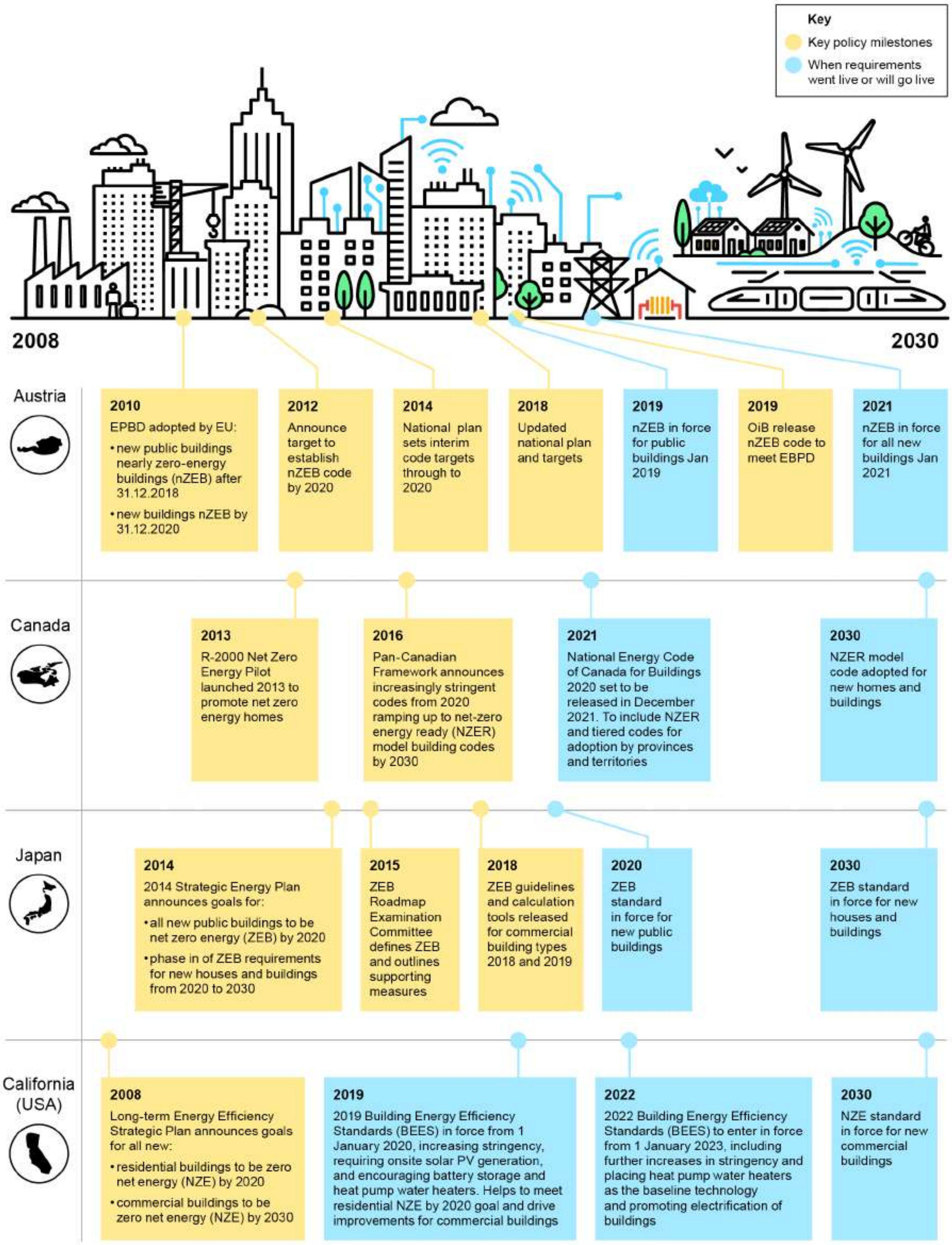
Efficiency in buildings can deliver the largest share of avoided energy consumption to 2030

In the IEA Net Zero Emissions by 2050 Scenario, it is expected that building floor area equivalent to that of the city of Paris is added every week globally between 2020 and 2050, 80% of which is in emerging market and developing economies. In advanced economies a more developed building stock means that fewer new buildings are needed with half of all existing buildings expected to still be standing in 2050.

In the scenario, retrofit rates for buildings to a "zero carbon ready" standard – that will be fully decarbonised by 2050 without any further changes to the building or its equipment – reach about 2.5% a year by 2030 in advanced economies and 2% a year by 2030 in emerging economies. In addition, the scenario includes a milestone that all new buildings constructed from 2030 are zero carbon ready. Building energy codes are the central policy mechanism to meet this goal. However, only 5% of new buildings constructed globally currently meet this standard.

Based on analysis of four jurisdictions, shown below, it has sometimes taken from six to 22 years from the announcement of such a goal to develop and implement the relevant building energy code. This suggests that to develop a zero carbon ready building code that comes into force by 2030 – and the necessary supporting policies, tools and capacity building measures – a one- to three-year window currently exists. Existing policy cycles for building code updates are also an important factor; they can range from two to five years.

Selected timelines for zero carbon ready building codes, from target announcement to codes coming into force



Jurisdictions without mandatory building energy codes face a greater challenge, as they need not only to develop codes but also to establish the necessary tools, training and compliance systems, and material supply chains across the buildings and construction sector.

Electrification of space and water heating: the vital role of heat pumps

One of the most important ways to enhance efficiency and decarbonise buildings is to switch water and space heating from using fossil fuel-fired boilers and furnaces to using electricity. Heat pumps, direct electric heaters and electric boilers are already in use in several countries, though are often more expensive than using natural gas. Heat pumps are the keystone technology for electrifying space heating in the Net Zero Emissions by 2050 Scenario, with global sales averaging over 3 million units per month by 2030 in the scenario, up from around 1.6 million today.

The United Kingdom plans to phase out the sale of gas-fired boilers as part of plans for implementing zero carbon ready building standards. In many countries in the European Union, including France, bans on sales of oil and gas boilers will come into force in the coming years. In Ireland, installation of oil boilers in new buildings will be banned from 2022, and gas boilers from 2025. Such policies are being supported in many countries with funding for building retrofits in Covid-19 recovery plans.

The Netherlands has introduced plans to deploy up to 2 million heat pumps by 2030 and will include subsidies to encourage installation of 100 000 heat pumps per year from 2024. In 2020, Norway distributed subsidies through the ENOVA programme to over 2 300 households and is focusing on increasing the market for high-temperature heat pumps for district heating systems.

To support the adoption of heat pumps, an important consideration is to ensure the building envelope is as efficient as possible by upgrading insulation and installing efficient windows. These measures help avoid unnecessarily oversizing heat pump systems, improving their effectiveness at heating homes and reducing energy demand required as well as their upfront and operational costs.

Effective policies to deploy heat pumps can take into account factors such as: incentives through public grants and energy pricing, standards for buildings to require net zero emissions and regulatory targets for phasing out installation of fossil fuel heating systems.

Targeting technology advances in heat pump development, such as increasing availability and reducing cost of plug-and-play heat pumps on standard residential voltage and low-amperage systems, is also an important consideration. Reducing the size of compressors and improving performance in very cold climates are areas for development.

Behavioural change in building use also plays an important role in achieving milestones in the Net Zero Emissions by 2050 Scenario. These include changing heating set points to 19-20°C and cooling set points to 24-25°C and reducing water heating set points by 10°C to avoid excessive temperatures. Such measures contribute to help reduce CO_2 emissions by almost 250 Mt CO_2 by 2030 in the Net Zero Emissions by 2050 Scenario.

Shifting to zero carbon ready buildings, as in the Net Zero Emissions by 2050 Scenario, brings numerous benefits. Such buildings can boost comfort, health and productivity. Enhancing insulation, glazing, weatherproofing and ventilation provides major improvements to thermal comfort, humidity levels, noise levels and air quality. For example, educational performance has been shown to improve by 2.9% for every 100 lux of better lighting and by 2.3% for every 1ºC reduction in overheating (above 28ºC). In healthcare settings, renovations and energy efficiency upgrades to hospitals and care rooms helped contribute to an 11% reduction in average length of stay.

In emerging economies, lowering financing costs can advance access, clean energy and efficiency

In emerging and developing economies, the population of urban areas is expected to grow by almost 2 billion by 2050. At the same time around 790 million people worldwide still did not have access to electricity in 2020, most of them living in sub-Saharan Africa and developing Asia. Around 2.6 billion people do not have access to clean cooking options such as electric cookers.

To support the Net Zero Emissions by 2050 Scenario, special attention to overcome barriers to investment in many emerging countries is an important consideration. Such countries are also often more reliant on public sources to finance energy efficiency and projects promoting energy access.

Financing costs are significantly higher in emerging and developing economies than in advanced economies, with nominal financing costs up to seven times higher than in the United States and Europe. This can be a barrier for clean energy projects seeking to raise debt finance and support sustainable development goals.

The construction industry is often composed of small and medium-sized enterprises for which access to finance can be costly and restricted, especially in emerging countries. For tenants, the upfront cost of new and more efficient equipment can often be a significant barrier. Additionally, payment options such as on-bill financing schemes with utilities are less available than in advanced economies.

In India, the Energy Conservation Building Code was updated in 2017 and is progressively becoming mandatory across the country. Since the update, energy intensity has fallen by 7% in new commercial buildings and 8% in residential buildings. The Indian Green Building Council also developed a Net Zero Energy Building Rating system in 2018.

In Colombia, the adoption of a new building code in 2015 and the endorsement of EDGE certification by the chamber of commerce enabled local banks to raise funds for green buildings. This was assisted by the Excellence in Design for Greater Efficiencies certification programme (EDGE) devised by the International Finance Corporation, a part of the World Bank Group. Local banks have issued around USD 260 million in green bonds to fund the construction of EDGE-certified green housing developments and two green office buildings. The green bond issuance was designed to help channel funds into the projects showed how such investment can be securitised and marketed to international investors.

Technical and financial support from international organisations can help emerging and developing economies make the necessary reforms in their financial and energy systems to facilitate clean energy financing. For example, the World Bank has played an important role in promoting China’s energy service company market since 1998 by providing funding and technical assistance, including the setup of a loan guarantee programme.

In 2015, the Mexican government worked with the Inter-American Development Bank and the Clean Technology Fund to launch Energy Savings Insurance (ESI), the first programme to use insurance mechanisms to address energy efficiency project risks. The Mexican government anticipated that ESI would stimulate USD 25 million of investment in 190 energy efficiency projects through 2020. ESI is being demonstrated in seven other Latin American countries, including Brazil, Colombia and Peru. If fully implemented in these seven countries, ESI could drive up to USD 100 billion in investment and reduce emissions by up to 234 Mt CO_2 a year by 2030.

2.4 Transport

Efficiency of all vehicle types needs to be increased as electrification gathers pace

The transport sector accounted for 25% of total final energy consumption in 2020, with emissions down 10% at just over 7 Gt CO_2, compared with 2019 levels, before the Covid-19 pandemic. Oil comprises 90% of transport energy demand. Road transport makes up about 75% of transport demand and emissions.

In the Net Zero Emissions by 2050 Scenario, transport sector energy consumption fall by 3% and emissions by 20% by 2030. This occurs as oil's share of transport demand falls to around 80% by 2030, due to an increase in efficiency across transport modes, including widespread electrification, as well as behavioural changes.

The different transport modes do not decarbonise at the same rate because technology maturity varies markedly between them. CO_2 emissions from two- and three-wheelers almost cease by 2040, followed by cars and vans (light-duty vehicles) and rail in the late 2040s. Emissions from heavy trucks, shipping and aviation fall by an annual average of 6% between 2020 and 2050 and collectively amount to about 0.5 Gt CO_2 in 2050.

Even in the Net Zero Emissions by 2050 Scenario 80% of passenger car stock remains conventionally powered by 2030, underscoring the importance of continuing to improve fuel efficiency of internal combustion engine vehicles.

Nearly 90% of new light-duty and 80% of new heavy-duty vehicles sales are currently covered by fuel economy standards, though under the Net Zero Emissions by 2050 Scenario they become more stringent, helping facilitate the shift to electric vehicles.

