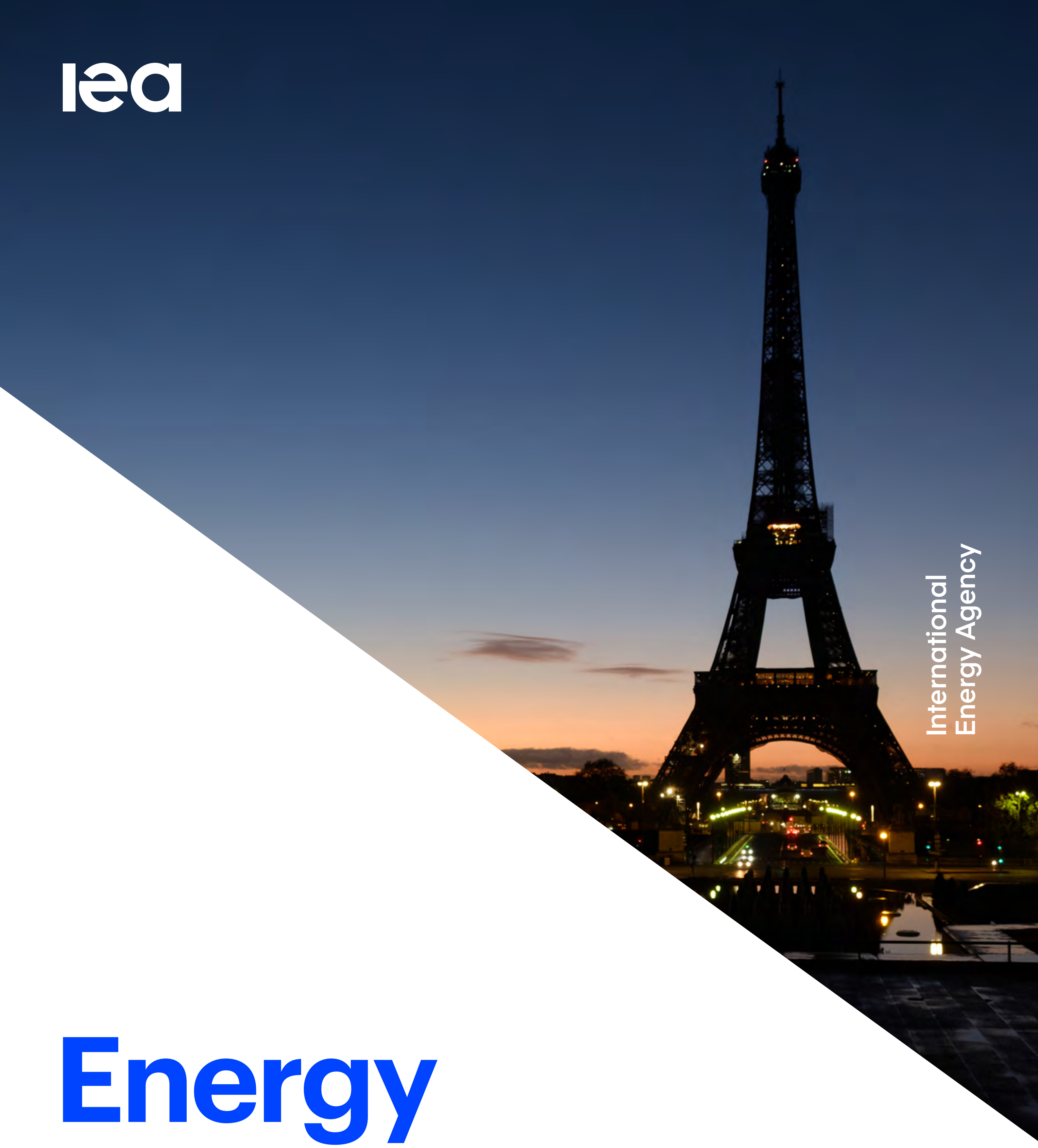

Energy Efficiency 2022

INTERNATIONAL ENERGY AGENCY

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Abstract

Energy Efficiency 2022 is the IEA's primary annual analysis on global developments in energy efficiency markets and policy. It explores recent trends in energy intensity, demand and efficiency-related investment, innovation, policy and technology while also discussing key questions facing policy makers.

This year record-high consumer energy bills and securing reliable access to supply are urgent political and economic imperatives for almost all governments. In response to the energy crisis countries are prioritising energy efficiency action due to its ability to simultaneously meet affordability, supply security and climate goals.

While efficiency investment has recently been increasing to reach new record levels, the pace of global energy intensity improvements had noticeably slowed in the second half of the last decade and virtually stalled during the first two years of Covid-19. With efforts to better manage energy consumption as a result of the crisis increasing the rate of improvement once more, the question as to whether 2022 will see a sustained efficiency turning point, and what more can be done, are key themes of this year's report.

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Table of contents

Executive summary

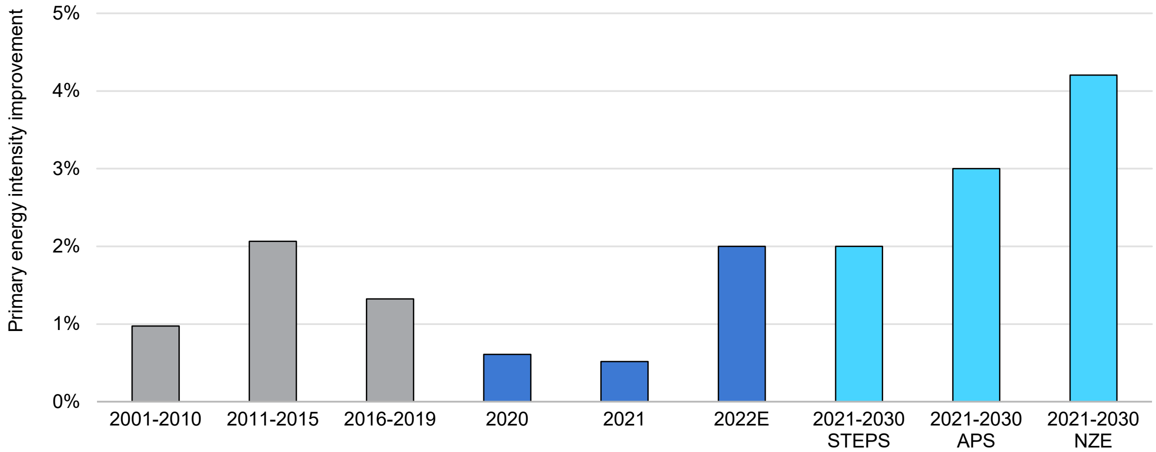
Efficiency action accelerates as countries move to contain economic pain from the energy crisis

The unparalleled global energy crisis sparked by the Russian Federation's (hereafter "Russia") invasion of Ukraine has dramatically escalated concerns over energy security and the inflationary impact of higher energy prices on the world's economies.

Lowering record-high consumer bills and securing reliable access to supply is a central political and economic imperative for almost all governments. While there are many ways for countries to address the current crisis, focusing on energy efficiency action is the unambiguous first and best response to simultaneously meet affordability, supply security and climate goals.

With efforts to conserve and better manage energy consumption in sharp focus since the onset of the crisis, efficiency progress has gained momentum, with annual energy intensity improvements expected to reach about 2% in 2022.

Annual global primary energy intensity improvement, by scenario, 2001-2022 and 2021-2030



Note: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; and NZE = Net Zero Emissions Scenario.

Global energy demand growth has declined sharply and is expected to be close to 1% this year. This comes after last year's 5% increase; one of the largest single-year rises in 50 years.

This year's improvement in intensity comes after the onset of Covid-19 led to two of the worst years ever for global energy intensity progress, with annual gains falling to around half of one percentage point in 2020 and 2021. Key factors included a higher share of energy-intensive industry in energy demand and slower efficiency progress, especially in the buildings and industrial sectors.

However, energy intensity progress had already slowed before the start of the Covid-19 pandemic in 13 of the G20 group of countries and improved in only four. From 2010 to 2020, the global rate of improvement fell from 2% in the first half of the decade to 1.3% in the second half. This highlights the challenge of re-accelerating efficiency progress to the 4% needed each year to 2030 under the IEA Net Zero Emissions by 2050 Scenario (Net Zero Scenario).

With consumers reducing energy consumption in an effort to rein in costs, this year's energy intensity improvement cannot entirely be viewed as a step forward. Businesses are under pressure to close or curtail operations and many people across the world are struggling to afford basic energy needs. The number of people without reliable access to heating, cooling, clean cooking and other energy services has risen to around 2.5 billion worldwide, and an extra 160 million households have been pushed into energy poverty since 2019.

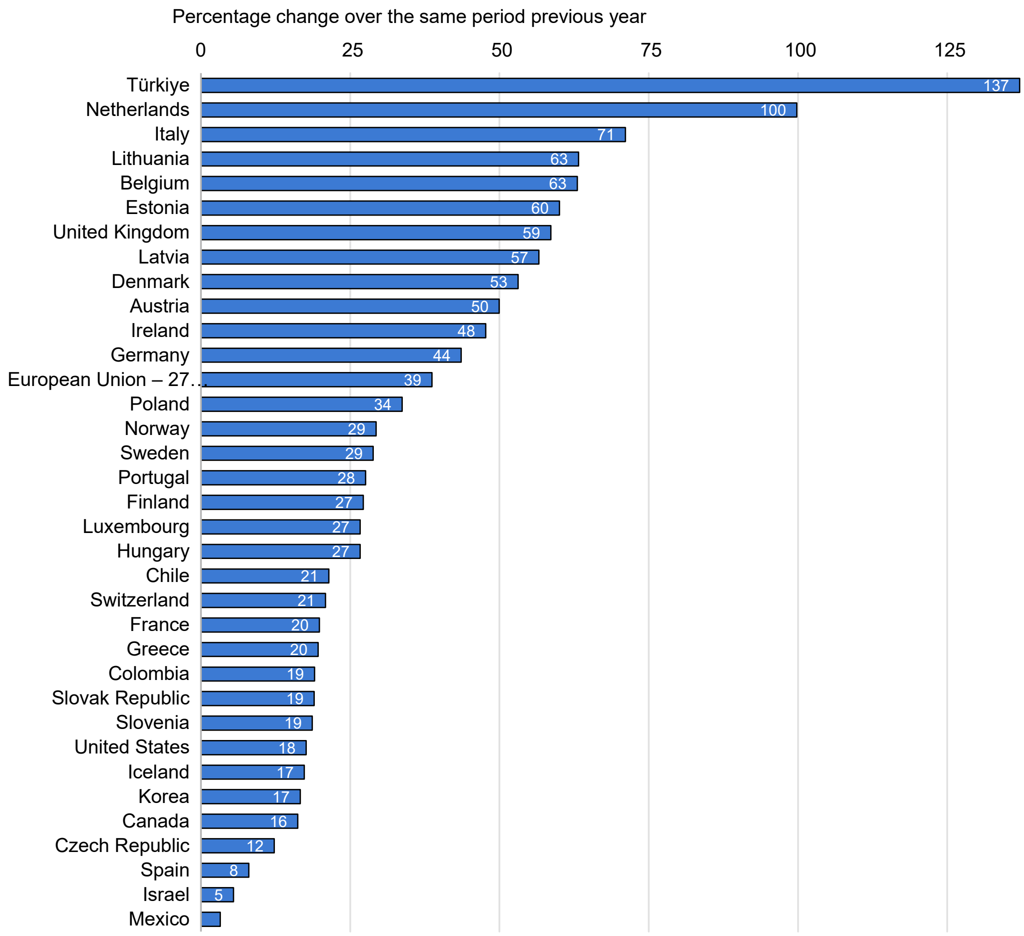
High fossil fuel prices are driving a cost-of-living crisis, worsening energy poverty and public health

Energy price inflation varies across countries depending on the fuel mix, the level of energy efficiency and the structure of the economy, as well as government polices such as fuel taxation and energy bill support strategies. While the current crisis is global, it is centred in Europe where reduced energy supply from Russia is exposing consumers to higher energy bills and risks of supply shortages over the winter heating months.

In the European Union, consumer energy price inflation for the year to October 2022 increased to 39%, with around a quarter of households estimated to be living in energy poverty. Vulnerable groups are the most exposed and often live in older, poorer-quality buildings, using less efficient appliances and older vehicles with lower energy performance levels. This not only means they can be paying several times more for household energy bills but also suffer colder, damper, and darker living conditions which exacerbate health risks.

This year has also seen a significant shift back towards using cheaper traditional biomass such as wood and charcoal for heating and cooking. Emerging and developing economies are particularly exposed. Around 75 million people who have recently gained access to electricity are estimated to have lost the ability to pay for it and 100 million people may need to switch back to using traditional stoves for cooking from LPG. This poses a particular health risk for women and children who are most exposed to household air pollution from cooking which in total is estimated to have contributed to 2.5 million premature deaths this year.

Year-on-year change in energy price inflation, October 2022



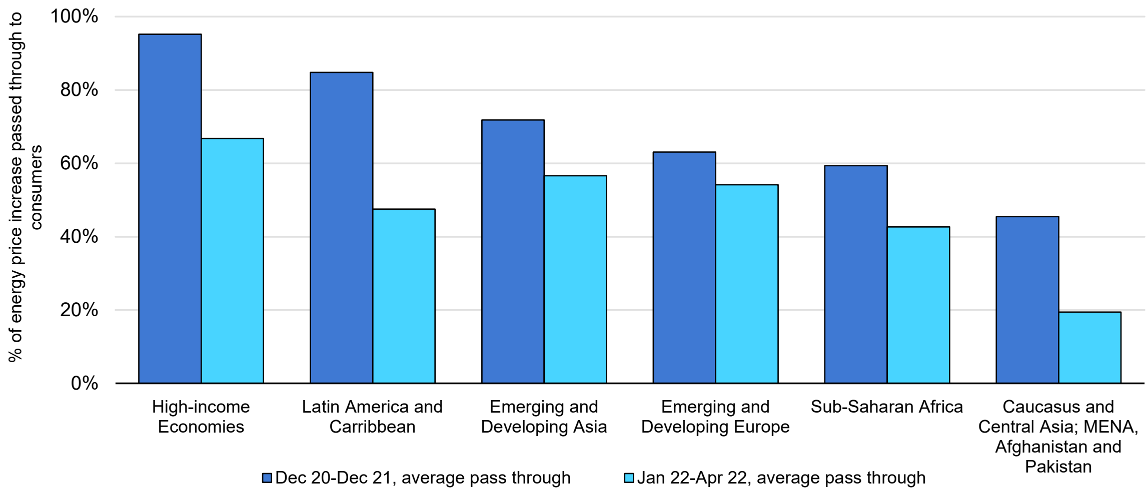
Source: OECD Database on Consumer Price Indices, as modified by the IEA.

Well-targeted public spending can support the vulnerable and enhance efficiency

With households and businesses facing significantly higher energy bills this year, governments in all regions have brought forward a range of interventions to provide support for consumers, including new or increased broad-based fuel subsidies as well as direct cash payments to assist households. The value of this emergency government spending is now over USD 550 billion. In emerging and developing economies, this short-term support now eclipses that provided for clean energy investments since March 2020. Support is set to further increase substantially, such as through a proposed package in Germany of up to USD 200 billion.

In the transport sector the percentage of energy price increases being passed through to consumers has fallen across many countries with the difference between market prices and end-user prices usually being met from public budgets.

Proportion of transport fuel price increases passed through to consumers, by region



Sources: Based on IEA data and the IMF (2022), Fiscal Policy for Mitigating the Social Impact of High Energy and Food Prices.

While offering important short-term relief, at the same time it is important such support does not weaken incentives to reduce energy waste or slow the switch to lower-carbon supply. The least efficient interventions are those that lower market prices for energy through direct fossil fuel consumption subsidies, indiscriminately applied to all consumers. Such subsidies risk removing the incentives to improve efficiency and disproportionately benefit wealthier consumers who are large energy consumers.

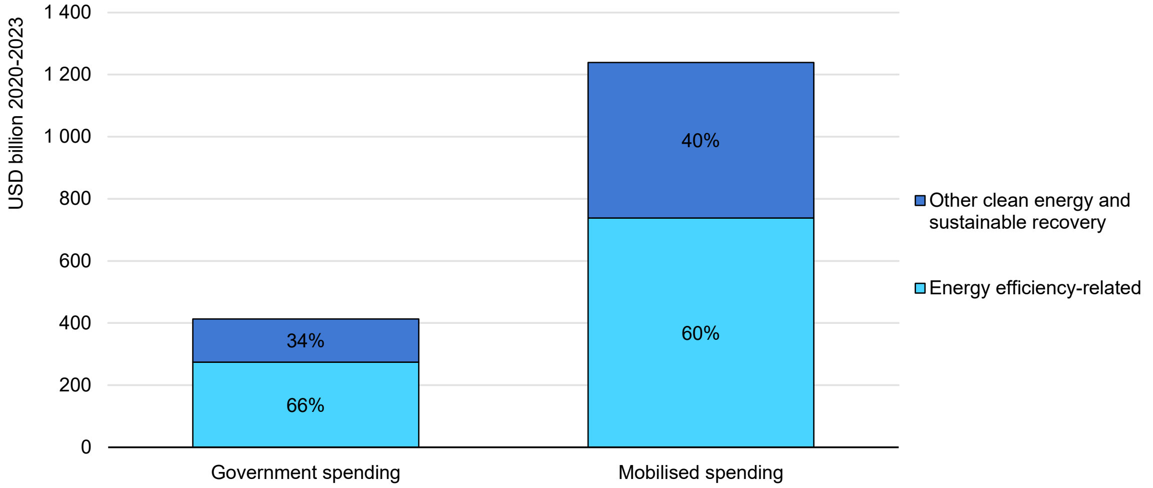
The IMF and the OECD have highlighted the need to scale down such broad-based energy subsidies and shift their balance towards targeted support for energy poverty and structural energy efficiency measures. Higher energy efficiency, which reduces energy consumption, also plays an important role in lowering the overall energy subsidy burden on public budgets in the longer term.

Energy efficiency spending tops USD 1 trillion, equal to two-thirds of all clean energy recovery packages

Since 2020, governments worldwide have helped mobilise around USD 1 trillion for energy efficiency-related actions such as building retrofits, public transport and infrastructure projects, and electric vehicle support. This amounts to approximately USD 250 billion a year being deployed from 2020 to 2023, equivalent to two-thirds of total clean energy recovery spending.

This is the result of USD 270 billion of direct public spending by governments, which is projected to mobilise a further USD 740 billion of private and other public spending. This provides a productivity boost to the economy and can contribute to minimising future energy-related cost-of-living pressures that may arise.

Global spending in clean energy and recovery, 2020-2023



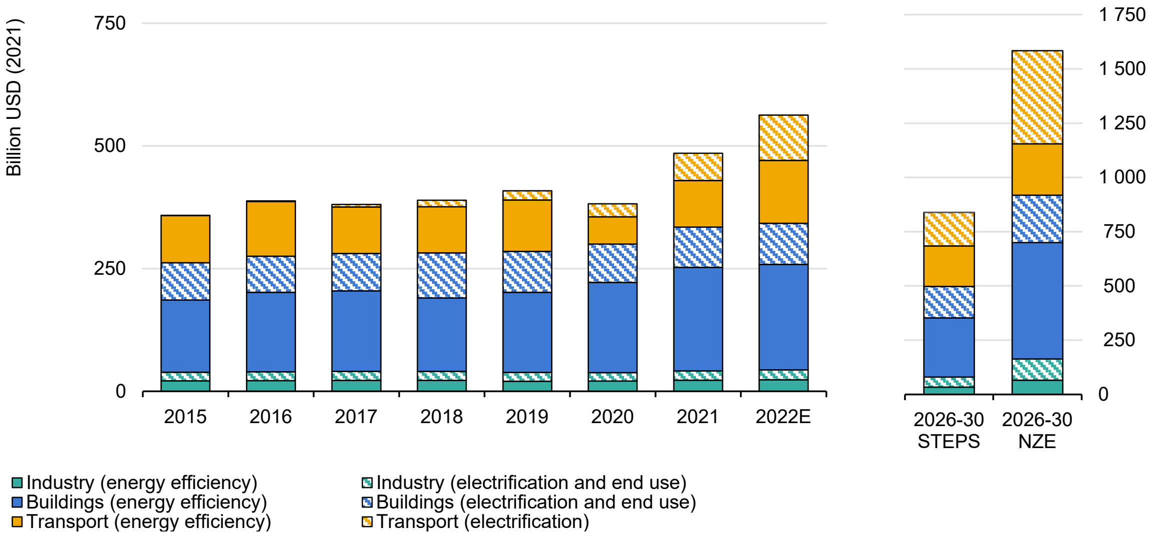
Note: Mobilised spending includes private and public spending mobilised by government action.
Source: Tracking Sustainable Recoveries, as of April 2022.

Global efficiency investment is up 16%, led by record growth in electric vehicle sales

Strong consumer spending on new fuel-efficient and electric cars is expected to help overall energy efficiency-related investment rise by 16% in 2022, to just over USD 560 billion. Under currently stated policies, this figure is set to increase a further 50% to almost USD 840 billion per year from 2026 to 2030. However, these levels are still only about half of the energy efficiency-related investment levels needed in the second half of this decade to align with the Net Zero Scenario.

Global efficiency-related transport investment is expected to rise 47% in 2022 to USD 220 billion. This includes just over USD 90 billion on electrification, which now makes up an estimated 42% of total efficiency-related transport investment, compared with just 19% in 2019. Growth in energy efficiency investment for buildings was down to 2% this year compared with 12% the year before as construction activity slowed and costs rose sharply from higher interest rates and supply chain pressures on materials and labour.

Global energy efficiency-related investment, by scenario, 2015-2022 and average annual investment, by scenario, 2026-2030



Source: World Energy Investment 2022.

Electric vehicle sales have almost doubled for the last two years in a row, reaching around 11 million units sold worldwide in 2022, up from just 1 million in 2017. This means that electric cars now account for 13% of new vehicle sales worldwide. Conventional energy efficiency investment in the transport sector also performed strongly, rising by USD 33 billion or 35%, to USD 128 billion, driven by investment in more efficient vehicles.

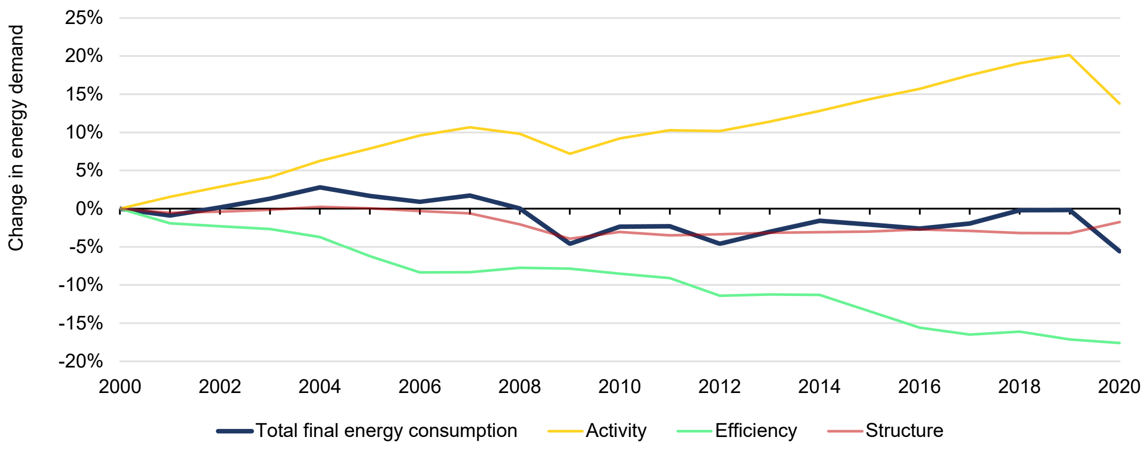
Despite this record growth, there is evidence that supply chain constraints are restricting even faster progress. This relates particularly to the availability of semiconductor and lithium processing. Longer waiting lists are now widespread for many popular new electric vehicle models and the prices of second-hand electric vehicles are increasing.

Energy savings from past efficiency actions are lowering energy bills by USD 680 billion this year in IEA countries

With consumer energy expenditures strongly rising this year in most countries, the value of improving energy efficiency in reducing costs and saving energy has risen exponentially. Efficiency gains will help mitigate financial hardship for residential consumers and provide critical cost savings for commercial users struggling in a weaker global economy. But, to achieve these goals, it is essential that policy makers adopt well-targeted and broad sets of energy efficiency measures.

Over the last 20 years, IEA member countries have implemented energy efficiency-related measures across the buildings, industry and transport sectors that are estimated to be saving households and businesses around USD 680 billion this year, or around 15% of the total 2022 energy bill of USD 4.5 trillion. This reflects end-use energy prices for fuels in IEA countries this year and 24 EJ of avoided energy demand from efficiency-related measures.

Change in energy demand and drivers, in IEA countries, 2000-2020



Source: Energy Efficiency Indicators 2022.

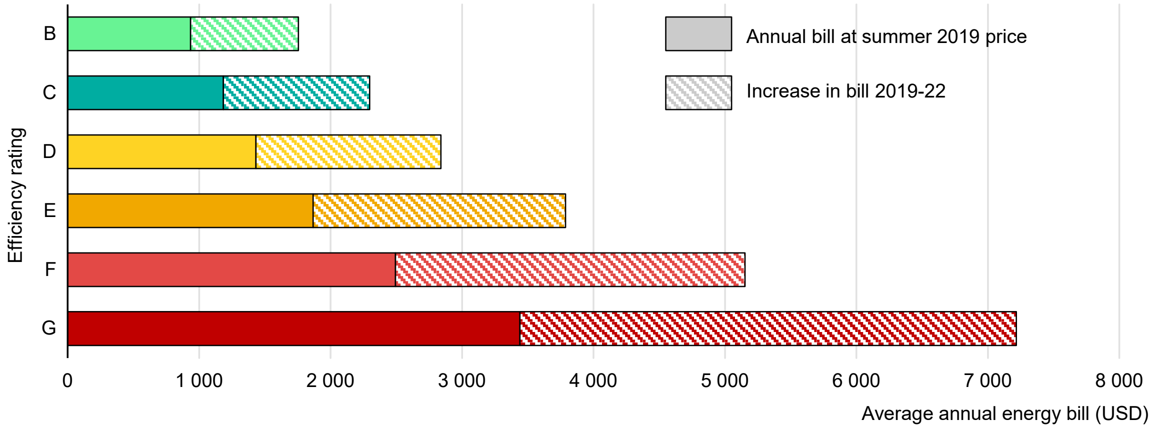
The accumulated effects of efficiency have been so large that final energy demand for IEA countries as a group has remained relatively steady at about 140 EJ for 20 years. This was achieved even as the economies of the group grew by 40% in real terms and overall economic structure only slightly shifted towards less energy-intensive activities.

Stronger efficiency is the first-best policy to bring down energy bills

There is a wide range of energy efficiency performance levels in homes, offices, businesses and vehicles. For example, evidence suggests that the reduction in running costs between the most efficient and least efficient homes or cars can be commonly as much as 40% and up to 75% depending on the initial level of efficiency. This means that it can cost some consumers two or even three times more to heat the same area or travel the same distance.

Variations in energy efficiency exist both within and among countries. For example, in some European countries with similar climates it can take twice as much energy to heat the same floor area or within one country the energy consumed between the most efficient and least efficient homes for a given size can vary by a factor of up to three.

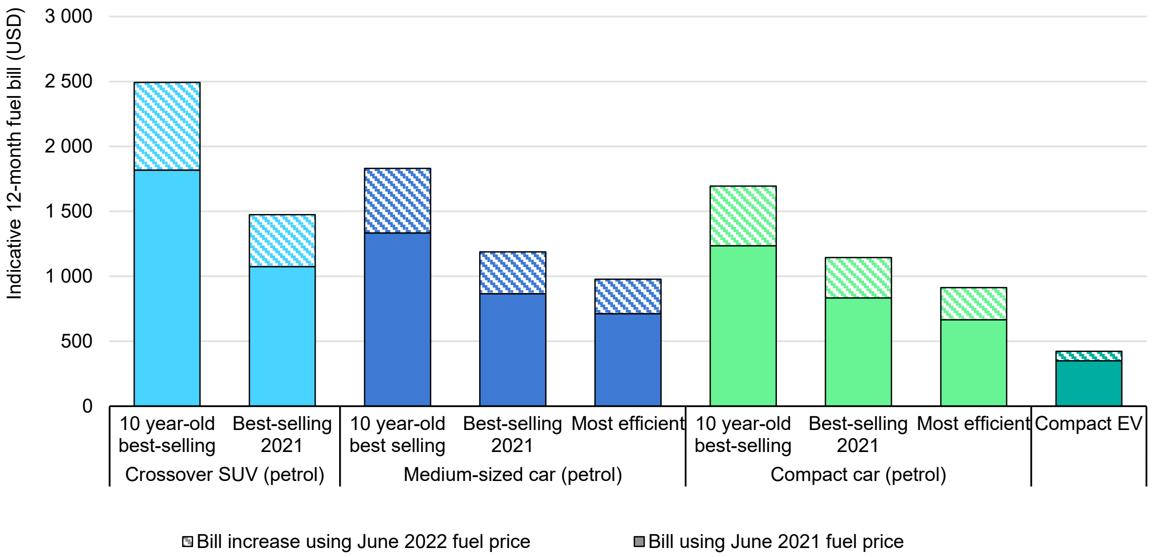
Typical annual household energy bills by building energy performance certificate rating, in the United Kingdom at summer 2019 and October 2022 prices



Sources: IEA analysis of data from [UK Department for Business, Energy and Industrial Strategy](#).

For transport, the differences in vehicle age, efficiency levels, size and fuel type have a major impact on annual fuel bills, as does the choice of travel mode. For example, the most efficient vehicles of the same size and weight use around half the energy of the same type of vehicle purchased ten years ago. Analysis of personal vehicles in Europe suggests a new compact electric car is by far the cheapest vehicle to run, with typical annual energy costs around half that of the most efficient new non-EV compact car.

Fuel bills for different personal vehicle types in Europe, June 2021 - June 2022



More efficient buildings will play a key role in enabling Europe to achieve independence from Russian gas

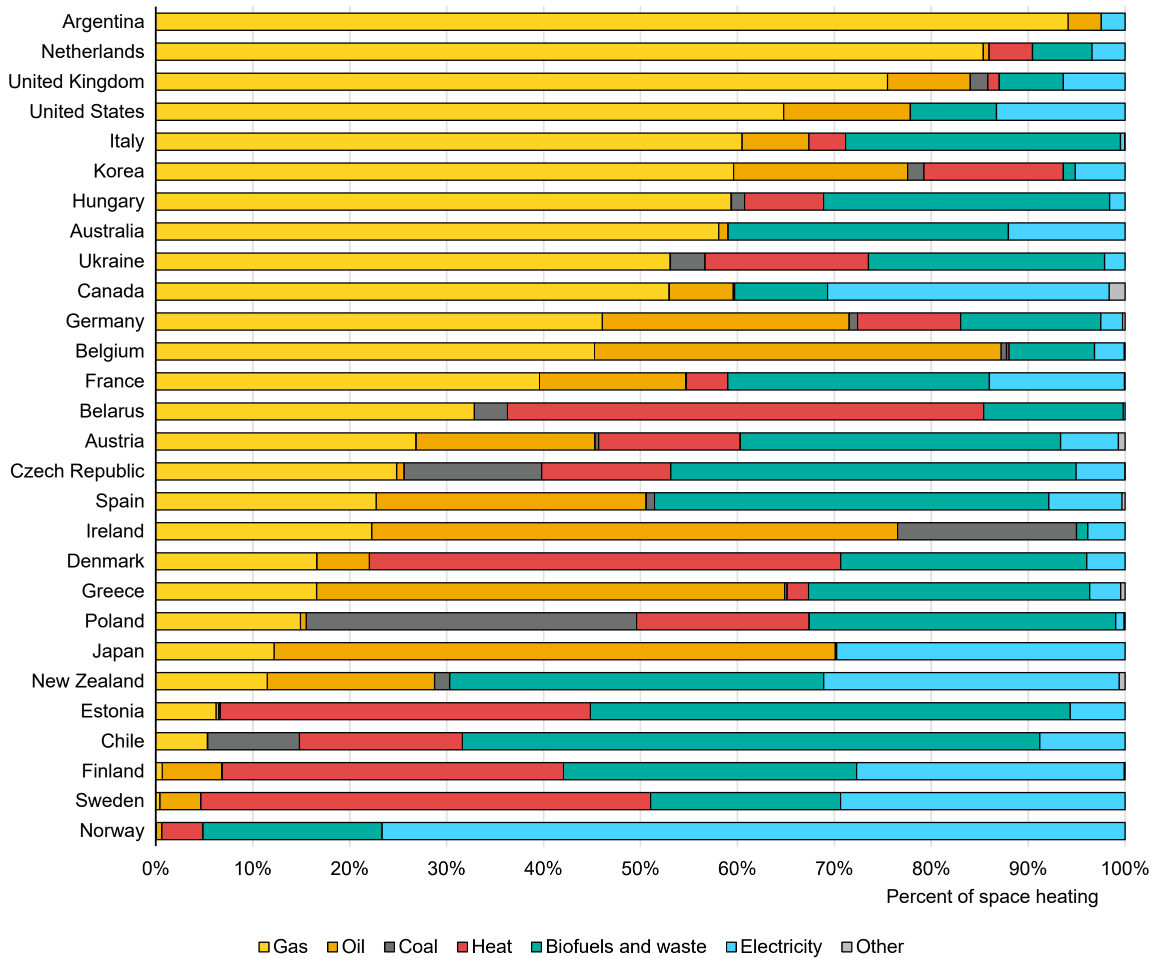
Natural gas is the most common fuel currently used globally for residential heating, accounting for 42% or 760 bcm of heating energy needs. Within Europe, gas dependency for heating ranges from over 80% in the Netherlands to almost total independence in some countries such as Norway and Sweden.

As a consequence of the current energy crisis, the share of Russian gas in total European demand has fallen from 47% in 2019 to around 9% in 2022. This loss of supply has precipitated an acute energy security crisis, given the limited availability of alternative affordable natural gas, and has brought into focus the pressing need for greater diversification of supply sources and routes.

In most countries across Europe, the price of gas relative to electricity for households has risen significantly. This has dramatically changed the economics of heating. For example, in Denmark, the cost of operating a gas heating system has risen for an average household by around 330% whereas the cost to heat the same space with an electric heat pump has risen by around 100%. While relative prices vary across Europe, efficient electric heat pumps are now the clear leader when it comes to the operating costs of heating most buildings.

A growing number of countries and sub-national governments have legislation underway proposing bans or phase-out schedules for gas and oil heating appliances. Across the European Union and the United Kingdom seven countries accounting for 80% of residential gas use in the region plan to ban new gas heating connections.

Proportion of residential heating energy consumption by fuel source in selected countries, 2020



Source: Energy Efficiency Indicators 2022.

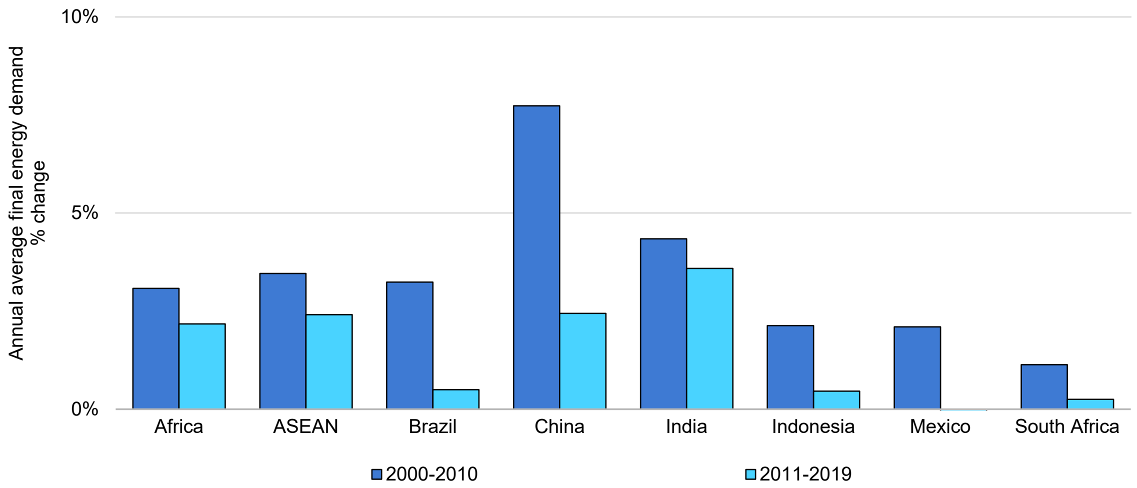
For example, Germany plans to put in place an implicit ban on new fossil fuel heating from 2024, when all newly-installed heating systems must be supplied by at least 65% renewable energy. France plans to ban new gas connections to buildings from 2023, Austria intends to implement a ban from 2023 and the Netherlands will require heat pump installations or heat network connections in buildings from 2026. The United Kingdom has announced plans to prohibit new gas heating systems and boilers by 2025, and ban them for all buildings by 2035.

In the United States, a small number of states have legislation underway proposing bans on new fossil fuel heating. In September 2022 California moved to bring in regulations which prohibit sales of gas-powered space and water heaters from 2030. Over 60 cities in California have already announced bans or are actively discouraging gas use in buildings. Oregon already outlawed natural gas use in any new construction since 2021. In Canada, the city of Vancouver and the province of Quebec also have plans to ban hot water systems powered by fossil fuels.

The largest energy efficiency opportunities of the future will be found in emerging and developing countries

Emerging market and developing economies (EMDEs) together account for around 260 EJ or 60% of global final energy demand. While the rate is slowing in many countries, under current policy settings final energy demand by 2030 is expected to grow almost 20% to around 305 EJ. This will increase EMDEs' global share by 5% as energy demand in advanced economies is expected to stay relatively steady.

Percentage of change in annual average final energy demand in selected emerging market and developing economies countries, 2000-2019



Behind this energy growth story is a rise in energy consumption per person in EMDEs as incomes grow. For example, an average person in an EMDE currently uses three times less energy in their home and four times less energy for transport, compared with an average person in an advanced economy.

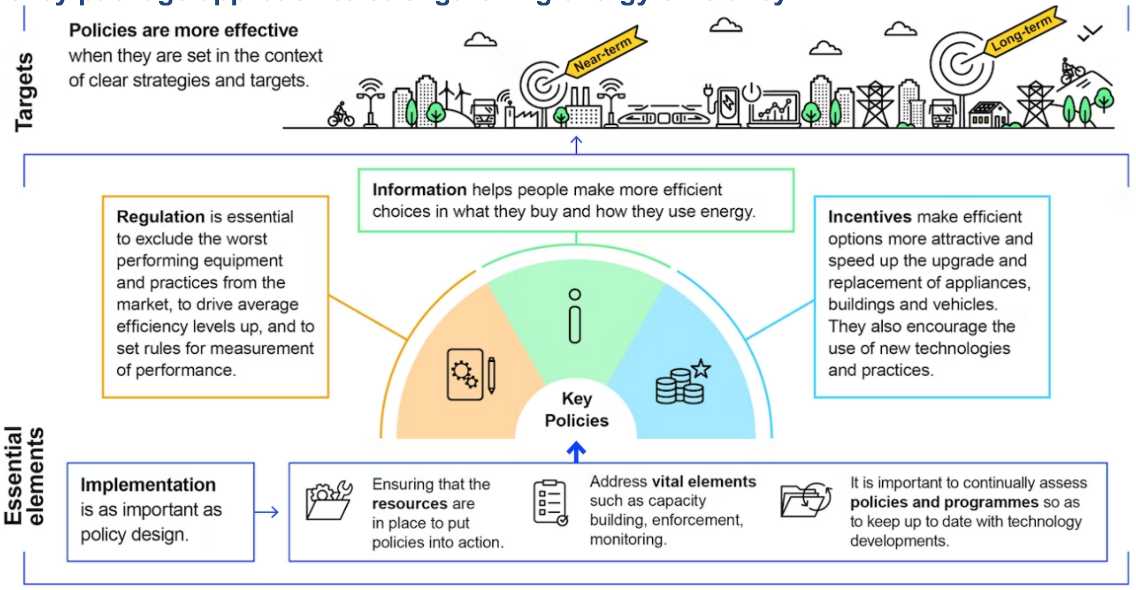
With emerging countries accounting for an ever-greater share of energy demand, the largest energy efficiency opportunities will increasingly be found in such countries as Brazil, the People's Republic of China (hereafter "China"), India, Indonesia, Mexico and South Africa. Given their critical importance to global energy security and climate goals, the IEA collaborates with these countries and others in Africa, the ASEAN and Latin American regions to support energy efficiency through its Energy Efficiency in Emerging Economies (E4) programme.

Historic moment for international cooperation on efficiency to help secure affordable clean energy

Not since the founding of the IEA in 1974 has the need for a coordinated effort on energy efficiency to reduce wasteful and inefficient use of energy been so great. No other energy resource can compare with energy efficiency as a solution to the energy affordability, security of supply and climate change crises. This is why the IEA calls energy efficiency the "first fuel" of all energy transitions.

In June 2022, the IEA held its 7th Annual Global Conference on Energy Efficiency in Sønderborg, Denmark. This was the largest ever gathering of ministers from countries around the world to specifically discuss the value of stronger action on energy efficiency. At the conference 26 governments issued a joint statement "calling on all governments, industry, enterprises and stakeholders to strengthen their action on energy efficiency" and welcoming the Sønderborg Action Plan on Energy Efficiency. This plan outlines a set of strategic principles and policy toolkits developed by the IEA that can help governments implement efficiency policies rapidly.