In the Net Zero by 2050 scenario, energy efficiency plays the dominant role in delivering energy savings through to 2030, responsible for approximately 50% of avoided demand in the scenario, followed by electrification and behavioural change that contribute around a quarter of avoided energy each. After 2030 electrification plays a steadily greater role, with its contribution rising to around half of avoided energy demand by 2050, with efficiency around 40% and behaviour around 10%.

Shift towards larger vehicles blunts fuel economy gains

Progress on energy efficiency has slowed for cars and vans, with global average fuel consumption improving only 0.9% between 2017 and 2019, compared with an average of 2.6% per year between 2010 and 2015. The slowing of improvements is due to a combination of larger, heavier and higher-powered vehicles, especially SUVs, and slower adoption of more fuel efficient powertrains.

Increasing vehicle weight, power and footprint has offset up to 40% of technical efficiency improvements to fuel economy in the United States, Europe and China, and 17% of the technical efficiency improvements made in India.

Globally, the SUV fleet was on course to exceed 280 million vehicles in 2020, up from less than 50 million in 2010. SUVs consume on average over 20% more energy than a medium-sized car for the same distance travelled.

To meet the Net Zero Emissions by 2020 Scenario, global average fuel consumption of new light-duty vehicles needs to be nearly half the 2020 level by 2030. To help achieve this result, under the Net Zero Emissions by 2050 Scenario, 20% of the passenger car stock will be electric in 2030 and have a market share of 64% of new car sales and 30% of new truck sales.

Financial and other measures can be used to encourage consumers to choose lighter, smaller vehicles over heavier, larger ones. To limit the rise of SUVs, countries such as France and Norway have implemented weight-based taxes on heavier cars. In Japan, incentives that includes lower acquisition and insurance taxes have promoted very small, lightweight vehicles known as kei-cars. Tax rates under the Indonesia's new Low-Carbon Emission Vehicle programme are no longer based on engine capacity alone, but also take engine efficiency and emissions into account. In Berlin, city authorities are currently considering proposals to charge SUV owners as much as USD 590 for annual parking permits, five times more than smaller cars. Similar proposals are being considered in Vancouver.

To phase out new conventional vehicles by 2035, targets for electric cars and vans mount

Electrification of transport plays a central role in the Net Zero Emissions by 2050 Scenario with new sales of internal combustion light vehicles phased out by 2035. Sales of plug-in hybrid, battery-electric and fuel cell electric light-duty vehicles rise, with 350 million such cars and vans on the road in 2030, up from 11 million in 2020.

Two- and three-wheelers lead deployment of electric vehicles, with a target of 85% of new sales by 2030, including widespread deployment in emerging and developing economies. As only 35% of new two- and three-wheelers sales are currently covered by fuel economy standards, increasing attention to the fuel economy of these vehicles is an important area for policy. Other benefits of increasing the efficiency of these vehicles includes improving local air quality and reducing noise.

Specific policy measures to facilitate adoption of electric vehicles are becoming more widely used. For example, the United Kingdom aims to ban the sale of new internal combustion engine cars by 2030. Canada and the European Union have similar targets for 2035, which are aligned with IEA Net Zero Emissions by 2050 Scenario milestones. To complement fuel economy standards, countries can require manufacturers to sell a certain number of electric vehicles as well as setting adoption targets more broadly. Localised schemes also have a role to play, including provision of charging infrastructure and preferential access schemes such as low- or zero-emission zones.

To better understand the system efficiency and greenhouse gas emissions impacts of different vehicle powertrains it is necessary to look beyond vehicle operation at the tailpipe or engine level. This is because electric vehicles, while more efficient to operate, still rely on electricity generated by systems predominantly powered by fossil fuels. For this reason a more complete perspective is provided by well-to-wheel analysis, which assesses the CO_2 emissions incurred in fuel supply and operating the vehicle.

Global average well-to-wheel greenhouse gas emissions intensity, 2019 and 2030

Powertrain	CO_2-eq per kilometre 2019 STEPS	CO_2-eq per kilometre 2030 APS
Gasoline internal combustion engine vehicle	205	130
Diesel internal combustion engine vehicle	180	130
Compressed natural gas internal combustion engine vehicle	180	140
Hybrid electric vehicle	135	100
Plug-in hybrid electric vehicle	105	40

Powertrain	CO_2-eq per kilometre 2019 STEPS	CO_2-eq per kilometre 2030 APS
Battery-electric vehicle	70	30
Fuel cell electric vehicle	130	40

Notes: 2019 based on IEA *World Energy Outlook* Stated Policies Scenario (STEPS), 2030 based on Announced Pledges Scenario (APS). Ranges are based on the WLTC rated performance. Well-to-wheel greenhouse gas carbon intensity across all passenger light-duty vehicles, values rounded for simplicity. Carbon intensity values for fuel cell vehicles reported here are a range between values using electrolytic hydrogen and natural gas steam methane reforming pathways. Carbon intensity values for internal combustion engine vehicles, hybrids and plug-in hybrids include biofuel blending.
Sources: IEA analysis based on IEA (2021), Global Fuel Economy Initiative.

Heavy trucks set to become main source of transport emissions by 2035

Heavy trucks are expected to become the main source of CO_2 emissions from 2035 onwards. In the Net Zero Emissions by 2050 Scenario, the average fuel consumption of internal combustion engine heavy trucks decreases by 19% by 2030 and 37% by 2050.

For heavy trucks, energy savings can be achieved through engine efficiency improvements, hybridisation and light weighting. Electric trucks are coming to market, but the lack of fast-charging infrastructure along long distance freight corridors can be an obstacle for regional and long-haul trucking operations.

As with passenger light-duty vehicles, more stringent targets will be important to achieve climate goals. Significant scope also exists to introduce standards, fiscal measures and incentives in countries where they are yet to be implemented. For example, Switzerland's road tax on diesel truck operations has led to fuel cell truck deployment. In cities, zero- and low-emission zones can also encourage the use of zero emissions trucks.

Rail and behavioural change lead other transport actions

Rail is one of the most energy-efficient and least carbon producing transport modes offering significant energy savings through modal shift. In the Net Zero Emissions by 2050 Scenario, regional flights are replaced by high-speed rail journeys where feasible such as is currently being pursued in France and Austria.

Electrification of rail can further improve efficiency and decarbonisation. Rail currently has an electricity share of around 43% in terms of total energy consumption. In the Net Zero Emissions by 2050 Scenario, the share of electricity increases to 65% by 2030 and 96% by 2050, with a small amount of hydrogen also included. In India, "electrify everything" has become a guiding principle for railways, with 71% or 48 000 kilometres of route in its network connected to electricity. According to the Indian Ministry of Railways, all tracks will be fully electrified by the end of 2023 to help reduce reliance on imported petroleum products, lift energy efficiency and help with the green transition.

Under the Net Zero Emissions by 2050 Scenario, aviation and shipping CO_2 emissions increase to the mid-2020s and then start to fall, though much more slowly than in passenger light-duty vehicles. As with heavy-duty vehicles, efficiency measures are particularly important in the short to medium-term.

As a result of Covid-19 restrictions, CO_2 emissions from aviation have fallen by around one-third to just over 600 Mt in 2020, levels last seen in 1997. Aviation efficiency measures will provide an important way to help reduce energy consumption as flight activity returns. These include fuel efficiency technologies for airframes and engines as well as operational improvements such as air traffic management.

For shipping, efficiency approaches include slow steaming and wind assistance technologies. Shipping currently accounts for around 12% of total transport CO_2 emissions, or 3% of total global energy-related emissions.

In the Net Zero Emissions by 2050 Scenario, behavioural change is an important component of decarbonising transport, helping reduce total transport emissions by 12% by 2030. Behavioural change covers all modes, with a particular emphasis on passenger transport and modal shift to less energy-intensive modes.

Behavioural changes on roads in advanced economies reduce passenger vehicle kilometres by 22% by 2030, facilitated by modal shift to public transport and increased car occupancy, while in emerging and developing economies activity grows by 35%.

For example, fuel economy can be substantially improved by revising speed limits and through eco-driving. The US Department of Energy found that around 22.7 billion litres is wasted annually by heavy-duty and light-duty vehicles idling unnecessarily. Addressing excessive idling for light-duty vehicles alone could avoid around 30 million tonnes of CO_2 annually, equivalent to removing around 5 million cars from the road. In New York City, "warming up" of vehicles is now outlawed. Citizens are able to report unnecessary idling offenders under the Citizens Air Complaint Program. This issue has gained some prominence in North America supported by increasing public awareness activities including the Billy Never Idles campaign, inspired by the 1980s rocker.

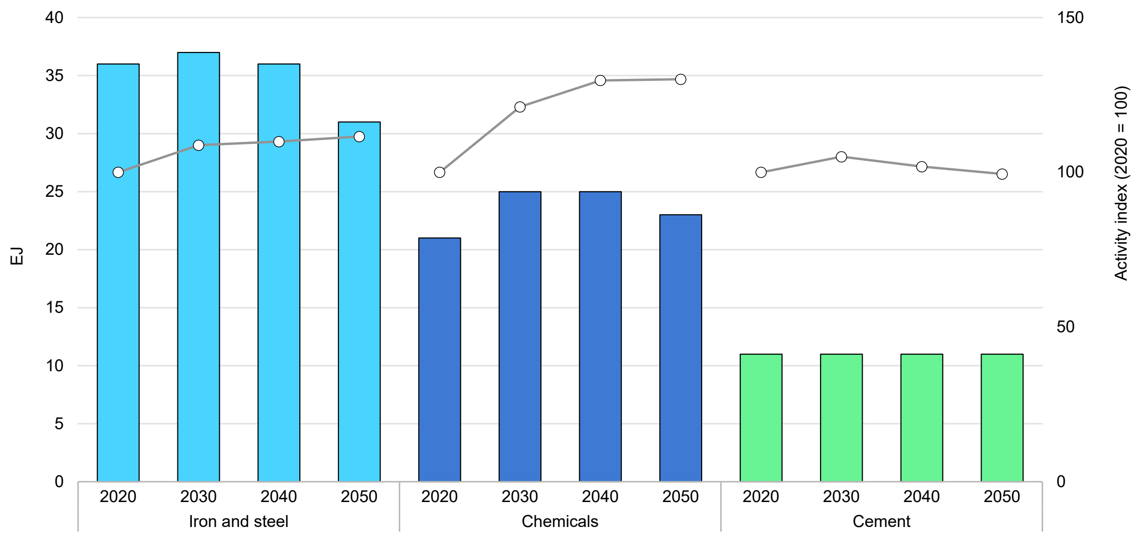
2.5 Industry

Industry is the second largest source of CO_2 emissions after the power sector, with total emissions of around 8.7 Gt CO_2 in 2020. Three heavy industries – chemicals, steel and cement – account for nearly 60% of industrial energy consumption and around 70% of CO_2 emissions.

In the last two decades global demand for these products has grown significantly, rising by 2.1 times for steel, 2.4 times for cement and 1.9 times for plastics, the major product of the chemicals sector. Emerging and developing countries account for 70-90% of the combined output of these commodities, with China alone responsible for almost 60% of global steel and cement production in 2020. In the Net Zero Emissions by 2050 Scenario, output of increases by 9% for steel, 21% for chemicals and 5% for cement by 2030, then mostly levels out. Energy consumption follows a similar path to 2030 then stabilises or falls slightly due to gains in material and energy efficiency.

Without the gains from energy efficiency incorporated in the Net Zero Emissions by 2050 Scenario, industrial energy consumption would increase by 16% by 2030 instead of 8%. In the scenario goals, the energy intensity of industry improves from 4.1 MJ/USD of value added today to 3.1 MJ/USD by 2030 and 1.8 MJ/USD by 2050.

Heavy industry energy consumption and activity in the Net Zero Emissions by 2050 Scenario, 2020-2050



Sources: IEA (2021), Net Zero by 2050. IEA (2021), World Energy Outlook.