Policy package approach to strengthening energy efficiency



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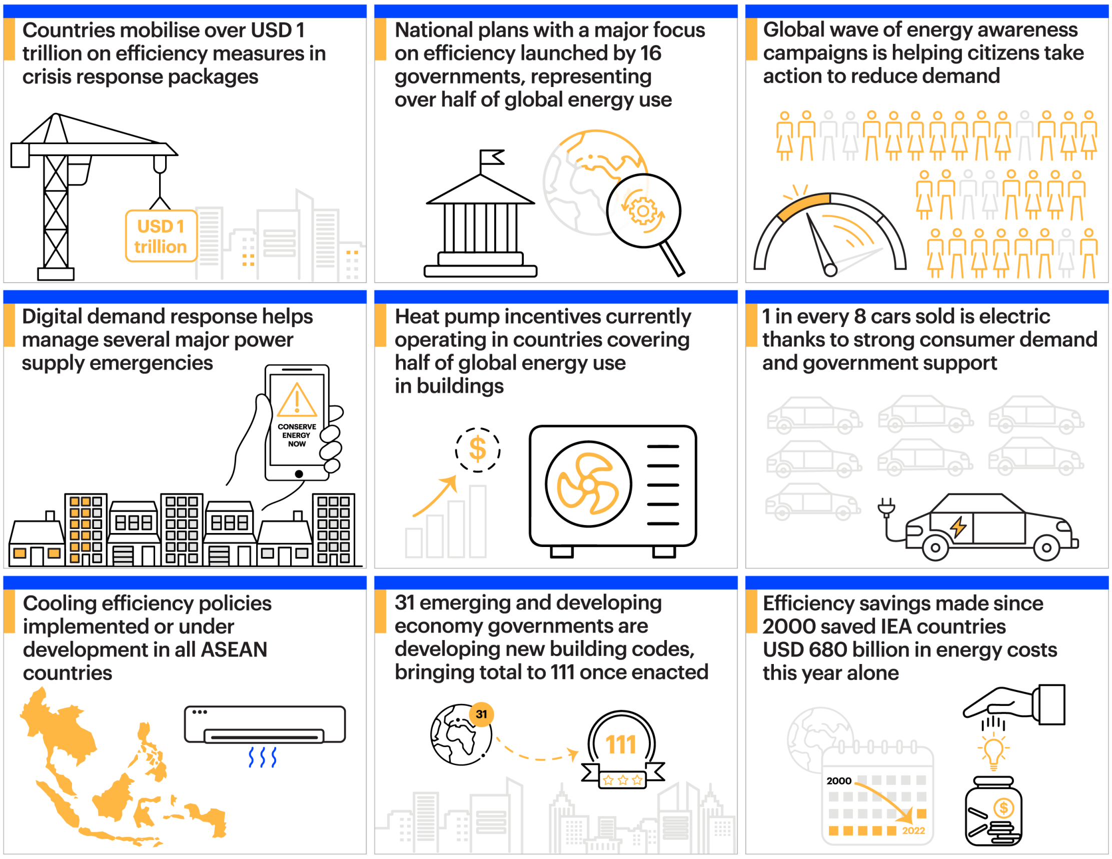
Is 2022 likely to be a turning point for energy efficiency?

A key question for policy makers right now is whether the energy crisis will bring about a global turning point for accelerating much-needed energy efficiency progress over this decade following the recent weak performance. The step up in energy intensity improvements from less than half a percentage point during each of the previous two years to almost 2% in 2022 is encouraging, though weaker-than-expected economic growth or higher energy consumption could still see this figure reduced by 0.3%. It is also only half of the 4% of annual intensity improvements needed, on average, over this decade to align with the Net Zero Scenario. And while there are causes for optimism, significant headwinds to faster progress remain.

Contributing forces to why 2022 could be a turning point for energy efficiency



The events of 2022 have nonetheless changed the dynamics of energy markets for decades to come. In the wake of these disruptions, energy efficiency has received a series of major global boosts:

- Global energy efficiency investment is increasing fast, with governments, industry and households investing USD 560 billion this year, which is a new record.
- Energy efficiency-related spending is making up two-thirds of all clean energy and recovery spending, with USD 1 trillion mobilised since 2020. At least 16 high profile national plans are driving this progress on efficiency, including the US Inflation Reduction Act, the REPowerEU Plan and Japan's Green Transformation (GX) Initiative.

- A rising wave of energy saving awareness campaigns is helping millions of citizens better manage energy use and make efficiency-related decisions.
- Existing building codes are being strengthened and new ones are being introduced in emerging and developing countries. Cooling strategies are being introduced in regions with the fastest-growing demand for air conditioning.
- The electrification of transport and heating looks to have reached a turning point. One in every eight cars sold globally is now electric, while almost 3 million heat pumps were sold in 2022 in Europe alone as they become the preferred heating option.
- The value that energy efficiency brings to consumers increased dramatically this year given sharply higher prices. While energy cost-of-living pressures have risen considerably, efficiency actions implemented over the last 20 years are now saving consumers in IEA countries USD 680 billion off their energy bills this year at current prices.

Despite these welcome causes for optimism several barriers to faster progress remain:

- There has been a massive scale-up of fossil fuel subsidies as governments seek to cushion the impact of higher energy prices on household bills. Over USD 550 billion of temporary support has been added over the last year. If support is not well targeted, this could weaken the case for energy efficiency.
- Energy efficiency investment is highly concentrated in advanced economies. If global efficiency improvements are to accelerate, investment and polices covering the other 60% of energy consumption in EMDEs must be strengthened.
- The Covid-19 crisis saw a shift towards more energy-intensive industry. Energy efficiency progress will continue to be stymied if strong industrial demand for energy persists without a major improvement in industrial energy efficiency.
- Much of the energy demand reduction that has taken place may be a negative consequence of slowing business, or consumers forgoing energy services to save money. Short-term efforts to save energy can easily revert back to past patterns of behaviour once the crisis eases.

In the midst of a global polycrisis, energy efficiency's role as the "first fuel" has been underscored by its ability to simultaneously meet energy affordability, security and climate goals. Efficiency actions reduce overall energy demand, putting downward pressure on energy prices and CO_2 emissions, generating employment and lowering bills for consumers.

The conditions are in place for 2022 to become a turning point year for energy efficiency progress. Governments worldwide are acting to strengthen their economies, helping struggling citizens and boosting businesses through energy efficiency action. But to capitalise on this opportunity and accelerate progress, it will be crucial that they continue to put in place more targeted, sustained and broader sets of measures.

Chapter 1. Energy efficiency trends

1.1 Energy intensity

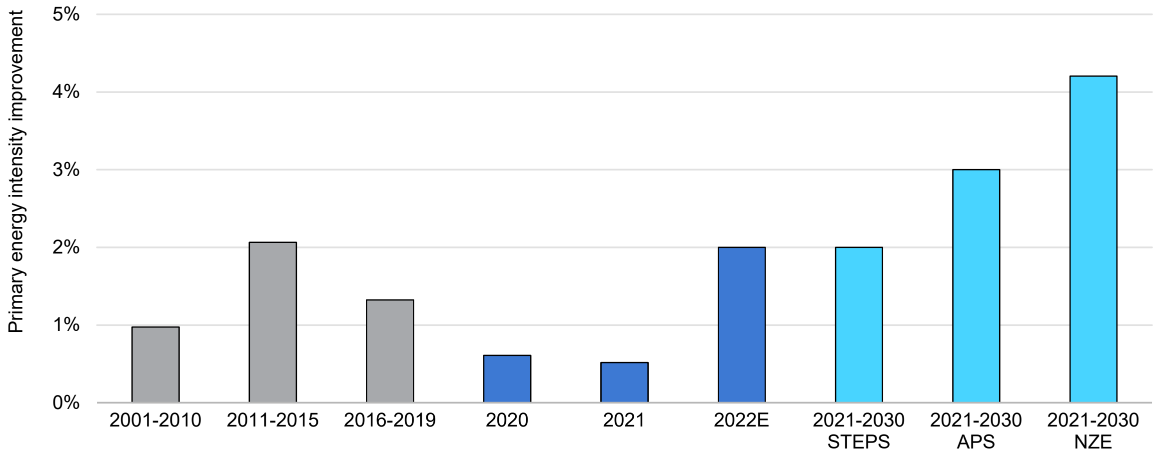
Energy crisis may reset the growth trajectory for efficiency gains after years of slow progress

The energy intensity of the global economy - a key measure of the energy efficiency of the economy - is expected to improve by almost 2% in 2022 following two years of stalled progress.

Surging energy costs, supply disruptions and looming shortages have sharpened the focus on improving efficiency, with consumers and governments around the world urgently implementing measures and adopting new policies to conserve and better manage energy consumption.

While this year's improvement in energy intensity is a significant step up from the last two years, recent trends are still far off track from achieving the 4% per annum needed, on average, from 2020 to 2030 to correspond with the pathway outlined in the Net Zero Scenario. To achieve net zero emissions, the link between economic growth and ever-rising energy consumption must be broken.

Annual change in global primary energy intensity, 2011-2022 and by scenario, 2021-2030



Notes: STEPS = Stated Policies Scenario; APS = Announced Pledges Scenario; NZE = Net Zero Emissions by 2050 Scenario. Primary energy intensity improvement is the percentage decrease in the ratio of global total energy supply per unit of GDP. GDP growth of 3.2% is assumed for 2022 based on the latest IMF forecast. However, if final estimates are lowered to 2.8% then intensity improvements of 1.7% would result, other things remaining equal.

Global energy demand growth is expected to moderate significantly in 2022, to around 1%, while an increasingly gloomy and uncertain economic environment has lowered expectations for GDP growth from around 5% to 3.2% over the year. If growth weakens further, this could bring down energy intensity improvements to 1.7%, other things remaining equal.

With people and businesses cutting back consumption in an effort to rein in costs and meet household budgets, caution also needs to be given to interpreting this year's energy intensity improvement as a step forward. Households are curtailing energy use, whilst many businesses are under pressure to reduce output or close due to high fuel prices. Emerging economies are particularly exposed. For example, around 75 million people who have recently gained access to electricity have now lost the ability to pay for it.

Overall, Covid-19 has proved a significant headwind to global energy intensity improvement. A shift towards more energy-intensive activities in 2020 and a stronger-than-expected rebound in energy consumption in 2021 were behind the slowdown, with the annual rate of improvement falling to about 0.5% in both these years. Previous expectations of a return to the ten-year average improvements of 1.9% in 2021 were not realised, as a robust post-Covid recovery led to the largest annual rise in energy consumption in 50 years, which saw particularly strong growth in energy-intensive industries.

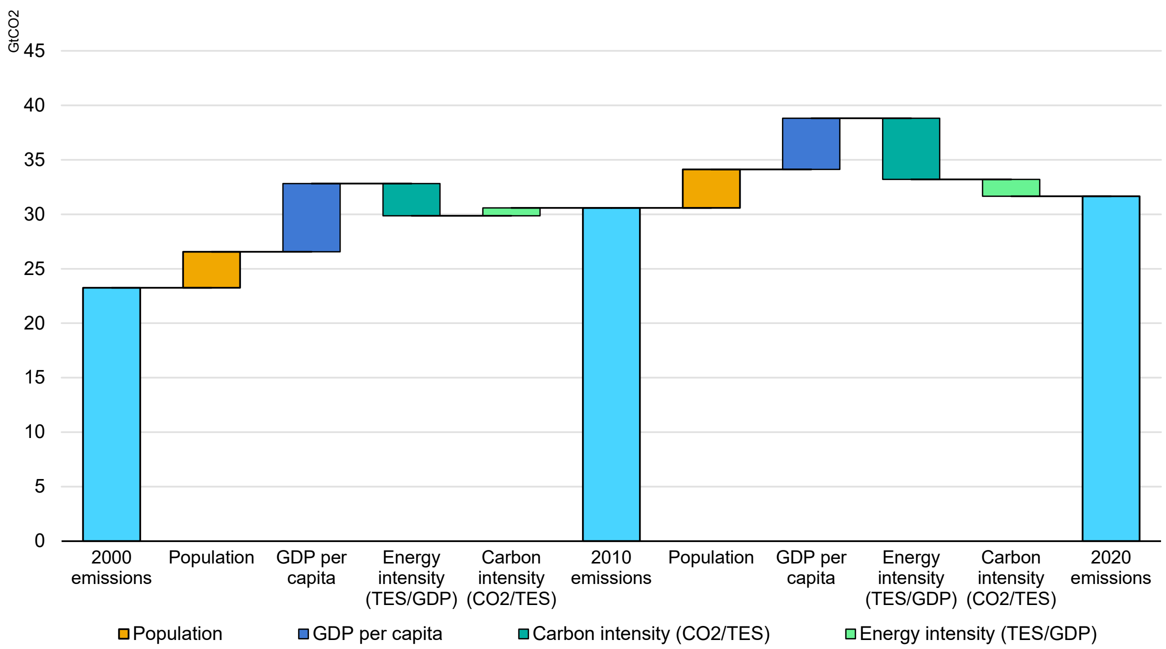
Taking a longer-term view, progress made on efficiency globally over the last decade was more positive. For example, annual average intensity improvements of about 1% over 2001-10 delivered around 3 Gt of CO_2 reductions compared with what would have been the case without any improvement. Building on this, a 1.7% average improvement over 2011-2020 delivered a 6 Gt reduction by 2020.

This doubling of the CO_2 reductions from intensity improvements helped offset almost half the total extra emissions that would have materialised as a result of global population and income growth. Without these intensity improvements over 2000-2020, emissions and energy consumption would be around 30% higher, with annual savings of 9 Gt CO_2 and 125 EJ at the start of this decade.

An acceleration of energy intensity improvements based on the 2% rate assumed in the Stated Policies Scenario (STEPS) to 4% per year consistent with the Net Zero Scenario would avoid 95 EJ per year of energy consumption in 2030. This would add an extra 5 Gt of CO_2 reductions above what would be achieved in STEPS by then.

Assuming emissions reductions of around 6 Gt per year from a 2% annual intensity improvement over 2020-2030 and the added 5 Gt per year from achieving 4% in the Net Zero Scenario, total CO_2 emissions reductions from intensity improvements could be as high as 11 Gt by 2030. This is almost one-third of current annual emissions from fuel combustion.

Global CO_2 emissions from fuel combustion and drivers, 2000-2020



Note: From 2019 to 2020 global CO_2 emissions fell by around 2 Gt CO_2 due to lower economic activity brought about by the Covid-19 pandemic.

Efficiency progress slowed in 13 G20 countries in the second half of the last decade and improved in four

At the country level, a few major energy consuming countries have the potential to shift the needle on energy efficiency progress. There is a wide spectrum of energy intensity among countries depending on the economic structure, energy prices, climate, and other social and political factors. For example, Russia requires almost four times as much energy to produce the same value of GDP compared with the United Kingdom.

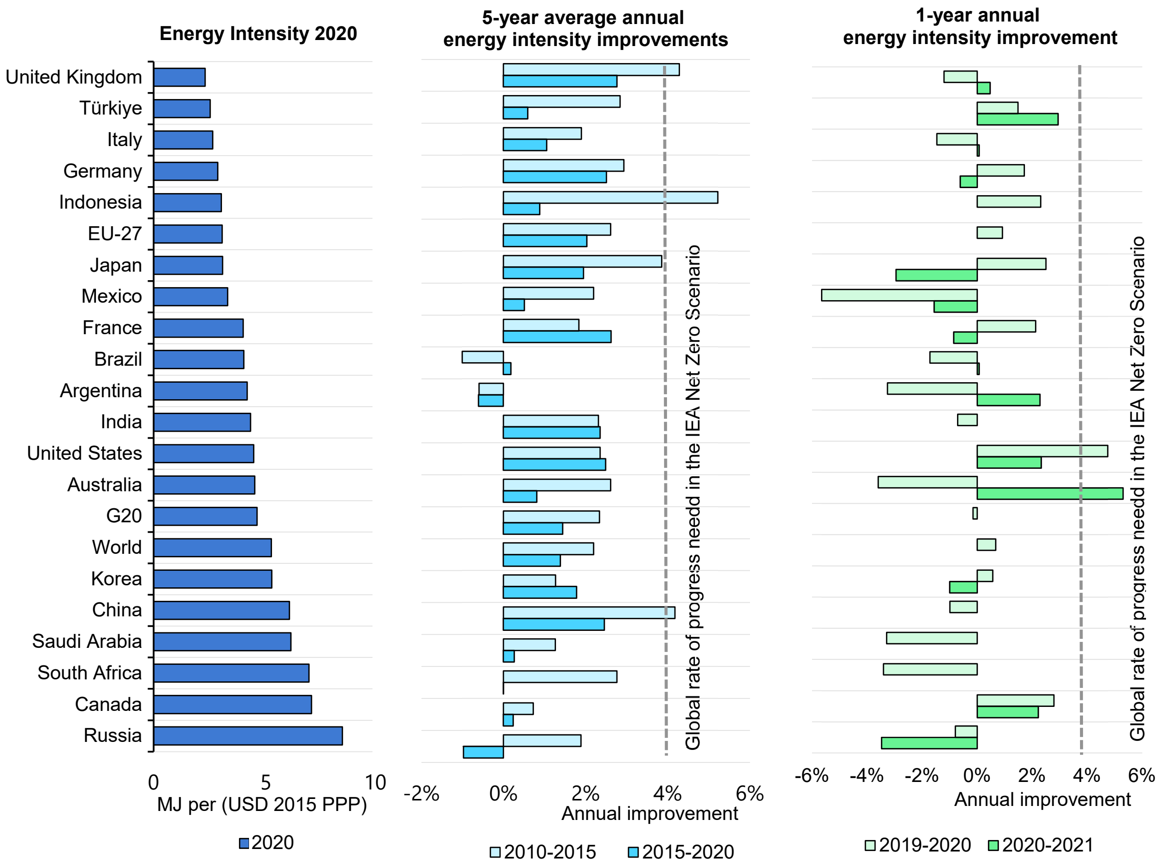
During 2020 and 2021 energy intensity progress fluctuated wildly at the country level, which reflected the impact of the pandemic and the attending economic disruption and rebound. This means a clearer view of progress can be seen from observing longer-term trends. For example, from 2015 to 2020 the countries with the largest annual energy intensity improvements were the United Kingdom at 2.8% per year, France at 2.6%, Germany, the United States and China at 2.5% and India at 2.4%.

While overall the global rate of energy intensity improvement decelerated from 2.2% over 2010-15 to 1.4% over 2015-2020, four countries managed to accelerate progress. France moved up from 1.8% per year in 2010-15 to 2.6% in 2015-2020 and Korea accelerated from 1.3% to 1.8% over the same period. Brazil staged a turnaround in the second half of the decade, from an economy that was becoming more energy intensive at a rate of 1% per year from 2010 to 2015, to one where energy intensity stabilised, improving slightly by 0.2% per year from 2015 to 2020.

In Asia, some of the world's fastest improving countries moderated markedly in the second half of the last decade. Comparing 2010-2015 to 2015-2020, China's strong progress of 4.2% per annum moderated to 2.5%, Indonesia fell from 5.2% per year to 0.9%, Japan slowed from 3.9% per year to 2%, and Australia dropped from 2.8% to 0.8% over the period.

Other notable slowdowns occurred in Europe, with the EU-27 showing annual improvement decelerating from 2.6% per year over 2010-2015 to 2% over 2015-2020. For individual countries, the United Kingdom dropped back from 4.3% to 2.8% per year, Germany eased from 2.9% to 2.5% and Italy from 1.9% to 1%.

Primary energy intensity, in G20 countries, 2020, and annual improvement, 2010-2021

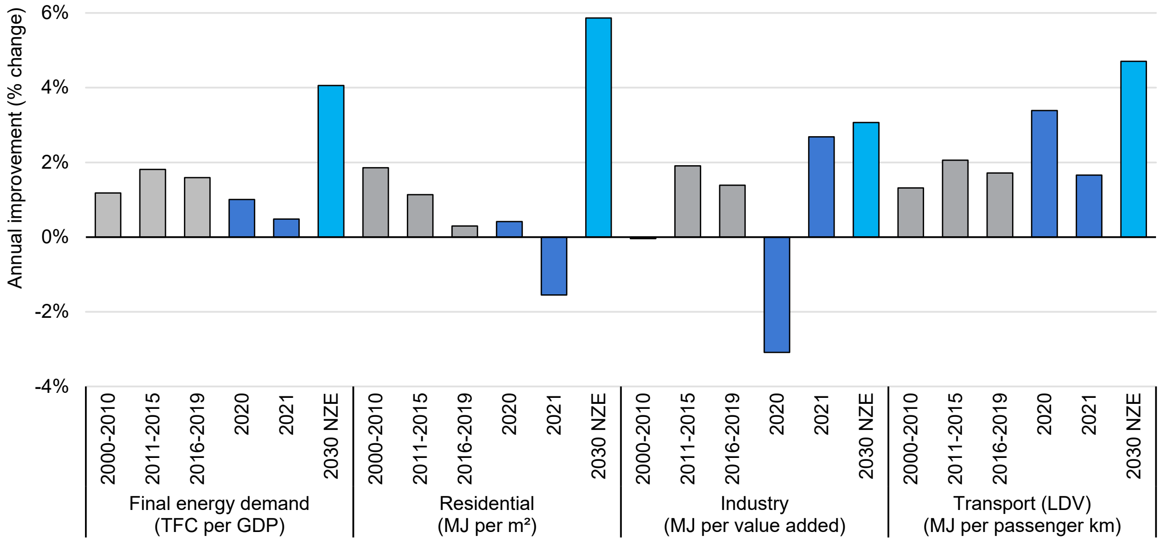


Note: 2021 data not yet available for South Africa, Saudi Arabia, China, India, and Indonesia.

Efficiency progress is slowing in the buildings and industrial sectors

From 2015 to 2020, the average improvements of energy per unit of floor space of residential buildings were 0.5% per year compared with historical rates of between 1.5% and 2%. In industry, the rate of improvement in the energy needed to produce one US dollar of industrial value added dropped back from almost 2% per year achieved over 2010-15 to just under 1% over 2015-2020. Only in the transport sector was energy efficiency progress relatively steady from 2010 to 2020, with energy per passenger kilometre travelled for light-duty vehicles declining (that is improving) by 2% on average.

Global final energy intensity improvement, by sector, 2000-2021, and in the Net Zero Scenario, 2030



IEA. CC BY 4.0.

Note: Transport = Light-Duty Vehicles (LDV).

1.2 Energy demand

Rising energy costs are putting greater pressure on consumers and businesses

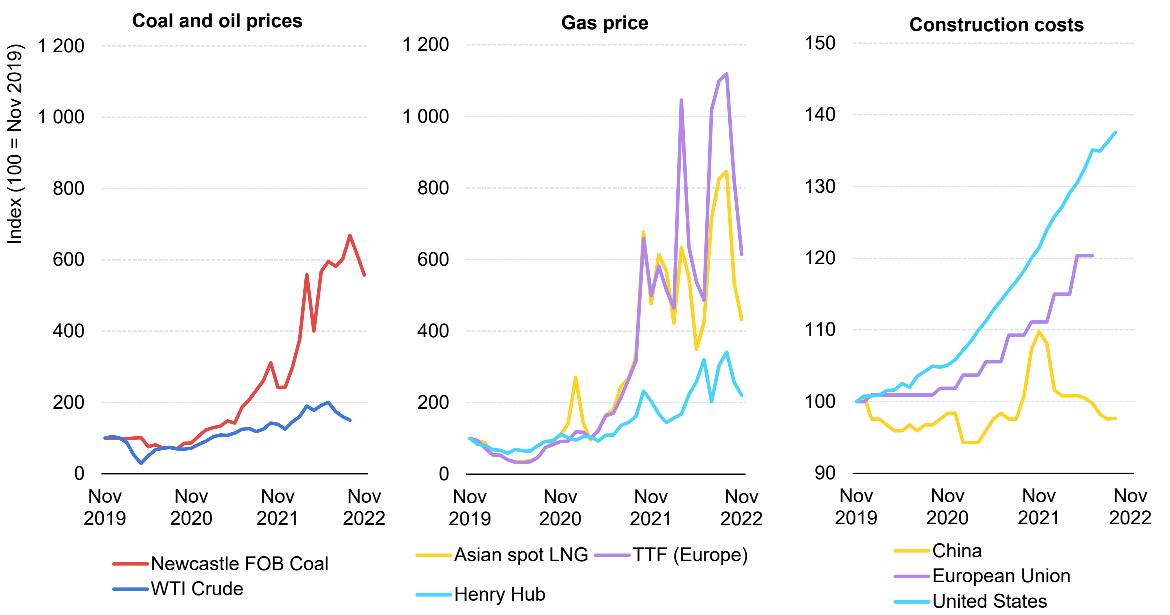
It has been a year of record highs in global energy prices for 2022. By January, natural gas, oil and electricity prices had been rising for more than 12 months as a result of the post-Covid recovery, a series of extreme weather events and unplanned supply outages. From the end of February, Russia's invasion of Ukraine brought about the most significant global energy price shock since the 1970s.

While Europe has been at its centre, the effects of the crisis have been felt across the world. In early 2022, spot prices for natural gas in Europe and Asia were more than five and six times those in November 2019. By August 2022, they reached USD 94/MMBtu in Europe and USD 67/MMBtu in Asia – the highest ever recorded in Europe – and an 18-fold and 12-fold increase since November 2019, respectively. Since summer, energy prices have receded from these record peaks, but remain at levels several times higher than in late 2019.

Rising prices for oil, coal and gas also fed into higher end-use prices, though this differs significantly among countries depending on the fuel mix, access to long-term contracts, taxation, USD exchange rates and government policies.

Steep energy costs are also running through supply chains for clean energy, including efficiency. Higher prices for key materials such as steel, copper, timber, chemicals and plastics are putting upward pressure on the costs of building construction, manufacturing, efficiency-related equipment, and heat pumps, among many other products. In Europe and North America, the energy price reductions of recent months have not yet been passed through into lower construction costs.

Key energy price and construction cost indices, November 2019-2022



Sources: IEA (gas and oil spot price data); Argus Media Ltd (coal price data); National Bureau of Statistics of China, Ex-factory price index of industrial products; Eurostat, Construction cost (producer prices), new residential buildings – quarterly data; United States Census Bureau, Construction Price Indices.

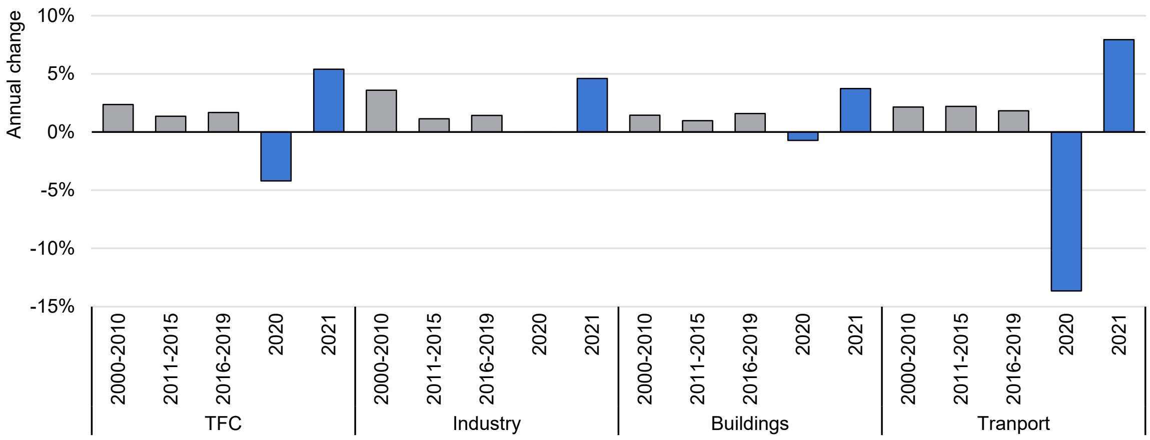
Energy demand growth moderates in 2022 after one of the largest single-year rises in 50 years

Global energy demand growth is expected to slow to around 1% in 2022 as economic growth moderates to 3.2% amid a more gloomy and uncertain outlook with estimates as low as 2.8% still quite possible.

Previous expectations of a recovery in energy intensity performance to 1.9% in 2021 did not materialise as the economic recovery from Covid-19 was fuelled by one of the largest increases in energy consumption in 50 years. A rise of 5.4% in energy demand in 2021 to 440 EJ more than offset the 4.1% fall experienced in 2020, and also delivered a 2 Gt increase in energy-related CO_2 emissions to over 36 Gt CO_2, the largest annual gain in history.

This was driven by a rebound in global economic growth to above 6% in 2021 following a contraction of 3% in 2020 due to Covid-19. Economic growth in emerging market and developing economies was almost 7% in 2021 compared with around 5% in advanced economies. This followed a contraction of 2% in EMDEs and 4.5% in advanced economies in 2020. China had particularly robust growth during the pandemic, with annual GDP around 2% in 2020 and 8% in 2021.

Change in global energy consumption, by sector, 2000-2021



By sector, energy consumption in buildings rose by five times more in 2021 than it fell in 2020 due to Covid-19, increasing 4% compared with a fall of 1% the year previously. While space and water heating are the largest energy consumers in buildings, responsible for almost half of energy demand, space cooling is experiencing the fastest growth, up 6.5% in 2021, compared with the year before.

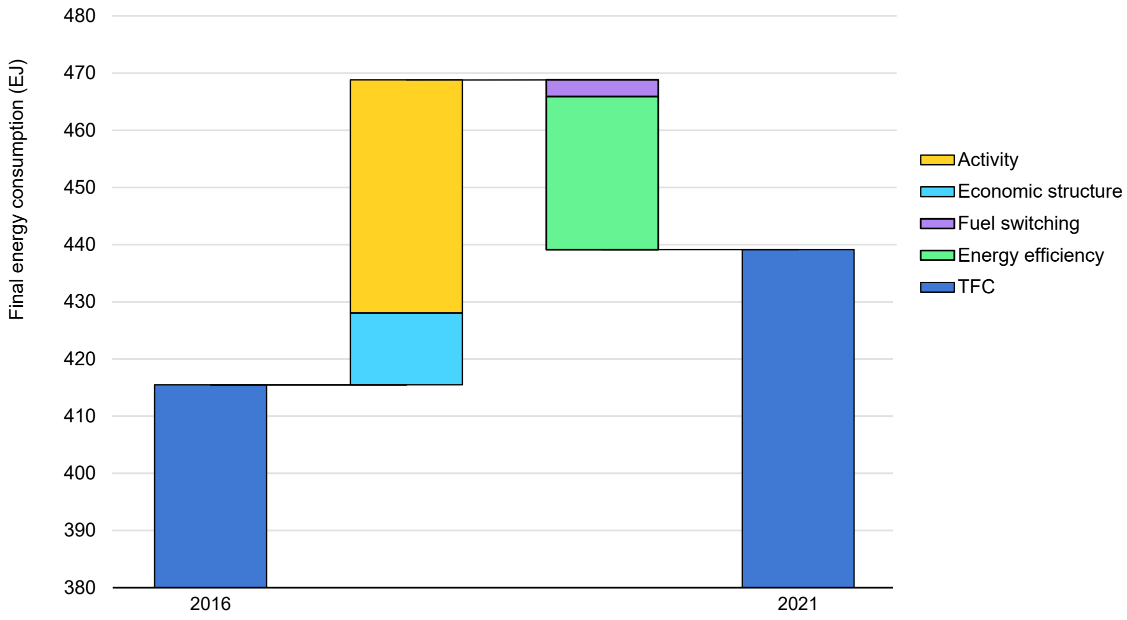
Transport energy demand is recovering but still below pre-Covid levels. However, in absolute terms, transport accounted for the largest increase in energy demand for 2021, adding around 8 EJ or 8%, following a collapse of 16 EJ or 14% in 2020.

Efficiency progress has more than halved the potential growth in global energy demand over the last six years

Energy savings from efficiency gains and changes in the fuel mix, including greater use of electricity for heating and transport, have acted together to lower global energy demand by 30 EJ from 2016 to 2021, compared with what would have been without these effects. This helped offset more than half of the energy demand growth from increased economic activity. Real GDP rose by 17% from 2016 to 2021, which, combined with a shift towards a more energy-intensive economic structure, put upward pressure of around 54 EJ in energy demand.

The net effect of these drivers meant that global final energy demand from 2016 to 2021 only rose by 24 EJ, or 6%, to around 440 EJ. Without the energy savings from efficiency gains, energy demand would have grown 13%, to almost 470 EJ. However, in the Net Zero Scenario, global final energy demand falls to just below 400 EJ by 2030, highlighting the much greater role efficiency needs to play in the coming years.

Decomposition of change in global total final energy consumption (TFC), 2016-2021

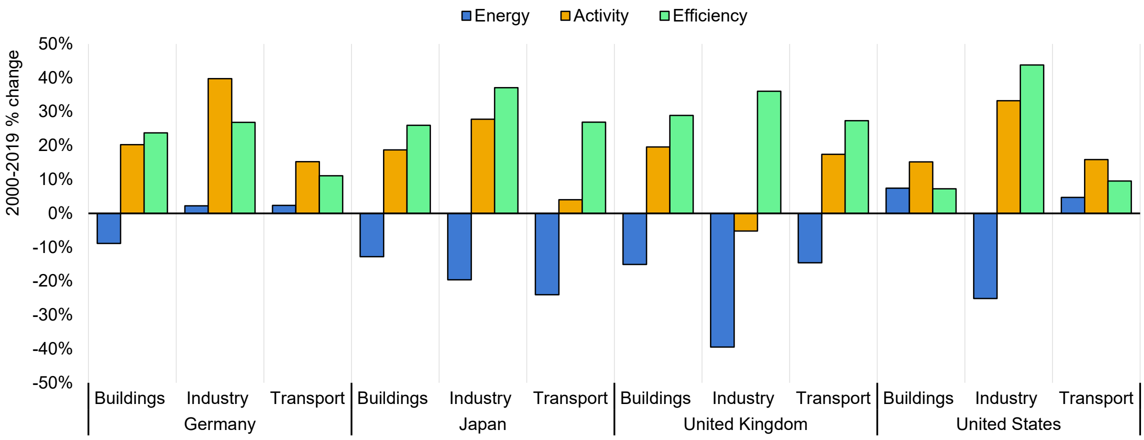


Despite recent slower progress, efficiency has delivered major reductions in energy use while activity levels rose

Over the last two decades energy efficiency improvements have been so significant that across the IEA countries as a whole total final energy demand has remained steady at around 140 EJ, even as economic activity rose 40% over the same period for the group. In some countries and sectors energy consumption has actually fallen.

In the United Kingdom, for example, total residential energy consumption from 2000 to 2019 fell by around 270 PJ, or 15%, even as 500 million m^2 of floor area was added. This is equivalent to an extra 5.3 million homes, or about 260 000 new homes being added every year. This reduction in residential energy demand came from a 29% increase in the overall efficiency of buildings, with energy intensity of floor space falling from 0.83 GJ per m^2 in 2000 to 0.59 GJ per m^2 in 2019.

Change in energy consumption, by selected drivers and countries, 2000-2019



Note: 2000-2019 is used as the time period rather than 2000-2020 to exclude the extraordinary effects of Covid-19 which significantly reduced 2020 energy consumption in many countries. For buildings: energy = residential, activity = floor area m^2; efficiency = GJ/m^2 floor area; for Industry: energy = manufacturing; activity = industrial value added USD 2015 PPP; efficiency = GJ/industrial value added USD 2015 PPP; for transport: energy = total road transport cars and light trucks; activity = vehicle kilometres travelled cars and light trucks; efficiency = cars and light trucks MJ / vehicle kilometre.

In Japan, vehicle efficiency progress is particularly strong. Longstanding policies have promoted very small "kei-cars" and hybrid electric vehicles are a high proportion of new cars sold. As a result, the rated fuel economy of new light-duty vehicles continues to improve. Total final energy consumption of cars and light trucks fell by more than 470 PJ or 24% for the two decades before the onset of Covid-19. This was achieved even as the distance travelled by Japanese motorists rose by 26 billion km per year—the equivalent of around 400 extra km for every car on the road in 2022.

In the United States, energy consumption in manufacturing fell by 25% or 3 500 PJ, even as the total value added from the sector rose by one-third. This included light industry such as food, textiles and paper, and heavy industries such as chemicals, plastics, basic metals and cement, as well as car manufacturing, electronic equipment and furniture.

The largest future energy efficiency opportunities will be found in emerging and developing economies

Emerging market and developing economies together account for around 260 EJ or 60% of global final energy demand. Under current policy settings, this demand is expected to grow almost 20% by 2030, to around 305 EJ, increasing its global share by 5% as energy demand in advanced economies stays relatively steady.

In emerging economies, higher rates of energy consumption are generally expected as new infrastructure is built requiring energy-intensive industrial products such as steel and cement. Many citizens are also gaining access to modern energy services for the first time, which will result in higher energy consumption in the building and transport sectors.

Behind this energy growth story is a rise in energy consumption per person in emerging economies as they modernise. For example, an average person in an EMDE currently uses three times less energy in their home and four times less energy for transport compared with an average person in an advanced economy.

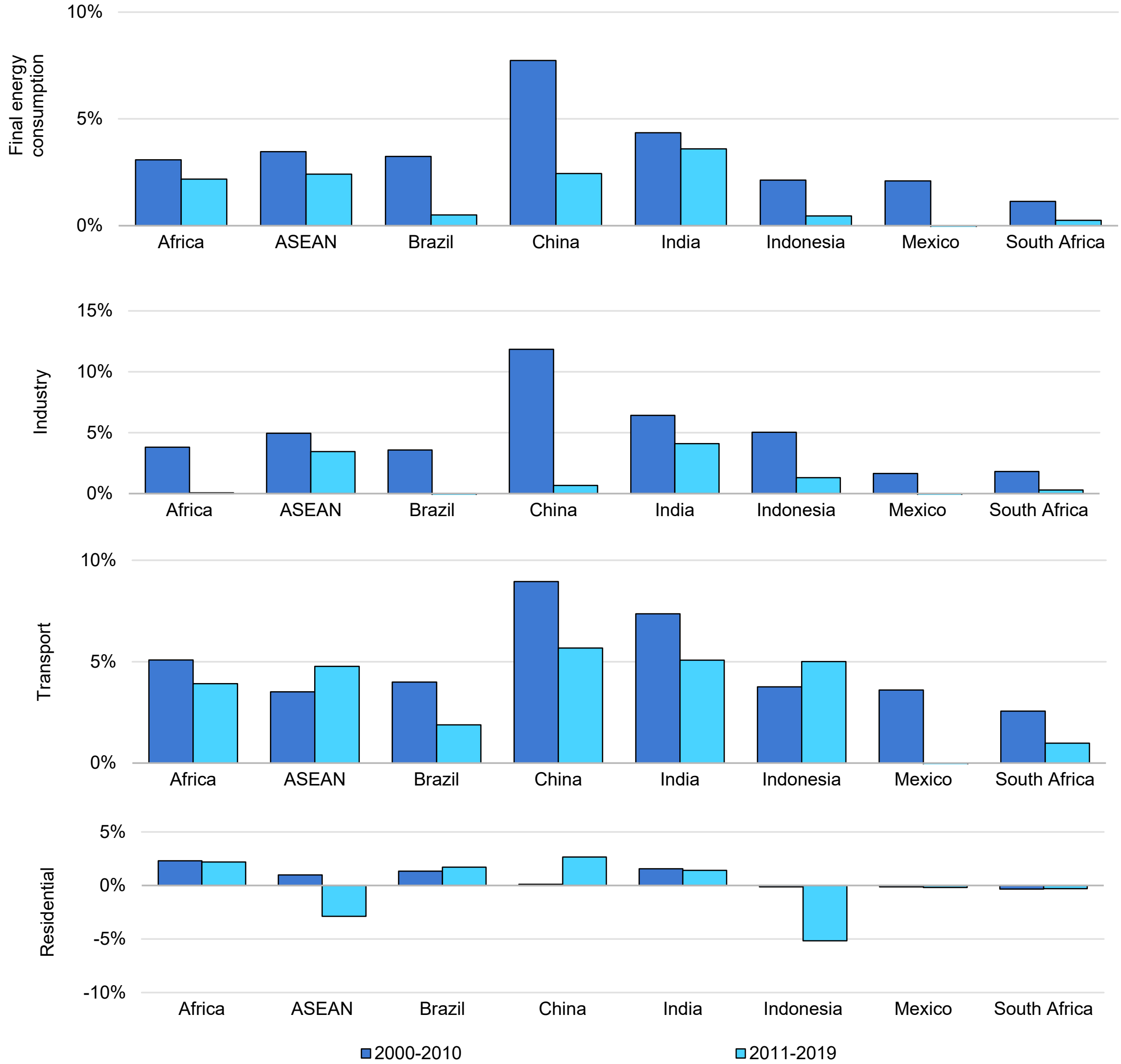
As emerging countries account for an ever-greater share of energy demand, the largest energy efficiency opportunities will increasingly be found in countries such as Brazil, China, India, Indonesia, Mexico and South Africa. Given the critical importance of these countries to global energy security and climate goals, the IEA is collaborating with them and others in Africa, the ASEAN and Latin American regions to support energy efficiency through its Energy Efficiency in Emerging Economies (E4) programme.

For example, the Brazilian Atlas of Energy Efficiency illustrates how growth in average incomes has been a prime driver of energy consumption and how efficiency policies and programmes have helped to mitigate demand growth. The Atlas, in collaboration with the IEA over the past few years, has developed a robust level of data providing strong insights to track efficiency improvements and assess policies across the household, industrial and transport sectors.

In many EMDE countries, before the onset of Covid-19 energy demand growth rates had decelerated, stabilised or even declined. For instance, average annual growth in industrial energy consumption fell from over 10% per year from 2000 to 2010 in China to around 1-2% from 2010 to 2019, from 6.5% to 4.5% in India and from 5% to 2% in Indonesia. In Brazil, Mexico and South Africa, industrial energy demand looked to have stabilised or even started to fall.

In China, several high-level energy efficiency policies have been announced in 2021 and 2022, including the Guidance on Carbon Dioxide Peaking, an Action Plan for Increasing Industrial Energy Efficiency, and a blueprint for carbon peaking and neutrality for urbanisation and rural development. These include targets to increase electrification of buildings to 65% by 2030 and upgrade old electric motors so that 70% of the stock use new efficient models. New minimum standards set in February 2022 for 17 energy-intensive industries also aim to encourage adoption of advanced equipment and new technology by 2025.

Annual average change in final energy demand, in selected EMDE countries, 2000-2019



China's steel sector accounts for over half (53%) of global production and has the ability to shift the needle on global energy intensity. Production hit record levels in 2021, but saw a 2.2% drop in crude steel output from January-October 2022, alongside an 11.3% drop for cement output. A further output reduction was expected following actions to cap new crude steel production capacity and push down production, both to reduce carbon emissions and relieve cost pressures for steelmakers. With additional impact from reduced demand in China's real estate sector, combined with plans to increase the share of scrap steel and Electric Arc Furnace (EAC) capacity, a consensus is developing across the industry that China's steel consumption could soon reach its upper limit, which would accelerate projected timeframes for a peak in emissions. China's petrochemicals industry has also seen controls introduced for crude oil processing capacity of 1 bn tonnes/year by 2025 as part of broader emissions peaking plans.

Growth in transport energy consumption has also moderated in the largest emerging countries. Demand growth in Brazil slowed to around 2% per year on average over 2010-19 compared with 4% the decade previously, China to 6% from 9%, India to 5% from 7% and South Africa to 1% from 2%. In Mexico, transport energy consumption was steady over 2010-19. Only in Indonesia was transport consumption higher, rising to an average 7% per year over 2010-19 compared with around 4% during the prior decade.

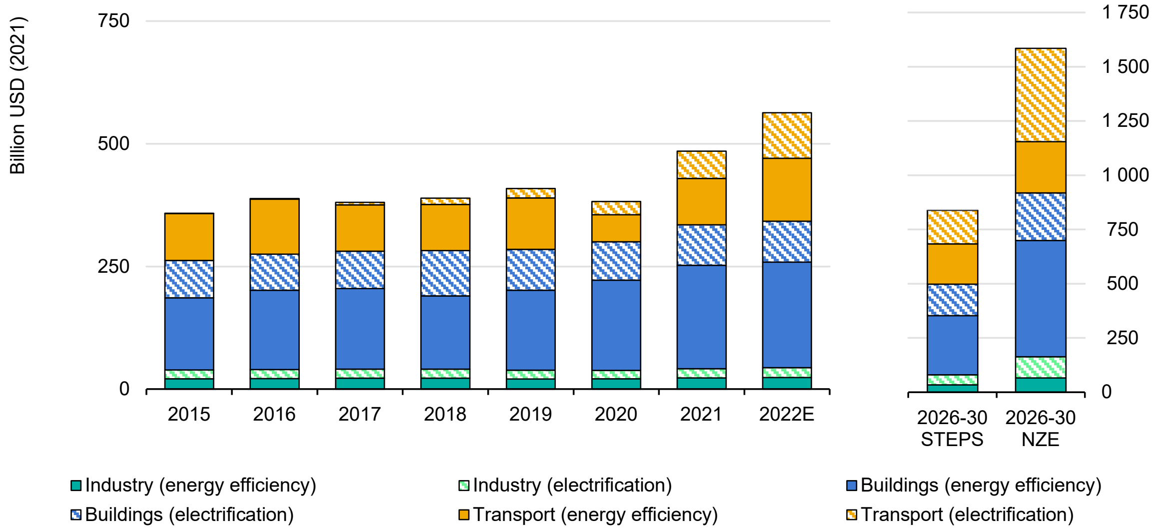
Residential energy consumption trends in emerging economies has been driven by energy savings from the transition away from the traditional use of biomass for heating and cooking being offset, in large part, by the added energy use from access to modern energy services such as air conditioning. Around 5 billion people live in areas requiring space cooling, but only one-third of households, mostly in advanced economies, currently have an air conditioner. The net effect of these drivers, combined with improving efficiency, has generally slowed energy consumption growth or even led to a decline for some countries such as Indonesia.

1.3 Finance and investment

Energy efficiency-related investment set to rise by a robust 16% in 2022

After years of weak or no growth in the second half of the last decade, energy efficiency-related end-use investment began to rise strongly in 2021. This was driven by government stimulus programmes in the buildings sector and a recovery in transport investment, after declining by around 50% in 2020 due to the pandemic. In 2022, strong overall growth continued, with transport overtaking buildings as the main sector for increased spending, driving total efficiency-related investment up by 16% to just over USD 560 billion. However, inflation and rising costs are offsetting around half of the growth in efficiency-related investment due to supply chain pressures, rising labour costs and higher material prices. Clean energy investments – comprised of energy efficiency and end-use spending – continue to be significantly lower in EMDEs than in advanced economies.

Global energy efficiency-related end-use investment, 2015-2022, and averages by scenario, 2026-2030



Note: Energy efficiency investment comprises the incremental spending on new energy-efficient equipment as well as the full cost of refurbishments that reduce energy use, which allows for capturing all spending that leads to reduced energy consumption. Investment in energy-efficient transport comprises additional spending on efficient road vehicles and road electric vehicles, including plug-in hybrid vehicles.
Source: World Energy Investment 2022.

Under current expected policies, efficiency-related investment is projected to rise by a further 50%, to almost USD 840 billion per year by 2026-30. However, these levels are only about half of the energy efficiency-related investment needed in the second half of this decade to meet the Net Zero Scenario goals. Massive efforts to accelerate investments in building efficiency and electrification of transport, heating, cooling and industrial production are required to realise global climate ambitions. In the Net Zero Scenario of the WEO 2022, the share of investment in energy efficiency and electrification rises from 17% of the current total to 32% by 2030, and 40% by 2050.

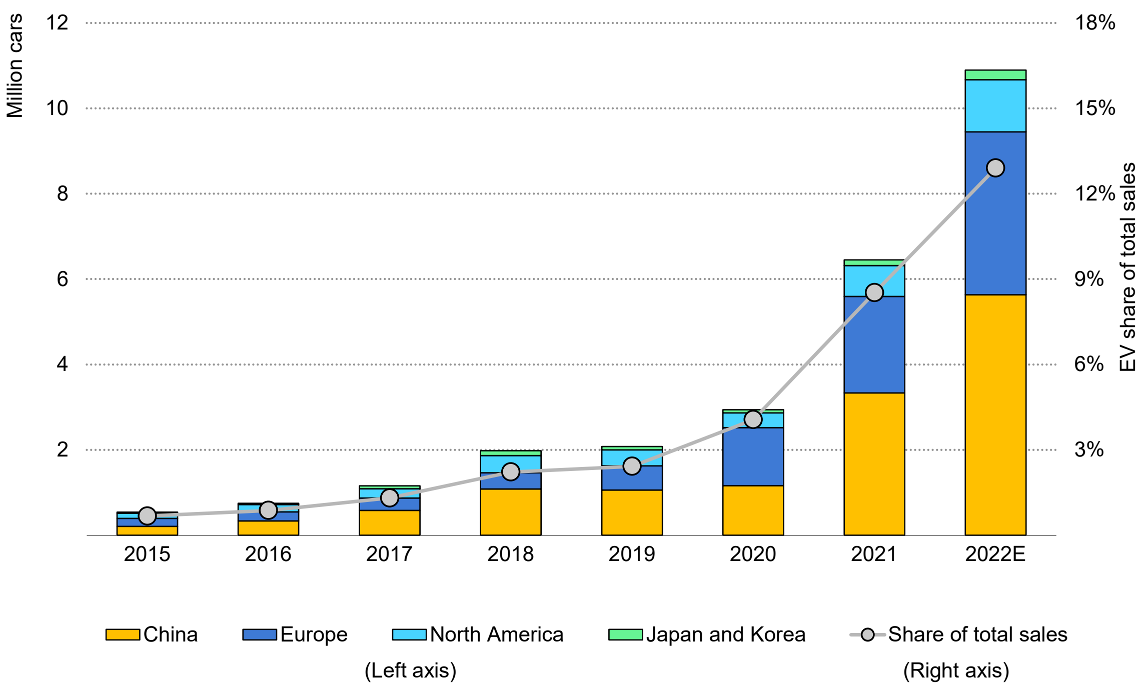
2022 is expected to see only a modest increase in building efficiency investment of 2%, just above USD 240 billion globally. The significant slowdown compared with the 12% year-on-year growth in 2021 results from higher construction and material costs, increased financing costs, as well as lower spending in emerging markets and developing economies.

Electric vehicle sales push transport efficiency-related investment up by almost 50% in 2022

Global efficiency-related transport investment is forecast to rise a substantial 47% in 2022, to USD 220 billion. This includes just over USD 90 billion for electrification, up USD 37 billion, or 67%, compared with the year before. Investment in the electrification of transport now accounts for around 42% of total efficiency-related transport investment, up from just 19% in 2019.

Electric vehicle sales have nearly doubled for the last two years in a row, hitting around 11 million units sold worldwide in 2022, up from just 1 million in 2017. This means that electric vehicles now account for 13% of new vehicle sales worldwide, up from just over 1% five years ago. This transition was supported by government spending on subsidies and incentives for EVs, which nearly doubled in 2021 to about USD 30 billion. Nonetheless, the decreasing share of government subsidies in total spending for electric light-duty vehicles and soaring sales numbers suggest that consumer choice is becoming a major driver in more advanced EV markets.

Global trends in new electric passenger light-duty vehicle sales, 2015-2022



Source: Global EV Outlook 2022.

Investment in conventional energy efficiency in the transport sector also performed strongly, rising USD 33 billion, or 35%, to USD 128 billion, driven by increased spending for more efficient vehicles, including hybrid electric vehicles. Fuel economy standards are one of the key policy instruments to improve vehicle efficiency of conventional vehicles, and if stringent enough, contribute to driving electric vehicles (EVs) into the market.

While EV sales doubled in developing Asia, and spiked in several markets in Eastern Europe, Latin America and the Caribbean, their market share is still low in large emerging economies like Brazil, India and Indonesia with less than 0.5% of car sales. The latter reflects a number of factors including lower cost competitiveness compared with conventional vehicles as well as a smaller portfolio of vehicle models available versus advanced economies. Global electric light commercial vehicle sales increased by more than 70% in 2021. Despite a strong economic case for electrifying light commercial vehicles, particularly delivery fleets in urban areas, their market share of sales is still only at 2%.

Investments in electric two- and three-wheelers, as well as in the electrification of buses and heavy-duty vehicles, also increased in 2021. In May 2022, the Green Climate Fund (GCF) approved a USD 1.5 billion private sector E-mobility Financing Programme for India, aiming to provide financing solutions to electric vehicle owners and operators, as well as charging infrastructure and batteries to support the development of the EV ecosystem. E-bus sales rose 40% and sales of electric medium- and heavy-duty trucks more than doubled compared with 2020 volumes. China dominates the market in all segments, reaching nearly 9.5 million or 95% of electric two- and three-wheeler registrations worldwide and 90% of e-bus and e-truck registrations in 2021.

Battery swapping is gaining traction in several markets, particularly for two- and three-wheelers in Asia. India introduced a draft battery swapping policy focusing on two- and three-wheelers in April 2022, and Indonesia's Ministry of Energy and Mineral Resources (ESDM) is revising Ministerial Regulation No. 13 of 2020 to increase the number of charging and battery swapping stations. China recorded sales of 250 000 battery swapping vehicles in 2021, which are expected to grow with the support of polices and innovative business models like battery-as-a-service.

Bulk procurement and mass electrification of buses in Chile and India

Under the fleet renewal and expansion tender of the Ministry of Transport and Telecommunications of Chile, almost 1 000 electric buses were procured for use in Santiago's public transport system. This brings the capital's public transport fleet to just above 1 700 electric vehicles (over 25% of the fleet), making Chile the country with the second-largest urban e-bus fleet after China.

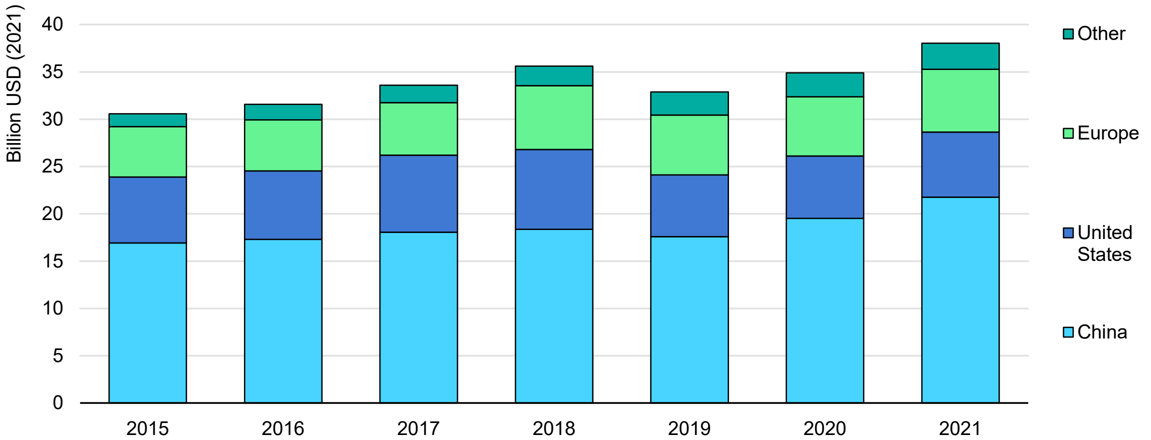
India aims to electrify its public bus fleet through bulk procurement programmes, with 50 000 buses procured over the next five years. In the Grand Challenge e-bus tender in early 2022, Convergence Energy Services Limited (CESL), a subsidiary of the Indian Super ESCO EESL, successfully tendered over 5 450 e-buses across five cities under its FAME II scheme. The tender led to the lowest price ever based on a Gross Cost Contract that provides e-mobility as a service. The buses are expected to operate around 7.1 billion km over 12 years, saving almost 1.9 billion litres of fuel and creating employment for at least 25 000 people. In July 2022, CESL also signed a MoU with fintech company Three Wheels United (TWU) for the procurement of 70 000 electric three-wheelers to be deployed across India in a phased approach starting in Bengaluru and Delhi.

China continues to drive global growth in ESCO market

Energy service companies (ESCOs) provide a wide range of services for consumers, from generation and supply to energy management and efficiency retrofits. ESCOs offer specialist support to make it easier for energy users to identify, finance and implement projects, and can play a particularly important role in reducing the upfront cost of efficiency-related investments.

The global ESCO market increased 9% to USD 38 billion in 2021. Investment in China, the biggest market, grew by 9% to USD 22 billion. Recent initiatives across the world include innovative and digital business models, and better project aggregation, including portfolio approaches, service packaging and Super ESCOs. Both Kenya and Senegal have embarked on setting up Super ESCOs, while Saudi Arabia and three of seven UAE emirates have operative Super ESCOs. Private Super ESCO SOFIAC in Canada and Climargy in the Philippines recently became operational.

Investment in ESCO projects, worldwide, 2015-2021



Source: Based on IEA annual ESCO market surveys, including the 2022 collaboration with the Global ESCO Network.

ESCO interventions in buildings dominate in many markets in Europe, North America and Asia, and in 2021 reached over 50% of market share in China for the first time. Industry sector projects are strongly represented in Japan, in the Republic of Türkiye (hereafter, "Türkiye") and several other Asian markets, while electric vehicle fleet acquisitions may open up new opportunities in both advanced and emerging economies. In November 2022, the European Investment Bank finalised a EUR 220 million fund to target energy efficiency and behind-the-meter renewable energy investments and support ESCOs across the European Union.

Results of the most recent annual IEA ESCO market survey suggest that while high energy prices and heightened awareness of energy efficiency measures provide new opportunities, obstacles such as the lack of available personnel and shortages of needed supplies as well as rising material costs, hamper project implementation. Credit risk on the client's side, a lack of demand and trust in the ESCO industry, as well as administrative and regulatory barriers, remain among the most important challenges. Delays in the phase out of energy subsidies in several markets, and government support programmes that exclude third-party actors like ESCOs, add further obstacles.

Tarshid the Super Energy Service Company of Saudi Arabia

Saudi Arabia's Public Investment Fund established Tarshid in 2017 with an initial capitalisation of USD 500 million as a Super ESCO. It focuses on improving energy efficiency in public buildings, including street lighting, government offices, schools and mosques, as well as projects in the commercial sector. All public bodies are mandated to contract with Tarshid on an exclusive basis and the ESCO is expected to cover 70% of all energy efficiency projects in the country, estimated at a USD 11 billion market. Tarshid uses energy performance contracting to acquire the services of private sector ESCOs to deliver energy efficient equipment and other solutions. For example, in 2022 Tarshid set about the rehabilitation of university buildings, with energy savings of an estimated 115 million kWh annually, equivalent to freeing 77 000 barrels of oil equivalent that can be used for export or other purposes. Tarshid also completed in 2022 a rollout of 54 000 LED public lamp posts, delivering estimated energy savings of 104 million kWh or 60% compared with previous public lighting.

Small and medium-sized enterprises look to save energy through efficiency measures

There are approximately 333 million businesses classed as MSME (Micro, Small and Medium-sized Enterprises) throughout the world, contributing from 9% to 29%

of national energy demand. In Asia, MSMEs account for 97% of all enterprises and 69% of the labour force, while Europe's 23 million small and medium enterprises (SMEs) employ around 83 million people or about 38% of the labour force. They account for about half of Europe's GDP and play a key role in adding value in every sector of the economy.

One recent survey found that more than half of MSMEs are planning to implement new measures to improve energy efficiency in the immediate future and 61% are already putting them in place to save energy. For example, in Mexico the government has helped provide concessional loans to small- and medium-sized enterprises, which represent 98% of the country's business, to implement around 36 000 standardised efficiency measures such as replacement of old equipment.

To help smaller businesses overcome these challenges and to sustain European economies, the European Commission and the IEA teamed up to raise the awareness of governments, businesses and related stakeholders about available options to empower and protect SMEs. Separately, an amendment to the Temporary Crisis Framework for state aid, which gives Member States more leeway to support companies and makes available EUR 40 billion of European Union Cohesion Funding, has been enacted.

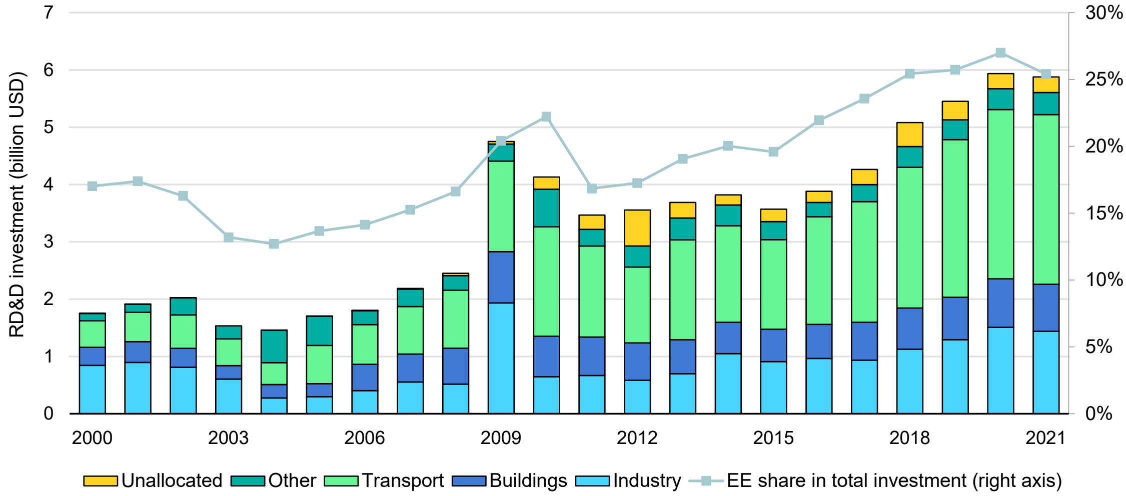
In 2022, the United Kingdom introduced a grant scheme to help households and small businesses invest in heat pumps and biomass boilers. The government built on this in its Autumn Budget Statement by allocating extra funding from 2025 to 2028. It will be overseen by a new taskforce charged with insulating homes, upgrading boilers and reducing overall energy demand by 15% this decade. The Czech Republic introduced a new guarantee for small- and medium-sized enterprises whose energy costs account for more than 10% of total operating costs. Meanwhile, the US Department of Energy (DOE) announced that USD 53 million will be directed at small businesses pursuing clean energy and climate solutions.

1.4 Innovation

Public energy efficiency RD&D spending steady following a decade of growth

Public spending on research, development, and demonstration (RD&D) in energy efficiency was steady in 2021 at around USD 6 billion. Spending remained 50% higher than in 2015 in real terms. Efficiency-related public RD&D spending in 2021 continued to be dominated by transport (49%), followed by industry (24%). Over the last decade energy efficiency as a share of total government energy RD&D investment has been rising steadily and now represents a quarter of all investment.

Government energy efficiency RD&D spending, in IEA member countries, 2000-2021



Source: IEA's Energy technology RD&D budgets database.

Venture capital investments in efficiency are on the rise but could face setbacks as economic conditions worsen

Much more innovation will be needed to develop better and cheaper clean energy technologies and put the world on track for net zero emissions by 2050. The role of clean energy start-ups – aside from government and business R&DD – is becoming more important, particularly to develop new products and services with lower upfront costs than traditional energy projects.

In 2021, despite the pandemic, venture capital (VC) investments in early-stage start-ups developing energy efficiency technologies for buildings, industry and power rose by over 30% to USD 1.1 billion. The increase was primarily led by companies advancing smart grids and integrated power flow optimisation concepts, which attracted more funds than any other year. Meanwhile, early-stage VC investments in transport electrification and battery technologies increased by over 40% to USD 1.8 billion, largely led by the expansion in battery markets.

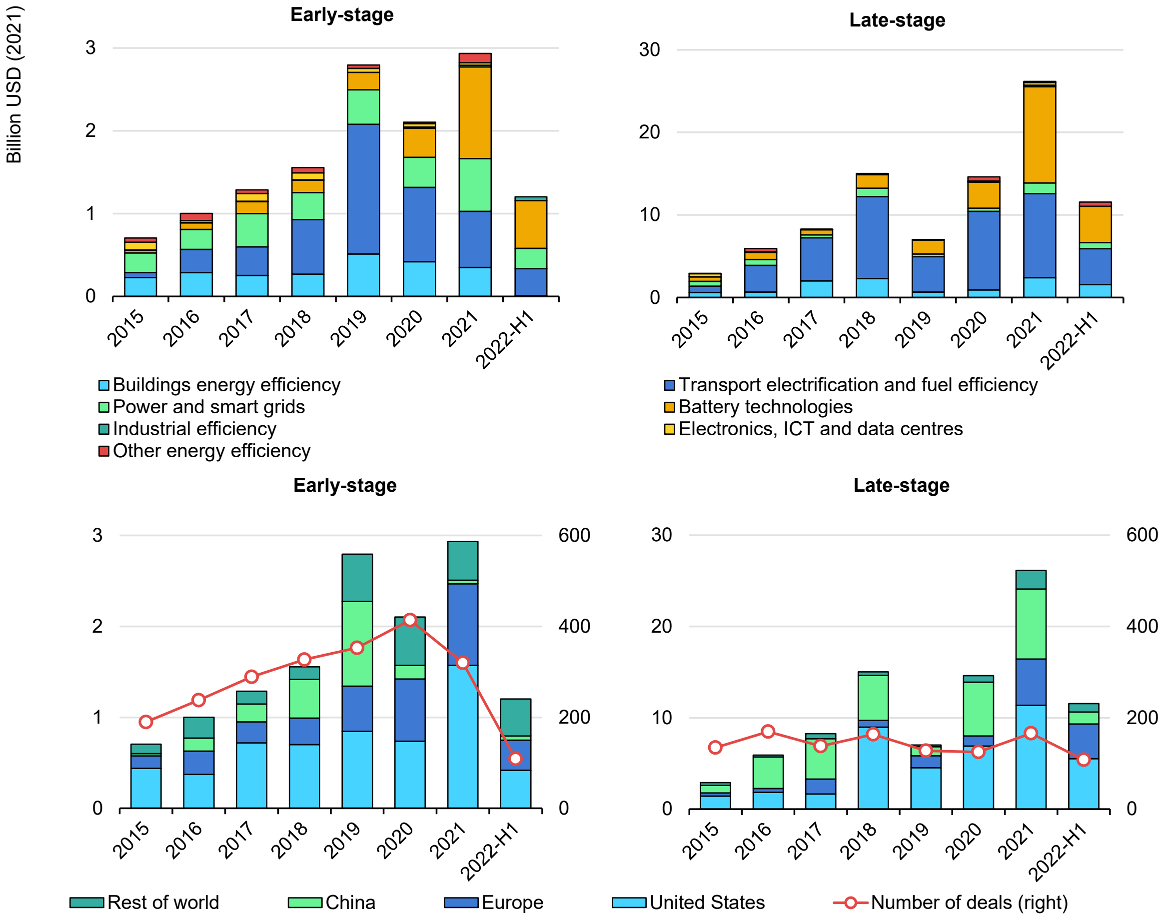
Late-stage VC investments in efficiency start-ups rose significantly in 2021 as well, more than doubling to USD 4.3 billion, to a new all-time high. The increase was led by power and smart grids, and energy efficiency in buildings. Electric mobility and battery companies raised nearly USD 22 billion – up 70% relative to 2020 – with funds targeted for growth, scale-up and market expansion, far ahead of other efficiency-related technology areas.

In transport, a technology revolution is underway with innovation extending electrification frontiers and steering investors' focus towards EV scale-up. In fact, as the industry matures, early-stage money in EV start-ups is clearing space for soaring later-stage financing rounds: in 2021 VC investments in transport electrification were down 25% in early stages but up by over 5% in late stages.

In parallel, innovation is accelerating at the battery level – from mineral extraction to manufacturing – as demand booms, with VC investments more than tripling at all stages. New cross-cutting fields are emerging, such as battery management systems, which attracted nearly USD 50 million in 2021. These included India-based ION Energy and Germany-based volytica, which develop battery diagnostics solutions to improve performance and lifetime.

The United States, Europe, and China, as in previous years, lead energy VC investments. Preliminary data suggest a possible slowdown in early-stage VC investments in the first half of 2022 as the sector is impacted by the risk-off approach to technology investment of financial markets this year.

Global venture capital investments in clean energy start-ups in the fields of efficiency and electrification, by technology area and by region, 2015-H1 2022



Note: This classification considers start-ups developing energy efficiency technologies, services and solutions including both hardware and software. Early-stage deals are defined as seed, series A and B deals. Very large deals in these categories – above a value equal to the 90th percentile growth equity deals in that sector and year – are reclassified as late-stage deals, which also include growth equity, late-stage private equity, and private investments in public equity. "Buildings energy efficiency" includes building envelopes, heating and cooling, energy management systems, lighting and smart devices for residential and commercial buildings. Transport electrification and fuel efficiency includes electric vehicles but excludes associated battery technologies, which are separated and include battery mineral extraction and processing, components, manufacturing, recycling and management systems. 2022 includes

*H1 2022: Preliminary data for the first half of 2022.

Source: IEA calculations based on Cleantech Group, i3 database (2022). Also see: World Energy Investment 2022.

Growth in digital energy efficiency models shifts from early-stage to late-stage venture capital funding

In the world of clean energy start-ups, digitalisation has become a buzzword as entrepreneurs increasingly seek new ideas based on digital tools or processes and pursue new digital business models, such as energy-as-a-service (EaaS) and virtual power plant (VPP) aggregator models for distributed energy resources (DERs). Innovation and access to new types of data are creating additional opportunities for traditional energy companies and utilities, as well as in industry, transport and buildings.

After showing impressive resilience through the pandemic, early-stage VC investments in energy efficiency start-ups that develop digitally-enabled business models dropped by about 20% in 2021 to USD 800 million. The decline was mainly because of much lower investments in EV charging as a service. This could reflect the broader trend that companies developing EVs and associated technologies, which received substantial funding over the last decade, have matured and moved to later stages of development. Excluding these, the observed decline would have been a 15% increase. Companies providing EaaS in buildings, as well as DERs and grid management, raised more early-stage VC money, at about USD 370 million and USD 200 million, respectively.

Digital technologies form the basis of new business models

The use of digital technologies increases access of new business models to end-user customers. The energy-as-a-service (EaaS) business model, where customers pay for an energy service without having to make upfront capital investments through a subscription scheme, shifts the focus away from asset-based to consumer-centric and service-oriented offerings. Business service model applications range from providing efficiency, lighting, cooling, or storage as a service, through to mobility services such as ridesharing, EV charging or battery-as-a-service.

The physical, digital and ICT infrastructure that is used opens the market for a wider range of players, including utilities, ESCOs, industrial equipment suppliers, telecom, and technology providers, among others.

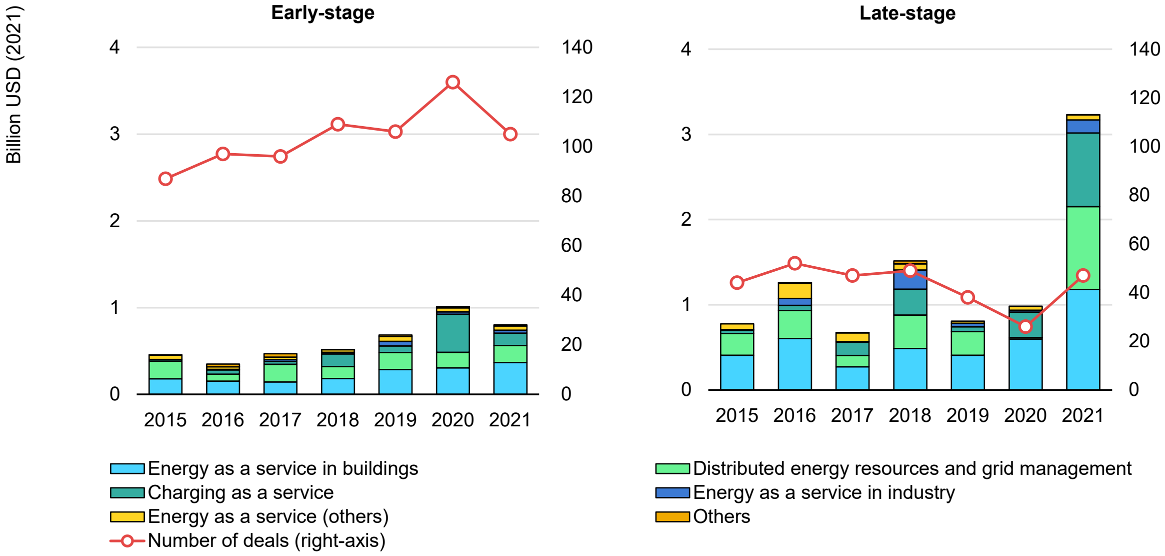
The market is expanding rapidly, although growth projections vary widely, with estimated potential ranging from USD 19 billion by 2025 up to USD 148 billion by 2029.

Batteries are the most expensive component of an EV, so separating the battery from the vehicle can reduce upfront investment costs – one of the major barriers to large-scale EV deployment. Battery swapping models can also allow customers to benefit from advances in battery technology and lead to better charging management, thereby extending battery life and improving options for vehicle-grid interactions. The most widely adopted approach to providing battery swapping is leasing batteries to customers through a battery-as-a-service model.

China's battery swapping market is one of the fastest growing markets for the technology. As of September 2022, over 1 760 battery swapping stations (BSS) had been deployed, a 98% increase year-on-year. According to Bloomberg New Energy Finance, six of the big Chinese battery-swapping providers plan to build 26 000 BSS by the end of 2025 – an almost 15-fold increase from current levels. India is also making important steps towards the scaling up of battery swapping, especially for two- and three-wheelers, with Niti Aayog releasing a draft battery swapping policy in April 2022. Three Indian states (Delhi, Maharashtra and Goa) currently offer purchase subsidies for electric two-wheelers without pre-fitted batteries and several states offer incentives for setting up swapping stations.

In contrast to the early-stage dip, late-stage VC investments more than tripled in 2021 year-on-year, to over USD 3 billion, with the number of deals recovering to pre-Covid levels. The increase was primarily led by DERs and grid management, which attracted almost USD 1 billion in 2021 from nearly zero in 2020, by charging as a service, and a doubling for EaaS in buildings. One example is Daystar Power, which provides hybrid solar systems to businesses in West Africa through a power-as-a-service model and raised USD 38 million in Series B in 2021.

Global VC investments in energy efficiency start-ups developing new types of digital business model, 2015-2021



Note: 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 (EaaS) in buildings includes smart heating and cooling, energy management systems, lighting and smart devices for residential and commercial buildings. Distributed energy resources and grid management includes virtual power plants, energy trading schemes like peer-to-peer, and off-grid access solutions such as pay as you go. Early-stage deals are defined as seed, series A and series B deals. Very large deals in these categories – above a value equal to the 90th percentile growth equity deals in that sector and year – are excluded and reclassified as late-stage investments, which also include growth equity, late-stage private equity, and private investments in public equity.

Source: IEA calculations based on Cleantech Group, i3 database (2022). Also see: Energy Efficiency Market Report 2021.

Chapter 2. Policy and technology

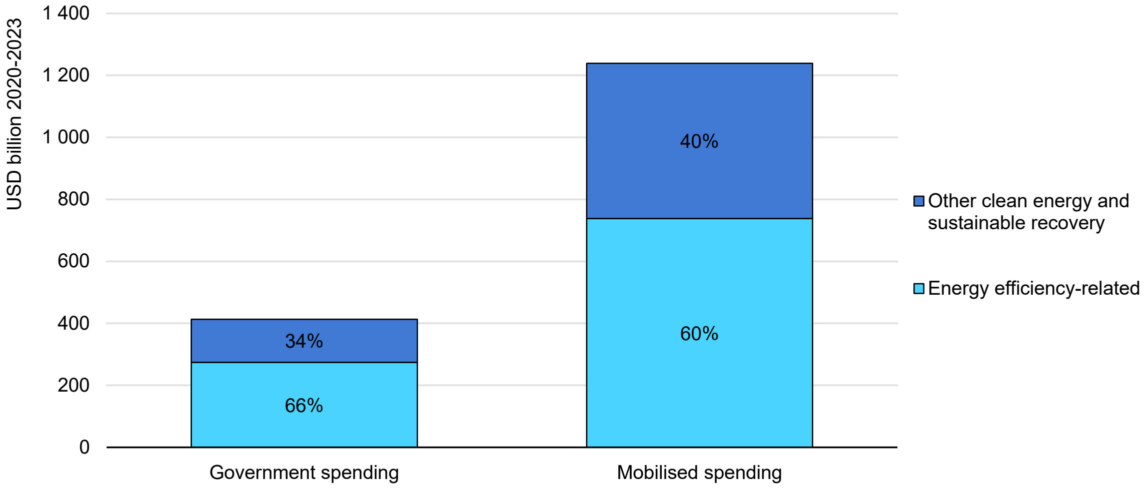
2.1 National and international developments

Over USD 1 trillion mobilised since 2020 to support energy efficiency in clean energy recovery packages

Total recovery spending monitored by the IEA's Sustainable Recovery Tracker has risen strongly as governments have ramped up clean energy investment since 2020 and responded to the energy crisis triggered by Russia's invasion of Ukraine.

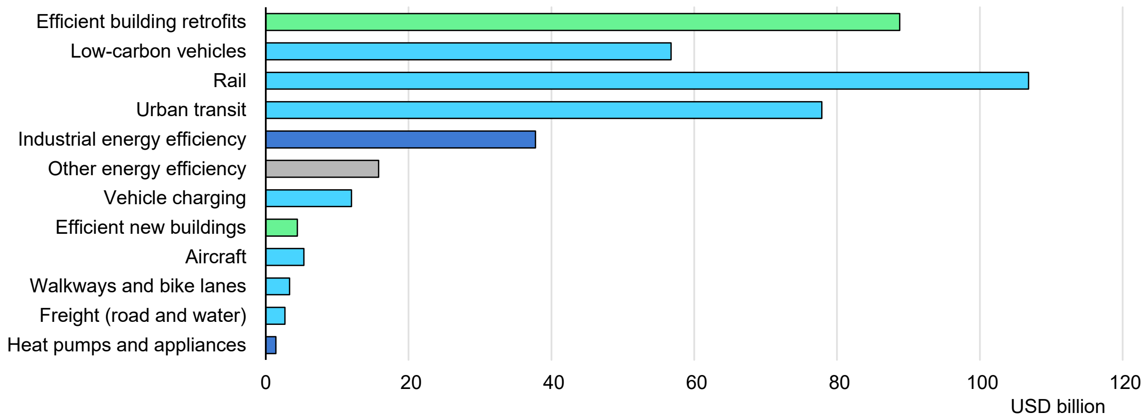
This analysis suggests over USD 1 trillion has now been mobilised for energy efficiency-related actions between 2020 and 2023. Approximately USD 270 billion is direct public spending and a further USD 740 billion is mobilised spending on efficient building retrofits, vehicles, transport infrastructure and industrial efficiency projects. Efficiency spending constitutes around two-thirds of the total government and leveraged private clean energy recovery spending of around USD 1.6 trillion since 2020 until 2023.

Clean energy and recovery spending, 2020-2023



Note: Mobilised spending includes private and public spending mobilised by government action.
Source: IEA Tracking Sustainable Recoveries; as of April 2022.

Cumulative clean energy recovery government spending earmarked until 2023



Source: IEA Sustainable Recovery Tracker; as of April 2022.

These spending numbers are expected to rise when this analysis is updated for the full year by the IEA as many governments have enacted new investment packages since mid-2022.

In the United States, Congress passed the Inflation Reduction Act in August 2022 to help address higher costs of living and other related issues. An unprecedented USD 369 billion of the total package of USD 737 billion has been allocated for energy and climate change measures to be spent over ten years. Energy efficiency provisions of the package are estimated at around USD 95 billion. This includes USD 20 billion of clean transportation tax credits for electric vehicles, investment in zero-emission vehicles for the US Postal Service, public services and zero-emissions equipment for port infrastructure.

About USD 53 billion has been earmarked for energy efficiency in buildings, including tax credits for residential electrification and energy efficient appliances. Another USD 16 billion is targeted towards the manufacturing sector, including grants and loans for electric vehicle production, and tax credits for other clean manufacturing. In a significant move to address supply chain challenges, funding has been made available through the US Defense Production Act to speed up the production of clean energy technologies such as heat pumps, insulation and photovoltaics panels.

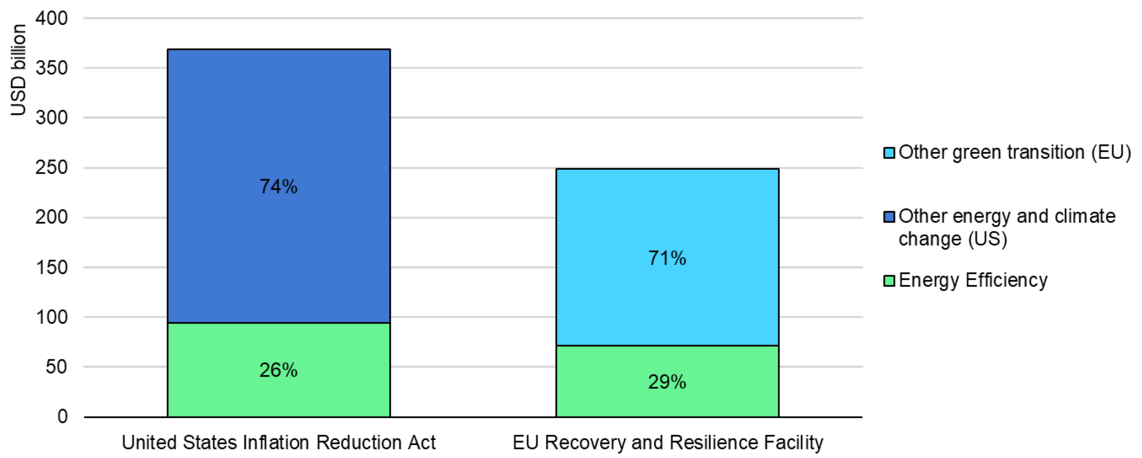
In another major development, the European Union launched the RePowerEU plan in May 2022 to accelerate the clean energy transition and to reduce reliance on Russian fossil fuels by aiming to cut its use by two-thirds by the end of 2022 and 100% by 2030. Energy savings is one of the plan's three central pillars. It foresees an increase of the previous target under the Energy Efficiency Directive for EU-wide energy savings from 9% to 13%, with the goal of doubling the deployment rate of heat pumps to around 10 million cumulative units over 2023-

27 and accelerating electrification, especially in industry. The EU Save Energy Communication, issued in August, outlines options for short-term savings from consumers, and the Commission has urged Member States to launch public awareness campaigns. Related to this is the European Gas Demand Reduction Plan, which sets out short-term measures to reduce gas use in Europe by 15% until spring 2023.

The European Commission has issued a proposal for financing of the plan by increasing the EU Recovery and Resilience Facility (RRF). The total estimated expenditure on the green transition pillar is EUR 249 billion, with the energy efficiency elements accounting for about 29%.

In France, the budget for the MaPrimeRénov retrofit grant scheme was increased by 20%--an extra USD 400 million. The scheme received 430 000 applications between 1 January and 11 September 2022. In Spain, contingency plans to address the energy crisis included a range of efficiency and demand-side measures, such as a reduction in public transport prices, limits on heating and cooling in public buildings, and a programme of residential building audits and retrofits.

Budget allocations in the US Inflation Reduction Act and the EU Recovery and Resilience Facility



Notes: Funding as of July 2022. The US Inflation Reduction Act includes budgets in several categories and the one under analysis here is "Energy and climate change". The EU Recovery and Resilience Facility focuses on six policy pillars, and the one under analysis here is "Green transition".
Sources: IEA based on data from Congressional Progressive Caucus Center, European Commission.

Italy's Superbonus retrofit scheme, the largest single retrofit grant programme in Europe, has offered tax credits worth more than USD 55 billion by October 2022. In late 2021 it was updated to be made more stringent, with eligible upgrades mandated to raise the building performance by two classes. Ireland's National Retrofit Plan was launched in February 2022 and seeks to upgrade 500 000 homes, representing 30% of the housing stock, by 2030 through grants of up to 50% of the cost of a deep retrofit, while the country's One-Stop Shops assist with project management, among other measures.

In Canada, a newly announced Green Buildings Strategy, aims to increase the rate of building retrofits and create a net-zero-ready buildings sector by 2050, backed by USD 109 million (CAD 150 million).

In Japan, the government has launched its Green Transformation (GX) Plan and strengthened the legal basis for improving its energy efficiency ambitions by amending the Act on Rationalizing Energy Use and Building Energy Efficiency Act. These measures strengthen building codes and annual energy reporting systems for large-scale consumers, including for demand response measures. It will also provide, through a three-year efficiency investment plan, subsidies of JPY 500 billion for replacing old facilities in factories and buildings.

In order to ease the burden of high power prices, the Japanese government has started the Setsuden Program, with an estimated budget for the programme of JPY 180 billion (USD 1.25 billion). It promotes utility-run demand response schemes with economic incentives whereby consumers earn points for every kWh of saved energy. Points can then be spent for payments for multiple uses like electricity bills and famous EC markets with one point roughly equivalent to one yen, which leads consumers to join these saving programmes.

The role of energy efficiency investment in Ukrainian reconstruction

The World Bank reported that as of 1 June 2022 the war has damaged around 817 000 residential units in Ukraine, of which more than 312 000 were completely destroyed. In July, at the Ukraine Recovery Conference in Lugano, Switzerland, EU president Ursula von der Leyen said that the war made the world realise that "the dream of a new Ukraine, not only free, democratic and European, but [it will also] be green and prosperous."

At the conference, the Ukraine Prime Minister promised new housing construction would be based on European standards and guidelines. According to the World Bank, Ukraine has potential for energy savings of 30% in the residential sector and about 70% of buildings have the potential for significant energy savings for heating through thermal modernisation and district heating (DH).

Ukraine's national law on energy efficiency was adopted in October 2021 and provides a framework for reconstruction. The Energy Efficiency Fund of Ukraine has attracted more than 800 projects after its launch in 2019. For example, one project for a 40-year-old five-story building in the city of Lutsk is expected to reduce energy use by 61.5% and save an average of UAH 18 100 per year for each family. Meanwhile 52 multi-storey buildings fully completed their energy modernisation projects, even in the midst of the war.

The European Investment Bank (EIB) is actively supporting Ukraine's reconstruction with its Ukraine Solidarity Urgent Response package worth EUR 2.26 billion, which includes energy efficiency measures and projects. The IEA, which welcomed Ukraine as its 11th Association country, is deepening and expanding its work on Ukraine's energy security, clean energy transition and reconstruction efforts.

In their October 2022 budget, the new Australian Government provided a further AUD 62.6 million in funding allocated to support small and medium enterprises that make energy efficiency upgrades, AUD 15 billion to develop a National Energy Performance Strategy and AUD 4 million to expand the Greenhouse Energy Minimum Standards programme and the Nationwide House Energy Rating Scheme. Industrial energy efficiency, through a Powering the Regions Fund, is also being targeted as well as a large-scale heat pump acceleration programme. The National Energy Performance Strategy, currently in development, will provide the framework to deliver the energy efficiency savings required to meet their 2030 and 2050 emissions reduction targets, and reduce pressure on consumers and the grid.

The new Dutch government's priorities include a National Insulation Program to insulate 2.5 million homes, making a total of USD 3.9 billion (EUR 4 billion) available. It also announced a strengthened energy efficiency obligation that makes it mandatory for companies to implement all efficiency upgrades with a payback period of less than five years.