Cement sector looks to reduce clinker and favour alternative fuels

The average energy intensity of producing conventional cement is around 3.3 GJ/t and each tonne results in emissions of around 0.7 t CO_2, of which 50-60% comes from clinker production. The remaining emissions originate from combustion of fuels such as coal, gas, oil and petroleum coke. The production of clinker, a binding agent, is the most energy-intensive and emissions-intensive component of cement manufacturing, so a key Net Zero Emissions by 2050 Scenario milestone is a reduction in the clinker-to-cement ratio by 8%, from 0.71 in 2020 to 0.65 in 2030.

Depending on the electricity energy mix employed, cement manufacturing also incurs indirect emissions from electricity production. While cement kilns are conventionally fuelled by fossil fuels, alternative fuels become more and more important in the Net Zero Emissions by 2050 Scenario. These are typically from municipal and industrial waste streams and can contain biomass.

Alternative fuels can serve a dual purpose in cement production. Not only do they deliver energy, but the residual ash can be directly added to the cement output as an organic component.

A range of materials can also be used to replace clinker in cement. These include finely ground limestone and by-products from other industries, such as granulated blast furnace slag from steel production or fly ash from coal-fired power plants. Such by-products will decline, however, as coal-fired power generation is phased out and alternative production methods and recycling rates of steel progress.

Countries can include in their building codes standards for concrete that favour cements with lower clinker content, without compromising safety and performance. Common short- to medium-term methods for reducing emissions include changing from wet to dry production processes and using recovered waste heat to preheat materials.

Increasing the lifespan of buildings can also reduce demand for cement, notably by investing more heavily in building retrofits and energy-efficient construction. Concrete is widely “down cycled” for use in road or foundation beds but could be recycled much more. Uniform concrete structural components could be designed for reuse, for example. Processing used concrete to separate the cement portion from the sand and aggregates can enable its reuse as a low-carbon raw material for cement production.

Cement production in India

As of 2020, India is the world's second largest cement market, both in production and consumption, with 7-8% of global installed capacity. In the third quarter of the 2021 financial year, Indian cement companies were reporting healthy growth in earnings and demand as construction activities resumed after the Covid-19 lockdown. Sales of cement in India stood at around USD 9.05 billion in the 2020 financial year.

India's cement production and consumption has been growing at an annual rate of around 6% in recent years, pushed up by demand for roads, urban infrastructure and buildings, including for new affordable houses. Cement production reached 329 Mt in the 2020 financial year and is expected to increase by over 10% to 381 Mt in the 2022 financial year and reach 550-600 Mt by 2025. The cement industry has an installed capacity of 545 Mt.

According to the Indian Cement Manufacturers' Association the Indian cement sector is on par with Japan's in energy consumption and adoption of green practices. It is the largest consumer of fly ash produced from thermal power plants and consumes 100% of the slag produced by the steel industry, which helps bring down its clinker-to-cement ratio. The industry has improved its use of alternative fuels and raw materials, and has promoted power generation based on waste heat recovery.

HeidelbergCement's Narsingarh plant has started generating power using waste heat from its kiln already in 2016. The installed capacity of the facility amounts to 12 MW. Another 22 MW waste heat recovery unit is planned to be built at the Yerraguntla plant. Moreover, alternative fuels are being used at several of HeidelbergCement's plants in India and investments are under way to further increase the use of local waste streams.

As part of its net zero roadmap Holcim, one of the world's largest cement companies, aims to reduce its scope two emissions – indirect emissions associated with the purchase of electricity, steam, and heat or cooling – by 65% by 2030 relative to 2018. The company is investing USD 108 million in waste heat recovery at six sites in India to reduce emissions by 500 000 t CO_2 per year. The use of waste heat from cement kilns to produce electricity also helps reduce electrical demand from the grid.

Holcim's Indian operations ACC and Ambuja Cement have been replacing clinker with by-product raw materials like fly ash from power plants and slag from steel production. Their operations have a combined clinker factor of 63%, with two ACC cement plants achieving a clinker factor as low as 44%.

Cement production in Turkey

The Turkish cement sector output decreased by 29% from 2019 to 2020 due to the Covid-19 pandemic. In 2020 it recovered somewhat reporting 27% growth, and total cement production of 76.5 million tonnes. In 2020 Turkey also became the world's second largest cement exporter.

Approximately 18% of industrial energy consumption in Turkey takes place in the cement sector. Between 2011 and 2020, a waste heat recovery facility with an installed power of 141.5 MW was commissioned. However, the government estimates that there is still 128.5 MW of such capacity to be developed.

Alternative materials

Cement consumption can also be reduced by using alternative building materials like timber. Timber is one of the oldest construction materials. The technology has also progressed with smaller timber pieces and different glues enabling higher stability and modern coatings increasing fire safety. The heat transmission capabilities of wood are significantly better for energy efficiency than concrete. Due to the carbon binding properties of wood, increased timber usage can turn buildings into carbon sinks. However, with deforestation being a concern, a transformation of construction towards more timber usage requires careful governance.

Timber used as a sustainable material in the Tokyo Olympics

In the Tokyo Olympics 2020, held in 2021, building design using timber was showcased. Japan has long history of using wood for construction. It also has the second largest percentage of forest area relative to its landmass in the world. The communal building at the Olympic village was built entirely out of timber sourced from different areas of Japan. The Japan National Stadium uses timber for the entire facade as well as its interior design, with its foundation based on concrete and steel.

To use less energy, iron and steel sector seeks greater share of scrap

Steel, a key material foundation for economies around the world, is also responsible for 7% of total energy-related CO_2 emissions and 8% of global final energy demand. There are two main production process – primary production using iron ore as its main source of metallic input and secondary production, which is based on scrap.

Conventional steel production involves a coke-powered blast furnace to process the iron ore. The blast furnace produces molten iron, which is then fed into a basic oxygen furnace, often in conjunction with some scrap, which oxygen in injected to lower the carbon content to produce steel. This conventional process makes up around 90% of primary steel production and 70% of overall global steel production. With the highest available efficiency, this process emits 1.8 t CO_2 per tonne of steel.

A newer alternative process is direct reduction electric arc furnace production where higher quality iron ore is melted in an electric arc furnace with oxygen and lime to make steel. Emissions from this method are 0.7 t CO_2 per tonne of steel, less than half of current best available conventional production emissions, when the electricity used is 100% renewable. This process makes up around 28% of global steel production.

Secondary steel production avoids the initial refining step where oxygen needs to be removed from the iron ore, and as a result requires about 80-90% less energy to produce a tonne of steel. However, a key constraint to this method is the availability of scrap produced from the recycling process.

In the Net Zero Emissions by 2050 Scenario, current technologies provide around 85% of the emissions reductions from steel production by 2030. One of the key measures is a major increase in recycling and reusing scrap metal in electric arc furnaces.

In 2019, around 30% of the metallic raw material for steelmaking globally was from recycled steel scrap. The sector has a relatively high recycling rate with approximately 80-90% of steel recycled globally. A major source for recycling is the buildings sector where around 86% of existing steel from building destruction is recycled. Overall, however, demand for steel far exceeds the availability of scrap.

In the Net Zero Emissions by 2050 Scenario, the use of coal for iron and steel production is replaced by electricity via the direct reduction electric arc furnace route using natural gas or electrolysis hydrogen. To enable this change, it is particularly important to increase the scrap recycling rate so that the share of scrap in metal input reaches 40% by 2030. This means recovering more steel from old cars, machinery and appliances.

A pilot project, HYBRIT in Sweden, produced its first batch of emission-free primary steel in August 2021 with a goal to make the technology ready for mass production by 2026.

As in the cement industry, steel can sometimes be replaced by alternative materials, like carbon fibre. While carbon fibre production is not less energy-intensive than steel production, the amount of carbon fibre necessary for the same stability of the end product can be significantly lower.

In the chemicals sector, recycling plastics is key to efficiency

More than one in every eight barrels of oil goes to the petrochemicals sector, to produce more than 173 million tonnes of primary plastics, which are the biggest end-use product in the chemical subsector. Plastics manufacturing has doubled its capacity since 2000 and uses energy for heat and to run machinery, in addition to the non-energy use of oil and gas as feedstock.

Material and energy efficiency are important actions to reduce emissions through to 2030 in the chemical industry. This can be achieved through increased recycling, replacing plastics with biomaterials and using nitrogen fertilisers more efficiently. A switch to producing plastics by using electric steam crackers or electrolysis-based chemical reactions also offers energy efficiency gains and could be powered by renewable energy rather than fossil fuels.

However, only about 14 to 18% of plastic is currently recycled at a global level. The remainder is incinerated (24%) or disposed of in landfills or illegally released into the environment including the oceans. The recycling of plastic also requires energy and transportation. One study recently suggested that virgin plastic requires about 83 MJ/kg of energy while recycled plastic including transport needs requires only 11 MJ/kg.

In light industry, boosting energy efficiency has many benefits

Light industry includes the manufacture of vehicles, machinery, food, timber, textiles and other consumer goods, together with the construction and mining sector. In contrast to heavy industries, most technologies that can decarbonise light industry are ready to deploy. This is because more than 90% of heat demand in light industry is low- and medium-temperature, which can be more easily switched from fossil fuels to more efficient electric processes, especially heat pumps.

As a result, despite having a lower energy footprint, light industry has a higher energy-saving potential than heavy industry, accounting for 70% of total energy savings of the industrial sector. These savings could help manufacturers produce twice as much value for every unit of energy consumed, along with many other benefits, including increasing competitiveness.

Light industries are major sectors of the economy that support a significant proportion of employment opportunities. For example, the textile sector is the second employer in India, behind agriculture, and employs mainly women. Improving its competitiveness with energy efficiency can trigger job creation by increasing the profitability of the sector. Job creation in turn can empower women and help to lower women's unemployment. Boosting energy efficiency has numerous other benefits, including reducing demand for other resources, such as water.

Textiles in India

In 2020, the IEA through its Energy Efficiency in Emerging Economies programme worked with the Indian government to develop an energy efficiency policy package for medium-sized textile companies. Carried out in partnership with the Bureau of Energy Efficiency, this work identified processes with the largest energy-saving potential at national level through comprehensive reviews, surveys, interviews and audits of the spinning (yarn manufacture), weaving (power loom) and wet processing (dyeing) industry.

The Indian spinning industry counts about 52 million spindles. Electricity accounts for 12 to 15% of the overall cost. The main energy consumer is the ring frame machine. The highest energy savings potential was identified for high-speed ring frame machines; invertors for suction motors; and energy-efficient motors.

The weaving industry counts about 2.8 million power looms, mostly small scale while the processing industry (dyeing) is highly energy and water intensive. Energy comprises around 16% to 20% of overall costs. The project identified key policies to overcome barriers towards the implementation of energy-efficient technologies in these industries, developed in cooperation with stakeholders and government.