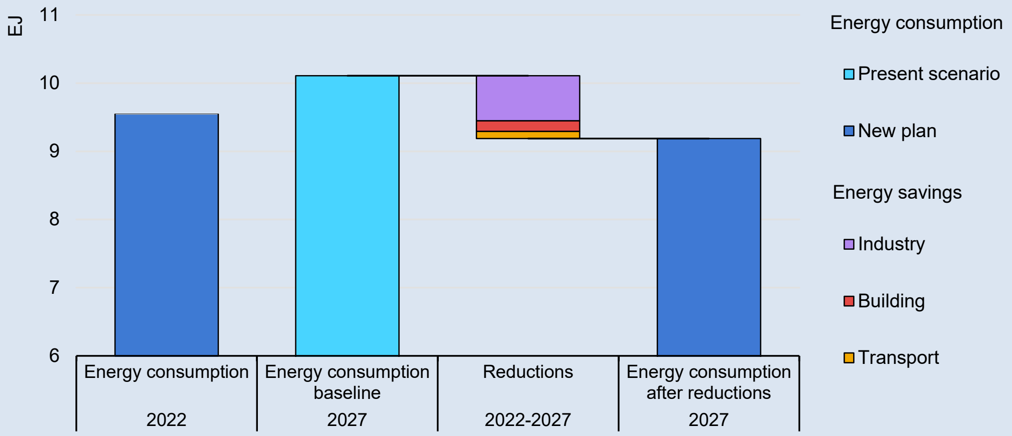
In August, India also amended its Energy Conservation Bill, which, among other measures, expands the scale and scope of its energy conservation regime through new building codes and enforcement measures.

Korea launches new national efficiency strategy to strengthen energy security

In Q1 2022, Korea spent almost twice as much for approximately the same quantity of energy imports as in the same period last year. To help address growing energy security concerns, the new Korean government, which took office in May 2022, announced an ambitious energy efficiency plan that aims to improve national energy intensity by 25% from 2022 to 2027 through 15 major tasks across sectors.

The plan aims to reduce total energy consumption of Korea by 22 Mtoe, equivalent to six years of power use in Seoul, the capital city. Once implemented it is expected to avoid 59 Mt of CO_2, KRW 1.3 trillion (USD 1 billion) of power transmission and distribution facilities costs, and KRW 14.6 trillion (USD 11.2 billion) in energy imports.

Decomposition of change in total final consumption, in Korea, 2022-2027



Source: Ministry of Trade, Industry and Energy (2022) as modified by the IEA.

In industry, which accounts for 62% of energy consumption in Korea, a new voluntary target management programme called Korea Energy Efficiency Partnership (KEEP) will be introduced. KEEP will focus on energy-intensive companies with annual consumption of at least 200 ktoe. In a 2020 pilot programme of 44 businesses, energy intensity at 19 high-performing sites improved by 9.5% compared with the average of the previous three years.

In the building sector, a new energy saving reward programme for apartment residents called Energy Cashback was launched in July 2022. In the pilot programme participants saved 14.1% of energy on average per household. The total electricity saving was 779 MWh, which is enough to fully charge 12 200 EVs.

For winter 2022-23, South Korea has put in place emergency measures that include curbs on energy demand, raising gas and electricity prices, securing LNG supply and supporting energy importers.

In February 2022 Chile launched its National Energy Efficiency Plan 2022-2026. The overall aim of the plan is to provide a strategic framework for the development of energy efficiency and to realise the energy savings potential that will lead to carbon neutrality by 2050. Since large consumers are responsible for around 40% of all the energy consumed in Chile, the plan includes seven specific measures for the industrial sector aimed at reducing the energy intensity of large consumers by 4% by 2026 and 25% by 2050 based on 2019 levels. More than 1 000 companies will be required to report their energy consumption and intensity over the next four years.

In Ecuador nine public policies to promote energy efficiency and reduce greenhouse gas emissions were approved in June 2022, and came into force in August. Measures include: universal access to more efficient technologies, including electric vehicles and e-bikes or scooters; new minimum energy efficiency standards for electrical devices, mechanical equipment, buildings and vehicles; encouraging the support of research, innovation, funding and entrepreneurship to develop and apply energy efficiency; mandating education around energy efficiency and the simplification of procedures to attract investment in energy efficiency.

Historic international gatherings of governments add new momentum in quest for energy efficiency progress

New actions, policies and spending commitments in 2022 have demonstrated that governments across the world recognise energy efficiency as a central tool in the response to the energy crisis. In June, representatives from 26 governments, including 17 ministers, attended the IEA's 7th Annual Global Conference on Energy Efficiency in Sønderborg, Denmark – the most significant ministerial gathering focusing exclusively on energy efficiency to take place in recent history.

A joint statement agreed at the conference by governments acknowledged the important role of energy efficiency and demand-side measures in addressing high energy costs and import dependence and called on "all governments, industry, enterprises and stakeholders to strengthen their action on energy efficiency". Governments also welcomed the Sønderborg Action Plan, consisting of strategic principles and policy toolkits developed by the IEA that can help governments rapidly implement efficiency policies.

In the 2022 G7 Communiqué, global leaders reaffirmed their commitment to energy efficiency, called for a rapid scale-up of energy efficiency investment and acknowledged the IEA and the Energy Efficiency Hub as leaders in facilitating international cooperation on energy efficiency. The G7 conference focused particular attention on energy efficiency and decarbonisation in buildings, as well as the importance of energy efficiency as the "first fuel" in the energy transition. At the G20 meeting in Indonesia on 15-16 November, a focus on energy security was reinforced by the publication of the IEA's Security of Clean Energy Transitions 2022 and Energy Sector Roadmap to Net Zero Emissions in Indonesia.as well as the Bali compact, which includes a strong energy efficiency focus.

Established in 2019, the Energy Efficiency Hub, with its Secretariat hosted by the IEA, gathered momentum with a number of high-level policy exchanges among members and through its task groups. These included the Super-efficient Appliances Deployment Initiative (SEAD), a joint body of the Hub and the Clean Energy Ministerial and driving force behind the COP26 Product Efficiency Call to Action, launched in 2021. The Digitalisation Working Group (DWG) of the Hub was established under US leadership to increase international cooperation in the field of energy efficiency and demand flexibility. The DWG's first report, Digitalisation for the Energy Efficiency of Buildings Operations: Lessons Learned from the EE Hub Digitalisation Working Group, assesses the challenges, opportunities, successes, and lessons from national policies to accelerate digitalisation of building energy systems. TOP TENs, led by China, focuses on domestic and international best practices and technologies, and the Energy Management Action Network (EMAK), led by Japan, facilitates public-private exchanges on systems for raising energy efficiency in industry and buildings.

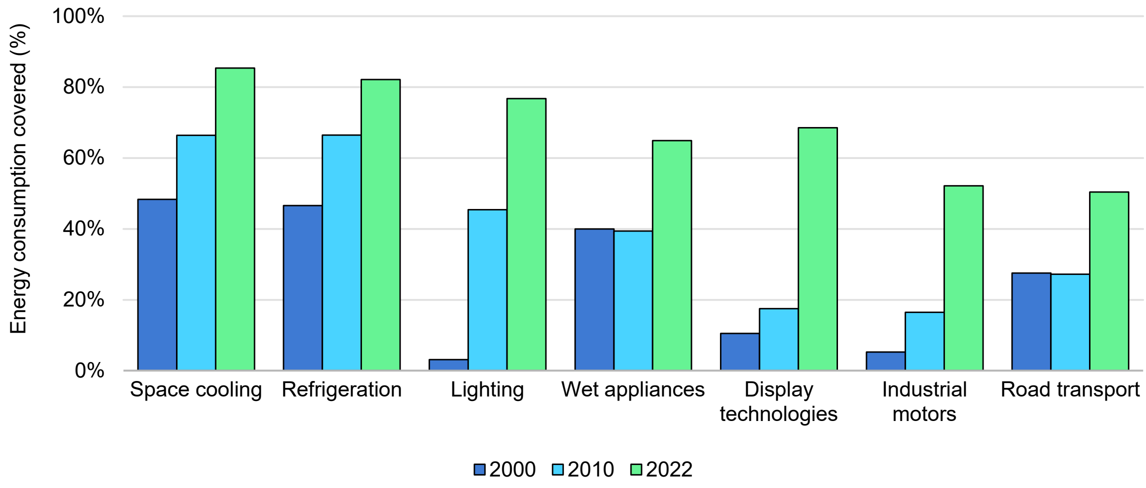
In October 2022, the European Commission and Germany led the establishment of the new Energy Efficiency in Buildings Task Group (EEB) with initial participation from Argentina, Brazil, China, Korea and Saudi Arabia. The EEB will initially focus on short-term energy savings actions as a response to the energy crisis, such as heat pump deployment, consumer campaigns and poverty alleviation and, like other task groups, will coordinate with other intergovernmental bodies.

2.2 Standards and labels

20 countries are in the process of developing new minimum energy performance standards

In recognition of their substantial cost-effective energy savings potential and other benefits, more than 100 countries now use mandatory minimum energy efficiency performance standards (MEPS) and/or energy labels for the most common appliances. However, policies are still absent in a range of markets where growth in ownership of appliances is rising rapidly, especially in emerging economies. Additional or expanded standards and labelling schemes are under development in over 20 countries, mainly in Asia, East Africa and Southern Africa.

Energy use coverage of minimum standards for key end uses, globally, 2000-2022



Note: Coverage for space cooling, refrigeration and lighting is shown for residential sectors.
Sources: IEA analysis based on IEA PAMS database, CLASP Policy Resource centre.

If ambition levels are regularly adjusted to reflect the latest technological progress, performance standards and labels can achieve substantial reductions in energy consumption, as long-established programmes have proven over recent decades, delivering annual savings of about 15%.

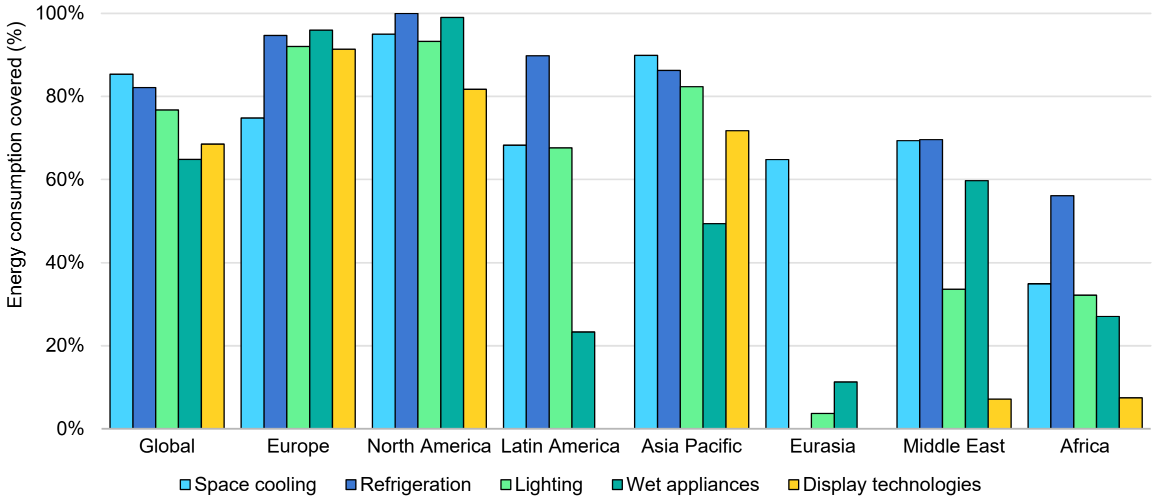
For long-running programmes, energy labels also need to be regraded either by adding additional categories for higher performance levels or updating the entire grading scale. The European Union recently upgraded its labelling programme, including an introduction of quick response (QR) codes linked to the European Product Registry for Energy Labelling. For the last upgrade of the refrigeration performance standard in the European Ecodesign Directive, a new measurement system was introduced to account for different refrigerator size and other technical features in a uniform way.

There is also a wide range of variation in the coverage and strength of programmes in different countries and regions, especially emerging and developing economies. For example, within the ASEAN region, there are ongoing efforts towards regional harmonisation of MEPS for appliances and equipment.

In Ghana, 17 new appliance types will be covered by mandatory MEPS and labels. Existing MEPS regulations for refrigerators and air conditioners are being upgraded and prohibitions will be introduced for the import of used electrical appliances as well as to the manufacture and import of incandescent light bulbs. Additionally, the ratings on labels are being re-categorised from one-star to seven-star to indicate their level of efficiency. The regulations are expected to be passed by the end of 2022.

Significant scope exists for enhanced international cooperation in this area to help governments bring in new standards, learn from past experiences and adopt best practices. The use of aligned mandatory energy labels across borders provides many benefits including a smaller number of testing methods, lower compliance costs for manufacturers and government check testing.

Energy use coverage of MEPS for key end uses, 2022



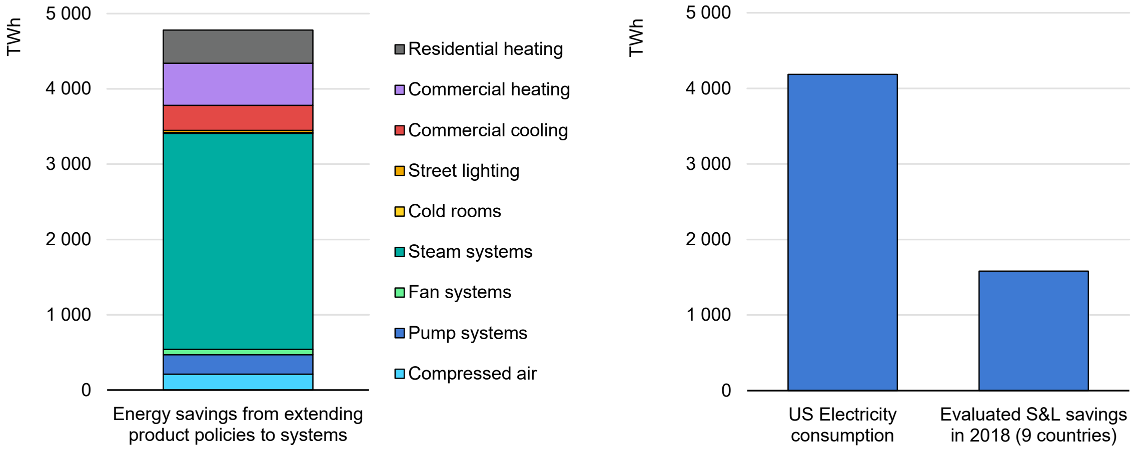
Note: Coverage for space cooling, refrigeration and lighting is shown for residential sectors.
Sources: IEA analysis based on IEA PAMS database, CLASP Policy Resource Centre.

Expanding product policies to the system level could cut energy consumption by a further 10%

Energy-using systems represent a largely untapped potential to extend the significant energy and greenhouse gas savings already achieved by efficiency regulations on individual energy-using products.

A recent study by the 4E Technology Collaboration Programme of the IEA, Progressing Energy Efficiency Policies for Systems, suggests extending product policies to cover relevant energy-using systems has the potential to reduce annual global consumption by 9% (17 EJ, 4 780 TWh). This would be larger than the total use of electricity in the United States in 2021 and more than three times the combined electricity savings generated by the nine most successful national standards and labelling programmes for individual products.

Estimates of global annual energy savings if product policies were extended to cover energy-using systems



Note: S&L = standards and labels.
Source: 4E TCP (2022), Progressing Energy Efficiency Policies for Systems, as modified by the IEA.

2.3 Market-based instruments

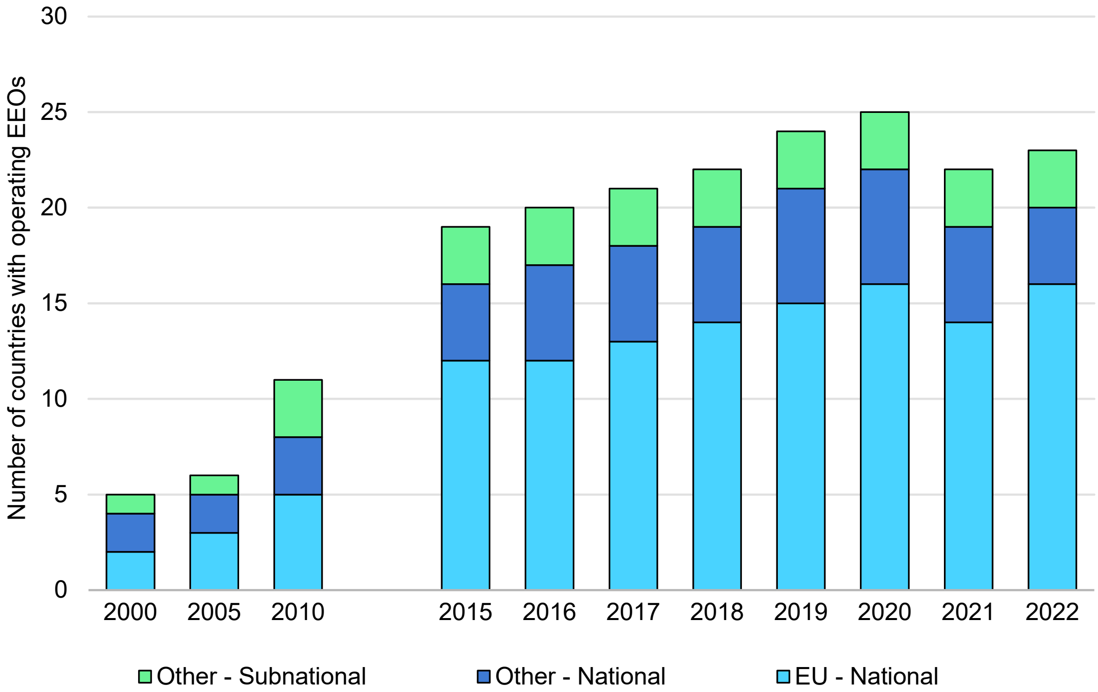
European countries and the United States continue to make most use of market-based instruments

Market-based instruments (MBIs) are commonly used programmes that specify an outcome, such as energy savings or cost-effectiveness, to be delivered by market actors, such as utility companies, without prescribing the delivery mechanisms. MBIs for energy efficiency generally fall under two main types of programmes: Energy Efficiency Obligations (EEOs) and Auction mechanisms.

- EEOs - including white certificate programmes and energy efficiency resource standards in the United States - require obliged market actors to carry out a defined level of energy savings without specifying the delivery route. In some cases (e.g. some Australian states), governments may develop a range of specific methods to demonstrate savings, and energy utilities or customers can choose from the options. Some schemes offer up-front incentives based on estimated deemed lifetime savings while others require ongoing monitoring to determine regular payments.
- Auction mechanisms - including tendering programmes and forward capacity auctions - allow market actors to bid for funds to deliver specific energy savings.

While both forms of MBIs have increased, EEOs remain the overwhelming majority, accounting for 96% of all MBIs.

Number of countries with energy efficiency obligations schemes, 2000-2022



As of 2022, there are 48 energy efficiency obligation programmes in 23 jurisdictions. In the EU, 16 countries are currently operating EEOs, and in the United States alone 24 states have EEOs, called Energy Efficiency Resource Standards (EERS). A new EEO was launched in Hungary in 2021 and currently there are EEOs under development in Korea and in Bosnia and Herzegovina.

Of the EEOs in force, the vast majority encompass multiple sectors. Only 4% of EEOs target the residential sector and 2% are aimed exclusively for the industrial sector. In February 2022 the Victorian Energy Upgrades EEO in Australia expanded to include new commercial and industrial heat pump replacement.

In 2021, Colorado introduced a clean heat target bill that requires public or municipal utilities with more than 90 000 retail customers, to submit a 'clean heat plan' to cut CO_2 and methane emissions from delivered gas to the Colorado Air Quality Control Commission. In Massachusetts and Vermont clean heat standards have been proposed that have credit-based performance standards applied to suppliers of heating energy (primarily gas and oil), obliging them to provide their customers with gradually increasing percentages of low- or zero-emissions heat.

Auction-based mechanisms remain less widespread than EEOs. Currently there are auction mechanisms in the United States, Switzerland (industry), Portugal, Germany and, most recently, Denmark. However, interest in the potential of implementing such systems is increasing in Greece, Italy, Türkiye and the United Kingdom.

The most recent energy auction scheme was established in Denmark in 2020 as a partial replacement mechanism for an EEO. The scheme, run by the Danish Energy Agency, is called the Business Pool. It was designed to deliver approximately 60% of Denmark's current EED energy savings obligation. In June 2022, it was agreed to adjust the criteria of the pool making it more attractive for companies to apply for grants for projects that save energy or CO_2, including the prioritisation of conversions away from gas. In order to accelerate uptake, the pool is no longer auction-based but is instead a fixed-rate approach where applications are prioritised on a first-come, first-served basis. The revised Business Pool entered into force on 1 November, is to run until 2029 and has a budget of DKK 3.5 billion (approximately USD 520 million).

India's Perform Achieve and Trade Scheme

The Perform, Achieve and Trade (PAT) scheme is a market-based mechanism to enhance cost-effectiveness of improvements in energy efficiency in large energy intensive industries and facilities through certification of energy savings that can be traded. PAT has achieved total energy savings of 17.57 Mtoe, avoiding about 31 Mt CO_2 emission in its first cycle and about 61.34 Mt in its second cycle. PAT covers 1 073 designated consumers (consuming around 50% of primary energy) from 13 energy-intensive sectors. PAT Cycle Seven, covering the period from 2022-23 to 2024-25, has an overall energy saving target of 6.627 Mtoe. In August, the Indian Parliament passed the Energy Conservation (Amendment) Bill 2022. A key part of this bill is the proposed establishment of a domestic carbon credit trading market, which would work in conjunction with the PAT scheme.

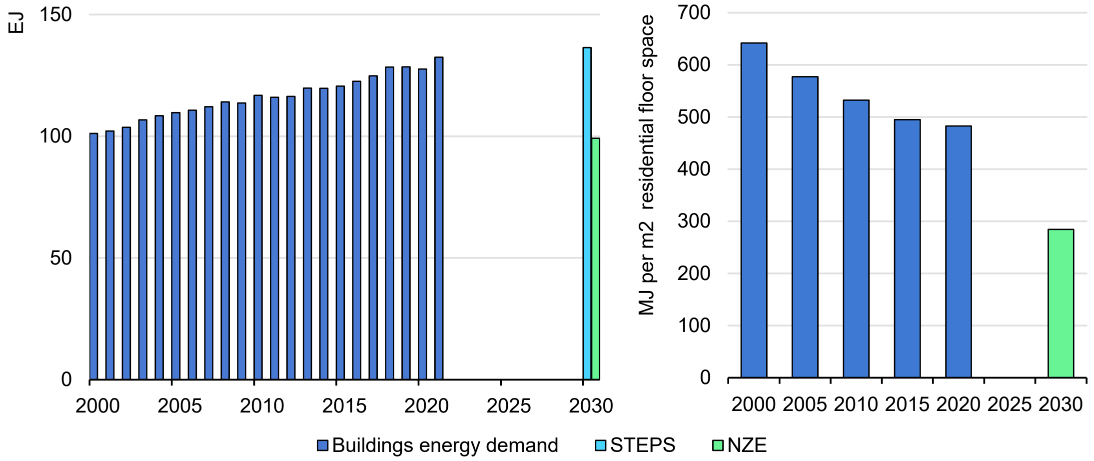
2.4 Buildings

Buildings' energy demand trend far off track for net zero emissions as efficiency improvements slow down

Global energy demand in buildings is set to be 3% higher in 2021 at around 130 EJ compared with levels before the impact of Covid-19. In 2020, energy consumption in buildings fell by around 1% in response to economic contraction and Covid-19 restrictions in the first year of the pandemic. In 2021, demand increased by almost 4%, the highest year-on-year increase in over 20 years.

In the IEA's Net Zero Scenario, energy consumption declines 24% by 2030, to levels of around 100 EJ. To achieve this, energy efficiency in residential dwellings would need to improve at a rate of around 5% per year from 2020 to 2030. This compares with progress of 1.5-2% per year over 2000-2015, and just 0.5% per year on average in the last five years of the decade.

Global buildings final energy demand and efficiency indicator, by scenario, 2000-2020



New building codes are under development while more existing ones are being upgraded towards net zero

Thirty-one countries currently have new building codes under active development in emerging and developing countries, which added to the 80 countries already fully operational means the total number of countries with codes will soon come to 111. Sixty-nine countries currently have mandatory requirements while 11 countries use performance standards such as voluntary, model codes, or city-based standards. Approximately 85 countries currently have no known building codes in place or under development. However, there is still much work needed to be done to align with the Net Zero Scenario, where all new buildings and retrofits are zero-carbon ready by 2030.

As a critical part of addressing energy performance of buildings, energy codes set minimum energy standards for new buildings and can also trigger requirements for major refurbishments or renovations to meet aspects of existing building codes. Building energy codes typically address operational energy use by focusing on envelope performance standards, including for walls, windows, and roofs as well as major end-use energy services equipment such as heating, cooling, lighting and ventilation.

In terms of the most recent progress, a new law came into effect in mid-2021 in the Republic of Georgia for energy efficiency in buildings that applies EU Directive

2010/31/EU. In addition, Kenya and Trinidad and Tobago have published draft energy efficiency building codes, but they are not yet in force. In the United States, a number of states have also increased the scope and stringency of mandatory and voluntary building energy codes, including California, Massachusetts, Wisconsin, Hawaii, and Oregon.

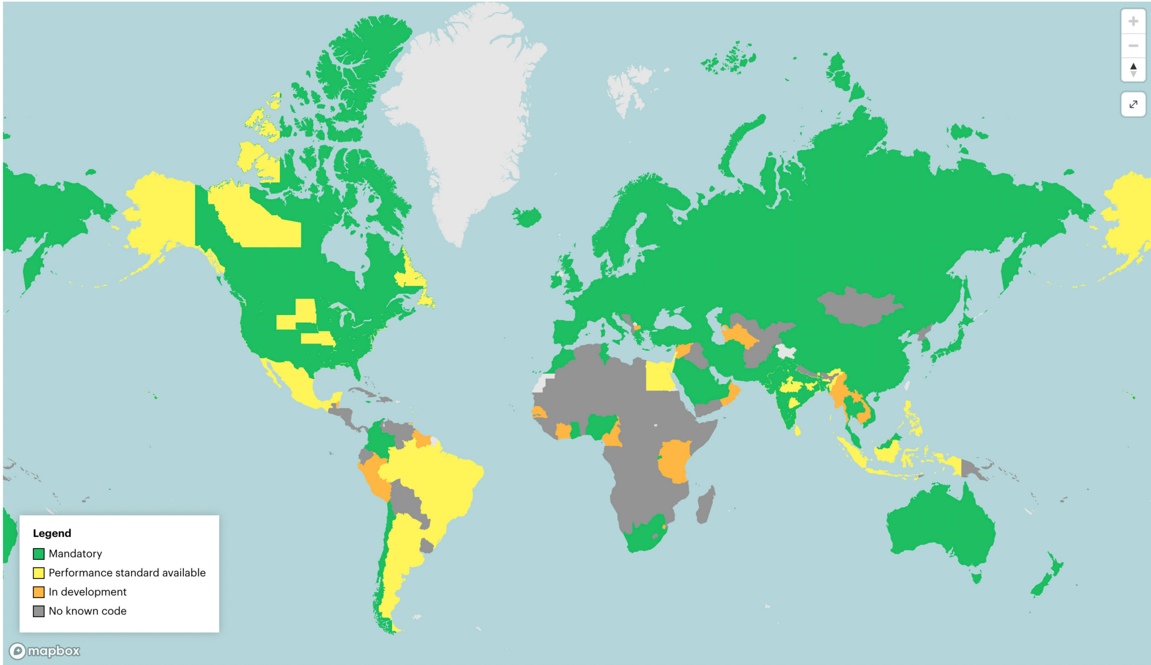
Australian national, state and territorial governments have agreed to an upgrade to national energy efficiency standards for new residential buildings that cover the building envelope, fixed appliances and on-site generation. This includes the biggest change to the Nationwide House Energy Rating Scheme since it began in 1993. Energy efficiency changes to the codes are voluntary from 1 October 2022, with a transition period until 1 October 2023.

In an effort to ensure building energy codes are aligned towards achieving net zero-carbon status, a new voluntary appendix to the International Energy Conservation Code 2021 works towards providing such a standard. For residential buildings, the supplementary energy can be generated through local projects, such as on-site solar PV arrays. The United States has also seen several codes align their standards towards reaching net-zero carbon, including California's Reach Codes and California ZERO code for commercial buildings. The French Code RE2020, which came into force 1 January 2022, includes improved mandatory thresholds for energy consumption and for the first time adds mandatory thresholds for GHG emissions (one for emission from energy and the second for emission related to construction, including embodied emissions in materials).

More than 60 countries have updated their Nationally Determined Contribution (NDC) to provide further details on their efforts to decarbonise buildings through energy efficiency actions, with 19 mentioning buildings for the first time. This marks a positive change in national efforts to put together policies that focus on improving energy efficiency for buildings through the UNFCCC.

With cities growing in size, the area of buildings needing to be cooled or heated set to expand by more 20% by 2030. Given that 80% of this growth is expected in emerging and developing countries, it will be important for building codes to cover the 20% share of the global population living in countries with NDCs that do not currently mention buildings as part of their climate action efforts.

Global status of building energy codes in 2022



The increasing role of building codes in cooling

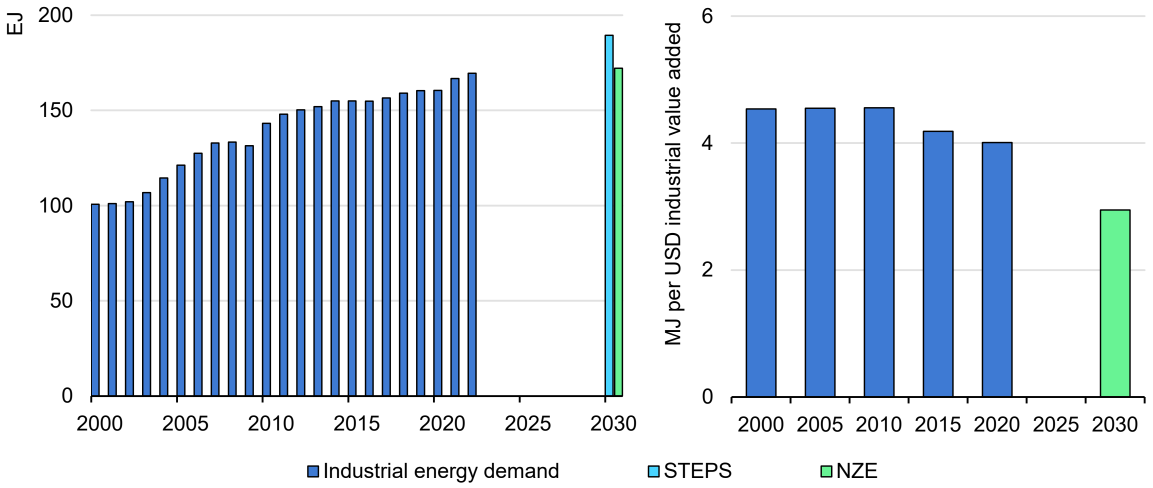
A number of building code revisions are increasing their focus on addressing cooling standards due to the outlook for increased cooling demand amid higher climate-related temperatures. Recently revised zero-carbon aligned building energy codes in the United States have clearly set out cooling demand reduction as a basis for the improvements. For example, both Maryland's Building Energy Transition Plan and Vermont's Building Code Roadmap have specifically noted that building code improvements will reduce cooling thermal energy demand intensity as part of their net-zero building strategies. The latest version of the International Energy Conservation Code (IECC) has optional performance standards for cooling equipment. For example, an air-source heat pump should have a Seasonal Energy Efficiency Ratio (SEER) of 16 and a ground-source system a coefficient of performance (COP) of 3.5. Largely cooling-dominant countries, such as Singapore, have also targeted cutting cooling energy consumption through their Super Low Energy Building Technology Roadmap, which includes tackling equipment alongside envelope performance through cooling surfaces and strategies to reduce heat gains (e.g. shading) as well as increasing the heat reduction performance standards for their Green Mark Gold.

2.5 Industry

Industrial demand is pushing global energy consumption higher as intensity progress slows

Global industrial energy consumption has experienced strong growth since the beginning of the pandemic, rising 4% from 2019 to about 165 EJ in 2021. This continued the trend of increased industrial energy use constituting a larger share of total final energy demand, which has risen from 33% in 2000 to 38% in 2022.

Global industrial final energy demand and energy intensity, by scenario, 2000-2022



Three heavy industries – chemicals, steel and cement – account for nearly 60% of industrial energy demand, with emerging and developing economies, in particular China, responsible for 70-90% of the output of these commodities. In the Net Zero Scenario, economic growth in EMDEs is expected to continue to drive industrial energy consumption higher, with output of these three commodities expected to rise 21%, 9% and 5%, respectively, by 2030.

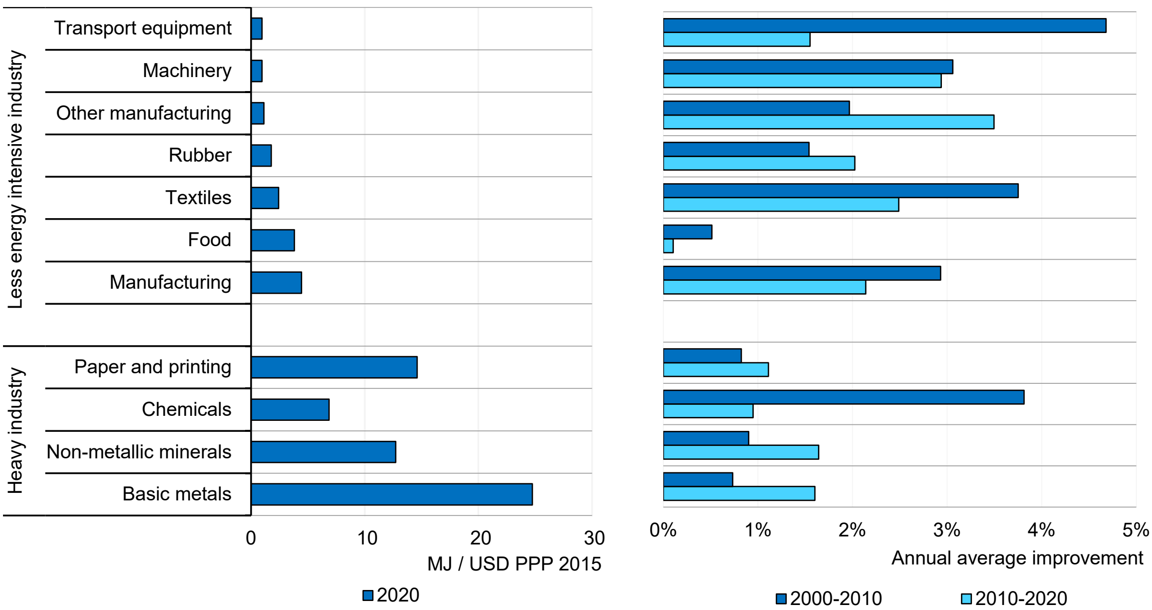
Overall, industry, which currently accounts for around one-quarter, or 9.4 Gt, of global energy-related CO_2 emissions, is not on track to meet the milestones in the Net Zero Emissions to 2050 Scenario. In addition to other measures, this would require the energy efficiency of the industry sector to improve at a rate of 3% per annum, from around 4 MJ per USD of industrial value added in 2020 to 3 MJ in 2030. This compares to the current rate of improvements of around 1% per year. An additional challenge for this pathway is that, while hydrogen enables the use of renewable sources for high temperature processes, it has a low efficiency in production leading to an increase of industrial energy consumption, albeit decreasing greenhouse gas emissions.

Efficiency is rising fastest in the less energy-intensive industrial sectors in IEA countries

In IEA countries, energy efficiency progress in less energy intensive manufacturing has been improving faster than in heavy industry. From 2000 to 2020, the textile and transport equipment sub-sectors achieved the greatest improvement in energy intensity at 47% each, followed by the production of machinery at 46% and other manufacturing at 43%. Food manufacturing performed relatively poorly in comparison, with an energy intensity improvement of 6% over this 20-year period.

Heavy industry saw smaller improvements in energy intensity over the past two decades, with chemicals posting the strongest gains at 38%, followed by non-metallic minerals at 23%, metals at 21%, and paper and printing at 18%. Annual average improvement shows the gains for chemicals, non-metallic minerals, and metals averaged 1-2% over 2010-2020. In less energy-intensive manufacturing, annual efficiency improvements averaged 2-4% per year over the same period.

Average energy intensity of major industrial sub-sectors, in IEA countries, 2000-2020



A 2022 global survey of over 2 200 industrial companies in 13 countries showed that 97% were already investing in energy efficiency or planning to, 89% expected to increase their investment in energy efficiency over the next five years and 52% aimed to achieve net zero within five years.

China's reform for the steel industry

The transformation of the steel industry was listed as a major goal in China's national 14th Five-Year Plan (2021-2025). This is a key air pollution prevention policy that will require iron and steel enterprises to merge, restructure and upgrade equipment, improve the overall green and low-carbon development of the steel industry, leverage effective social investment, and help stabilise economic growth.

From January to July 2022, 251 enterprises and 681 Mt of crude steel production capacity had completed or were implementing ultra-low emission transformation. According to the latest statistics, albeit incomplete, the cumulative investment in ultra-low emission transformation of iron and steel enterprises nationwide has exceeded CNY 150 billion (about USD 21 billion).

Data released by China Steel Association, shows 800 Mt of steel capacity transformation projects will be completed by 2025 (up from 400 Mt now), with about 400 Mt still to be implemented. Based on an average investment of CNY 360 (about USD 50) per tonne of steel, the additional investment will be no less than CNY 150 billion.

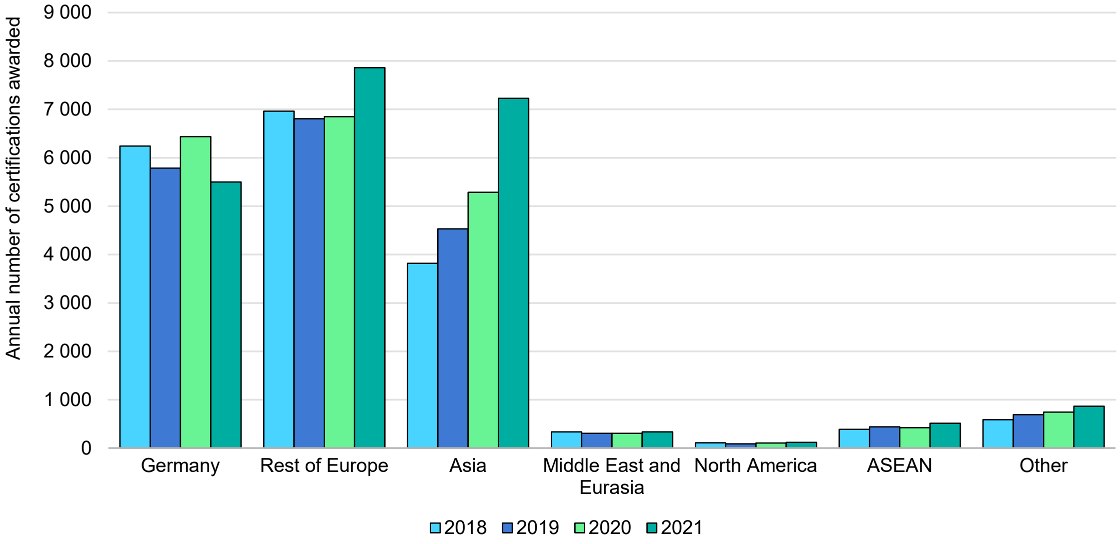
Interest and engagement in energy management best practices growing

With higher energy prices and inflationary pressures upending business operations everywhere, companies are increasingly turning to energy management systems (EnMS) to achieve critical cost savings. They essentially provide a framework of procedures and best practices to ensure the systematic planning, analysis, control, monitoring and improvement of energy use and efficiency. The deployment of an EnMS can significantly reduce energy consumption, improve energy efficiency and increase visibility of energy use and spend for companies.

The adoption and growth of energy management systems is typically tracked by comparing the annual uptake of international standards and the number of certifications issued published in annual survey by the International Organization for Standardization (ISO). The main international industrial energy management system standard, ISO 50001, was established in 2011, and then revised in 2018. Data is gathered on global certification levels on an annual basis.

A new standard, ISO 50005, was launched in September 2021 to primarily target small- and medium-sized business sectors and companies that may have limited resources to put in place a comprehensive energy management system. This simplified standard allows for a phased approach in implementing a system to monitor and improve energy performance, which can then later be used towards meeting the more stringent requirements of ISO 50001. Amid the current energy crisis, the new EnMS standard will enable an increasing number of companies to better manage energy use and improve efficiency levels. As yet, no data on certification uptake has been published.

ISO 50001 certifications issued in selected regions, 2018-2021

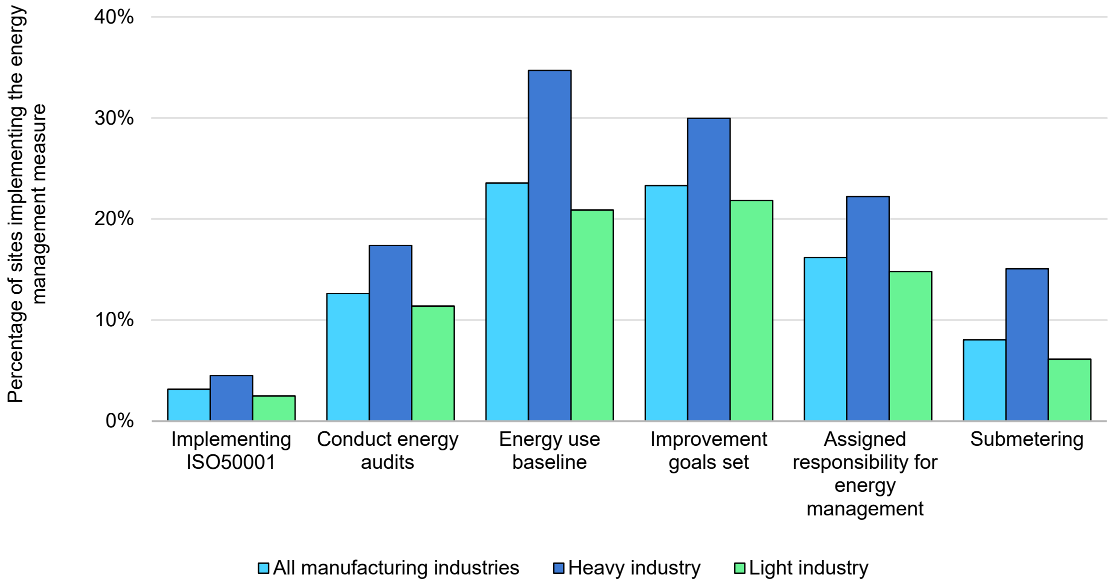


Sources: IEA based on data from ISO (2022), ISO Survey of Certifications, 2021.

In 2021, the number of new ISO 50001 certificates issued rose by 11% over year-ago levels. The most significant increase was in Asia, up by 37%, followed by ASEAN countries at 21%. Germany, the country with the highest number of certifications, dropped by 15% to a four-year low. Certificates were awarded in eight new countries, bringing the total number of countries where the standard is being implemented to 108. Certificates were issued to Mongolia, Montenegro, Tanzania, Jamacia, Ghana, Gabon, Zambia and the Côte d'Ivoire.

While ISO 50001 is widely used, it is neither universal nor unique in terms of energy management systems for industry. Analysis of the most recent quadrennial Manufacturing Energy Consumption Survey (MECS) carried out by the US Energy Information Administration highlighted that almost half (48%) of all manufacturing establishments participated in general energy management activities, far exceeding those going through the ISO 50001 certification process (3%). However, that the survey also showed that energy submetering of the individual industrial processes was low (8%), highlighting a lack of dedicated monitoring and targeting systems, essential for effective energy management and sustained energy efficiency.

Reported energy management activities in the industrial sector in the United States, 2018



Sources: IEA based on data from U.S Energy Information Administration, (2021), MECS.

Electric motor systems use about 70% of electricity in industry, but more efficiency standards needed

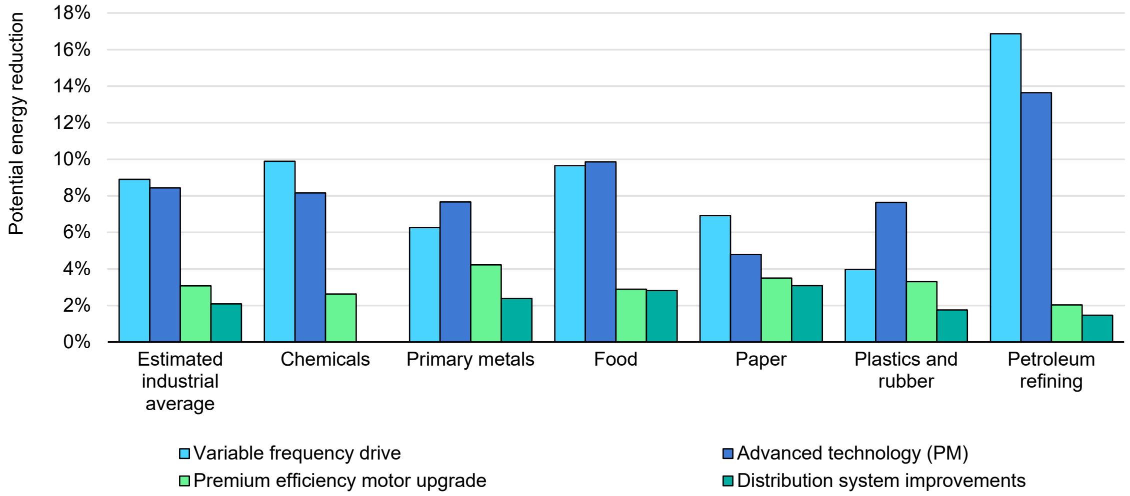
Electric motors and motor-driven systems account for around 70% of the total global electrical use of the industrial sector. Governments use International Efficiency (IE) standards to specify efficiency levels for the minimum energy performance of low voltage (AC) motors. The IE standards have four distinct levels, ranging from IE1 to IE4 or “super-premium efficiency” motors.

In 2022, 57 countries have MEPS (minimum energy performance standards) for industrial electric motors in place, covering about 50% of the global electricity consumption of industrial motors, up from 20% ten years ago. The widely accepted IE efficiency classes for electric motors facilitate the further implementation of MEPS, creating leeway to further significantly increase policy coverage of motors electricity consumption. Ukraine is the most recent country to introduce standards, which came into effect in 2021. While most governments only regulate new motors, Pakistan introduced MEPS and labels for refurbished second-hand motors in 2021. Starting as a voluntary programme, it will eventually transition to compulsory registration and IE3 minimum performance requirements in 2023.

Since mid-2021, China and Colombia have extended the number of product categories required to meet the IE3 efficiency level. In the EU, United Kingdom and Switzerland from 2023 onwards, some motor types will have to meet the IE4 Super Premium requirements.

Currently, 11 countries make use of mandatory comparative labels to incentivise sales for more efficient industrial motors, but eight additional countries offer voluntary comparative or endorsement labelling. Various countries have recently strengthened label levels and extended scope. In 2022 Thailand adopted High Energy Performance Labels for 1 phase motors, 3 phase motors and Variable Speed Drives (VSDs), on a voluntary basis.

Potential motor system energy reduction in selected industry sectors, in the United States



Source: IEA based on data from LBNL, (2022), U.S. Industrial and Commercial Motor systems Market Assessment Report. Volume 3: Energy Saving Opportunity. Note: VFD is variable frequency drive.

An investigation into the energy efficiency opportunities of industrial motors systems in the United States found that the top four energy saving measures were installing Variable Frequency Drives (VFDs) for processes with varying loads, using advanced technologies (permanent magnet), upgrading to premium efficiency motors and improving distribution system.

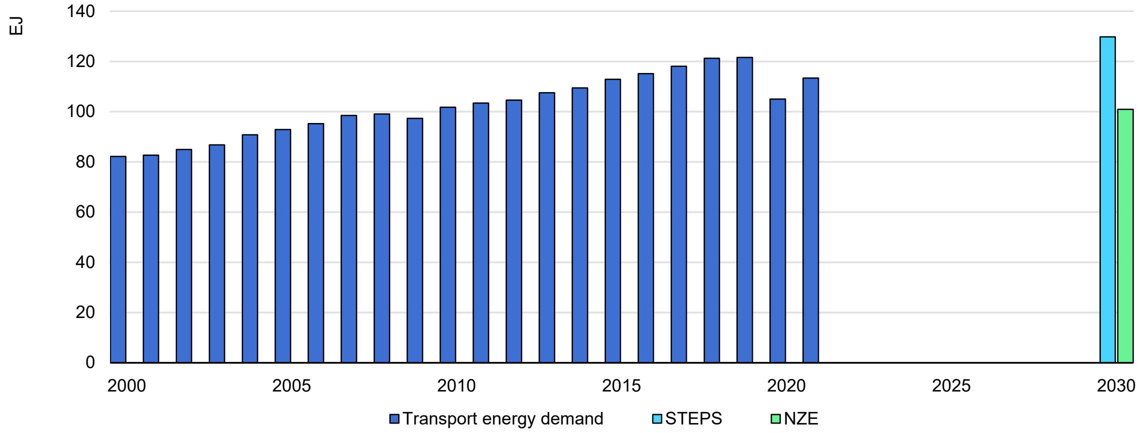
2.6 Transport

Transport energy demand is recovering but remains below pre-Covid-19 levels

Transport was the sector most affected by Covid-19 restrictions, with energy consumption falling by 14% in 2020 and rebounding by 8% in 2021, which is still well below levels in 2019. While electrification is gathering pace, oil products still dominate the sector, providing around 91% of its final energy use. Road transport makes up around 75% of energy demand and emissions. Prior to Covid-19, energy consumption in the sector was growing at an average 2% per year from 2000-2019.

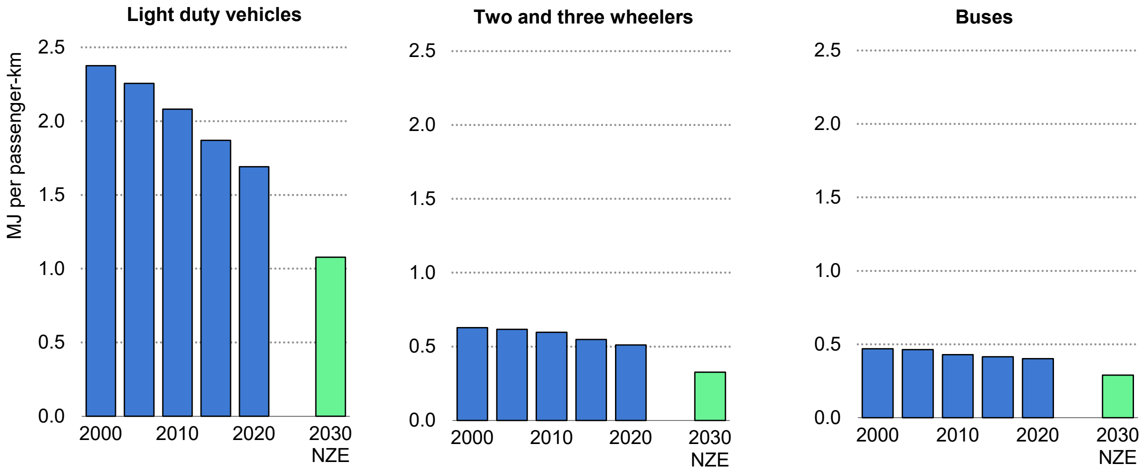
In the Net Zero Scenario, transport energy demand is around 100 EJ in 2030 or 22% lower than what is expected with existing policies. As part of the shift to Net Zero Emissions, the share of oil in final demand falls to 80% in 2030. This underscores the continued importance of improving the efficiency of internal combustion engine vehicles which still make up around 80% of the global fleet by 2030, including via hybrids.

Global transport final energy demand, 2000-2021, and by scenario, 2030



The average annual improvement (reduction) in energy consumed per passenger kilometre travelled (specific fuel consumption) from 2000 to 2020 of cars and light trucks was 1.7%, followed by two- and three-wheelers at 0.8% and buses at 0.8%. To reach levels consistent with the IEA Net Zero Scenario, average efficiency improvements would need to rise to around 4.5% per year for light-duty vehicles and two-wheelers and 3% for trucks. Past improvements were driven by an increase in the share of electric vehicles in fleets, continued improvements in engine technology and the introduction of hybrid powertrains.

Global road transport efficiency indicators, 2000-2020, and in the Net Zero Scenario, 2030



IEA. CC BY 4.0.

Vehicle fuel economy standards and incentives are being strengthened

The EU's Fit for 55 emission reduction targets for new cars and commercial vehicles aims to speed up the transition to zero- and low-emission mobility. A new target of a 100% reduction for 2035 has recently been introduced, meaning all new cars or vans sold in the EU from 2035 will be zero-emission vehicles. As part of the EU Fit for 55 programme, the Alternative Fuels Infrastructure Regulation (AFIR) sets targets for the deployment of (re)charging and hydrogen (re)fuelling infrastructure for cars, vans, trucks and buses. It also sets targets for deploying infrastructure to provide electricity to ships, inland waterway vessels and aircraft when these are stationary.

In the United States, a strengthening of Corporate Average Fuel Economy (CAFE) standards was enacted by the government in 2022. CAFE standards require an industry-wide fleet average of approximately 49 mpg for passenger cars and light trucks in model year 2026. The new standards will increase fuel efficiency by 8% annually for model years 2024-25 and by 10% annually for model year 2026. They will also increase the estimated fleetwide average by nearly 10 mpg for model year 2026, relative to model year 2021.

In California a USD 10 billion zero-emission vehicle (ZEV) package to accelerate the transition to zero-emission vehicles and fight climate change was announced. Significant investments are earmarked for zero-emission vehicles and infrastructure for use in lower income neighbourhoods; heavy-duty zero-emission vehicles and supporting infrastructure; zero-emission mobility (sustainable community-based transportation equity projects that increase access to zero-emission mobility in low-income communities); and emerging opportunities (e.g. off-road applications, and vehicle grid integration at scale).

In Chile, the first energy efficiency law was enacted in February 2021, which mandates fuel economy standards for new vehicles. The standard for light-duty vehicles was published in February 2022 and calls for compliance from importers and manufacturers by 2024. From a baseline of 14.9 km/Lge in 2020, the target is 18.8 km/Lge from 2024 to 2026, increasing to 22.8 km/Lge in 2027 and to 28.9 km/Lge in 2030. For medium-duty vehicles, the standards will be defined in 2024, taking effect in 2026. The heavy-duty vehicle standards will be defined in 2026, taking effect in 2028.

In New Zealand, the Clean Vehicle Standard was passed in 2022 and will come into effect in 2023. In 2023, light passenger vehicles must meet a standard of 145 g CO_2e/km, while light commercial vehicles must not emit more than 218 g CO_2e/km. These standards will increase in stringency to 63.3 g CO_2e/km and 87.2 g CO_2e/km in 2027 for light-duty passenger and light commercial vehicles, respectively.

Additionally, New Zealand is the latest country to establish a feebate programme. The country introduced a rebate for BEVs and PHEVs in July 2021 and expanded the programme to a full bonus-malus scheme in April 2022, which applies to new and used imported passenger cars and light commercial vehicles. In April 2022, New Zealand's Vehicle Fuel Economy Labelling scheme updated its label to now include CO_2 emissions data and easier-to-understand data on cost savings and rebates. On the 1st November the government has also agreed an NZD 569 million Clean Car Upgrade programme, an equity-oriented pilot and rollout of a scrap-and-replace scheme, which will provide targeted assistance to lower- and middle-income households to shift to low-emissions alternatives upon scrapping their old vehicle.

China began offering incentives for EVs in 2009 as part of the "Ten Cities, Thousand Vehicles" pilot projects initiative. Subsequent expansion programmes have been credited with creating the world's largest EV market. The subsidies were due to expire in 2022, but have been extended to December 2023. In Malaysia, a series of tax incentives was launched in January 2022 to benefit manufacturers and purchasers, including tax exemptions for imports and sales, as well as tax relief for those owning an electric vehicle. In May 2022, Thailand announced measures to implement electric vehicle tax and customs incentives for 2022-25. These aim to equalise the purchase cost of electric versus ICE vehicles.

Since October 2021 Indonesia has levied differing motor taxation rates for manufacturers depending on the vehicle's emissions. The tax rate for electric vehicles is 0%, hybrid vehicles 2% to 12%, and for fossil-fuelled vehicles ranging from 15% to 40%.

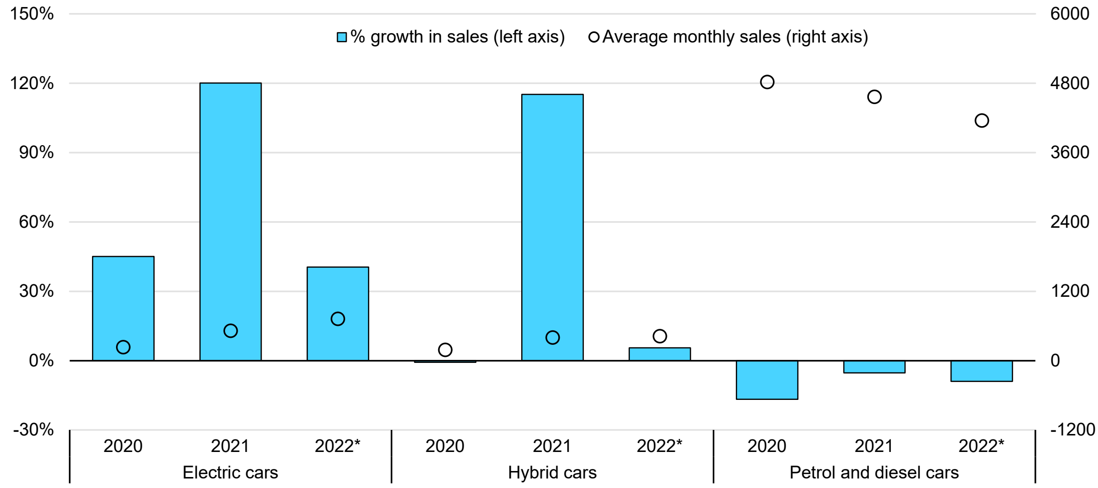
Sales of more efficient and electric cars are increasing

While global car sales in the first half of 2022 were lower than those of 2021, sales of more efficient cars, and especially electric vehicles, were performing relatively strongly compared with less efficient petrol and diesel cars.

In the United States, sales of EVs increased by 60% in the first three months of 2022, in spite of an overall decline in the US car market of nearly one-fifth. In Ireland, a doubling of new EV registrations in early 2022 (compared to the same period in 2021) has been attributed to high fuel prices, supported by changes in vehicle taxes.

Reports from dealers suggested an increase in interest for more fuel-efficient cars in the United States and United Kingdom with the impact of high energy prices also reflected in searches relating to purchases. In mid-March 2022 online searches for EVs in the United Kingdom increased by nearly 40% week-on-week, taking these to levels that were 150% more than in the comparable week in 2021. In the United States, the number of searches increased by 40% month-on-month, corresponding with research at the start of 2022 which suggested that nearly a quarter of US motorists would consider switching to an EV if fuel prices kept increasing.

Average monthly change in growth of car sales by vehicle type, 2019-2022



*2022 % growth using monthly average across January-August.
Source: IEA analysis based on Marklines data.

Globally, over 3 million hybrids have been purchased so far in 2022, making up around 8% of sales. They have played a key role in Europe, where their proportion of total sales increased from around 5% at the end of 2020 to almost 20% in the first half of 2022.

Mild hybrids assist the engine, making it more fuel efficient and can offer up to a 15% reduction in CO_2 emissions compared with conventional technologies. Full hybrids, on the other hand, use the combustion engine and electric motors to drive the car simultaneously or independently, which results in greater CO_2 savings of up to 30%. These electric motors are not plugged in but are charged through the operation of the combustion engine.

Electrification has also been growing in other transport modes. Sales of electric buses increased by 40% in 2021 and electric truck sales more than doubled. China accounted for over 90% of these sales, although registrations in Europe and the United States also increased. Electric medium- and heavy-duty truck sales, however, represented less than 0.3% of the total number of registrations for medium- and heavy-duty vehicles worldwide.

In 2021, 46% of cars sold were SUVs, up 2% from the previous year. In 2010, just 17% of cars sold were SUVs. From 2010 to 2019, new light-duty cars became 6.2% heavier when considering the sales-weighted average, 20% more powerful and had a 7% larger footprint. A key cause of this trend has been a shift from cars to SUVs and light trucks. Increasing vehicle size and power has eroded as much as 40% of the fuel consumption improvements that would otherwise have occurred thanks to technical advances in vehicles and engines.

About half of the electric car models available in major markets in 2021 were SUVs, far ahead of small (10%) or medium-size models (23%). SUVs and luxury models typically generate much larger profit margins, which is one reason why automakers promote them and boost supply.

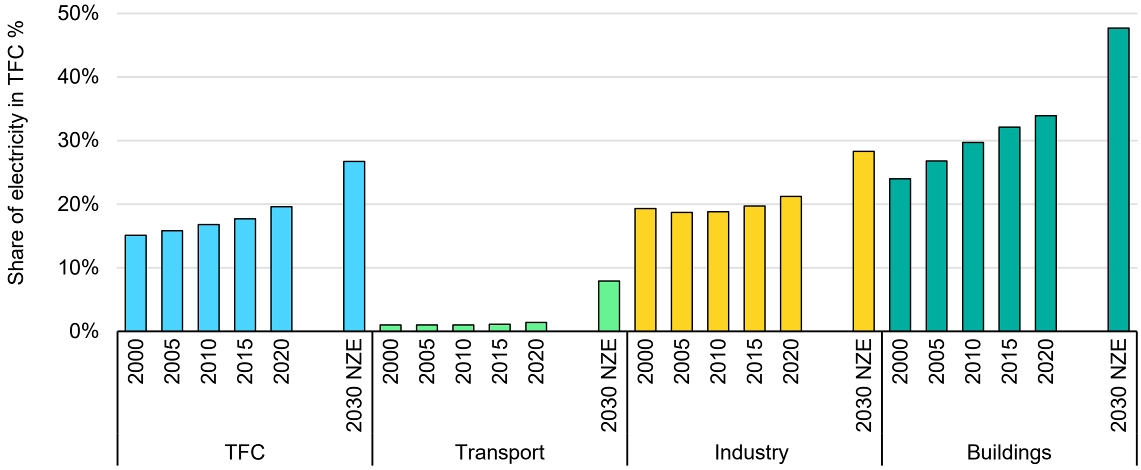
2.7 System level energy efficiency

Electrification and growing share of renewable power require efficiency policies targeted at the system level

The share of electricity in the total energy consumption has been steadily increasing over the last ten years, rising from 15% in 2000 to 20% in 2020. As part of the transition to meet net zero goals, a rapid increase in electricity demand, fuelled by renewable energy, is needed to power fuel switching from internal combustion engines to electric vehicles and from gas heating to heat pumps.

However, if unmanaged, this additional electricity demand will place huge strains on the power systems. This is especially true in systems with increasing levels of variable renewable energy sources.

Share of electricity in global final energy consumption, by sector, 2000-2020, and in the Net Zero Scenario, 2030



Increasing the flexibility of electricity demand will provide benefits to the electricity grid. Energy efficiency and demand-side measures are increasingly about reducing peak power use, and shifting power consumption toward the time of maximum renewable production.

Digitalisation plays an important role in enabling this through more granular data, new ways of analysing data for better insights and greater visibility on the performance and capacity of assets. For instance, digitalisation allows more controllability and adjustability of operations, enabling consumers to react to signals sent by the power system. As automation diminishes the cost of reacting to a price signal, it makes it much easier for smaller sources to participate in markets for flexibility. This can in turn provide power system services, such as reducing grid congestion and enhancing resilience.

Tools such as digital twins can also help target energy efficiency efforts to reduce peak demand and the strain on power systems. For example, Adger Energi, a Norwegian electric utility, is using digital twins to identify ways to operate its electrical grid more efficiently through distributed energy resources, device controls, and predictive forecasting—thus avoiding costly and time-consuming network reinforcement and infrastructure upgrades.

In Europe, the energy crisis has brought a renewed push towards market design optimisation and power system flexibility. The European Commission presented exceptional electricity demand reduction measures, with the aim of reducing electricity consumption by at least 5% at peak hours, and overall demand by 10%. Reducing demand at peak times would lead to a reduction of gas consumption by 1.2 bcm over the winter. According to ENSTSO-E, a 5% peak shaving could help mitigate most of the reliability risks in continental Europe this winter.

The forthcoming EU Digitalisation of Energy Action Plan is expected further promote harmonisation of rules and support for solutions towards more flexible demand and systems efficiency.

To avoid a situation this winter where cold days in combination with low levels of wind could necessitate the interruption of supply for customers, the UK National Grid ESO in November launched a new programme, Demand Flexibility Service, to deliver more than 2 GW demand response when needed. The operator has developed this programme in close coordination with suppliers, aggregators, industry, Ofgem and BEIS, and electricity customers.

UK regulator Ofgem estimates that around 30 GW of total low carbon flexible capacity in 2030 and 60 GW in 2050 will be needed to maintain energy security and cost-effectively integrate high levels of renewable generation. The UK Smart Systems and Flexibility Plan 2021 estimates that the domestic market for the development of intelligent systems and flexibility solutions in 2050 will be worth more than GPB 1.3 billion per year and create more than 10 000 jobs.

In India, extreme weather events in 2021 and 2022 highlighted the energy security risks of climate change. For example, the 2022 heatwaves created unprecedented spikes in peak demand from air conditioning and fans, causing power outages for millions and leading to plans to boost coal production by 100 Mt over the next three years. More efficient and smarter cooling systems and demand response plays an essential role in mitigating peak demand and avoiding outages.

Increasingly, policy is focused on developing approaches to encourage systems efficiency. For instance, California has established a “loading order” that calls for first pursuing all cost-effective efficiency resources, then using cost-effective renewable resources. Only then may conventional energy sources be used to meet new load. A growing number of countries have opened their flexibility market to demand response.

Japan’s Ministry of Economy, Trade and Industry’s (METI) Agency for Natural Resources and Energy has outlined a strategic plan with a heavy focus on demand-side measures. New frameworks are being put in place to allow large users to be rewarded for optimising their energy demand in response to the fluctuation of energy supply. Greater sophistication of the secondary energy structure, including effective use of distributed energy resources such as batteries, is being targeted, specifically promoting aggregation businesses utilising these resources.

Earthquake in Japan and emergency reduction in energy demand

In March 2022, a magnitude 7.4 earthquake in the Tokyo Electric Power Company (TEPCO) region led to several thermal power plants going offline and a sudden reduction in transmission capacity. A subsequent surge in electricity demand due to unusually cold weather resulted in the highest demand in March since the Great East Japan Earthquake in 2011. In addition, solar power generation decreased significantly and the electricity reserve margin in the region was expected to fall well below 3%, to as low as 0% in Tokyo.

METI issued a "power crunch alert" to save electricity use on the evening of 21 March. In the first such alert since 2012, transmission operators, retail companies and local government urgently called for companies and citizens to reduce their electricity use, including demand response. Over 21-22 March, the TEPCO twice requested that end-users save power, communicating via LINE, a popular messenger application with 2.5 million Japanese accounts. TEPCO urged households to set the heating temperature to 20°C and to turn off unused lights. In addition, TEPCO informed users of the possibility of a power outage for up to 3 million households and emphasised the need for urgent actions to save 2 million kWh.

As a result of vigorous energy conservation efforts in the Tokyo and Tohoku regions, 44 GWh of electricity was saved on 22 March, achieving 70% of the maximum savings target. As supply reinforcement measures such as in-house power generation and increasing thermal power output were carried out at the same time, power supply and demand conditions were stabilised in the morning of March 23.

In South Africa, in 2022 the total number of hours of national rolling blackouts more than doubled from 1 150 to 2 400 hours as a result of aging infrastructure and energy system strains. As part of the response to the energy crisis, the Standard Offer Programme is being used to purchase energy savings from energy efficiency programmes, including efficient lighting, hot water and solar systems and industrial process optimisation. This allows for a dynamic price option where the value of energy savings is set day-ahead for each hour of the following day, taking into account the avoided cost of generation.

Meanwhile, the United Kingdom launched a programme for energy smart appliances to test interoperable demand response, including through smart meters and energy management systems.

Growth in the stock of smart meters is enabling more sophisticated options for energy efficiency actions

Smart meter deployment is on the rise, opening up new opportunities to harness energy efficiency and demand response at the system level. Smart meter data, associated with other data series such as weather and production, can also be used to generate insights to balance renewable energy supply against demand profiles and facilitate correct sizing of heat-networks, heat pump installations and energy storage options, including EV infrastructure.

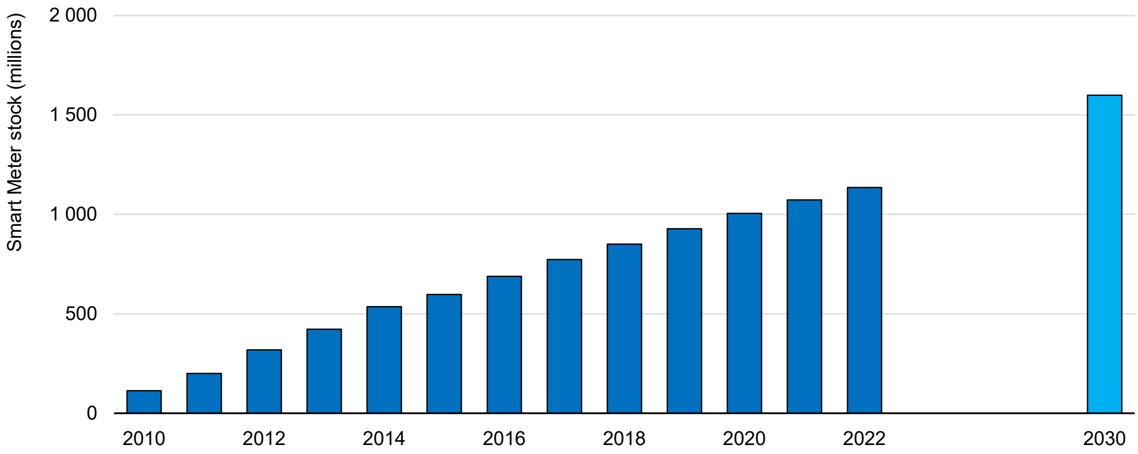
Buildings are capable of providing a wide range of flexibility services to the grid without compromising on energy needs of consumers, if they have the ability interact with the grid through various digital tools and devices, such as smart meters and smart automation and controls of main building end uses.

Globally, in 2021, the stock of smart meters was about 1 billion and is expected to grow to 1.6 billion units by 2030. While some countries have reached full rollouts, others, especially in developing and emerging economies, are still in the initial stages of deployment. Investments in electricity networks in EMDEs fell 15% in 2020-21, to around 60% of the 2015-16 average level. Overall, EMDE investments in smart meters totalled less than USD 2 billion per year over the past five years, while advanced economies spent over USD 10 billion annually.

By enabling the collection of granular consumption data, smart meters can help gather improved insights into consumption patterns and factors. This can then be used to improve energy efficiency programmes, or harness distributed flexibility from consumers. However, smart meters can only realise their full promise if they are complemented by an enabling environment, which includes good data infrastructure, compatible communication protocols, energy management system or connected appliances, markets sending the right incentives, and proper consumer engagement.

Beyond smart meters, further deployment and use of digital technologies can create efficient grid-interactive buildings that can send signals to and receive signals from the grid to respond to its balancing needs at a given moment in time. By responding to the signal from the grid, such buildings can dynamically adjust their energy consumption by shifting energy use from peak demand hours to a time when electricity is the cleanest or by stopping electricity use for short periods of times to reduce the pressure on the grid without noticeable adverse impacts on the quality of energy services to consumers.

Global smart meter stock, 2010-2030



Notes: Meters are considered smart if they include Integrated onboard data storage and processing, enabling energy readings at frequent intervals (at least once hourly) and integrated, two-way communications between the meter and a utility's IT systems, enabling remote reading and control (remote disconnect-reconnect) of the meter. The projected 2030 value is what is expected under a scenario of current policies.

Sources: IEA analysis based on Guidehouse (2022) and BloombergNEF (2017).

If buildings are equipped with systems to generate their own electricity, such as using rooftop solar PV, then their on-site renewable electricity production can be also managed depending on the information coming from the grid. The excess of produced renewable energy can be directed to the users that need it or to available storage facilities to be dispatched later.

There are many such buildings now under construction. For example, the National University of Singapore has constructed a net-zero energy building by combining a super-efficient innovative hybrid cooling system with rooftop solar which enables the building to feed their 30% surplus energy to the campus grid to power neighbouring buildings during the day and to provide electricity back to cover demand at nights.

Chapter 3. Energy efficiency and the energy crisis

3.1 Reducing bills and fighting energy poverty

Energy savings from past efficiency actions are lowering energy bills by USD 680 billion this year in IEA countries

Energy efficiency measures adopted before the crisis are delivering significant energy savings for consumers today. As end use energy prices have risen, the value of these past efficiency actions has gone up.

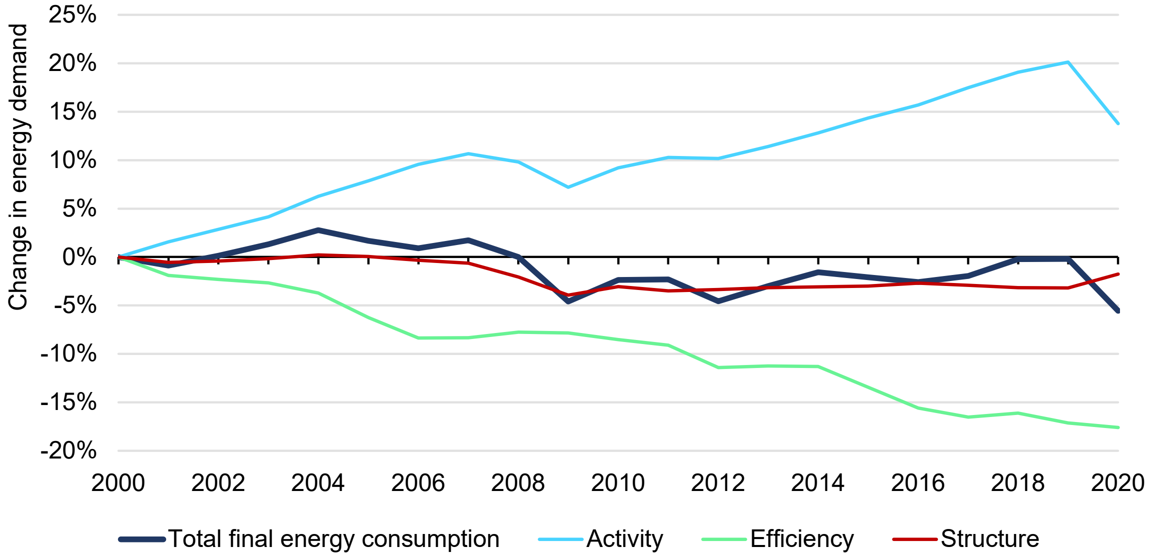
For example, since 2000, within the 31 IEA member countries alone energy efficiency-related measures that have delivered energy savings of just over 1 EJ per year across the buildings, transport and industrial sectors. This means that by 2020 around 24 EJ of final energy demand, or 16% of current levels of about 140 EJ, were being avoided thanks to energy efficiency.

Thanks to more efficient cars, buildings and industrial facilities, energy demand has stayed relatively stable at just under 140 EJ despite a 40% increase in real GDP for IEA countries as a group. This includes a much higher number of passenger kilometres travelled, floor area in buildings, and value added in the industrial and services sectors. At the same time, overall structural effects have been relatively steady contributing only a minor decline to overall energy consumption.

If households and businesses had used this 24 EJ of energy instead of saving it, their bills would have been around USD 680 billion higher this year (based on 2022 energy prices) around 15% of total estimated energy expenditure of about USD 4.5 trillion in IEA countries.

These efficiency savings have also provided a wide range of other multiple benefits. For example, CO_2 emissions are 20% lower than they would otherwise have been, energy security has been strengthened, demand pressure on energy prices is lower, and health and well-being outcomes have been improved through cleaner air and more comfortable homes.

Change in energy demand and drivers, IEA countries, 2000-2020



Note: Change in total final energy consumption is the net effect of changes in activity, efficiency and structure across buildings, transport and industry. For example, in residential buildings, activity refers to population, structure refers to per capita floor area, efficiency to energy use per floor area. See IEA Energy Efficiency Indicator Documentation for a full explanation.

Source: Energy Efficiency Indicators 2022.

High fossil fuel prices are driving an energy cost-of-living crisis, hurting vulnerable communities the most

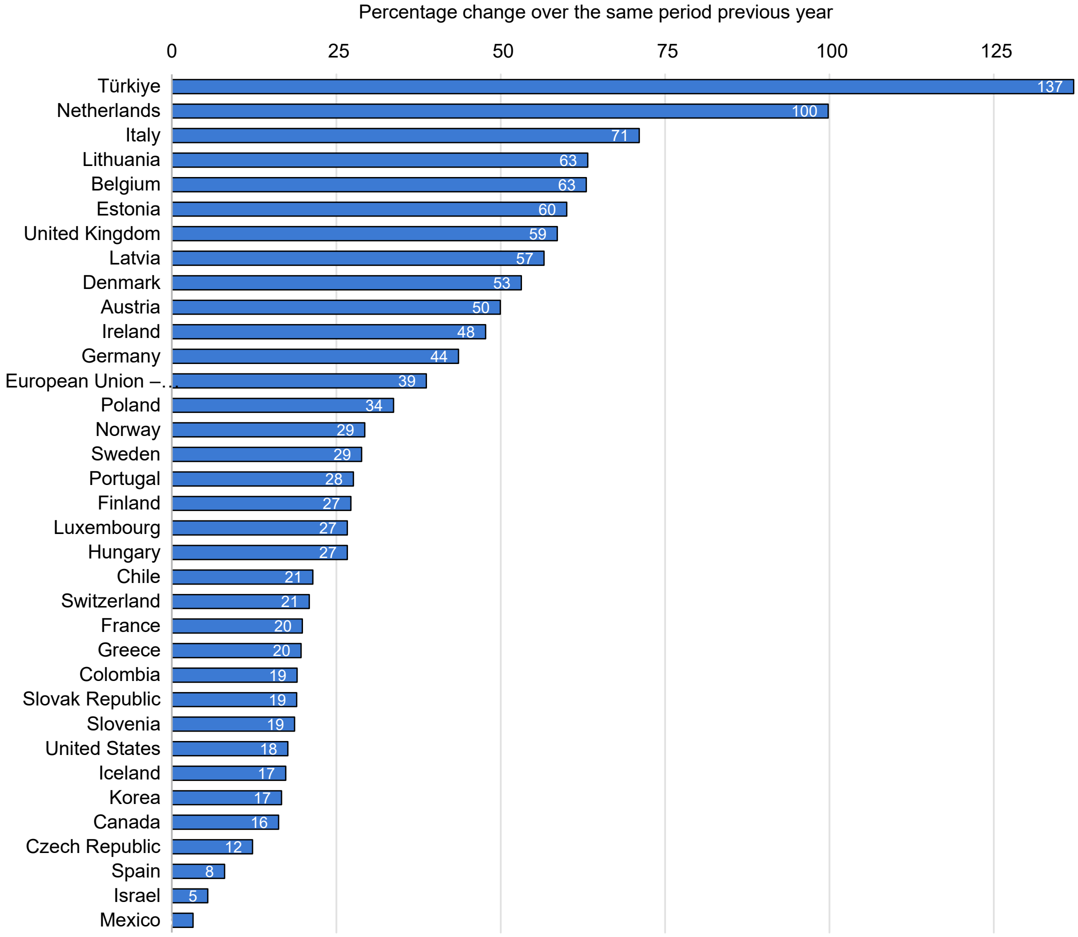
As a global average, households typically spend around 7% of income on energy, with generally accepted thresholds of "affordability" at around 6% of household income and energy poverty becoming a problem when the proportion spent rises to over 10% of household income. Typically, around half of household energy expenditures are for the home, primarily heating, cooling and cooking, and half for transport.

Increased energy costs have been the single biggest contributor to the rise in inflation experienced in most countries in 2022. This is posing a major threat to global growth, amplifying energy poverty, as well as restricting access to modern energy services in many emerging economies.

While the current energy crisis is global, it is centred in Europe, which is recording some of the highest rates of energy price inflation. In March 2022 the European Healthy Homes Barometer estimated that around 50 million households are living in energy poverty in Europe--a figure now likely to be significantly higher due to the ongoing energy crisis.

Energy poverty is not only a financial issue for consumers, but also a health one – with the impact of cold housing and its well-understood association with illness and excess winter deaths. For example, doctors in the United Kingdom are warning of a "significant humanitarian crisis" this winter as half of all households' face fuel poverty. This underscores the importance of support to help vulnerable consumers manage energy costs this winter and beyond.

Year-on year change in energy price inflation, October 2022



Source: OECD Database on Consumer Price Indices, as modified by the IEA.

Energy is also an important indirect driver of costs for food and many other goods with the price of oil accounting for as much as 64% of food price movements. This is major concern in emerging market and developing economies where food comprises a much higher share of household income and increased energy costs are exacerbating the food crisis.

The burden of rising prices is unfairly distributed, both within and among countries, impacting the least able to afford it the most. New analysis in the 2022 IEA World Energy Outlook highlights that in advanced countries the poorest 20% of households consume only a third of the energy of the richest 20%, but spend a much larger share of their income on it. This picture is even starker in emerging market and developing economies where the poorest households consume nine times less energy than the wealthiest.

Access to modern energy services and more efficient clean cooking and heating has been set back

From 2019 to 2022, the number of people without reliable access to heating, cooling, clean cooking and other energy services has risen to around 2.5 billion worldwide, with an extra 160 million households spending at least 10% of their income on energy. Around 75 million people who had recently gained access to electricity are likely to have lost the ability to pay for it. This will lead to a significant increase in the use of fire wood, charcoal and other traditional biomass for heating and cooking.

This is the first decline in the number of people without access to electricity in decades and is having a particularly severe effect in Sub-Saharan Africa, home to 80% of the world's population without access. This has been the result of slowing electrification programmes due to the combined effects of the Covid-19 and energy crises. In South Africa, for example, transport fuel costs were 56% higher in July than 12 months previously.

IEA activities on energy efficiency in Africa

A recent IEA report, the Clean Energy Transitions in the Greater Horn of Africa, found that while energy demand in Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan and Uganda has grown by 35% per year over the last decade, around half of the population still lacks access to electricity and only one in six people cooks with modern fuels. This group of countries accounts for one-quarter of the GDP of Sub-Saharan Africa but uses less energy than that of Belgium and the Netherlands combined, while having ten times the population.

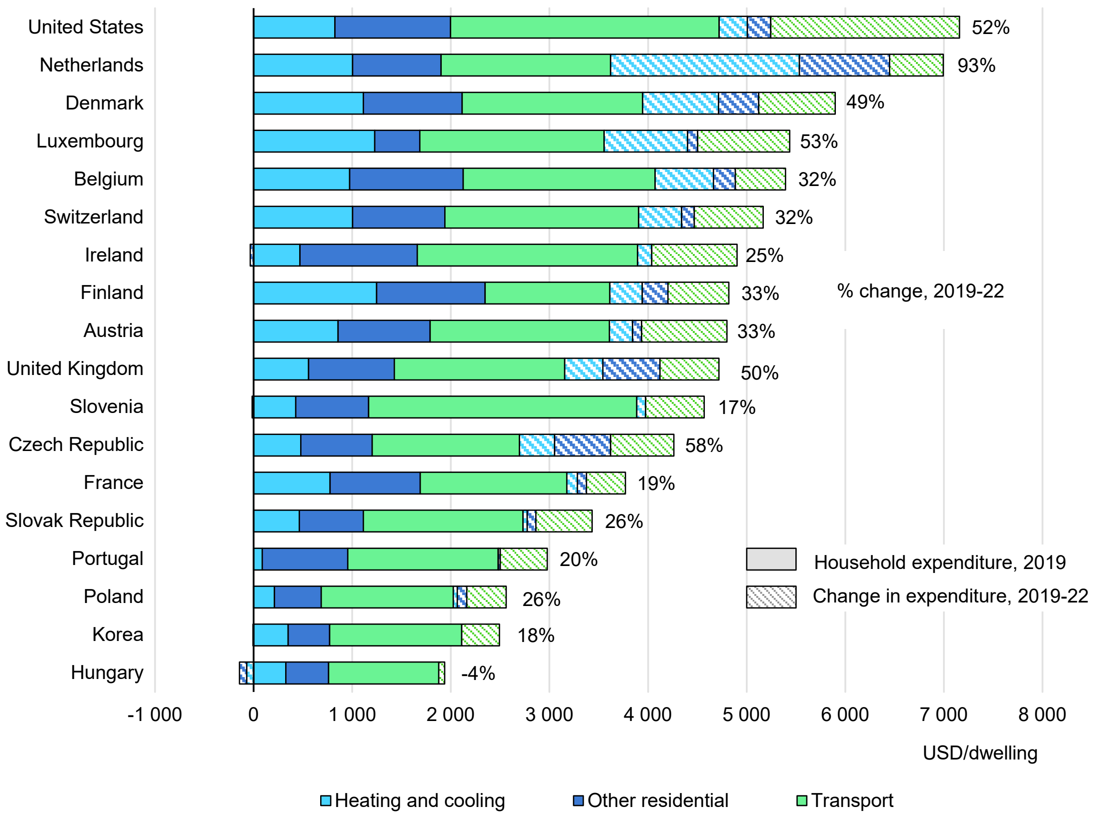
The IEA supports energy efficiency capacity building in Africa through the Clean Energy Transition Programme. In late 2022, an IEA Regional Training on Energy Efficiency Policy Packages for Sub-Saharan Africa was held, which discussed how strengthening energy efficiency can contribute to a range of economic, social and environmental goals. The policy packages are a combination of regulation, information and incentive measures for major end uses such as appliances, buildings, industry and transport, which have provided successful results in boosting efficiency when used in combination. The workshop explored concrete international and regional case studies and contributed to building a community of energy efficiency professionals in the region.