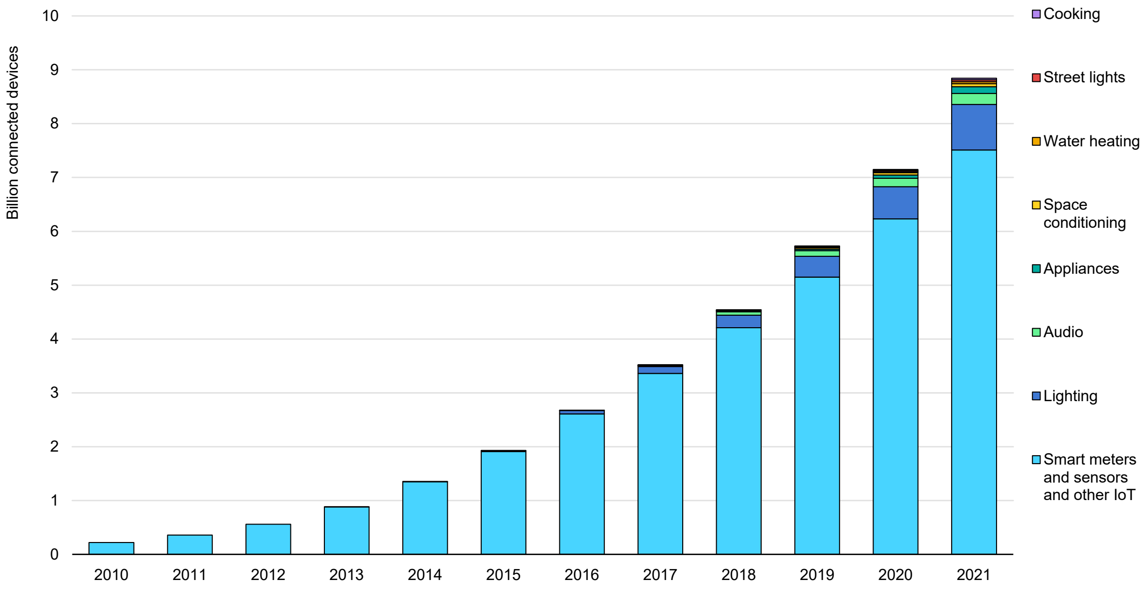
Chapter 3. Digital energy efficiency markets

3.1 Expanding the energy efficiency resource

The extent of digital deployment is now reshaping the scale of energy efficiency possibilities

In 2021 the number of connected devices with automated controls – appliances, devices and sensors – is expected to overtake the number of people on the planet. Over the last five years the deployment of such devices grew by around 33% per year to reach 9 billion in 2021, up from 7 billion the year before.

Stock of connected appliances, devices and sensors, 2010-2021



Notes: Estimate from 2020 onwards. IoT = internet of things. This figure does not include information and communications technologies such as personal computers and mobile phones, entertainment devices such as smart TVs and speakers, or security sensors and controls.
Source: EDNA Total Energy Model, Total automated devices.

Most of these devices are devices measuring and collecting data, such as sensors and smart meters. In 2020 these accounted for 87% of devices in the automation sub-category of devices tracked by the Total Energy Model developed by the

Electronic Devices and Networks Annex of the IEA Technology Collaboration Programme on Energy-Efficient End-use Equipment (4E).

Many devices closely related to automation and end-use energy efficiency achieved market take-off in 2018 and are now expanding rapidly. For example, the deployment of connected appliances is expected to double from 2020 to 2021 and the number of smart lighting devices is approaching 1 billion.

Not only are new smart appliances and systems usually more efficient than the older, less efficient appliances that they replace, they also offer the possibility of improved control both at the device and power system levels. This has expanded both the potential energy savings possible from efficient equipment and the value they bring in terms of demand response, flexibility and optimisation provided to the power system.

The rapid uptake of smart meters has helped utilities and other energy efficiency-related businesses to develop new business models. If frameworks are in place to access and utilise data, these devices allow market participants to access meter-based data on electricity consumption from many different locations in real time or close to real time. When linked to displays or home energy management systems, smart meters can provide users with valuable information and control over energy consumption that can help them reduce energy waste.

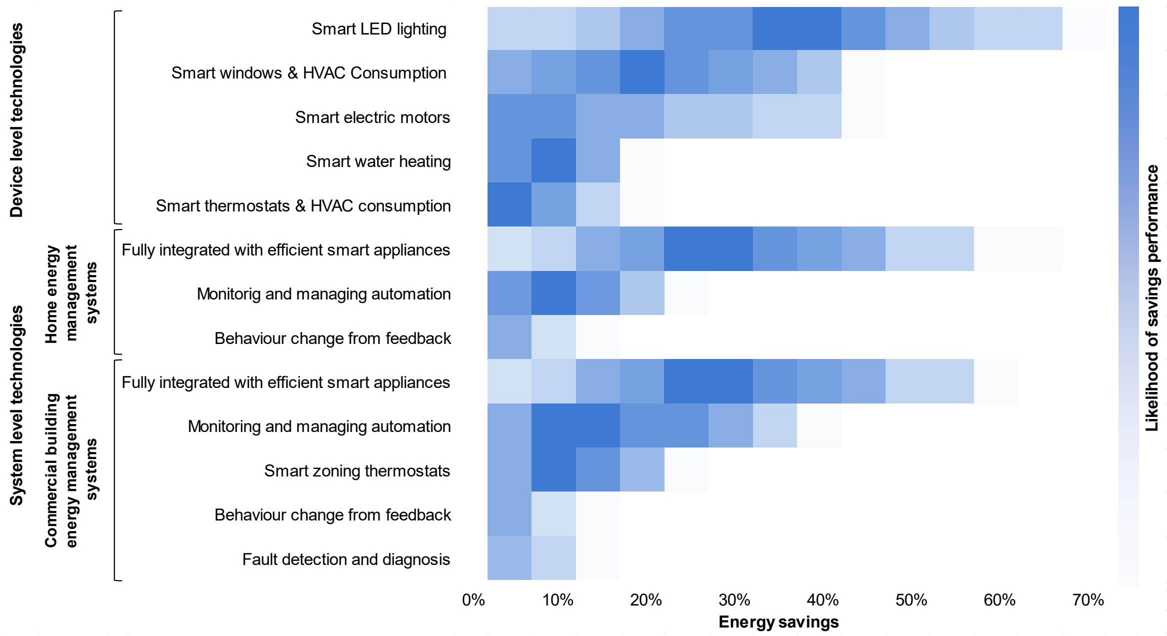
Smart meter deployment is expected to reach nearly 1.3 billion by 2025 from an installed base of 1 billion in 2019, with an estimated market size of USD 17 billion by 2025. Deployment is returning to pre-pandemic levels. In 2021 Enel started rolling out 300 000 smart meters in São Paulo and India announced earmarked funding to install 25 million prepaid smart meters between 2021 and 2023. In April 2021 Saudi Arabia completed the installation and replacement of more than 10 million smart meters in less than 13 months.

Home energy management systems and commercial building energy management systems involve a variety of smart automated appliances, equipment, sensors, controls and software that allow building users or facility managers to monitor and control energy usage. Technologies that can be integrated with such systems include smart thermostats, rooftop solar PV, battery storage, electric vehicle chargers, smart meters, smart appliances, smart plugs and connected lighting.

The home energy management systems market is expected to be valued at USD 7.7 billion by 2025, with smart home device shipments expected to increase by around 100 million over the next decade.

On-the-ground case studies in a range of contexts show that energy management systems and related technologies can help reduce energy consumption significantly. While results vary depending on the context, these case studies highlight how use of such technologies is increasing.

Expanding the scale of energy efficiency with digital devices



Note: HVAC = heating, ventilation and air conditioning.
Source: IEA analysis based on case studies.

Studies in the United States suggest that median energy savings of 11% to 22% are possible in the second year after installation of building energy management systems in commercial buildings. In the US Government Services Administration, 20% of building operating costs could be cut by making the buildings grid-interactive and efficient. In the United Kingdom, energy savings of up to 33% were recorded in family households and possible reductions in energy use of 20% to 30% were estimated by the IEA 4E Technology Collaboration Programme. In India, energy savings of over 55% were achieved in an office building by introducing dynamic chilled water balancing and smart lighting solutions. In Greece, smart zoning of thermostat loads led to energy savings of more than 15% and improved comfort by more than 25%.

At the device level, many smart technologies enable significant changes in energy consumption and costs. Smart water heating has been shown to reduce energy consumption by 12% and energy costs by 35%. Smart lighting in commercial buildings can reduce lighting energy consumption by up to 65% in large open plan offices. Smart windows reduced cooling energy consumption by up to 45% in Singapore. Other smart devices with significant energy savings potential include dishwashers, refrigerators and freezers, clothes washers and dryers, pool pumps, cooling fans and electric vehicle supply equipment.

Smart LED street lighting

Smart LED street lighting, which adjusts output according to light levels, dimming or brightening as needed to adapt to conditions and vehicle flow, can reduce electricity use by 40% to 80%. For example, if no vehicle passes for more than 10 minutes a streetlight can dim by 50%, saving around 15% in lighting electricity demand.

The world's 320 million street lighting poles consume electricity equivalent to the power consumption of Germany, and less than 3% is digitally enabled, so the potential for savings is large. For cities, street lighting can represent around 40% of municipal energy consumption and up to 65% of budgets. In the United Kingdom, street lights are also being used to develop electric vehicle charging infrastructure for motorists who do not have access to off-street parking.

Energy management systems can also provide extra value to grid operation by reducing peak demand and helping consumers to better align consumption with times of variable renewable energy supply.

In the European Union, starting from 2025, building automated control systems will be compulsory in non-residential buildings using cooling or heating equipment consuming over 290 kW at peak, where technically and economically feasible. This measure is estimated to offer energy savings of up to 20% in the commercial sector. The investment is estimated to have a payback period of two to three years with a capital cost of around EUR 30/m^2.

The United States has set a target to triple energy efficiency and flexibility in residential and commercial buildings by 2030 from 2020 levels, and in May 2021 elaborated a roadmap for grid-interactive efficient buildings. Over the next two decades, grid-interactive efficient buildings could save the US power system USD 100-200 billion and help reduce CO_2 emissions by 80 million tonnes per year.

ENERGY STAR certification of connected devices

The United States Environmental Protection Agency's ENERGY STAR is a voluntary programme that promotes energy efficiency using standardised test methods and quantification criteria that help consumers identify devices with superior efficiency. ENERGY STAR includes certification for products with connected functionality and interoperability that offer low energy use, energy use reporting and consumer ownership of all data. The Environmental Protection Agency monitors the smart product market and provides data and operability security specifications to reduce risks, guide manufacturers to common standards and inform consumer choice. Appliances certified by ENERGY STAR can typically provide alerts for energy wasting conditions for instance a refrigerator door left open. They can also provide an ability to communicate with local utilities through a demand response programme (with the permission on consumer) and ensure ultimate control over the product of the consumer, including ability to override utility requests.

In order to support market development, it is key to ensure that home energy management systems enhance user experience and trust in regard to new technologies. A study by the IEA Users TCP and 4E TCP, based on evidence review, focuses on issues related to poor usability and steps to address this.

A key issue for creating market value is interoperability, or the ability of devices to communicate with each other and work in an integrated system. International agencies with initiatives to promote interoperability of connected devices include the International Electrotechnical Commission, International Organization for Standardization and International Telecommunications Union. Measures to overcome interoperability challenges are also being explored by the IEA TCP International Smart Grid Action Network.

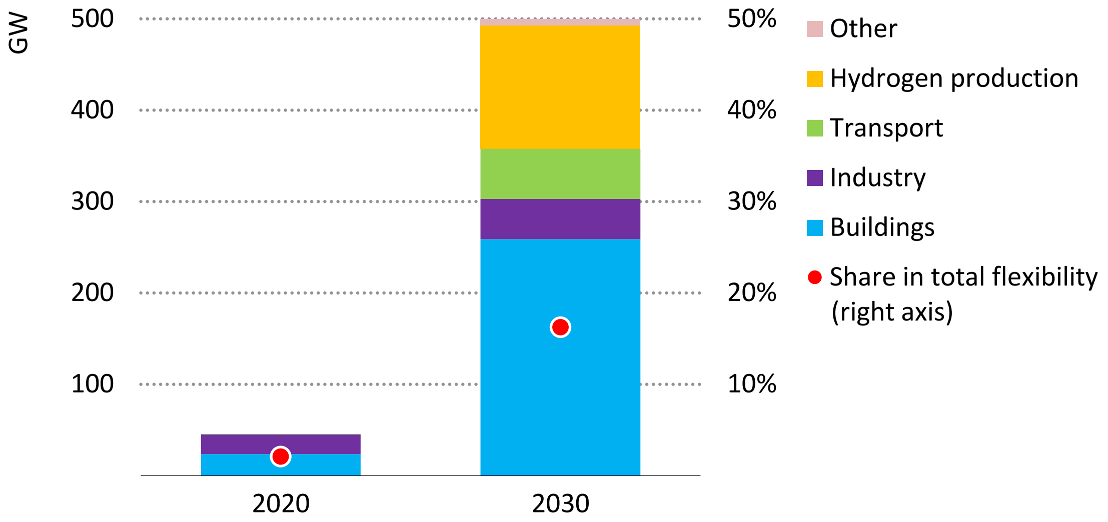
Many jurisdictions, including the European Union, the United Kingdom and the United States, are developing guidelines for connected devices with common features such as the ability to allow devices to participate in demand flexibility. However, the treatment of other features, such as status reporting and open communication protocols, is not always included. The Electronic Devices and Networks Annex of the IEA 4E Technology Collaboration Programme is providing policy guidance in this area to work towards common definitions to support smooth adoption.