From 2019-21, the number of people living below the poverty line in Latin America increased from 28% to 30% – a jump of 14 million people. This number is increasing further due to the global energy and cost-of-living crisis. Since the 1990s, countries in the region have strengthened social support programmes for the poorest people. This includes support for energy bills: 40% of countries in the region are dedicating an average of 1% of GDP to subsidise electricity, primarily to households. These measures are critical short-term steps to protect vulnerable people and households while longer-term solutions are put in place.

Policies as well as the existing structure of energy consumption determine the impact of energy price rises

In addition to the underlying efficiency of transport systems and buildings, energy bills are also a function of the amount of energy consumed in each household, distances travelled by car, the fuel mix and price of various fuels, as well as any taxation and energy bill support measures. These differences mean that exposure to higher prices varies significantly around the world, with some countries more exposed to higher electricity prices for residential use, gas prices for heating, or oil prices for transport.

Average household annual energy expenditure, selected countries, 2019 and 2022



Sources: Estimated based on IEA Energy Prices and Energy Efficiency Indicators databases.

For example, due to the Hungarian government's utility cost reduction programme, Budapest is one of the cheapest places to buy natural gas in the European Union, while in other countries the cost of heating and other residential use has almost doubled. The degree to which higher market prices for transport fuels, gas and electricity are passed through to consumers is a significant determinant of end-user prices, with the difference often being absorbed through increased public subsidies.

Targeting spending can protect the vulnerable, improve public budgets and maintain incentives for efficiency

With households and businesses facing significantly higher energy bills this year, governments in all regions have brought forward a range of interventions to provide support for consumers. The value of this emergency government spending is now over USD 550 billion.

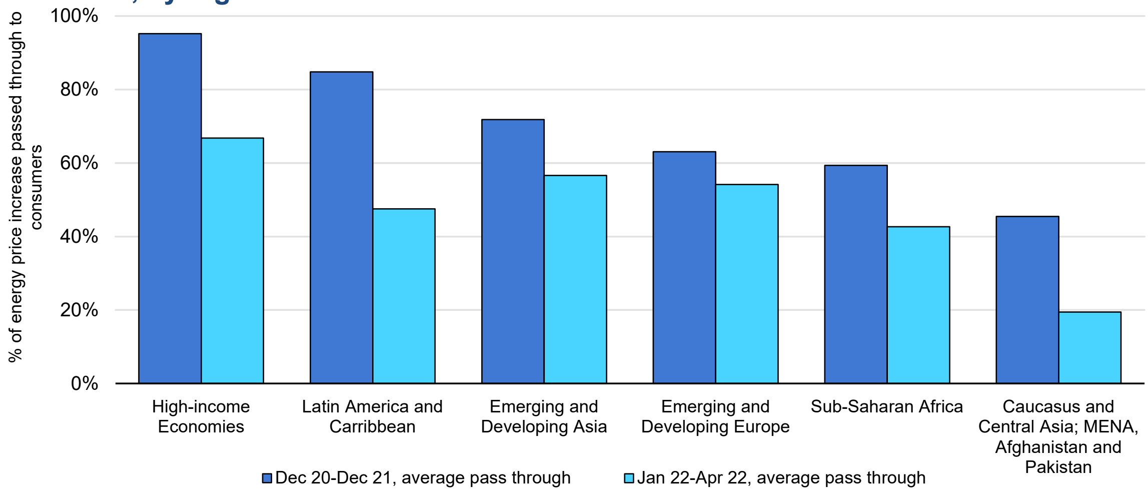
In emerging and developing economies this short-term support now outweighs that provided for clean energy investments since March 2020. Overall support is set to further increase substantially, such as through the very large USD 200 billion package in Germany.

Interventions have varied in coverage and size, but generally follow one of two approaches:

- Energy price controls set a limit on the amount a consumer pays, usually per unit of energy. They use a combination of price caps on wholesale price rises, limiting supplier margins or removing components of bills such as network or policy costs. Foregone supplier revenue is compensated by governments. Examples include price caps introduced in Portugal and Spain; the United Kingdom's Energy Price Guarantee; and France's cap on regulated electricity price rises at 4% through 2022 and 15% in the longer term. In October, the European Commission proposed a Dynamic Price Ceiling for imported gas.
- Income transfers that provide money directly to consumers regardless of how much energy they use. This is often, though not always, means-tested to target less well-off consumers where social security systems allow for it. For example, Germany has paid a one-off energy price allowance of EUR 300 to income tax payers, with extras for those with children or on low incomes. Identifying and making transfers to vulnerable consumers is dependent on national social security systems having adequate coverage.

For example, in the transport sector the percentage of energy price increases being passed through to consumers has fallen across all countries with the difference between market prices and end-user prices generally being met by public budgets. For instance, a recent IMF note suggests that 26 out of 31 advanced economies surveyed have announced at least one measure to limit the pass-through of higher international prices to domestic consumers and 45 out of 103 EMDE countries have also moved to limit pass-through this year.

Proportion of international transport fuel price increases passed through to domestic consumers, by region



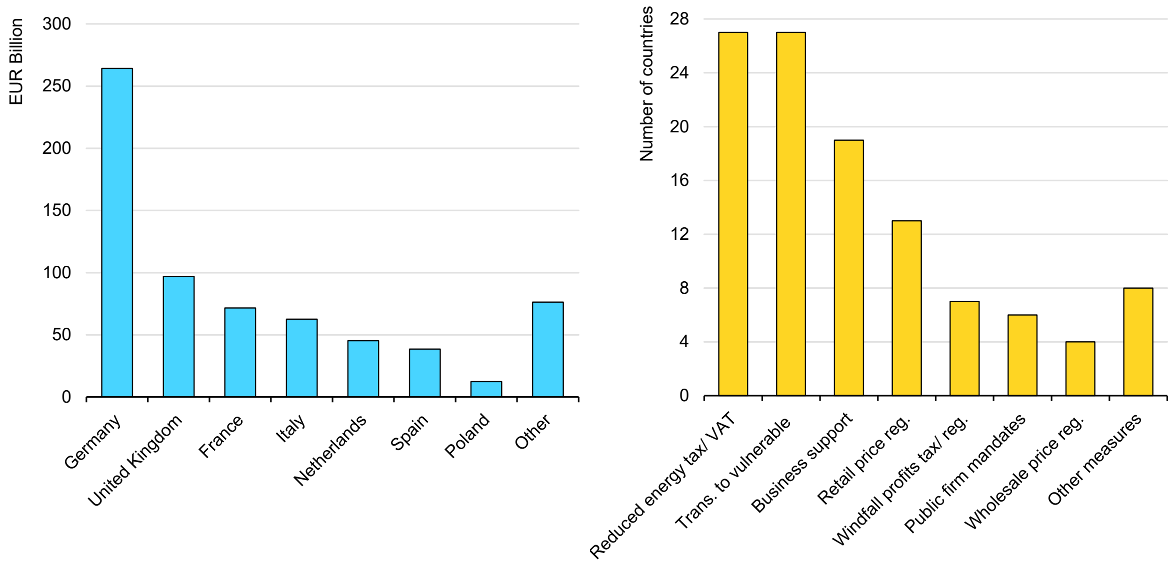
Sources: IMF (2022), Fiscal Policy for Mitigating the Social Impact of High Energy and Food Prices, as modified by the IEA.

Governments in every region absorbed varying proportions of the oil price rises of early 2022 putting pressure on public budgets. As of mid-October 2022, the think tank Bruegel estimated that European governments have allocated around EUR 670 billion to such schemes since September 2021.

Such subsidies can redirect public budgets away from more effective poverty-reduction schemes. It was for this reason that in August, Indonesia announced a reduction in the national petrol subsidy, which it will instead use to better target low-income households. As energy efficiency lowers energy consumption, it can also provide a reduction in public budgets spent on such subsidies.

During 2022 the OECD and International Monetary Fund have recommended winding down general subsidies and price controls and shifting the balance towards providing more targeted support, especially to vulnerable households. More focused policies on housing quality is equally important given that people living in the least efficient homes can face energy bills of more than an order of magnitude higher than those in the most efficient. Targeted policy support that improves efficiency reduces bills while providing in-kind income support that permanently locks in savings.

Public funding to shield consumers from the energy crisis, September 2021-October 2022

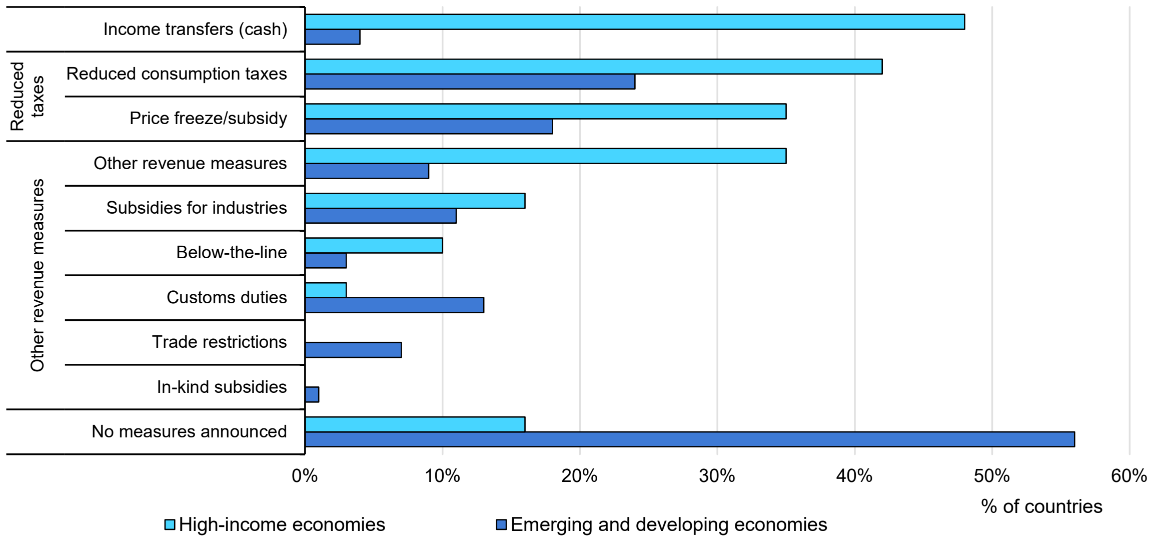


Source: Bruegel, as of 21 October 2022. National Policies to shield consumers from rising energy prices, as modified by the IEA.

Gas and electricity price controls under the German government's EUR 200 billion "double ka-boom" energy support package have also been targeted so that consumers pay a subsidised rate for energy demand up to a threshold, and after which a market rate applies. Linking this threshold to a previous year's energy consumption incentivises continued demand reduction.

Governments in emerging and developing economies have also turned to a range of measures to reduce consumer pressure. Some have focused on price controls, such as reduced taxes and adjustments to domestic prices. However, more than half have not implemented any new measures.

Proportion of countries introducing measures to shield consumers from price rises in April 2022



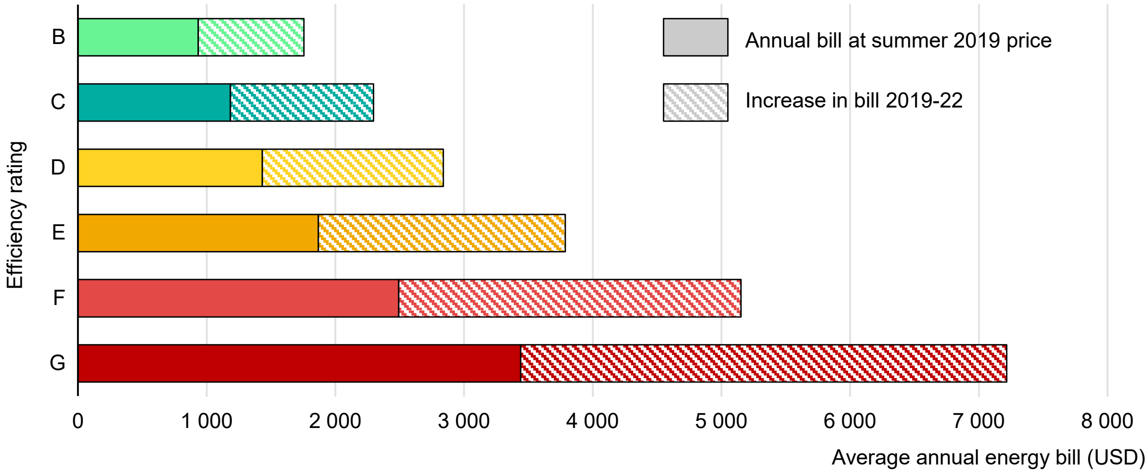
Source: IMF Fiscal Policy for Mitigating the Social Impact of High Energy and Food Prices, as modified by the IEA. Responses to an IMF survey of 134 countries conducted in April 2022.

Least-efficient homes can result in energy bills several times higher than in the most efficient

The wide range of efficiency levels in buildings means that many citizens are heading into winter with vast differences in their exposure to high energy prices. For example, in the United Kingdom, the majority of households live in dwellings with an energy performance rating of D or lower. Even in 2019, a typical consumer in the very worst-performing buildings faced estimated annual home energy bills of USD 3 440 – more than three times the USD 935 paid by households in buildings rated at B.

With recent energy price rises, annual UK household energy bills from October 2022 are estimated to be around double the level of 2019. Following the government’s Energy Price Guarantee plan, the same amount of energy usage in a G-rated dwelling as in 2019 would incur a bill of USD 7 220 compared with USD 1 800 in a B-rated building. This has led to increased attention on the value of energy efficiency in supporting households with rising energy costs.

Typical annual household energy bills, by building energy performance certificate rating in the United Kingdom at summer 2019 and October 2022 prices



Note: 2019 bill estimated as 12 months of energy use at GB default tariff cap level April-September 2019. Bill increase estimated as difference in cost between this and 12 months of October 2022 Energy Price Guarantee level.
Sources: IEA analysis of data from UK Department for Business, Energy and Industrial Strategy 2019 Fuel Poverty Statistics; Office of Gas and Electricity Markets, Default tariff cap level: 1 April 2019 to 30 September 2019, Energy Price Guarantee, Decision for Typical Domestic Consumption Values 2020.

A similar picture emerges from other countries. In Denmark, for example, it takes more than ten times the energy, to heat the least-efficient, typical-size homes than it does the best-performing homes of the same size.

Households already living in more efficient buildings face lower bills while enjoying a healthier, more comfortable home. By installing further upgrades, they are also able to shield themselves against continued high prices into 2023 and beyond. Installing solid wall and loft insulation in the United Kingdom could reduce a typical household bill by over 10%, for example – representing an estimated USD 400 saving in an E-rated building. Simple, low-cost technologies, such as smart space heating thermostats, can also facilitate energy demand reduction and cost as little as USD 80 to purchase and install.

Proper maintenance of heating systems through “hydronic balancing” – or optimising the water pressure in a heating system - can provide inexpensive energy savings of up to 15%, particularly in larger buildings. In July, the German government made it compulsory for all owners of large buildings with a central heating supply to carry out hydronic balancing within the next two years.

In the United States, higher energy costs are expected to add between 19% and 28% to the natural gas bill of the average home from October 2022 to March 2023, depending on winter temperatures. The US Environmental Protection Agency has estimated that homeowners can save an average of 15% on heating and cooling costs through insulation-based retrofits. The American Council for an Energy

Efficient Economy (ACEEE) has warned that price increases will hurt low-income and Black, Hispanic and Native American households the most, who pay a much larger share of their income on energy bills. Other groups that spend a greater proportion of their income on energy include the elderly and renter households.

Smart thermostats provide a low-cost means of reducing energy bills

One of the recommendations of the IEA's 10-Point Plan to Reduce the European Union's Reliance on Russian Natural Gas is to encourage a temporary thermostat adjustment by consumers of one degree, which could lead to an estimated 10 bcm saving of natural gas each year. Connected thermostats, smart heating controls (such as thermostatic radiator valves, TRVs) or well-designed automation can facilitate temporary temperature adjustments by consumers, helping to save energy, particularly at peak hours.

The French national agency responsible for energy efficiency, ADEME, has found that programmable thermostats can reduce heating energy demand by up to 15%, depending on the type of building. The US Department of Energy found that lowering the temperature by 4-5.5°C for eight hours per day (e.g. overnight or during hours away from home while at the office) reduces energy consumption for heating and cooling by up to 10%. An automated thermostat makes this easier to achieve than manually switching heaters on and off. For this reason, some countries have introduced incentives for smart thermostats, such as France's Coup de Pouce (2020), Belgium's Eco Vouchers, or the SEEH scheme in the Netherlands (2019).

To date, over 130 million units of connected and smart thermostats, and home energy management systems as a whole, have been installed worldwide. Deployment is increasing rapidly. Total installations are expected to reach between 510 million and 640 million by 2030. Industry estimates suggest that around 70 million homes in the EU have TRVs fitted and up to 130 TWh of energy could be saved annually by upgrading those that do not yet have them.

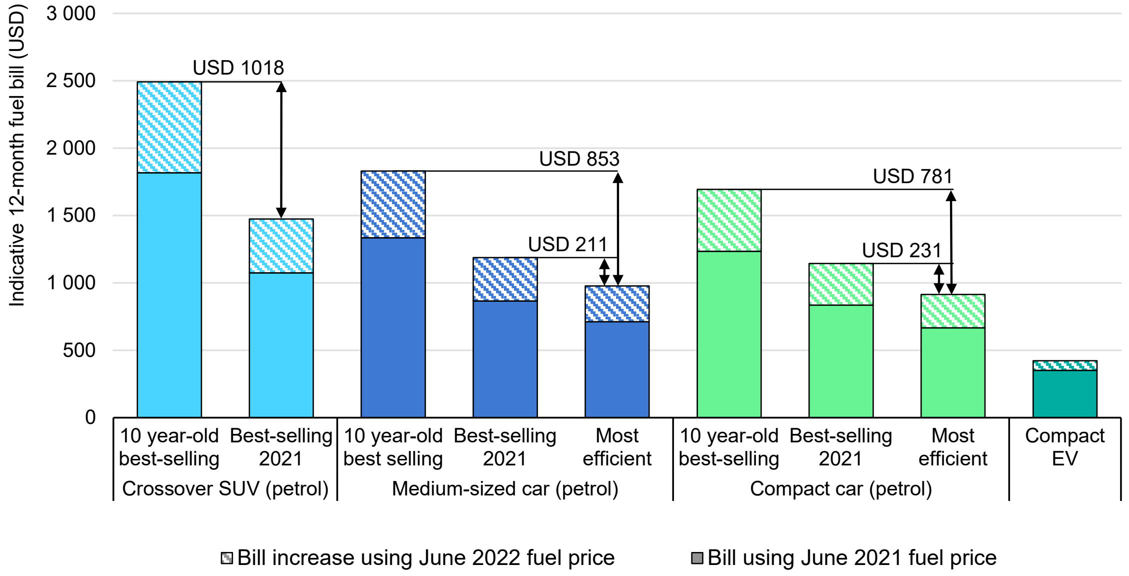
Buying newer, smaller and electric vehicles can lower transport fuel bills substantially

Choices around the size and efficiency of cars that consumers buy has a significant impact on fuel bills. Looking at petrol cars, European buyers choosing the best-selling compact or medium-sized models face bills that are 20%-25% higher than if they had chosen the most efficient model of the same size. This represents an estimated annual saving of USD 210-230 at June 2022 petrol prices, around USD 60 higher than they would have been a year ago.

Even greater savings are available to drivers who choose smaller cars. European buyers opting for the most efficient medium-sized car over a best-selling crossover SUV have fuel bills that are 30% lower while broadly retaining the same level of utility. At June 2022 prices this replacement leads to an annual fuel bill saving of almost USD 500 per year.

Thanks to new European fuel economy standards that came into force in recent years, fuel cost savings are largest for consumers that replace an old vehicle with a new one. In 2022, the difference in efficiency between a 10-year-old version of today's best-selling model, and today's most efficient model of the same size, translates into a saving of USD 850 for a medium-sized car or USD 780 for a compact car. Annual savings of more than USD 1 000 are available to drivers replacing a 10-year-old SUV with a similar new and more efficient car.

Fuel bills for different vehicle types, in Europe, June 2021 and June 2022



Electric vehicle drivers have access to the greatest potential fuel bill savings. For example, a typical European electric car driver has an estimated annual bill of just USD 420 when charging at home, despite household electricity price rises over the past year. This bill – significantly lower than those of any petrol vehicle type analysed – is the result of the much higher efficiency of an electric powertrain relative to an internal combustion engine.

Similar results have also been shown by the Department of Energy in the United States, where in August 2022 electric vehicles were found to have by far the lowest annual fuel cost of all light-duty vehicles, of around USD 1 000 or less per year compared with gasoline cars, which generally cost at least triple this amount to drive.

This estimate for lower bills from using electric vehicles also must be qualified by the cost of charging using public charging point that varies considerably and can be from 30% higher to three times more expensive than charging on a home charger. Preventing price gouging from public charging operators and supporting access to fair prices is a key issue as the charging infrastructure expands.

Analysis by the IPCC in April 2022 suggests that battery electric vehicles could use around three to four times less energy per kilometre than an internal combustion energy vehicle with the same mass. While tank-to-wheel efficiencies are very high for electric vehicles, due to the removal of thermal losses from combustion in the engine, there are combustion and other loses in power generation, transmission and distribution. Low-GHG emissions electricity is needed for full climate change benefits. To obtain a more complete picture of efficiency and CO_2 emissions, a well-to-wheel analysis of electric vehicles is important, especially where power is still predominantly generated by coal.

3.2 Greater consumer awareness and behaviour change to save energy

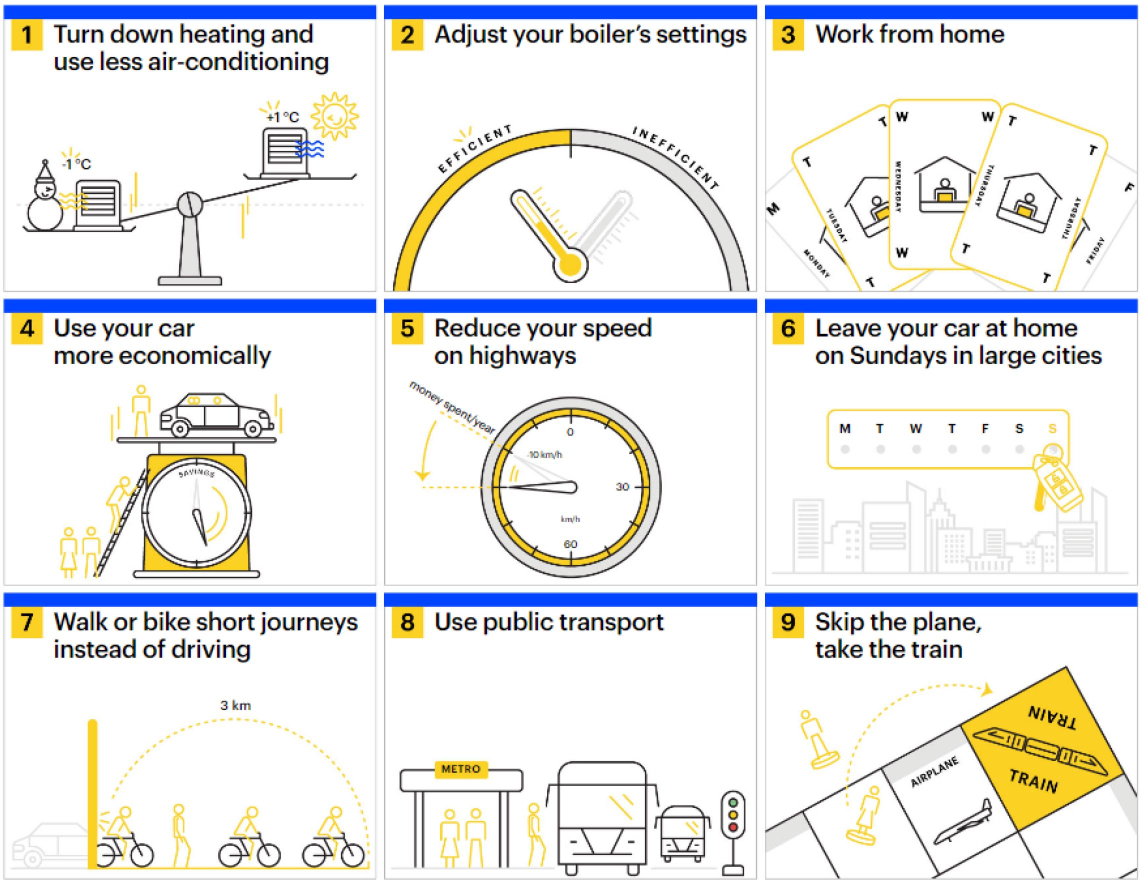
Governments turn to behaviour change campaigns as a source of rapid energy demand reduction

Since the beginning of the year, at least ten European governments have launched behaviour change and awareness campaigns to give consumers information on how they can lower their energy use. Awareness campaigns tend to encourage citizens to turn down their thermostats, shorten their showers, line-dry clothes and minimise energy use from driving. In April, the IEA and European Commission launched the Playing my Part campaign, outlining simple actions that citizens can take to reduce their bills and aggregate energy demand.

In May, the EU Save Energy Communication outlined the European Commission’s two-pronged approach of promoting mid- to long-term efficiency improvements while achieving immediate energy savings through behavioural changes. This is reflected in many national strategies, including Denmark’s Sammen sparer vi på energien (Together we save energy) campaign and Germany’s 80 Millionen gemeinsam für Energiewechsel (80 million together for energy saving), which also provide users with information to help citizens carry out home energy retrofits.

Campaigns have also been used to great effect outside of Europe to tackle past and current energy crises. In response to a hydroelectricity supply crisis in Brazil during 2021, the government implemented an awareness campaign alongside financial incentives to reduce energy use at peak hours. In Korea, following large-scale blackouts in 2011, awareness campaigns use social media and popular culture channels, as well as conventional media and in public advertisements. To address the current crisis, the newly-elected Korean government plans to use these campaigns alongside an 'Energy Cashback' incentive scheme to encourage members of the public to reduce their energy use by 10% this winter. In recent years, the Indian government has encouraged air conditioner users to run appliances at 24°C or more by making it the default appliance temperature upon purchase and via an awareness campaign.

Playing my Part campaign: Nine simple actions citizens can take to reduce energy



Characteristics of successful behaviour and energy awareness campaigns

The IEA has analysed a wide range of energy awareness and behaviour campaigns across countries in 2022, and outlined the key features of successful campaigns.

Getting the message right: Campaigns are more likely to succeed if the messages are targeted, relatable and actionable, and hit the right tone with their audience. Depending on the context, governments may highlight cost, environmental or social benefits. Denmark's campaign focuses on the strength of solidarity, with a message focused on saving energy together.

Getting the message across: The choice of messenger and channels to convey messages can have a strong impact on a campaign’s reception by citizens. The Netherlands leveraged the support of businesses, prominent NGOs and foundations in its Zet ook de knop om (Flip the switch) campaign. Using visuals, catchy names and dedicated website can increase shareability. Campaigns are often shared across a range of print, online and broadcast media, and tracking digital impact can further improve reach. Notably, Korea demonstrated an effective use of social media, using messaging platform Kakao, in addition to more conventional media.

Combining information with behavioural insights: While good information is essential, it is not enough to achieve a sustained result. Pairing a campaign with real-time feedback, relevant nudges, demand response programmes, home energy reports, and more can further stimulate energy-saving behaviour. Using insights from behavioural specialists can greatly enhance the success of behavioural change campaigns.

Campaigns in a crisis context: Citizens’ awareness of energy issues and their willingness to act is usually higher in times of crisis, which may justify stronger messages. Many countries already have the experience of developing and launching citizen-oriented campaigns in response to other energy supply crises. In addition to the example of Japan’s response to the 2022 earthquake, Brazil launched consumer campaigns in response to its hydro crises in recent years, while South Africa had experience with the Day Zero campaign, anticipating water shortages. In California, an emergency cell phone alert to reduce energy demand in September is credited with a 2.6 GW drop in demand within 45 minutes.

The potential to work more at home to save fuel is also being discussed in Germany, Ireland, South Africa and the Philippines. However, energy savings from avoided travel are partially offset by increased household energy consumption from heating and other behavioural shifts. Household bill payers bear the burden of increased energy bills from operating remotely from home offices, estimated at between USD 20 to 100 per month.

Governments are also supporting public transport use, with Germany having provided unlimited public transport for a month at EUR 9 over the summer and extending an adapted version moving forward. In the first three months of the scheme, over 52 million people bought these tickets and the reduction in car use cut carbon dioxide emissions by 1.8 Mt, around 6% of transport emissions over the same time period.

Italy is subsidising the purchase of monthly or annual public transport tickets for those on low incomes, the US state of California provided public transport free for three months, and England will cap the price of a bus ticket for three months in 2023. Action has also been taken to reduce public transport fares in Austria, Ireland and Spain.

Luxembourg has implemented one of the world's most generous public transport programmes, making busses, trams, funiculars second class train tickets free of charge in Luxembourg City and throughout the entire country. This includes pets and luggage brought on board by passengers.

Advice has also been produced on how private cars and fleet vehicles can be driven more efficiently in order to reduce fuel use, while countries are also promoting electromobility, walking and cycling. There are opportunities afforded by introducing these measures in the longer term. As a part response to the 1973 oil crisis, the Netherlands and Denmark introduced measures that helped prioritise cycling as a mode of transport and continued to build on this after the crisis had passed. The Copenhagenize Index provides a holistic global ranking of how bicycle-friendly a city is with links to some of the most recent success stories.

In Japan, Tokyo Electric Power Company launched Power Saving Challenge 2022 where power saving points can be earned and exchanged for goods using online services such as Amazon. A new five-level scale ranking system has been introduced that evaluates and publishes the annual status of energy-saving communication efforts by energy retailers. The system examines the level of energy-saving-related information and services that energy retailers such as power and gas companies provide to their customers. Retailers are given additional points for evaluation if they provide extra information for consumers such as visualising hourly energy consumption, signalling for engaging in demand response, and predicting future energy charges and usage.

3.3 Energy security and Russian gas

Rapid deployment of efficiency measures in industry and buildings can reduce the need for Russian gas in Europe

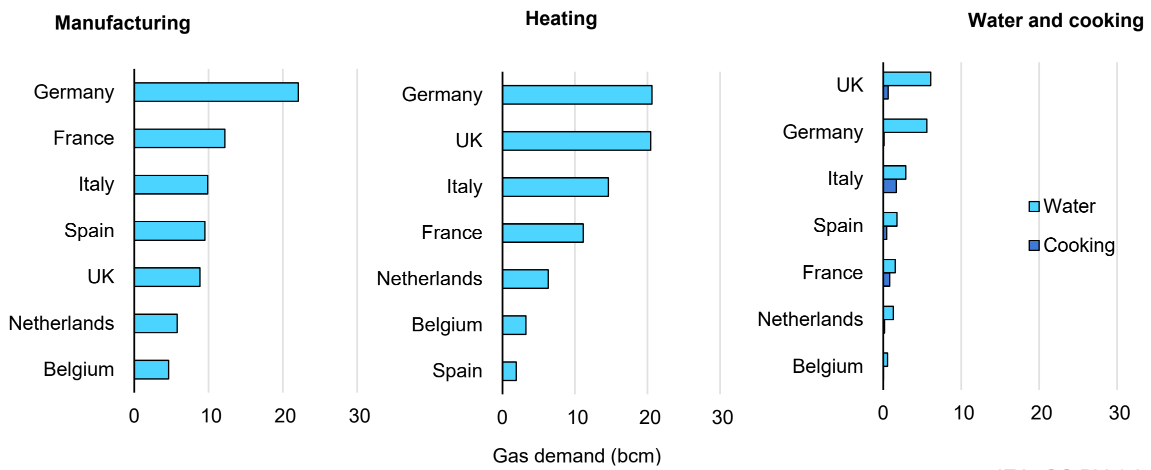
Europe's reliance on Russian supplies of natural gas was thrown into sharp focus in 2022. The IEA's most recent Gas Market Report shows that Russian gas increased its share in European supply from 30% in 2009 to 47% in 2019. As a consequence of European sanctions and Russian supply cuts, this figure is expected to drop to 9% in 2022.

While the shortfall has largely been made up for with alternative supplies, this has also been accompanied by a 10% year-on-year reduction in gas demand in the first half of 2022. The European Commission's main policy response to the Russian gas crisis is the REPowerEU Plan, which aims to reduce its use by two-thirds by the end of 2022 and by 100% by 2030.

Energy saving is one of the plan's three central pillars. It increases its previous target under the Energy Efficiency Directive for EU-wide energy savings by 2030, to 13% from the previous 9%. It also aims to double the deployment rate of heat pumps to achieve 10 million cumulative installations over 2023-27, and accelerate electrification, especially in industry. According to the plan, such measures could reduce gas use in the residential sector by 37 bcm per year and in industry by 12 bcm per year by 2030.

Behavioural change measures, laid out in the EU Save Energy Communication and Playing my Part campaign, include encouraging reduction of thermostats by 1°C and could save around 10 bcm of gas per year. Combined, the plan's energy-saving measures could save the equivalent of 42% of the 140 bcm of natural gas imported by Europe from Russia in 2021.

Main end uses of natural gas in major consuming, in European countries, 2019



Note: This does not include gas used in power generation.
Source: Energy Efficiency Indicators 2022.

Energy-saving measures implemented in Europe over the summer appear to have affected demand. Several studies suggest that in October, weather-adjusted gas demand in Germany was around 20% lower than the same period in 2021. However, gas demand is highly weather-dependent. Colder-than-expected conditions over winter 2022-23 could counteract much of the achieved savings.

As Europe looks ahead to 2023, the focus on immediate energy savings will become secondary to the more urgent question of the structural energy efficiency improvements governments can make in the next 10-12 months, which will be critical for European energy security next winter.

Rapid electrification of industrial heat is possible, especially in textiles, and food and drink manufacturing

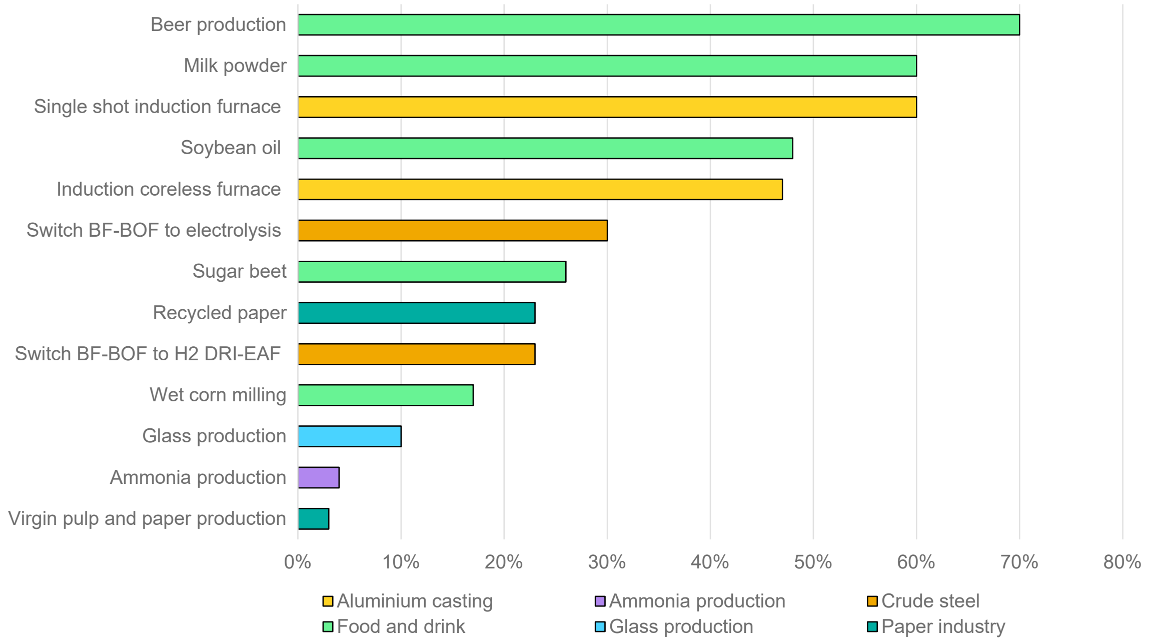
Globally, heat represents two-thirds of all energy demand in the industrial sector, and one-fifth of energy demand across the globe. Electrifying industrial processes offers the simultaneous benefits of directly reducing fossil fuel demand, increasing process efficiency and potentially supplying the remaining energy demand with increasingly low-carbon electricity. Additionally, electrification can offer industry the potential for new business models because of increased flexibility in location and sizing of plants when compared with fuel combustion-based processes.

In light industry, electrification normally entails a switch from fossil fuels to electricity as a source of process heat. This can be achieved using a heat pump, a microwave or induction process, or mechanical methods of separation for dewatering like reverse osmosis.

By contrast, electrification in heavy industry generally involves replacing the main process technology. In steelmaking, for example, this involves replacing a blast furnace with an electric arc furnace (EAF) or induction coreless furnace. This technology holds significant potential for energy saving and decarbonisation. Using secondary, or recycled, steel produced from scrap with an EAF can save approximately 70% of energy compared to the conventional blast furnace (BF-BOF) route for primary virgin steel.

There is great potential for the rapid electrification of industry, with several options available in the short term.

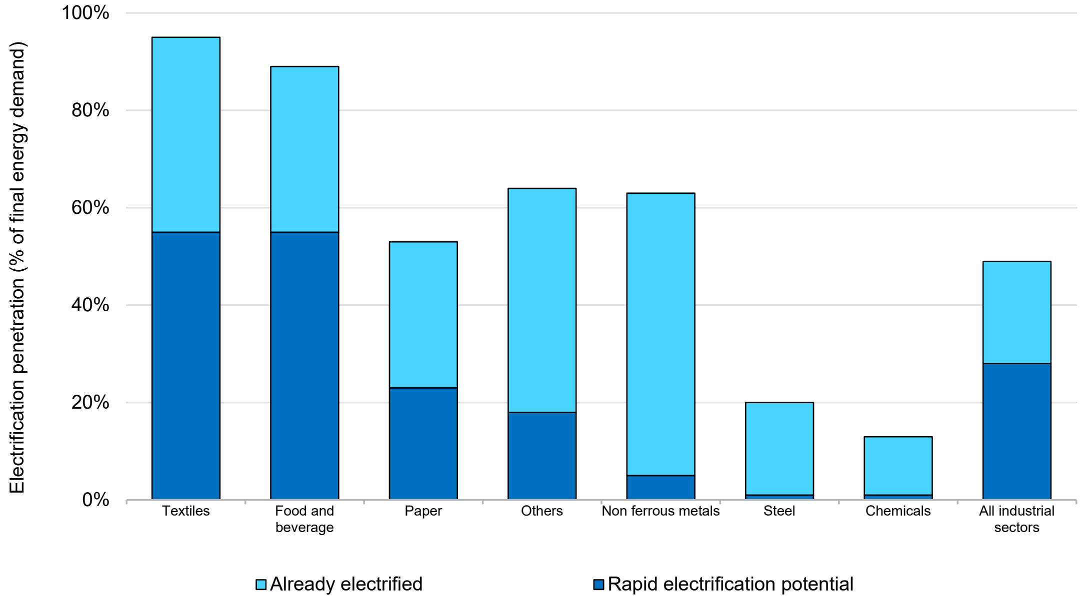
Potential energy savings from electrification of industry in the United States



Note: Bf-BOF = Conventional blast furnace route in steel production. DRI = Direct reduced iron. EAF = Electric arc furnace

One industry with relatively high potential to benefit from rapid electrification is beer brewing, where thermal energy constitutes around 70% of typical energy consumed. Beer brewing uses steam generators to cook large vats of water with malted grain and other ingredients to around 70°C to 90°C before cooling for fermentation. For example, global beer manufacturer Carlsberg has prioritised energy efficiency, and eight of its breweries are now supplied wholly by renewable electricity and heat. Relatedly, Ahascragh whiskey distillery became the first zero-emission distillery in Ireland through the use of heat pumps and renewable electricity.

Potential for rapid electrification of industry in Europe



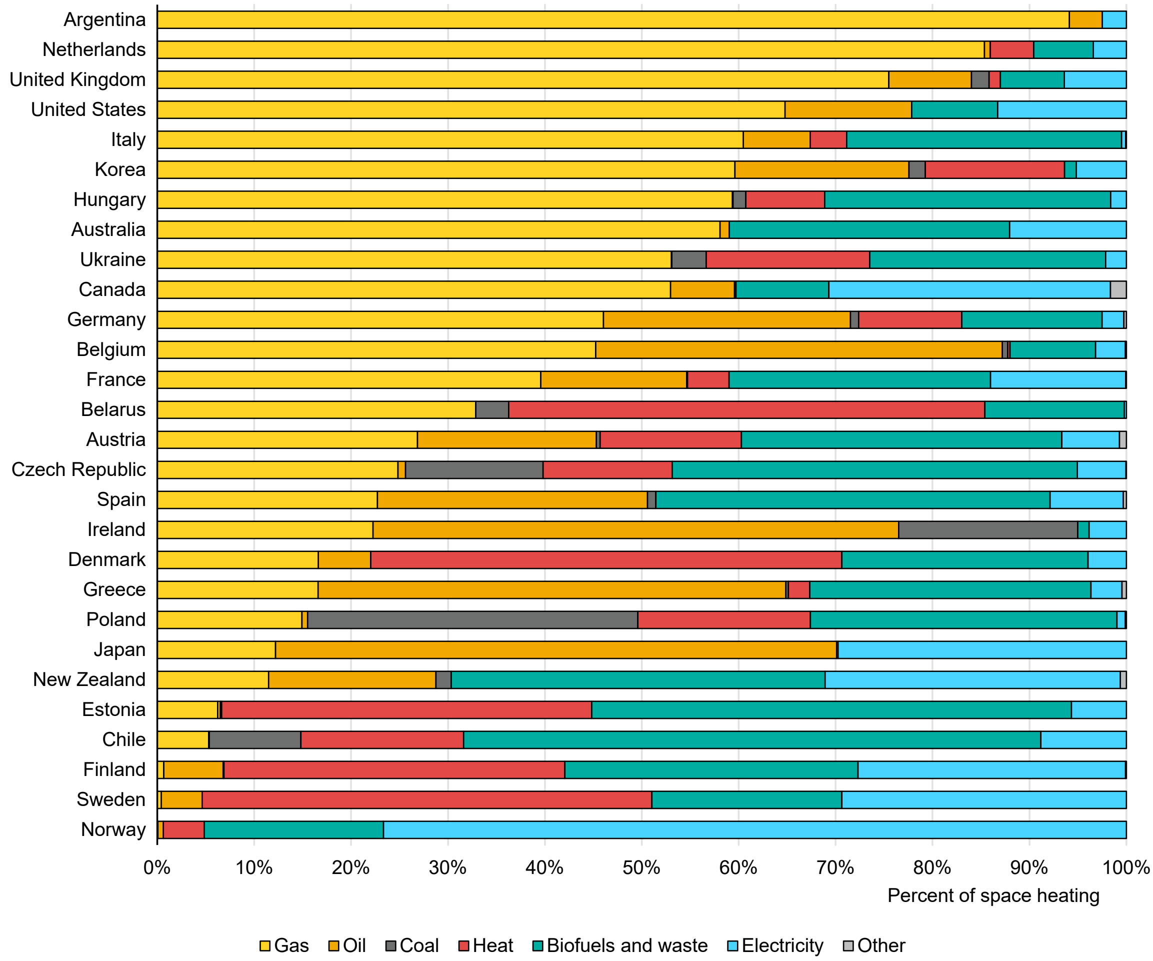
Note: The difference to 100% is electrification potential that requires more complex systemic process changes.
Source: Schneider Electric Sustainability Research Institute (2022), as modified by the IEA.