3.2 Wider system level benefits

Enhancing power system flexibility and optimisation with new levels of control

As the share of power provided by coal and gas diminishes so does the flexibility capacity they provide to the grid. When combined with a scale-up in variable renewable energy, this means batteries and demand response from efficient connected devices must provide a greater share of flexibility. In 2019, global capacity of all forms of demand-side flexibility expanded 5% year-on-year. In the Net Zero Emissions by 2050 Scenario, more than 500 GW of demand response is brought to market by 2030 to support the power system.

Demand response availability at times of highest flexibility needs and share in total flexibility provision in the Net Zero Emissions by 2050 Scenario, 2020 and 2030



Note: DSR availability in 2020 is estimated based on a review of DSR capacity contracted for deployment in 2020 across capacity, balancing, frequency response and other markets.
Source: IEA (2021), World Energy Outlook.

In the Net Zero Emissions by 2050 Scenario, by 2030 all new buildings become flexible resources for the energy system, using connectivity and automation to manage electricity demand and the operation of energy storage devices, including electric vehicles. In addition, 20% of existing buildings are retrofitted by 2030 and 85% by 2050 with efficient and grid-interactive appliances. This highlights the importance of broadening energy efficiency policies to focus on demand flexibility and intelligent efficiency.

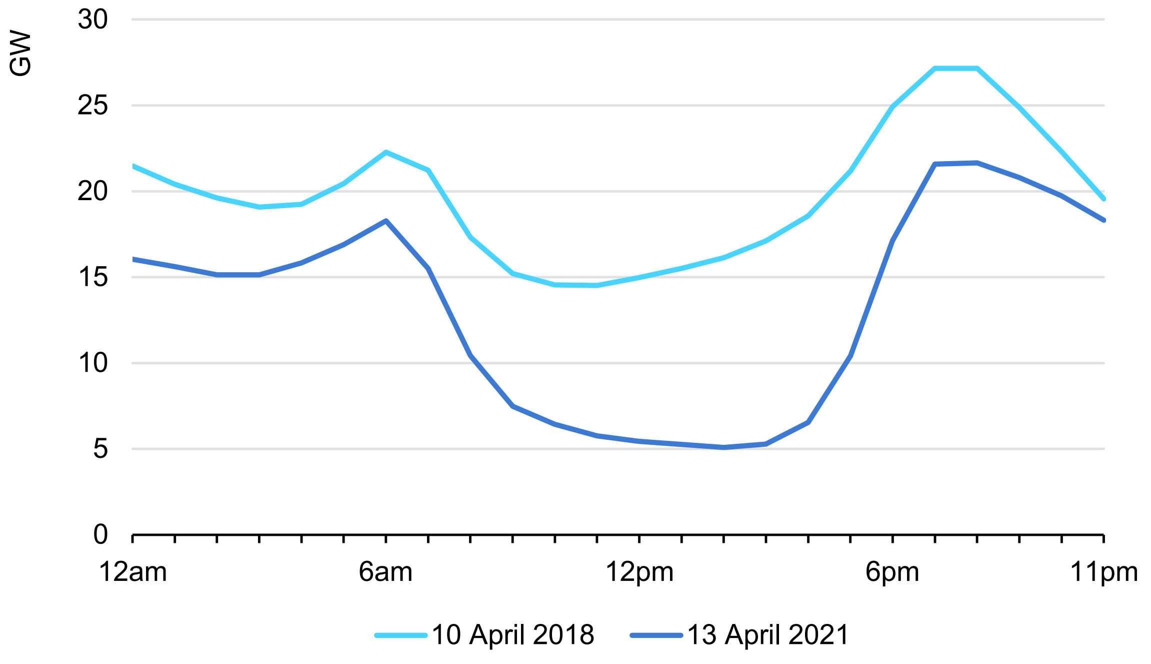
Digital energy efficiency is key to support integration of more variable renewable energy

In 2020, annual renewable energy capacity additions increased 45% to almost 280 GW compared with 2019, including a record-breaking 162 GW of solar PV. In the Net Zero Emissions by 2050 Scenario, solar PV more than quadruples to reach 630 GW by 2030. This growing share of variable renewable energy, coupled with electrification of heat and transport, increase the need for system flexibility.

With some grids now almost wholly supplied by utility-scale variable renewable and residential distributed solar energy resources in the middle of the day, hourly changes in net load and the gap between minimum and peak net load are increasing. This means the value from saving electricity at peak times or shifting demand from peak to off-peak times is becoming greater. Digitally enabled energy-efficient devices and systems have a crucial role to play facilitating these savings and shifts.

For example, energy efficiency is becoming more valuable when it comes to reducing peak loads in the early evening in California. As a greater amount of distributed solar energy is added with generation coming on line in the middle of the day, the drop-off in what has historically been termed a "duck curve" has steepened considerably.

Hourly net load in California, April 2018 and 2021



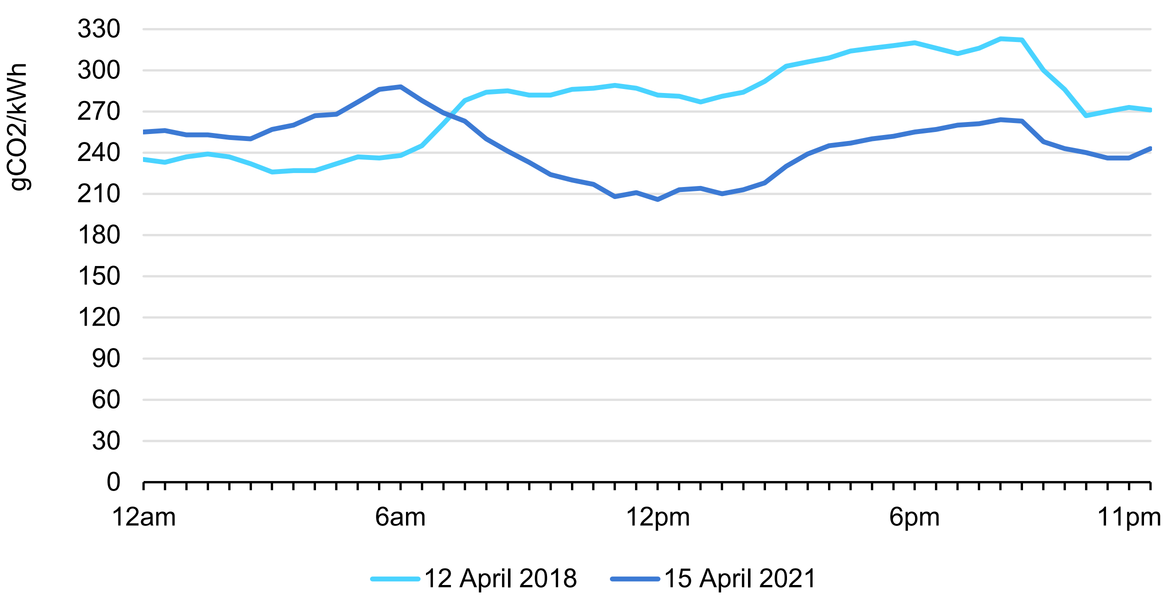
Note: Net load = system demand minus wind and solar generation.
Source: California ISO (2021), Net Demand Trend, www.caiso.com/TodaysOutlook.

The highest net load on 13 April 2021 was 21.6 GW, at 7pm. Five hours before, the net load was at its lowest at 5.1 GW. This means a 16.6 GW ramp-up. On a similar day three years before, the difference was only 12.6 GW, meaning there has been a 32% increase in the ramp-up.

When the share of variable renewables reaches high levels, available electricity supply at a marginal cost of zero can exceed electricity demand. Such a negative net load can result in wholesale prices of electricity that are zero or even negative as power generation must be matched with demand. Without power system flexibility and storage capabilities, renewable energy supply can be forced to work below its maximum capacity to avoid excess supply that cannot be met by demand, or curtailed. This can be a significant source of overall system inefficiency which can increase costs for consumers.

The timing of energy savings from efficient devices also becomes more important as renewable energy penetration increases because the CO_2 intensity of electricity generation changes at different times of the day. For example, the lowest CO_2 intensity of electricity generation in the United Kingdom in April 2021 occurred in the middle of the day, at 206 g CO_2/kWh, increasing to 264 g CO_2/kWh in the evening once fossil fuel generators replaced solar.

Half-hourly carbon intensity in the United Kingdom, April 2018 and April 2021

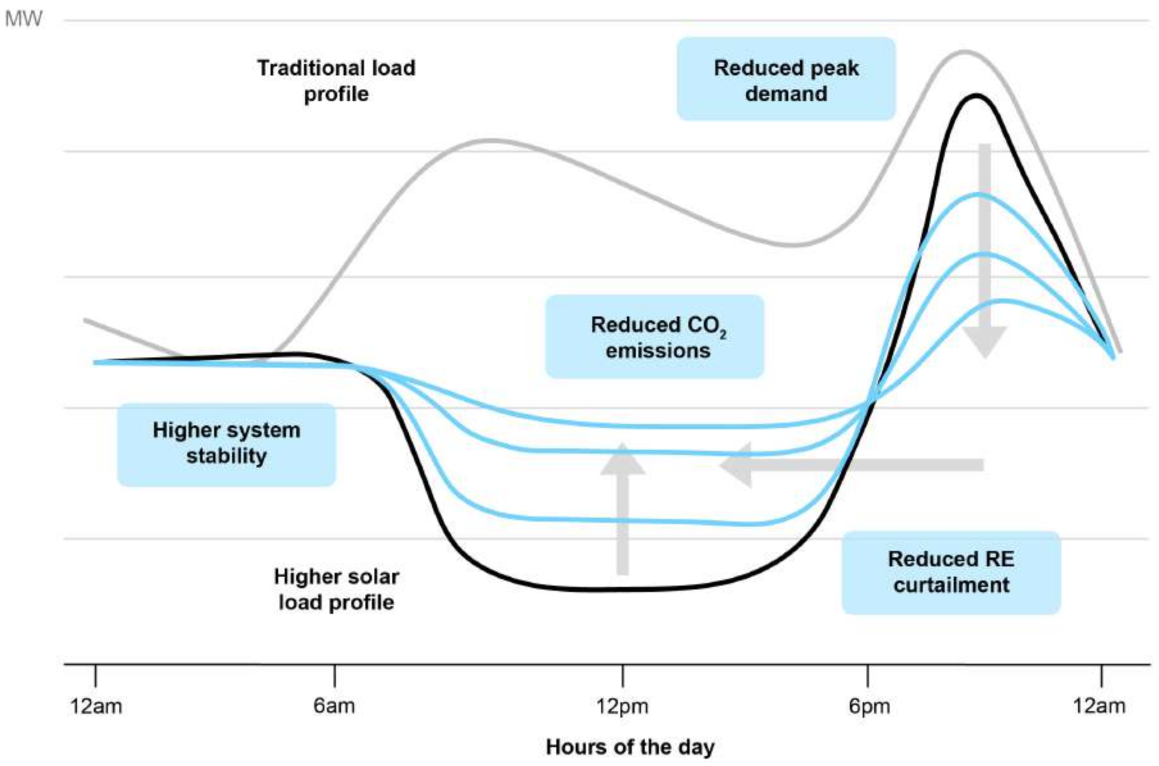


Source: National Grid ESO (2021), Carbon Intensity API.

Increasing the energy efficiency of activities that use electricity when CO_2 intensity is high and renewables low can thus contribute more to reducing carbon emissions. In addition, any demand shifted with digital flexibility to midday reduces emissions, even without reducing energy consumption. With UK carbon prices of around GBP 50 per tonne in the United Kingdom's new carbon trading scheme, and recently reaching EUR 60 per tonne in the European Union Emissions Trading System, it becomes more important to reflect temporal changes to value of energy efficiency by strengthening incentives to save energy in the evening.