Achieving energy savings is heavily reliant on the successful integration of the electrified element into the process, digital feedback on performance, and ongoing control of the operational parameters. While much of the technology is proven and available, delivering and operating new electrified systems in industrial plants will require significant policy, management and technical actions. This relates to the design, optimisation, build, operation, maintenance, monitoring, targeting and control of the plants and their processes, and the resources required to deliver them.

Dependency on natural gas for residential heating ranges from 90% to close to zero

As detailed in the IEA's Tracking Clean Energy Progress, natural gas is the most common fuel used to heat households globally, accounting for 42% of residential heating energy demand and a total of 760 bcm in 2021.

Residential heating energy consumption by fuel source, in selected countries, 2020



Note: Heat refers to heat produced for direct sale, mainly through district heating networks and thermal heat from industrial processes and other sources. “Other” includes mainly conventional biomass.
Source: Energy Efficiency Indicators 2022.

In Argentina, Italy, Korea, the Netherlands, Türkiye, the United Kingdom, and the United States, natural gas provides over 60% of heating energy. Finland, Norway and Sweden use practically no natural gas for heating, despite Norway being the largest gas producer in Western Europe. Norway leads the world on residential heat electrification with almost an 80% share of heating provided by electricity. Other notable countries include Canada, Finland, Japan, New Zealand, and Sweden, all with a roughly 30% share of electricity for residential heating.

District heat accounts for 10% of heating of buildings globally, with the fuels used for it ranging from fossil fuels, waste heat from power generation and industrial processes, wastewater, data centres and renewable energy. In Europe, there are over 6 000 district heating networks meeting around 11% of heating demand.

Stockholm is one city where 98% of heating is provided by renewable or recycled waste heat using large-scale heat pumps – an approach that some cities in

Germany are looking to emulate as part of a move away from natural gas. With a capacity of 126 MW for heating and 80 MW for cooling, the Katri Vala district heating and cooling plant in Helsinki is the largest heat pump system for heating and cooling in the world. New district heating networks using heat pumps can use reversible technologies that can provide cool water circulation.

In the Net Zero Scenario, the share of fossil fuels in the global heating mix drops from 64% today to 45% in 2030. This can be achieved by a combination of improved building efficiency and a shift to electric, renewable and other low-emission heating technologies. In the scenario, the share of electricity in the heating mix rises from 15% globally in 2021 to 20% in 2030.

Countries accounting for 80% of residential gas in Europe have plans to ban new gas heating connections

A growing number of countries, sub-national governments and cities have announced bans and phase-outs of gas-burning appliances. The European Union has an overall ambition to phase down gas use in buildings, with some countries specifically stating they will implement bans. This includes Austria, starting in 2023, and the Netherlands, which will permit only heat pump installations or heat network connections in buildings as of 2026.

Ireland announced a ban of oil boilers for new buildings starting this year and gas boilers by 2025. The United Kingdom has set a target that bans new homes from installing gas heating systems and boilers as of 2025 and for all buildings as of 2035. Germany also started the legislative process to put in place an implicit ban on fossil fuel heating starting in 2024, after which every newly-installed heating system would have to be powered by at least 65% renewable energies. France has introduced an implicit ban in new buildings beginning this year by mandating a maximum CO_2 intensity for new heating systems that fossil fuels cannot meet in almost any building.

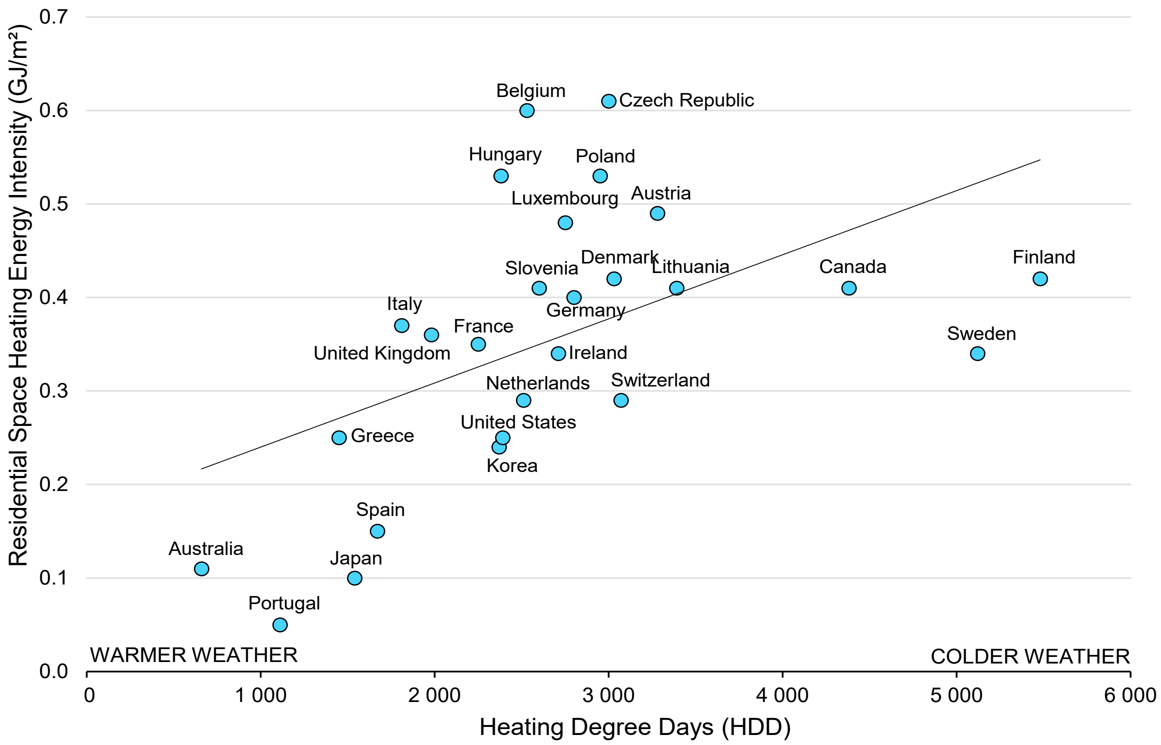
In the United States, more than 60 cities in California have announced bans or are discouraging gas use in new buildings. In September 2022 the California Air Resources Board, directed state agencies to draft a rule which would result in a ban on the sale of all new natural gas-fired space heaters and water-heating appliances by 2030. By 2023, some cities, including Eugene, Oregon, have a ban on natural gas in any new construction. Similar measures are planned in Washington, DC (2026); Ithaca, New York (2030); and New York City (2040). While comparable bills have been introduced in at least eight US state legislatures, others have introduced laws prohibiting municipalities from banning natural gas.

The city of Vancouver and the province of Quebec in Canada have also set requirements for new building construction to be zero emissions and are banning replacement of space heating and hot water systems powered by fossil fuels.

Efficiency regulations have reduced gas consumption by 21% in Europe for space and water heating in buildings

In Europe, buildings are responsible for almost 40% of energy demand. Over the past ten years the sector's energy consumption has fallen by 14%, driven by improving energy efficiency. Yet even in EU countries with similar climates there is a wide range of energy performance levels in buildings. This means that in in some countries with similar climates it takes twice as much energy to heat the same space. For example, the energy intensity of residential space heating ranges from around 0.3 GJ per m^2 in countries such as the Netherlands, Switzerland and Ireland up to 0.5-0.6 GJ per m^2 in Belgium, Czech Republic, Austria and Poland.

Residential energy intensity and heating degree days, in Europe, 2019



Source: Energy Efficiency Indicators 2022.

European health data have also shown that countries in milder climates, where buildings are less well insulated and heated, have higher levels of excess mortality in winter due to indoor cold: excess winter deaths are higher in Portugal than they are in Finland.

In the IEA's 10-Point Plan to Reduce the European Union's Reliance on Russian Natural Gas, a rapid scale up of retrofit efforts focusing on least-efficient homes and non-residential buildings can save more than 1 bcm, or 10 TWh, of gas in time for the 2023 European winter.

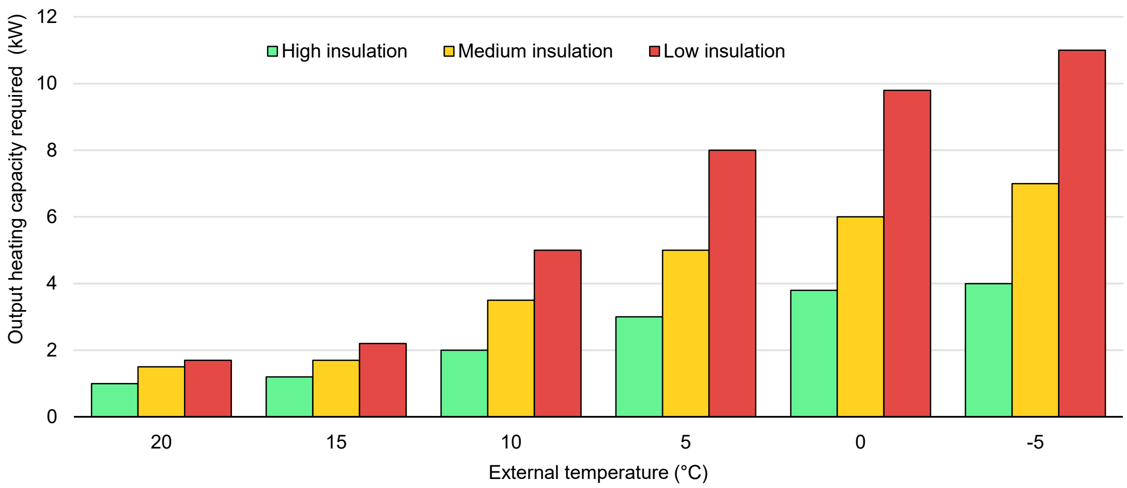
With space and water heating alone, Ecodesign regulations have saved around 730 TWh from 1990 to 2020 compared with baseline energy consumption of 3 400 TWh in 2020. This is around a 21% reduction from what would have been used without such regulation. Around 640 TWh of energy savings came from direct use of fossil fuels such as natural gas, coal and oil for heating buildings – equivalent to the total energy consumption for space and water heating of Germany and Poland combined.

There is significant scope to improve insulation of the European building stock, with some estimates suggesting that upgrading F and G class buildings to B or C class through a combination of thermal insulation and heat pumps could save about 71 bcm, while upgrading to E class levels could save 22 bcm.

Better insulated homes can use one-third the energy of poorly insulated buildings, especially in cold climates

Increasing building performance can be achieved by adopting measures like replacing windows, air sealing or the application of inside insulation material. The cost for an average home to go from class F to class E is about USD 1 500 and slightly more to go further up to class D. With current energy prices in Europe, this investment can pay back after just over one year.

Required heat capacity (kW) by external temperature for different levels of insulation



Notes: Mean heat loss levels (W/K) for efficiency group quintiles are: High insulation (188 W/K), Medium Insulation (335 W/K), and Low Insulation (563 W/K).
Source: Based on Summerfield et al (2017).

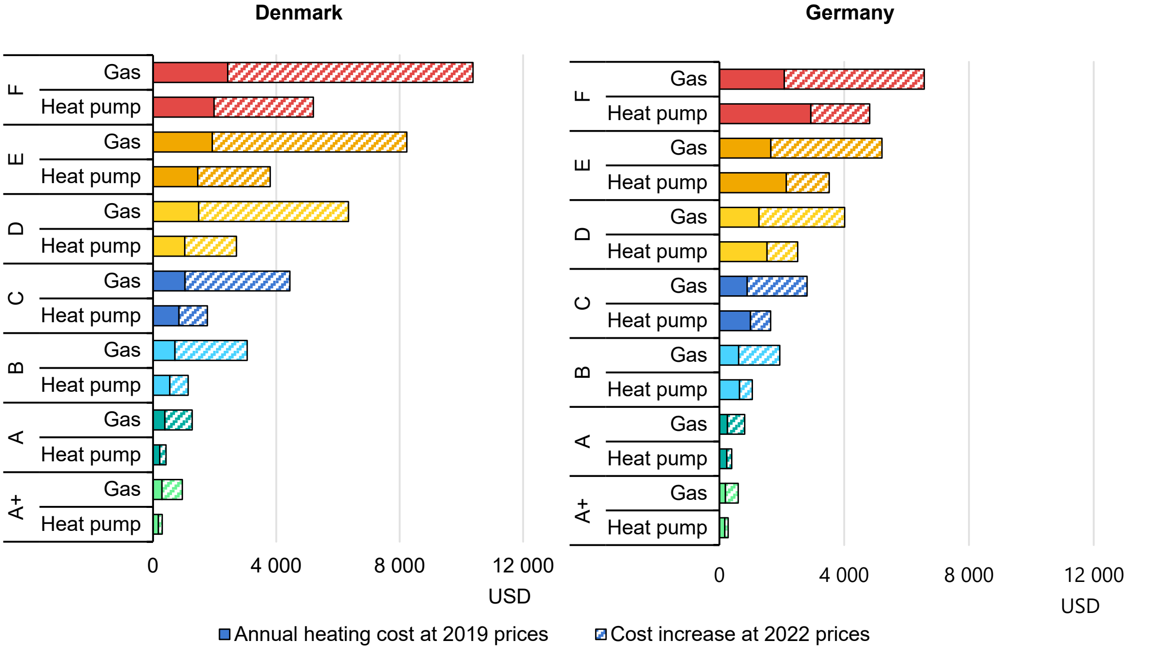
Analysis from a large energy performance monitoring study in the United Kingdom shows just how effective insulation is in reducing heating capacity demands (kW) at different outdoor temperatures among houses with differing levels of mean heat loss (W/K). Heating requirements for dwellings with more insulation were around one-third of the least efficient dwellings. The benefit from insulation becomes stronger when the outside temperature is colder.

Higher European gas prices mean heat pumps are by far the better choice for households to lower energy bills

In most countries across Europe the price of gas relative to electricity has risen significantly. While each country has its own particular mix of relative prices, the scale and magnitude of higher gas prices has dramatically changed the economics of heating.

In Denmark, in a B or C energy performance-rated home the cost of operating a much more efficient heat pump was only marginally less than that of a gas system. However, this situation has changed dramatically. Following recent price rises, the cost of operating a gas heating system has risen for an average household by around 330%. In contrast, the cost to heat the same space with an electric heat pump has risen by around 100%. For comparison, in Germany gas heating would have been more economical at 2019 prices, but current prices have reversed the dynamics.

Annual heating cost for 100m², for gas versus heat pump, by building performance, in Denmark and Germany, at 2019 and September 2022 prices



Notes: For comparability, the threshold values of building performance classes in energy consumption per m² as used in Denmark has been applied also to the analysis of Germany. However, each country defines their own national threshold values according to regional climate. Class A relates to the Danish A2015, Class A+ to the Danish A2020.

Sources: IEA based on Statistics Denmark, Environment and Energy Statistics, Energistyrelsen.

Scaling up heat pump deployment will require a systems approach to manage higher winter peak electricity loads

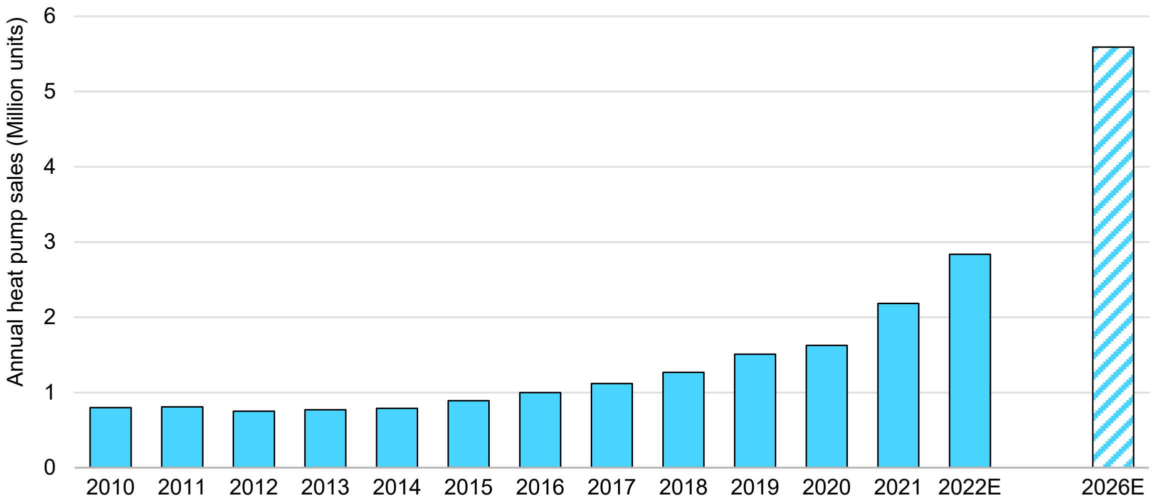
Heat pumps have replaced around 20% of the boilers in Europe saving consumers around USD 100 billion per year according to the European Heat Pump Association (EHPA). Sales of heat pumps in Europe grew by over 30% during the past two years, with almost 3 million units sold this year. Annual sales are expected to reach about 5.5 million units by 2026. These and other global developments are covered in a new IEA World Energy Outlook Special Report – The Future of Heat Pumps, released in December 2022.

The RePowerEU plan has set a target to double the diffusion of heat pumps, including an extra 10 million units to be added in the next five years and 30 million by 2030 that use water as output medium. Such water-based units are responsible for about half of the European heat pump sales.

One result of increased use of heat pumps will be higher peak winter electric loads. As temperatures drop in the winter, heat pumps will draw more electrical power for longer periods to extract heat from cold outdoor air. The implication is a greater demand on the electricity grid during these cold periods

A recent study shows that the shift from a gas boiler to an electric heat pump in a traditional multi-family apartment building in Europe could double electricity demand in the early evening, when people return home from work. This will mean smart heat pump controls and demand side management will become increasingly more important as heat pump diffusion grows.

Heat pump sales in Europe 2010-2021 and projection to 2026



Note: Europe sales include 21 countries from the EU plus Norway and the United Kingdom.
Source: IEA based on data from the European Heat Pump Association.

In order for electrical grids to cope with a surge in load at peak times, demand-side management (DSM) technologies are necessary to benefit from the heat pumps and the flexibility potential of buildings.

In the IEA Announced Pledges Scenario (APS), heat pumps will provide around 12% of demand-side flexibility in Europe in 2030. However, to be able to shift heat pump operation out of peak hours without reducing comfort, heat needs to be either stored or produced on demand by other means.

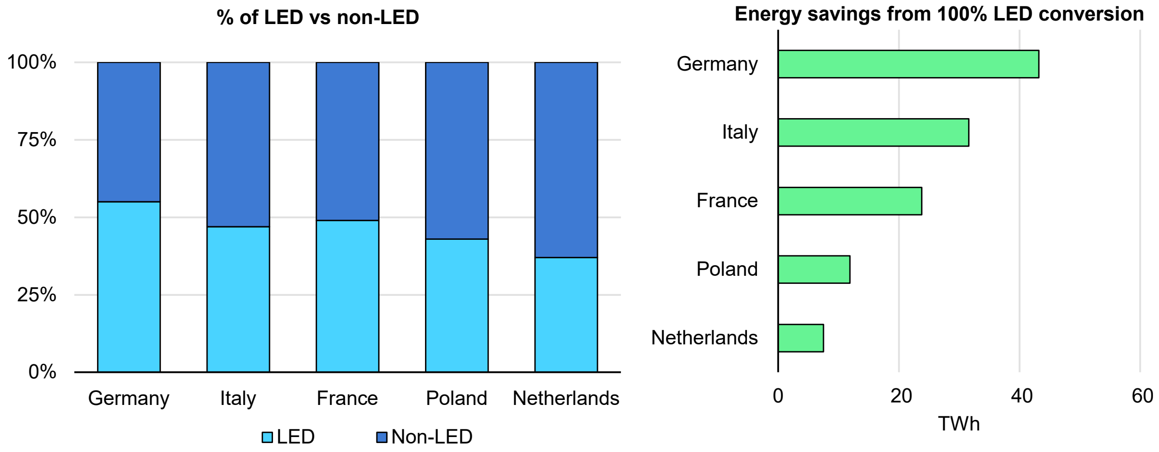
The thermal inertia of buildings can be a large source of storage if buildings are sufficiently well-insulated to prevent a major drop in indoor temperature while the heat pump runs on reduced power to balance grid load. This means that well-insulated buildings not only reduce annual and peak electricity demand for heating, but also facilitate demand flexibility allowing for a longer duration of heating load shifting without compromising thermal comfort.

Heat pump systems will increasingly need to allow automated, or remote control, by grid operators to assist with managing higher winter peaks. Minimum energy performance standards could be adapted to include a basic level of such communication capabilities.

In exchange for providing flexibility services to the grid, consumers could be rewarded with a lower electricity tariff or separate payments by the grid operator. Octopus Energy in the United Kingdom has run a series of pilot projects of innovative models to give a monetary value to flexibility. Changes in market design can also support the uptake of heat pump flexibility to benefit all parties. Pilot projects such as EcoGrid EU, in which 270 households with heat pumps provided up to 167 kW in peak shaving, help illustrate the potential.

Another way to manage increased electrical demand, due to electrification of heating systems is through other efficiency measures in the home. Analysis from Signify suggests that converting all lighting in the European Union to LEDs could save around 188 TWh per year. This is the equivalent of the electricity required to operate 47 million heat pumps, meaning one-quarter of all European Union households – or around all the households in Germany and the Netherlands.

Potential energy savings from scaling up LED lighting



Source: Signify, as modified by the IEA.

Policy action can further reduce up-front investment needed for new heat pumps

One of the major barriers to increased heat pump uptake is their higher up-front cost relative to fossil fuel boilers. Almost all European Union member states, as well as the United Kingdom, Norway and Switzerland, have now implemented supportive policies for heat pumps and insulation.

Early indications from the German Federal support programme for heat pumps suggests that 148 000 households applied in August 2022 alone – roughly the same number as during the entire year 2021. Italy is using a tax benefit under its Superbonus scheme, under which heat pumps are eligible. As of October 2022, EUR 55 billion (USD 57 billion) had already been granted. Driven by regulation, the number of heat pumps installed in Dutch homes is also expected to increase by 37% this year, to almost 100 000. Heat pumps are the preferred option for new built homes, with a third of new instillations for existing homes.

Outside of Europe, as part of the Inflation Reduction Act of 2022, the US federal government is offering a 30% tax credit, up to a ceiling of USD 2 000, for the installation of a heat pump. Low- and moderate-income households can benefit additionally by up to USD 8 000 in rebates.

Installing heat pumps was also one of the most popular retrofit options in the Canada Greener Homes Grant, with about 3 200 Canadian homeowners receiving CAD 13.2 million (USD 9.76 million) in grants since June 2022. In New Zealand, the Warmer Kiwi Homes programme has targeted lower income households, providing up to 80% of the cost for insulation and approved heating appliances like heat pumps. Heating grants are capped at NZD 3 000 (USD 1 800).

3.4 Strengthening supply chains and skills for faster deployment

Heating transition requires stronger supply chains to keep costs down and speed up deployment

Given the ambitious rate of global heat pump deployment targets, the ability of the international supply chains to keep up with demand has come into focus. The US government, for example, has triggered the Defense Production Act for several clean energy technologies including heat pumps. The Act allows more influence by public bodies in production of heat pumps as well as granting access to public funding. The Inflation Reduction Act foresees USD 500 million for this purpose as part of the Clean Manufacturing Investment tax credit. The Act could significantly improve supply chain capabilities, leading to a higher heat pump output and increased potential for export.

The main bottleneck for fast heat pump deployment is the limited availability of installers. Plumbers and pipefitters have the highest-ranking shortage for all occupations in the EU, closely followed by electricians, according to the European Labour Authority. In Germany, up to 60 000 additional heat pump installers are needed to reach the EU uptake target for heat pumps. Currently, a heat pump installer is not a certified skill in many jurisdictions. In order to streamline training, qualification requirements should be defined on a supranational level to ensure efficient labour allocation.

Waiting times for heat pumps are currently between 6-12 months and prices have increased as a result of this skills shortage. In the short term, fossil fuel boiler installers can be retrained within one to two weeks to install heat pumps, according to the EHPA. But due to the current high demand, additional newly-trained installers are urgently needed in the medium term. However, training for new recruits takes three to four years, underlining the need for labour policy planning to incentivise careers as heat pump installers. Furthermore, heat pump installations can be divided into different tasks, requiring differing skill levels, which would optimise the division of labour and allocate resources more efficiently.

In Europe, over 20 companies producing heat pumps are attempting to quickly scale up production. Daikin is investing EUR 1.2 billion (USD 1.25 billion) in their European production sites, focussing mainly on heat pumps and production digitalisation. Viessmann is investing EUR 1 billion (USD 1.04 billion) in clean heating technologies and Stiebel Eltron is spending around EUR 600 million (USD 620 million) in establishing additional heat pump production capacity. Many other manufacturers have announced large investments in 2022, with additional production lines expected to be operational in 2023-24 and new production sites expected by 2025.

In a 2022 survey among EHPA members, about 75% of respondents considered it possible to achieve the 15% annual growth rate necessary to reach RePowerEU targets and, in many cases, suggested rates of over 25% can be achieved. However, the ongoing global shortages of several input materials, especially semiconductor chips, copper, aluminium and steel, has put upward pressure on costs and slowed some expansion plans.

Compressors are the highest cost component of a heat pump and in most cases are bought from specialised manufacturers. However, compressors are also used in many other technologies resulting in demand competition in the compressor market. The availability of refrigerants and skilled labour in the production of heat pumps is also a rising concern. Production process optimisation and controlled testing environments are also key tools by industry to manage these constraints.

Supply constraints are affecting vehicle availability

While sales of EVs (BEVs and PHEVs) and hybrids (full and mild) have been increasing, car production generally is struggling in the face of supply constraints. By mid-July 2022, over 2.5 million cars had been cut globally from production lines, mainly in Europe and North America, largely as a result of a shortage of semi-conductors. Even prior to the Covid-19 pandemic, demand for semi-conductors exceeded supply. The situation was substantially exacerbated by Covid and the conflict in Ukraine, adversely affecting the supply of raw materials to the automotive sector. Furthermore, there is an ongoing skills shortage, particularly in battery production for electric vehicles in Europe and Asia.

In France, Germany, the United Kingdom and the United States, the lack of supply of new cars as a result of the semi-conductor shortage and increasing prices of raw materials has had a knock-on impact on the used car market. With the supply of new cars low, some consumers turned instead to the second-hand market, leading to increased sales and prices for used cars. Demand is such that there are reports of electric vehicles being resold for a profit rather than being used.

In April 2022, Ford stopped taking orders for its signature electric cross-over, the Mach-E, because they were not able to produce a sufficient number of vehicles to meet demand, although production has since increased. Nissan has expressed concern that the supply constraints facing electric vehicles in the United States will mean that EVs will not be able to fully capitalise on high fuel prices. Similar impacts have been seen in Europe. In the United Kingdom, by mid-2022 there were long waiting lists for consumers to receive a new EV; for some models the waiting time is now up to two years.

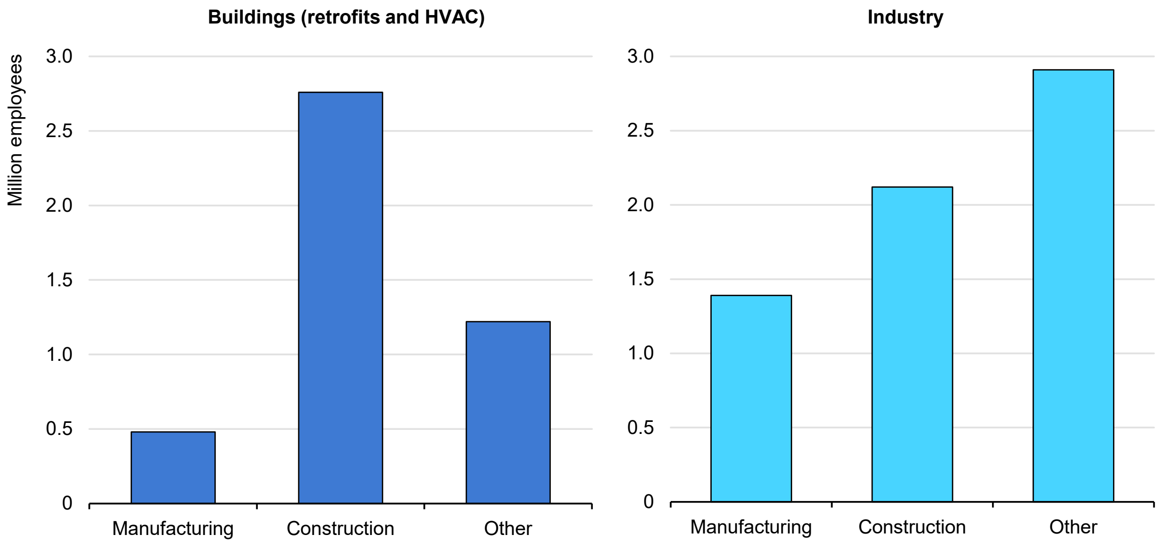
Strengthening the energy management skills base is key for improvement in energy efficiency

A lack of access to skilled workers is one of the key barriers to implementing energy efficiency. This extends throughout the energy efficiency delivery supply chain, from specialist consultancy to skilled process floor workforces. A lack of experienced energy advisors is reportedly negatively affecting the delivery of services. Embedded throughout its 2022 Industrial Decarbonisation Roadmap, the US Department of Energy recommends a range of actions to increase skills and knowledge that are essential to achieving the roadmap targets.

Implementing energy efficiency projects is extremely labour-intensive, especially in the buildings sector. Recent IEA analysis from the 2022 World Energy Employment Report found that around 10.9 million people were employed in energy efficiency in buildings and industry in 2019, with one-third of these jobs located in China, followed by around 2 million in North America.

Successful examples of upskilling highlighted in the IEA report Skills Development and Inclusivity for Clean Energy Transitions include India's Skill Council for Green Jobs, Energy Academy of Germany and Jordan and the Philippines' Green Jobs Act of 2016. An example of an initiative underway in 2022 is the Brazilian Government's project PotencializEE (Investments Transforming Energy Efficiency in Industry Programme), which promotes energy efficiency in industrial SMEs.

Employment in energy efficiency by end-use sector and economic sector, 2019



Note: HVAC = Heating, ventilation, and air conditioning. Other includes employment in utilities, professionals, wholesale, and transport sectors.
Source: World Energy Employment Report.

3.5 Meeting climate goals

Greater efficiency progress can drive lower emissions this decade

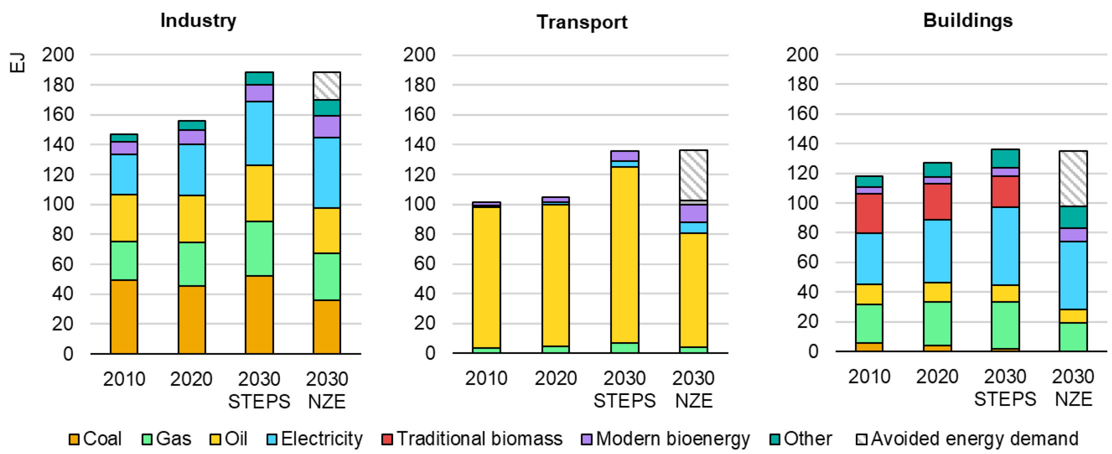
Doubling the rate of global energy intensity improvement from the 2% per year achieved from 2010 to 2020 to just over 4% from 2020-30 is necessary to put the world on a pathway consistent with the Net Zero Scenario. Doing so will require enhanced action on a wide spectrum of energy efficiency and demand-side measures covering technical efficiency, behaviour change and electrification, as well as material efficiency, digitalisation and fuel switching in industry.

The IEA's Value of Early Action on Energy Efficiency report estimates that all these measures can help avoid about 95 EJ and 5 Gt CO_2 per year by 2030 in the Net Zero Scenario. This compares with a scenario based on current efficiency-related policies (STEPS) where total final energy demand is around 18% higher in 2030 instead of 5% lower in the Net Zero Scenario.

The greatest short-term energy savings potential is in the buildings and transport sectors, with around 37 EJ and 34 EJ of avoided energy demand by 2030 available, respectively. The energy savings potential of industry by 2030 is about half as much despite it being the largest energy consuming end-use sector.

In terms of fuels, efficiency-related avoided energy demand measures could help displace around 55 EJ, or 30 mb/d, of oil demand and 23 EJ, or 650 bcm, per year of natural gas globally by 2030.

Global final energy demand, 2010, 2020, and by scenario, 2030



Note: Total avoided energy demand of 95 EJ includes further energy savings of 6 EJ in other sectors (agriculture).

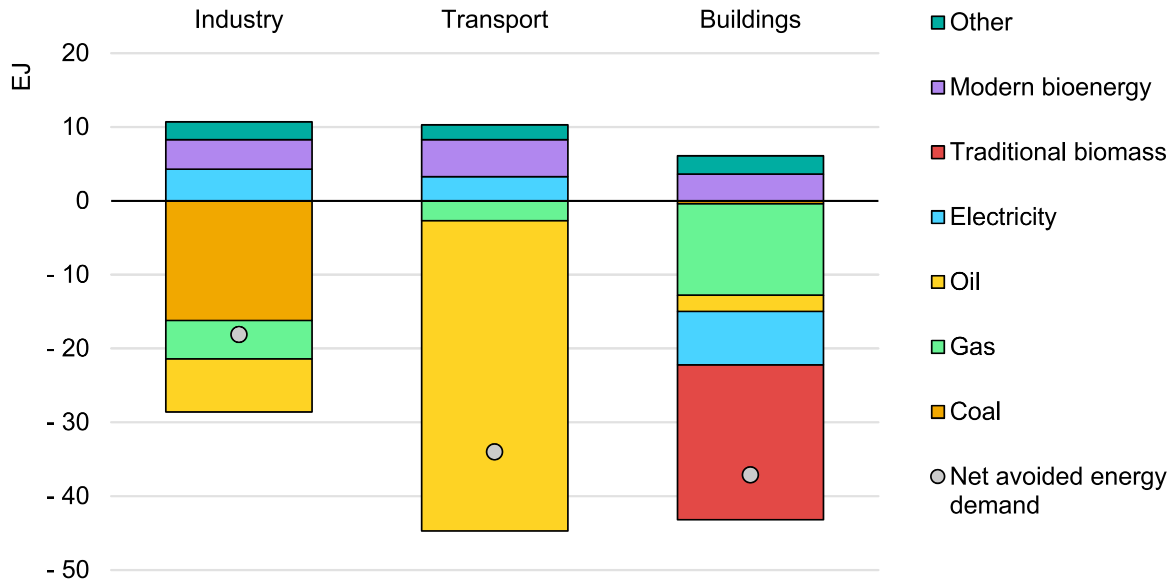
The Net Zero Scenario also includes large energy savings from providing access to clean and efficient cooking and heating to those who lack it today. By 2030, around 20 EJ can be avoided by reducing the use of traditional biomass like wood and charcoal. This can dramatically improve the lives of billions of people, particularly women and children, whose health is disproportionately negatively affected by indoor air pollution.

These energy savings are also achieved even as the economy grows by 40% by 2030, and around 800 million more people gain better access to energy services.

Improving the efficiency of internal combustion engine vehicles through technical efficiency measures provides one of the largest opportunities to reduce energy consumption by 2030 in the Net Zero Scenario. Technical and material efficiency measures in buildings and greater reuse and recycling rates of materials used in industry also have significant potential to avoid energy demand and reduce CO_2 emissions.

Electrification is a major driver of avoided energy demand in the Net Zero Scenario, primarily through the faster uptake of electric vehicles. The avoided CO_2 impact of electrification in transport is relatively high due to the simultaneous transition towards renewable energy in the electricity generation, which rises from 28% in 2020 to 61% by 2030.

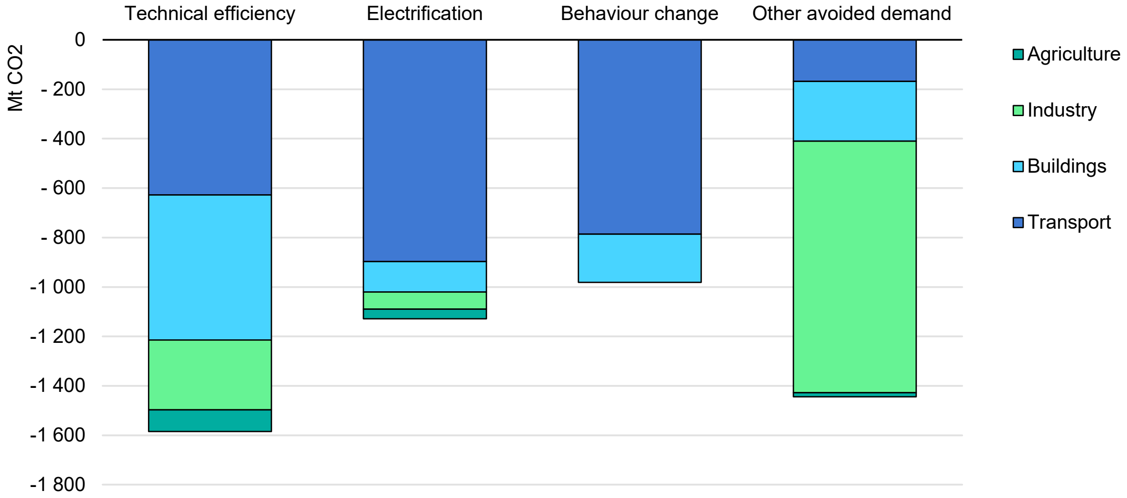
Avoided energy demand by fuel source, between Stated Policies Scenario and Net Zero Scenario, 2030



The rise of variable renewable energy in the Net Zero Scenario also underscores the importance of enhanced electricity system flexibility. This is delivered through the greater adoption of digital sensors and controls in parallel with the electrification of road transport, heating in buildings and industrial processes. Such smart flexibility is needed to smooth the load curve and help align energy demand when renewable energy supply is at its highest during the day.

Digitalisation and smart controls of efficient end-use technologies also play a much greater role in supporting power system efficiency and reliability in the Net Zero Scenario. For example, end-use technologies that can time energy consumption to when renewable power is at its peak can bring down energy bills and reduce CO_2 emissions for users.

CO_2 reduction by efficiency-related mitigation measure, in the Net Zero Scenario 2020-2030,



Chapter 4. Special focus on energy efficiency in ASEAN countries

4. 1 Overview of ASEAN energy use

Enhancing efficiency in ASEAN countries is vital to the global clean energy transition

In this chapter we look more in-depth at one of the regions with the world's fastest growing energy demand and options for a clean energy transition. Regional ambitions to achieve net zero emissions and carbon neutrality vary: Lao People's Democratic Republic (Lao PDR), Malaysia, Singapore, Thailand, and Viet Nam (by 2050); Indonesia (by 2060 or sooner); Brunei Darussalam and Cambodia (policies announced, though no specific 2050 targets yet), while the Philippines and Myanmar have not made any official net zero announcements.

While energy demand growth has most recently slowed due to the pandemic and price increases, in 2010-2020 electricity demand grew by 63% in the ASEAN region compared with 24% globally. Energy consumption in ASEAN countries has doubled since 2000, fuelling a regional economy that is now two and half times larger with a current population of over 660 million people. This increase in consumption can be largely attributed to rising standards of living alongside population growth and urbanisation. At the same time, the ASEAN region achieved an energy intensity reduction of 21% by 2018, surpassing its aspirational target of 20% in 2020 (over 2005 levels).

While there is a diverse set of energy profiles and priorities in the region, all countries have collectively endorsed regional targets aimed at accelerating the rate of improvements in energy efficiency. The ASEAN Plan of Action for Energy Cooperation (APAEC) outlines the region's plan to reduce energy intensity by 32% in 2025, based on 2005 levels, and encourage further energy efficiency and conservation efforts, especially in the transport and industry sectors. The ASEAN Centre for Energy is the main multilateral body which aims to accelerate the integration of energy strategies within the region.

Energy efficiency targets in ASEAN countries

Country	Efficiency policy targets
Brunei Darussalam	Reduce total energy consumption by 63% from business-as-usual (BAU) levels by 2035. EV share of total annual vehicle sales to reach 60% by 2035.
Cambodia	By 2030 and relative to BAU, cut energy consumption by 19%.
Indonesia	Reduce energy intensity by 1% per year to 2025.
Lao PDR	Reduce final energy consumption by 10% from BAU level.
Malaysia	52 233 GWh of electricity savings over a 10-year period from 2016 to 2025 against BAU, corresponding to an electricity demand growth reduction of 8%.
Myanmar	Lower primary energy demand 8% by 2030 from the 2005 level.
Philippines	Reduce energy intensity 40% by 2030 from the 2010 level. Decrease energy consumption 1.6% per year by 2030 from baseline forecasts. Reduce energy intensity and total energy consumption by 24% relative to the BAU level by 2040.
Singapore	Improve energy intensity by 35% by 2030 from 2005 levels.
Thailand	Reduce energy intensity by 30% by 2036 from 2010 levels.

Source: IEA Southeast Asia Energy Outlook 2022, updated for Cambodia and Malaysia.

Energy efficiency improvements have been key to help temper the growth of energy consumption, three-quarters of which is still provided by oil, coal and natural gas. From 2010 to 2020 the use of coal doubled in the region's fuel mix, driving the region's emissions up 42%, from 1.2 Gt CO_2 to 1.7 Gt CO_2.

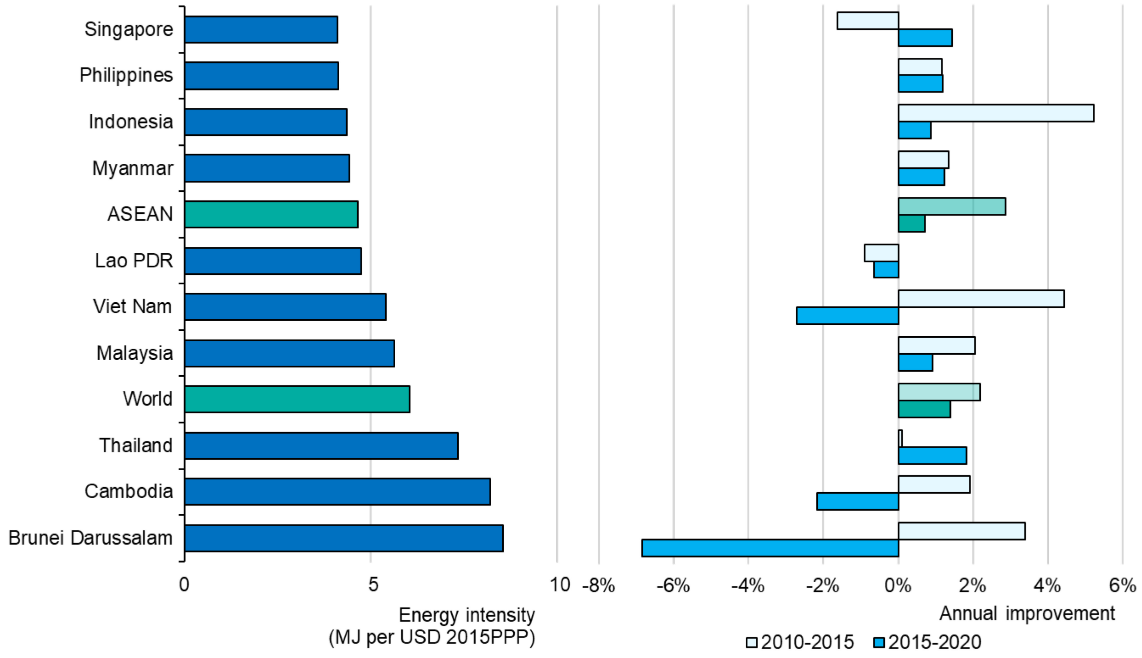
Power generation has almost tripled in the past two decades, with the largest increase coming from coal-fired power plants. Renewables are increasing quickly, and in 2020 they accounted for 255 TWh or about 23% of total generation of 1 100 TWh, with coal providing 43% and gas 32%.

There is a diverse range of energy intensity profiles across the region

Seven of the ten countries in the region are less energy intensive than the world average and three are above. Singapore, which has the region's highest per capita income and an economy dominated by services, uses about half as much energy to produce the same value of GDP as Brunei Darussalam, which is the region's most energy-intensive economy. This is because Brunei Darussalam, which has the region's second highest per capita income, has an economy where energy-intensive industries based on oil and gas play a larger role.

The slowdown in energy intensity improvements observed globally over the second half of the last decade was also experienced in the ASEAN region, with an annual rate of 2.8% per year from 2010 to 2015 slowing to 0.9% from 2015 to 2020. In 2021, energy intensity actually worsened, rising by half of a percentage point following exceptionally strong growth in industrial energy demand.

Primary energy intensity, in the ASEAN region (left), 2020 and annual intensity improvement, 2010-2020 (right)



Indonesia is the most populous country in the ASEAN region with approximately 275 million people and has the largest economy. It accounts for around one-third of the group's energy demand and is the third most efficient in terms of its level of energy intensity.

4.2 Sectoral considerations

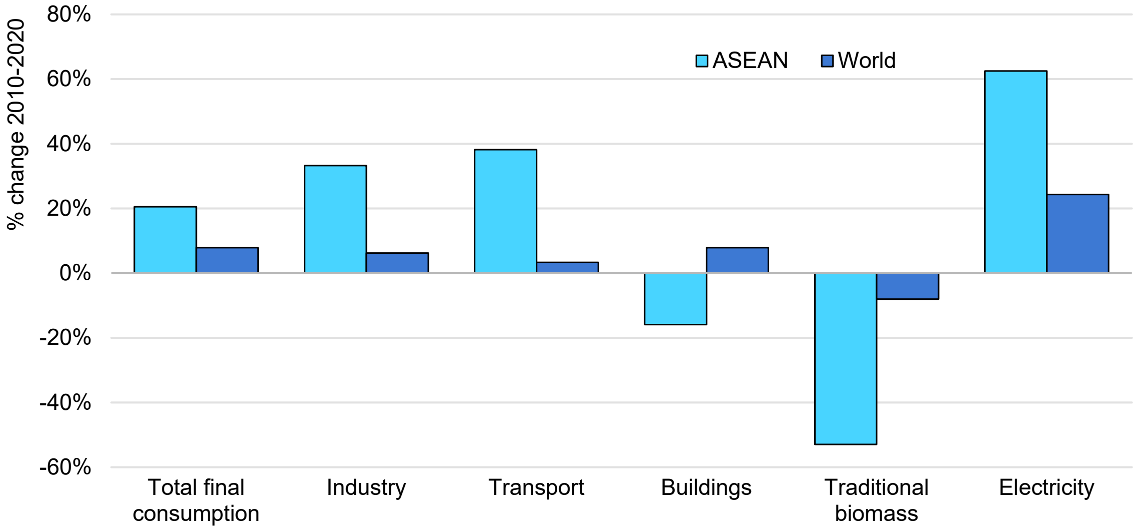
Energy demand has grown rapidly, but differs across sectors

Industry is the largest energy consuming sector in the ASEAN region, responsible for around 44% of final energy demand, followed by transport with 27% and buildings with 23%.

Growth in industrial energy demand accelerated in the second half of the last decade, rising from 1.6% per year in 2010-15 to 8.1% per year during 2016-2019 - a total increase of 33% over the decade. This trend was a major catalyst for the slowdown in energy intensity improvement. Steel, cement and petrochemical production, while critical for new infrastructure and economic development, are particularly energy intensive.

Energy consumption in the transport sector rose 40% over the last decade, with annual growth of 5% to 6% each year driven by increasing ownership of passenger cars, two- and three-wheeler vehicles and a greater use of trucks. Oil products account for 90% of transport fuel use.

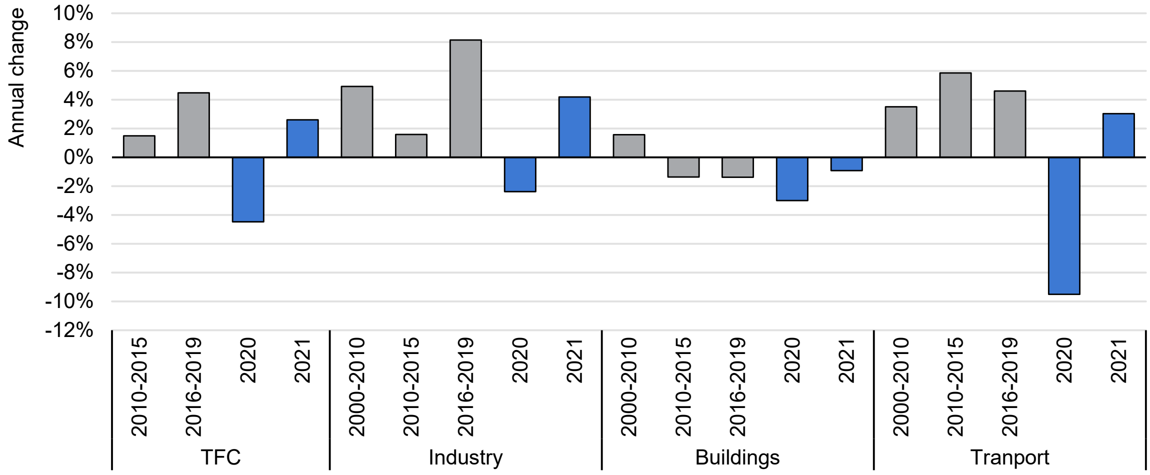
Share of change in energy consumption trends, in the ASEAN region and World, 2010-2020



Energy consumption in buildings across the region fell by 16% from 2010 to2020, led lower by a 53% fall over the decade of traditional biomass for cooking and space heating. Around 95% of households now have access to electricity and 70% have use of more efficient, clean cooking such as LPG and improved cook stoves.

The buildings sector has also led the increase in electricity consumption, driven by urbanisation with the number of people living in cities rising by 70% since 2000. This, along with increasing wealth, has led to strong growth in air conditioner and appliance use, while the number of people with access to refrigeration has doubled since 2000.

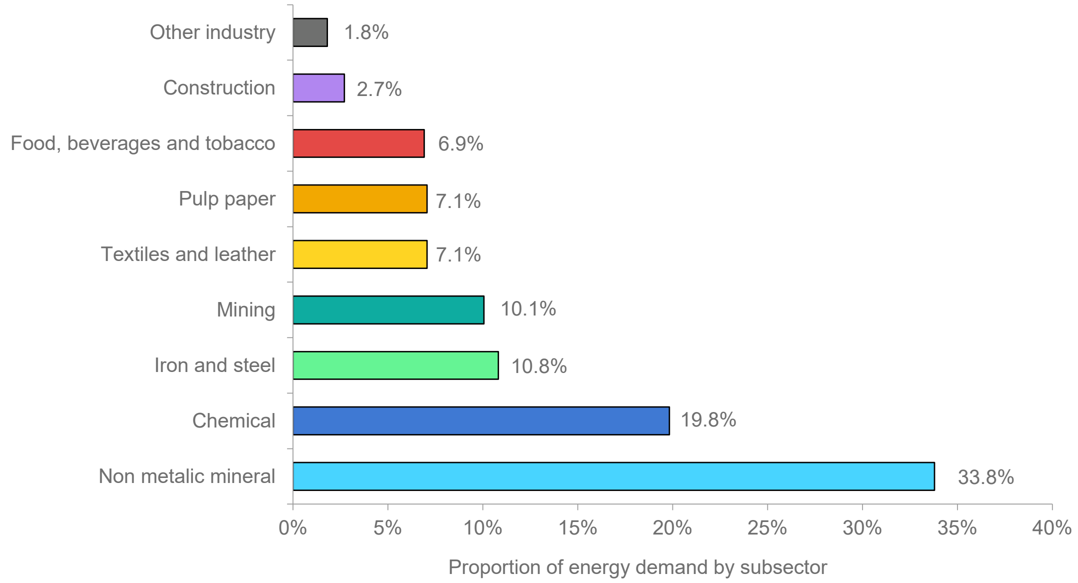
Annual change in energy consumption, in the ASEAN region, 2000-2021



Energy use in ASEAN heavy industries continues to dominate the sector

The Industrial sector is not homogenous across ASEAN countries. The range of industries varies widely across the countries, from primarily oil and gas in Brunei Darussalam, to a mix of textiles, construction, machinery, cement, chemicals, pulp and paper and many other small sectors in Thailand. Furthermore, data coverage for ASEAN subsectors differs greatly between countries, making detailed analysis of the area difficult. This data gap results in approximately one-third of the final industrial energy demand in ASEAN countries being unspecified. However, three heavy industries – iron and steel, cement, and chemicals – account for 64% of industrial energy demand in Southeast Asia.

Percentage of industrial energy demand by subsector, in Southeast Asia, 2020



Source: IEA based on data from the ASEAN Centre for Energy (ACE), '7th ASEAN Energy Outlook'.

Iron and steel manufacturing is one of the fastest growing sectors in ASEAN, with energy use more than tripling in the last decade. From 2016 and 2020 steel production almost doubled from 8.6 Mt to 16.7 Mt, led by sharply higher levels in Indonesia (437%), Malaysia (380%) and Viet Nam (174%). By 2050, ASEAN iron and steel energy use is expected to increase at least four-fold, to 43.9 Mtoe.

Growth is also expected in the chemical sector, which is projected to grow three- to four-fold from 2020 to 2050. Currently, about 65% of energy demand in the chemical industry is met with the use of fossil fuels, comprised of natural gas (40%), oil (19%) and coal (5%).

Despite the dominance of large industry in energy use, light industry plays an important role throughout the region and is increasingly a focus area for energy efficiency improvements. There are 70 million Micro, Small and Medium enterprises (MSMEs) in ASEAN, accounting for around 97% of the total number of businesses in the region. The MSMEs provide 85% of employment, 45% of GDP and 18% of national exports.

An Experts' Roundtable on energy efficiency policy recommendations for Southeast Asia, convened by the IEA in 2017, highlighted four industry-specific recommendations to address barriers and help realise the tremendous energy efficiency potential of the region. Given the diversity of industry across the region and within countries, it was recommended that governments should consider policies that have broad application across industrial sub-sectors and process types, with a strategic focus on:

- Energy management in industry (ISO 50001, ISO5005).
- High-efficiency industrial equipment and systems (MEPS).
- Energy efficiency services for micro, small and medium enterprises (MSMEs).
- Complementary policies to support industrial energy efficiency, such as the forming of coalitions of stakeholders, creating active roles for ESCOs in promoting energy efficiency and sharing best practices among countries.

Some progress has been made on these recommendations. For example, seven ASEAN countries (Indonesia, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Viet Nam) are currently implementing ISO 50001, and certifications increased by 24% from 2018 to 2021.

More generally, since 2017 most of the ASEAN countries have introduced policies relating to industrial energy efficiency, whether through their Nationally Determined Contribution (Brunei Darussalam, Malaysia, Myanmar, Thailand), the introduction or strengthening of MEPS (Viet Nam), green industry standards (Indonesia), energy consumption targets for industry (Cambodia), Energy Efficiency Opportunities Assessments (Singapore) or a National Energy Efficiency and Conservation Plan (Philippines). However, there remains significant scope to strengthen the implementation of these measures.

Efficiency standards and electrification are key for the transport sector

In the transport sector, fuel economy standards play a key role in reducing future oil requirements. The ASEAN Fuel Economy Roadmap has a target of an average fuel economy of 5.3 litres of gasoline equivalent (Lge) per 100 km by 2025 for new light-duty vehicles, this is in comparison with an estimated 7.2 Lge/100 km in 2015. To date, however, none of the ASEAN member states have adopted fuel economy or CO_2 emission standards for any modes of transport. For passenger cars, positive steps have been made in Indonesia, Malaysia, Thailand and Singapore through an agreement on technical measurement processes.

A range of incentives and information to facilitate improvements in fuel economy are in use. For passenger cars, differentiated taxation is employed in Indonesia, Malaysia, the Philippines, Singapore and Thailand. For Indonesia, this was updated to focus on CO_2 emissions and engine size with the regulation taking effect in October 2021. Labelling to provide information to consumers on fuel economy and CO_2/km emissions is mandatory in Singapore, Thailand and Viet Nam and voluntary in Malaysia and the Philippines.

Two- and three-wheelers are key transport modes in ASEAN countries and provide opportunities for electrification. In Viet Nam 230 000 electric two-and three-wheelers were sold in 2021 constituting around 10% of two-wheeler sales.

Electric passenger light-duty vehicles comprised only 1% of sales in the ASEAN region in 2022. Thailand and Indonesia aim to become leaders in EV markets. Thailand has announced plans to achieve 30% of domestic vehicle production to be zero-emission vehicles (ZEVs) by 2030 and 100% of new vehicle registrations to be ZEVs by 2035. As of September 2022, Indonesia requires government offices to procure and use electric vehicles.

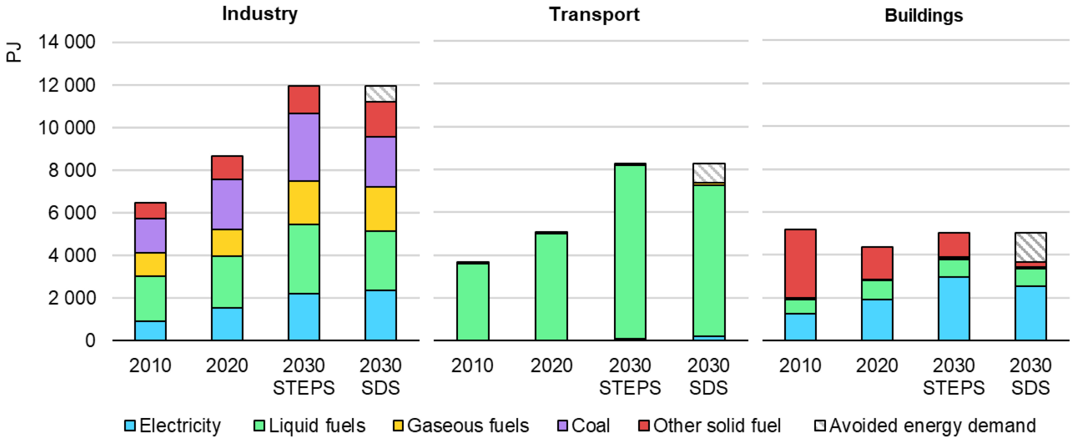
In January 2022, Malaysia launched tax incentives to benefit manufacturers and purchasers, including tax exemptions for imports and sales, as well as tax relief for those owning an electric vehicle. In May 2022, Thailand announced measures to implement electric vehicle tax and customs incentives for 2022-25.

To support this growing EV market, Indonesia recently created a government-owned battery corporation that aims to build 140 GWh of battery capacity by 2030, of which 50 GWh will be for export. In comparison, today's global battery manufacturing production capacity is about 871 GWh. As of September 2022, Indonesia requires government offices to procure and use electric vehicles.

Space cooling is key for energy efficiency in buildings

Despite having the smallest share of final energy consumption in the ASEAN region, the buildings sector provides 1.4 EJ or 46% of the avoided energy demand potential in the Sustainable Development Scenario from 2020 to 2030. More efficient air conditioners can play a major role in avoiding electricity demand, and the phase out of traditional biomass for cooking can lead to significant gains in overall avoided energy demand in buildings.

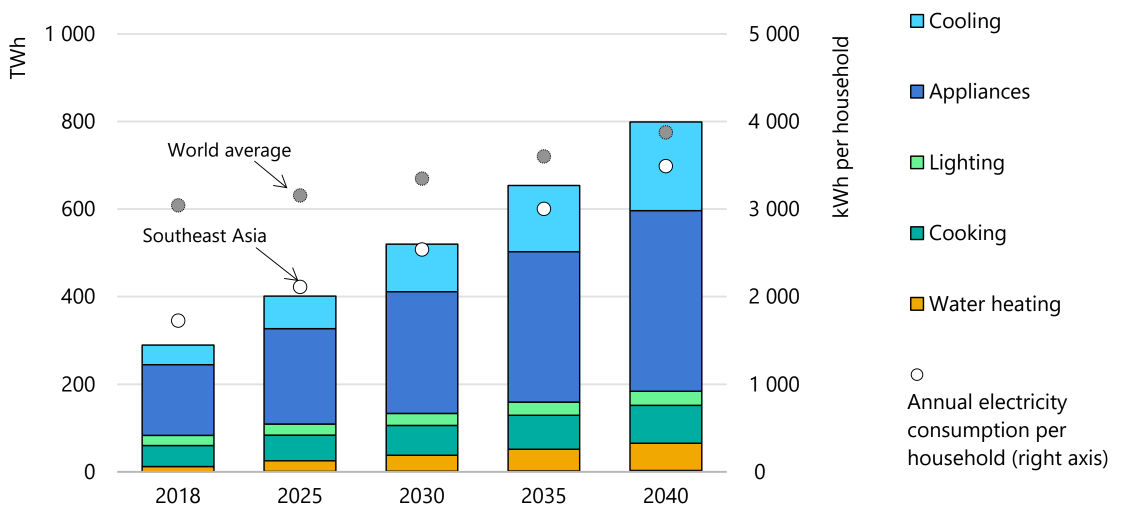
Energy demand by fuel and avoided energy potential, in the ASEAN region, in the Stated Policies Scenario vs Sustainable Development Scenario, 2010-2030



Note: STEPS = Stated Policies Scenario; SDS = Sustainable Development Scenario.

Space cooling is among the fastest growing end uses in the region, with energy consumption expected to more than quadruple by 2040. This reflects the growing populations and rising incomes in relatively hot and humid climates. As a result, electricity demand for space cooling is projected to rise from 88 TWh in 2019 to 314 TWh by 2040, with about 200 TWh to come from residential buildings.

Residential building energy consumption by end use, in the ASEAN region, 2018-2040

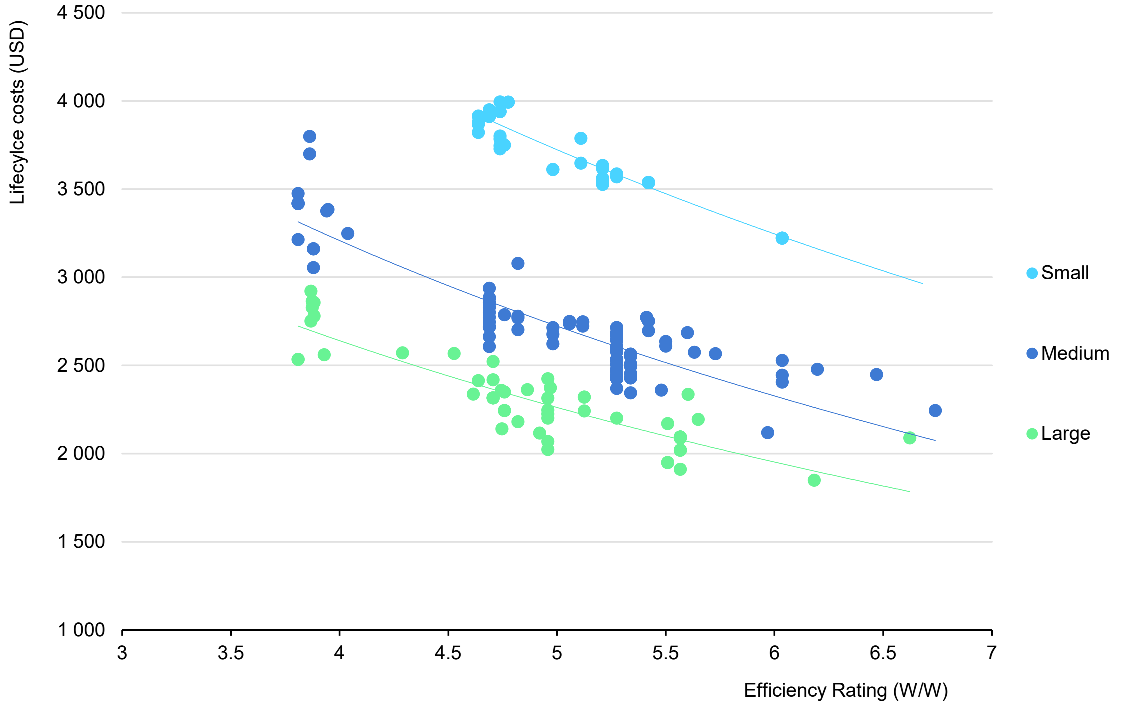


Space cooling is also estimated to account for almost 30% of peak electricity demand in the region by 2040, up from around 10% in 2017, and will require about 150 GW of additional generation capacity to meet the peak levels.

Policy action supporting the deployment of more efficient air conditioners, along with other measures such as the use of efficient fans and building envelope improvements, could help ASEAN member states save 110 TWh of electricity in 2040, cutting the projected space cooling energy use by over one-third. These same actions would also reduce GHG emissions by over 55 Mt of CO_2 in 2040, which, alongside decarbonisation of the electricity supply, could see CO_2 emissions from space cooling in the region drop below 2018 levels.

New market data for Thailand confirm that more efficient air conditioners provide lower life cycle costs. Annual electricity costs, included on the energy label for ten years of operation, help consumers make informed choices. In many cases the more efficient air conditioner also results in no, or a negligible, increase in the upfront purchase price of the unit. Further, air conditioners with lower cooling capacity have lower life cycle costs than those with higher cooling capacity.

Life cycle cost vs efficiency of new air conditioners, in Thailand, 2022



Notes: Analysis based on market data collected through Premise crowdsourcing. Small capacity: 6 000 BTU/hr < CC ≤ 11 000 BTU/hr, medium capacity: 11 000 BTU/hr < CC ≤ 15000 BTU/hr, large capacity: 15 000 BTU/hr < CC ≤ 20 000 BTU/hr Normalised to 12 000 BTU. The life cycle cost is based on the purchase cost and a 10-year lifetime.

Besides improving energy efficiency of air conditioners and fans, some countries in the region are also making efforts on efficient district cooling. In Malaysia, the Megajana plant provides district cooling services to buildings in Cyberjaya. This system reduces energy consumption, lowers operating costs of buildings and ensures environmental sustainability supporting Cyberjaya in becoming a green city. A green district, Northgate Cyberzone, in the Philippines, also relies on district cooling to meet thermal comfort needs and reduces related energy use by 40%.

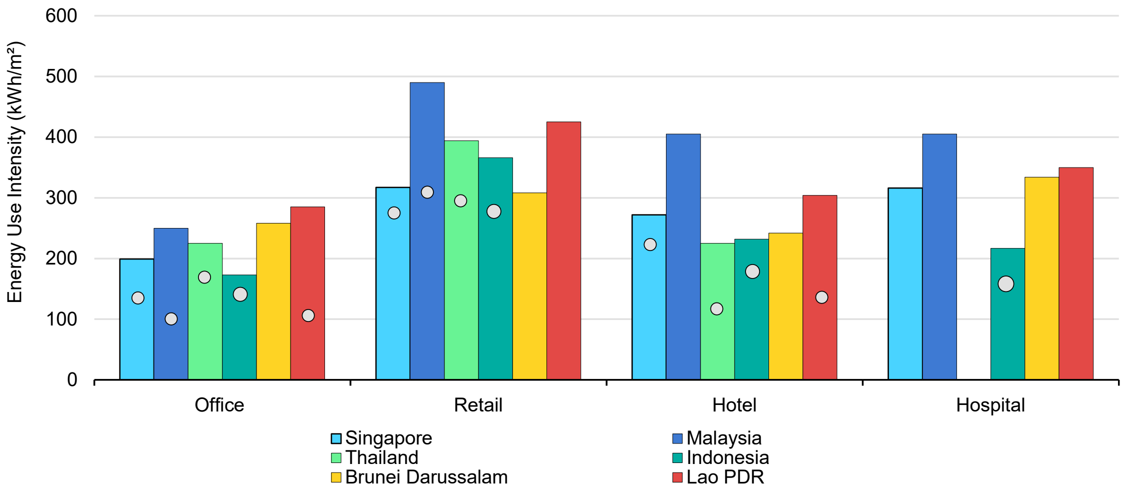
Singapore has started the development of a smart Punggol Digital District (PDD), with plans to use efficient district cooling technologies for a business park, community, retail outlets, and transportation nodes within the district. The plant will have a cooling capacity of close to 30 000 refrigeration-tons, equivalent to cooling 8 000 four-room apartments. The district cooling system will be integrated into the Open Digital Platform, together with a smart grid and smart metering,which will allow for real-time tracking and optimisation of energy use at the district level.

Efficiency measures in commercial buildings greatly reduce energy consumption

A recent IEA assessment found that efficiency actions in non-residential buildings in the ASEAN region could reduce a building's energy use by 20%-70%, depending on the building type and depth of measures. This includes efficient ventilation and cooling systems, LED lighting and smart lighting controls, shading, insulation, rooftop solar photovoltaic systems, building automation, energy management sytems, and smart metering.

Office buildings demonstrated the lowest energy use intensities, while retail space consistently show the highest values across different ASEAN countries. Retail buildings tend to consume more energy than other commercial buildings like offices or hotels, due to use of more energy-intensive refrigeration systems, limited ability to reduce energy use through behaviour, and lack of training for operating personnel. This shows the importance of capacity building and behavioural changes for improving actual energy performance of buildings.

Energy use intensity (EUI) of non-residential buildings, in selected ASEAN countries



Notes: The EUI data were collected from government databases, available publications and other secondary sources covering more than 700 buildings of four non-residential building types (offices, retail, hotels, hospitals) in five ASEAN countries: 432 in Singapore; 153 in Indonesia; 123 in Lao PDR; 53 in Brunei Darussalam; and 21 in Malaysia.

Grid interactive buildings, smart chargers, and smart meters can provide flexibility and efficiency

ASEAN has set targets to achieve a 23% renewable energy share in total primary energy supply and a 35% share of renewable energy in installed power capacity by 2025. Grid interactive buildings and smart charging for EVs can help to manage this expanding share of variable renewable energy (VRE) to ensure the reliability, flexibility and security of electricity grids as electricity demand grows.

Grid-interactive efficient buildings are energy efficient buildings with smart technologies characterised by the active use of distributed energy resources to optimise energy use for grid services, occupant needs and preferences, and cost reductions in a continuous and integrated way. In the ASEAN region the number of smart buildings is estimated to more than triple by 2026 and to exceed 4 million.

The five-storey extension to a School of Design & Environment building at the National University of Singapore, completed in 2019, combines energy efficient strategies, on-site renewable energy generation and interactions with the campus' grid, which enables the building to produce approximately 30% more energy than it needs during the year. Daily surpluses are fed back into the campus grid and used by surrounding buildings.

Singapore, Malaysia, the Philippines, and Thailand, have started implementation of pilot projects on peer-to-peer renewable energy trading using blockchain technology, with the help of 'regulatory sandboxes'. In these projects a limited number of buildings within a microgrid can generate electricity through rooftop solar PV systems and sell part of this electricity to other buildings within the network. The project in Bangkok is the world's largest real-time blockchain-based, peer-to-peer electricity trading pilot project. As of 2021, it included a 1.2 MW marketplace with ten buildings and provided evidence to considering regulatory changes for further replication beyond the regulatory sandbox.

Smart meters are key enablers of interactions between buildings and the grid. Malaysia's national electricity supplier TNB rolled out free installation of smart meters starting in 2016. By the end of 2021, 1.8 million were installed in the states of Melaka and Klang Valley and by 2026 9.1 million are expected to be installed.

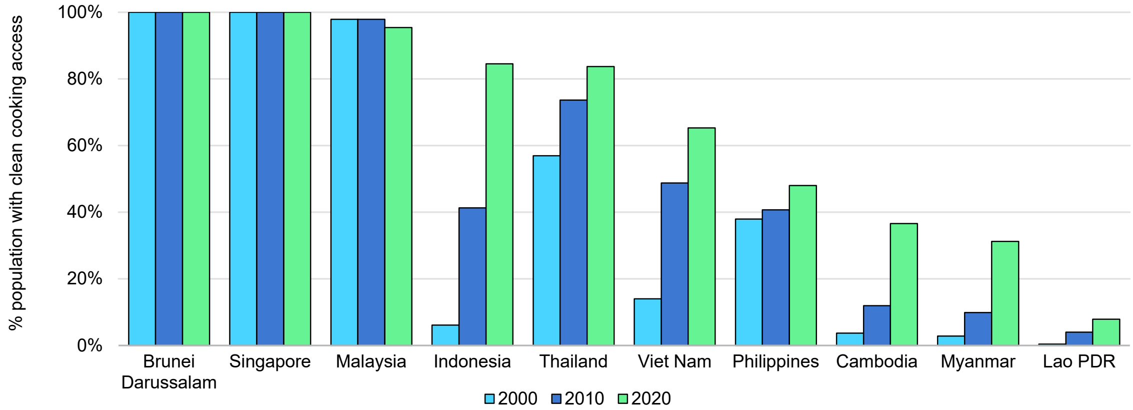
Brunei Darussalam is also planning to install new smart electricity and water meters in 200 000 homes and buildings from 2021 to 2026. These meters will allow the consumers to monitor and manage their energy and water use online and reload credit on the unified smart metering system through the website or smart phones.

A rapid transition to clean cooking is improving the lives of millions, especially women and children

The number of people with access to clean cooking technologies has been continuously increasing in the region - it has almost quadrupled during the past two decades. However, as of 2020 more than 200 million people in the region still lack access to clean cooking, having to rely mainly on traditional biomass.

The costs for health, gender equality, and the environment due to failure to achieve universal access to clean cooking in Southeast Asia are estimated at USD 280 billion per year, with women and children at being more severely affected, because of their higher share of time spent near cooking fumes compared with men in the region.

Share of population with access to clean cooking, in ASEAN countries, 2000, 2010 and 2020



Source: ESCAP (2022) as modified by the IEA.

While close to 87% of people living in ASEAN's cities cook with modern and relatively clean technologies, this number barely exceeds 50% for rural populations across the region. For example, in the Philippines only 28% of the rural population have access to clean cooking, in Cambodia the figure is 25%, in Myanmar 11%, and in Lao PDR it is just 2.5%.

In 2018, around 74% of residential cooking in ASEAN used traditional biomass sources, with wood being the most common fuel. In Indonesia, the region's largest energy consumer, the use of traditional biomass represented almost 30% of the buildings sector's energy demand in 2021. Cooking with LPG is a low-cost, short-term option for replacing traditional biomass, however this still relies on a fossil fuel and has a lower efficiency than electric stoves. In 2021, almost 50 million Indonesian households relied on LPG for cooking while 11 million households were cooking with electricity. Without substantial policy interventions, the high share of biomass is expected to stay relatively steady until 2040. Policies have focused on improving the quality of traditional biomass cookstoves, replacing them with modern fuels such as LPG, kerosene and electricity, and utilising renewable sources for clean cooking, including biogas, solar, and bioethanol. One successful programme to replace kerosene with LPG for cooking reduced infant mortality by 16%-34%, and lowered the problem of low birth weight of babies by 8%-25%.

Cooking with traditional biomass results in negative impacts on people's health with exposure to smoke linked with a range of conditions including acute and chronic respiratory diseases. Indonesia and the Philippines have the highest premature death rates per 100 000 people in the ASEAN region from indoor air pollution while in Cambodia it is estimated to result in 14 000 premature deaths per year.

Raising awareness about the benefits of clean cooking, creating demand, offering results-based financing and building local capacity for manufacturing and maintenance of equipment are among key factors for enhancing the local market for encouraging the adoption of clean cooking technologies.

4.3 Raising energy efficiency ambition

Stronger policies and regulations will counter growing energy demand from appliances

Despite the differing sizes, characteristics and potential for energy savings of end-use sectors across the region, substantial progress can be made in each sector by adopting a policy package approach that brings together regulatory and information instruments with financial and non-financial incentives under one coordinated framework. In April 2022, the IEA and ASEAN Centre for Energy showed how such an approach could be developed in buildings across the region, in two Roadmaps for Energy Efficiency in ASEAN (Buildings and Construction and Space Cooling). Governments across the region are beginning to adopt such policy packages, particularly for appliances and buildings.

In appliances, standard harmonisation is a vital step towards market integration and improved appliances in the region by reducing production costs for efficient appliances. The process can be accelerated by using a regional product efficiency “ladder” for air conditioners and fans. Ladders are a tool for visualising the current and future efficiency levels that policy package measures set, such as MEPS and label levels. The approach, as described by the IEA-led Super-efficient Equipment and Appliance Deployment (SEAD) Initiative and Product Efficiency Call to Action, simplifies regulation setting and compliance, and allows policy makers to raise ambition more quickly. Indonesia joined the SEAD Initiative and Call to Action in 2021, demonstrating a commitment to improving energy efficiency of appliances.

A number of countries have recently introduced new appliance policies, with a particular focus on air conditioners. As a result, all countries in the region now have some level of MEPS and labelling policy in place or under development for the technology. Brunei Darussalam implemented efficiency standards and labelling regulations for electrical appliances in 2022. They focus primarily on air conditioning systems, which account for about 60-70% of electricity consumption in buildings, and include measures for standards, labelling and improved compliance. It is estimated that these measures could reduce Brunei Darussalam's energy intensity by 45% by 2035 relative to 2005. In Indonesia, the government adopted a new MEPS and labelling regulation for air conditioners, fans, refrigerators, rice cookers, and LED lamps. Indonesia is also developing MEPS for several other types of appliances, which are expected to be enforced in 2022 to 2024. Recently Malaysia has carried out the third phase of its Sustainability Achieved via Energy Efficiency (SAVE 3.0) programme, which provides grants to purchase appliances rated 4 or 5 stars.

Despite these advances, considerable scope still remains to increase the stringency of MEPS in the ASEAN region. For example, in September 2022 the IEA noted in An Energy Sector Roadmap to Net Zero Emissions in Indonesia that 100% of air conditioner models on the Indonesian market already complied with the new regulation when it came into force – meaning it had no effect in removing low-efficiency products – and 16% of units were already within the five-star label threshold. There is also a significant regulation gap in industrial electric motor systems, with only Singapore and Viet Nam applying any MEPS and only Viet Nam applying a labelling system. This is a missed opportunity to benefit from improved energy efficiency. It is estimated that implementation of robust appliance efficiency standards, energy pricing reforms and building energy codes and standards in Indonesia alone can help to avoid 225 TWh of electricity demand growth to 2050.

Status of selected energy efficiency policies, by ASEAN country

	Residential air conditioner		Residential refrigerators		Residential lamps		Industrial motors		Passenger light-duty vehicles		Buildings	
	MEPS	CL	MEPS	CL	MEPS	CL	MEPS	CL	MEPS	CL	BECs	BC/L
Brunei Darussalam	In force	Under development	None	None	None	None	None	None	None	None	In force only for certain building types	In force only for certain building types
Cambodia	Under development	Under development	Under development	Under development	None	None	None	None	None	None	Under development	Voluntary
Indonesia	In force	In force	In force	In force	In force	In force	None	None	None	None	In force only for certain building types	Voluntary
Lao PDR	Under development	Under development	None	None	None	None	None	None	None	None	Under development	None
Malaysia	In force	In force	In force	In force	In force	None	None	None	None	None	In force only for certain building types	Voluntary
Myanmar	Under development	Under development	None	None	None	None	None	None	None	None	Voluntary	Voluntary
Philippines	In force	In force	None	In force	In force	In force	None	None	None	Under development	In force only for certain building types	Voluntary
Singapore	In force	In force	In force	In force	In force	In force	In force	None	None	In force	In force	Voluntary
Thailand	In force	In force	In force	None	In force	None	None	None	None	In force	In force only for certain building types	Voluntary
Viet Nam	In force	In force	In force	In force	In force	None	In force	In force	None	None	In force only for certain building types	Voluntary

Level of implementation: None; Under development; In force; In force only for certain building types; Voluntary

Notes: MEPS – minimum energy performance standards; CL – comparative label; BECs – Building Energy Codes; BC/L - Buildings Certification/ Labelling

Countries make progress on efficiency in buildings, but building codes could be strengthened significantly

A similar picture emerges when considering energy efficiency policy in buildings. Several ASEAN countries have recently implemented or are developing building codes, standards or other schemes. For example, a new building code adopted in Indonesia in 2021 defines buildings, technical standards, and compliance measures, as well as requirements for green buildings. A separate Assessment of Green Building Performance sets mandatory green building energy efficiency requirements for many types of large buildings such as residential blocks of at least four stories. Cambodia plans to accelerate energy efficiency improvements in public buildings as part of a wider national policy on energy efficiency, scheduled for adoption by the end of 2022.

Singapore launched a Green Building Masterplan in 2021 to support more ambitious sustainability standards for its buildings. It also updated a Green Mark certification and labelling scheme to raise energy performance standards, and released the Green Mark Incentive Scheme for Existing Buildings 2.0 (GMIS-EB 2.0) to lower the upfront cost of energy efficiency retrofits for owners.

However, across the region most codes and standards remain voluntary or applicable to only a few building types, and in some countries compliance and enforcement of those policies that do exist is poor. Given that buildings existing today are estimated to make up half of the residential building stock in 2050, it is crucial that codes and standards are updated regularly with increasing stringency, and target not only new construction but also existing buildings.

The IEA recommended policy packages for buildings also include green certification and labelling schemes for new and existing structures, and financial incentives tied to energy performance. Strong data frameworks to support monitoring, verification and enforcement are particularly important, and there are several examples in the ASEAN region to learn from.

In Singapore, mandatory energy performance data reporting for non-residential buildings has been in place since 2012 through the online Building Energy Submission System (BESS). In Indonesia, an online reporting system managed by the Ministry of Energy and Mineral Resources is in place for large energy users. The IEA has assisted Indonesia in developing an energy efficiency information website (SINERGI), which features energy reporting, an appliance efficiency database, energy management tips, as well as information and case studies for energy saving in companies. This year, SINERGI received a national award as one of the Top Public Sector Innovations for its contribution to national energy efficiency and emissions reduction targets.

Applying an "energy efficiency first" framework can help to align climate, development, and energy security goals

Under current policy settings, the ASEAN region is expected to see a rapid rise in energy demand, with annual average growth of more than 3% from 2021 to 2030. In line with economic growth, regional energy demand is expected to triple that of 2020 levels by 2050 with large increases in all fuels and technologies, led by oil.

However, measures including energy and material efficiency, electrification, and behaviour change, can help avoid around one-quarter of total expected energy demand. This amounts to 3 EJ of energy demand per year by 2030 in the IEA SDS compared with the STEPS. The measures discussed in this chapter provide a robust framework for reducing energy consumption while promoting economic development and skills, as well as social and health benefits.

Taking a policy package approach of regulation combined with information and incentives across all sectors can help ASEAN members ensure that their energy efficiency policies are effective in meeting the needs of their growing societies while also achieving climate goals.

In order to ensure better implementation, however, several ASEAN countries will require large-scale investment and substantial financing in order to deliver on their efficiency and climate objectives. Investment in energy efficiency among developing economies in Southeast Asia has struggled with the continued impact of the pandemic, with continued disruption to construction activities and limited public investment programmes. Financing future energy investments in Southeast Asia will also require more private capital.

Despite increasing in recent years, investing in energy efficiency and end-use technologies accounts for around one-fifth of total clean energy spending and less than 10% of total energy investment in the region. A major challenge will be to meet its growing domestic energy needs by scaling up clean investments rather than a focus on investments in fossil fuels. Energy efficiency investments combined with a strong policy and regulatory framework can help to bridge this gap and put the ASEAN region on a path to environmental and economic resiliency.

General annex

Abbreviations and acronyms

APS	Announced Pledges Scenario
ASEAN	Association of Southeast Asian Nations
CO_2	Carbon Dioxide
COP	Coefficient of Performance
DSM	Demand-side Management
E4	Energy Efficiency in Emerging Economies
EaaS	Energy-as-a-Service
EEO	Energy Efficiency Obligation
EMDE	Emerging Market and Developing Economies
ESCO	Energy service company
EV	Electric Vehicle
GDP	Gross domestic product
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
MBI	Market-based instrument
MEPS	Minimum energy performance standard
MSME	Micro, Small and Medium-sized Enterprise
PHEV	Plug-in Hybrid Electric Vehicle
RD&D	Research, development and demonstration
SME	Small and medium-sized enterprise
STEPS	Stated Policies Scenario
SUV	Sports Utility Vehicle

TCP	Technology Collaboration Programme
UNFCCC	United Nations Framework Convention on Climate Change
WEO	World Energy Outlook
ZEV	Zero-Emissions Vehicle

Units

bcm	billion cubic meters
Btu	British thermal unit
MMBtu	Million Metric British Thermal unit
EJ	Exajoule
GJ	Gigajoule
Gt	Giga tonne
kW	Kilowatt
MW	Megawatt
GW	Gigawatt
Ktoe	Thousand tonnes of oil equivalent
Mt	Million tonnes
Mtoe	Million tonnes of oil equivalent
PJ	Petajoule

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