Policies that encourage a levelling of the net load curve can help reduce energy costs and greenhouse gas emissions by maximising the use of variable renewable energy. Such policies can also optimise existing generation, transmission and distribution capacity, helping postpone or avoid costly grid reinforcement. An analysis by the Rocky Mountain Institute involving electric water heaters, electric vehicle charging, space heating and cooling, and smart plug loads, found that demand response could not only eliminate the so-called "duck curve" but also halve the daily load range. In addition, it could save a fourth of non-renewable capacity, make renewables one-third more valuable and pay back investment costs in five months.

Benefits from levelling the net load curve with digitally enabled demand response



Note: High solar load profile = net load (system demand minus wind and solar).

A 2021 demand-side management study of the Ngurdoto solar microgrid in the city of Arusha in Tanzania explored the system benefits of demand flexibility on off-grid systems. The study coupled data from smart meters on the microgrid with mathematical modelling based on time-of-use tariffs. It showed that the demand-response strategies of load shifting and load reduction resulted in cost savings of up to 15% for the customer, 31% in peak load, and 5% in overall energy savings.

Recent simulations for New York City show that smart building flexibility could reduce emissions from the power sector by 3% given the current energy mix of renewable energy. With renewable energy expected to increase to 36% by 2030, emissions could be reduced by 10%. A similar study in Europe showed that 2% to 18% of residential sector electricity could be shifted, helping to reduce CO_2 emissions by 1% to 8%, depending on the energy mix in the countries included.

First movers are changing their regulatory approach to capture the total system benefits from efficiency

In recognition of the wider scope of the benefits that digitally enabled energy efficiency is providing, policymakers in some countries are beginning to develop new energy efficiency regulations. These include evaluation metrics that support time-targeted planning and operation as well as incentivising flexible resources such as demand response.

In 2021, California's Public Utility Commission moved to introduce a new metric called total system benefit to provide incentives via its utility energy efficiency programmes. Instead of focusing on cost-effective energy savings measured in kWh, the total system benefit targets the highest total system value of those savings in dollar terms. This recognises that a kWh saved at different times and in different locations can have very different values to the electricity system in terms of lifecycle energy, capacity and emissions reduction benefits.

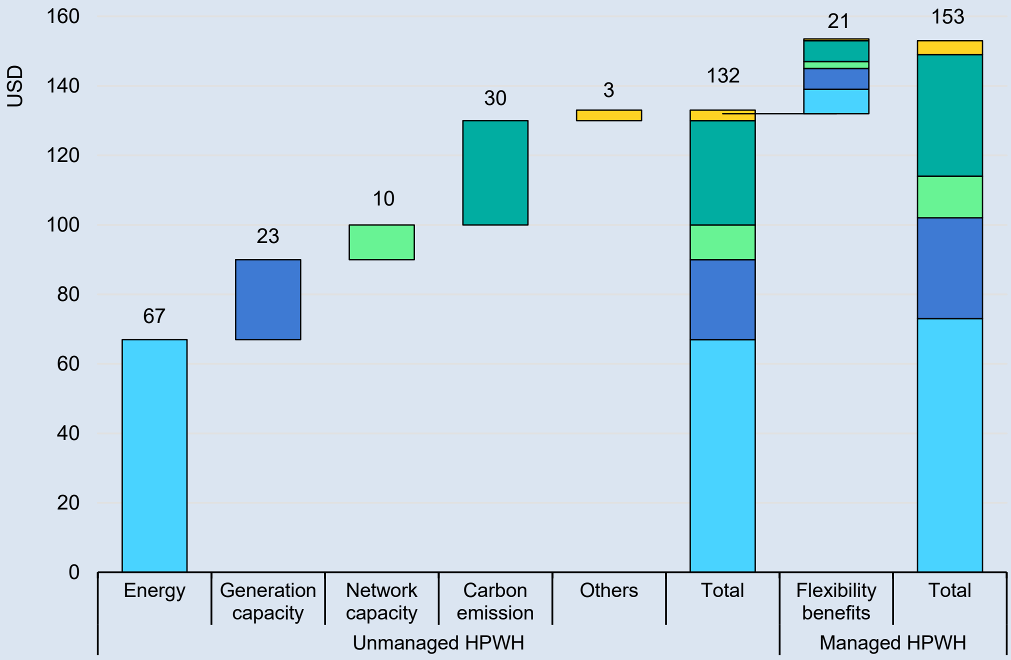
The total system benefit of efficient smart heat pump water heaters

A heat pump water heater can provide more energy than it draws from the network and can manage its power demand when equipped with a smart controller. A smart heat pump water heater is both energy-efficient and flexible, and is an example of an "embedded" integrated approach. Replacing an inefficient electric resistance water heater with a heat pump water heater can thus provide several benefits to the power system.

Heat pump water heaters can save a substantial amount of water heating load in the early morning and evening peak periods, reducing consumer energy bills and grid stress. When equipped with a smart controller, the heat pump water heater can preheat water and shift its evening power demand to match solar generation, reducing additional peak load.

In terms of total system value, an unmanaged heat pump water heater can provide up to USD 132 per year for its useful life of 13 years when it replaces an electric resistance water heater in 2021. This is mostly made up of USD 33 of avoided generation and network capacity costs, USD 30 of avoided carbon emission cost and USD 67 of avoided energy cost. A heat pump water heater managed by a smart controller can save USD 21 more each year by providing flexibility to enable better management of peak generators and assistance with grid services.

Levelised annual total system benefits of a heat pump water heater



Notes: HPWH = heat pump water heater. Energy = avoided generation energy and grid losses costs. Generation capacity = avoided generation capacity cost. Network capacity = avoided transmission and distribution capacity costs. Carbon emission = avoided cap and trade and greenhouse gas adder and rebalancing costs. Others = avoided ancillary services and methane leakage costs. Flexibility benefits = additional avoided costs of the managed HPWH. The annual total system benefits were levelised over the useful life of an HPWH, 13 years, from 2021. The avoided cost calculation was based on input variables of Pacific Gas and Electric Company, on the service territory of which the modelled water heaters were located. The calculation did not include the incremental costs of replacing an electric resistance water heater with a heat pump water heater.

Sources: Calculations based on California Public Utility Commission (2021), 2021 Avoided Cost Calculator Electric Model; data from NRDC, and Ecotope (2018), Heat Pump Water Heater Electric Loading Shifting: A Modelling Study.

Vermont Energy Investment Corporation in the United States implemented energy efficiency measures “time-targeted” to peak hours. Among the measures, LED lights provided benefits that most closely matched Vermont’s winter demand curve by saving both the morning and evening peak demands in winter without significantly reducing off-peak load. LEDs helped reduce steep daily ramp-up needs and flattened Vermont’s load profile. Energy-efficient pool pumps served a similar function in the summer.

The United States elaborated a roadmap for grid-interactive efficient buildings in May 2021. Over the next two decades, grid-interactive efficient buildings could save the US power system USD 100-200 billion and help reduce CO_2 emissions by 80 million tonnes per year.

In the European Union, the Energy Performance of Buildings Directive introduced the Smart Readiness Indicator to assess the capability of buildings to interact digitally with occupants and the grid, and to respond to their needs or signals. More broadly, in 2020 the European Union launched a strategy on energy system integration.

In March 2021, the South Australian government introduced new demand response capability requirements for electric water heaters, air conditioners, pool pump controllers and electric vehicle chargers. The introduction of demand response readiness requirements was found to have benefit-cost ratios of 2.7 for pool pump controllers, 1.5 for electric vehicle chargers, and 2.6 for water heaters and air conditioners.

In Turkey, a 2021 study estimated that digitally enabled smart heating, cooling and electric vehicle charging could reduce peak demand by up to 10 GW in 2030, including 6 GW flexibility from smart space heating and electric vehicle charging alone (for a baseline peak demand of 73 GW). This could provide a net total system benefit, including operational savings and avoided capacity, of EUR 550 million per year by 2030. As part of its overall strategy to reduce primary energy consumption by 14%, the Turkish government has introduced Action E10 of the National Energy Efficiency Action Plan to encourage flexibility in the power system.

In China the demand response market is less mature than in some other countries, but there is great potential following the roll out of 500 million first-generation smart meters, the largest deployment of any country.

3.3 Digitally-enabled business models

New business models have emerged to provide enhanced services

With the rapid diffusion of digital technologies expanding both the scale and scope of energy efficiency benefits, new business models are evolving to tap into these larger markets by finding new ways to deliver value to consumers and energy system operators. One indicator of this is the number of digital energy start-ups, which has been steadily rising, reaching up to 64% of total global energy start-ups in 2020.

In the past, energy efficiency business models have typically revolved around a product- or supply-led focus. As energy supply shifts from centralised systems to decentralised sources of supply with higher electrification and connectivity, business models are now focusing on more user-centred energy services. Traditional utilities, network operators and third parties are seeking ways to take advantage of these trends. For example, one recent analysis found that energy business models related to distributed energy resources and electric mobility could yield USD 8.5 million to USD 10.4 billion (EUR 7.2 million to EUR 8.8 billion) by 2030 across France, Germany, Italy, the Netherlands, Spain and the United Kingdom.

Despite the Covid-19 pandemic, early-stage venture capital investments in clean energy start-ups increased in 2020. When focusing on energy efficiency start-ups that feature new or innovative business models, early-stage venture capital investments have steadily increased since 2016. In 2020, such investments totalled USD 900 million, up 20% from 2019 and nearly three times more than in 2016. Preliminary analysis for the first half of 2021 indicates investment will come in at a similar level as 2020.

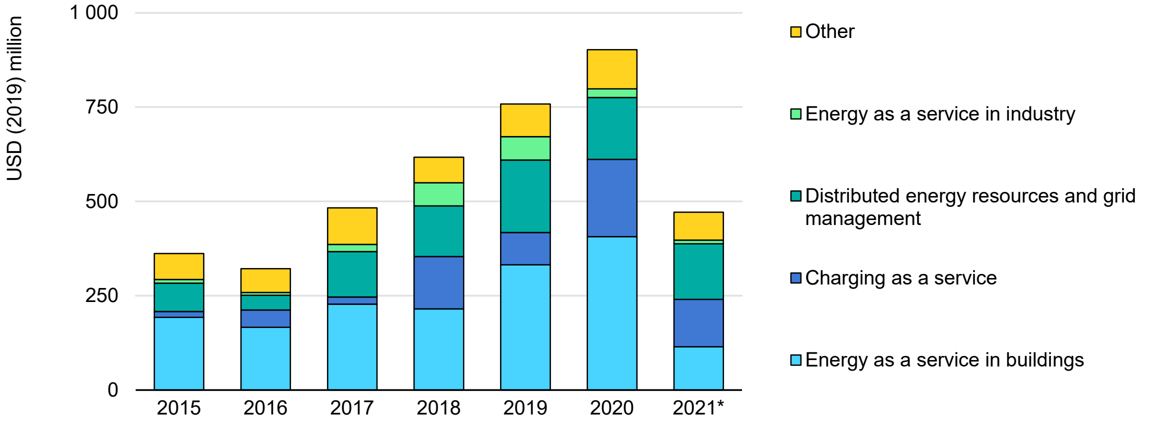
Start-ups are particularly well suited to develop new digital tools and services based on software and advanced techniques including artificial intelligence and big data management due their relatively limited capital costs. Drawing on highly skilled graduates from around the world, they can bring to market digital products quickly before expanding overseas.

In the last decade, excluding transport electrification from the sample, over 75% of the early-stage VC investments in energy efficiency were made in companies developing some digital tools or services as part of their products or solutions. An increasing number of large digital companies such as Google and Tencent are also investing in clean energy start-ups.

Energy as a service (EaaS) schemes in buildings account for the bulk of investments in early-stage companies. Countries that have put in place more ambitious energy efficiency codes have attracted more of this funding. Charging as a service models for electric vehicles are also gaining momentum. For example, the US-based company Volta Charging has quickly scaled up with support from a dozen investors including Schneider Electric. Between 2018 and 2021, it raised over USD 170 million in growth equity.

Early-stage venture capital investments in companies developing solutions for distributed energy resources and grid management have more than doubled since 2015. They account for a smaller share of start-up activity than buildings or electric vehicle charging, however. One example is Gridwiz, a Korean aggregator of flexibility resources that raised about USD 15 million in early-stage financing in 2017, and another USD 40 million in growth equity in 2021.

Global early-stage venture capital investments in energy efficiency start-ups, by type of new business model, 2015-2021 (H1)



Notes: This classification considers start-ups developing energy technologies, services and solutions including both hardware and software and that are engaging with end users directly. Start-ups that focus on manufacturing or distributing hardware only are excluded. Energy as a service in buildings includes smart heating and cooling, energy management systems, lighting and smart devices for residential and commercial buildings, as well as "pay as you go" business models. Distributed energy resources and grid management includes virtual power plants, energy trading schemes including peer to peer, energy as a service for power grids, and off-grid access solutions. Early-stage investments include seed, series A and B financing rounds. The figure excludes outlier investments of above USD 150 million in a single deal that distort annual trends. These aggregated to about USD 350 million in 2020. *Preliminary data up to mid-July 2021 are included.
Source: IEA analysis based on Cleantech Group, i3 database.

Value is being created via digital tools by aggregating energy efficiency benefits, improving integration of electricity demand and supply, and meeting the need to service prosumer and vehicle-to-grid interactions. As new business models transform the roles of customers, utilities and grid operators, it is important that regulations are adapted to provide a clear legal framework for this new technological environment.

Energy as a service business models are helping overcome traditional barriers to efficiency investment

A wide spectrum of energy as a service business models is offering customers packages of energy services in return for subscription-like periodic payments. This market is expanding rapidly. Its compound annual growth rate over the next five years is expected to be 21%, moving towards a market valued at USD 19 billion.

Energy service providers often use performance-based payment contracts, also known as pay for performance, to manage risks and provide incentives to optimise operations. For example, in the United States, Redaptive Inc, in partnership with AT&T, offers retrofits of buildings and implements Internet of Things solutions by employing energy as a service coupled with pay for performance so that customers pay for energy savings as verified by meters. By 2019, the partnership had retrofitted 650 commercial buildings, saving USD 20 million of energy costs per year.

Across 15 European countries, 57% of pay for performance companies that participated in a survey reported growth in their national pay for performance markets, boosted by energy savings guarantees and the public sector. However, around half of survey respondents reported that the complexity of contracts and a lack of trust in service providers were major barriers preventing clients from engaging in pay for performance schemes.

An enabling regulatory environment is vital to foster energy as a service models. Under the European Union's 2019 electricity market directive, for example, energy users can allow third parties to manage the energy systems "required for their activities, including installation, operation, data handling and maintenance".

Energy as a service models are also attracting the interest of heating providers. A recent study showed that although new heating as a service schemes can enhance the energy efficiency of heating systems, customers can lack trust in their effectiveness and there is a need for supportive policies and subsidies. In Ontario, Cascara has further developed the heating as a service concept by coupling it with electricity services, aiming to increase its customers' aggregate energy efficiency by 80%.

Pay as you go is a business model that transfers the ownership of solar and efficient appliances kits, as well as clean cooking solutions, to customers over time through small periodic fees. Such schemes are reaching rural communities with limited energy access and financial resources, helping to improve their standard of living and fostering economic growth. Pay as you go programmes have also been a major contributor to the growth of the off-grid solar sector in recent years. For example, in sub-Saharan Africa, more than 53% of lighting-solar products were sold this way in the second half of 2020. One company, Fenix Intl has provided more than 600 000 households with clean energy, helping to create 3 300 local jobs and enabling people to replace kerosene lamps with safer, more efficient LED lights.

Virtual power plants are offering a new source of flexibility to power systems

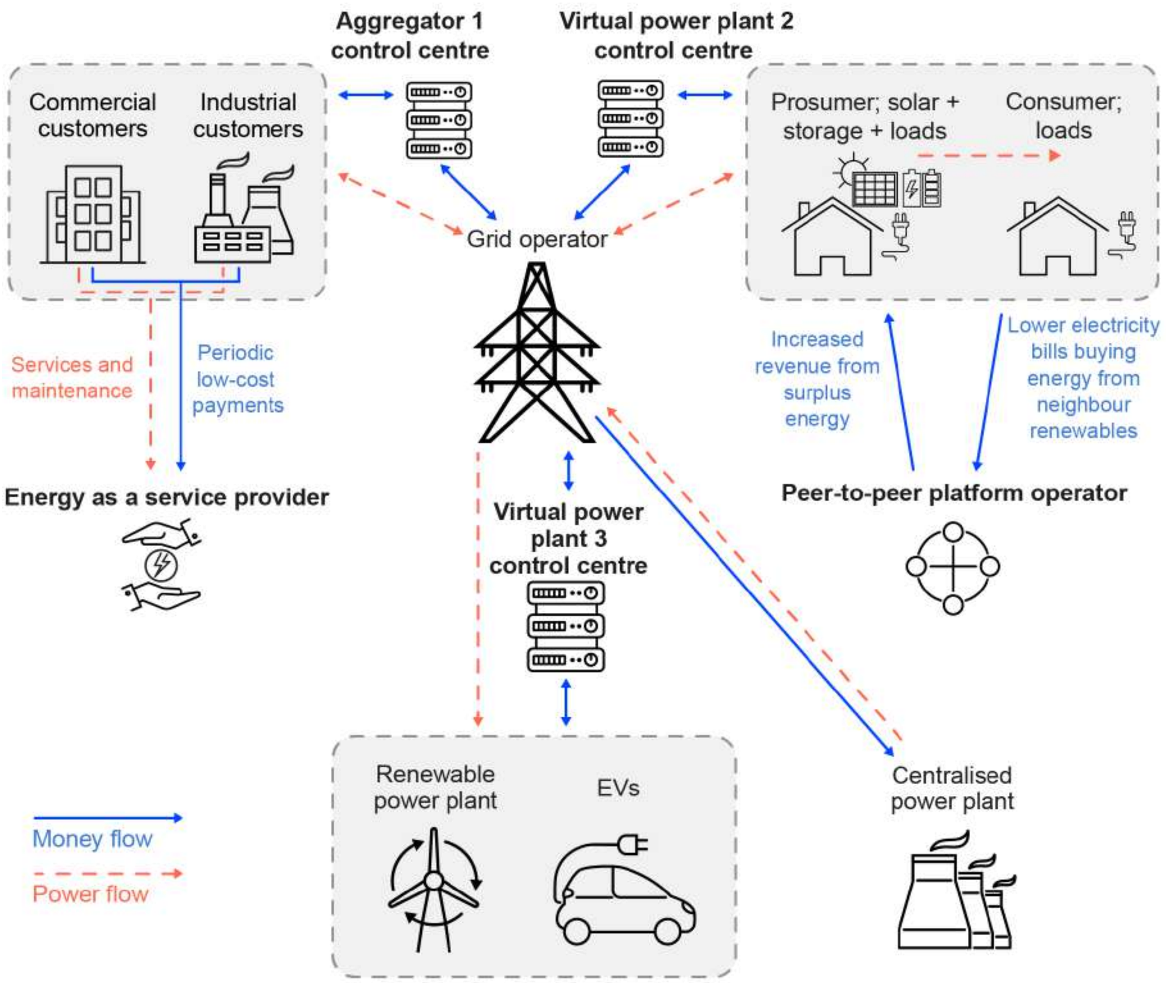
A virtual power plant is a digitally enabled network that links, aggregates and centrally controls distributed energy resources like batteries and rooftop solar PV panels, as well as demand-side flexibility and utility-scale power plants. The aggregation creates revenue for the virtual power plant operator and unit owners by offering flexibility and ancillary services to the grid and by trading power in wholesale or retail markets. Distributed energy resources' share of world virtual power plant capacity was 51% in 2020 and is expected to reach 83% in 2029.

One recent study suggests that global virtual power plant aggregations are growing faster than traditional demand response which typically involves utilities contacting large power consumers to reduce demand. While the capacity of demand-response programmes is expected to double by 2029, virtual power plant capacity is expected to rise from 4.5 GW in 2020 to 43.7 GW in 2029. Revenues from virtual power plant businesses are also anticipated to grow faster than those of demand response and overtake them by 2027.

Regulation is a key enabler for such investments. In September 2020, for example, the US Federal Energy Regulatory Commission implemented an order enabling distributed energy resource aggregations to compete in wholesale power markets. In the following weeks, investors committed to more than USD 1.2 billion to virtual power plant installations. Another order, settled in a July 2020 court decision, opened aggregations for energy storage facilities. In the European Union, customers have the right to join aggregations and participate in cross-border competition through the 2019 electricity market directive.

In South Australia, Tesla is developing a large virtual power plant to aggregate the residential batteries and rooftop PVs of 3 000 households. The plant will carry 20 MW of generation capacity and 54 MWh of energy storage. There are plans for this scheme to be extended to encompass 50 000 units, equivalent to a capacity of 350 MW. It earns revenue from selling power to the grid and acting as a backup for the grid operator when needed. The Australian Energy Market Operator estimates that between 6 to 19 GW of dispatchable resources are required by 2040 to support VRE generation.

Innovative digitally-enabled business models in decentralised energy systems



In China, Shanghai's Electric Power Demand Response Centre developed a virtual power plant project that integrates more than 10 000 electricity users, including industrial plants, building heating and cooling systems, and electric vehicle charging stations. The virtual power plant's decentralised energy reserves can raise up to 1 GW of capacity to meet peak demand.

Aggregations can also link electric vehicle fleets through smart charging that enables a bidirectional flow of power between electric vehicles and the grid. These vehicle-to-grid connections can charge electric vehicles when demand is low and dispatch power back to the grid during peak hours – Nuvve in Denmark being an example of successful five-year vehicle-to-grid in action. The company has recently announced, with BYD, a joint deployment of electric vehicles across the United States powered with vehicle-to-grid technologies. This market could reach USD 860 million by 2027, with growth centres in Europe, the Asia-Pacific region and North America

3.4 Energy efficiency in digital strategies

Market innovation demands policy innovation

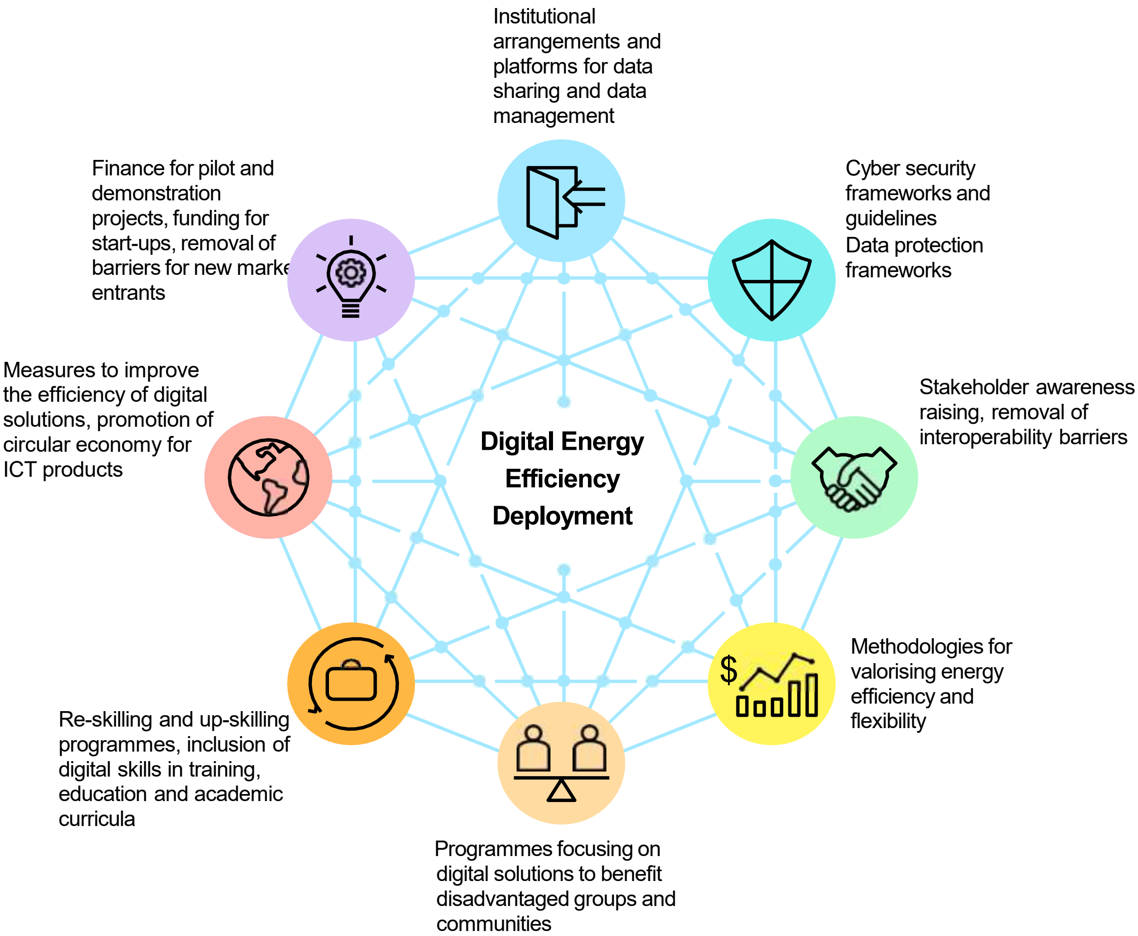
The digitalisation of energy efficiency markets presents both opportunities and risks that policy makers will need to navigate. To reflect the new technological landscape, many jurisdictions are evolving their regulatory approaches to include the new energy paradigms of demand flexibility and intelligent efficiency. Common issues involve the needs for research and development, infrastructure development, interoperability standards, cybersecurity and privacy measures, as well as increasing "digital literacy".

For example, governments are working with manufacturers and market players to support the adoption of standardised, open communications protocols. This is necessary in order encourage the production of "energy-smart digital devices" that can deliver demand flexibility, intelligent efficiency or status reporting of energy consumption and fault conditions. Other desirable requirements include that devices are easy to install, configure and operate, and allow consumers to override any autonomous device functions.

To have lasting impact, regulations must not only facilitate digital technology deployment but also ensure a readiness to harness digitalisation at its best, as part of a coherent strategy. In 2019, the IEA introduced the Digital Energy Efficiency Policy Readiness Framework to support this process. This has now been updated to reflect the growing focus on deployment.

Policies and regulations also need to ensure digitalisation benefits everyone by considering its social and economic impacts, as well as people's concerns. That means taking into account reskilling, social impacts, data privacy and cyber security, and the energy efficiency of digital solutions.

Strategies for digital energy efficiency deployment



Addressing broader social considerations is an important policy focus

While digitalisation is expanding the potential for business to harness energy efficiency gains, deliberate policy support can help ensure that such gains contribute to important social goals such as combatting energy poverty.

For example, in California the energy efficiency market is supported by around USD 1 billion rate-payer funded programmes. An important shift has been to segment programmes which maximise the size and economic value of the energy efficiency resource from other programmes aimed at achieving equity or technology specific market transformation goals. This helps ensure that the benefits of energy efficiency are provided to hard-to-reach or underserved communities, who ordinarily would not be recipients of interventions if a pure maximisation of resource value was taken. Segmentation has also been found to better support specific market transformation goals, such as the instillation of heat pumps where the market is not mature enough for easy deployment.

Digital technology can be a key part of boosting energy access. The Lighting Africa programme, for example, has provided with access to energy, including mini-grids that supply solar electricity for isolated communities. Measures that promote affordability for vulnerable groups include subsidies, improved access to financing, prepaid meters and pay as you go systems. In Kenya, M-Pesa, a digital service provider, has helped households facing extreme poverty by providing access to financial services.

In South Australia, the state's virtual power plant was also able to support low-income consumers. Of the project finance, AUD 61 million was covered by the Clean Energy Finance Corporation, the South Australian government and Tesla, so that there was no upfront cost for the 3 000 social housing residences participating.

In 2020 the Italian Ministry for Technological Innovation and Digitalisation launched the National Coalition for Digital Skills and Jobs. The coalition builds on Repubblica Digitale, an initiative that promotes digital skills at all levels of the economy and society. The coalition has launched more than 100 initiatives, most of which are aimed at improving the skills of residents and counteracting the digital divide. In addition, Italy's National Recovery and Resilience Plan targets 27% of total funding at digital transition measures. And the strategy Digital Italy 2026, aims to improve skills and enable access to digital solutions.

In South Africa, the 2020 National Digital and Future Skills Strategy sets out a series of initiatives intended to help South Africans meet the challenges arising from the deployment of digital technologies. The strategy focuses on closing existing skills gaps and building workers' digital skills for job areas such as additive manufacturing, app development and data analytics. It pays particular attention to those at risk of a technology-related job loss.

Supporting equitable access to digital resources and solutions

While digital technologies are bringing benefits to many parts of the world, there is a risk that they increase the consequences of the digital divide, further impeding those without access to the internet and related digital services.

The unconnected population includes people who live in areas not covered by mobile internet and those in areas covered by mobile internet who do not use mobile internet services. In sub-Saharan Africa, for example, there is 75% geographical coverage of mobile internet networks, but only 26% of the population is using mobile internet services, with lack of connectivity disproportionately affecting older people. Even when consumers have access to the internet, a lack of digital skills may impede their use of digital services. Globally, 51% of the population is still not using mobile internet.

If people do not have access to the internet, they cannot take advantage of basic digital energy services such as paying bills online, prepaid-recharge and energy consumption monitoring. Lack of connectivity can cause systemic inefficiencies that widen the energy access and affordability gap in low-income communities, making energy efficiency measures less effective.

Directing effort towards low-income communities or groups with less access to digital technologies, such as older people, can increase the reach of digital energy efficiency programmes. However, targeting communities with less access to digital is not only about offering them state of the art technology. A study in the United States showed that while installing smart thermostats generated energy savings on average, the gains were lower when householders did not have internet access, stayed home most of the day, or did not have a good understanding of how the device worked. This made the devices less useful for some older and poorer households, highlighting the need to tailor digital efficiency programmes to the needs of households.

Managing data and cyber security risks

Digital technologies are dramatically increasing not only the quantity and speed of energy data that is being shared, but also concerns about privacy. Alleviating these concerns is crucial to enable widespread deployment of digital technologies such as smart meters and connected devices.

India’s approach to these concerns, as part of its DataSmart Cities strategy, is to consider the data collected as open by default and to be shared publicly in an anonymised way unless classified otherwise. The strategy addresses data security and privacy concerns via a “privacy first” policy approach, which allows municipalities to regulate data ownership, collection, sharing and use in a clear way.

With growing numbers of electricity system assets connected to networks, vulnerabilities are increasing, especially in electricity distribution and on the grid edge. While full prevention of cyberattacks is not possible, electricity systems can become better able to withstand, adapt to and rapidly recover from incidents and attacks, while preserving the continuity of critical infrastructure operations.

Policy makers, regulators, utilities and equipment providers have key roles to play in supporting the cyber resilience of the entire electricity value chain. Policy measures can range from general frameworks to more prescriptive regulation, and can consider supply chain security, including through international standards and certifications. The IEA report Power Systems in Transition – Cyber Resilience provides guidance on this topic.

Can efficiency advances keep digital technology energy consumption contained?

Energy efficiency and operational improvements have been driving a decoupling of data use, internet traffic and associated electricity use over the past decade. Overall energy use by connected devices, including PCs, laptops, tablets, smartphones and Internet of Things devices, and excluding TVs and other consumer electronics, has decreased moderately over the past decade. The decline is due to increasingly energy-efficient devices and screens, and a shift towards smaller and more efficient devices (e.g. from desktop PCs to laptops, tablets and smartphones).

However, the rapid growth in connected devices and data flows demands more and more digital infrastructure, including new data centres and networks that consume significant amounts of energy. Enhancing their efficiency is crucial, so that the benefits from digitalisation are not offset by increased energy consumption. Policy efforts and technology solutions to reduce network standby energy use will also be increasingly important to reduce the overall energy use of an increasing number of connected devices.

Despite a large increase in activity, data centre energy use is estimated to have risen only modestly from 2010 to 2018, and currently comprises around 1% of global final electricity demand. This figure excludes cryptocurrency mining. Demand for data centre services is expected to grow strongly over the next decade, pushed up by cloud services and emerging technologies such as artificial intelligence, virtual reality, blockchain and increased data consumption fuelled by 5G.

Just because the efficiency of data centres has been able to keep up with rising activity does not mean this trend will continue. Research development and demonstration of more efficient technologies are important so that efficiency can keep pace with growing data demand.

Data on the energy use of data centres and networks is generally very poor globally, so a key policy priority for understanding energy efficiency of digital infrastructure is to improve efficiency metrics and data reporting. Rating systems for data centres are traditionally based on power usage effectiveness, which measures the rate of energy used for cooling and power provision compared with energy used for IT equipment. The National Australian Built Environment Rating System and US Energy Star Score for Data Centres, which is currently being updated, use power usage effectiveness.

A new generation of rating systems is being developed that, in addition to power usage effectiveness, take into account the level of utilisation of IT infrastructure, data centre energy recycling capabilities and carbon emissions. Such systems are now being deployed and could increase efficiency. One leading example is the Swiss Datacentres Emission Label, launched in 2020.

Policy makers can also encourage other sustainable practices by data centres, including improving equipment life, reusing and recycling components and critical raw materials, optimising water use for cooling and recovering waste heat for district heating.

For example, in 2018 the European Union launched a project on a circular economy for the data centre industry. In 2020, South Dublin Council created a district heating company that recovers waste heat from data centres. And in 2021 Norway announced that data centres will be required to investigate opportunities to use waste heat.

Data transmission networks are another large contributor to energy consumption in the digital world. They accounted for just over 1% of global electricity use in 2019. Despite a 40% to 50% increase in data traffic in 2020, some network operators, including Telefónica and Cogent, reported flat or decreasing energy use. Mobile networks, which account for a growing share of network energy use, are shifting towards 5G, but the overall energy implications of 5G remain uncertain. On TMobile USA's large 5G network, which it began building in 2019, energy use has risen but energy intensity per unit of data transferred has fallen.

In February 2021, France published a Digital and Environmental Roadmap, which sets out 15 measures to bring together digital and ecological transition objectives. The roadmap includes steps to reduce the environmental impacts of digitalisation, as well as to utilise digital tools and advanced analytics to accelerate the transition.

Beyond country efforts, international initiatives to minimise the negative environmental impacts related to digitalisation. For instance, the International Telecommunications Union is encouraging the IT industry to reduce emissions by 45% between 2020 and 2030.

General annex

Abbreviations and acronyms

APS	Announced Pledges Scenario
DSR	Demand-side response
EaaS	Energy as a service
EDNA	IEA Electricity Devices and Networks Annex
ESCO	Energy service companies
ESI	Energy Savings Insurance
GDP	Gross domestic product
HFC	Hydrofluorocarbon
ICT	Information and communications technologies
IEA	International Energy Agency
IMF	International Monetary Agency
IPCC	Intergovernmental Panel on Climate Change
IT	Information technology
MEPS	Minimum energy performance standards
NDC	Nationally Determined Contributions
NRDC	Chinese National Development and Reform Commission
PAT	Perform, Achieve and Trade
PV	Photovoltaics
QR	Quick response
RD&D	Research, development and demonstration
SEAD	Super-Efficient Equipment and Appliance Deployment
STEPS	Stated Policies Scenario
TCP	Technology Collaboration Programme
VC	Venture capital
VRE	Variable renewable energy

Units

bbl	barrel
EJ	exajoule
GJ	gigajoule
GW	gigawatt
GWh	gigawatt hour
KWh	kilowatt hour
TWh	terawatt hour

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